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AN INVESTIGATION INTO THE FIRE RESISTANCE
OF TIMBER DOORS

by

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SUMMARY

An investigation has been carried out into the performance of eighteen timber door sets under the conditions of the British Standard fire test. An attempt has been made to establish some of the parameters which are significant in determining the fire resistance of timber doors. Some of the important factors which have been examined are: the effect of the depth of rebate, the 'fit' of the door, and the effect of using an intumescent strip to seal the edges of the door; the effect of door thickness, and the effect of incorporating glazed vision panels in the doors.

The tests have shown that the 'fit' of a door can be more important than the frame dimensions as a factor in deciding the effectiveness of a door as a fire barrier. With normal clearances a fire resistance of $\frac{1}{2}$ hour can be achieved by providing a seal at the edges of a door using intumescent materials. In the case of a swing door having no rebated frame a seal is essential if the door is to achieve recognised fire protection standards. Panels of wired glass up to 0.9 m^2 in size may be incorporated in timber fire doors. These may be retained by untreated timber beading if $\frac{1}{2}$ hr fire check standards are required, but for a full $\frac{1}{2}$ hour fire resistance it is necessary to protect the beading. Glazing in 1 hour fire doors must be located in a suitably designed non-combustible frame.

KEY WORDS: Doors, fire resistance tests, glazing, wood.

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AN INVESTIGATION INTO THE FIRE RESISTANCE OF TIMBER DOORS

by

W. A. Morris

1. Introduction

Doors form a vital link in the chain of fire protection measures for buildings. They provide closure for the openings in walls and it is important that their presence should not substantially lower the level of protection for which the wall has been designed. The nature of doors with the facilities for access is such that some inherent weak features are introduced which require attention to ensure that a satisfactory barrier to the passage of fire will be provided, the most important being the clearance between the door and the frame without which a door cannot function. For this reason it is necessary to examine the performance of a door/frame assembly for its fire protection characteristics rather than the door by itself. The space in front of doors is kept clear hence there is some justification for relaxing the rigid requirements which are appropriate for walls.

The majority of doors used in residential and office type buildings are made of timber. Previous experience has shown that these can be designed to provide protection for a maximum period of 1 hour. A British Standard¹, prepared after the last war when there was scarcity of timber, specifies the design features for $\frac{1}{2}$ and 1 hour 'fire-check' doors of hollow core construction. Since its publication many manufacturers have produced successful designs for doors made entirely of wood. There are many problems requiring resolution in judging the performance of doors particularly if they incorporate glazing. This note describes a co-operative programme of testing with the 'Doors Committee' of the British Woodwork Manufacturers Association (BWMA) to resolve some of the problems.

2. The test programme

2.1. Scope of the investigation

Eighteen doors were included in the programme. These were manufactured and supplied complete with frames by members of the British Woodwork Manufacturers Association. The following factors have been studied in the programme.

1. Effect of depth of rebate
2. Effect of fit between door and frame
3. Effect of using an intumescent strip at the edges of the door
4. Effect of thickness of the door
5. Effect of positive pressure
6. Effect of glazing the door.

Sixteen of the doors were designed to give protection against fire for a period of up to $\frac{1}{2}$ hour and the other two for one hour.

2.2. Door constructions

The doors tested were nominally 1980 mm x 760 mm (6 ft 6 in x 2 ft 6 in) and of the type normally found in residential and commercial buildings. The essential features of each door are summarised in Table 1. The construction specified in British Standard 459 : Part 3, illustrated in Fig. 1, was used for the majority of the specimens. Two types of door constructed from wood particle board were included for comparison purposes. In all, ten different types of door were made and these were referred to as types 'A' to 'J'. Types 'A' to 'H' were nominally $\frac{1}{2}$ hour doors and doors type 'I' and 'J', one hour doors. Types 'A' to 'H' were supplied in pairs, giving a total of eighteen specimens including the one hour doors. Drawings of the doors tested are provided in figures 2 to 19 and a brief description of each door is given in the Appendix.

Each door was supplied complete with frame; the frames were of softwood of the size specified in B.S. 459, the depth of rebate being achieved by means of a planted stop. The swing doors type 'D' had no stops. The doors were hung on $1\frac{1}{2}$ pairs of 102 mm (4 in) butt hinges with the exception of doors 'E' which were hung on a single pair of hinges. The swing door 'D' pivoted on pins and was provided with a spring closure mechanism located beneath a floor plate cast into the threshold. Where appropriate the doors were provided with a mortice latch and handles, locks were not fitted to any of the doors tested.

3. The test method and performance criteria

The doors were tested in pairs, built into a 230 mm (9 in) fletton brick wall and were provided with a concrete threshold. After the frames had been fitted any gaps at the edges of the frame were pointed with vermiculite plaster. The tests were carried out in the sequence given in Table 2.

Table 2 - Sequence of door tests

| | |
|--------|---|
| Test 1 | Doors 'A ₁ ' and 'B ₁ ' |
| Test 2 | Doors 'C ₁ ' and 'D ₁ ' |
| Test 3 | Doors 'G ₁ ' and 'H ₁ ' |
| Test 4 | Doors 'E ₁ ' and 'F ₁ ' |
| Test 5 | Doors 'B ₂ ' and 'D ₂ ' |
| Test 6 | Doors 'A ₂ ' and 'G ₂ ' |
| Test 7 | Doors 'E ₂ ' and 'H ₂ ' |
| Test 8 | Doors 'I' and 'J' |
| Test 9 | Doors 'C ₂ ' and 'F ₂ ' |

The doors were tested in accordance with British Standard 476 : Part 1 : 1953², one face of the door being subjected to the heating conditions specified in the Standard.

The performance of the doors was judged by the criteria of stability and integrity. Stability is the resistance of the door against collapse and integrity failure may be defined as the appearance of cracks, fissures, or orifices through which the flames and hot gases may pass. The criterion of limiting the temperature rise on the unexposed face is usually waived in tests on doors on the assumption that combustible materials would not be stored in contact with the face of the door.

The determination of integrity failure can be somewhat subjective as B.S. 476 does not specify a precise procedure for this purpose. In the present investigation integrity failure has been construed as:

The appearance of flaming on the unexposed face of the door persisting for 15 seconds or more, or, the development of a gap estimated to be greater than 6 mm ($\frac{1}{4}$ in) wide, accompanied by charring and glowing in the vicinity of the gap.

The flue arrangements for the furnace are such that there is a slight negative pressure on the fire side of the specimen and the typical pressure differentials across a door of 2 m height are -5 N/m^2 (-0.5 mm WG) at the top decreasing to -15 N/m^2 (-1.5 mm WG) at the sill. To determine the effect of having a positive pressure on the furnace side test No. 6 was conducted with a damper in the flue outlet of the furnace. The pressure was controlled to give a value of 10 N/m^2 (1.0 mm WG) at the top of the door and the pressure at the sill level was found to be -5 N/m^2 (-0.5 mm WG) with the neutral axis occurring at a height of approximately 800 mm above the sill.

4. Test results

The records of each test are given in the appendix and are summarised in Tables 4, 5 and 6.

Door type 'A₁'

Integrity failure occurred at 20 minutes due to sustained ignition on the unexposed face. This occurred at the head of the door, at the gap between the door and the frame. The glazing bead ignited due to heat transfer through the glass at $27\frac{1}{4}$ minutes. The door retained its stability for the $\frac{1}{2}$ hour period at which time the test was terminated.

Door type 'B₁'

Integrity failure occurred at 22 minutes due to the formation of openings at the edge of the door. Ignition of the glazing bead due to heat transfer through the glass occurred at $22\frac{1}{2}$ minutes. The door retained its stability for the $\frac{1}{2}$ hour period at which time the test was terminated.

Door type 'C₁'

Integrity failure occurred at 12 minutes due to the formation of openings at the edges. Sustained ignition of the unexposed face occurred at 15 minutes (top edge). The test was terminated at 20 minutes with the door still in position. Ignition of the glazing bead had not occurred at the end of the test.

Door type 'D₁'

Integrity failure occurred at $11\frac{1}{2}$ minutes due to the development of openings at the edges of the door. Sustained ignition occurred on the unexposed face of the door on the hinge edge towards the top of the door, at $14\frac{1}{2}$ minutes. The test was terminated at 20 minutes with the door still in position. Ignition of the glazing bead had not occurred at the end of test.

Door type 'E₁'

This door (solid particle board core) deformed more than the other doors and integrity failure occurred at 30 minutes due to gap formation; flame penetration did not occur until 35 minutes, at a point near the lower edge where the bowing was greatest, about 12 mm ($\frac{1}{2}$ in). Flames also penetrated close to the latch at 38 minutes.

Door type 'F₁'

No significant gaps developed between the door and its frame during the first 30 minutes of the test. Fire penetrated through the face of the door however at 26 minutes and ignition of the facing occurred at 38 minutes. The test was terminated at 39 minutes.

Door type 'G₁'

The door retained its integrity for a 20 minute period. Ignition of the glazing bead due to heat transfer through the glass occurred at $21\frac{1}{2}$ minutes. The test was terminated at 35 minutes with the door retaining its stability.

Door type 'H₁'

Ignition of the glazing bead occurred at $18\frac{3}{4}$ minutes, the glass started to fall out at 33 minutes. At 26 minutes, large gaps had developed at the perimeter of the door. The test was stopped at 35 minutes with the door retaining its stability.

Door type 'A₂'

Integrity failure occurred at $12\frac{1}{4}$ minutes due to the flame penetrating the top edge of the door, (positive pressure), the flames spread to the glazing bead at 17 minutes. The door retained its stability for the $\frac{1}{2}$ hour test period.

Door type 'B₂'

Glowing of the frame near the latch occurred at 23 minutes and a gap 12 mm in width had developed by 26 minutes. Ignition of the top glazing bead occurred at $30\frac{1}{2}$ minutes and 15 seconds later the treated beading around the centre pane ignited (flames appeared to have been transmitted from the upper bead). The test was terminated at 31 minutes with the door retaining its stability.

Door type 'C'₂

Integrity failure occurred at 28 minutes when gaps developed between the glazing bead and the door, sustained flaming had occurred by 29 minutes. The door retained its stability for the $\frac{1}{2}$ hour test period.

Door type 'D'₂

The intumescent strip had expanded by 13 minutes, this expansion did not appear to start until 9 minutes. The upper glazing bead ignited at 25 minutes, and the beading at the side ignited after 29 minutes. The test was stopped at 31 minutes, the door retaining its stability.

Door type 'E'₂

Severe bowing occurred with this door (solid particle board) a significant gap developing by 21 minutes. The top hinge had broken away from the frame at 24 minutes. This was followed by ignition of the face of the door. The door collapsed completely at 30 minutes.

Door type 'F'₂

Although some distortion of this door occurred it retained its stability and integrity for a period of 30 minutes.

Door type 'G'₂

Integrity failure of the door occurred at 17 minutes when the unexposed face of the door adjacent to the aluminium glazing bead ignited. At 24 minutes the glazed vision panel collapsed into the furnace. Significant gaps had formed at the top edge of the door by 25 minutes.

Door type 'H'₂

Gaps occurred at the edges of the door at 18 minutes. At $23\frac{1}{2}$ minutes ignition of the unexposed face of the door occurred adjacent to the PVC glazing bead, flaming also penetrated around the door at the top edge at about this time. The door retained its stability for the 30 minute test period.

Door type 'I'

Integrity failure occurred at $34\frac{3}{4}$ minutes when distortion of the door enabled flames to penetrate at the top edge. Severe distortion of the welded steel glazing surround was evident and ignition occurred beneath the beading at $55\frac{3}{4}$ minutes. The door retained its stability for the 1 hour test period.

Door type 'J'

Ignition of the unexposed face of the door occurred at 40 minutes when the flames penetrated behind the steel glazing bead. The door retained its stability for the full test period.

5. Discussion of results

5.1. General

Timber fire doors are used in buildings where the fire resistance requirements are for $\frac{1}{2}$ hour or 1 hour. Of these, doors for the $\frac{1}{2}$ hour requirement represent the major usage. Some typical examples of their use are the front doors of flats, doors in corridors and to staircases, and doors to service ducts.

The performance of a timber door is measured on the basis of the criteria given in B.S. 476 for stability, integrity, and insulation. The last named requirement is usually waived in the case of doors on the grounds that no combustible contents will be stored against the door and hence there is no hazard of their ignition by conducted heat. The duration for which a door complies with the stability and integrity requirements enables it to be classified either as a 'fire check' or as a 'fire resisting' construction. The following specification is used for this purpose.

Table 3 - Classification of doors

| <u>Type of door</u> | <u>Minimum duration for compliance</u> (minutes) | |
|-----------------------------------|---|------------------|
| | <u>Stability</u> | <u>Integrity</u> |
| $\frac{1}{2}$ hour fire check | 30 | 20 |
| $\frac{1}{2}$ hour fire resisting | 30 | 30 |
| 1 hour fire check | 60 | 45 |
| 1 hour fire resisting | 60 | 60 |

It is apparent that a fire check door possesses lower integrity than a corresponding fire resisting door. In the majority of cases the integrity failure occurs by the formation of orifices or openings along the edges of the door, (Plate 1) an inherent weakness due to the nature of the door construction. The present tests have highlighted the importance of detailing at the edges of doors and have shown some ways of improving the resistance to fire penetration.

5.2. The effect of the depth of rebate

British Standard 459 specifies that for both $\frac{1}{2}$ hour and 1 hour fire check doors the depth of the rebate should be 1 in. The $\frac{1}{2}$ hour door can have planted stops whereas for the one hour door they must be cut from solid material. Additionally, the frame for the one hour door is required to be impregnated with flame retardant chemicals.

In the tests on $\frac{1}{2}$ hour doors, rebate depths of 12.5, 19, and 25 mm ($\frac{1}{2}$, $\frac{3}{4}$ and 1 in) were used. However as the specimens with the 19 mm ($\frac{3}{4}$ in) rebates were provided with additional means for sealing the gaps, the test data cannot be used for comparative purposes.

The door specimen A_1 with 25 mm (1 in) rebates and specimens B_1 and C_1 with 12.5 mm ($\frac{1}{2}$ in) rebates were tested with their stop sides exposed to the furnace. The times at which the three doors suffered loss of integrity by the formation of orifices at the edge were 20, 22 and 12 minutes respectively. Measurements on the doors (see appendix) showed that the initial gap sizes were 2.8-3.5 mm for A_1 (at the top of the door where failure first occurred), 1.5 mm for B_1 , and 2.0-3.0 mm for C_1 . The close fit in the case of door B_1 enabled it to give a much better performance than door C_1 , slightly better even than door A_1 . A direct comparison between doors A_1 and C_1 is possible and it is apparent that with a normal fit, i.e. gaps up to 3 mm between the door and the frame, it is not possible to satisfy the integrity requirements for 20 minutes (as appropriate for $\frac{1}{2}$ hour 'fire check' doors) if the frame rebate is 12.5 mm ($\frac{1}{2}$ in). Even with 25 mm (1 in) rebates and a good fit, failure will probably occur at the edges before 30 minutes.

The swing door specimen D_1 had no stops but it was a very tight fit in its frame (average clearance less than 0.5 mm ($\frac{1}{64}$ in)). The penetration of the fire through this door occurred at 11 $\frac{1}{2}$ minutes and the failure would have occurred earlier had the clearances been larger.

5.3. The effect of the fit of the door

Specimens B_1 and C_1 allow a direct comparison to be made on the effect of door fit, i.e. the size of the gaps between the door and the frame. Both doors had stops providing 12.5 mm ($\frac{1}{2}$ in) rebates with average gaps of 1.5 mm ($\frac{1}{16}$ in) and 3.0 mm ($\frac{1}{8}$ in) respectively. The integrity failures were recorded at 22 and 12 minutes respectively.

It is apparent that the penetration of a door by fire is influenced not only by the depth of rebate but also by the gap sizes, the latter probably being the more important factor. When comparing specimens A₁ and B₁ it can be seen that with a smaller stop, but much tighter fit, it is possible to achieve a comparable performance.

If doors are to perform their fire protection purposes reliably it is essential that not only should the frame members be of the right dimensions but the fit of the door should be up to a specified standard. This could be achieved in practice if such doors were hung in their frames at the factory and delivered to site as a complete assembly. This would eliminate the normal procedure of trimming the door edge to fit the frame, a process difficult to control.

It is also apparent from the test on door D₁ that a swing door having no stops and no special sealing arrangements cannot reach the standard required of a $\frac{1}{2}$ hour fire check door even if extremely carefully made. If the gaps between the door edge and the frame, or between meeting edges had been 3 mm or so, penetration of fire might have occurred in less than 10 minutes.

5.4. The effect of sealing the door edge

The first penetration of fire through a timber door generally occurs at the edge of the door, usually in the upper part. Failure is caused by the fire exploiting the gaps between the door edge and the frame. Wider gaps quicken the fire penetration as shown in 5.3. A door may have a very good fit and give a good performance in a standard test, but unless control is exercised to ensure that a similar fit is maintained in practice the behaviour of the door in an actual fire may not be equally reliable. One of the ways in which the influence of the gaps can be minimised and a good performance assured is by the use of a special material along the edges of the door which have the property of intumescent at high temperatures. One type of intumescent material is available in the shape of a 3 mm x 12 mm ($\frac{1}{8}$ x $\frac{1}{2}$ in) strip and this was employed in eight of the specimens tested, two of which were the one hour door types 'I' and 'J'. There was a significant improvement in the performance of all the doors where the strip was used (Table 4) with the exception of door E₂. This door had a wood particle board core and was only fitted with a single pair of hinges. The door was tested with the hingeside exposed to the furnace and bowing of the door caused the top hinge to pull away from the frame. (Plate 2).

The most significant improvements were in the cases of loosely fitted doors and the swing doors having no rebated stop. Door C₁ was similar to, and was exposed in the same manner as, door C₂. The fire penetration time for the latter door, which incorporated an intumescent strip, more than doubled. (Plate 3). The swing door D₁ was a very good fit in the frame (average gap less than 0.5 mm ($\frac{1}{64}$ in)); fire penetration occurred at 11½ minutes without the strip, but when the strip was fitted no penetration had occurred with a similar door after a test duration of 31 minutes. The strips used in the 55 mm door 'J', which had 25 mm (1 in) rebated stops, enabled the door to retain its integrity at the perimeter for a 65 minute test period, even though the frame had not been impregnated. The other 55 mm door, door 'I', failed when the fire penetrated the edge of the door at 35 minutes. Failure in this case however was due to excessive warping of the door.

The intumescent strips used in these tests did not swell sufficiently to seal the gaps until the door has been subjected to direct fire attack for a period of 10 to 15 minutes. In many situations where a door is required to prevent the passage of smoke it is located in a position where it may not be exposed to the full severity of fire and the temperatures may not be sufficient to cause intumescence of the sealing strip. Hence the use of these strips cannot be taken as a means of reducing the smoke penetration during the early stages of a fire.

5.5. The effect of door thickness

Six of the doors tested were of 40 mm thickness as opposed to the 45 mm required by B.S. 459. Four of these doors were otherwise of B.S. 459 construction and the other two doors had a solid wood particle board core. The latter two doors suffered badly from distortion during the test and this was aggravated by the fact that only two hinges had been fitted to these doors. Door 'E₂' in fact collapsed into the furnace 30 minutes after the start of the test. Of the six doors tested, five were provided with intumescent strips at the edge. Door 'G₁' with a 25 mm stop and no seal just attained a ½ hour fire check performance. The 40 mm doors appeared adequate for fire check requirements and in the case of five of the doors the fire had not penetrated through the thickness of the door panel at 30 minutes. However, in the case of door 'F₁', a 40 mm door of B.S. 459 construction, charring and

penetration over a small area occurred on the face of the door at 26 minutes, (Plate 4) this appeared to be due to a localised fault in the plasterboard core. Even on the other doors of similar construction there were char patterns forming at about 30 minutes and therefore there is no safety margin in hand for a door of 40 mm thickness and of hollow construction. It is suggested that for 30 minute fire check purposes a 40 mm door of either type is adequate, but for a fully fire resisting door for the same period a thickness of 45 mm (1 in) may be necessary if this type of construction is used.

Two doors of 55 mm thickness were tested one similar to a B.S. 459 door in construction and the other having a solid chipboard core. Door 'I' the B.S. 459 door, opened towards the furnace and suffered integrity failure at 35 minutes, because of excessive distortion. Both of these doors could provide one hour fire resistance if adequate attention is paid to sealing the edges of the door. To be certain of a full hour's fire resistance with the door of B.S. 459 construction it may be necessary to design a latch mechanism which restrains the free edge of the door more effectively. The distortion may have been exaggerated by the presence of the offset glazing panel. When exposed from the opposite direction the distortion would be reduced and an improved performance could have been expected.

5.6. Door furniture

An investigation into the performance of door furniture was not directly included in the programme. It is, however, worth stressing that the performance of a door is very dependent on the nature of the fittings used. A lock was not included in any of the doors tested and previous experience has shown that unless a lock is fitted satisfactorily local loss of integrity can occur. Two of the doors supplied for test were fitted with plastic latches; this was an error which was rectified before test. It does, however, draw attention to the fact that materials of low melting point should not be used in the furniture of fire doors where a failure of the component could lead to a failure of the door. In addition to plastics, these remarks also apply to components made from low melting point alloys such as brass and aluminium.

5.7. Glazing

If a door incorporates glazed panels, integrity failure may occur by the ignition of the beading or the frame on the unexposed face due to heat being transmitted through the glass. (Plate 5). This is usually due to the combined effects of conduction, radiation, and convective heating. In the tests, ignition of untreated timber beading occurred in every case except for doors 'C₁' and 'D₁' where the tests were terminated at 20 minutes. The ignition time for the beading varied between 17 and 31 minutes, and in only one case, i.e. door 'B₂' was the ignition time just in excess of 30 minutes. It can be concluded that a door having glazing retained by untreated timber beads is unlikely to attain a $\frac{1}{2}$ hour fire resistance. For the majority of the doors ignition occurred between 20 and 30 minutes. One glazed section in door 'B₂' had the bead on both sides of the door painted with an intumescent paint. The failure time of 30 $\frac{1}{2}$ minutes showed that this type of paint can be used successfully to protect the beading of a $\frac{1}{2}$ hour fire resisting door. (Plates 6 and 7). Such a treatment however would often be outside the direct control of the manufacturer. As yet no information is available on the continued effectiveness of this method of protection if overpainted with normal decorative treatments at a later date. A similar performance could be achieved by providing a decorative metal capping over the bead. It therefore seems that to achieve the $\frac{1}{2}$ hour fire check standard in a glazed wooden door the timber beading and the frame members do not require any flame retardant treatment, but to attain a $\frac{1}{2}$ hour fire resisting standard some preventative treatment is necessary. To eliminate doubts about the durability of flame retardant treatments the beading should be either non-combustible or covered with a non-combustible material.

No direct relationship was noted between the ignition times and the size of the glass. There was perhaps a tendency for the smaller sizes of glazing to result in earlier ignition probably due to a higher level of radiation falling on the glazing bead. This increase in radiation was attributable to the increased flaming on the exposed face of the door due to the combustion of the unglazed area.

Glazing beads of 13 mm section were sufficient to retain the glass in the door even when the panel size was 0.93 m². If multiple glazed panels are used it is important that the intermediate glazing bars are of sufficient thickness to prevent the fall of glass. Test observations indicate that the minimum depth of glazing bar should be 60 mm and its thickness should be at least 45 mm, the rebates for the glass being worked from the solid material.

The timber glazing bead of door C_2 was treated with an intumescent paint but premature failure occurred when the fire penetrated between the planted beads and the door frame. (Plate 8). It is preferable to locate the glass in a rebated frame rather than by planted beading on both sides of the glass.

In two tests (doors ' G_2 ' and ' H_2 ') the glazing was retained by aluminium and PVC beading. Door ' G_2 ' with the aluminium beading failed at 17 minutes the glass collapsing before the end of the test. (Plate 9).

Door ' H_2 ' with PVC beading failed at $23\frac{1}{2}$ minutes. The aluminium beading on the exposed side of the door deformed and came away and the PVC beading was destroyed early in the test. Neither of these methods of retaining the glass are considered suitable for fire doors.

In the case of the two 1 hour doors ('I' and 'J') the glazing was retained in position by steel beads with inserts of asbestos tape. Ignition in the vicinity of the beading occurred at 55 and 40 minutes respectively. The buckling of the metal beading was primarily responsible for flame penetration (Plate 10) and allowance for expansion would have minimised this effect. With this modification this method of fixing would appear to be adequate for 1 hour fire check doors, but to prevent ignition for 60 minutes it will be necessary to improve further the method of fixing. The use of steel beads with better insulating and masking arrangements to minimise heat transmission and to prevent the formation of gaps, or the employment of a separate framing of asbestos insulation board or similar material seem possible solutions.

The tests have shown that it is not necessary to limit the size of glazed panels to less than 0.9 m^2 (10 ft^2) provided that adequate precautions are taken to prevent the ignition of beading and the framework. When no precautions are taken even with panels as small as 0.2 m^2 , ignition of the beading can occur in about 20 minutes. The factor likely to limit the size of the glass in a glazed door is the amount of radiant heat being transmitted through the glass. It has been stated elsewhere³ that if the ignition of combustible materials is the criterion the maximum acceptable radiation level is 3.3 kW/m^2 . Since the expected maximum radiation level from a compartment fire equivalent to a $\frac{1}{2}$ hour fire resistance test is 1.9 kW/m^2 it would seem unnecessary to limit the size of glass in $\frac{1}{2}$ hour fire doors.

The stability of large glazed panels in one hour fire tests has not been a subject of this investigation.

5.8. Direction of exposure

Six types of door were tested both opening towards and away from the furnace. In only three cases (types B, E and H) could a direct comparison be made of the effect of exposing one or other of the faces to fire conditions, the interaction of variables influencing the result in the other instances. Doors type 'B' performed similarly in both directions, doors type 'H' however showed a difference, door 'H₁' opening away from the furnace failing at 26 minutes and door 'H₂' opening towards the furnace failing at 18 minutes. Doors 'E₁' and 'E₂' also showed a difference in performance, 'E₁' failing at 30 minutes and 'E₂' failing at 21 minutes. It appeared that if a door had a tendency to deform when subjected to heating, failure occurred at an earlier time when tested opening towards the fire. The direct fire attack on the hinges and the latch plate assists this tendency. This finding is contrary to the commonly held view that exposure of the stop side represents an equivalent⁴ or more severe test condition.

5.9. The effect of positive pressure

Doors 'A₂' and 'G₂' were tested under positive pressure of 10 N/m² (1.0 mm wg) applied to the fire side of the door. The penetration time of the 'A' type door was reduced from 20 minutes to 12 minutes. Door 'G₂' achieved fire check standard but this result was influenced by the PVC strip used to seal the edge of the door.

6. Conclusions

An examination has been made of the performance of timber doors subjected to the fire resistance test of B.S. 476 : Part 1 : 1953 a limited number of tests being carried out to establish the effect of certain design variables and to ascertain the influence of changing the test conditions. A total of eighteen doors has been examined. Fourteen of these doors incorporated vision panels of 6 mm ($\frac{1}{4}$ in) Georgian wired glass, sixteen were designed to give protection against fire for a $\frac{1}{2}$ hour period and two for a period of 1 hour.

This investigation has not been concerned with the use of doors and no attempt has been made to establish the performance requirements for a door that is to serve a particular purpose. There is a definite need for a rationalisation of the requirements concerning the fitting of fire doors in various types of occupancies and in particular it is necessary to draw a clearer distinction between those doors which are required as barriers to contain a spreading fire, and those doors whose main function will be to restrict the flow of smoke and hot gases.

From this investigation the following conclusions are drawn:

1. A door with 12.5 mm rebates is not adequate for 'fire check' purposes unless tolerances on fit are controlled to better than 1.5 mm.
2. A door having 25 mm rebates will achieve the $\frac{1}{2}$ hour fire check standard with gaps of up to 3 mm but will not generally provide a full $\frac{1}{2}$ hour fire resistance unless some additional precautions are taken.
3. Doors having no rebated frame, i.e. swing doors, would have a low fire resistance even if very close tolerances are specified.
4. The fit of a door is relatively more important than the dimensions of the rebated frame in determining the fire performance. A door having clearances in excess of 3 mm is likely to fail before 20 minutes even if the rebates are 25 mm in depth.
5. The use of an intumescent strip to seal the edges of a door under fire conditions greatly enhances the performance of timber doors, including swing doors without rebated frames.
6. Intumescent seals provide a possible method of achieving a 1 hour fire resistance without the need for impregnation of the door frame.
7. Use of intumescent strips should not, however, be regarded as a substitute for a poor fit as the door would not then be an efficient smoke barrier until the seal had been activated.
8. A 40 mm thick door of B.S. 459 construction can meet the requirements for a $\frac{1}{2}$ hour 'fire check' door.
9. If the thickness is increased to 45 mm the door will retain its integrity for the 30 minute period providing attention is paid to the rebates and to sealing the gaps at the edge.
10. Doors 55 mm in thickness can provide a 1 hour fire resistance if care is taken in sealing and restraining the edges of the door.
11. The door frame sizes examined in the investigation were adequate for the periods of fire resistance for which they were designed.
12. Materials of low melting point should not be used for doors furniture as their collapse may result in a premature failure of the door.
13. Glazing retained in a door by untreated timber beads would not generally impair the ability of the door to attain $\frac{1}{2}$ hour 'fire check' standard.

14. In order to achieve a $\frac{1}{2}$ hour fire resistance standard it is necessary to treat the timber glazing beads. Intumescent paints proved satisfactory for this purpose but metal trim or non-combustible capping would provide a more durable and reliable protection. Aluminium and PVC are not satisfactory materials to use for beading.
15. Beading 13 mm in depth is adequate to retain glass up to 0.9 m^2 in area in $\frac{1}{2}$ hour doors.
16. If the glass is retained by planted beads on both sides flames can penetrate beneath the beads. It is therefore recommended that the glazing should always be located in a rebated frame.
17. Glazed panels up to 0.9 m^2 size are considered satisfactory for $\frac{1}{2}$ hour doors.
18. Glazed panels can be used in 1 hour doors providing the glass is retained in a suitably designed non-combustible frame.
19. Intermediate bars when using multiple glazed panels can be a source of weakness. These should be at least 60 mm in depth and 45 mm thick for $\frac{1}{2}$ hour doors.
20. Doors subject to marked distortion will fail at an earlier time when tested opening towards the heat source.

Acknowledgements

The author would like to express his thanks to Mr. H. L. Malhotra for his guidance throughout the test programme and Messrs. J. S. Hopkinson and G. D. Simpson for undertaking much of the experimental work. Thanks are also due to the British Woodwork Manufacturer's Association who provided the door-sets for test.

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APPENDIX

EXPERIMENTAL OBSERVATIONS

Door Type A - 1 Construction - B.S. 459

Thickness - 45 mm

Rebate - 25 mm

Glazing - One panel 0.37 m², 510 mm x 740 mm
 Beading: chamfered hardwood

Exposure - Opening away from furnace

Time to failure - 20:00 integrity failure

Test Results

| Time from start of test min sec | Observations |
|---------------------------------------|--|
| 05.00 | Flaming of exposed beading |
| 07.00 | Exposed face delaminating |
| 08.00 | Considerable amount of smoke from top of door |
| 12.00 | Outer skin, exposed face, fallen away completely |
| 20.00 | Occasional flames from top left gap |
| 22.00 | Top rail alight |
| 27.15 | Ignition of window frame, bottom and L.H.S. |
| 29.00 | Vertical edges of door burning well |
| 30.00 | Test stopped |

Door Type A - 2 Construction - B.S. 459

Thickness - 45 mm

Rebate - 25 mm

Glazing - One panel 0.37 m², 510 mm x 740 mm
 Beading: chamfered hardwood treated with fire retardant paint

Exposure - Opening towards the furnace
 A positive pressure was maintained throughout the test

Time to failure - 12.15 integrity failure

Test Results

| Time from start of test | Observations |
|----------------------------|---|
| min sec | |
| 06.15 | Smoke from top and sides to glazing level |
| 08.15 | Beading fallen into furnace from top of window |
| 10.45 | All panelling and beading alight - exposed face |
| 10.50 | Smoke extended to bottom half of door |
| 12.15 | Flames from top of door - unexposed face |
| 17.00 | Flames spread down to glazing |
| 27.30 | Plasterboard core fallen into furnace |
| 30.00 | Test concluded, glass still in place. Flaming limited to glazing area on unexposed face |

Door Type B - 1 Construction - glazed

Thickness - 45 mm

Rebate - 12.5 mm

Glazing - Three panels of 0.31 m², 530 mm x 585 mm

Total area 0.93 m²

Beading: hardwood. 19 mm x 19 mm on upper panels

19 mm x 13 mm on lower panel

Exposure - Opening away from the furnace

Time to failure - 22.00 integrity failure

Test Results

Time from start
of test

Observations

min sec

| | |
|-------|---|
| 05.00 | Flaming of exposed face beading |
| 11.00 | Slight smoke from top of door |
| 15.00 | Stop breaking away. Lower pane beading falling away. |
| 20.00 | Furnace visible down closing edge, crack - 3 mm wide |
| 22.00 | Furnace visible along edges below handle level |
| 22.30 | Ignition of window beading on all panes |
| 25.00 | Ignition of closing edge below handle |
| 27.00 | 20 mm gap along hinge edge, top rail well alight |
| 29.00 | Vertical edges well alight |
| 30.00 | Test stopped. Cross rails were nearly burnt through and the glass of the top panel was free at the upper edge, being close to falling out |

Door Type B - 2 Construction - glazed

Thickness - 45 mm

Rebate - 12.5 mm

Glazing - Three panels of 0.31 m², 530 mm x 585 mm
 Total area 0.93 m²

 Beading: Upper panel, untreated hardwood
 Centre panel, hardwood with intumescent paint
 Lower panel, asbestos 19 mm x 19 mm

Exposure - Opening towards the furnace

Time of failure - 26.00 integrity failure

Test Results

| Time from start of test | Observations |
|----------------------------|--|
| min sec | |
| 06.00 | Upper window beading ignited on exposed face |
| 10.00 | Centre beading ignited on exposed face |
| 23.00 | Glowing of frame near latch |
| 25.00 | Gap by latch 70 mm x 5 mm approximately |
| 26.00 | Gap increased to 12 mm |
| 30.30 | Top panel beading, ignited |
| 30.45 | Centre panel beading ignited |
| 31.00 | Test concluded |

Door Type C - 1 Construction - B.S. 459

Thickness - 45 mm

Rebate - 12.5 mm

Glazing - One panel 0.37 m², 300 mm x 1200 mm

Beading: chamfered hardwood

Exposure - Opening away from the furnace

Time to failure - 12.00 integrity failure

Test Results

Time from start
of test

Observations

min sec

| | |
|-------|--|
| 05.00 | Warping top right hand corner |
| 06.00 | Smoke from top of door |
| 08.40 | Intermittent flaming from top left hand side of door |
| 12.00 | Furnace visible all round door, gaps exceed 6 mm |
| 15.00 | Sustained ignition on unexposed face |
| 16.00 | Top of door well alight |
| 17.00 | Top and sides of door well alight |
| 18.00 | Gap along closing edge about 25 mm |
| 20.00 | Test stopped |

Door Type C - 2 Construction - B.S. 459

Thickness - 45 mm

Rebate - 12.5 mm with intumescent strip fitted to perimeter of door

Glazing - One panel 0.37 m², 300 mm x 1200 mm

Beading: chamfered hardwood treated with fire retardant paint
 on fire side

Exposure - Opening away from the furnace

Time to failure - 28.00 integrity failure

Test Results

Time from start
of test

Observations

min sec

| | |
|-------|--|
| 06.00 | Smoke from top of door |
| 12.00 | Top left strip began to operate |
| 12.45 | Strip starting to seal at top right |
| 13.45 | Strip sealed top of door |
| 16.00 | Beading falling on exposed face |
| 16.15 | Sealing strip appears effective down to handle |
| 22.00 | Smoke from beading |
| 26.45 | Intermittent flaming of top left beading |
| 28.00 | Failure between frame and beading bottom left |
| 28.55 | Ignition of top left beading |
| 32.40 | L.H.S. window beading ignited |
| 33.00 | Extensive flaming on both vertical beads |
| 33.15 | Test concluded |

Door Type D - 1 Construction - glazed S - 0.001 m²/m²

Thickness - 45 mm, single leaf of double swing door S - 0.001 m²/m²

Glazing - One panel 0.93 m², 550 mm x 1675 mm S - 0.001 m²/m²

 Beading: chamfered hardwood, 19 mm x 12.5 mm

Time to - 11.30 integrity failure S - 0.001 m²/m²

failure

Test Results

| Time from start of test | Observations | S - 0.001 m ² /m ² |
|----------------------------|--------------------------------------|--|
| min sec | | |
| 08.00 | Intermittent flaming from top L.H.S. | 00.10 |
| 11.00 | Smoke from top of door | 01.00 |
| 11.30 | Gap at closing edge about 6 mm | 01.30 |
| 14.00 | Gaps of 10-15 mm | 02.30 |
| 14.30 | Flaming on hinge edge at top | 02.40 |
| 17.30 | Gaps at lower half about 25 mm | 03.00 |
| 20.00 | Test stopped | 03.10 |

Door Type D - 2 Construction - glazed

Thickness - 45 mm, single leaf of double swing door

Glazing - One panel 0.93 m², 550 mm x 1675 mm

Beading: chamfered hardwood, 19 mm x 12.5 mm

Intumescent strip fitted to perimeter of door

Time to failure - 25.00 integrity failure

Test Results

Time from start
of test

Observations

min sec.

| | |
|-------|---------------------------------------|
| 09.00 | Strip at top of door intumescing |
| 13.00 | Most of closing edge sealed by strip |
| 25.00 | Ignition of top bead - unexposed face |
| 29.00 | Ignition of side bead |
| 30.00 | 10-15 mm inward warp at closing edge |
| 31.00 | Test stopped |

Door Type E - 1

Thickness - 40 mm, solid wood particle board core

Rebate - 12.5 mm

Intumescent strip fitted to frame

Exposure - Opening away from the furnace

Time to failure - 30 minutes

Test Results

Time from start
of start

Observations

min sec

| | |
|-------|---|
| 07.00 | Furnace visible along hinge edge and top left of closing edge |
| 11.00 | Large gap top left vertical edge |
| 12.00 | Smoke from top left |
| 14.00 | Strip sealing at top |
| 20.00 | 4 mm gap lower L.H.S. |
| 30.00 | Bottom edge deformed outwards beyond strip |
| 35.00 | Bottom corner burnt through |
| 38.00 | Flaming around latch area |
| 39.00 | Test stopped |

Door Type E - 2

Thickness - 40 mm, solid wood particle board core

Rebate - 12.5 mm

Intumescent strip fitted to frame

Exposure - Opening towards the furnace

Time to failure - 21.00 integrity failure

Test Results

Time from start
of test

Observations

min sec

| | |
|-------|---|
| 06.30 | Smoke from top of door |
| 09.00 | Flaming visible (not penetrating) at bottom R.H.S. |
| 13.00 | Glowing visible centre L.H.S. |
| 16.00 | Smoke from centre L.H.S. |
| 21.00 | Bowing at top right corner, with consequent gap formation |
| 23.00 | Bowing at top about 10-15 mm with flaming along top and sides |
| 24.00 | Top hinge broken away |
| 30.00 | Door fallen into furnace |
| 30.30 | Test concluded |

Door Type F - 1 Construction - B.S. 459

Thickness - 40 mm

Rebate - 19 mm

Intumescent strip fitted to frame

Exposure - Opening away from the furnace

Time to failure - 26.00 integrity failure

Test Results

| Time from start of test | Observations | Temperature of face |
|----------------------------|---|------------------------|
| min sec | | |
| 10.00 | Plywood falling from exposed face | 32.0 |
| 16.30 | Plasterboard cracked on exposed face | 32.0 |
| 22.00 | Some plasterboard falling into furnace | 32.0 |
| 25.00 | Charring of unexposed face, lower half centrally | 32.0 |
| 26.00 | Small penetration on face | 32.0 |
| 30.00 | Bottom edge deformed beyond strip leaving a gap | |
| 34.00 | Strong char pattern. Strip not forming smoke seal | |
| 38.20 | Ignition of unexposed face | 32.0 |
| 39.00 | Test concluded | 32.0 |

Door Type F - 2 Construction - B.S. 459 1000 x 2000 mm
 Thickness - 40 mm 1000 x 2000 mm
 Rebate - 19 mm 1000 x 2000 mm
 Intumescent strip fitted to frame 1000 x 2000 mm
 Exposure - Opening towards the furnace 1000 x 2000 mm
 Time to failure - No failure 1000 x 2000 mm

Test Results

| Time from start of test | Observations |
|----------------------------|--|
| min sec | |
| 07.40 | Fierce flames on exposed face |
| 15.00 | Gap at top R.H.S. about 5 mm |
| 17.00 | Plasterboard panels visible on exposed face |
| 21.05 | R.H.S. top corner distorted about 5 mm |
| 21.40 | Smoke from top of door momentarily |
| 23.00 | Bowing increased to 10 mm |
| 23.20 | Smoke from all along top edge |
| 32.00 | Unexposed panels beginning to darken |
| 33.15 | Test concluded - door intact except for scorching of panels and at top R.H.S. corner |

Door Type G - 1 Construction - B.S. 459

Thickness - 40 mm

Rebate - 25 mm

Glazing - One panel 0.23 m²; 480 mm x 480 mm

 Beading: chamfered hardwood 19 mm x 13 mm

Exposure - Opening away from the furnace

Time to failure - 21.30 integrity failure

Test Results

| Time from start of test | Observations |
|----------------------------|---|
| min sec | |
| 11.00 | Inner plywood skin fallen into furnace. |
| 19.30 | Gap along hinge edge about 3 mm |
| 21.30 | Ignition of beading on all but R.H.S., unexposed face |
| 23.00 | Ignition of R.H.S. bead, gap at edge 6 mm |
| 33.00 | Glass falling out |
| 35.00 | Test stopped |

— 225 —

• **Stressors** – factors that cause stress

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• *Journal of the American Academy of Child and Adolescent Psychiatry*, 1999, 38(12):1339-1347.

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Journal of Management Education 30(6)

2

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

1

Figure 1. The effect of the concentration of the *Agrobacterium* suspension on the transformation efficiency of *Agrobacterium* strains.

✓ 2 - 1

| Condition | Control (%) | MCI (%) | AD (%) |
|-----------|-------------|---------|--------|
| 1 | 95 | 85 | 75 |
| 2 | 90 | 80 | 70 |
| 3 | 85 | 75 | 65 |
| 4 | 85 | 75 | 65 |

•

from top of pane

panel, unexpose

•

Door Type H - 1 Construction - B.S. 459

Thickness - 45 mm

Rebate - 25 mm

Glazing - One panel 0.23 m², 750 mm x 300 mm

 Beading: chamfered hardwood, 19 mm x 12.5 mm

Exposure - Opening away from the furnace

Time to failure - 18.45 integrity failure

Test Results

| Time from start of test | Observations |
|-------------------------|------------------------------------|
| min sec | |
| 11.00 | Slight charring of window bead |
| 17.00 | Hole developed behind bead |
| 18.45 | Ignition of beading |
| 26.00 | Frame glowing at top |
| 30.00 | Gap at centre hinge about 10-15 mm |
| 35.00 | Test concluded |

Door Type H - 2 Construction - B.S. 459

Thickness - 45 mm

Rebate - 25 mm

Glazing - One panel 0.23 m², 750 mm x 300 mm

Beading: P.V.C. quadrant, 9.5 mm radius on both faces of
glazing secured with panel pins

Exposure - Opening towards the furnace

Time to failure - 18.00 integrity failure

Test Results

Time from start
of test

Observations

min sec

| | |
|-------|---|
| 10.15 | P.V.C. beading peeling away from frame. |
| 12.00 | Beading melting at top of glazing, unexposed face. |
| 18.00 | Bowing towards furnace at top R.H. corner, with consequent gap formation. Beading burning and falling into furnace. Beading smoking on unexposed face |
| 20.00 | Flames visible top R.H. corner |
| 21.00 | Glowing under beading, bottom left of panel |
| 22.00 | Beading fallen R.H.S. |
| 23.30 | Ignition top L.H.S. by glazing |
| 30.30 | Test concluded |

Door Type I

Construction - B.S. 459

Thickness - 55 mm

Rebate - 25 mm. Frame - one hour type but no impregnation

Glazing - One panel 0.36 m², 1200 mm x 300 mm

Beading: stainless steel, secured with screws, embedded on woven asbestos

Intumescent strips were located in the door perimeter and the frame

Exposure - Opening towards the furnace

Time to failure - 34.45 integrity failure

Test ResultsTime from start
of test

Observations

min sec

07.30

Exposed face steel beading distorted L.H.S. and bottom corners

08.30

Spalling of asbestos facing on exposed face

10.30

13.00

Small quantity of smoke top R.H.S.

15.45

Vertical steel beading buckled by 20-30 mm on exposed face

30.00

Exposed face asbestos board peeling away

32.30

Unexposed R.H.S. bead buckling

33.20

Char visible through gap at top R.H.S.

34.10

Occasional flames from top L.H.S.

34.45

Ignition unexposed face top corners. Door bowed away from stop. Serious distortion of beading

40.00

Gap to hinge from top

41.30

Top edge flaming

46.10

Window beading buckled away from wood on vertical sides

53.00

Flames around top corners of window beading

55.00

Top gap 70-80 mm. Extends to 150 mm above handle

55.45

Beading area ignition at centre of R.H.S.

60.00

Flames around beading down to handle

65.00

Test concluded. Exposed face plasterboard still in position

Door Type J Construction - solid particle board
 Thickness - 55 mm
 Rebate - 25 mm. Frame - one hour construction but no impregnation
 Glazing - One panel 0.5 m², 1000 mm x 500 mm
 Beading: stainless steel, secured by screws, embedded on woven asbestos

Intumescent strips were located in the door perimeter and the frame

Exposure - Opening away from the furnace

Time to failure - 40.00 integrity failure

Test Results

| Time from start of test | Observations |
|-------------------------|--|
| min sec | |
| 14.00 | Slight smoke from top L.H.S. |
| 16.15 | Smoke emitted R.H.S. above handle |
| 17.20 | Smoke from window frame both sides |
| 18.15 | Smoke increasing on R.H.S. and around handle |
| 29.00 | Steel beading not buckled. Smoke from lower L.H.S. |
| 40.00 | Ignition of unexposed face above top beading |
| 46.30 | Flames confined to beading at top |
| 48.00 | Steel buckling only at top edge |
| 52.00 | Bowing outwards at handle |
| 53.00 | Smoke from top L.H. corner |
| 65.00 | Test concluded |

Table 1. Summary of Door Constructions

| Door Ref. | Construction | Thickness (mm) | Depth of Rebate (mm) | 'FIT' (Approx) (mm) | Type of Seal | Approximate Area of Glass (m ²) | Pane Size (mm) | GLAZING BEAD | | |
|----------------|--------------|----------------|----------------------|---------------------|--------------|---|----------------|--------------|------------------|---|
| | | | | | | | | Section (mm) | Rebated one side | Type of treatment |
| A ₁ | 459* | 45 | 25 | >3.0 | None | 0.37 | 510 x 740 | 19 | Yes | None |
| A ₂ | 459 | 45 | 25 | 1.5 | None | 0.37 | 510 x 740 | 19 | Yes | None |
| B ₁ | Fully Glazed | 45 | 12.5 | 1.5 | None | 3 x 0.31 = 0.93 | (530 x 585)x 3 | 19 | Yes | None |
| B ₂ | Fully Glazed | 45 | 12.5 | 1.5 | None | 3 x 0.31 = 0.93 | (530 x 585)x 3 | 19 | Yes | 1. None 2. Int. Paint ⁺ 3. Non Combustible |
| C ₁ | 459 | 45 | 12.5 | 3.0 | None | 0.37 | 300 x 1200 | 13 | | None |
| C ₂ | 459 | 45 | 12.5 | 3.0 | IS* | 0.37 | 300 x 1200 | 13 | | Int. Paint ⁺ |
| D ₁ | Fully Glazed | 45 | Swing | <1.0 | None | 0.93 | 1675 x 550 | 13 | | None |
| D ₂ | Fully Glazed | 45 | Swing | <1.0 | IS | 0.93 | 1675 x 550 | 13 | | None |
| E ₁ | Chipboard | 40 | 12.5 | 1.5 | IS | Nil | - | - | - | - |
| E ₂ | Chipboard | 40 | 12.5 | 1.5 | IS | Nil | - | - | - | - |
| F ₁ | 459 | 40 | 19 | 1.5 | IS | Nil | - | - | - | - |
| F ₂ | 459 | 40 | 19 | 1.5 | IS | Nil | - | - | - | - |
| G ₁ | 459 | 40 | 25 | 1.5 | None | 0.23 | 480 x 480 | 13 | | None |
| G ₂ | 459 | 40 | 25 | 1.5 | P.V.C. | 0.23 | 480 x 480 | | | Aluminium |
| H ₁ | 459 | 45 | 25 | 1.5 | None | 0.25 | 750 x 300 | 13 | | None |
| H ₂ | 459 | 45 | 25 | 1.5 | None | 0.25 | 750 x 300 | | | P.V.C. |
| I | 459 | 55 | 25 | 1.5 | 2 x IS | 0.36 | 1200 x 300 | | | Steel |
| J | Chipboard | 55 | 25 | 1.5 | 2 x IS | 0.50 | 1200 x 300 | | | Steel |

* 459 - Denotes door to B.S. 459 Construction where applicable

* IS - Denotes Intumescent Strip Seal

+ Int. Paint - Denotes Fire Retardant Intumescent Paint

Table 4. Summary of results showing performance of door/frame assembly

| Door | Direction | Pressure | Time of gap formation (min) | Time of ignition of unexposed face at edge (min) | Test operation (min) |
|----------------|-----------|----------|--------------------------------|---|----------------------------|
| A ₁ | | | 20 | 22 | 30 |
| A ₂ | R | Positive | Not observed | 12 $\frac{1}{4}$ | 30 |
| B ₁ | | | 22 | 25 | 30 |
| B ₂ | R | | 26 | None | 31 |
| C ₁ | | | 12 | 15 | 20 |
| C ₂ | | | Not observed | Not observed | 33 |
| D ₁ | | | 11 $\frac{1}{2}$ | 14 $\frac{1}{2}$ | 20 |
| D ₂ | | | Not observed | Not observed | 31 |
| E ₁ | | | 30 | 35 | 39 |
| E ₂ | R | | 21 | Not observed | 30 |
| F ₁ | | | 30 | 26 (on face) | 39 |
| F ₂ | R | | Not observed | Not observed | 33 |
| G ₁ | | | 23 | Not observed | 35 |
| G ₂ | R | Positive | Not observed | 25 | 30 |
| H ₁ | | | 26 | Not observed | 35 |
| H ₂ | R | | 18 | 20 | 30 |
| I | R | | 55 | 34 $\frac{3}{4}$ | 65 |
| J | | | Not observed | Not observed | 66 |

R denotes door opening towards furnace (stops exposed to heating)

Table 5. Summary of test results showing performance of glazing

| Door | Time of ignition of beading (min) | Test duration (min) | Radiation falling on beading at 20 min (kW m ²) | Comments |
|----------------|-----------------------------------|---------------------|---|--|
| A ₁ | 27½ | 30 | 2.7 | Radiation failure |
| A ₂ | 17 | 30 | ... | Positive pressure, flame transfer from top of door |
| B ₁ | 22½ | 30 | 4.6 | Radiation failure |
| B ₂ | 30½ | 31 | | Radiation failure (treated bead flashed from untreated bead above) |
| C ₁ | Not observed | 20 | 9.6 | Test stopped 20 min |
| C ₂ | 28 | 33 | | Flames under bead |
| G ₁ | 21½ | 35 | | Radiation failure, glass fell out at end of test |
| G ₂ | 17 | 30 | | Positive pressure, glass fell at 25 min |
| H ₁ | 18¾ | 35 | | Flames under bead |
| H ₂ | 23½ | 30½ | | Flames under bead |
| D ₁ | Not observed | 20 | 5.4 | Test stopped 20 min |
| D ₂ | 25 | 31 | | |
| I | 55¾ | 65 | | 1 hr door |
| J | 40 | 65 | | 1 hr door |

Table 6. Ranking of doors in order of failure times

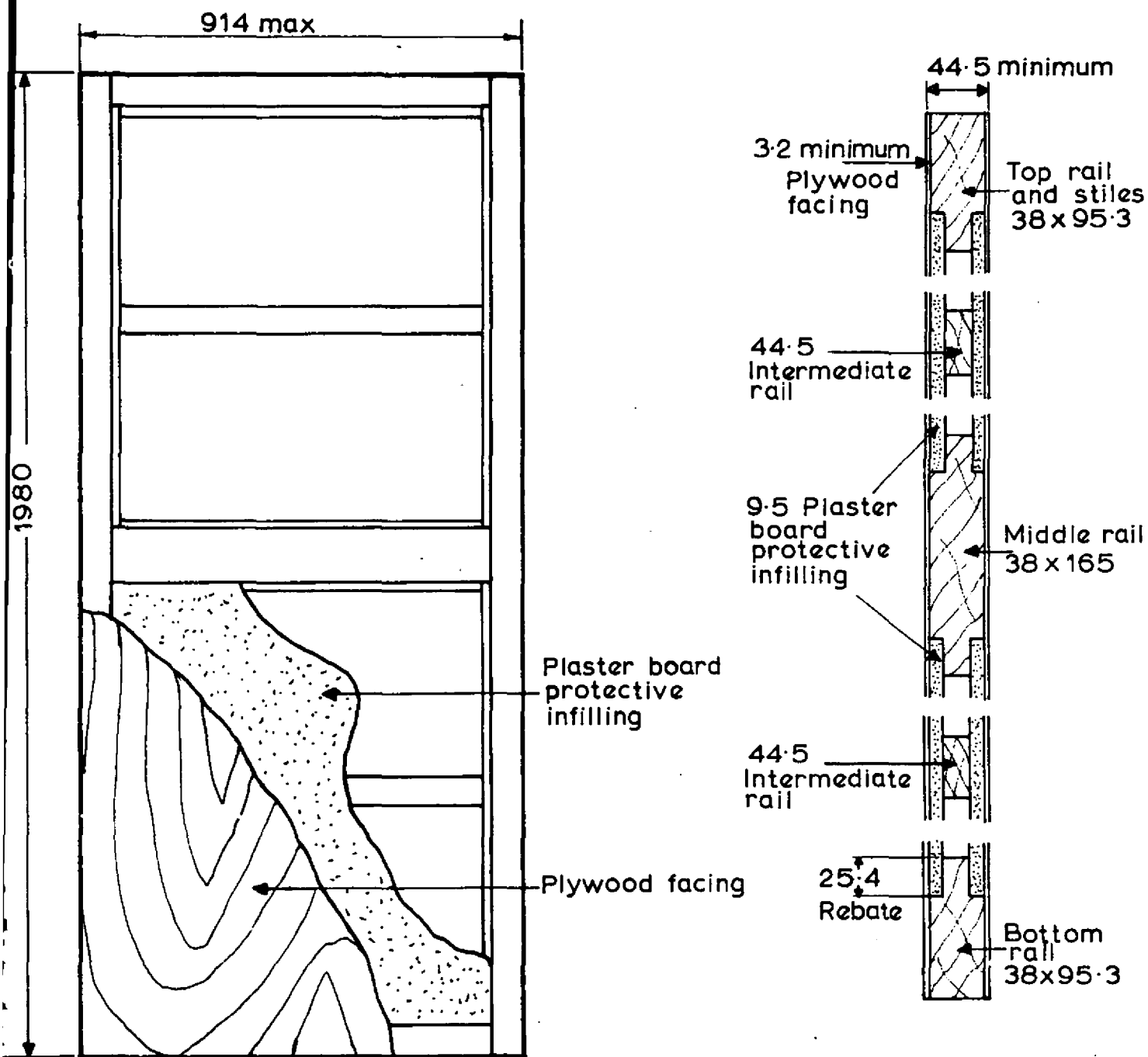
| | Overall failure Door Time (min) | | Edge failure Door Time (min) | | Glazing failure Door Time (min) | |
|----|------------------------------------|-----|---------------------------------|-----|------------------------------------|-----|
| 1 | D ₁ | 11½ | D ₁ | 11½ | A ₂ | 17 |
| 2 | C ₁ | 12 | C ₁ | 12 | G ₂ | 17 |
| 3 | A ₂ | 12¼ | A ₂ | 12¼ | H ₁ | 18¾ |
| 4 | G ₂ | 17 | H ₂ | 18 | G ₁ | 21½ |
| 5 | H ₂ | 18 | A ₁ | 20 | B ₁ | 22½ |
| 6 | H ₁ | 18¾ | E ₂ * | 21 | H ₂ | 23½ |
| 7 | A ₁ | 20 | B ₁ | 22 | D ₂ | 25 |
| 8 | G ₁ | 21½ | G ₁ | 23 | A ₁ | 27¼ |
| 9 | E ₂ | 21 | G ₂ | 25 | C ₂ | 28 |
| 10 | B ₁ | 22 | B ₂ | 26 | B ₂ | 30½ |
| 11 | D ₂ | 25 | H ₁ | 26 | C ₁ | 20+ |
| 12 | B ₂ | 26 | F ₁ * | 30 | D ₁ | 20+ |
| 13 | F ₁ | 26 | E ₁ * | 30 | I | 55¾ |
| 14 | C ₂ | 28 | F ₂ * | 33+ | J | 40 |
| 15 | E ₁ | 30 | C ₂ * | 33+ | | |
| 16 | F ₂ | 33+ | D ₂ * | 31+ | | |
| 17 | I | 34¾ | I* | 34¾ | | |
| 18 | J | 40 | J* | 65+ | | |

* Denotes use of intumescent strip

+ Denotes test terminated at this time

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All dimensions in millimetres - 25.4mm=1in

FIG. 1. HALF-HOUR TYPE FIRE-CHECK FLUSH DOOR
TO B.S. 459 : PART 3 : 1951

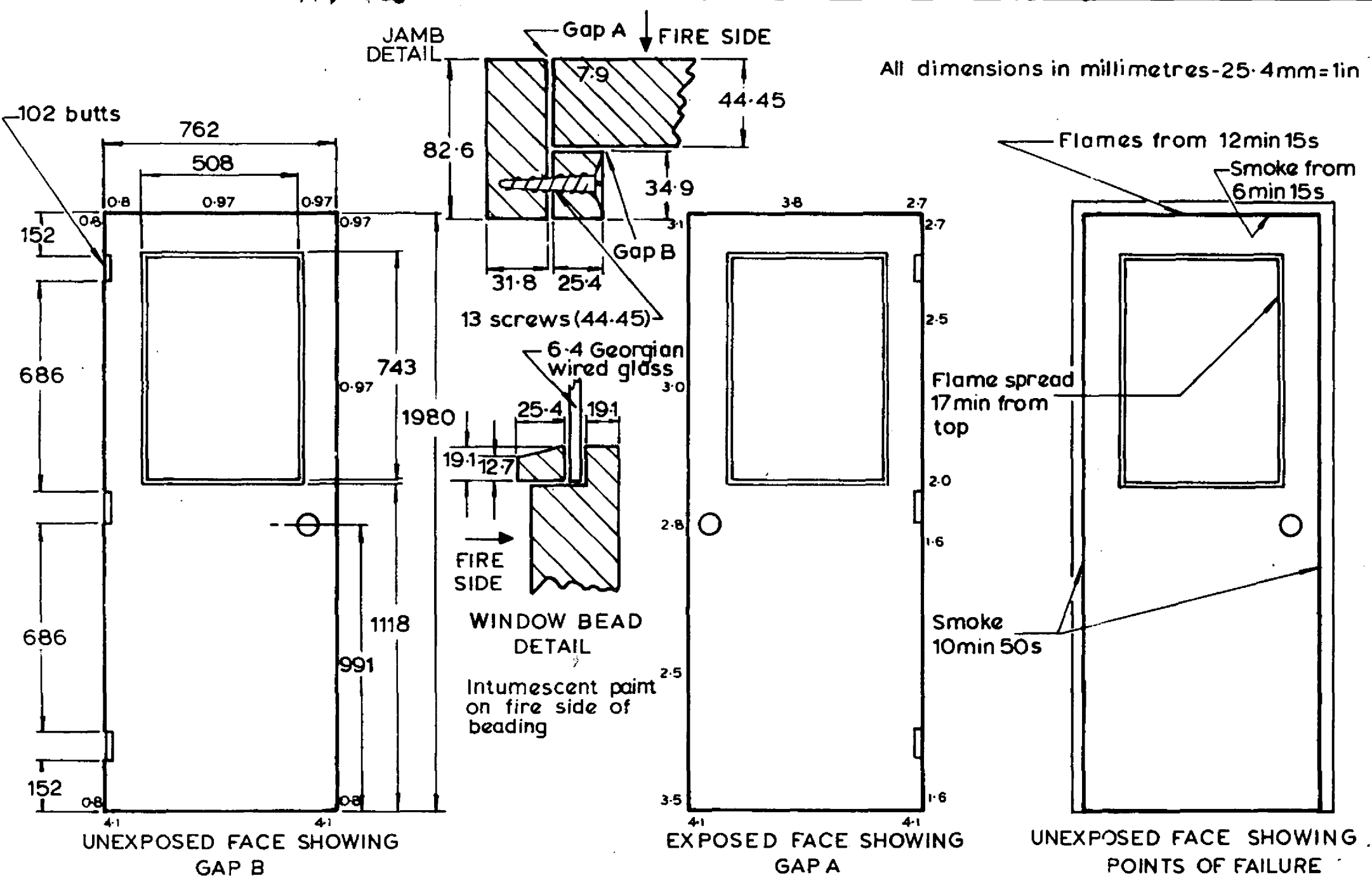
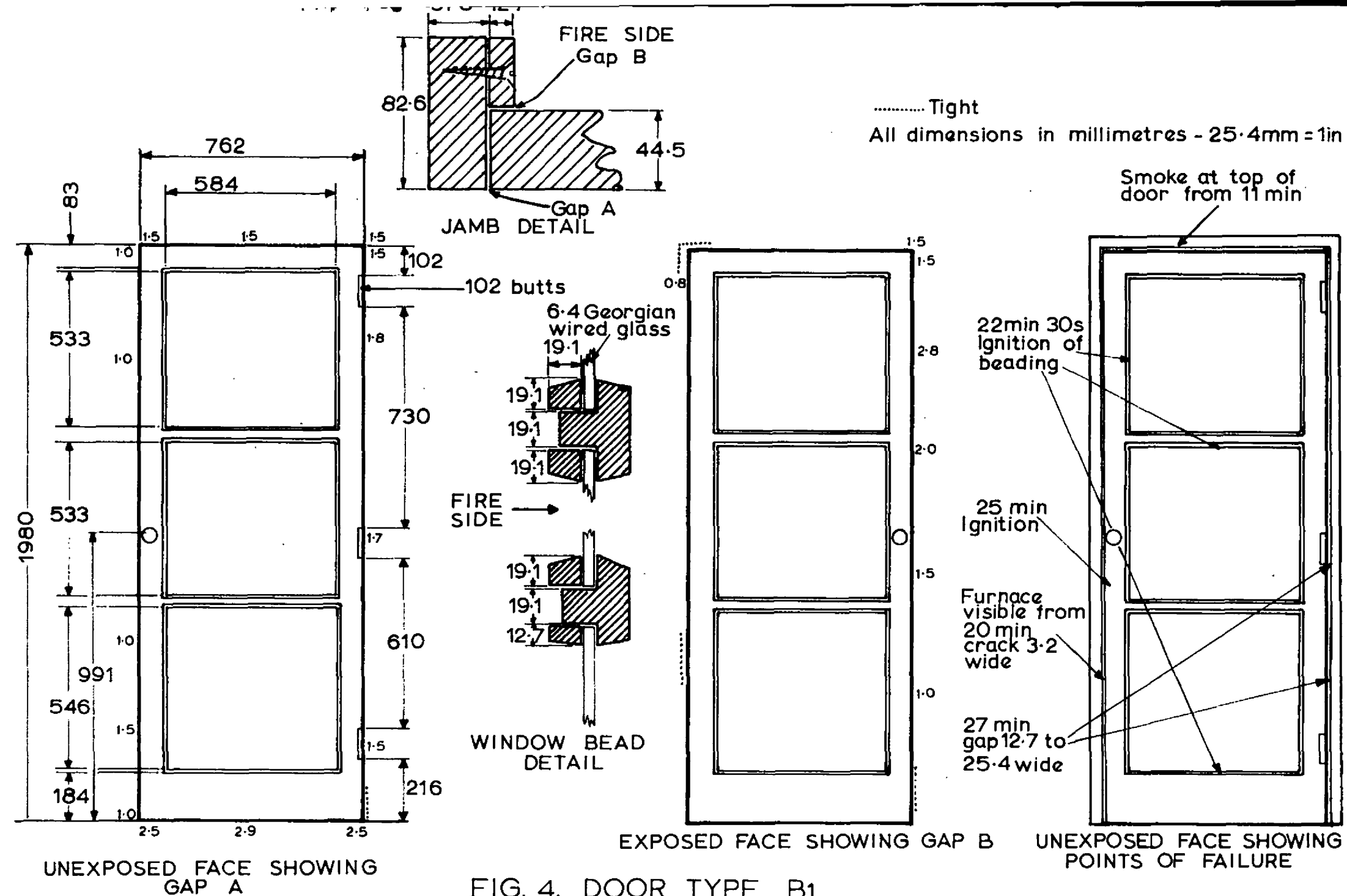


FIG.3 DOOR TYPE A2



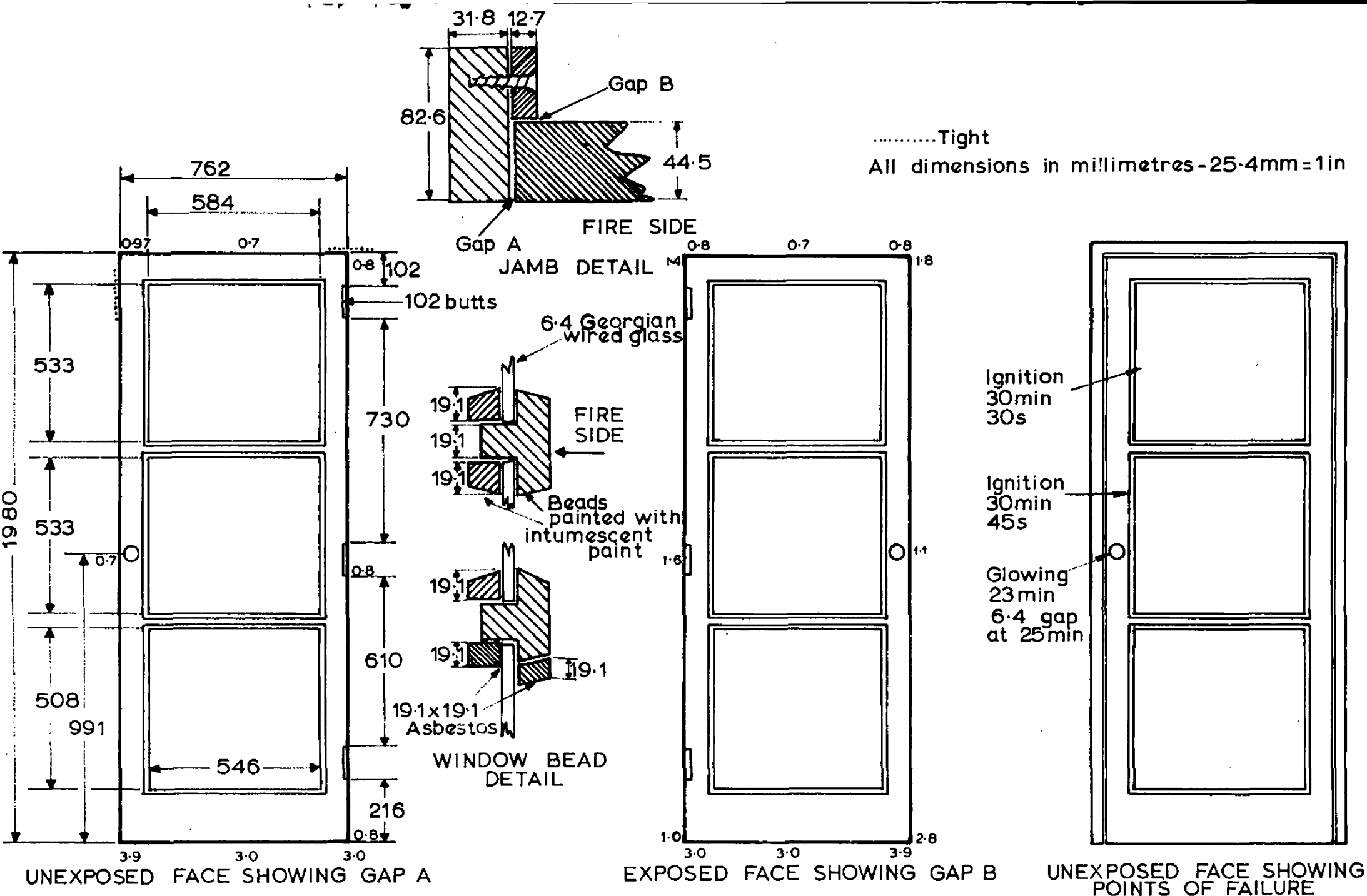


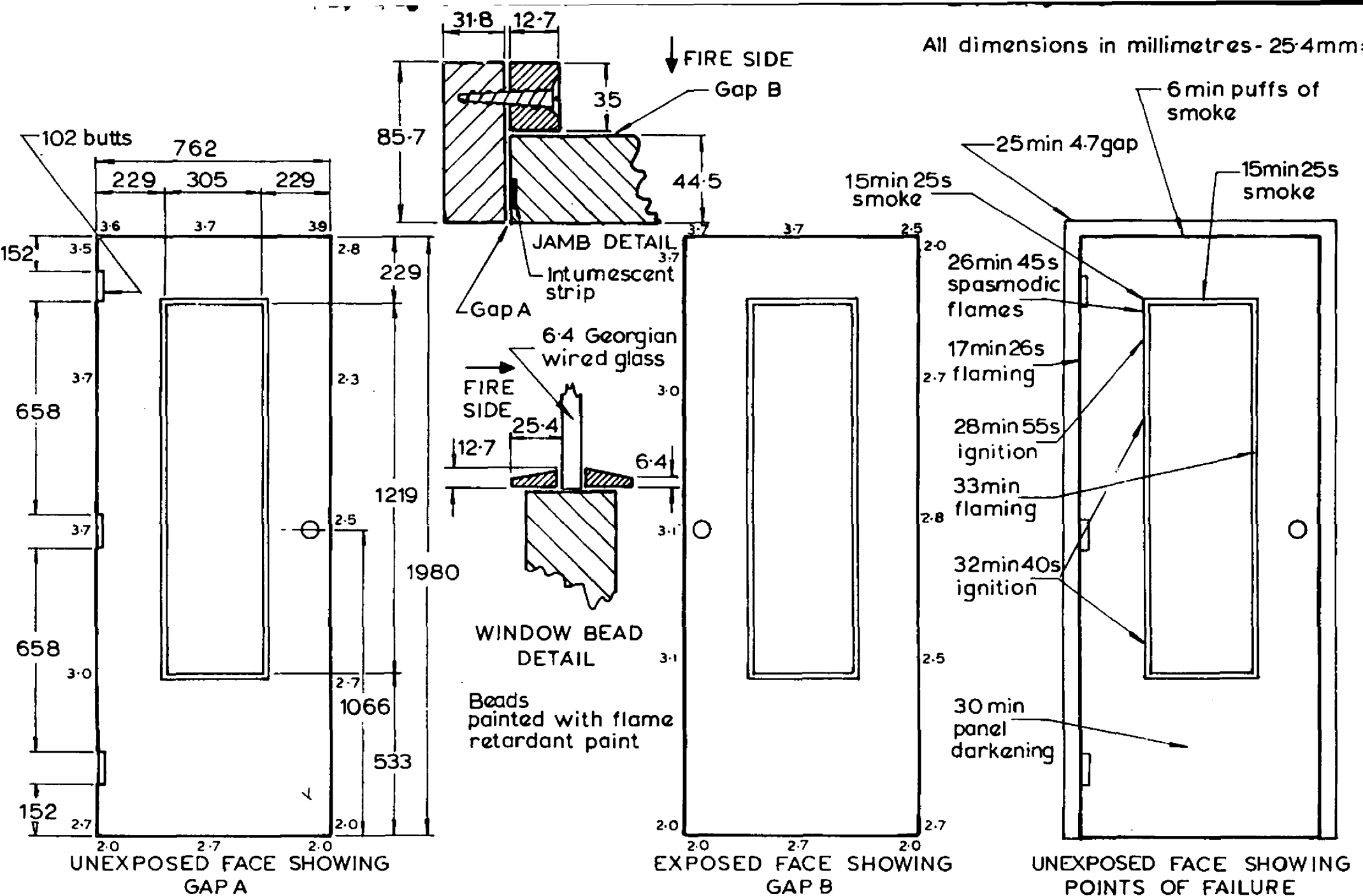
FIG. 5. DOOR TYPE B2

[illegible]

UNEXPOSED FACE SHOWING POINTS OF FAILURE

FIG. 6. DOOR TYPE C1

All dimensions in millimetres- 25.4mm=1in

FIG. 7 DOOR TYPE C₂

All dimensions in millimetres
25.4 mm = 1 in
..... Tight

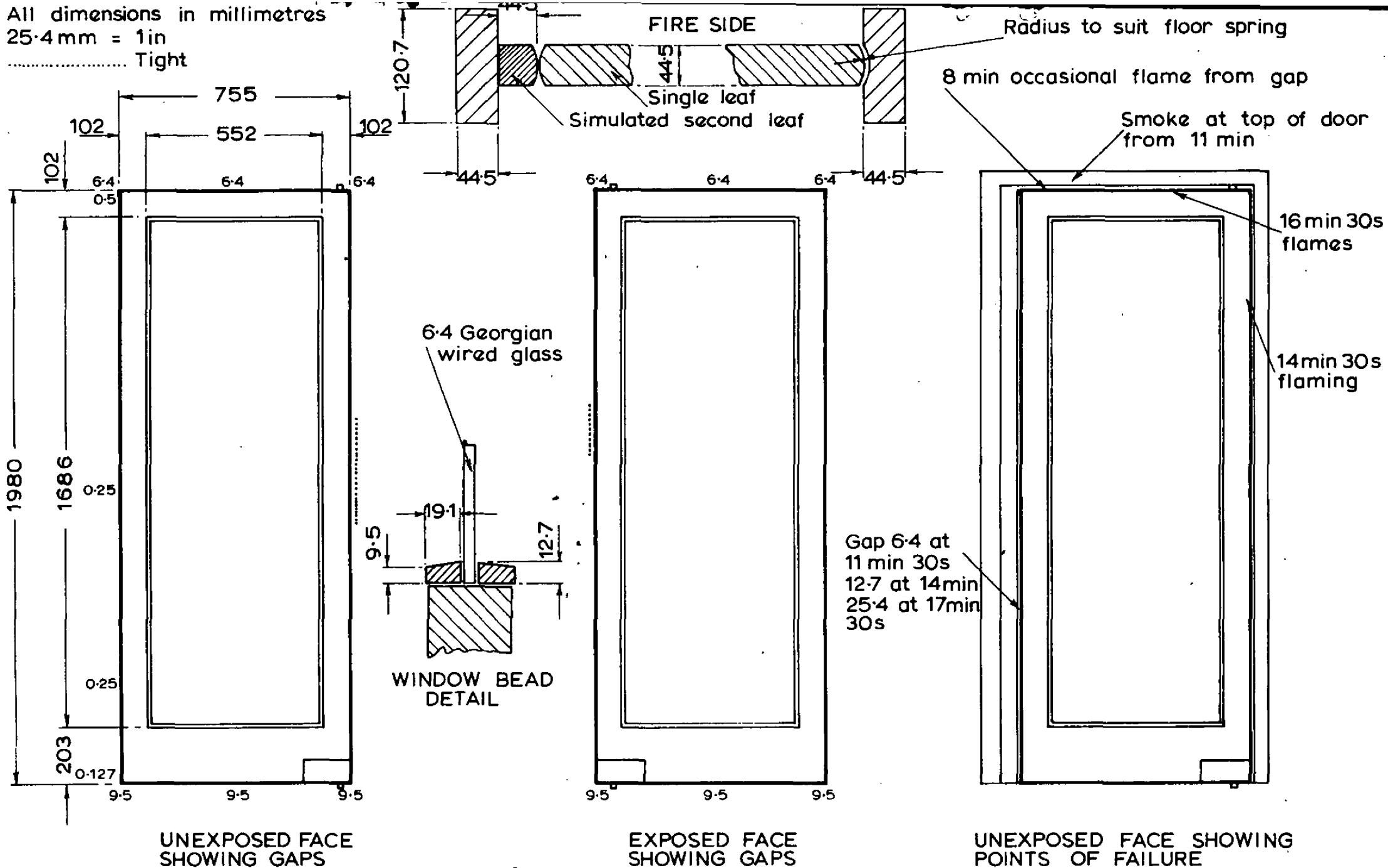


FIG.8. DOOR TYPE D₁ (SINGLE LEAF OF A SWING DOOR)

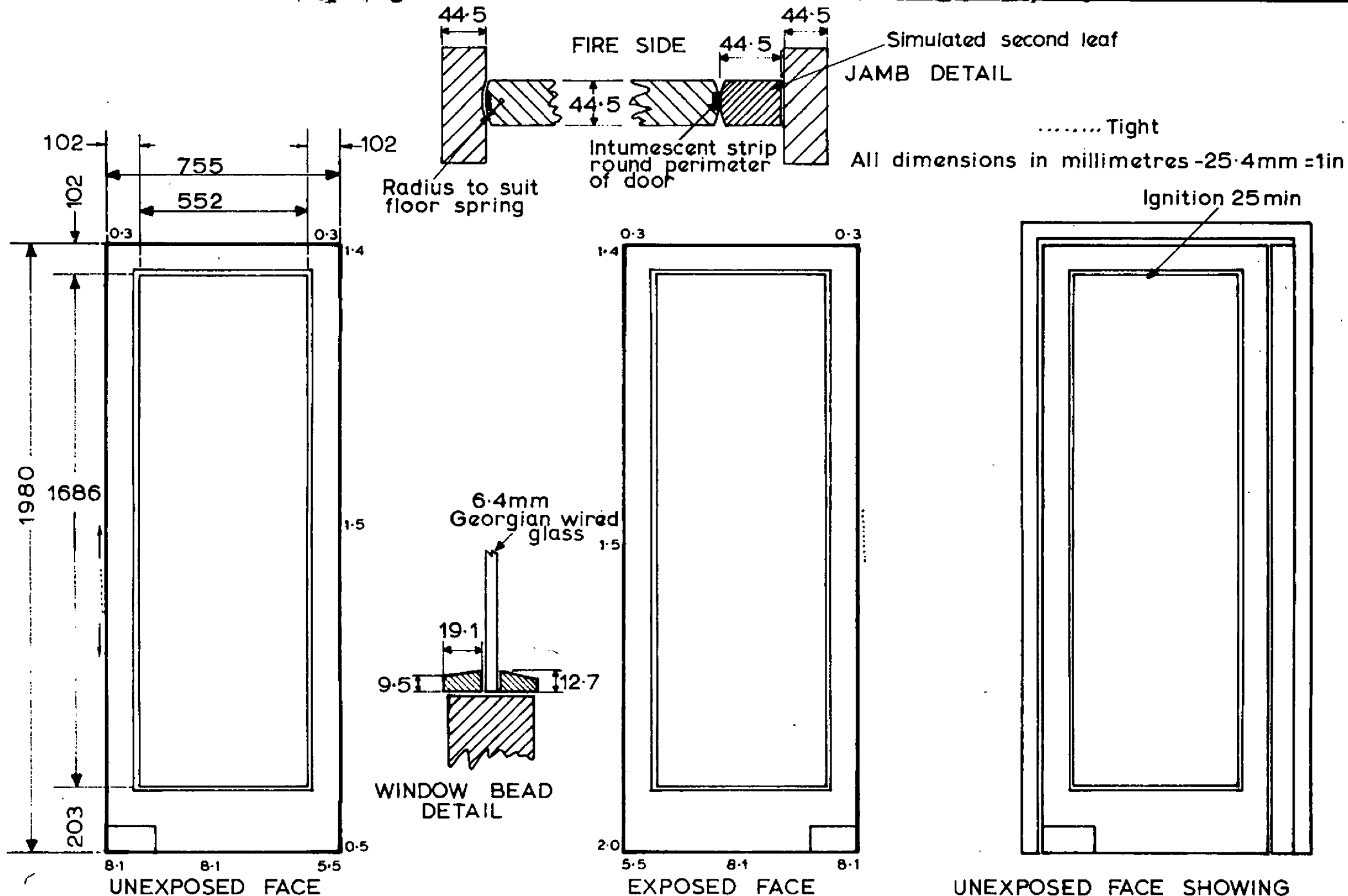


FIG. 9. DOOR TYPE D2

Technical drawing of a rectangular structure with dimensions and labels. The overall width is 762 and the overall height is 1980. The drawing includes various internal dimensions and labels:

- Top width segments: 1.4, 1.6, 1.6
- Top right corner dimensions: 2.0, 229
- Right side height segments: 1219, 1.4, 229
- Bottom right corner dimensions: 2.5, 229
- Bottom width segments: 2.7, 3.1, 3.6, 3.6
- Left side height segments: 991, 2.7
- Internal horizontal dimension: 1.4
- Label: 76 butts

31.8 12.7

76.2

38.1

FIRE SIDE

Gap B

40 chipboard solid

JAMB DETAIL

Gap A

Intumescent strip

38min flaming

35min flaming

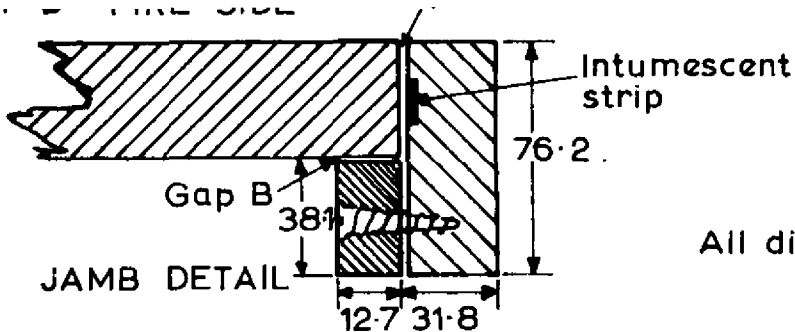
30 min bowing to produce gap

1.6 0.8 0.7 .25

UNEXPOSED FACE SHOWING
POINTS OF FAILURE

FIG.10 DOOR TYPE E₁

40
Chipboard
solid



All dimensions in millimetres-25.4mm=1in

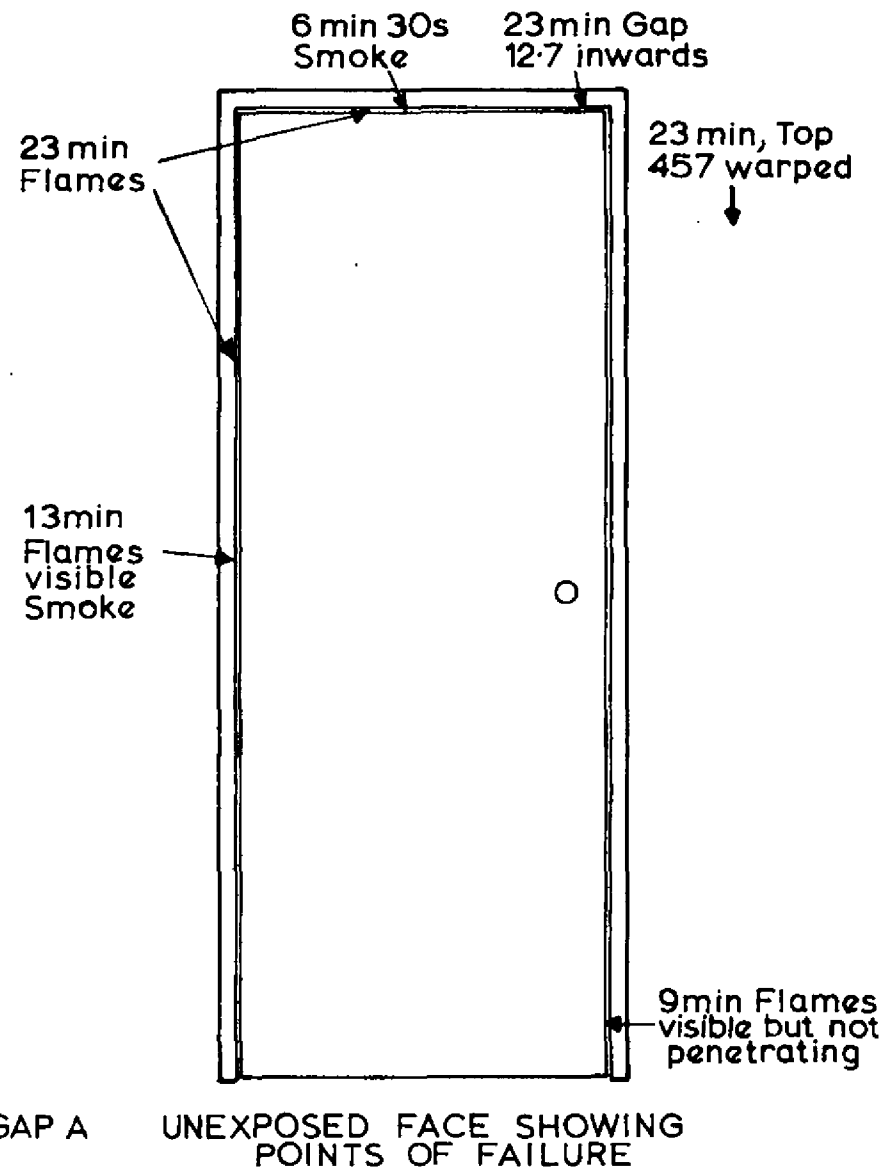
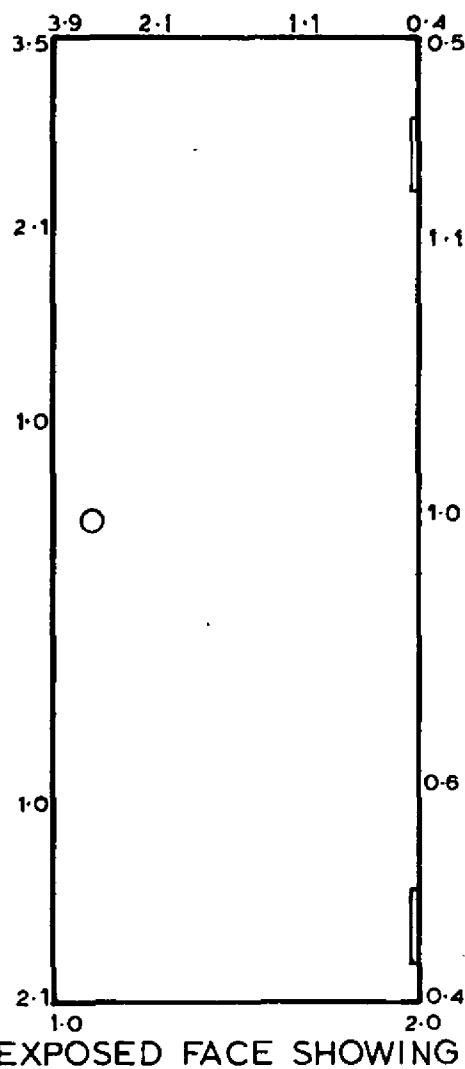
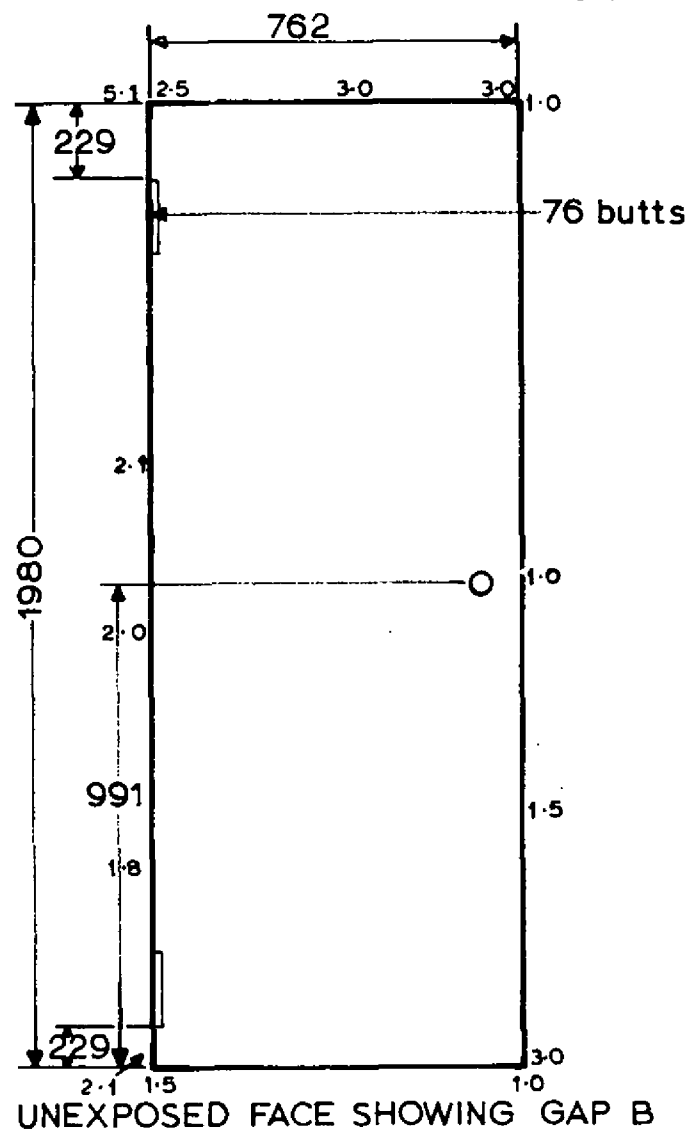


FIG.11. DOOR TYPE E2

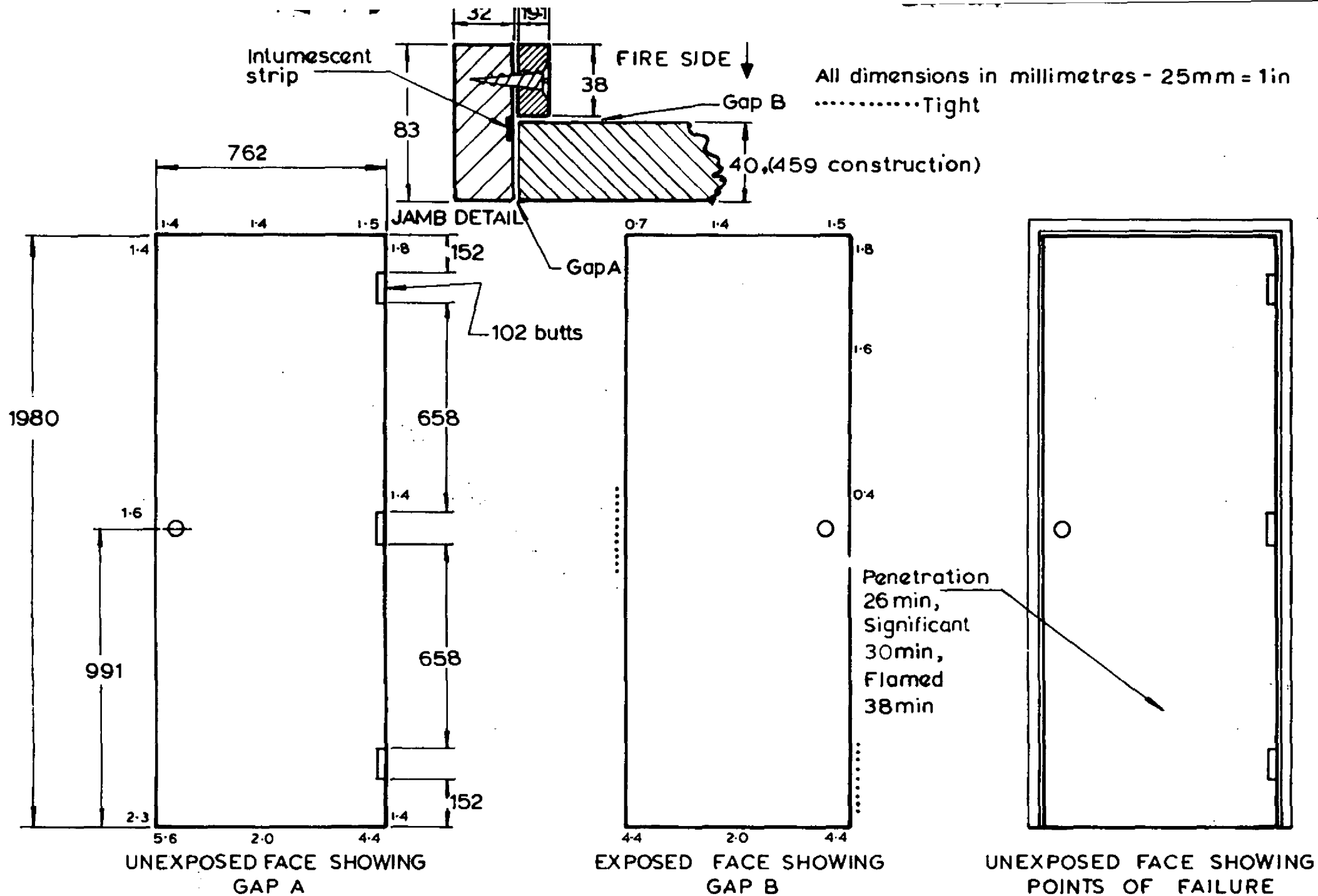


FIG.12 DOOR TYPE F₁

UNEXPOSED FACE SHOWING
POINTS OF FAILURE

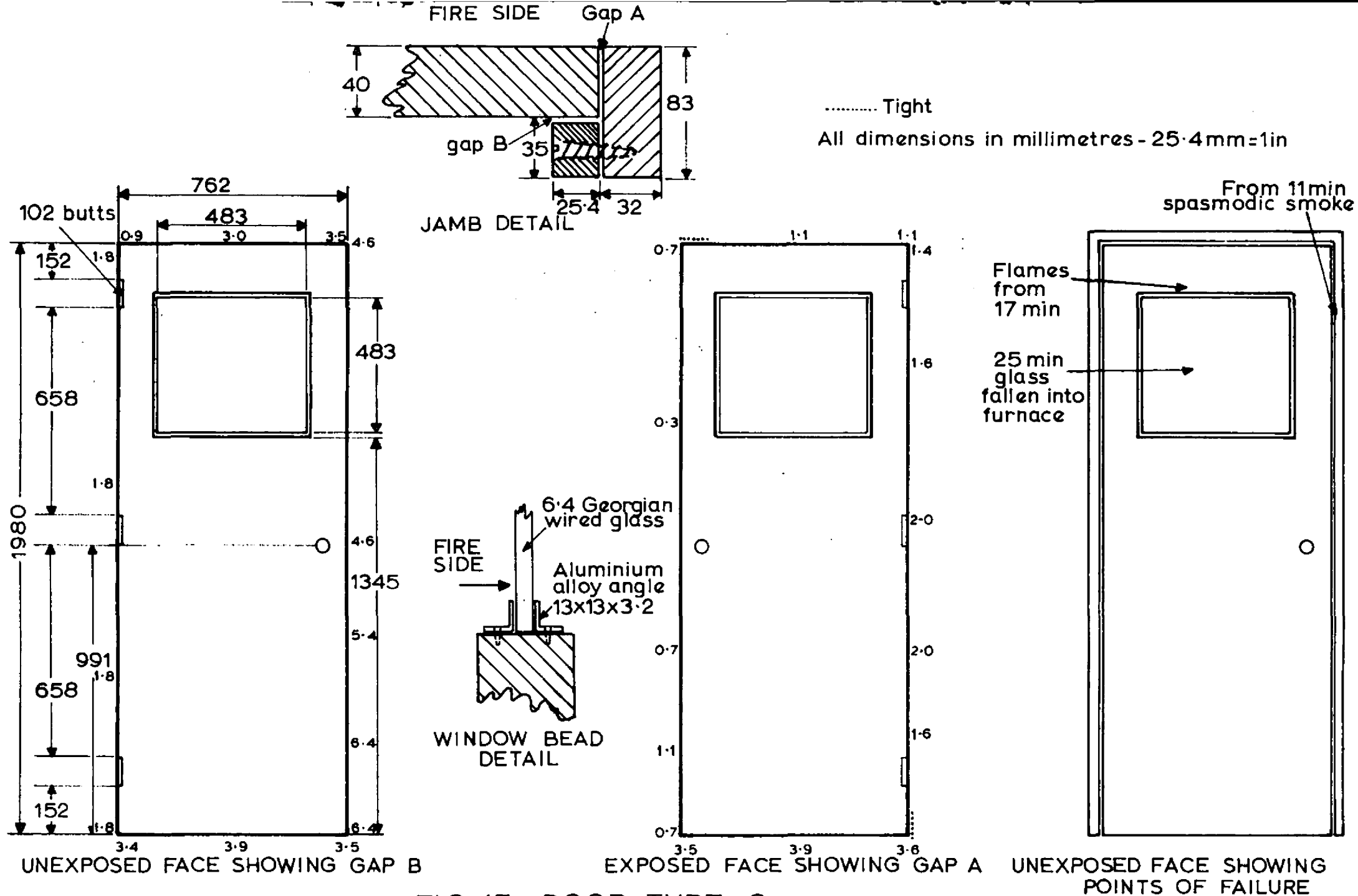


FIG.15. DOOR TYPE G2

All dimensions in millimetres — 25.4mm = 1in
 Tight

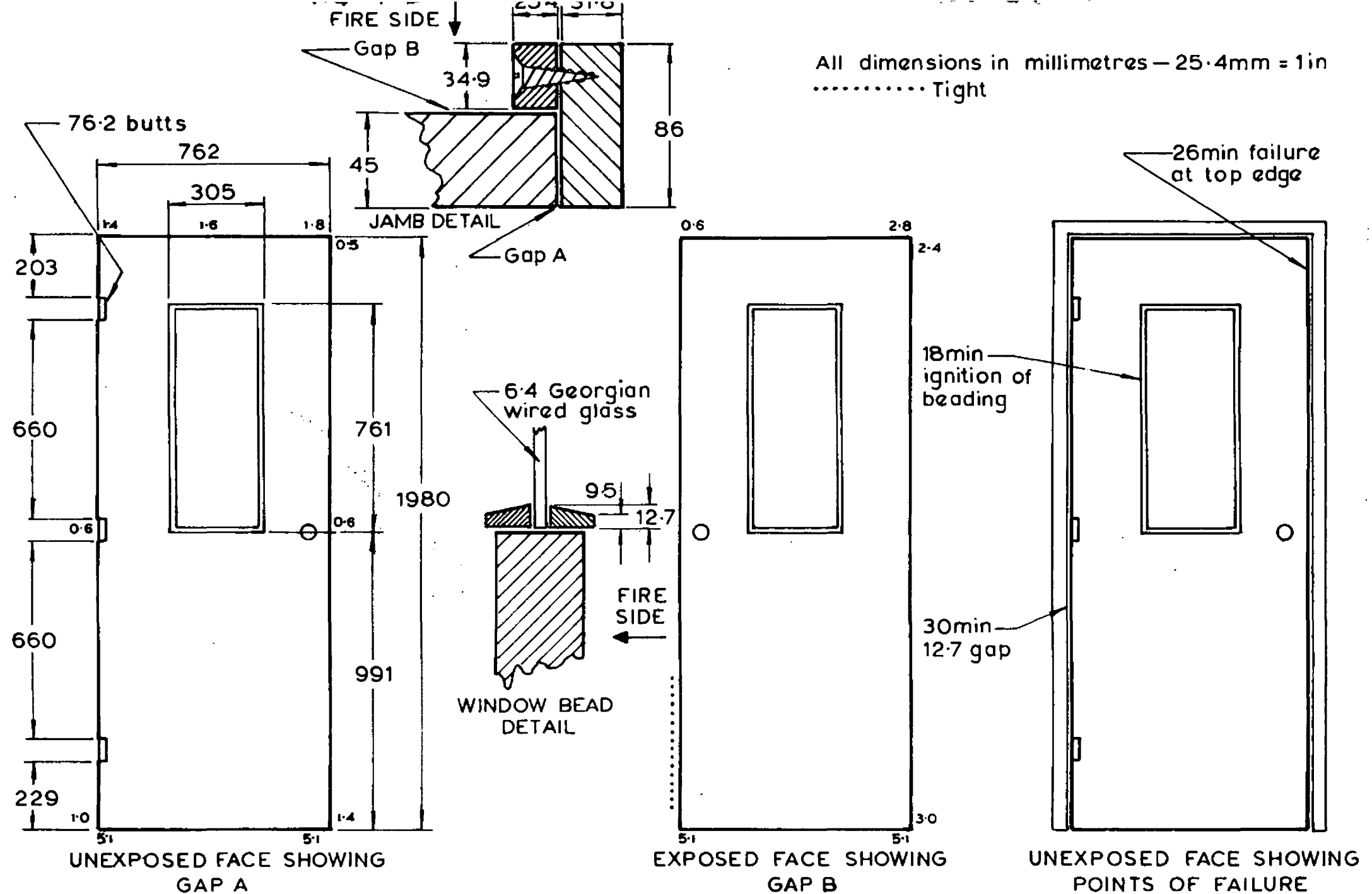


FIG.16 DOOR TYPE H1

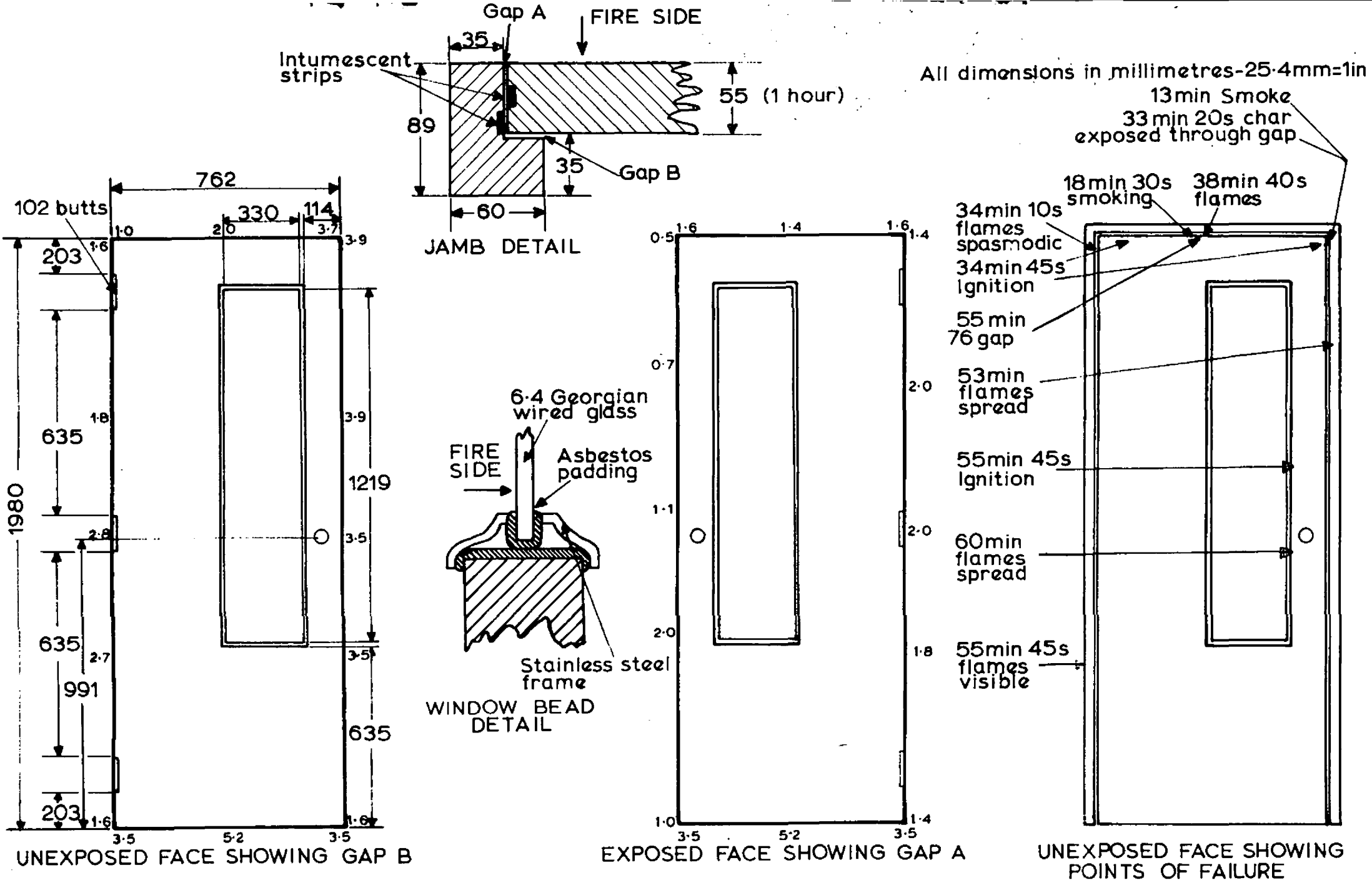


FIG. 18. DOOR TYPE I

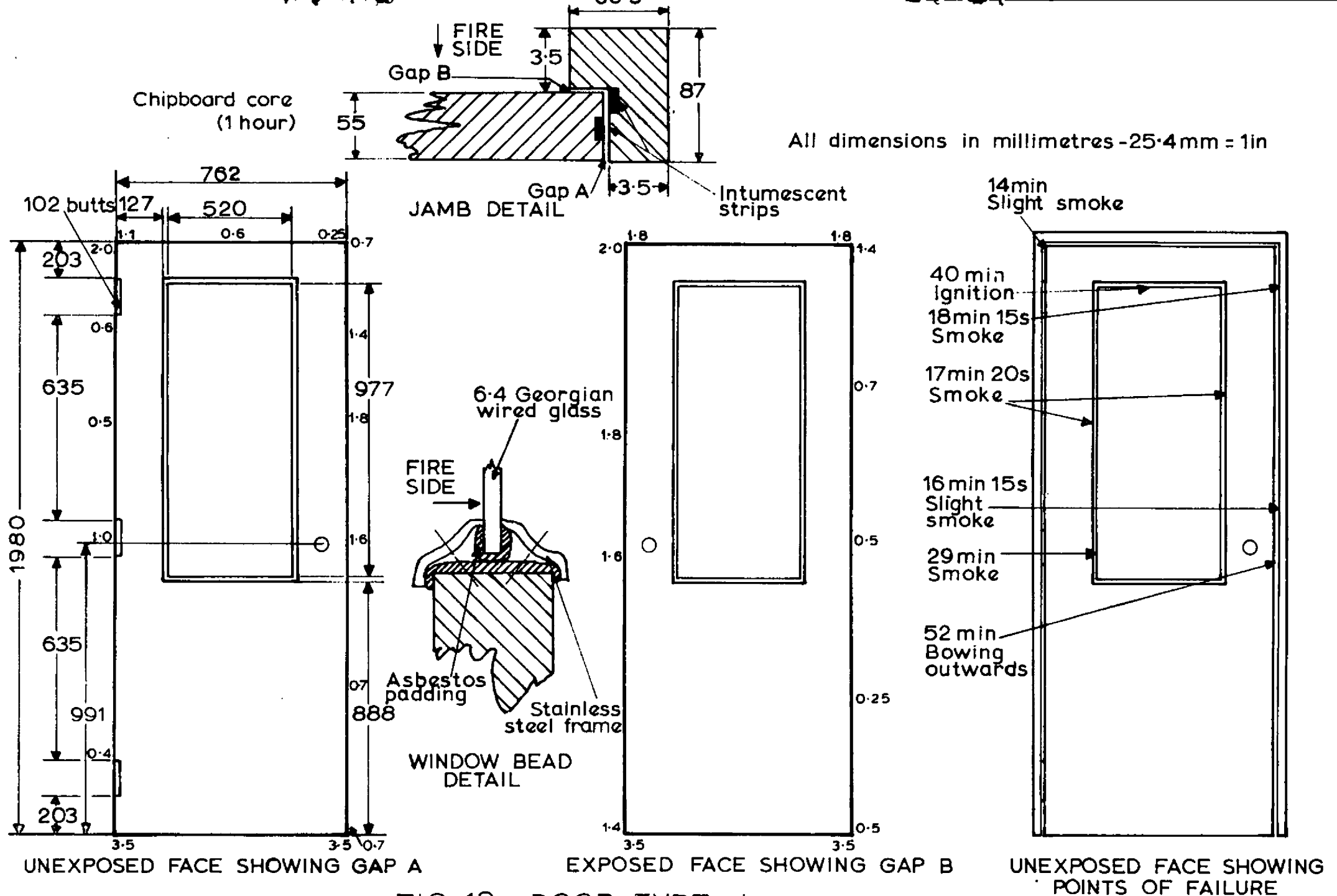
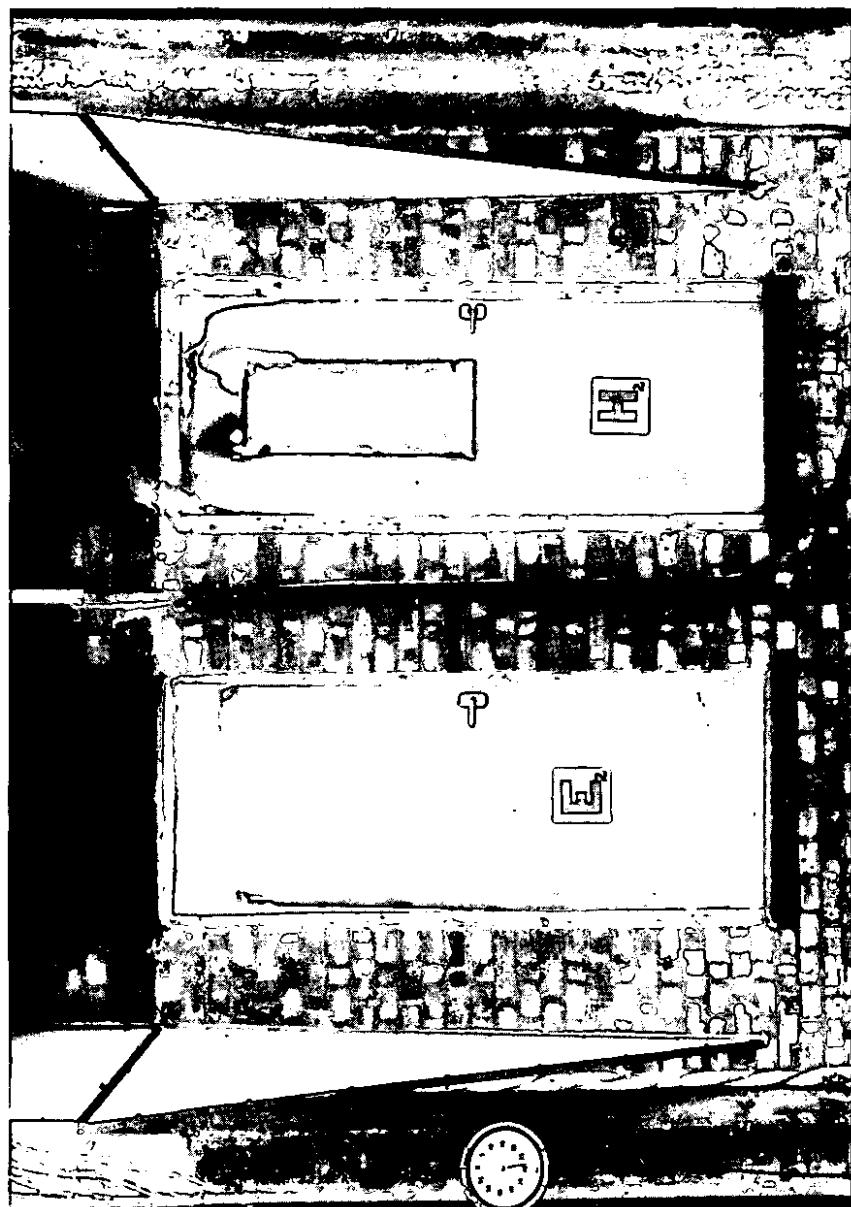


FIG. 19. DOOR TYPE J



FLAMES PENETRATING AROUND THE DOOR EDGES 17 MINUTES
AFTER THE START OF A TEST
PLATE 1



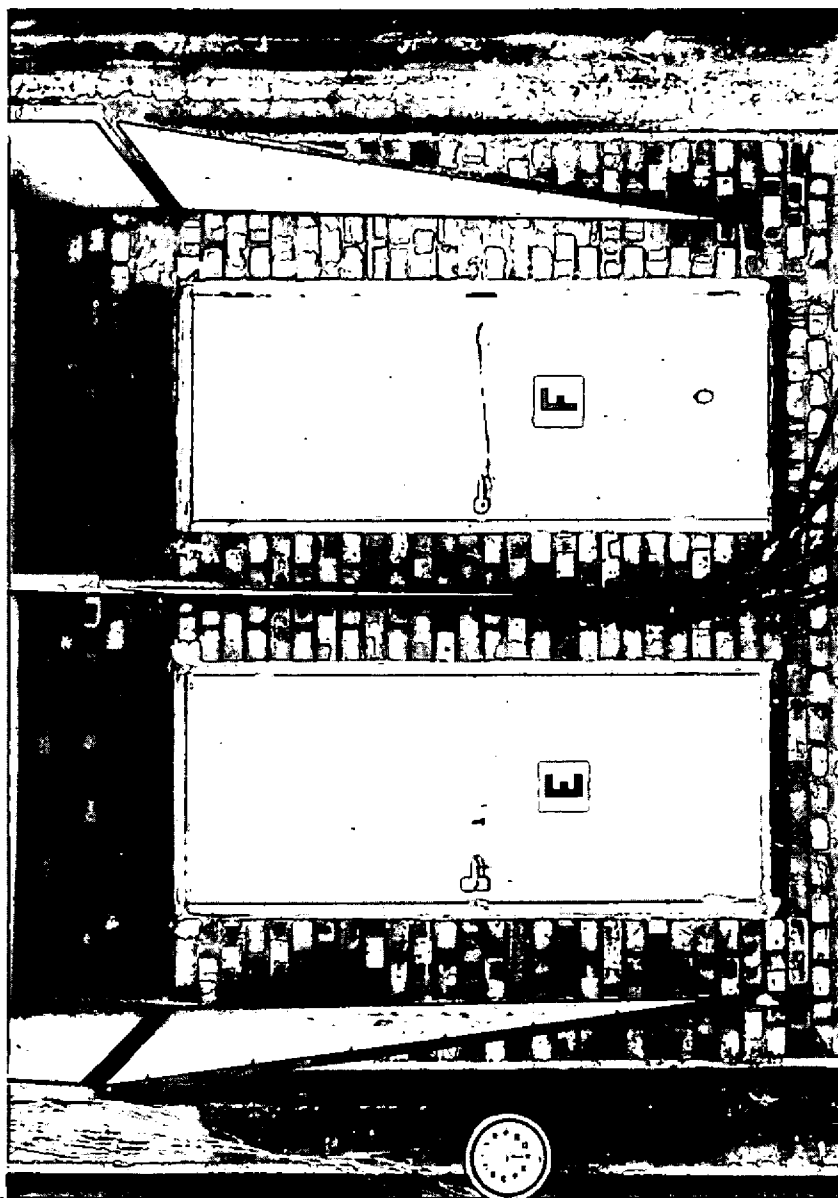
SEVERE BOWING OF A DOOR HUNG ON ONLY TWO HINGES (DOOR E)

PLATE 2



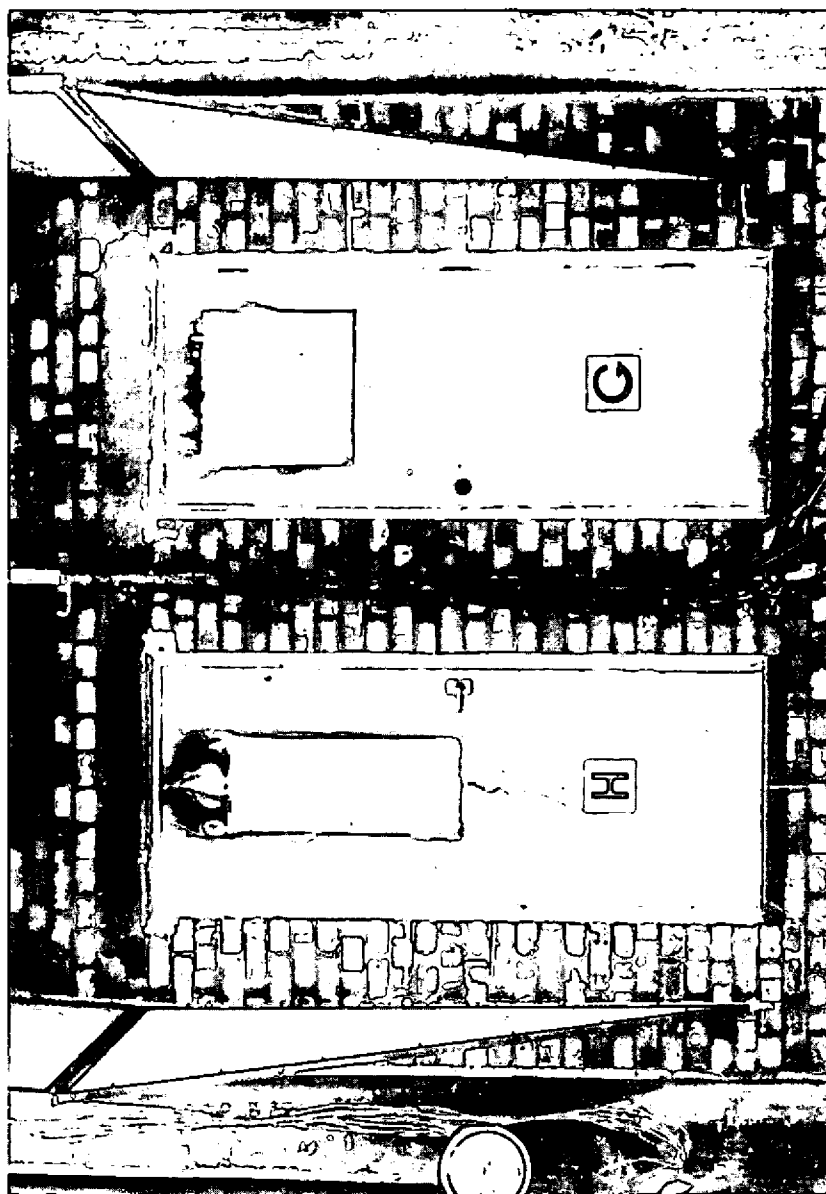
DOORS HAVING THE EDGES SEALED WITH AN INTUMESCENT
STRIP AFTER 30 MINUTES OF TEST. DOOR 'C' IS A POOR FIT

PLATE 3



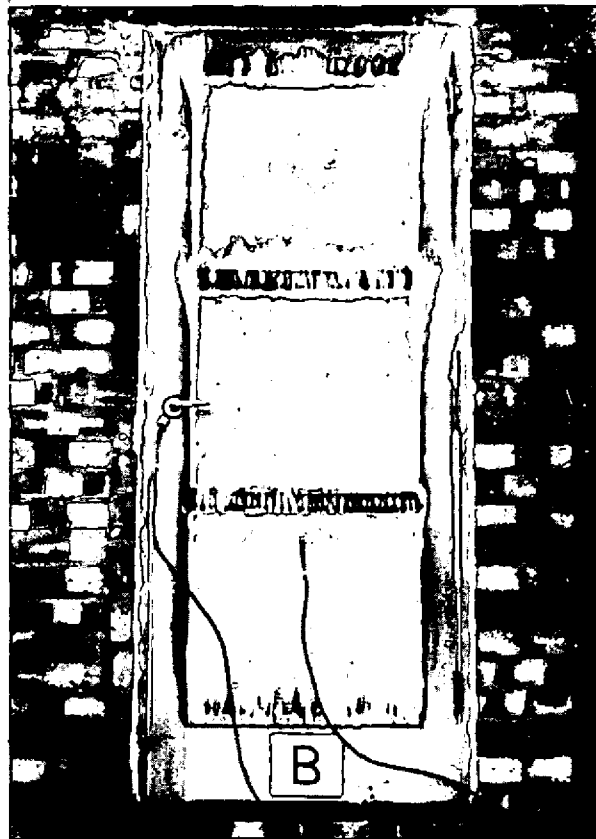
PENETRATION THROUGH THE FACE OF DOOR 'F', A 40 mm DOOR

PLATE 4



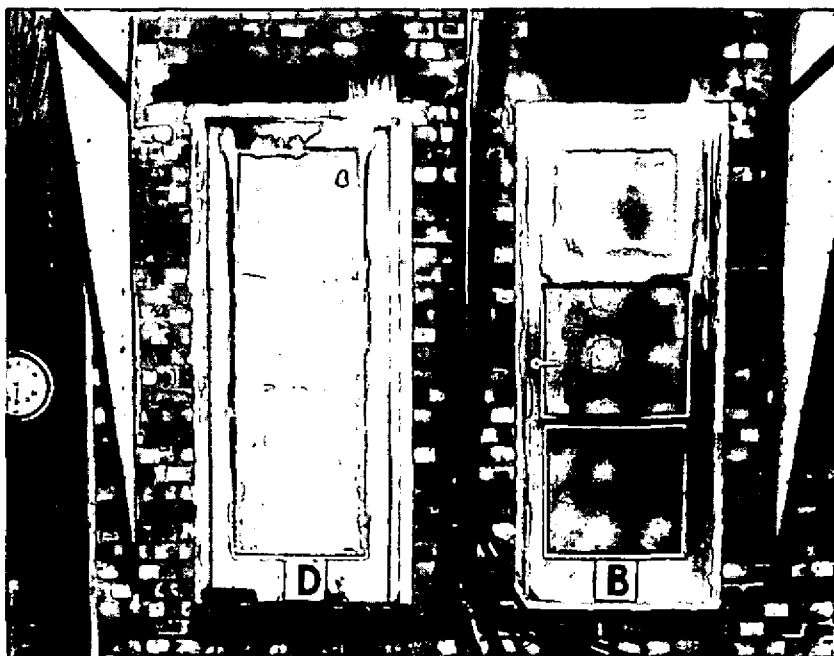
TYPICAL FAILURE DUE TO HEAT TRANSFER THROUGH GLAZING

PLATE 5



FLAMING OF GLAZING BARS 23 MINUTES AFTER
START OF TEST

PLATE 6



FLAMING OF THE UNPROTECTED BEADING AT $30\frac{1}{2}$ MINUTES
AFTER THE START OF TEST - PROTECTED BEADS STILL NOT IGNITED

PLATE 7



FLAME PENETRATION BENEATH THE BEAD WHEN THE
GLAZING IS NOT LOCATED IN A REBATE



COLLAPSE OF THE GLAZING RETAINED BY ALUMINIUM BEADS (DOOR G_2)

PLATE 9



EXCESSIVE DISTORTION OF THE GLAZING SUBFRAMES
BECAUSE NO ALLOWANCE HAS BEEN MADE FOR EXPANSION

PLATE 10

▷

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