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MAXIMUM SIZES FOR FIRE RESISTING DOORS AND SHUTTERS

by

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

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SUMMARY

It is often necessary to protect openings in fire resisting walls of buildings by means of doors and shutters exceeding appreciably in size specimens which have been subjected to the standard fire test. An examination has been made of the factors affecting the ability of various types of door and shutter to act as barriers to the spread of fire, and how far test data may be safely extended. Recommendations for maximum heights and widths of the different types, except timber doors, have been made, and for the spacing of combustible materials of construction and contents to avoid risk of ignition by heat radiated from doors and shutters of the maximum dimensions.

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1. Introduction

Certain walls of buildings have the function of acting as barriers to fire. Where it is necessary to have openings for transit purposes in such walls the installation of doors or shutters which will give protection at these points of weakness is essential. Walls, and the protective devices for openings, are required to provide "fire resistance", expressed as a period from $\frac{1}{2}$ hour to 6 hours, of a magnitude which is determined by the use and size of a building. Fire resistance is defined in British Standard 476 : Part 1 in terms of a laboratory test made on specimens of the same construction as those intended to be used, but having overall dimensions which are likely to be smaller than those encountered in the building.

For walls the test specimen is full size in thickness but is limited to 3.05 m (10 ft) high and 3.05 m (10 ft) wide. Doors and shutters can only be properly tested as a complete assembly, that is with their frame and all operating hardware. They must therefore be mounted in a brick or concrete wall, and in order to anchor the frame securely it is not feasible to provide a door opening of greater size than about 2.75 m (9 ft) high by 2.5 m (8 ft) wide.

One of the problems in applying the results of fire resistance tests made on specimens of limited size to elements of structure of much larger dimensions in buildings is the absence of any means of confirming the validity of a design based on extrapolation. An analysis of the factors affecting the fire resistance of a structure is possible at present for relatively few types of structural element since the problem is complex, involving many properties of the component materials and their interaction. For walls the difficulty of prescribing a construction exceeding greatly 3 m x 3 m (10 ft x 10 ft) can be overcome to some extent, though not perhaps in the most economic way, by increasing the thickness or applying insulating coatings, so that stability under thermal stresses and thermal movements is assured. With doors and shutters these solutions are not possible, but on the other hand the behaviour of a specimen in the test enables an appraisal to be made of the maximum increase in height and width which can be accepted with a given design to ensure maintaining its fire resistance.

This note has been prepared after an examination of all the data obtained during tests at the Fire Research Station on a large number of doors and shutters of various types and sizes, except on timber doors, which are not amenable to extrapolation, up to the maximum sizes that the furnaces can accept. The objective has been to find a means, if possible, of assigning maximum dimensions to each type for a given period of fire resistance, taking into account the behaviour of the test specimen and the properties of the materials of construction at high temperatures. All the tests were sponsored by manufacturers, and do not represent a systematic series which could cover all the variables. On this account data have not been sufficient to make unequivocal assessments possible in every instance.

2. Fire resistance tests and their relation to buildings

For elements of structure having the function in buildings of separating spaces and acting as barriers to the spread of fire, for example walls, doors and shutters, their suitability for this purpose is judged by the successful compliance of an identical test specimen with three requirements when it is subjected to heat by a suitable furnace in accordance with the standard time/temperature relationship specified in B.S. 476 : Part 1[1]. Observations are made throughout the test to determine the occurrence of failure under any one of these requirements;

(a) Stability. The specimen shall not collapse

(b) Integrity. Cracks, fissures or other orifices through which flame can pass shall not develop

(c) Insulation. The temperature on the unexposed surface of the specimen shall not exceed specified limits.

The time is noted at which the specimen ceases to comply with one or more criteria, or if the test is terminated without failure occurring, the time elapsing from start to finish. The fire resistance of the specimen is that grading period in the following list which is most nearly equal to, but does not exceed, the relevant test period: $\frac{1}{2}$, 1, 2, 3, 4, 6 hours.

For doors, shutters and glazing against which it is not expected that combustible materials will be placed in service, the insulation requirement (c) may be waived. This requirement is intended to be a safeguard against ignition of materials in the spaces adjacent to fire resisting walls by direct heat transmission. It has long been the practice in this country to accept uninsulated steel doors and shutters for providing fire resistance, and therefore when testing such specimens their insulating properties have seldom been measured.

Of the other two criteria for judging performance, stability is unmistakable since the collapse of a specimen can be observed as soon as it occurs. It is, however, such a rare occurrence with doors and shutters, and then only for timber doors, that it can be ignored. In general, collapse would be preceded by deformations leading to integrity failure. The problem of assessing the performance of doors and shutters under fire test conditions is therefore virtually reduced to finding how and when integrity is no longer maintained. With most types of non-loadbearing wall, on the other hand, the critical point in a test is failure by heat transmission, a phenomenon amenable to computation to a large extent. Doors and shutters from their nature as moving elements start with a disadvantage from the integrity point of view, compared with walls, since initially in their closed position they must have clearances at the edges.

The need for protection of openings in walls in buildings by fire resisting doors and shutters arises either for complying with Building Regulations, by-laws, or for insurance purposes. Under statutory requirements a period of fire-resistance is specified for certain walls and the means of protecting openings, usually in the range $\frac{1}{2}$ hour to 4 hours. Any door or shutter having the appropriate grade of fire resistance is acceptable for Building Regulations and by-laws purposes. Doors of not less than one half of the specified fire resistance are usually regarded as a suitable alternative when used as double doors, one on each side of a wall opening.

The Rules of the Fire Offices' Committee[2] give detailed specifications for various types of door and shutter based on experience and the results of tests in accordance with B.S. 476 for a period of not less than 2 hours. The suitability of doors and shutters for inclusion in the Rules is judged not only by test results but also by features which are regarded as essential for reliability in service, such as resistance to impact damage. For each type of door and shutter the Rules specify the maximum height and width of opening for which it can be accepted as a protection, the limiting dimensions being 2.5 m (8 ft) in width and 2.75 m (9 ft) in height, with a maximum area for any type of 5.2 m^2 (56 ft^2). These limiting dimensions are in fact those which are possible with the furnace equipment at the Fire Research Station, although for certain types of door it is possible to accommodate specimens protecting a maximum size of opening of 6.7 m^2 (72 ft^2). The problem of protecting openings in walls by closing devices of greater size than those which can be tested often occurs. One solution is to use double doors, and it is possible to say with a fair degree of confidence that any type of door which has successfully achieved the 2 hour grade of fire resistance can be used to protect for the same period an opening of the largest size which will be required to serve the functions of the building if installed to form double doors.

3. Types of door and shutter

Definitions of the terms "door" and "shutter" are desirable at this stage. In this note a device of one or two panels mounted on the face of the wall, which closes an opening either by moving parallel to the face of the wall, or of panels swinging about an axis at one or both sides of the opening, is termed a door. A shutter is defined as a collapsible device consisting of two or more laminae which either slide in the same direction in the plane of the wall, or roll or coil, or fold when operating. Examples of the whole range of types of door and shutter which have been tested are shown in Figure 1(a) and (b). From their nature, rolling shutters and certain types of folding shutter cannot be constructed of thick plates and therefore these types, being made of relatively thin steel sheet, do not provide insulation.

In those types of door and shutter where thickness is not limited by such operational considerations, it is possible to incorporate suitable insulating materials so that the heat transmitted from the face not exposed to fire can be controlled to reduce the hazard to combustible materials to any desired extent. It is the practice in this country, however, to waive the insulation requirement (11 c) of B.S. 476 : Part 1 when testing doors and shutters. The requirement limits the mean increase in temperature of the unexposed face of the specimen to 139 deg.C and the maximum increase at any point to 180 deg.C, which could only by complied with for the higher periods of fire resistance by constructions of substantial weight and thickness. Experience with uninsulated steel doors and shutters often erected in pairs in actual fires has shown their protective value when closed. The danger of ignition of combustible materials by radiation from such doors and shutters does not appear to be significant in practice, partly, perhaps, because door openings are intended to afford passage between adjacent spaces and therefore goods are not likely to be placed close to them, and partly because combustible parts of construction such as flooring or wall and ceiling linings are generally not close enough to doors to ignite. Such doors are often installed to conform with the requirements of the Fire Offices' Committee which call for double doors. The 18 cm (7 in) air gap between the two doors ensures lower heat transmission than with single doors. Also the Fire Service can cool steel doors from the side not exposed to fire so that the radiation hazard is reduced. Any great increase, however, in the acceptable dimensions of uninsulated doors and shutters based on their ability to act as barriers to flame will entail significantly larger radiation hazards which must be taken into account.

4. Judging the test performance of doors and shutters

The problem of assessing the effect of increase in dimensions of doors and shutters beyond the size of test specimens may appear to be simplified because their mode of failure in the standard test is invariably under the integrity requirement (11 b). In fact the solution is not simple, because, as the British Standard is written at present, the requirement is entirely subjective. The same difficulty has been encountered in testing laboratories in other countries where the maximum acceptable extent of the deformation of doors or the opening of gaps is specified. It is widely recognised that the present methods of judging performance in the test are unsatisfactory, and means of finding technically sound alternatives which relate also to practical conditions are being sought in a Working Group of a Committee of the International Standards Organisation. But until new methods are accepted, failure of test specimens must still be determined by the existing somewhat arbitrary criteria.

The door or shutter assembly for test will have been installed in an opening of a brick or concrete wall so that there are no through gaps at the edges at right angles to the plane of the wall, except at the sill. As the test proceeds deformations of the specimen occur, generally through restraint of thermal movement, which may lead to the appearance of through gaps exceeding in size an arbitrary limit.

For the purpose of this note, in making estimates of deformations, it is necessary to decide on a test period to provide a basis of comparison, and two hours has been adopted since this is generally the maximum requirement and is the standard adopted for the F.O.C. Rules. After 2 hours of test the furnace temperature is about 1000°C. The temperature of a door or shutter at this time depends to a great extent on whether it is insulated or not, and it appears reasonable to assume its rise in temperature to be 900°C. Precise data on the coefficient of expansion of mild steel over this temperature range are not available but it is unlikely that the figure will be very different from 12×10^{-6} per deg.C.

In estimating the effect of increase in dimensions under the specified conditions of a specimen which has been subjected to test, change in height will be considered separately from change in width. It will be assumed that between two points at an edge of a door or shutter where constructional features impose a high degree of fixity, the restraint under thermal expansion leads to the door bending to an arc of a circle. The amount of deformation (d) can be calculated from the formula:

i.e. the deformed height of the door when heated;

i.e. the original height of the door.

$$S = C + \frac{8d^2}{3C}$$

where S is the length of arc i.e. the deformed height of the door when heated
and C is the chord length i.e. original height of the door

This formula is accurate to 1 part in 10000 when d is less than $^C/_{12}$.

Since, $$S = C(1 + \alpha t)$$

where t is the temperature to which the door is heated
and α is its coefficient of linear expansion = 0.000012 per deg.C.

$$\frac{S - C}{C} = \alpha t = \frac{8}{3}\frac{d^2}{C^2}$$

hence,

$$d = C\sqrt{\frac{3}{8}\alpha t}$$

$$= 0.002\ C\sqrt{t}$$

The deflection is proportional to the height of the door and to the square root of the temperature to which it is raised.

If a door 10 ft high were heated to 400°C the deflection would be 0.4 ft at the centre or about 5 in.

With most types of steel door and shutter, deformations in a fire can be reduced by avoiding a close fit between the bottom edge and the sill. Since in a fire air will normally be drawn under the door from its unheated side into the fire area a gap of about 6 mm ($\frac{1}{4}$ in) between door and sill would not impair the value of the door as a fire barrier. Consideration might be given to allowing larger initial clearances than this, since the advantage of expansion gaps in reducing deformations of doors exposed to fire is clear.

When dealing with the hazard of radiated heat from doors and shutters it is necessary to make assumptions of the temperature of their unexposed surface and their emissivity since test data are generally lacking.

5. Effect of increased dimensions on behaviour of different types of door and shutter

(a) Hinged doors. The Rules of the Fire Offices' Committee accept hinged doors of steel, or steel and asbestos up to 2.75 m (9 ft) high and 1.1 m (3 ft 6 in) wide when in one leaf. For protecting wider openings, two-leaf doors up to a maximum width of 2.1 m (7 ft) are required, each leaf not exceeding 1.1 m (3 ft 6 in) wide. With two-leaf doors a rebated joint is necessary at the meeting edges of the two leaves, and in addition to a central bolt or latch each leaf must be secured by a bolt at top and bottom. It is doubtful if there is likely to be a demand for hinged doors greatly in excess of the permitted dimensions in the F.O.C. Rules, since they would be inconvenient, and for protecting such large openings other types would be preferred. The effect of a small increase in size will, however, be examined.

During the early stages of exposure to heat a door expands to close gaps between its edges and the frame or between adjacent leaves. As the temperature of the door continues to rise the restraint provided by the frame and any fixing points such as hinges or bolts will cause it to distort. When the edge of a hinge door bows perpendicular to the wall to form a clear gap of at least 6 mm ($\frac{1}{4}$ in) beyond its frame failure is deemed to have occurred. The amount of deformation a door must undergo for failure under this criterion depends on the depth of the frame in which the door is mounted. With doors of hollow construction the depth of frame will generally be the thickness of the door, but with plate doors which are commonly 6 mm ($\frac{1}{4}$ in) thick, the frame depth may be several times the door thickness.

The initial clearances between door and frame are important, since the greater these gaps are the more they can accommodate expansion, with consequently less deformation under given conditions. No record of measurements of clearance in test specimens is available, and therefore, for calculation purposes 3 mm ($\frac{1}{8}$ in) will be assumed. A single leaf door 1.2 m (4 ft) wide, having an initial gap at the closing edge of 3 mm ($\frac{1}{8}$ in), would increase in temperature to

$$t^o = \frac{1}{8} \times \frac{10^6}{48 \times 12}$$

$= 220^oC$ before beginning to deform

The further rise in temperature to the end of a two hour test is therefore 680°C approximately, with the assumed final temperature of 900°C for the doors (see p.6). From the formula the maximum deformation of 1.2 m (4 ft) of door between fixings will be 66 mm (2.6 in). Deformations of this magnitude could only be accommodated if they took place within the frame, that is the frame would need a minimum depth of 66 mm (2.6 in).

Similar considerations apply to increase in width of the separate leaves of two leaf doors and to increase in height of the leaves. The conclusion is that, with frames not more than 51 mm (2 in) deep, the width of leaf should not be greater than 1.2 m (4 ft), nor the height be over 2.75 m (9 ft) without an increase in the depth of frame or additional bolts.

(b) Sliding doors. For operational reasons sliding doors are mounted with an appreciable clearance from the face of the wall, because walls are never true planes and the risk of a door rubbing the wall is to be avoided. The only portion of the wall, however, which is important for the door as a fire protection device is the strip on the face at the perimeter of the openings which is overlapped by the door when it is in the closed position. This portion should be rendered with cement plaster to give as close contact as possible with the door. The amount of overlap of the door at top and sides of the opening in the wall is important, and 3 in is regarded as the minimum allowable.

As with hinged doors, sliding doors may be either single or two-leaf. In the two-leaf or bi-parting door, the leaves may move either horizontally or vertically. The two types need separate examination.

A single leaf door of steel or steel and asbestos, either hollow or solid, will not function for long as an effective fire barrier, because of the bowing caused by increase in temperature, unless measures are taken to restrain movement of the vertical edges away from the face of the wall. The method which has been proved successful by test is illustrated in Figure 2. The closing edge of the door fits into a continuous steel channel and a similar member is used to house the top edge. At the bottom a frame member on the door slides in a channel track. The trailing edge of the door has a continuous channel or double angle which engages in a groove formed by an angle member fixed to the jamb of the opening.

If the door and frame are of robust construction a considerable increase in the present maxima for sliding doors of 2.1 m (7 ft) in width and 2.5 m (9 ft) in height could be allowed with the assurance that the door would be no less effective as a fire barrier than the size tested. Width is probably less critical for performance than height when these dimensions are increased as long as there is an allowance for expansion at the edges, and with doors designed in accordance with F.O.C. Rules a width of 4.6 m (15 ft) could be accepted. For the height a maximum of 3.7 m (12 ft) should present no difficulties, and an increase to 4.6 m (15 ft) could be made without introducing a serious weakness. The construction and the methods of fixing frame members should be similar to those specified for the smaller doors. An increase in size of such components of the door as hangers, rails, runners etc., will be necessary, but no detailed design guidance can be given here to take account of all the variables of type and size.

A special type of single leaf sliding door is the metal covered door which has a core of layers of timber boards. The faces of the door are formed by interlocking light gauge steel sheets of such a size and so fitted that when exposed to fire they have no distorting influence on the door. From its construction such a door is virtually free from deformation and less stringent precautions are needed at the edges than for steel doors. In the F.O.C. Rules two stops are specified to grip one vertical edge of such a door at one third and two thirds of its height with the addition of a roller guide at the bottom edge. The present maxima of 2.1 m (7 ft) wide and 2.75 m (9 ft) high could both be increased to 4.6 m (15 ft) with the stops fixed not more than 0.9 m (3 ft) apart and suitable increase in section of those parts of the construction where the larger size and weight demand it.

Bi-parting or centre opening doors, moving either horizontally or vertically, present a more difficult problem. The edges of each leaf adjacent to the wall opening when the door is closed can be housed as in the single leaf door, but the meeting edges usually require different treatment. For safety reasons it would be objectionable to have the edge of one leaf entering a steel channel on the other leaf, and the practice is to fix a rubber or neoprene astragal or buffer to one or both edges. Experience with testing doors of this type has shown that the astragals are gradually destroyed, there is nothing to prevent deformation of the leaves at the meeting edges and a gap of increasing width forms at this point. Such defects would be accentuated with increase in size of such doors and it is therefore considered undesirable at present to accept them for protecting larger openings than those used in a test.

(c) Folding shutters. This type of shutter consists of thin sheet steel leaves, generally about 15.2 cm (6 in) wide, hinged together along their vertical edges, interlocking to make a smoke-tight joint. When the shutter is open the leaves fold together so that the bunched shutter occupies the minimum space at one side of the opening. The shutter moves between the jambs of the wall, the leaves being carried by upright channel pickets connected by controlling lattice bars. The closing edge of the shutter is made solid and is provided with a clutch bolt lock. A surrounding frame is required to give fixity of the shutter at one jamb, and includes a suitably rebated slam post at the other jamb, support for the track assembly and a track at the threshold. In order to cover the gaps at the top of the leaves when the shutter is closed a horizontal cover plate is fixed to the top track housing to extend beyond the leaves and having an initial clearance over their top edges of 3 mm ($\frac{1}{8}$ in).

Shutters of this type when constructed in accordance with the F.O.C. Rules can have a width of opening considerably greater than the maximum of 2.4 m (8 ft) which has been tested. As there is virtually no restraint on thermal movements horizontally the width of a shutter could be increased to any desired extent without affecting its ability to act as a fire barrier. Other considerations than the integrity under fire conditions are, however, likely to impose a limit on width, such as the hazard from radiated heat.

In fire tests on shutters of this type having heights of opening up to 2.23 m (7 ft 4 in) relatively small distortions due to restrained vertical expansion have been recorded. This favourable feature is accounted for partly by the initial clearances at top and bottom of the leaves between the cover plate and the sill respectively, partly by the yield of the cover plate under the upward forces, and partly by the restraining action of the pickets. It does not appear, therefore, that in this instance the influence on fire resistance of increase in height is amenable to calculation. An important factor is to ensure that the closing edge of the shutter, which normally has only one fixing point, does not deflect away from the frame, causing gaps to form. The proper safeguard is to fit stops to the slam post say of square section steel bar forming a closure on each side of the shutter. With such a feature incorporated and the details of construction following F.O.C. specifications, there appears to be no reason for limiting this type of shutter for openings 2.1 m (7 ft) high. A height of 3 m (10 ft) should entail no risk of performance inferior to that of the smaller shutter, and a maximum of 3.7 m (12 ft) is reasonable. No increase in the thickness of the leaves would be needed beyond the present specification of 2 mm (14 S.W.G.) but other details of construction would need examination for their suitability for operational use with the larger size.

(d) Sliding shutters. Under this heading are the multi-leaved type of shutter consisting of panels, which in the open position are superimposed on each other at one side of the opening in the plane of the wall, or at both sides with the centre meeting type. One panel is fixed to the frame at the jamb, and in closing the other panels slide in separate tracks to meet the other jamb or the other door leaf, as the case may be, separate top tracks being provided to support the panels. The panels move at different speeds, and a lever mechanism, pivotted at one end to the frame and intermediately to each panel, is provided. In the closed position the panels overlap adjacent panels at leading and trailing edges, where a suitable method of sealing is introduced. At the top, to cover the track and edges of the panels it is usual to provide a deep valance of steel sheet which might be insulated. The panels for this type of shutter are likely to be of hollow construction consisting of steel sheet with an infill of insulating material.

At present, the test experience with multi-leaf shutters is relatively small and no information is available on the behaviour of centre meeting types. They are not likely to be proposed for large openings and the dimensions of the opening protected by the largest test specimen of 2.3 m (7 ft 7 in) high by 1.5 m (5 ft) wide may not be greatly exceeded in practice. The principal drawback to increase in height is the large deformations which occur. In one test, on a shutter of this size, after 30 minutes the panels had deflected 76 mm (3 in) at the centre, and although this distortion did not lead to failure, the lack of restraint against deformation and the dependence on the fit at the edges of panels give grounds for considering 2.4 m (8 ft) as the maximum height which should be used. The width is not so critical since the method of construction enables any thermal movements in the horizontal direction to be taken up without the formation of gaps between panels. Cost and complication in construction are likely, however, to restrict such shutters to openings of small width suitable for those of "3-speed" or perhaps "4-speed" types.

(e) Rolling shutters. A rolling shutter consists of a curtain of interlocking steel slats housed in a steel shutter box supported on the jambs above the wall opening. To close the shutter the steel curtain is uncoiled, the vertical edges running in channel guides at the jambs, and the lower edge which is formed by a steel rail provided with handles, making close contact with the sill in its closed position. The maximum dimensions of opening accepted for shutters of this type by the F.O.C. Rules are 2.1 m (7 ft) in height and 2.4 m (8 ft) in width.

Fire tests made on rolling shutters of these maximum sizes have shown no points of weakness. When the channel guides are fixed in chases in the jambs with appropriate clearances from the edges of the shutter for expansion then a significant increase in width of shutter is feasible which will maintain the same standard of fire resistance as the test specimens. If the methods of construction and the expansion allowances of the F.O.C. rules are adopted a maximum width of 4.6 m (15 ft) might be accepted, but as indicated in the discussion of other types, attention will need to be given to ensuring that all parts of the construction for support and operation of the shutter are designed for the increase in size and weight.

Failure of a shutter of greater height than those tested could occur only by actual collapse of the whole shutter or a local collapse of the slats. At present the minimum thickness of the material accepted for the slats is 1.2 mm (18 S.W.G.). For heights exceeding 3 m (10 ft) the slats could be increased in thickness to 1.6 mm (16 S.W.G.) to ensure safety, and the suitability of the shutters for openings up to 3.7 m (12 ft) might be accepted.

6. Hazard of heat radiation

Guidance on safe distances for combustible materials from fire resisting doors and shutters can be given for uninsulated types by making some assumptions, which are necessary in the absence of radiation measurements from similar types in a fire test, and to take account of the nature of combustible materials and how they may be located in relation to a shutter in service. The maximum temperature of the unexposed surface of insulated doors and shutters will depend on the materials used. It is not possible to generalise and each type needs separate consideration. When a high standard of insulation is provided, as in the metal covered door, heat transmission will not be significant and no requirements for space separation are needed.

Shutters of the rolling and folding types will always be uninsulated, and assumptions can be made of their radiating temperature and emissivity. Earlier a temperature of 900°C was taken as reasonable for doors or shutters after 2 hours of test, but the temperature of the unexposed face will be lower, say 800°C or 1073°K. Emissivities are likely to be less than unity, but if this value is adopted, calculations will err on the safe side. The materials exposed to radiation will be subjected to intensities which increase with time, and if the intensity is high enough spontaneous ignition will occur. Minimum intensities at which ignition of various materials occurs have been determined, and for wood or textiles over a wide range of moisture contents[3] the intensity for spontaneous ignition may be taken as 0.75 $cal/cm^2/sec$.

Two locations are important for materials in relation to a door or shutter when calculating safe distances: (1) at a point on the axis of the shutter with the surface of the material parallel to the plane of the wall; (2) at a point on a line at right angles to one edge of the door, the surface of the material being perpendicular to the plane of the wall. These situations are shown in the diagram Figure 3.

The intensity of radiation I falling on a small area located at the points specified is approximately $1.36 \times 1100^4\ \phi \times 10^{-12} = 2.0\ \phi$ $cal/cm^2/sec$, where ϕ is the configuration factor. If the limiting value for I is 0.75, ϕ must not exceed 0.75/2.0 = 0.37. For any given dimensions of uninsulated door or shutter the safe distance for materials can be calculated from geometrical considerations so that ϕ does not exceed 0.37.

The recommended maximum sizes in the foregoing analysis were for hinged doors 2.75 m x 2.4 m (9 ft x 8 ft) and for other types 3.7 m x 4.6 m (12 ft x 15 ft).

In the following table the safe distances from uninsulated doors and shutters of the present and the proposed maximum sizes are given, calculated from the data and the assumptions specified to the nearest 30 cm (1 ft) greater than the calculated distance.

Size of door or shutter	Safe distance of combustible material (1) Facing shutter in parallel plane	(2) At perimeter of shutter perpendicular to its plane
2.75 x 2.4 m (9 x 8 ft)	2.1 m (7 ft)	0.61 m (2 ft)
2.4 x 2.1 m (8 x 7 ft)	1.8 m (6 ft)	0.61 m (2 ft)
3.7 x 4.6 m (12 x 15 ft)	3.1 m (10 ft)	0.9 m (3 ft)

If the combustible contents and materials of construction of a building are spaced from doors and shutters at distances not less than those shown in the Table there should be no risk of fire spreading from the part of a building involved in fire to an adjacent part by radiation from the door or shutters.

7. Conclusions

An examination of the data from fire tests on various types of doors and shutters, other than timber doors, has shown the factors which are important if they are to maintain their integrity as barriers to fire. Tests are made on specimens of relatively small dimensions, and limiting the size of doors and shutters installed in buildings to that of test specimens is unduly restrictive in some instances. From the observed behaviour of specimen doors and shutters and a knowledge of the effect of high temperatures on the components an attempt has been made to show how performance is affected when the height and width of each type is increased. Maxima for these dimensions have been proposed, based on assumptions that standards of construction will follow those which are appropriate in the Rules of the Fire Offices' Committee, but detailed guidance on the design of components such as hinges, bolts, locks, wheels, hangers etc., to ensure their suitability for larger doors and shutters cannot be given.

With uninsulated steel doors and shutters heat radiation can be a greater hazard to combustible materials adjacent to the side not exposed to fire than flames or hot gases issuing from gaps which may occur round the shutter by its distortion. Recommendations have therefore been made for the spacing of combustible materials from such doors and shutters.

References

(1) British Standard 476 : Part 1. Fire tests on building materials and structures.

(2) Rules of the Fire Offices' Committee for the construction and fixing of fireproof door compartments and shutters.

(3) Fire Research 1965.

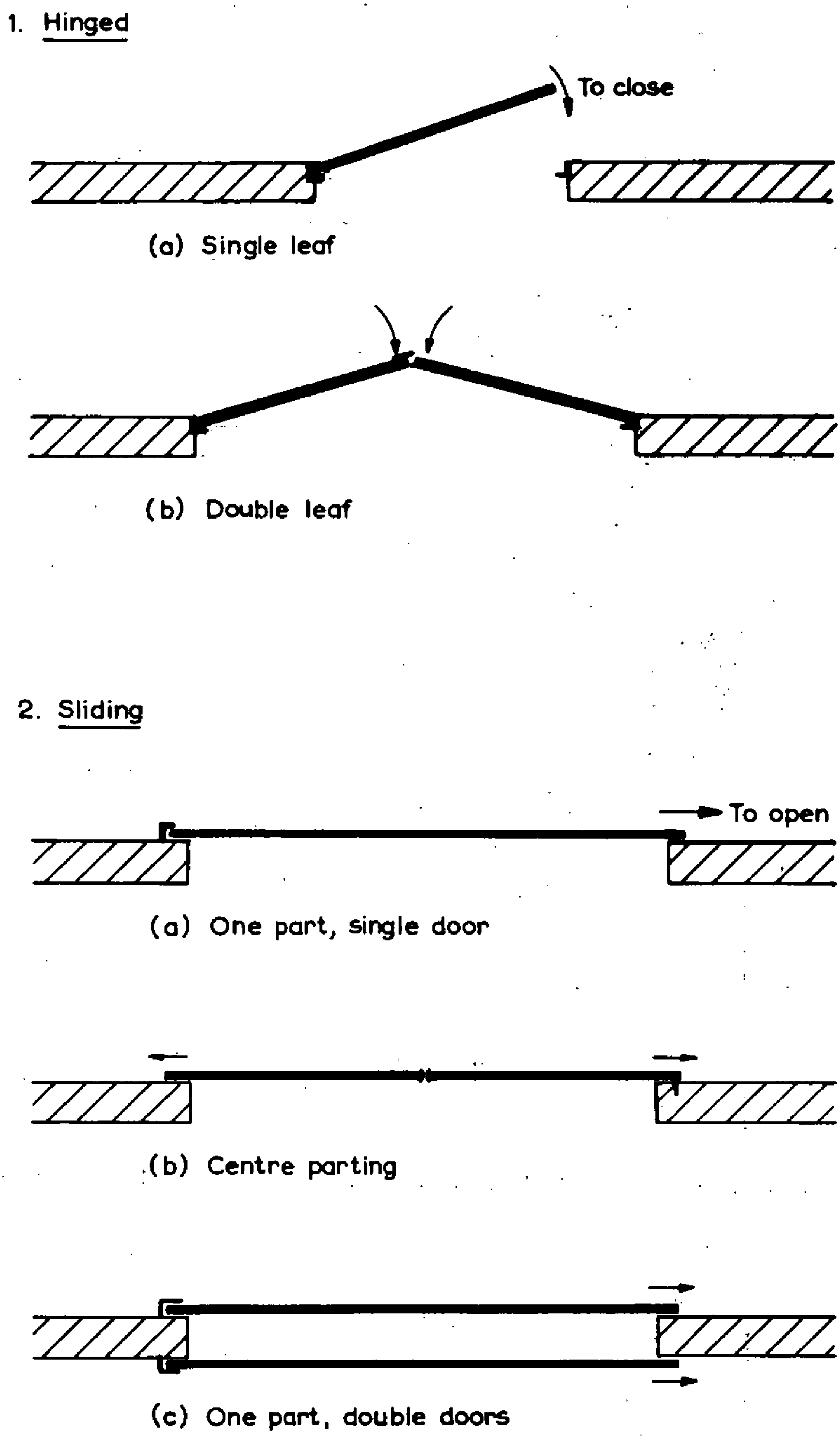
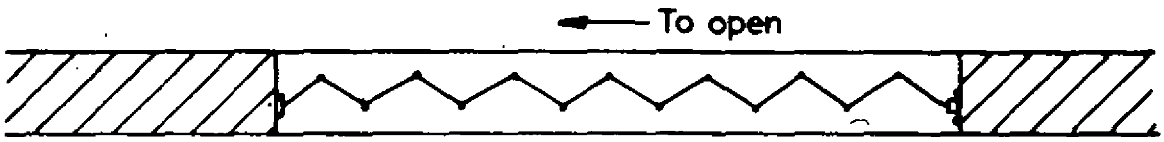
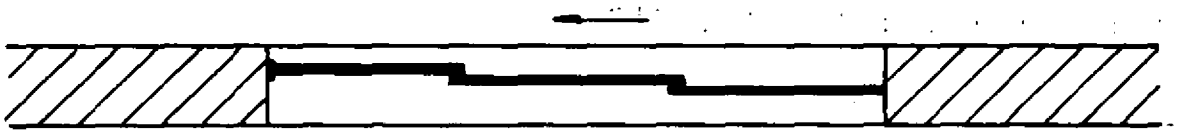


FIG. 1(a) TYPES OF DOORS



2. Sliding



3. Rolling

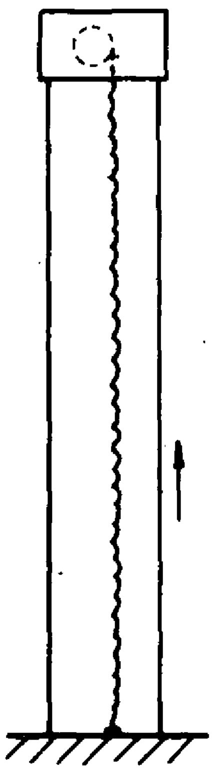


FIG. 1 (b) TYPES OF SHUTTER

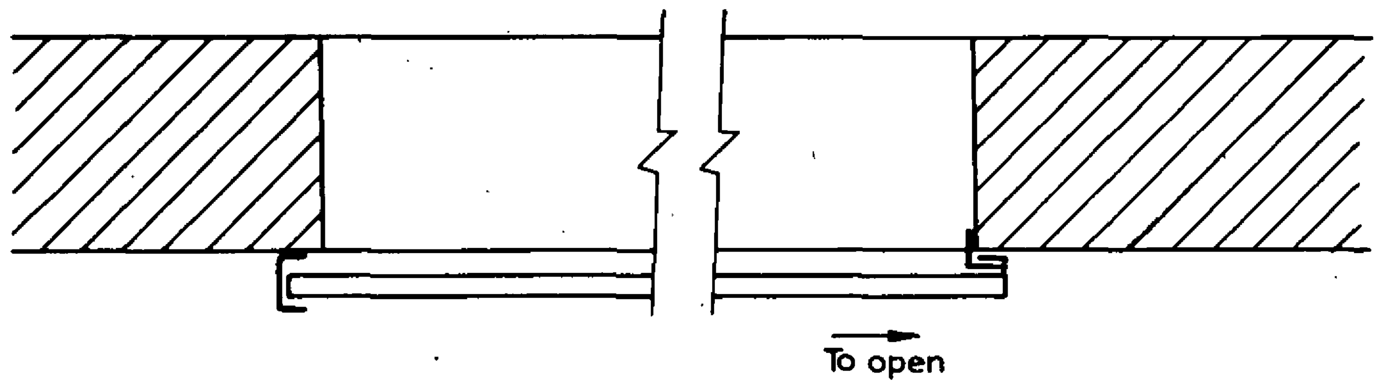


FIG. 2. METHOD OF CLOSURE AT EDGES OF SLIDING DOOR

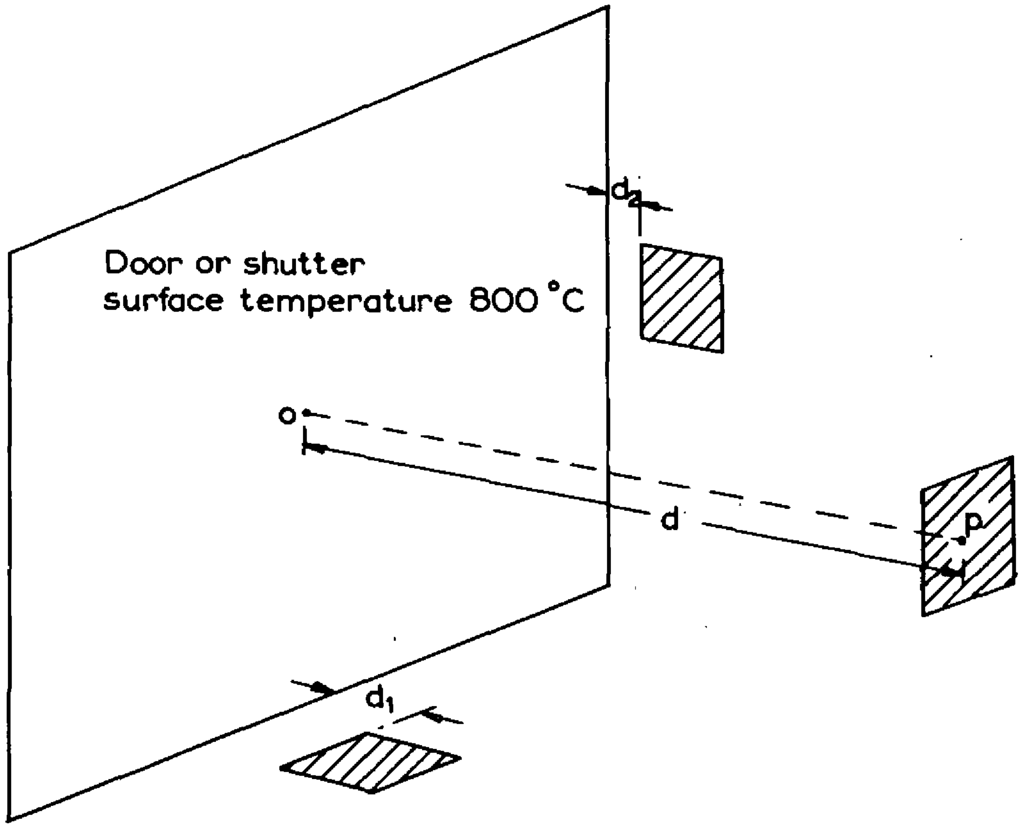


FIG. 3. SAFE DISTANCE d FOR COMBUSTIBLE MATERIAL FROM DOOR OR SHUTTER

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