Spread of fire in corridors: a progress report

McGuire, J. H.

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SPREAD OF FIRE IN CORRIDORS

(A Progress Report)

by

J.H. McGuire

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PREFACE

The results of a series of flame spread tests on a one-quarter scale model corridor having materials of various flame spread indices on floor, walls and ceiling are now reported. This work was carried out to provide a basis for further understanding of the significance of flame spread indices, particularly in relation to spread of fire along corridors, and to show the influence of different combinations of floor, wall, and ceiling surfaces. It is now planned to extend the study in the near future to a corridor model of normal dimensions. The author, a research officer with the Fire Research Section, has a special interest in the spread of fire.

Ottawa
October 1960

N.B. Hutcheon
Assistant Director.

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For fifteen years or so tests have existed by which materials can be given comparative ratings so far as their spread of flame characteristics are concerned. Although the various tests impose different conditions, the sequence in which materials are listed in order of merit, for each of the tests, is very similar. It would seem, therefore, that the tests are generally valid in so far as they determine which materials will more readily propagate fire.

Precisely how the results of such tests should be applied has been in some doubt. The average room, hall or other compartment of a building almost invariably has sufficient combustible material in it to allow a fully developed fire to become established. The nature of the building materials and contents will certainly be a factor influencing the likelihood of such a fire and the time it takes to develop. The relationship is so complex, however, that no quantitative analysis capable of universal application has yet been derived.

Nevertheless one case, the corridor, merits special attention for two reasons. Firstly, it often plays a substantial part in the spread of fire from one compartment to another, and secondly it is almost unique in that it can have very few combustibles in it and hence can be designed so that it will not of itself sustain a fully developed fire.

The desirability of such a design of corridor must not be related to the question of the escape of occupants in the immediate vicinity of the origin of a fire but rather to restricting the spread of fire within buildings. Where lining materials with a moderate or low flame spread rating are involved, conditions in a corridor usually become untenable due to smoke or heat before the lining materials have become appreciably involved in the fire.

The object of designing a corridor which would not of itself sustain a fully developed fire would be to reduce the rate of spread of fire throughout a building. This function is similar to that of fire resistance which is to confine a fire to a particular compartment. The choice of flame spread characteristics discussed above would thus perform the same function as firefighting in restricting a fire to dimensions even less than those of a fire resisting compartment. Such action might well reduce the life hazard associated with smoke and heat which could exist in neighbouring areas, particularly those on the floors directly above the source of the fire.

The object of the studies that are here reported is to determine which combinations of floor, wall, and ceiling lining materials, in a corridor, will sustain and propagate a fully developed fire. The work is not yet completed and this report is merely a statement of progress to date.

Experimental Method

At the outset of the work it was appreciated that between 20 and 100 tests would be required and that some decision was called for as to the dimensional scale to be adopted for the experimental work. An investigation confined to the full scale would have proved expensive and could not have been carried out within any of the N.R.C. laboratories. Control of the conditions would thus have been difficult and experimental work out of doors would have been virtually impossible during the winter months.

A dimensional scale such that experiments could be conducted in an enclosed burn area of the Fire Research Laboratory was chosen and the test apparatus illustrated in Fig 1 was constructed of asbestos board and angle iron. It consists of a model corridor from which a model room opens. For each test the latter was completely lined with fibre-insulation board to give a rapidly developing fire which was initiated with 50cc of gasoline. The corridor was lined with the materials being investigated and the primary observation was the progress of the fire at floor level. Where incombustible flooring was used a "marker" strip of $\frac{1}{2}$- by $\frac{1}{2}$-in. timber was laid along the length of the centre of the corridor.

The distribution and size of the vent openings were determined by the requirements that the corridor should be subjected to a severe fire exposure from the fire in the room and that the conditions in the corridor should represent the most favourable for the propagation of fire that would be commonly expected in practice. The first requirement was met by having one vent, between the room and the exterior, at a low level so that the exhaust gas flow in the room was in the direction of the door opening to the corridor. In meeting the second requirement the size of the openings was governed by the principles outlined in Appendix A.

Preliminary tests were carried out to ensure that satisfactory test conditions had been established. About 40 seconds after the primary ignition, the room was completely involved in fire and flames were impinging on the ceiling lining material of the corridor and emanating from the upper vent at that end of the corridor. Within about two minutes the floor of the corridor or the marker on the floor ignited. Where the corridor was lined only with incombustible materials the flames from the primary fire only extended along a small proportion of the length of the corridor ceiling. These were the required test conditions so far as the primary fire was concerned.

When flammable lining materials were used it was found that a fully developed fire would progress rapidly to the end of the corridor within about 3 minutes. During the main series of tests the influence of ventilation often appeared to be more important than was indicated by the preliminary tests. Thick smoke was common and occasionally an oscillatory alternation between growth and decay was evident.

When some borderline combinations of materials were tested it was found that a fully developed fire could progress quite rapidly along the greater part of the length of the corridor and yet not completely involve the last few inches of the floor. Since this phenomenon was solely associated with the abrupt change in conditions at the open end of the corridor, an assembly was described as "failed" if the fire at floor level reached a point 18 in. from the end of the corridor. Observations were discontinued either when the fire reached this point or when it died out.

Results and Discussion

The results obtained to date are given in Table I. They are of themselves, of course, of some interest but in the form given they only refer to the particular combinations of materials tested. With a view to making the results more widely applicable, consideration has been given to the derivation of a composite spread of flame index relating to the whole assembly and based on the ASTM fire hazard spread of flame indices for the materials involved. These indices were obtained from manufacturers, from Underwriters' Laboratories lists and from an independent research laboratory. In several instances the index related to a type of material and not directly to the product used.

Composite indices were derived by summing arbitrarily weighted values of the flame spread indices for floor, wall, and ceiling lining materials. The validity of this approach depends on the linearity of the flame spread index scale and since it is scarcely possible even to describe the quantity or quantities measured by the flame spread index it is not possible to discuss this question theoretically.

Several composite indices using different weighting factors are listed in Table II. The rows of the Table that have been underlined relate to two identical tests. Because one defined the combination as having failed and the other as having passed, the results are borderline. The common composite index in these two cases is thus particularly significant. Column 7 of Table II has been derived by adding together the indices for the individual materials. If the failure value were arbitrarily defined as about 86 then two of the test assemblies which were found to be satisfactory would be defined as unsatisfactory.

Column 8 of Table II has been derived by adding together the ceiling and floor indices and twice the value of the wall index. Although one of the results is inconsistent, this particular approach has practical appeal, from the point of view of simplicity, since the weighting factors correspond to the area ratios and the composite index if divided by 4 may thus be described as an average index, averaging being on an area basis.

Column 9 might also be described as having an area basis except that the floor covering is considered to be less significant by a factor of two. It is the most interesting approach to the problem since it gives no inconsistent results.

Columns 10 and 11 are included to illustrate other approaches.

The fact that column 9 gives no inconsistencies indicates that the summation of the weighted flame spread indices, within the wide range of materials tested, has been empirically justified.

Conclusion

The results of the model tests carried out so far indicate that the derivation of a composite spread of flame index by the summation of weighted flame spread indices will give a useful criterion for corridors in terms of the ASTM flame spread indices of component materials.

While the progress of a fully developed fire along a corridor is obviously undesirable, the spread of fire along a ceiling alone must also be guarded against. In this respect it is interesting to note that the possible composite failure index given by column 9 (75) is one of the figures commonly regarded as a suitable limiting value for the flame spread index of ceiling lining materials. The choice of this composite index therefore, might well provide the solution to both problems.

Subsequent to the preparation of this report, results of Danish full-scale tests on ships' corridors have been received (1). Taking the scale into account the corridor length only corresponded to a quarter of the N.R.C. model so that interpretation of the results in terms of the progress of a fully developed fire is not easy. Both ends of the corridor were open and a cabin (room), in which the fires were started, opened from the centre.

In every test the floor was lined with linoleum and it would appear that in all but one of the tests a fully developed fire progressed in each direction along the corridor. One of these tests referred to wooden linings treated with an intumescent fire-retardant paint which should give a surface commonly described as one of low flame spread. The above results appear to agree with the results of the small-scale tests discussed in this note.

Where completely incombustible wall and ceiling lining materials were used in the Danish tests it appeared that the fire involving the linoleum would not have progressed indefinitely whereas in the DBR model work linoleum alone gave a continuing fire. It might well be that the Danish result may be attributed to the fact that the corridor was extremely narrow.

In so far as the Danish work can be compared with the present work it supports the concept that the propagation of a fire in a corridor may be related to a composite index.

References:

1. "Report on Tests concerning Fires in Ships' Corridors". Directorate of the Government Ships Inspection Service. Pindstrup, Denmark, 1958.

2. Hird D. and Fischl C.F. "Fire Hazard of Internal Linings". National Building Studies Special Report No. 22. H.M.S.O. London, 1954.

3. McGuire, J.H. "St. Lawrence Burns: Ventilation Rate Measurements". D.B.R. Internal Report 154.

TABLE I

RESULTS

Test No.	Type of Ceiling	Flame Spread Index	Type of Wall	Flame Spread Index	Type of Floor	Flame Spread Index	Flame Spread ft	Time, min, to Farthest Point on Floor	Remarks
1	Asbestos	0	Asbestos	0	Carpet (roll)	200	F*	3	
2	"	0	"	0	Linoleum (roll)	201	F	6	
3	"	0	"	0	Rubber (tile)	36	10.5	7	Thick black smoke
4	"	0	"	0	Asphalt (tile)	56	9	10	
5	"	0	"	0	Vinyl (tile)	18	9	19	
6	"	0	"	0	Plywood ½" fir	100	7.5	-	
7	" Painted	5	" Painted	5	Plywood ½"fir	100	8	8	
8	Plaster-board	15	Plaster-board	15	Carpet (roll)	200	F	2	Less than 6' of ceiling burnt
9	"	15	"	15	Linoleum (roll)	201	F	4.5	Less than 6' of ceiling burnt
10	"	15	"	15	Asphalt (tile)	56	F	5	Less than 2' of ceiling burnt
11	"	15	"	15	Asphalt (tile)	56	12.5	8	
12	Plaster-board	15	Plaster-board	15	Rubber (tile)	36	12	8	Thick black smoke
13	"	15	"	15	Vinyl (tile)	18	13	6	Thick black smoke
14	"	15	"	15	Vinyl (asbestos)	8	7	5	
15	"	15	"	15	Plywood (treated)	30	9.5	-	
16	"	15	"	15	Plywood ½"x2"x16'	0	9	4	
17	Painted	15	Painted	15	Plywood ½" fir	100	F	3.5	
18	Fibreboard (untreated)	250	Asbestos	0	Plywood (treated)	30	F	14	
19	"	250	"	0	Plywood ½"x½"x16'	0	F	7	
20	"	250	Asbestos	0	Rubber (tile)	36	F	7	
21	Acoustic (treated)	30	"	0	Plywood (treated)	30	10	10	First 4' of ceiling fell
22	Plywood (treated)	30	Plywood (treated)	30	Asphalt (tile)	56	F	7	

*F = Failed (14'6")

TABLE II

Composite Indices

1	2	3	4	5	6	7	8	9	10	11
Test No.	Time to Fail, min ≠	Distance of Spread	Flame Spread Indices			Weighting Factors				
			Ceiling	Wall	Floor	1:1:1	1:2:1	1:2:½	1:1:½	2:1:1
8	2	-	15	15	200	230	245	145	130	245
1	3	-	0	0	200	200	200	100	100	200
17	3.5	-	15	15	100	130	145	95	80	145
9	4.5	-	15	15	201	231	246	145	130	246
10	5	-	15	15	56	86	101	73	58	101
2	6	-	0	0	201	201	201	100	100	201
20	7	-	250	0	36	286	286	268	268	536
19	7	-	250	0	0	250	250	250	250	500
22	7	-	30	30	56	116	146	118	88	146
18	14	-	250	0	30	280	280	265	265	530
13	-	13	15	15	18	48	63	54	39	63
12	-	12	15	15	36	66	81	63	48	81
11	-	12.5	15	15	56	86*	101*	73	58	101*
3	-	10.5	0	0	36	36	36	18	18	36
21	-	10	30	0	30	60	60	45	45	90
15	-	9.5	15	15	30	60	75	60	45	75
4	-	9	0	0	56	56	56	28	28	56
5	-	9	0	0	18	18	18	9	9	18
16	-	9	15	15	0	30	45	45	30	45
7	-	8	5	5	100	110*	115*	65	60*	115*
6	-	7.5	0	0	100	100*	100	50	50	100*
14	-	7	15	15	8	38	53	49	34	53
Possible Composite Failure Index..................................						85	100	75	60	100

* Would be defined as "failed" if index listed were adopted as criterion.

≠ i.e. for fire to involve flooring 18" from end

APPENDIX A

THE SCALING OF VENTILATING OPENINGS

Following previous work (2) the fire modelling technique described in this note is based on the establishment of a time scale which is independent of dimensional scale. The progress of a fire along corridors of different scales is considered to correspond if, at corresponding times, corresponding areas of lining material are involved in the fire.

For such correspondence, the air supply per unit area of lining material must be independent of dimensional scale. To allow this, the scale (m) of the height of the openings has been taken as an independent variable. Let all other dimensional scales be represented by n, so that mass air flow must be arranged to scale as n^2. Where the vertical separation between openings scales substantially as n, despite the fact that the heights of the openings themselves may scale by the different factor m, an application of Bernoulli's theorem (3) shows that the velocity of the inlet air scales as $\sqrt{n}$. The mass flow therefore scales as $nm\sqrt{n} = n^{3/2}m$. Since the mass flow is required to scale as n^2 it follows that $m = \sqrt{n}$.

The venting areas on a small-scale model are thus proportionally larger than the corresponding openings in a large-scale model.

Modelling on the above basis establishes gas velocities within the model that are not directly dependent on the dimensional scale. Considering the flames spreading along the underside of a ceiling it is therefore to be expected that, although the rate of evolution of volatiles will scale approximately proportionately, (i.e. as n^2), the flame lengths will scale by rather less than the dimensional scale factor. There will also be a flame thickness scaling, however, which will influence emissivity, so that the two effects will tend to balance the preheating of materials prior to their ignition.