NOT FOR PUBLICATION

NATIONAL RESEARCH COUNCIL
CANADA

DIVISION OF BUILDING RESEARCH

WARNING

THIS IS A SPECIAL DOCUMENT WHICH D.B.R. IS PRIVILEGED TO HAVE FOR REFERENCE PURPOSES ONLY. IT MUST NOT BE QUOTED OR LISTED IN ANY REPORT OR PUBLICATION UNLESS SPECIFIC WRITTEN PERMISSION FOR THIS HAS BEEN OBTAINED THROUGH THE DIRECTOR.

SPATIAL SEPARATION OF BUILDINGS

BY

J. H. McGUIRE

(PREPARED FOR THE NRC ASSOCIATE COMMITTEE ON THE NATIONAL BUILDING CODE)

THIS REPORT HAS BEEN PREPARED FOR INFORMATION AND RECORD PURPOSES AND IS NOT TO BE CITED AS A REFERENCE IN ANY PUBLICATION

OTTAWA

NOVEMBER 1959

DBR INTERNAL REPORT NO. 187

NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

SPATIAL SEPARATION OF BUILDINGS

by

J. H. McGuire

(Prepared for the NRC Associate Committee on the National Building Code)

ANALYZED

Internal Report No. 187

of the

Division of Building Research

OTTAWA

October 1959

PREFACE

One of the reasons why work on the National Building Code of Canada (which is issued under the authority of the N.R.C. Associate Committee on the National Building Code) is carried out by staff of the Division of Building Research - always to the direction of the Associate Committee - is so that the Code may benefit by the latest information on building design, and building techniques, available through the work of the Division. Correspondingly, one of the most effective ways in which the results of the research work of the Division can be of public service is through application in revisions of the National Building Code.

Up to this time, relevant information from the Division has been passed directly to the Associate Committee for their use, thus being confined, in the first instance, to necessarily private Committee papers. In order to make all such information more quickly available for general use, it has been decided that in future it shall be recorded in the regular series of D.B.R. Internal Reports. This is the first report to be prepared and issued for this purpose, but it will be the first of a continuing series.

The author is a research officer in the Fire Section of the Division of Building Research; he joined the staff of the Council after service with the British Joint Fire Research Station, being a graduate in physics of the University of London. He was an active participant in the St. Lawrence Burns, from which some of the information herein recorded was obtained.

The report is now issued for information, and in the hope that the Division may be favoured with critical comments upon its conclusions. It must be understood that these are presented for convenience only; the use that is made of the information herein recorded by the Associate Committee on the National Building Code is naturally a matter for decision by the Committee. The Division, however, is pleased to be able to make in this way this further contribution to the progress of the National Building Code.

Ottawa
November 1959

Robert F. Legget
Director

SPATIAL SEPARATION OF BUILDINGS

by

J. H. McGuire

The spread of fire between two buildings may result from (1):

1. Flying brands,
2. Convective heat transfer, and/or
3. Radiative heat transfer.

Flying brands may initiate secondary fires at substantial distances from the primary fire, e.g., a quarter of a mile (2), and thus it is not practical to consider spatial separation between buildings as a means of combatting this hazard. Fortunately other means are available (2).

Convective heat transfer will only cause ignition if the temperature of the gas stream is several hundred degrees Centigrade. Such high gas temperatures are only to be found in or very near to the flames emanating from the windows of burning buildings.

Since ignition by radiation from a burning building can occur at distances greater than those to which the flames generally extend (3) it follows that radiative heat transfer is the factor of primary importance in producing spread of fire across a space separation between buildings. The writer recently visited the scene of a fire in a dwelling in which the neighbouring houses were ignited. The separating distances in each case were 14 ft 8 in. and it might therefore be thought that the spread of fire could have been caused directly by the flames or at least by hot gases. That it was, in fact, radiative heat transter is clearly demonstrated by the following (4):

"... the secondary fires on the side walls of the two neighbouring dwellings had only been initiated on the vertical faces directly exposed to radiation from the burning dwelling. The undersides of the eaves were only discoloured where flames from the secondary fire had played on them; the under edges of certain exposed boards were not discoloured at all."

That the radiation level is the factor of prime importance in determining the separation which should be established between buildings has, of course, been known for a long time and it is this principle which forms the basis for the relevant section of the 1953 National Building Code (5).

With a view to simplifying this code a number of assumptions were adopted. Now that the code has been in use for some years and the underlying principle is more generally understood an attempt can be made to refine the space separation requirements. The object of this report is to attempt to make such a development without unduly complicating the code.

The 1953 National Building Code

It is scarcely possible to formulate a code that could be successfully implemented if it is to refer directly to the space separation of buildings. The requirements of the 1953 code are, therefore, very wisely referred to the boundary of the lot upon which the building will be erected. The exterior wall of a building would meet the requirements of the appropriate section of the code:

(i) if, having no windows, its fire resistance time complied with column 2 of Table I (see below), the independent variable being fire load, or

(ii) if, its fire resistance complied with column 2 of Table I, except that up to 20 per cent of its area were occupied by window space or other unprotected opening, and if in addition its separation from the lot line were at least half the value given by column 3 of Table I, or

(iii) if its separation from the lot line were at least that given by column 3 of Table I.

TABLE I

NBC REQUIREMENTS FOR CONSTRUCTION AND SPACE SEPARATIONS

Column 1	Column 2	Column 3
Fire Load	Fire Resistance Time	Space Separation (referred to lot line)
10 lb/ft^2	1 hour	15 feet
20 lb/ft^2	2 hours	20 feet
30 lb/ft^2	3 hours	25 feet

Possible Developments

The code has already introduced the concept that distances of separation must be related to percentage window opening but only three values of window opening are listed: zero, 20 per cent and 100 per cent. It might be desirable to include intermediate values.

A more important factor for which provision is desirable is that the distance from a building at which a particular level of radiation is given is a function of the dimensions of the building in addition to the percentage window opening. If two sources have the same temperature, emissivity, and shape then the distances from the two at which the intensities are the same are related by the dimensional scale factor. This property is illustrated in Fig. 1 where the radiating surfaces are related by the scale factor 3 ft ÷ 2 ft = 18 inches ÷ 12 inches = 1.5. The two receiving surfaces have the same level of radiation incident upon them since their orientation and relative geometrical location are the same and their distances from the radiating surfaces are also related by the factor 1.5.

It must be emphasized that although the distance at which a particular intensity is given increases with both size of building and percentage window opening the relationships are not linear and hence the distance is not a function of the product, i.e. of the total window area.

The possible application of a principle such as this requires a knowledge of the levels of radiation to be expected from building fires and of the levels of radiation that will ignite common building materials.

Available Information

The formulation of a separation code, based on the principles discussed above has been considered by Bevan and Webster (1). They report that consideration of the maximum temperature to which timber can be raised without undue risk of fire suggested a radiation level of 0.2 $cal/cm^2/sec$ is the maximum to which timber should be subjected. It was assumed that the window openings of a building constitute the radiating areas and that their black body temperature is 1000°C. On this basis the configuration factor* F of the window openings, at an exposed building, should be reduced to 0.056. The validity of the configuration factor concept in this application is discussed in Appendix A.

---

* The configuration factor of a radiating area with respect to an elemental receiving area may be defined as the ratio of the intensity of radiation at the receiving element to the intensity near to the radiator. Its value is dependent solely on the geometrical relationship between the radiator and the receiving element and may lie between zero and unity.

This theoretical approach was supported by observations at two fires. In the first the behaviour of a series of exposed window frames was as shown in Table II (Table 3 of the Bevan and Webster Report).

TABLE II

DAMAGE RELATED TO CONFIGURATION FACTOR

F	Condition of Window Frame
0.067	Paint blistered
0.067	Paint blistered, little charring
0.081	Surface charring
0.093	Burned
0.112	Burned

Such practical results suggest that the configuration factor should undoubtedly be reduced to less than 0.093 if not to less than 0.067. In the second example a timber boarding had ignited at a configuration factor of 0.092. This merely confirms that such a value of F is too high to be safe.

A conflagration that occurred at Winnipeg in June 1956 (6) probably gives the most valuable information on the acceptable limit of the configuration factor since values can be derived for both of the conditions: ignition occurring and not occurring. A plan of the buildings involved is shown in Fig. 2. When the fire was confined to the Time Building alone and all the walls of the building remained intact the maximum value of the configuration factor of the window openings at the T. Eaton Building was approximately 0.05. Shortly afterwards the east wall of the Time Building collapsed, the Dismorr Building ignited and, when both buildings were burning furiously a number of the window surrounds of the T. Eaton Building either caught fire or began charring. Sparks and flying brands would have been passing near to the building most of the time and the available evidence leads to the conclusion that the mechanism involved was pilot ignition. The maximum configuration factor at the T. Eaton Building at about this time was about 0.1.

All the above information relates to fires which have been accidentally initiated and which have been combatted by fire departments. Further pertinent information was obtained from some experimental fires which were carried out during the winter of 1957-8 in buildings rendered derelict as a result of the St. Lawrence Seaway and Hydro-Electric Power Project.

Radiation measurements were made at three locations relative to each building and in addition a total radiation measurement was made at one window for each fire. Table III, which is taken from the relevant reports (3, 7), lists the maximum intensities which were recorded. To make this information applicable to the prediction of radiation intensities from other buildings as discussed in Appendix A, the configuration factors of the window openings at each of the points of measurement were calculated. Dividing the radiation intensities (I) by these values of F, the configuration factor, gave the hypothetical radiation levels I/F emanating from the windows.

It must be emphasized that these derived levels are not real, but are the values that would have been required to produce the measured radiation levels had the window openings been the sole source of radiation. This fact is illustrated by comparing the values with those corresponding to the maximum black body temperatures registered by the total radiation pyrometer(7). The hypothetical values exceed the maxima given by the total radiation pyrometer by as much as a factor of 10. The difference between these two values is associated with the intense flaming from the windows of the buildings, which made a greater contribution to the maximum level of radiation than did the window openings themselves. That the concept is useful as a means of comparison, however, is demonstrated by the order of agreement for each building between the values of I/F derived from the readings of the two radiometers at different distances from, but on the same side of, the building. In one case (the school) the agreement is very poor. This results mainly from the fact that the windows of the school annex made a substantial contribution to the configuration factor for the more distant radiometer but not for the nearer. At the time when the radiation from the main body of the building was a maximum the fire in the annex was not fully developed. The value of I/F referring to the more distant radiometer is thus much lower than for the nearer one.

The maximum values of I/F for houses Nos. 4 and 7 are of the same order, as are those for houses Nos. 3 and 5. It would therefore seem that the use of clapboard exterior cladding on a house does not appreciably increase the hazard it presents to its neighbours. It will be seen that where a house is lined throughout with a highly combustible material, as in the cases of houses three and five, values of I/F of about 37 $cal/cm^2/sec$ can be obtained. Where the linings are incombustible as in the case of houses Nos. 4 and 7 and the two larger buildings the maximum levels are about half this value.

TABLE III

MAXIMUM RADIATION INTENSITIES

Building and Burn No.	Exterior Cladding	Interior Lining	Radiometer Location	Wind Speed	Intensity (I) $cal/cm^2/sec$	F Configuration Factor of Openings	I/F $cal/cm^2/sec$
2	Brick	Downstairs: fibreboard (walls & ceilings) except for plywood wainscot in kitchen Upstairs: plaster	15' leeward 30' leeward 15' windward	4-5 mph	0.47 0.18 0.08	0.05 0.016 0.04	9 11 2
3	Brick	Fibreboard	15' leeward 30' leeward 15' windward	13-14 mph	1.25 >0.18 0.46	0.034 0.013 0.034	37 >14 14
4	Clapboard (brick infilling to timber frame)	Plaster	20' leeward 40' leeward 20' windward	11-12 mph	0.56 0.17 0.46	0.032 0.011 0.028	18 15 16
5	Clapboard (on cedar shingles)	Pressed paper	20' leeward 40' leeward 20' side	10-14 mph	1.05 0.32 0.35	0.027 0.008 0.012	37 40 29
6 Fraternity Hall	Brick	Plaster, wooden ceiling and wainscot	20' leeward 40' leeward 20' windward	7-8 mph	0.9 >0.41 0.42	0.075 0.031 0.075	12 >13 6
7	Brick	Plaster	15' leeward 30' leeward 15' windward	13 mph	0.9 0.38 0.08	0.058 0.018 0.044	16 21 2
8 School	Brick	Plaster, wooden ceiling	20' east 40' east 20' west	very low	0.83 0.17 >0.5	0.049 0.019 0.088	17 9 > 6

House No. 2 gave a maximum value of only 11 $cal/cm^2/sec$ although it included fibreboard and plywood linings downstairs. It is thought that this was due partly to the fact that the upstairs linings were incombustible and partly to the low velocity of the prevailing wind. Induced ventilation rate measurements (3), and theoretical considerations indicated that the inlet velocities in a dwelling fire did not usually exceed 7 mph, as long as the roof remained intact. Ambient wind velocities of the order of 10 to 14 mph as prevailed in cases of burns 3, 4, 5, and 7, inclusive, could therefore have had a substantial effect on the rate of burning.

Before the results of these measurements can be applied to the question of the separation of buildings the permissible levels of radiation at an exposed building must be discussed. The most likely material to be exposed is timber and since, in fact, the minimum intensities that will cause the ignition of most common materials are of the same order it is sufficient to list those relating to timber (8),(see Table IV).

Interpretation of Results

It is usual in a building fire for a large number of sparks and flying brands to be discharged and these are capable of producing the pilot ignition of suitably irradiated materials. The Ottawa dwelling house fire (4) is a practical example in which it was conclusively demonstrated that pilot ignition was the mechanism by which fire spread to the neighbouring house. Considering Table IV, the separation between buildings should therefore be based on the lower of the two intensities specified. If, in addition, from the results of the St. Lawrence burns, we take 37 $cal/cm^2/sec$ as the maximum value of I/F likely to be encountered where a building includes a substantial proportion of combustible lining materials then we obtain a value of 0.008 for the permissible upper limit of the configuration factor with respect to this class of building. Using the result that the radiation levels from buildings without combustible linings appear to be lower by a factor of 2, the permissible upper limit with respect to this class of building becomes 0.016.

TABLE IV

MINIMUM INTENSITIES FOR IGNITION

Intensity	Mechanism of Ignition
0.8 $cal/cm^2/sec$	Spontaneous ignition
0.3 $cal/cm^2/sec$	Pilot ignition (with an igniting source in the gas stream)

As a basis for a table of separations these two values are far too low to be economically practical. They are also very much lower than the critical values calculated for the practical examples quoted. This fact alone suggests that higher values would be acceptable. Further examination of the St. Lawrence results shows that the high levels of radiation referred to were only attained between 16 and 35 minutes from the start of the fire, although evidence of the fire, e.g., smoke, was visible from outside within a few minutes of the onset. Had such fires occurred in practice a fire department appliance would almost certainly have been in attendance by the time radiation had reached its maximum. Under these circumstances it is probable that the radiation levels would never have been so high and in any event the spread of fire by radiation at this time would have been prevented by the wetting down of exposed combustibles.

A building code could therefore be considered acceptable if it almost eliminated the spread of fire by radiation up to this time. The levels of radiation up to 16 minutes after the start of the fire are in fact less than the maximum values obtained by a factor of about 4 except in the case of house No. 5 where $\frac{1}{4}$ the maximum value was reached in 10 to 11 minutes. The walls and ceilings of this house were lined with pressed paperboard. If, on economic grounds, a building code will allow some element of risk then configuration factors of 0.07 and 0.035 should be accepted, based on the lower values of radiation level already discussed. The value 0.07 relates to the most commonly occurring occupancy and the lower value of .035 need only be invoked in the cases of buildings which because of substantial quantities of combustible wall linings or for other reasons are likely to produce high radiation intensities .

While the St. Lawrence experiments imply that the configuration factor values suggested above are too high to give 100 per cent safety, the other examples quoted, where of course firefighting was carried out, suggest that separations based on such values would easily have eliminated the spread of fire in these cases. Thus in the case of the Winnipeg conflagration the Time Building included a substantial number of combustible partitions but the T. Eaton Building did not become involved until the configuration factor rose from 0.05 to 0.1 owing to collapse of a wall. Bevan and Webster recommend a single value of 0.056 but with the additional data on radiation levels now available it would be desirable to economize on space separation by taking advantage of the finding that the radiation levels from buildings with incombustible linings are lower than those from buildings with combustible linings.

Implementation of Results

The main obstacle that must be overcome in applying the principle of a limiting configuration factor to the formulation of a building code governing spatial separation is that the concept of a configuration factor, as discussed so far, relates to the separation of buildings. The space separation which it is customary to discuss in a building code, on the other hand, is the separation between a building and the boundary of the lot on which it is erected. It is difficult to conceive of any other definition of spatial separation which could be included in a code in such a way as to be capable of rational implementation.

It is probable that this incompatibility will always exist but it need not preclude the application of the configuration factor to the formulation of a separation code. The most obvious way of defining a distance from a boundary when the distance calculated is that which should exist between buildings is to halve the calculated value. Where identical buildings are to be erected on either side of a boundary no inconsistency arises and the same value of separation of buildings is arrived at whichever way the calculation is made. Where, for example, one building is very large and another very small this is not the case. For a large building, configuration factor considerations might give the result that the nearest adjacent building should be at least 80 ft away. The value derived from a table referring to separations from the lot line would thus be 40 ft. For a small dwelling the corresponding distances might be 15 ft and 7 ft 6 in. respectively. On the basis of a code requirement relating to distances from lot boundaries the separation between these two buildings, were they adjacent, would then be 47 ft 6 in. With this arrangement the larger building would be in no danger as a result of a fire in the dwelling, but in the event of a fire in the larger building the dwelling might well be ignited.

For a variety of reasons this inconsistency should be accepted. Firstly, it is difficult to conceive of any otherwise rational code requirements which would eliminate it. Secondly, in any one area of a city one generally finds buildings of a similar nature rather than, for example, a sequence of factories with dwelling houses interspersed. The situation described will therefore only arise at such locations as the outskirts of factory areas. Thirdly, it will be noticed that it is the smaller building that suffers the higher risk. The result of accepting the inconsistency will therefore be that when certain large buildings on the outskirts of factory areas are destroyed by fire a small number of dwellings, probably not exceeding one, will also be involved in the fire. This state of affairs of course already exists almost all over the world.

Since separation requirements are dependent on percentage window opening, dissimilarities in this respect between adjacent buildings could also be disturbing.

The relations which have been derived between the separation, width and height of buildings, and percentage window opening are given in Tables V and VI. Table V refers to particularly hazardous conditions which might include the cases (a) where more than 25 per cent of the wall and ceiling linings are combustible, (b) where the fire load is high, or (c) where the contents of a building are particularly flammable. The calculations have been based on a configuration factor of approximately 0.035 with a further 3 ft 6 in. added to each resulting distance of separation. The effect of this addition is that the shorter distances are greater than they might have been if a pure configuration factor basis had been adopted. This policy has been adopted firstly because the horizontal projections of flames from windows will not follow a linear geometrical relationship and secondly because firefighting becomes progressively more difficult with reduction in space separation.

Table VI relates to all other conditions not covered by Table V and hence will be the more frequently used. The calculations have been based on a configuration factor of approximately 0.07 with a further 2 ft 6 in. added to each resulting distance of separation.

Both the heights and the widths listed in the tables refer to fire resisting compartments. For the purpose of implementing this table a compartment should be considered fire resisting if its bounding walls and ceilings and the ceiling of the story beneath meet the requirements based on fire load given elsewhere in the code.

In applying the tables a note is necessary as to the adoption of a value of percentage window opening. The tables relate to uniformly distributed openings and cases may thus arise where the value adopted in using the tables should refer to a very localized area where the window density is high. A further point is that the adoption of a value of window opening of less than 100 per cent is only valid where the fire resistance time of the remainder of the wall, from the point of view of penetration only, meets the requirements based on the fire load concept given elsewhere in the code.

Where this is not the case, then the window opening should be taken as 100 per cent even if, apparently, there are no openings at all in the wall in question.

TABLE V

SEPARATION FROM LOT LINE: PARTICULARLY HAZARDOUS CONDITIONS

Width of Compartment (feet)	Percentage of Window Openings	Height of Compartment (feet)									
		10′	20′	30′	40′	50′	60′	70′	80′	90′	100′
30′	100	29	38.5	47	53.5	60	65	70.5	75	79.5	84
	80	25.5	35	42.5	48	53.5	58.5	63	67.5	71.5	75.5
	60	22	31	37	42	47	51	55	59	62.5	65.5
	40	18.5	26	31	35	38.5	42	45	47.5	50	52
	20	13	17.5	21.5	24	26.5	28.5	30.5	32	33	34
40′	100	32.5	44.5	53.5	62	69	75	81	86	91	96
	80	29	40	48	55.5	61.5	67	72.5	77.5	82	86.5
	60	25.5	35	42	49	54	59	63.5	67.5	71.5	75.5
	40	20.5	29	35	40	44	48	51.5	54.5	57.5	60
	20	14	20	24	28	31	33	35	37	38.5	40
50′	100	36	49.5	60	69	76.5	83.5	90	96	101.5	106.5
	80	32.5	45	53.5	61.5	69	75	81	86	91	96
	60	28	39	47	54	60	65.5	70.5	75	79.5	83.5
	40	22	31.5	38.5	44	49	53.5	57.5	61	64	67
	20	15	22	26.5	31	34	36.5	39	41.5	43.5	45
60′	100	38.5	54	65	75	83.5	91	98	104.5	110.5	116.5
	80	34	48	58.5	67	75	82	88	94	99.5	104.5
	60	29.5	42	51	59	65.5	71	76.5	82	86.5	91
	40	24	34	42	48	53.5	58	62.5	66.5	70	73.5
	20	16	23.5	28.5	33	36.5	40	43	45.5	48	49.5
70′	100	41	58	70.5	81	90	98	105.5	112.5	119	125.5
	80	36.5	51.5	63	72.5	81	88	95	101	107	112.5
	60	31.5	44.5	55	63.5	70.5	76.5	82.5	88	93.5	98
	40	25	35.5	45	51.5	57.5	62.5	67.5	72	76	80
	20	16.5	24.5	30.5	35	39	43	46	49	51.5	54
80′	100	43	62	75	86	96	104.5	112.5	120	127.5	134
	80	38	54.5	67.5	77.5	86	94	101	108	114	120
	60	33	47	59	67.5	75	82	88	94	99.5	104.5
	40	26	37	47.5	54.5	61	66.5	72	76.5	81	85
	20	17	25	32	37	41.5	45.5	49	52	55	57.5
90′	100	44.5	65.5	79.5	91	101	110.5	119	127.5	135.5	142
	80	39.5	58	71.5	82	91	99.5	107	114	121	127
	60	34	50	62.5	71.5	79.5	86.5	93.5	99.5	105.5	110.5
	40	27	40	50	57.5	64	70	76	81	86	90
	20	17	26	33	38.5	43.5	48	51.5	55	58.5	61
100′	100	46	68	84	96	106.5	116.5	125.5	134	142	149.5
	80	41	60	75.5	86.5	96	104.5	112.5	120	127	134
	60	35	52	65.5	75.5	83.5	91	98	104.5	110.5	116.5
	40	27.5	41	52	60	67	73.5	80	85	90	95
	20	17	26.5	34	40	45	49.5	54	57.5	61	64
120′	100	49.5	73.5	91.5	104.5	116.5	127.5	137	147	155.5	163.5
	80	44	65.5	82	94	104.5	114	123	131.5	139	146.5
	60	37	57	71	82	91	99.5	107.5	114	120.5	127
	40	29	44	56	65	73	80	87	92.5	98	103.5
	20	17	28	36	43	48.5	53.5	58	62.5	66.5	69.5
150′	100	53	81.5	101	116.5	130	142	153	164	173	182
	80	47	72	89.5	103.5	115.5	127	137	146	155	163
	60	39	62	77.5	90	100	110	119	127	134	141
	40	30.5	48	60.5	70.5	80	88	96	102.5	108.5	114.5
	20	17	29.5	39	46.5	53	59	64	68.5	73	77
200′	100	58	89.5	115	134	149	163.5	176	188	199	210
	80	50	79.5	103	119.5	133.5	146.5	157.5	168	178	188
	60	41	66	85	100	113	124.5	135	145	154	163
	40	31	51.5	66.5	79	89.5	99	108.5	116	123.5	131
	20	17	30	41	50	58	65	71	77	82	87

TABLE VI

SEPARATION FROM LOT LINE: NORMAL CONDITIONS

Width of Compartment (feet)	Percentage of Window Openings	Height of Compartment (feet)									
		10′	20′	30′	40′	50′	60′	70′	80′	90′	100′
	100	19	26.5	33.5	38.0	41.5	45	48.5	51.5	54.5	57
	80	17	24.0	30	34	37.5	41	43.5	46	48.5	50
30′	60	14.5	21.0	25.5	29.5	32.5	35	37.5	39.5	41	42.5
	40	12	16.5	20	23	25.5	27.5	29.5	31	32.5	33.5
	20	8.5	11.5	14.5	16	17	18	19	19.5	20	20
	100	21.5	30.5	38	43	48	52	56	59.5	63	66
	80	19.5	28	34	39	43.5	47.5	51	54	56.5	59
40′	60	16.5	24	29.5	33.5	37	40.5	43.5	46	48	50
	40	13	19	23	27	30	32.5	34.5	36.5	38	39.5
	20	9	12.5	16	18	19.5	21	22	23	24	24
	100	24	33.5	41.5	48	53.5	59	63	67	71	74
	80	21	30	37.5	43.5	48	52.5	56.5	60	63.5	66.5
50′	60	17.5	26	32.5	37	41	45	48.5	51.5	54.5	56.5
	40	14	21	25.5	30	33	36	38.5	40.5	42.5	44
	20	9	13.5	17	19.5	21.5	23.5	25	26.5	27.5	28
	100	26	37	45	52	59	64.5	69	73.5	78	82.5
	80	22.5	33	41	47.5	52.5	57.5	62	66	69.5	73
60′	60	19	28	35	40.5	45	49.5	53	56	59	62
	40	14.5	22.5	27.5	32.5	36	39	42	45	47	48.5
	20	9	14	18	21	23.5	25.5	27.5	29	30	31
	100	28	39	48.5	56	63	69	75	80	84.5	89
	80	24	35	43.5	51	56.5	62	66.5	71	75.5	79.5
70′	60	20	30	37.5	43.5	48.5	53	56.5	60.5	63.5	67
	40	15	24	29.5	34.5	38.5	42	46	48.5	51	53
	20	9	14.5	19	22	25	27.5	29	31	32.5	34
	100	29	41	51.5	59.5	67	73.5	80	85.5	90.5	95
	80	25	37	46	54	60	66	71	76	80.5	84.5
80′	60	21	32	39.5	46	51.5	56	60.5	64.5	68	71.5
	40	15.5	25	31	36.5	40.5	45	48.5	51	54	56.5
	20	9	14.5	19.5	23	26.5	29	31	33	35	36.5
	100	30	43.5	54.5	63	71	78	84.5	90.5	95.5	100.5
	80	26	39	48.5	56.5	63.5	69.5	75.5	80.5	85	89.5
90′	60	22	32.5	41	48	54.5	59	63.5	68	72	75.5
	40	16	25.5	32	38	42.5	47	51	54	57	60
	20	9	15	20	24	27.5	30	32.5	35	37	38.5
	100	30.5	45.5	57	66	74	82.5	89	95	100.5	106
	80	26.5	40	50	59	66.5	73	79.5	84.5	89.5	94
100′	60	22.5	33	42.5	50	56.5	62	67	71.5	75.5	79.5
	40	16	26	33.5	39.5	44	48.5	53	56.5	60	63.5
	20	9	15	20	24	28	31	34	36.5	38.5	40.5
	100	32	48.5	61.5	71.5	81	89.5	97	103.5	109.5	115
	80	28	42	54.5	64	72	79	86	92	97.5	103
120′	60	22.5	34.5	45.5	53.5	61.5	67.5	73	78	83	87
	40	16	27	36	42	47.5	53	57.5	61.5	65.5	69.5
	20	9	15	20	25	29	32	35	38	41	44
	100	33.5	53.5	67	78.5	89	99	107.5	114.5	121.5	128
	80	29	46.5	59.5	69.5	79	86.5	94.5	101	107.5	114
150′	60	23	37	49.5	58.5	67	73.5	80	86	92	97
	40	16.5	28	38	45.5	52	58	63	67.5	72	76.5
	20	9	15	21	26	31	34.5	38	41.5	44.5	47.5
	100	34	57.5	74	88	100.5	111	120.5	129	137	145
	80	29	50.5	65	77	87.5	97.5	106.5	114.5	122.5	130.5
200′	60	24	40.5	53.5	64	73.5	82.5	90.5	97.5	104.5	111.5
	40	17	29.5	40.5	49.5	57	64	70	76	81.5	86
	20	9	16	22.5	28	33.5	38	42.5	46.5	50	53.5

Special Cases

If the exterior wall of a projected building is not to be parallel with the lot boundary then the possibility of relaxing the separation requirement at the corner of the building must be considered. Using the same basis of calculation as previously the distances related to the corners of buildings prove to be, in general, between 65 and 95 per cent of those listed in the tables. As firefighting near to the corner of a building is easier some relaxation is desirable and a factor of 80 per cent is suggested. The resulting limiting boundary location is illustrated in Fig. 3.

Figure 3 also gives the conditions required beyond the extreme corners of the building. In the case illustrated on the left of Fig. 3, it might be considered some hardship that the boundary may not lie in a line with the imperforate fire resistant wall. This restriction can be eliminated simply by ensuring that there are no window openings in the section CE of the adjoining wall. So far as separation requirements are concerned that wall then terminates at E and the boundary restriction would be as illustrated by the dotted line EBF (Fig. 3). It might often be desirable to apply a similar argument to the case illustrated on the right of this Figure.

The exterior wall of a building is often irregular in shape as in the two cases illustrated in Fig. 4. In such cases the preliminary considerations should be referred to a line joining the extremities of the exterior wall. Where the building is entirely contained within this line no further steps are required, for so far as levels of radiation are concerned the irregular exterior wall is exactly represented by an imaginary wall having the same percentage window openings and located on the line referred to. Where a portion of the building projects beyond this line the representation can break down under certain conditions. A precise description of these conditions is not called for in this report but has been discussed elsewhere (9). It is sufficient that the separation requirements will be approximately fulfilled if the lot boundary follows the outer limit of (a) the boundary as calculated above and (b) a boundary referred solely to the projecting portions of the building. Such composite lot boundaries are illustrated in Fig. 4.

Conclusion

Development of the separation aspect of the National Building Code by the inclusion of the dimensions of an exterior wall as an independent variable will lead to a more economic use of space as a means of reducing the spread of fire.

Acknowledgment

The configuration factor calculations involved in the derivation of Tables V and VI were carried out by P. Huot of the Fire Section, Division of Building Research, National Research Council.

References

(1) Bevan, R.C., and C.T. Webster. Investigations on Building Fires, Part III, Radiation from Building Fires. National Building Studies, Technical Paper No. 5, London, England, H.M.S.O. 1950.

(2) Galbreath, M. Note on Lanark Fire (in preparation).

(3) Shorter G.W., and J.H. McGuire. Summary Report of St. Lawrence Burns, (to be published as DBR Internal Report No. 158).

(4) McGuire, J.H., and G.W. Shorter. An Example of the Spread of Fire by Radiation. National Research Council, Division of Building Research, DBR Internal Report No. 145. 1958.

(5) National Building Code of Canada (1953), Part 3: Use and Occupancy. National Research Council, Associate Committee on the National Building Code.

(6) Shorter, G.W., and C.G. Burnett. Fire Investigations by the Fire Research Section, 1950-1954. National Research Council, Division of Building Research, DBR Internal Report No. 78. March 1956.

(7) Stephenson, D.G. Radiant Temperature of Openings, St. Lawrence Burns. (to be published as DBR Internal Report No. 156.)

(8) Lawson, D.I., and D.L. Simms. The Ignition of Wood by Radiation. Brit. Jour. Appl. Phys., Vol. 3, p.288-292, September 1952.

(9) McGuire, J.H. Heat Transfer by Radiation. Fire Research Special Report No. 2, H.M.S.O., London, England. 1953.

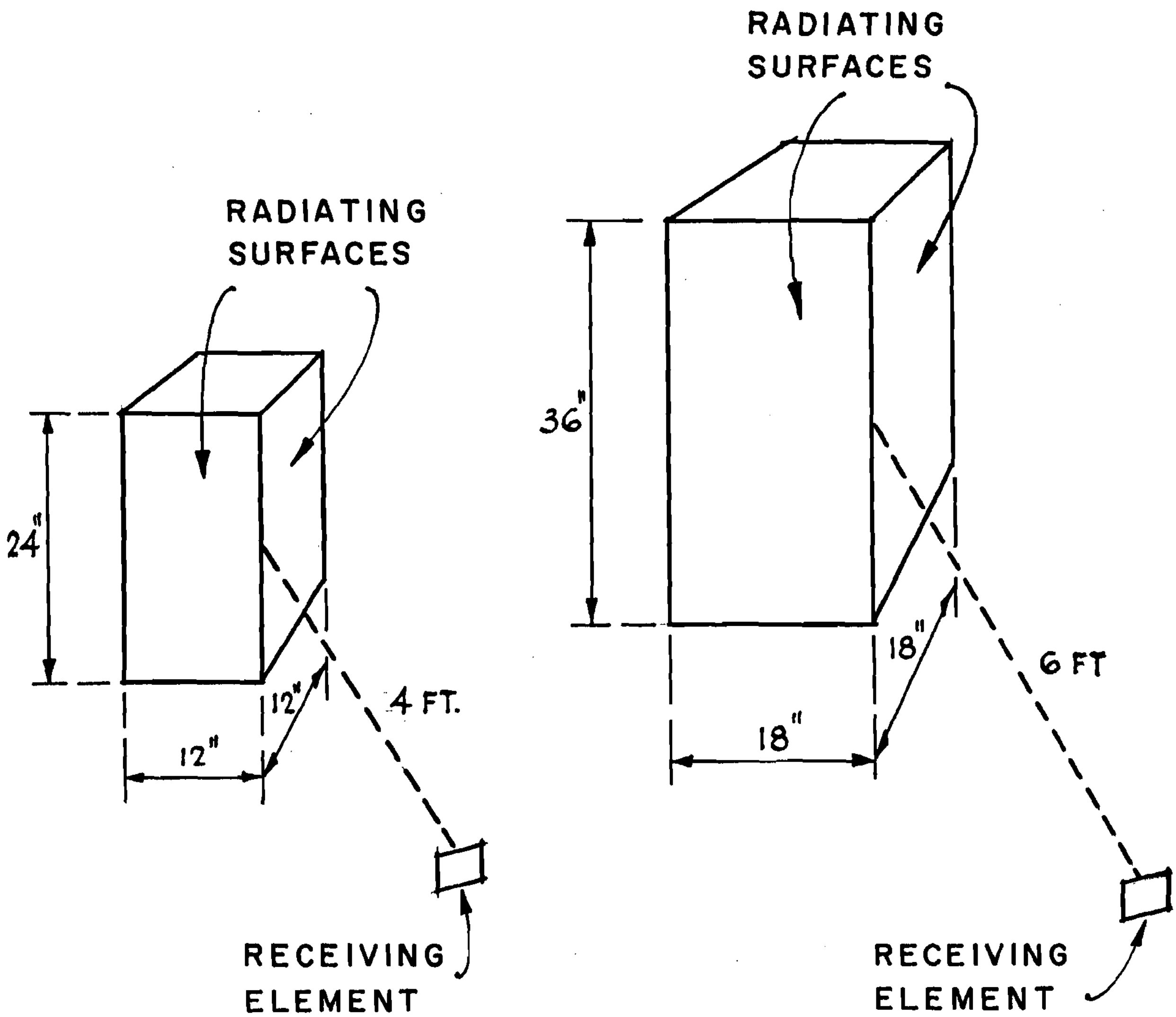


FIGURE I
GEOMETRICAL RELATIONSHIPS

BR 1983-1

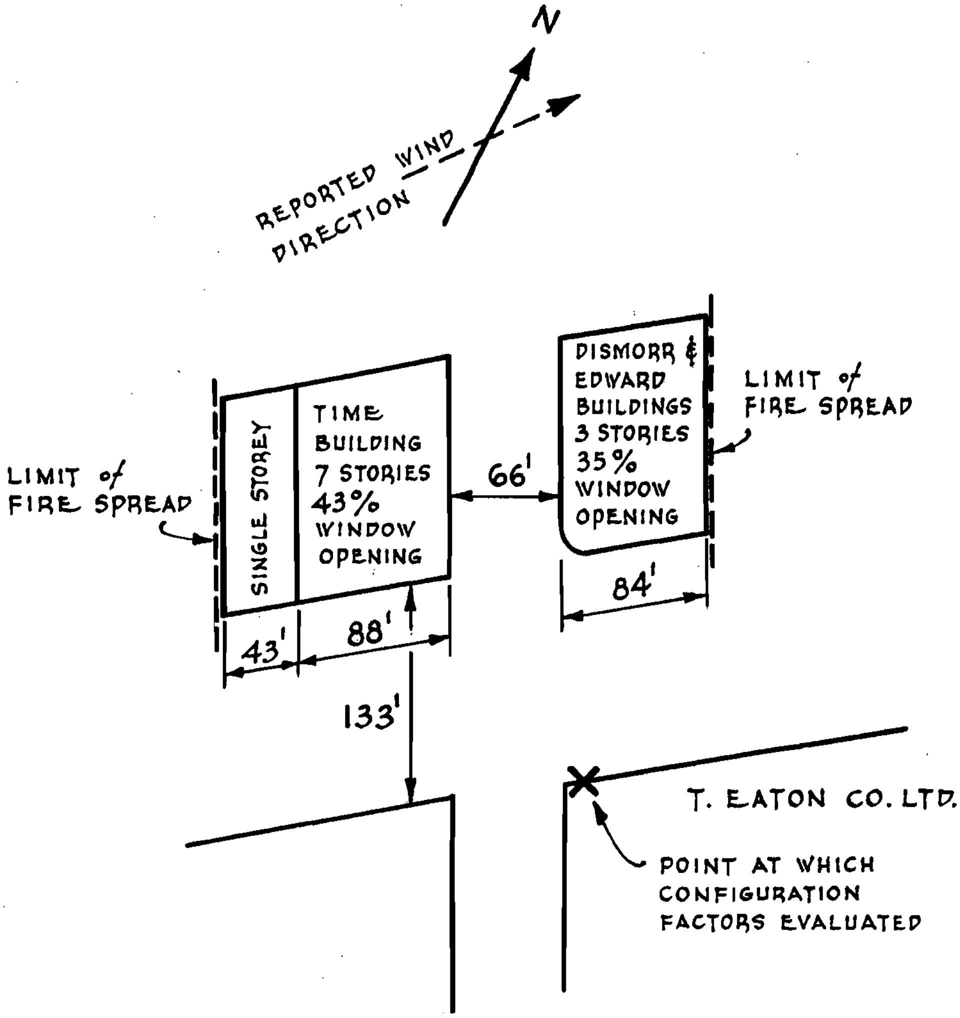


FIGURE 2

PLAN OF AREA INVOLVED IN WINNIPEG FIRE

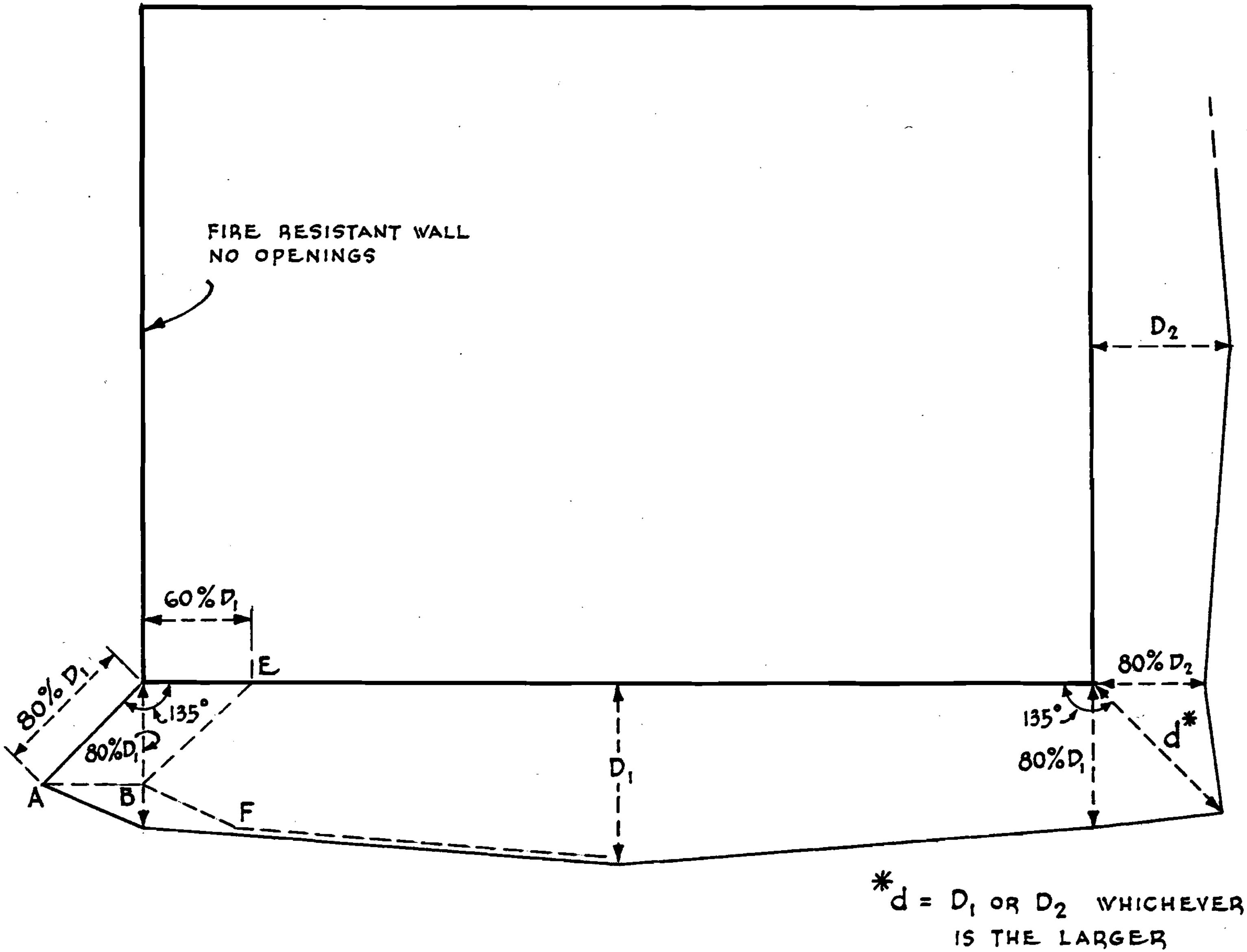
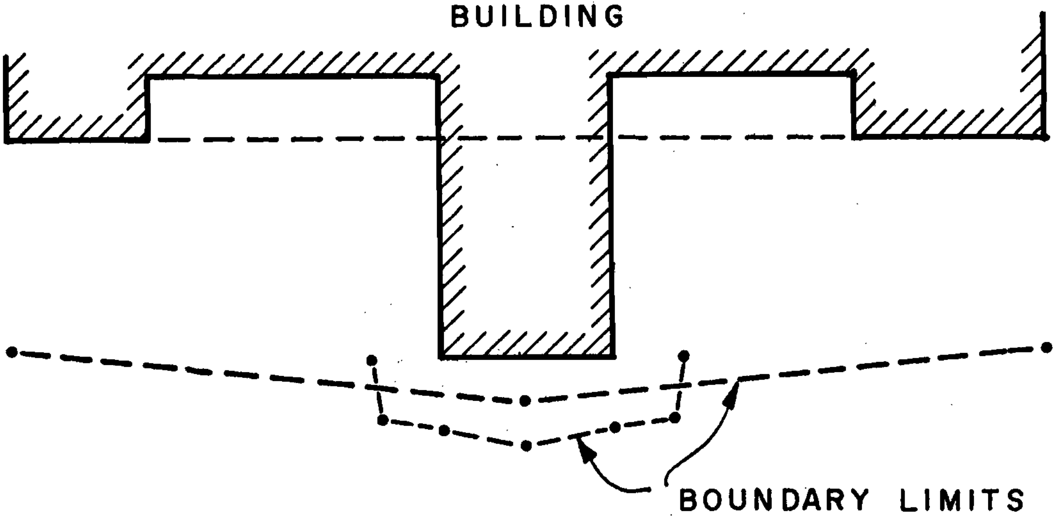


FIGURE 3

BOUNDARY CONDITIONS AT THE CORNERS OF BUILDINGS

BR 1983-3



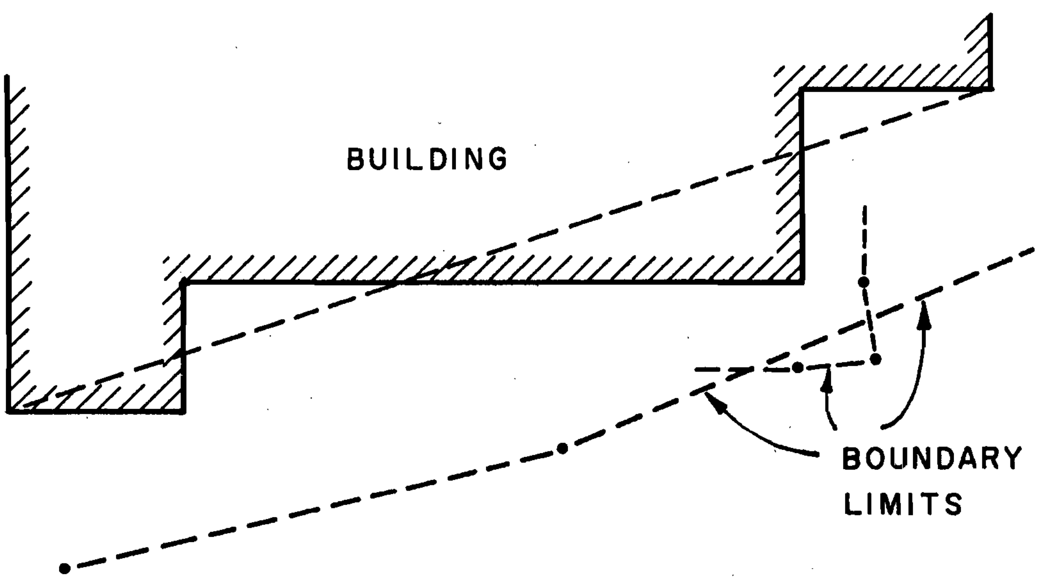


FIGURE 4

BOUNDARY CONDITIONS FOR IRREGULARLY SHAPED BUILDINGS

APPENDIX A

THE CONFIGURATION FACTOR CONCEPT

The radiation level I at a distance from a source emitting radiation at a level I_O is related to I_O by the expression $I = I_O \times F$, where F is the configuration factor* and has the property that it is dependent solely on the geometrical relationship of receiver and source.

The practical application of the above expression to building fires is complicated by the fact that very little data are available on the radiating nature of the flames emanating from burning buildings. Even if information were available it would be difficult to apply since the emissivity of flames is a variable and hence an integral form of the above expression is required.

The most simple method of overcoming this difficulty is to represent the radiation conditions at the side of a building by a level of radiation higher than is found in practice but emanating only from the window openings. An assumption of this nature must, in fact, be accepted implicitly if a building code is to discuss percentage window openings instead of the precise geometry of openings in a building facade. Even if percentage window opening is maintained constant, variation in the geometry of window openings will affect the levels of radiation at a distance from a building. In general, however, the extent of the variation can be neglected.

On the assumption that only the windows are radiating the relationships between intensities of radiation at various points are given quite simply in terms of the appropriate configuration factors. If I be the measured radiation level at some point P away from a burning building then on the assumption that only the windows are radiating, but at a radiation level I_W which will produce a radiation level I_P at the point P, then

$$I_P = I_W F_{PW} \quad \text{or} \quad I_W = I_P / F_{PW} .$$

F_{PW} is the configuration factor of the window area with respect to an elemental receiving area at point P and depends only upon the geometrical relationship of the window area and the elemental area at P.

---

* The configuration factor of a radiating area with respect to an elemental receiving area may be defined as the ratio of the intensity of radiation at the receiving element to the intensity near to the radiator. Its value is dependent solely on the geometrical relationship between the radiator and the receiving element and may lie between zero and unity.

Now since I_W is not a real intensity, it may be preferable to refer to it simply as the ratio I_P/F_{PW} or simply I/F, it being understood that F in this case is the configuration factor relating the window area to the elemental area at the point at which the measured intensity was I.

The real object of this procedure is that it now permits an estimate to be made of the radiation level at any point Q from the radiation level I_P measured at P.

$$I_Q = I_W \times F_{QW}$$

but I_W was given by I_P/F_{PW}

$$\therefore I_Q = I_P \times \frac{F_{QW}}{F_{PW}}$$

F_{QW} in this case is the configuration factor of the window area with respect to an elemental receiving area at point Q.

Now, if a number of measured or estimated radiation levels corresponding to I_P are known for a number of different cases, it is possible, using the approach outlined, to compare these by calculating the equivalent window radiation levels, I/F in each case. A value of I/F representative of a particular fire situation may then be selected.

In considering the possibility that a fire in one building will ignite another by radiation, and having estimated an equivalent window radiation level for burning buildings and established the maximum tolerable radiation level at the building to be protected, it becomes possible to refer to limiting values of F for which the radiation levels at the building to be protected will be kept within the desired limits. F in this case is the configuration factor relating window areas of the compartment on fire to the exposed surface of the building to be protected. This then, in effect, means that the level of radiation imposed on one building can be described in terms of the size, arrangement, and geometry of the windows of the compartment on fire as related to the surfaces to be protected.

In the work described in this report, it has been assumed that the radiation from the flames and openings at the side of a building will be linearly related to the area of the openings. This approximation may tend to break down where large percentage window openings are considered and the predicted levels of radiation may then be exaggerated for two reasons:

1) when the flames from adjacent windows overlap, the levels of radiation from the combination will be less than the sum of the levels related to each window opening since flame emissivities vary exponentially with thickness, asymptotically approaching an upper limiting value of unity.

2) with large window openings ventilation becomes a less important factor governing rate of burning and the volume of flame emanating from openings will not necessarily increase linearly with increase in percentage window opening.