Space between buildings as a means of preventing the spread of fire. Report C: survey of an average density residential area on steeply sloped terrain in Vancouver

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DIVISION OF BUILDING RESEARCH

SPACE BETWEEN BUILDINGS AS A MEANS OF PREVENTING THE SPREAD OF FIRE

Report C -- Survey of an Average Density Residential Area on Steeply Sloped Terrain in Vancouver

by

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Vancouver, B. C.

A Joint Project of the School of Architecture
and the Graduate Program in Community and Regional Planning,
University of British Columbia
and the
Division of Building Research, National Research Council

Internal Report No. 282

of the

Division of Building Research

OTTAWA

November 1963

The late Professor Fred Lasserre, as Director of the School of Architecture at the University of British Columbia, was one of the original sponsors of this research project. His contribution is remembered appreciatively by all connected with this Report.

R. F. Legget

PREFACE

This report is one of a series of four which are concerned with space between buildings as a means of preventing the spread of fire, which in turn forms part of a main research project "Performance Standards for Space and Site Planning for Residential Development."

This project has been undertaken for the Division by the School of Architecture at the University of British Columbia. Two reports have already been issued: An Annotated Bibliography on Performance Standards for Space and Site Planning for Residential Development (NRC 6442) and DBR Internal Report No. 273, "A Study of Performance Standards for Space and Site Planning for Residential Development." The latter contains a discussion of the factors that determine the spacing of residential buildings. This present series of four reports deals with one of these factors -- fire. The other factors, including daylight, noise and privacy, will be dealt with in subsequent reports. When all of these reports are issued, they will form a complete evaluation of the conditions that must be considered in the planning of residential areas in Canada.

The first two authors of this report are on the staff of the University of British Columbia. Professor Oberlander, besides his duties on the staff of the School of Architecture, is Head of the Graduate Program in Community and Regional Planning; Professor Gerson, at the time this report was written, was Acting Director of the School of Architecture. Mr. Goldsworthy, a graduate architect, was engaged as research assistant to the project. Professor Henry Elder is the present Head of the School of Architecture; the project was initiated under the direction of his predecessor, the late Professor Fred Lasserre.

This information is being issued in the Divisional series of internal reports so that those responsible for the work can have the benefit of informed comments prior to publishing in a more formal way. Comments will therefore be welcomed and should be sent either to Professor Oberlander at the University of British Columbia or to the writer at Ottawa.

Ottawa
November 1963

R. F. Legget
Director, DBR/NRC

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INTRODUCTION

The volume of post-war housing across Canada has revealed a great number of problems in the use of site planning standards as a basis for achieving a high quality of residential communities. This unprecedented volume, coupled with the concentration of new housing in the suburbs of Canadian cities, has made a rational layout of the many hundreds of units in relation to each other and to their communal facilities very difficult. Traditional space and location standards for large-scale housing have not been able to control resulting development adequately. In most instances, it has merely allowed housing to be built in a mechanically neat and orderly fashion. More flexible and imaginative standards of house grouping and layout seem essential if the next flood of housing in Canadian cities is to add more to urban Canada than merely further volume of accommodation.

Throughout the post-war decade Canadian cities and towns became aware of the value of community planning and of their respective responsibilities for controlling the individual's use of his land for the benefit of the community as a whole. Traditionally, town planning has been closely linked with rules and regulations laid down in bylaws, uniformly applied throughout the jurisdiction of a given city or town. These rules and regulations, usually contained in a zoning or subdivision control bylaw, restrict the way in which buildings may be sited on their respective lots and the amount of space on that lot that has to remain open and unobstructed by any construction. These regulations often include minimum front and rear yard dimensions as well as side yard limitations and related restrictions as to the height of buildings. It is usually contended that it is in the community's interest to set certain space standards between and around buildings to achieve safety, minimum health standards, amenity and aesthetic appearance. These space regulations as a rule are expressed in absolute measurements of distance, and result in monotonous and rigid spacing of buildings. This is particularly true of residential areas that have been built in large groups of single units; the typical post-war housing subdivision falls into this category.

The main purpose of the research project is to demonstrate that adequate space around and between buildings for functional and aesthetic purposes can be achieved with greater flexibility and without unduly restricting the siting of residential buildings. Such flexible standards are usually referred to as performance standards since they determine space between and around buildings by the variety of functions that they are to perform and in relation to the size and dimension of land and buildings in a given situation. In the post-war decade, performance standards were used in the siting and building of industrial and commercial structures. This experience demonstrated that performance standards provide a more flexible framework for the designer of individual buildings or groups of buildings and also enable government agencies to administer regulations effectively.

The present report forms a portion of this research. The research began with a survey of literature from which an annotated bibliography was prepared (2). This gave the initial direction to the work and was used extensively during the following studies. The factors which determine the spacing of residential buildings were then investigated (3). The full range of community objectives are fire, daylight, air, noise, privacy, view, traffic and outdoor space.

It is the general aim of this part of the investigation, now reported, to study the application of the prevention of fire as a determinant of space between buildings in residential areas and to develop specific methods for the application of these standards. This particular field of investigation was chosen because of the critical nature of fire safety and because information was more readily available than for some of the other community objectives. The information which is here discussed is based on fire studies conducted by the Division of Building Research and similar bodies throughout the world.

The first part of this investigation consists of three field surveys of actual residential developments in Metropolitan Vancouver*. The information thus obtained provides the basis for formulating a technique for applying performance standards to the prevention of fire spread from building to building through the flexible use of the space between them (contained in DBR Internal Report No. 283 by H. P. Oberlander and R. S. Ferguson).

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* This report (DBR Internal Report 282), and DBR Internal Reports 280 and and 281 by the same authors.

PART 1

THE ANALYTIC METHOD

It is the purpose of this stage to examine current conditions and standards; hence the investigation begins with a survey of existing residential areas of a varied nature in order to obtain as wide a view as possible of the total range of residential development in a typical Canadian metropolitan area.

These surveys consist of field questionnaires and measured drawings for each building. A summary of this information for all of the buildings within the area now reported on will be found in Appendix A. This method yields an adequate explanation of the construction and geometry of the buildings but does not fully show the relationship of a building to its neighbours. To demonstrate this a scale model of the area was constructed (Figures 1, 2 and 3).

The model indicates not only the relationships of buildings in the area but, more important, it indicates the types and qualities of the spaces between and around the buildings much more clearly than any other form of presentation. In addition to showing the existing spaces, the model also allowed graphical illustration of the spatial separations which would be required if the layout of the buildings on the site were to conform to certain standards other than those which were in effect at the time of construction. These standards will be more fully explained in the following pages and the analyses of the spaces will be found in Part 3 of this report.

Any study of existing conditions is incomplete without an investigation of the forces which shaped them. Among others, great influence is exercised by the building and zoning bylaws through which the public controls the siting and the form of individual buildings for purposes of public safety. Since this survey is restricted to the control of conflagrations by space separations, the extent to which these regulations are based on considerations of fire safety will become evident. This will allow demonstration of the effect of these regulations on the pattern of residential development.

Analyses of existing spaces consist of checking the spaces against three standards: Table IV of the Housing Standards; 1962 (7), Table VI contained in the Division of Building Research Internal Report No. 187 by J.H. McGuire (5) and a conversion of Table VI. For convenience, these tables shall be referred to as Tables 1, 2 and 3 respectively in this present report (see pages 9, 10 and 11).

The reasons for choosing Table 1 were twofold. First, it allowed comparison between the municipal regulations concerning the use of spatial separations and those contained in the National Building

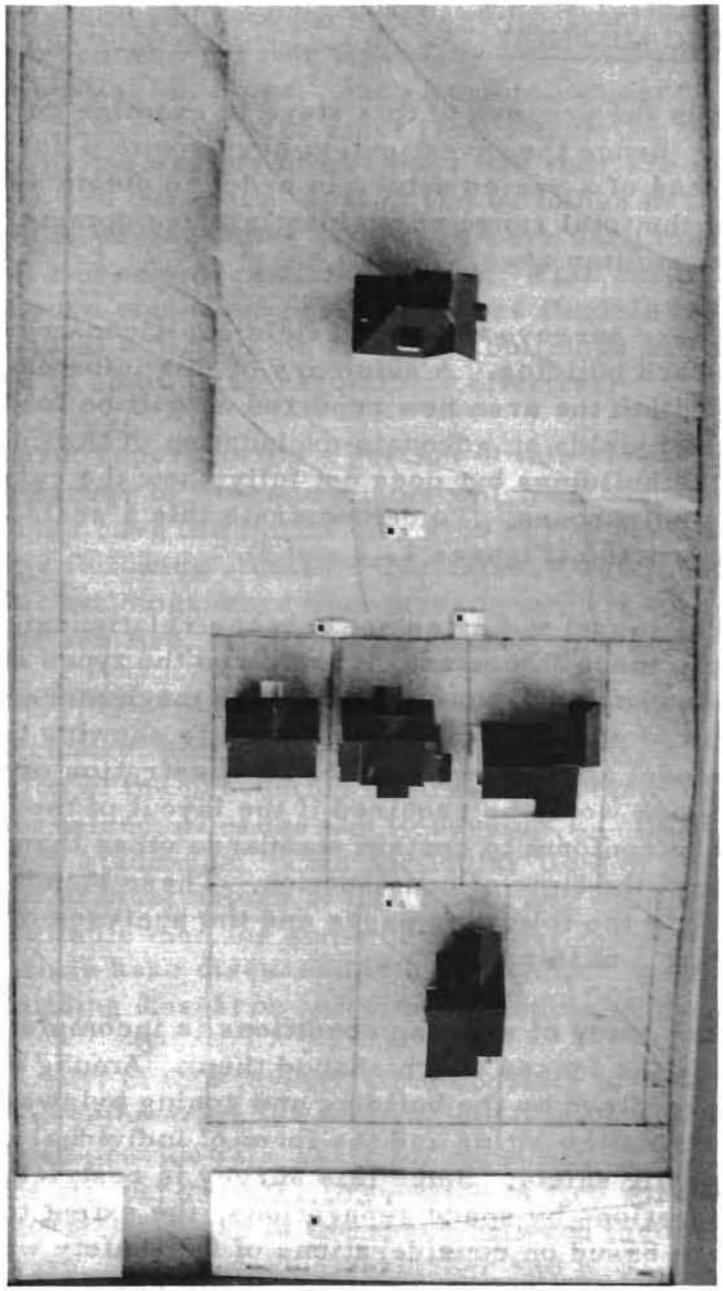

FIGURE I

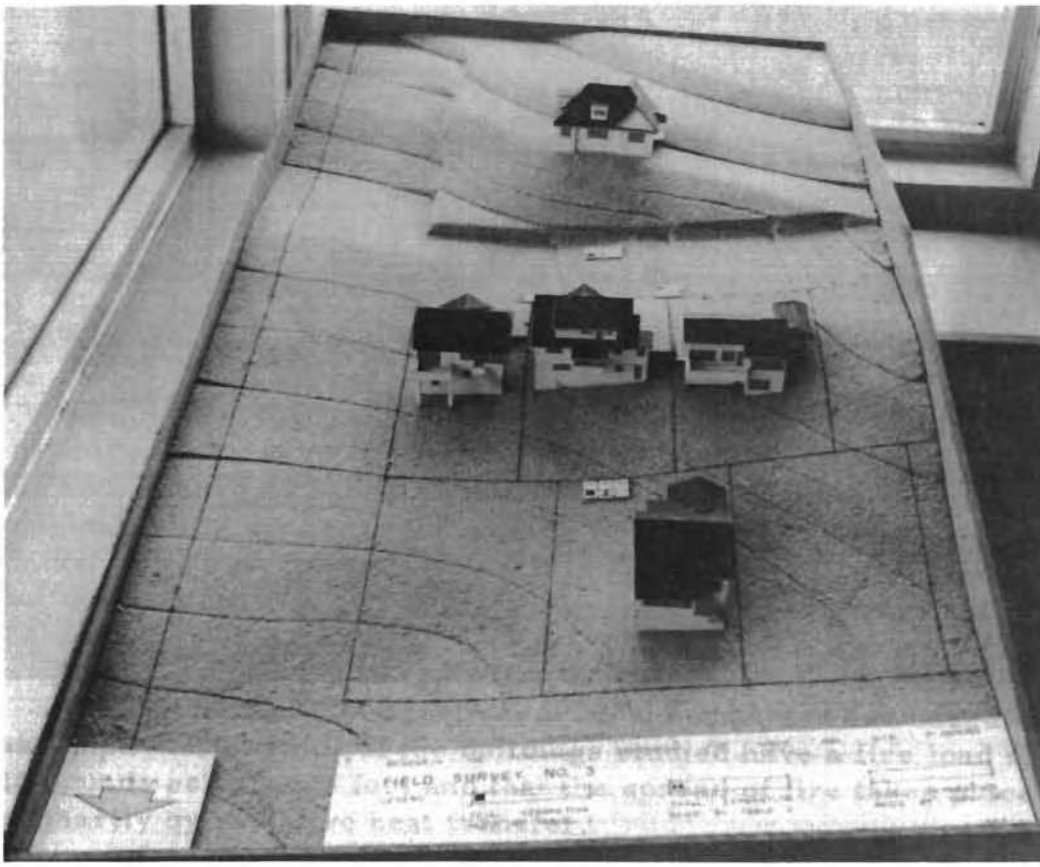

FIGURE 2

FIGURE 3

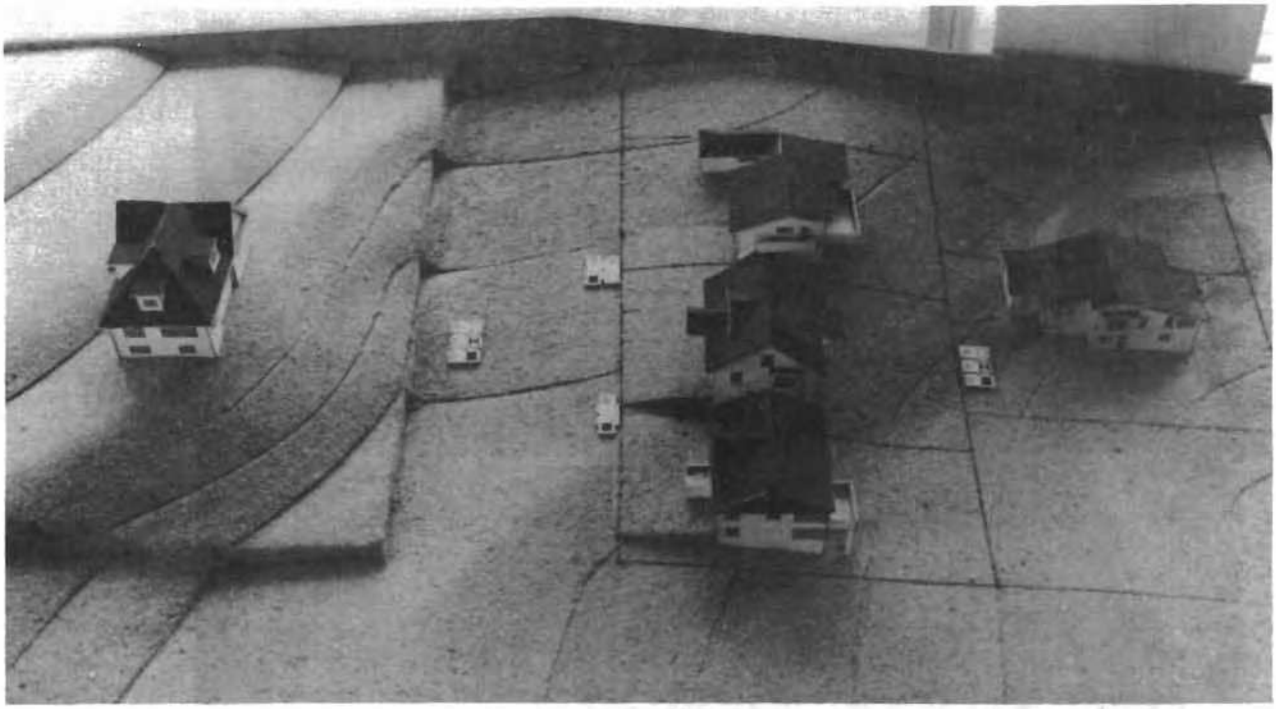

FIGURE 4

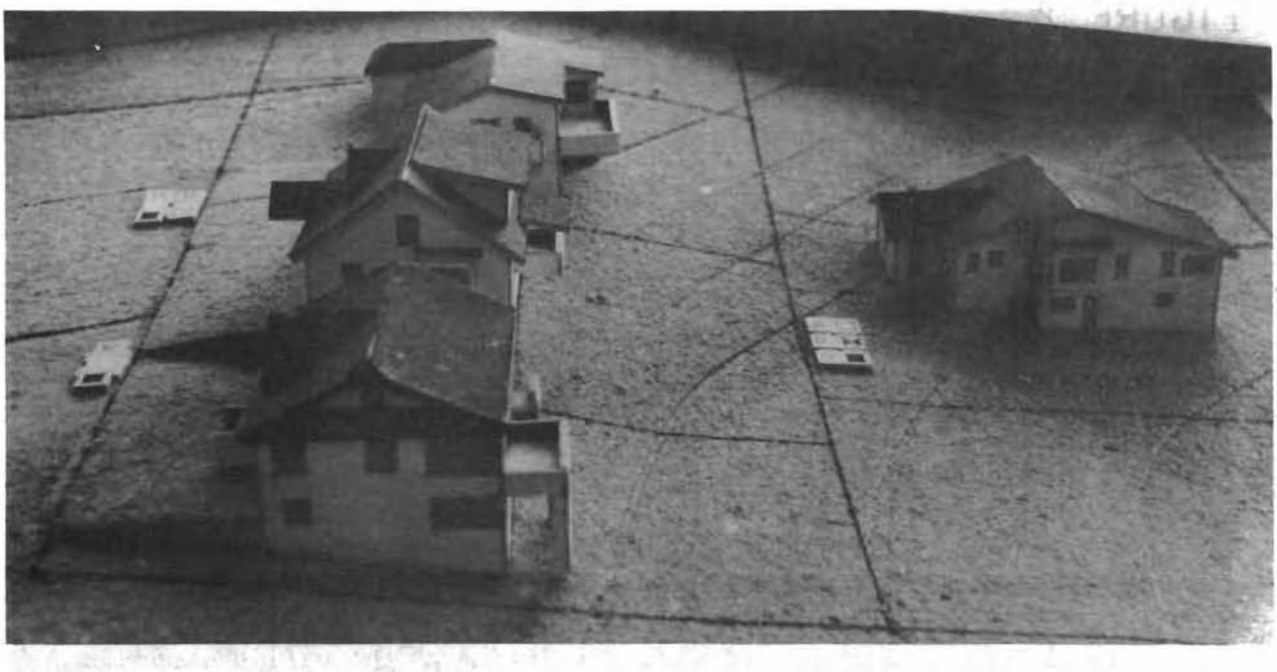

FIGURE 5

Code. Also, the project could be used as a testing ground for the use of the table, as a basis for comment on its workability and discussion of its advantages and limitations under a variety of conditions. These comments will be found in Part 3 of this report. Table 2 was used because it formed the basis for Table 1. It was therefore of interest to compare the results of these two standards in order to assess the agreement between them and to comment on the workability of the two different forms of presentation.

Tables 1 and 2, however, give the required spatial separations in terms of distance from the building face to the lot line. This was done to simplify the application and to avoid administrative difficulties. In order to increase the flexibility of the standards and, incidentally, to make them more consistent with the results of original research conducted by the Division of Building Research, Table 2 was converted to give the separations in terms of space from building to building. The conversion is included in this report as Table 3.

It should be mentioned that the analyses are based on two assumptions; that all of the buildings studied have a fire load of 10 pounds per square foot and that the spread of fire takes place primarily by radiative heat transfer.

The fire load concept has been defined as follows:

> "If the ... amount of the combustible contents of a building are divided by the floor area, a figure is obtained which allows comparison between different buildings, or different parts of the same building. Fire load is thus determined in B. Th. U's per sq. ft. by the formula:
>
> $$\frac{\text{cal. value of contents in B. Th. U's per lb.} \times \text{weight of contents in lb.}}{\text{Floor area in sq. ft.}}$$
>
> "Because most buildings are built for a specific occupancy, it is possible to predetermine fairly accurately their maximum fire loads in full use." (1, p. 47, 48).

From discussions with officials of the Division of Building Research, it was found that the value of 10 pounds per square foot is the one on which the table of separation in the National Building Code was based. This is also approximately the same as the values assumed in the St. Lawrence Burns experiments which were conducted by the Division in 1958 (11).

As for the assumption that the spread of fire from building to building takes place by radiation, it is stated in "Spatial Separation of Buildings" (5, p. 1) that:

"The spread of fire between two buildings may result from:

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, and thus it is not practical to consider spatial separation between buildings as a means of combatting this hazard. Fortunately other means are available.

"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 it follows that radiative heat transfer is the factor of primary importance in producing spread of fire across a space separation between buildings ...."

TABLE 1

SEPARATION FROM LOT LINE

Area of Exposed Building Face, sq ft	Ratio L/H or H/L*	LIMITING DISTANCE, ft									
		4	6	10	15	20	30	50	70	100	140
		Permissible Area of Unprotected Openings in Exposed Building Face, per cent									
less than 300	less than 3:1	5	7	15	32	57	100	100	100	100	100
	3:1 to 10:1	6	9	18	34	63	100	100	100	100	100
	over 10:1	9	13	25	44	68	100	100	100	100	100
300 and over but less than 400	less than 3:1	5	6	12	23	41	65	100	100	100	100
	3:1 to 10:1	6	8	15	27	45	80	100	100	100	100
	over 10:1	8	11	20	35	55	100	100	100	100	100
400 and over but less than 500	less than 3:1	4	6	11	21	34	73	100	100	100	100
	3:1 to 10:1	5	7	13	23	37	75	100	100	100	100
	over 10:1	7	10	18	31	47	87	100	100	100	100
500 and over but less than 600	less than 3:1	4	6	10	18	19	60	100	100	100	100
	3:1 to 10:1	5	7	11	19	32	70	100	100	100	100
	over 10:1	7	10	17	28	41	80	100	100	100	100
600 and over but less than 800	less than 3:1	4	5	8	15	23	50	100	100	100	100
	3:1 to 10:1	5	6	10	16	25	52	100	100	100	100
	over 10:1	7	8	14	23	35	60	100	100	100	100
800 and over but less than 1000	less than 3:1	4	5	7	12	19	40	100	100	100	100
	3:1 to 10:1	5	5	9	14	22	44	100	100	100	100
	over 10:1	6	8	13	21	30	50	100	100	100	100
1000 and over but less than 1500	less than 3:1	3	4	6	9	14	28	73	100	100	100
	3:1 to 10:1	4	5	8	11	16	31	75	100	100	100
	over 10:1	6	7	11	17	23	40	87	100	100	100
1500 and over but less than 2500	less than 3:1	3	3	5	7	10	19	44	88	100	100
	3:1 to 10:1	3	4	6	9	12	21	48	90	100	100
	over 10:1	5	7	9	13	17	34	50	100	100	100
2500 and over but less than 3500	less than 3:1	3	3	4	6	8	14	34	62	100	100
	3:1 to 10:1	3	4	6	8	10	16	47	67	100	100
	over 10:1	5	6	8	11	15	23	50	73	100	100
3500 and over but less than 5000	less than 3:1	2	3	4	5	7	11	25	44	88	100
	3:1 to 10:1	3	3	5	7	8	13	35	48	90	100
	over 10:1	5	6	7	10	12	19	38	50	100	100
5000 and over	less than 3:1	2	2	3	5	6	8	19	34	50	100
	3:1 to 10:1	2	2	4	6	7	10	22	37	55	100
	over 10:1	4	5	7	9	10	15	30	47	60	100
Column 1	2	3	4	5	6	7	8	9	10	11	12

* L = length of building face; H = height of building face.

TABLE 2

SEPARATION FROM LOT LINE

Width of Compartment (feet)	Percentage of Window Openings	Height of Compartment (feet)									
		10	20	30	40	50	60	70	80	90	100
30	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
	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
40	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
	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
50	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
	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
60	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	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
70	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
	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
80	100	29	41	51.5	59.5	67	75.5	80	85.5	90.5	95
	80	25	37	46	54	60	66	71	76	80.5	84.5
	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
90	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
	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	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
	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
120	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
	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
150	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
	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
200	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
	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

TABLE 3

SEPARATION FROM BUILDING TO BUILDING

Width of Compartment (feet)	% of window openings	Height of compartment (feet) 10	20	30	40	50	60	70	80	90	100
30	100	33	48	62	71	78	85	92	98	104	109
	80	29	43	55	63	70	77	82	87	92	95
	60	24	37	46	54	60	65	70	74	77	80
	40	19	28	35	41	46	50	54	57	60	62
	20	12	18	24	27	29	31	33	34	35	35
40	100	38	56	71	81	91	99	107	114	121	127
	80	34	51	63	73	82	90	97	103	108	113
	60	28	43	54	62	69	76	82	87	91	95
	40	21	33	41	49	55	60	64	68	71	74
	20	13	20	27	31	34	37	39	41	43	43
50	100	43	62	78	91	102	113	121	129	137	143
	80	37	55	70	82	91	100	108	115	122	128
	60	30	47	60	69	77	85	92	98	104	108
	40	23	37	46	55	61	67	72	76	80	83
	20	13	22	29	34	38	42	45	48	50	51
60	100	47	69	85	99	113	124	133	142	151	160
	80	40	61	77	90	100	110	119	127	134	141
	60	33	51	65	76	85	94	101	107	113	119
	40	24	40	50	60	67	73	79	85	89	92
	20	13	23	31	37	42	46	50	53	55	57
70	100	51	73	92	107	121	133	145	155	164	173
	80	43	65	77	97	108	119	128	137	146	154
	60	35	55	70	82	92	101	108	116	122	129
	40	25	43	54	64	72	79	87	92	97	101
	20	13	24	33	39	45	50	53	57	60	63
80	100	53	77	98	114	129	142	155	166	176	185
	80	45	69	87	103	115	127	137	147	156	164
	60	37	59	74	87	93	107	116	124	131	138
	40	26	45	57	68	76	85	92	97	103	108
	20	13	24	34	41	48	53	57	61	65	68
90	100	55	82	104	121	137	151	164	176	186	196
	80	47	73	92	108	122	134	146	154	165	169
	60	39	60	77	91	104	113	122	131	139	146
	40	27	46	59	71	80	89	97	103	109	115
	20	13	25	35	43	50	55	60	65	69	72
100	100	56	86	109	127	143	160	173	185	196	207
	80	48	75	95	113	128	141	154	164	169	183
	60	40	61	80	95	108	119	129	138	146	154
	40	27	47	62	74	83	92	101	108	115	121
	20	13	25	35	43	51	57	63	68	72	76
120	100	59	92	118	138	157	174	189	202	214	225
	80	51	79	104	123	139	153	167	179	190	201
	60	40	64	86	102	118	130	141	151	161	169
	40	27	49	67	79	90	101	110	118	126	134
	20	13	25	35	45	53	59	65	71	77	83

PART 2

DESCRIPTION OF THE AREA

It was mentioned in Part 1 of this report that the investigations were to consist of surveys of existing residential areas of a varied nature in order to obtain as wide a view as possible of the total range of residential development in a typical Canadian metropolitan area. The site for the third study was chosen with this in mind. The selected site differs significantly from the other areas being investigated.

Whereas the first study area was located in a fully developed district adjacent to Vancouver's Downtown and the second was in a very low density subdivision on the outskirts of the city, the present area is located in a residential district with a density somewhere between the previous examples.

The main reason for the choice of the area, however, was the topographical condition. The first two survey areas were quite flat, whereas this one is steeply sloping in two directions. This allowed investigation of the effect that a difference in ground elevation has on the separation required to prevent the spread of fire from building to building by means of radiative heat transfer.

FACTORS THAT SHAPED THE AREA

Building and Zoning Bylaws

The historical method of urban development has been to exploit every piece of land within the lot lines as far as structural considerations allow. The congestion of cities, however, caused by the rapid industrial expansion in the nineteenth and early twentieth centuries led to a reaction.

Two methods have been used in the past to control the development of private property. The first, such as the regulations governing the materials of construction incorporated into the Redevelopment of London Act, intended to achieve the community value by requiring minimum standards of materials and building construction. The second, also based on structural considerations, achieved its purpose by imposing a dimensional limitation on the interior space.

The attitude today is still the same; yet in an attempt to safeguard the general welfare of the public, residential building regulations enforce standards of spatial separation as well as structural standards. Although both forms of control are exercised in modern building regulations, it is the effect of spatial separation that is important in this study. It is controls on the dimensions of space which are involved in space and site regulations.

Contemporary space and site controls appear to have evolved from these early efforts of communities to protect themselves against hazards to safety and health which might otherwise arise if development by the individual land owner was uncontrolled. Structural safety and protection from fire spread and health hazards still provide the basis for all bylaws in Canada dealing with the construction and use of buildings.

The history of regulations governing the materials and methods of construction has progressed through three stages of development; "primitive standards", specification standards and performance standards (8). To date it is still the accepted practice to formulate space and site regulations with reference to a specification standard. Such a standard gives quantitative meaning to the regulation and defines the extent to which a community can control the right to develop the land. Providing the developer complies with the minimum standard specified in the regulation when erecting a structure on his property, it is assumed that the community interest has been satisfied insofar as the community value basic to the regulation is concerned. For reasons already stated, however, it is the contention of the authors that performance standards should also form the basis for space and site planning.

In Canada, where timber construction is still prevalent, space separations are utilized as barriers to the spread of fire in place of fire-resistive construction. Setback regulations in building codes and zoning ordinances in North America appear to have originated as devices to prevent the spread of fire.

The variety of minimum setbacks quoted in various building and zoning bylaws in Canada for similar circumstances suggests that; first, other functions are now critical in establishing setback requirements in certain cities, or second, some cities have given no recognition to technological improvements in fire-resisting materials of construction, hence are out-of-date with respect to current building practice.

Subdivision of Land

Because of the traditions of home ownership in Canada, subdivision of large parcels of land into individual lots has normally preceded the construction of housing units. The R. A. I. C. Committee of Inquiry noted the following practice common in current residential development.

> "The developer decides what plot dimensions he can sell to prospective dwelling owners. He shows the tract of land to technical advisers: salaried or consultant surveyors, site planners, utility engineers. About a third of his land will have to be dedicated for

thoroughfares and public open space. The remainder of his tract he will ask to be divided for the optimum sale of plots of the chosen size. It is possible, and not uncommon, for a whole township to be reduced to little pieces of identical dimensions; on each plot only one sort and size of house can be built." (10, p. 191).

To meet these conditions, regulations which were intended to control the spacing of structures in relation to one another were related to the legal lot lines to permit spatial control despite the absence of structures on the adjacent lots. This form of regulation still exists today. It is sufficient to state here that this approach opposes variety in site development.

Results of These Factors

The Committee of Inquiry also emphasized the adverse effect that existing site and space regulations are having upon residential development.

"Where municipal codes governing physical development are demonstrably linked to such future contingencies, their clauses must be respected. But this sensible linkage is hard to discover in many of the by-law restraints put upon residential area design. For instance it is commonly laid down that an access road allowance must be 66 feet wide, with all buildings set back another 25 or 30 feet from that road line. These provisions sterilize 1000 square feet of land that some family should be allowed to enjoy. They also separate opposite house fronts by something like ten times their height, thus making illegal the grouping of houses for best effect at lowest cost. There are many other examples of this unreason." (10, p. 191).

The community values generally accepted as underlying current site and space controls are related to safety, health and welfare. Urban areas and particularly urban residential areas are now, in comparison with those of the last century, safe and healthy places in which to live.

It is the continuing purpose of residential building regulations to improve the existing environment. While progress has certainly been made in the past, the process must continue.

The space and site planning regulations for the study area are contained in the zoning bylaw of that municipality (9, p. 3). This document commences with the following statement of purpose:

"Whereas after considering the recommendations of the Point Grey Town Planning Commission, it appears advisable and expedient to make regulations and divide the Municipality into districts as hereinafter provided, persuant to the Town Planning Act, having due regard to:

a) The promotion of public health, safety, convenience and welfare;

b) The prevention of the overcrowding of land and the preservation of the amenity of residential districts;

c) The securing of adequate provisions for light, air and reasonable access;

d) The value of the land and the nature of its use and occupancy;

e) The character of each district, the character of the buildings already erected, and the peculiar suitability of the district for particular uses;

f) The conservation of property values and the direction of building development."

The regulations attempted to achieve these aims by enforcing the following specification standards, among others:

Height of Dwellings:

Not to exceed 35' nor two and one-half storeys.

Front Yard:

Not less than 24'.

Rear Yard:

Not less than 25'.

Side Yards:

Not less than 5' on each side of the dwelling.

Open Space:

Not less than 60% of the area of the site.

A point worth considering is the fact that regulations that control the dimensions of residential space for the purpose of safeguarding health and safety have significantly, although unintentionally, influenced the visual appearance of residential environment. The problem in urban residential development is the growing concern about the absence of satisfactory design in the spatial arrangement of housing. The model furnishes graphic proof of the rigid and monotonous spacing of the buildings in the study area.

In situations where housing is being constructed for sale or rent, the economic return from a residential lot within the same neighbourhood is roughly proportional to the space enclosed by the structure. Under these circumstances, the building envelope defined by the site and space regulations and which establishes the maximum permissible enclosed space, effectively shapes the structure. In cases where economy is secondary to design the specific nature of the standards permits no substitution which might equally well achieve the purpose basic to the regulation, hence they exert a confining effect on imaginative layout design. It is the main purpose of the research project to demonstrate that adequate space around and between buildings for functional and aesthetic purposes can be achieved with greater flexibility and without further restricting the individual's choice in siting and building his dwelling units.

PART 3

All buildings in the area have been numbered for the sake of convenience. This allows us to refer to a space and its surrounding buildings with ease. For example, Buildings 1 and 2 define space 1-2. The numbering system and the relationship of the buildings may be seen in the aerial photographs of the model (see figures 1, 2, 3, 4 and 5, pages 4 to 6).

The procedure to be followed is to analyze each building to determine the space required around it to prevent the spread of fire to the neighbouring buildings. Based on this, the total requirements for the space according to a number of standards will be given.

DEFINITIONS

Compartment

This refers to a fire-resistive compartment. A compartment may be considered fire-resistive if its bounding walls, ceiling and floor meet the requirements for fire safety given in the National Building Code. It has been assumed that if the containing elements resist the passage of fire for three-quarters of an hour they may be considered as fire-resistive. When the "enclosing rectangle" concept (defined below) is used, however, the compartment is considered to be the rectangle shown on the sketches which accompany the analyses, whether or not it is bounded by fire-resistive elements.

Enclosing Rectangle

This is the rectangle which, drawn on the façade of a building, will enclose all the openings in the area of maximum exposure hazard. This rectangle is referred to as a compartment in the analyses although it is not necessarily bounded by fire-resistive elements.

Opening

It is of utmost importance to realize that it is the openings that are considered to be the radiating areas. An opening can be defined as any portion of the wall that does not have the required fire resistance. This is usually a window or a door since, for our purposes, it has been assumed that the exterior walls will resist the passage of fire for a period of time sufficient to allow the Fire Department to arrive and combat the fire. Some authorities believe that combustible cladding increases the hazard; results from the St. Lawrence Burns, however, indicate otherwise (11). "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." (5, p. 5).

Distribution of Openings

The tables of fire separation prepared by the Division of Building Research are based on the assumption that the openings in the wall are infinitely small and are distributed uniformly across the wall. In many cases this approach is not applicable as, for example, where the openings are concentrated in one portion of the façade only. Here it is more accurate to deal only with the local area having the high concentration.

Plane of Reference

The plane of reference is usually the plane of the major wall surface but this may not be the case if the wall surface has projections or setbacks. If the setbacks are not more than 5 ft back from the face of the building it can be assumed, for purposes of calculation, that they lie in the same plane as the face of the building (12). Generally speaking, the plane of reference is that plane which contains the openings, either in fact or projected onto the plane from a wall surface behind the plane. It is from this point that the separations are measured.

Separation

There are two types of spatial separation referred to in this report; total separation and separation to the boundary (lot line). Total separation refers to the space between buildings; the separation to the boundary refers to the space between the building and the lot line. It is important to remember that separation means open and unobstructed space. Roof overhangs of approximately 2 ft 6 in. or less need not be considered, but other projections, such as balconies which are liable to ignite and aid in the transfer of the fire should be considered. One method of dealing with these elements is to assume that the required separation should be measured from the extremity of the projections.

Open and Enclosed Interior Stairs

An enclosed stair is one which is contained within suitably fire-resistive walls so that it will not permit a fire, having its origin in one storey of the structure, to spread to the other storeys. An open stair is one which will permit the spread of fire vertically through the structure. All buildings in the study area are assumed to have open interior stairs.

ANALYSES OF SPACES

Numerous illustrations of the buildings have been included in Part 3 to give more meaning to, and to clarify, the analyses of the spaces. The openings which are considered to be emitting radiative heat, the compartment under investigation and the barriers which resist the spread of fire through the building are all superimposed on the façades. These are shown in Figure 3/1. The emitting windows are shaded, the compartment boundaries are indicated by the heavy broken line and the fire-resistive walls, floors and ceilings, by the light broken lines.

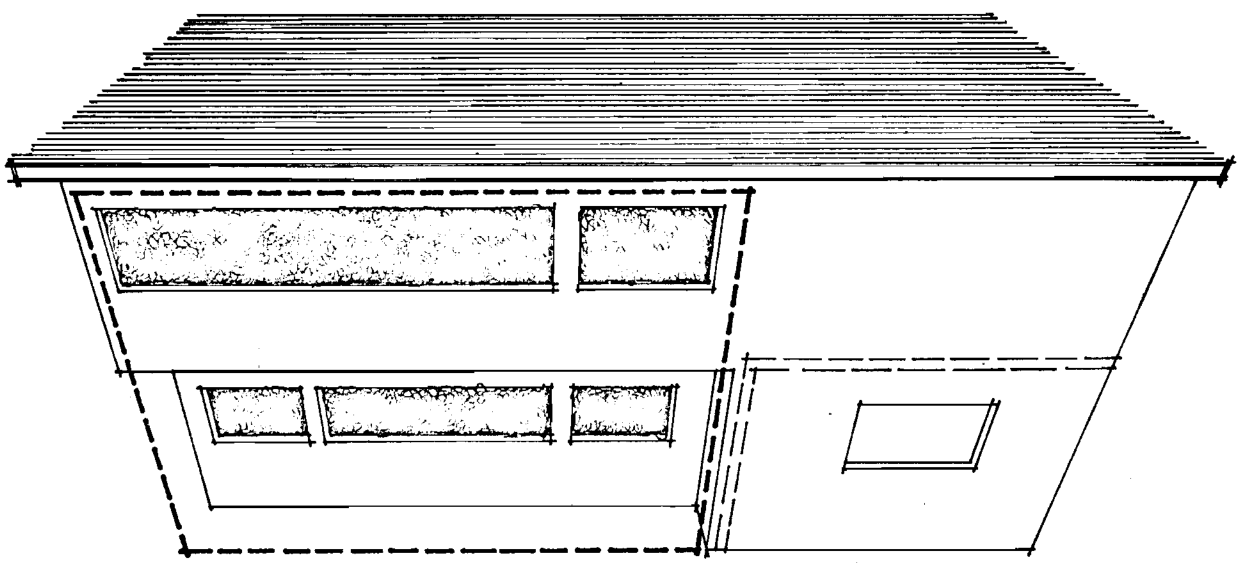

FIGURE 3/1

ANALYSIS OF SPACE 1 - 3

BUILDING 1

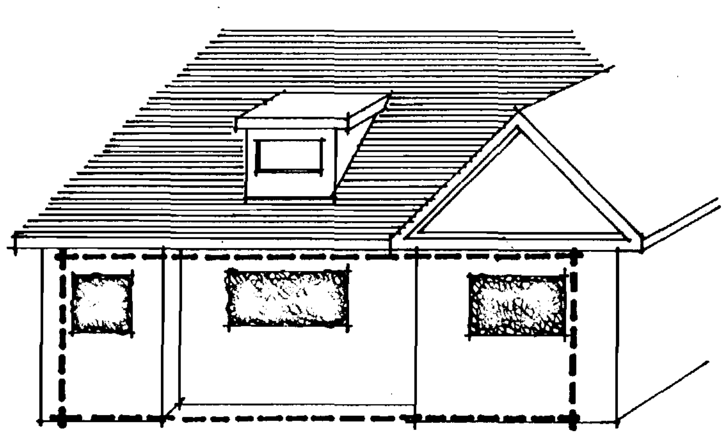

FIGURE 3/2

Note 1: It is assumed that the recess in the wall, since it is less than 5', may be considered to lie on the plane of reference. A more detailed discussion of this may be found in "Report A -- Space Between Buildings as a Means of Preventing the Spread of Fire" (DBR Internal Report 280).

Note 2: The enclosing rectangle shown on the above illustration is the one which was found to give the maximum separation requirements.

Width of compartment	41'
Height of compartment	14'
Area of compartment	575 sq. ft.
Total area of openings	115 sq. ft.
Percentage of openings	20.%

Separation required by Table 1	10' to the boundary
Separation required by Table 2	10.6' to the boundary
Separation required by Table 3	16.2' total

BUILDING 3

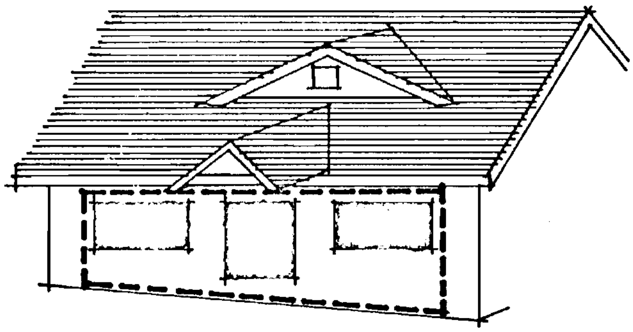

FIGURE 3/3

Width of compartment	29.'
Height of compartment	10.'
Area of compartment	290.' sq. ft.
Total area of openings	112. sq. ft.
Percentage of openings	38.6%

Separation required by Table 1	11.3' to the boundary.
Separation required by Table 2	11.5' to the boundary.
Separation required by Table 3	18.' total.

SUMMARY OF SEPARATIONS

TABLE 1

Building 1: The maximum value is 10.' to the boundary.

Building 3: The maximum value is 11.3' to the boundary.

Total separation required is 21.3'

TABLE 2

Building 1: The maximum value is 10. 6' to the boundary.

Building 3: The maximum value is 11. 5' to the boundary.

Total separation required is 22. 1'.

TABLE 3

Building 1: The maximum value is 16. 2' total.

Building 3: The maximum value is 18. ' total.

Total separation required is 18'.

Note 3: It will be noticed from the photographs of the model that there is a substantial difference in elevation between the buildings.

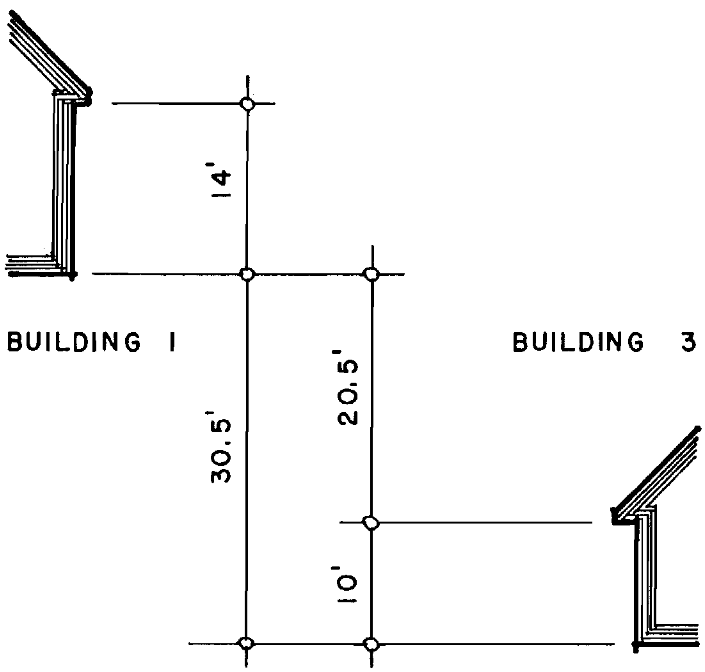

FIGURE 3/4

Note 4: This analysis allows us to determine the effect that a difference in ground elevation will have on the separation required between buildings to prevent the spread of fire by radiative heat transfer.

It has been assumed that the configuration of the boundaries is as shown in the following illustration.

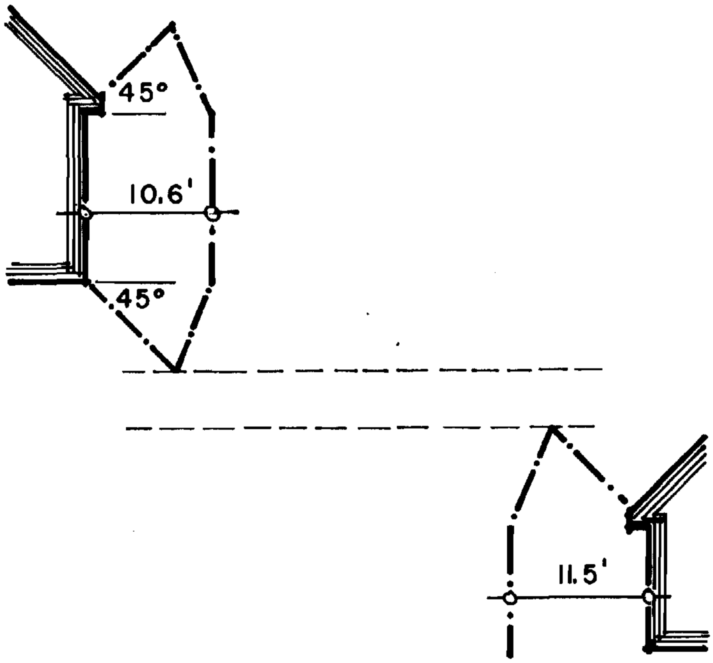

FIGURE 3/5

Note 5: It is evident that the vertical separation is sufficient to prevent the spread of fire, making any horizontal separation unnecessary in this case.

ANALYSIS OF SPACE 2 - 3

BUILDING 2

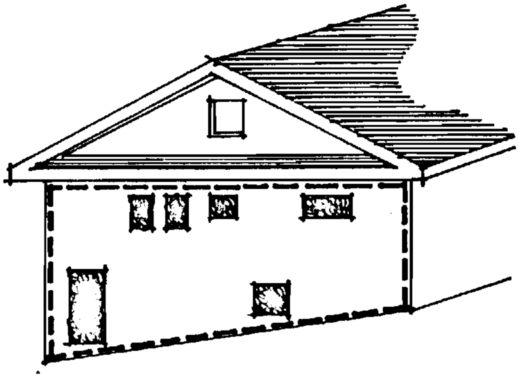

FIGURE 3/6

Note 1 : The sloping ground gives an irregular facade. This was overcome by assuming an average height of the compartment in order to conform to the tables of separation.

Width of compartment .... 30.'

Average height of compartment .... 13.'

Area of compartment .... 390. sq. ft.

Total area of openings .... 50.5 sq. ft.

Percentage of openings 13.%

Separation required by Table 1 .... 7.' to the boundary.

Note 2 : Tables 2 and 3 are not applicable in this case since their accuracy fails when the percentage of openings falls below 20.%

BUILDING 3:

Note 3: A habitable roof space must be considered as contributing to the radiation hazard since it is assumed to be the same as any other portion of the dwelling. While this has been assumed for all buildings in the area, in some cases the rectangle which includes the habitable roof space has not required the maximum separations.

METHOD 1

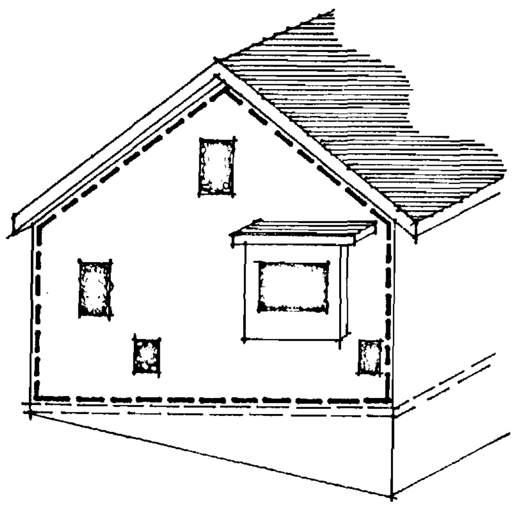

FIGURE 3/7

Width of compartment	30'
Average height of compartment......................	19'
Area of compartment................................	570 sq. ft.
Total area of openings	57 sq. ft.
Percentage of openings	10. %

Separation required by Table 1	5. 3' to boundary
Separation required by Table 2	N. A.
Separation required by Table 3	N. A.

METHOD 2

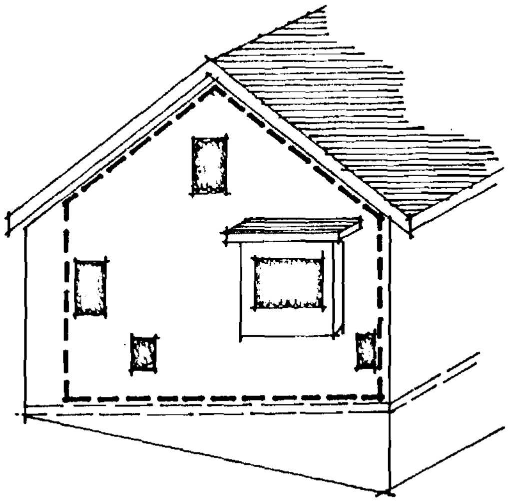

FIGURE 3/8

Width of compartment	20'
Average height of compartment	19'
Area of compartment	380 sq. ft.
Total area of openings	63 sq. ft.
Percentage of openings	17.%

Separation required by Table 1	8' to boundary
Separation required by Table 2	N. A.
Separation required by Table 3	N. A.

SUMMARY OF SEPARATIONS

TABLE 1

Building 2: The maximum value is 7' to the boundary.

Building 3: The maximum value is 8' to the boundary.

Total separation required is 15'.

ANALYSIS OF SPACE 3 - 4

BUILDING 3

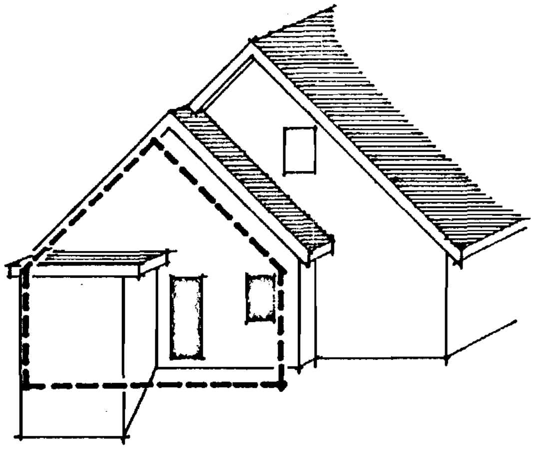

FIGURE 3/9

Width of compartment	20'
Average height of compartment	13'
Area of compartment	260 sq. ft.
Total area of openings	28 sq. ft.
Percentage of openings	10.8%

Separation required by Table 1	4.5' to the boundary
Separation required by Table 2	N. A.
Separation required by Table 3	N. A.

BUILDING 4

METHOD 1

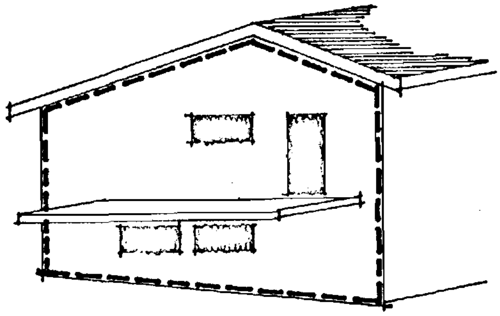

FIGURE 3/10

Width of compartment	28.'
Average of height of compartment	16.'
Area of compartment	450. sq. ft.
Total area of openings	57.5 sq. ft.
Percentage of openings	13.%

Separation required by Table 1	7.' to the boundary
Separation required by Table 2	N.A.
Separation required by Table 3	N.A.

METHOD 2

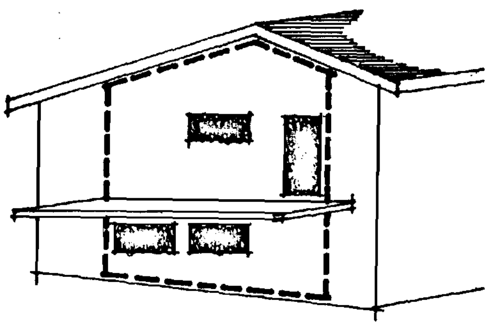

FIGURE 3/11

Width of compartment	16.'
Average height of compartment	16.'
Area of compartment	256. sq. ft.
Total area of openings	57.5 sq. ft.
Percentage of openings	22.5%

Separation required by Table 1	8.5' to the boundary
Separation required by Table 2	8.5' to the boundary
Separation required by Table 3	12.' total.

Note 1 : The tables of separation are based on an open space between the buildings. In this case there is a balcony projecting into the space. This element increases the hazard by facilitating the spread of fire from building to building. It will be assumed that the separation must be from the face of the projection.

SUMMARY OF SEPARATIONS

TABLE 1

Building 3: The maximum value is 4.5' to the boundary.

Building 4: The maximum value is 8.5' to the boundary.

Total separation required is 13.' total.

TABLE 2

Not applicable.

TABLE 3

Building 3: Not applicable.

Building 4: The maximum value is 12.' total.

ANALYSIS OF SPACE 3 - 5

BUILDING 3

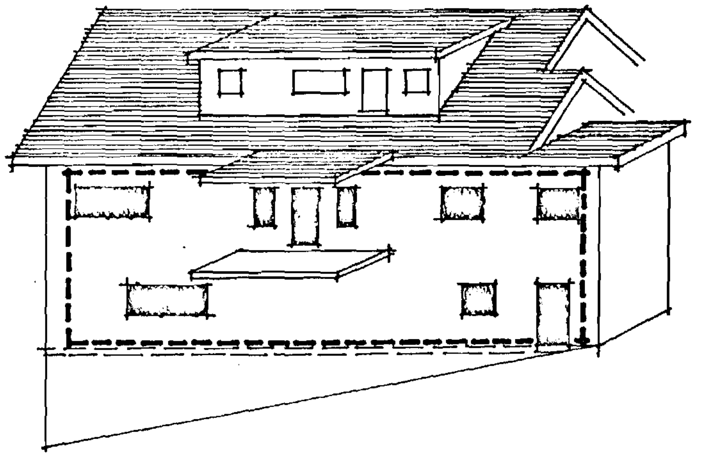

FIGURE 3/12

Width of compartment	40'
Height of compartment	16'
Area of compartment	640 sq. ft.
Total area of openings	123 sq. ft.
Percentage of openings	19. %

Separation required by Table 1	11. 4' to boundary
Separation required by Table 2	11. 1' to boundary
Separation required by Table 3	17. 2' total

Note 1: These separations are to be measured from the edge of the balcony for the reasons previously stated.

BUILDING 5

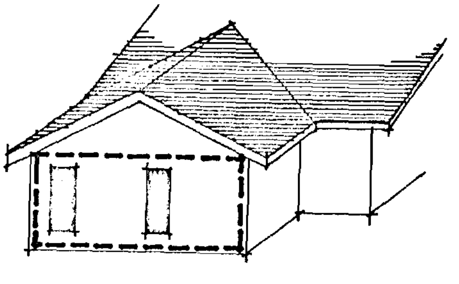

FIGURE 3/13

Width of compartment .... 18.'

Height of compartment .... 8.'

Area of compartment .... 144. sq. ft.

Note 2: The area of the compartment is considerably less than the minimum figure in Table 1. This would tend to make the figures inaccurate since the separations required by the table are, in this instance, based on an area of close to 300 square feet. It would be more accurate to expand the area, arbitrarily, while retaining the same general proportion of the wall and the same area of openings.

Area of compartment .... 299. sq. ft.

Total area of openings .... 25. sq. ft.

Percentage of openings 8.4%

Separation required by Table 1 .... 4.' to the boundary.

Separation required by Table 2 .... N.A.

Separation required by Table 3 .... N.A.

S U M M A R Y   O F   S E P A R A T I O N S

TABLE 1

Building 3: The maximum value is 11.4' to the boundary.

Building 5: The maximum value is 4.' to the boundary.

Total separation is 15.4' to the boundary.

Note 3: However, there is a substantial difference in elevation between the buildings.

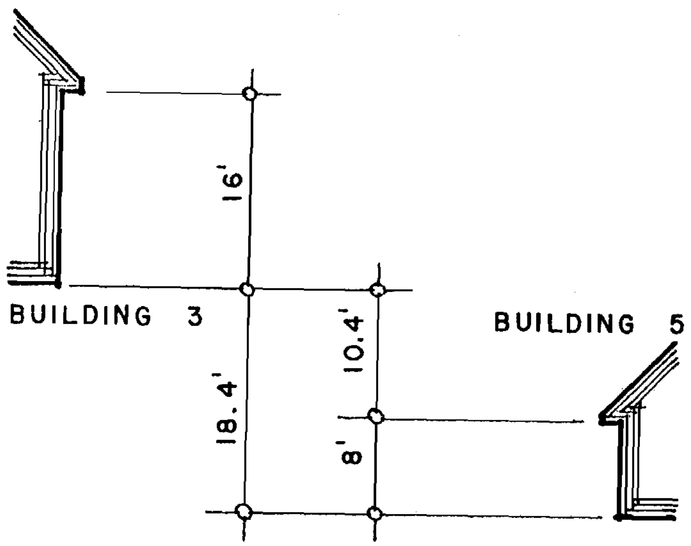

FIGURE 3/14

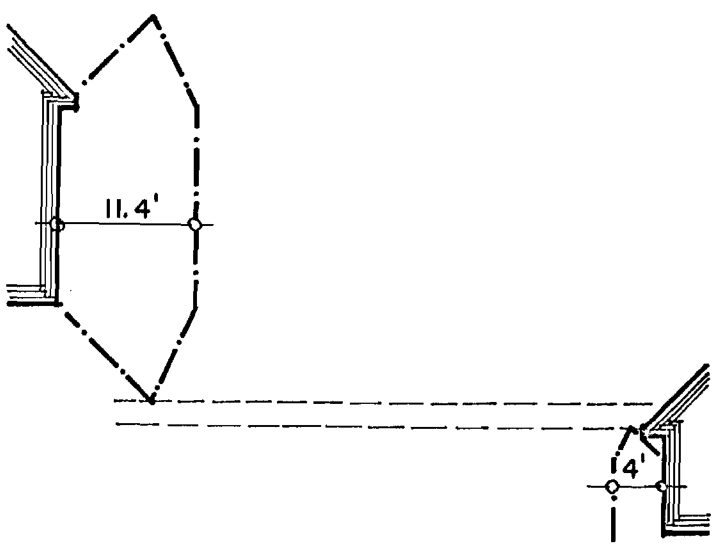

FIGURE 3/15

Note 4: As in the analysis of Space 1-3, the vertical separation is sufficient to prevent the spread of fire by radiative heat transfer, making any horizontal separation unnecessary.

COMMENTS ON ANALYSES

LIMITATIONS OF TABLE 1

This table of separation does not apply to compartments of much less than 300 square feet. Although the first separation requirements shown in Table 1 are for areas of "less than 300 square feet," the separations are, in fact, based on an area of something very close to this figure.

LIMITATIONS OF TABLES 2 AND 3

It is not possible to use Tables 2 and 3 in many cases since their accuracy fails when the percentage of openings falls below 20.% . Another limitation is the fact that these tables do not consider any compartment of less than 30.' x 10.' .

RECESS IN THE WALL

It is generally assumed that a recess of 5.' or less from the plane of reference may be considered to lie on the plane for the purposes of calculation. This assumption was accepted and used in the analyses.

NON-UNIFORM DISTRIBUTION OF OPENINGS

The tables of separation prepared by the Division of Building Research are based on the assumption that the openings in the wall are infinitely small and are distributed uniformly across the wall. However, there are cases where the openings are concentrated in a localized area. In such instances the method of analysis tends to break down. It was shown that it is safer to use the enclosing rectangle concept in such cases.

HABITABLE ROOF SPACE

A habitable roof space must be considered as contributing to the radiation hazard since it is assumed to be the same as any other portion of the dwelling. It was similarly assumed that it was the openings in the roof which were the radiating bodies.

SEPARATION AS OPEN SPACE

It is important to remember that separation means open and unobstructed space. In this study area we have cases of building elements, such as balconies, which project past the plane of reference. In order to deal with these elements it was assumed that the required separation should be measured from the extremity of the projections.

DIFFERENCE IN GROUND ELEVATION

It was shown in the analyses that a difference in ground elevation between adjoining buildings can have a very real effect on the separation requirements. In the two spaces thus analyzed, the vertical separations were so large as to render unnecessary any horizontal separations to prevent the spread of fire by radiative heat transfer. However, it should be mentioned that in order to effect a reduction in the space due to a difference in ground elevation, the bottom of one compartment must be higher than the top of the other compartment. See the analyses of Spaces 1-3 and 3-5 for illustrations of this principle.

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APPENDIX A

DESCRIPTION OF THE BUILDINGS
IN THE STUDY AREA

B U I L D I N G   1

Building Type .... Single family dwelling
1½ storeys.

Date .... 1928.

Construction .... Wood frame.

Cladding .... Stucco.

Openings .... Wood frames

Roofing material .... Asphalt shingles.

Roof overhang .... 2.'

B U I L D I N G   2

Building Type .... Single family dwelling.
1½ storeys.

Date .... 1926.

Construction .... Wood frame.

Cladding .... Stucco.

Openings .... Wood frames.

Roofing material .... Asphalt shingles.

Roof overhang .... 2.'

B U I L D I N G   3

Building type .... Single family dwelling.
1½ storeys plus basement.

Date .... 1927.

Construction .... Wood frame.

Cladding	Clapboard.
Openings	Wood frames.
Roofing material	Asphalt shingles.
Roof overhang	2.'

B U I L D I N G 4

Building type	Single family dwelling.
	1 storey plus basement.
Date	Post-war.
Construction	Wood frame.
Cladding	Vertical siding.
Openings	Wood frames.
Roofing material	Asphalt shingles.
Roof overhang	2.'

B U I L D I N G 5

Building type	Single family dwelling.
	1 storey plus basement.
Date	1920.
Construction	Wood frame.
Cladding	Cement asbestos shingles.
Openings	Wood frames.
Roofing material	Asphalt shingles.
Roof overhang	2.'