CI/SfB			
81			(19.964)
Date	August 1996		

TECHNICAL

RECOMMENDATION

NO. 13 (1996)

METHOD FOR DETERMINING SAFE SEPARATION DISTANCES BETWEEN BUILDINGS IN THE EVENT OF FIRE

Peter Collier

ISSN: 0111-8161

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METHOD FOR DETERMINING SAFE SEPARATION DISTANCES BETWEEN BUILDINGS IN THE EVENT OF FIRE

BRANZ Technical Recommendation No. 13 **Peter Collier**

REFERENCE

Collier, P.C.R.1996. Method for determining safe separation distances between buildings in the event of fire. Building Research Association of New Zealand Technical Recommendation No. 13. Judgeford.

ACKNOWLEDGMENTS

This work was funded by the Public Good Science Fund of the Foundation for Research Science and Technology, and the Building Research Levy.

KEYWORDS

Building Fires; EIFS; Fire Separation; Fire Spread; Fire Protection; Ignition; Neighbour; Non Combustible; Radiation; Safe Separation.

RELEVANCE

This document describes a method for determining safe separation distances for adjacent buildings. A fire in one building carries the risk of spreading to an adjacent building.

Current methods for determining separation distances in New Zealand are based on Acceptable Solution C4/AS1 Appendix C, in the New Zealand Building Code (BIA 1992). It is assumed in C4/AS1 that the neighbouring building is the same distance from the boundary as the building under consideration. In many cases, therefore, it yields non-conservative results, and lacks flexibility.

The method proposed in this document allows an alternative means of determining safe separation distances. It allows the critical incident radiation to be varied for various facade materials, and different radiation source intensities to be specified. The effects of changes to existing buildings resulting from renovations can also be evaluated.

This method of determining safe building separation distances is particularly useful for limiting fire spread in isolated locations and where there are limited fire-fighting resources.

ACCEPTANCE

It is recommended that the method described in this document for determining safe separation distances of buildings be accepted as a partial means of compliance with the New Zealand Building Code, Clause C3.3.5 "External walls and roofs shall have resistance to the spread of fire, appropriate to the fire load in the building and to the proximity of other household units or other property". It is an alternative to methods described in C4/AS1 Fire Safety Annex Appendix C.

BACKGROUND

The spread of fire, by radiation, is prevented by providing adequate separation between opposing external walls of neighbouring buildings, so the level of received radiation is below that necessary for ignition.

A big advantage of the method described here is its versatility. It allows the level of the critical radiant flux for ignition on the exposed building to be varied in accordance with current knowledge of the ignitabilty of modern cladding materials.

This document aims to provide a user-friendly method of ensuring safe separation distances. To achieve this the method has been simplified. However, this introduces very little conservatism.

To make this method easier to use a software version is included for rapid calculations.

SCOPE OF APPLICATION

The procedures described in this document can be applied in the following situations:

1. Determining a minimum separation distance between two buildings to prevent fire spread.

2. Determining a minimum distance to boundaries where a neighbouring building does not yet exist.

3. Determining the incident radiation received on a neighbour's building.

4. Determining the maximum size of openings permitted on the owner's building if the separation distance is fixed.

5. Checking the safety of existing building situations, which can be improved by:

   - fitting fire windows to either building
   - reducing the number of and/or size of openings
   - raising the level of critical radiant flux for ignition of existing claddings, recladding or overcladding
   - installing external drenches.

In all the above cases it is IMPORTANT to check the level of radiation in both directions.

CAUTIONS AND LIMITATIONS

Buildings must not be so close together that fire-fighting operations are impeded. Guidance on requirements for Fire Service access is given in C3/AS1 Paragraph 2.16.

- This procedure caters for buildings facing each other, with walls vertical and parallel to each other. However, where building facades are at an angle to each other, they can be treated as if they are parallel (giving a conservative result).

- Pitched roofs can be treated as radiating from a vertical flame front, once skylights are penetrated or if burn-through occurs.

- Where a neighbouring building does not yet exist, its distance to the boundary should be assumed to be half the separation distance required if the neighbouring building was identical to the existing building.

- Complex building shapes can be simplified as follows:

  In situations where the distribution of openings is uneven there may be local variation in the separation distance required. In such cases groups of openings may need to be considered separately. Recessed openings may also affect the level of radiation, but in this method are treated as though they are in the same plane as the main facade.

- Changes to buildings such as renovations, recladding, reglazing, change of occupancy type etc, should be checked for increased hazard.

DEFINITIONS

ASPECT RATIO is the ratio of the enclosing rectangle's height to width or vice versa, such that its value is between zero and unity.

CONFIGURATION FACTOR is the ratio of the area of the radiator to the area of the field of view, as seen from the neighbour's building. An alternative definition is the ratio of the received radiation to the emitted radiation.

CRITICAL INCIDENT RADIATION is the minimum level of radiation on the neighbour's building that will cause ignition.

EMITTED RADIATION is the intensity of radiation leaving the enclosing rectangle.

ENCLOSING RECTANGLE is the area bounded by a rectangle whose perimeter just encloses the openings in the firecell being considered. Where the external wall cladding is not fire-rated or the walls are less than the required fire resistance, then the entire area of the external wall is considered as the enclosing rectangle (a conservative assumption).

FIRECELL is any space, including a group of contiguous spaces, on the same or different levels within a *building*, which is enclosed by any combination of *fire separations, external walls*, roofs, and floors.

FIRE RESISTANCE of the firecell is the period of time that the fire is required to be confined within the firecell. The expected level of radiation emitted from the firecell is a function of the fire temperature at the end of the period (FRR), as predicted by the standard time-temperature curve.

FIRE WINDOWS differ from ordinary windows by remaining intact and are assumed to reduce the transmitted radiation by approximately 50%.

NEIGHBOUR'S BUILDING is separated from the owner's building by a finite distance and receives radiation in the event of a fire.

OWNER'S BUILDING is considered as the one which is on fire, where heat is radiated through its openings and is received by the neighbour's building.

PROJECTION DISTANCE is the distance that the flames project from the face of the burning building. For non fire-rated glazing the projection distance is assumed to be two metres and for fire-rated glazing zero metres.

RADIATION DISTANCE is the distance between the flame front of a burning building and the face of any exposed building (owner's or neighbour's).

RADIATOR is the enclosing rectangle of the building which is on fire, providing the radiation source.

REDUCTION FACTOR is the ratio of the area of the openings to the area of the enclosing rectangle.

SEPARATION DISTANCE is the distance between two buildings. The objective is to achieve a separation large enough to reduce the level of radiation on the neighbour's building to below that required for ignition, thus preventing the spread of fire.

UNPROTECTED AREA is the area of the windows in a wall or skylights in a roof. The unprotected area may be covered with fire windows or ordinary glazing.

PROCEDURE

The spread of fire, by radiation, between adjacent buildings can be prevented by making changes to any combination of the following:

a) separation distance;

b) level of critical radiation emitted and received on neighbour's facade, through appropriate material selection;

c) amount of unprotected area; or

d) type of glazing (ordinary or fire windows).

Where the owner's and neighbour's buildings both exist, the adequacy of separation distance should be checked in both directions.

Where the neighbour's building does not yet exist, the owner's building should be sited at least at such a distance from the boundary that will allow the safe erection of an identical neighbouring building at the same distance on the opposite side of the boundary ("mirror imaging"). In other words, the boundary is half the safe separation distance. "Identical" means the same emitted radiation and facade material.

Figure 1 outlines the steps for applying the method. The flow chart is divided into three columns; the choice of column depends on the unknown factor being determined: separation distance (S), incident radiation (I_s), or maximum unprotected area (A_o). The following notes explain each step.

Establishing the hazard source

Step 1. Determine boundaries of the fire compartments and establish the enclosing rectangle(s) based on the unprotected areas (see Figure 2).

Where the facade of the owner's building under consideration is irregular in shape, the enclosing rectangle is approximated by projecting the shapes of the unprotected areas onto a plane of reference (see Figure 2). The plane of reference is vertical and located such that it touches at least one part of the building, but does not pass through it.

Step 2. Determine the area of the enclosing rectangle.

$A_e = H \times W$

Step 3. Determine the aspect ratio of the enclosing rectangle.

$AR = H/W$ or (W/H) such that $AR \leq 1$.

Step 4. Determine the radiation intensity of the source, I_s. This is based on a fire temperature of 1000°C, which is expected to cover most situations, and equates to a radiation intensity level of 149 kW/m^2. If, however, the fire load or ventilation conditions cause the radiation to be significantly more or less intense, then adjustments can be made based on the expected fire temperature as follows:

$I_s = 5.67 \times 10^{-11} \times T^4$ in kW/m^2

where T is the fire temperature in Kelvin (°C + 273)

The fire temperature can also be equated to the fire resistance rating of the compartment, by determining the fire temperature at the appropriate (FRR) time on the standard fire curve.

$T = 345 \log_{10} (8t + 1)$ (temperature in °C)

where t is the fire resistance time in minutes.

Determining the separation distance, S

OWNER'S BUILDING:

Step 5a. The size of the unprotected areas limits the intensity of the radiation transmitted. Whether there are fire windows or ordinary glass makes a significant difference. Fire windows will remain in place for the duration of the fire, reducing the radiation through the unprotected areas by approximately 50%. Ordinary windows are expected to crack and fall out, allowing flames to exit from unprotected areas. Where flames do project from the unprotected areas, this is allowed for by positioning the plane of the enclosing rectangle outwards from the facade. The projection distance of the flames is assumed to be 2 metres, but a different projection distance may be used if known.

The ratio of the unprotected areas to the area of the enclosing rectangle is the factor by which the radiation intensity at the source is reduced to determine the emitted radiation.

$Rf = Ao / Ae$

where Rf = reduction factor
Ao = unprotected areas
Ae = area of enclosing rectangle

If the owner's building is of non fire-rated construction, then the whole facade is considered to be the source of radiation, and the reduction factor is unity.

Step 6a. Determine emitted radiation.

$Ie = Is \times Rf$

where Ie = emitted radiation
Is = source radiation
Rf = reduction factor

(further reduce by 50% if fire windows are fitted to the owner's building)

Step 7a. Determine the critical incident radiation, Icr (see Table 1).

The radiation received on the neighbour's building must be less than this critical level of intensity expected to cause ignition.

Data on the critical level of radiation intensity that may be received on the facade of the neighbour's building is required. This is usually a function of the surface composition. The following values for ignition are provided as a guide.

Table 1: Critical Incident Radiation Received By Neighbour's Building

	Maximum radiation permitted (= critical incident radiation), Icr (kW/m^2)		
Surface composition of neighbour's facade	No openings	Non fire-rated glazing used	Fire-rated glazing used
EIFS(1)	9.0	9.0	9.0
Timber	12.5	12.5	12.5
Fibre-cement board	25.0	12.5	25.0
Non-combustible(2)	no limit	12.5	50.0

(1) EIFS (exterior insulation and finish systems) comprise a backing panel like plasterboard with a foamed polymeric insulation sheet affixed and the panel coated with a plaster finishing system.

(2) Non-combustible refers to concrete, brick, steel or aluminium.

Ignition of a neighbour's building can occur in the following ways:

a) piloted ignition: is likely to occur where ordinary glazing on the owner's building shatters, allowing flames and flying brands to issue from the unprotected areas and ignite the facade of a neighbouring building.

b) non-piloted ignition: where fire glazing on the owner's building remains intact, so that radiation alone is the only means by which ignition of the neighbour's building can occur.

c) ignition inside a compartment in the neighbour's building.

If fire-rated glazing is fitted on the neighbour's building, ignition inside a compartment will always be non-piloted. For timber furnishings, a critical radiation intensity of 25 kW/m^2 inside the compartment is assumed. If a transmission loss of 50% through fire glazing is included, then the incident radiation on the neighbour's building can be as high as 50 kWm^2. This assumes that the cladding on the building is non-combustible, such as concrete, and can withstand that level of radiation.

It is assumed that ordinary glazing will break under impressed radiation. Therefore, the contents of the compartment will have a critical level of radiation intensity of 12.5 kW/m^2, irrespective of the external cladding.

Step 8a. Determine the permissible configuration factor, ∅.

∅ = Icr / Ie

Step 9a. Determine the separation distance, S.

S = R + P

where R = radiation distance

P = projection distance

Radiation distance is obtained from the factor using Figure 3.

The flame projection distance is zero metres if fire windows are fitted.

Where fire windows are not fitted, the projection distance is assumed to be 2 metres, to allow for a flame front projecting from the face of the building.

Determining the incident radiation, Is

Step 5b. Determine reduction factor, as for 5a.

Step 6b. Determine emitted radiation, as for 6a.

Step 7b. Determine the radiation distance, R.

R = S - P

refer to procedure for step 9a above for guidance.

Step 8b. Use Figure 3 to determine the configuration factor, ∅.

Step 9b. Determine the incident radiation, Ir.

Ir = Ie x ∅

Determining the maximum unprotected area, Ao

Step 5c. Determine critical incident radiation, as for 7a.

Step 6c. Determine the radiation distance, R.

R = S - P

refer to procedure for step 9a above for guidance.

Step 7c. Use Figure 3 to determine the configuration factor, ∅.

Step 8c. Determine the maximum emitted radiation from the burning building, Ie.

$$\frac{Icr}{\varnothing . FW}$$

Step 9c. Determine the maximum unprotected area, Ao permitted.

Ao = Ae x (Ie / Is)

SYMBOLS

Ae	=	area of enclosing rectangle (m^2)
AR	=	aspect ratio of enclosing rectangle
Ao	=	unprotected areas, windows, skylights and non-fire rated construction (m^2)
C	=	factor C (a function of distance and area)
H	=	height of enclosing rectangle (m)
Icr	=	critical incident radiation (kW/m^2)
Ie	=	emitted radiation intensity of the fire (kW/m^2)
Ir	=	incident radiation (kW/m^2)
Is	=	radiation intensity of source (kW/m^2)
P	=	flame projection distance (m)
R	=	radiation distance (m)
Rf	=	reduction factor
S	=	separation distance (m)
W	=	width of enclosing rectangle (m)
Ø	=	configuration factor

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Appendix A Calculation Sheets

Method to Calculate Safe Separation Distances, Incident Radiation or the Maximum Unprotected Area.

Brief description of problem:

Step 1. Establish enclosing rectangle(s) for the owner's building.

Step 2. Area, Ae = Height (H) x Width (W) Ae = [ ]

Step 3. Aspect ratio, AR = H/W or W/H : ($AR \leq 1$) AR = [ ]

Step 4. Source radiation intensity, Is = [ ]

The level of radiation at the source is generally considered to be that generated by hot gases at 1000°C, which is 149 kW/m^2. If it is considered that the level of radiation generated will be significantly greater or less than that above then adjustments may be made as follows:

$$Is = 5.67 \times 10^{-11} \times (T + 273)^4 \text{ in kW/m}^2$$

where T is the fire temperature in °C.

The fire temperature can also be equated to the fire resistance rating of the compartment, by determining the fire temperature at the appropriate (FRR) time on the standard fire curve.

$T = 345 \log (8t + 1)$ where t is the FRR time in minutes.

To find separation distance

Step 5a. Window area of owner's building

Ao = [ ]

(if the facade is non fire-rated then Ao = Ae)

Reduction factor Rf = [ ]

Is fire glazing fitted ?

If "Yes" FW = 0.5, P = 0 FW = [Yes / No]

If "No" FW = 1, P = 2 P [ ]

Step 6a. Emitted radiation intensity

Ie = Is x Rf x FW = [ ]

Step 7a. Critical incident radiant flux, Icr Icr = [ ]

(of facade on neighbour's building)

Step 8a.	Configuration factor, Ø = Icr / Ie Ø =		
	Factor (from Figure 3)	C =	
Step 9a.	Separation distance, S = C x $\sqrt{Ae}$ + P	S =	

To find Incident Radiation, Ir

Step 5b.	Window area of owner's building Ao = (if the facade is non fire-rated then Ao = Ae)		
	Reduction factor, Rf =	Rf =	
	Is fire glazing fitted ? If "Yes" FW = 0.5, P = 0	FW =	Yes / No
	If "No" FW = 1, P = 2	P =	
Step 6b.	Emitted radiation intensity, Ie = Is x Rf x FW =		
Step 7b.	Radiation distance, R = S - P (S, Separation distance between buildings) C = R/ $\sqrt{Ae}$	R =	
		C =	
Step 8b.	Configuration factor, Ø (from Figure 3)	Ø =	
Step 9b.	Incident radiation, Ir = Ie x Ø	Ir =	

To find maximum unprotected area permitted

Step 5c.	Critical incident radiation, Icr	Icr =	
Step 6c.	Is fire glazing to be fitted ? If "Yes" FW = 0.5, P = 0	FW =	Yes / No
	If "No" FW = 1 , P = 2	P =	
	Radiation distance, R = S - P	R =	
	C = R/ $\sqrt{Ae}$	C =	
Step 8c.	Configuration factor, Ø (from Figure 3)	Ø =	

Step 9c. Maximum emitted radiation, $Ie = \frac{Icr}{\varnothing FW}$ Ie = [ ]

Maximum emitted unprotected area, Ao = Ae x (Ie / Is) Ao = [ ]

Note: In cases where the unprotected areas are widely spaced it is possible that local concentrations of radiation, which exceed the critical incident radiation, may occur on the neighbour's building. This can be checked by considering individual unprotected areas as the enclosing rectangle and repeating the calculation.

Appendix B Worked Example 1

Brief description of problem: Parallel exposure between two buildings. Enclosing rectangle on owner's building measures 5 m (high) x 10 m (wide) with 32 m^2 of ordinary glazing. If the critical level of incident radiation is 12.5 KW/m^2, find the separation distance to the neighbour's building.

Step 1.	Establish enclosing rectangle(s) for the owner's building			
Step 2.	Area,	Ae = Height (H) x Width (W)	Ae =	50
Step 3.	Aspect ratio,	AR = H/W or W/H : (AR $\leq$ 1)	AR =	0.5
Step 4.	Source radiation intensity,		Is =	149

The level of radiation at the source is generally considered to be that generated by hot gases at 1000°C, which is 149 kW/m^2. If it is considered that the level of radiation generated will be significantly greater or less than that above then adjustments may be made as follows:

$$Is = 5.67 \times 10^{-11} \times (T + 273)^4 \text{ in } kW/m^2$$

where T is the fire temperature in °C.

The fire temperature can also be equated to the fire resistance rating of the compartment, by determining the fire temperature at the appropriate (FRR) time on the standard fire curve.

T = 345 log (8t + 1) where t is the FRR time in minutes.

To find separation distance

Step 5a.	Window area of owner's building Ao = (if the facade is non fire-rated then Ao = Ae)		32 m^2
	Reduction factor, $Rf = \frac{Ao}{Ae}$	Rf =	0.64
	Is fire glazing fitted ?		NO
	If "Yes" FW = 0.5, P = 0	FW =	1
	If "No" FW = 1 , P = 2	P =	2

Step 6a.	Emitted radiation intensity, $Ie = Is \times Rf \times FW =$		95.36 KW/m^2
Step 7a.	Critical incident radiant flux, Icr (of facade on neighbour's building)	Icr =	12.5 KW/m^2
Step 8a.	Configuration factor, = Icr / Ie	∅=	0.131
	(from Figure 3)	C =	1.44
Step 9a.	Separation distance, $S = C \times \sqrt{Ae} + P$	S =	12.18 m

Appendix B Worked Example 2

Brief description of problem:
Same two buildings as example 1, except that separation distance is 10 m and the permitted maximum unprotected area on the owner's building is to be determined.

Step 1.	Establish enclosing rectangle(s) for the owner's building			
Step 2.	Area,	Ae = Height (H) x Width (W)	Ae =	50
Step 3.	Aspect ratio,	AR = H/W or W/H : ($AR \leq 1$)	AR =	0.5
Step 4.	Source radiation intensity, Is =			149

The level of radiation at the source is generally considered to be that generated by hot gases at 1000°C, which is 149 kW/m^2. If it is considered that the level of radiation generated will be significantly greater or less than that above then adjustments may be made as follows:

$$Is = 5.67 \times 10^{-11} \times (T + 273)^4 \text{ in } kW/m^2$$

where T is the fire temperature in °C.

The fire temperature can also be equated to the fire resistance rating of the compartment, by determining the fire temperature at the appropriate (FRR) time on the standard fire curve.
T = 345 log (8t + 1) where t is the FRR time in minutes.

To find maximum unprotected area permitted

Step 5c.	Critical incident radiation	Icr =	12.5 KW/m^2
Step 6c.	Is fire glazing to be fitted ?		NO
	If "Yes" FW = 0.5, P = 0	FW =	1
	If "No" FW = 1 , P = 2	P =	2
	Radiation Distance, R = S - P	R =	8
	$C = R/\sqrt{Ae}$	C =	1.131
Step 7c.	Configuration factor, ∅ (from Figure 3),	∅=	0.19
Step 8c.	Maximum emitted radiation, Ie = Icr / ∅ / FW	Ie =	65.8 KW/m^2
Step 9c.	Maximum unprotected area, Ao = Ae x (Ie / Is)	Ao =	22.1 m^2

Appendix C Software Method

The calculation method described in this Technical Recommendation is also available in a software version suitable for use on IBM and compatible PC's. A diskette is enclosed in the back cover of this Technical Recommendation.

Two files are required to run the program, SEP.EXE and SEP.DAT. SEP.EXE is an executable file and includes the calculation method and a supporting menu. SEP.DAT stores the data from the last saved calculation and re-enters it the next time the program is run.

To load, place the diskette in the appropriate drive and type SEP "enter" at the DOS prompt.

e.g A:> SEP

The menu items are:

1. Introduction
2. Calculate source intensity
3. Calculate separation distances
4. Calculate incident radiation
5. Calculate maximum area of openings
6. Colour selection
7. Save calculations
8. Return to DOS

ENTER CHOICE #

The choice "Introduction" explains on screen how to operate the software from editing the inputs, manipulating an optimum output result and printing the results.

Choice 2 calculates the source intensity, using either the source temperature or fire resistance rating (FRR) of the compartment as the basis. The flame projection distance can also be changed from the default setting of two metres. Subsequent consideration of the addition or subtraction of flame projection distances, as required in the text version above, are automatically included in the software.

The choices 3, 4 and 5 are in the form of spreadsheets and permit the input values to be changed. If the unknown is other than option 3, 4, or 5 the required result can be determined by a process of iteration.

For example, how could we determine the permitted maximum unprotected area, if the distance between two buildings on adjacent sites is already fixed. Coupled with this, the owner's building is still in the design phase. The known data entered into the spreadsheet (option 5) would include the enclosing rectangle height and width, the radiation level expected to be developed within the firecell, the separation distance to the neighbour's building, and the critical incident radiation on the neighbour's building. The new outputs are calculated by pressing "enter".

In addition, the option of including fire windows can be utilised. This will reduce the emitted radiation by approximately 50% and eliminate flame projection, thus allowing an increase in the permitted area of openings.

"Colour selection" enables the colour of the various screen output parameters to be changed to suit individual preferences.

The menu option of "save this calculation" writes the input and output data to a data file. Each time the program is re-run, the data from the previous saved calculation is re-entered.

Finally, option 8 "return to DOS" returns the PC to the DOS prompt.

If at any time a print-out of the screen is required, this can be obtained by pushing key "P". The screen output is also written to a file SCR.PRT to allow merging with other text or for later printing.

Examples of screen output

To find Safe Separation Distance			
Owner's Building, Enclosing Rectangle			
Height, m	5	Width, m	10
Unprotected area, m^2	32	% unprotected area	64
Fire windows, Y/N?	N	Radiation, kW/m^2	149
Aspect ratio	0.5	Emitted radiation, kW/m^2	95.36
Neighbour's Building			
Crit. incident rad, kW/m^2	12.5	Configuration factor, ∅	
	0.131		
Separation distance, m	12.05		

To find the Maximum Unprotected Area			
Owner's Building, Enclosing Rectangle			
Height, m	5	Width, m	10
Unprotected area, m^2	22.1	% unprotected area	44.2
Fire windows, Y/N?	N	Radiation, kW/m^2	149
Aspect ratio	0.5	Emitted radiation, kW/m^2	65.94
Neighbour's Building			
Crit incident rad, kW/m^2	12.5	Configuration factor, ∅	0.18
Separation distance, m	10		

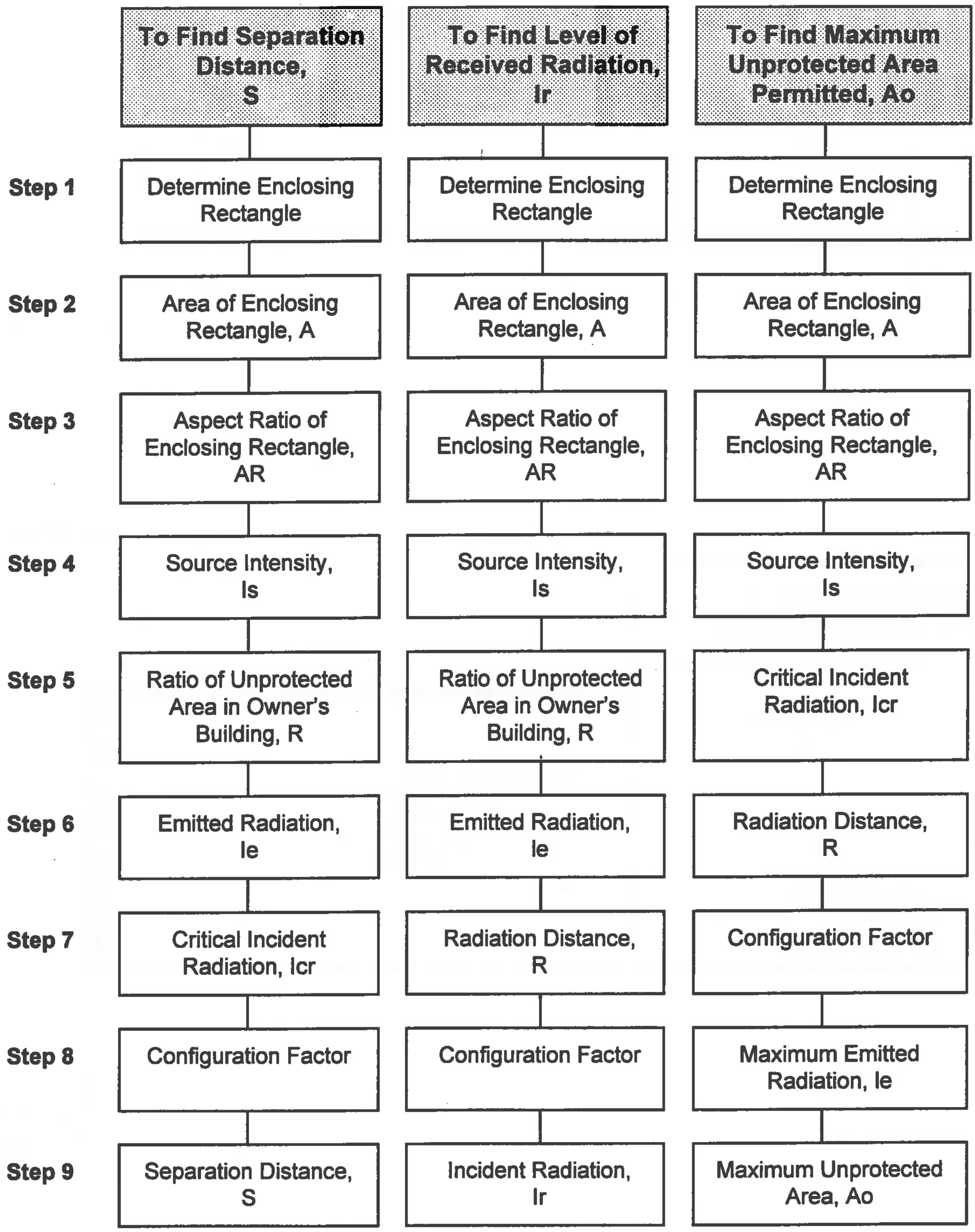

Figure 1 : Flow chart of procedure

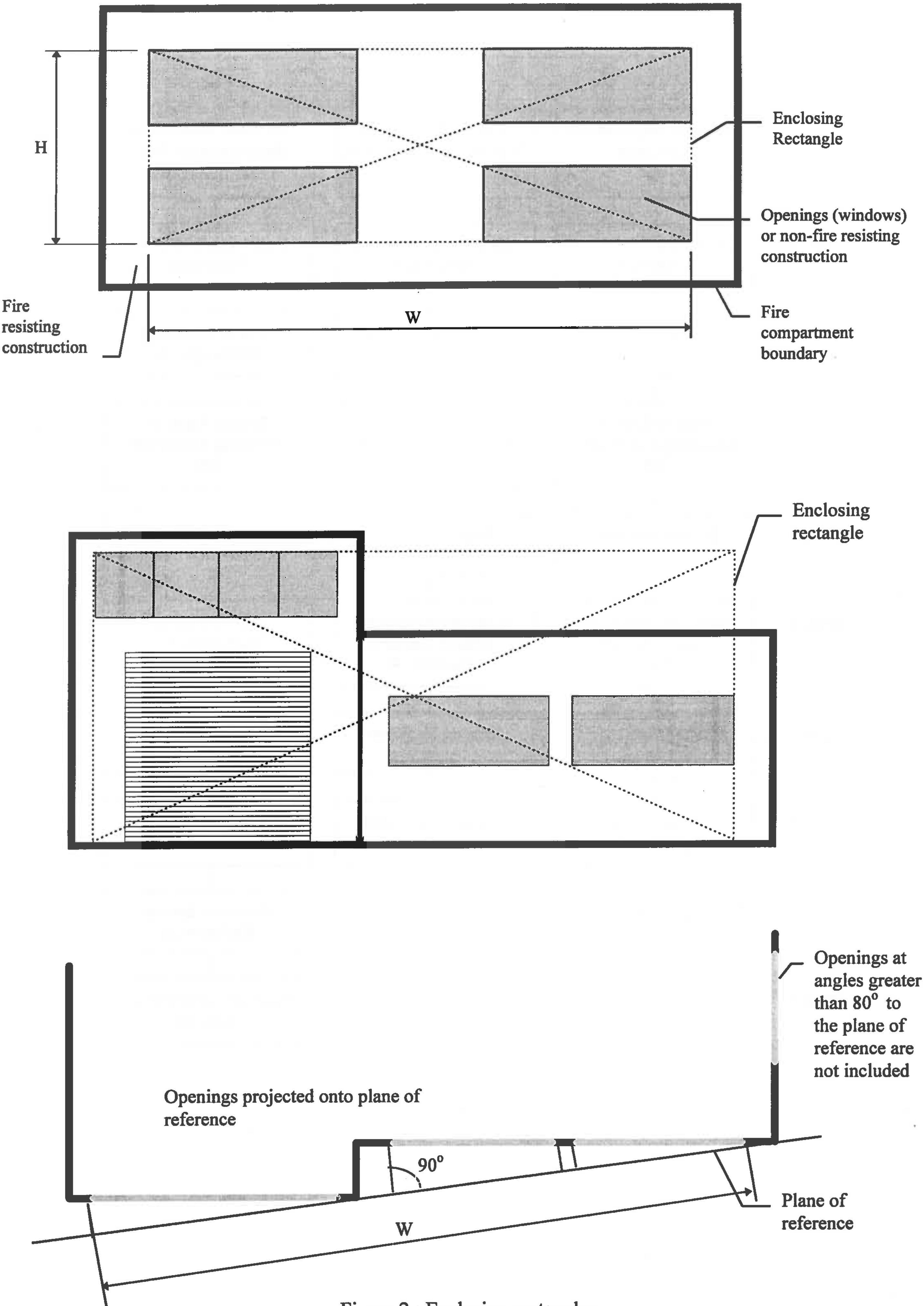

Figure 2 : Enclosing rectangles

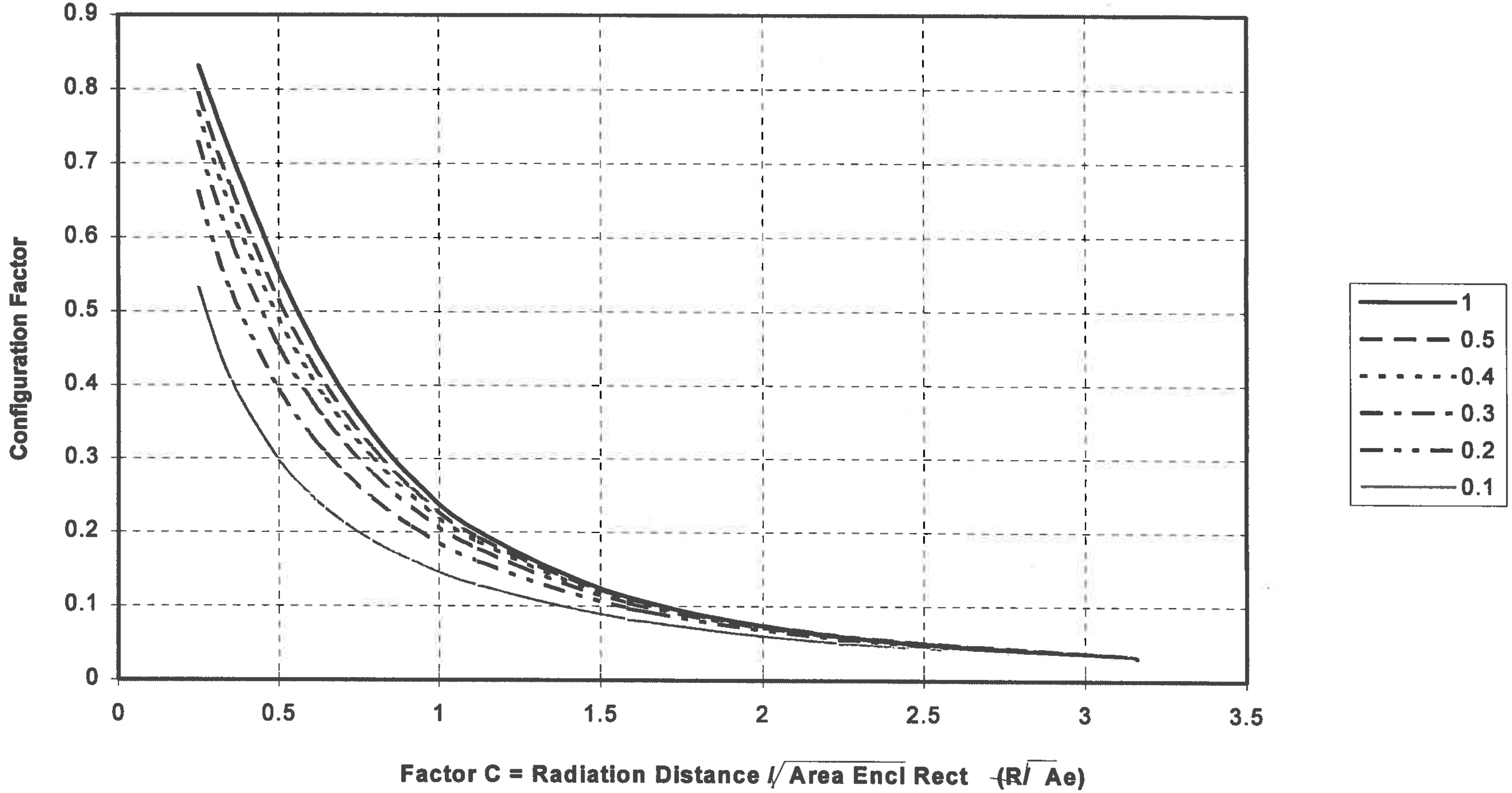

Figure 3 Configuration factors

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