This Section Contains

Fire Safety Strategy Report

ArupFire

Broadway Malyan

N V Buildings - Salford Quays

Fire Safety Strategy

Issue 5
Completion issue

ArupFire

Broadway Malyan

N V Buildings - Salford Quays

Fire Safety Strategy

June 2004

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Job number 114338

Job title	N V Buildings - Salford Quays	Job number	114338
Document title	Fire Safety Strategy	File reference	
Document ref	Report Ref 01MS		

Revision	Date				
Issue 2	08/01/03	Filename	0001Report MS D1 30-08-02.doc		
		Description	Issue 2 – Stage 2 design		
			Prepared by	Checked by	Approved by
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		Signature			
Issue 3	27/11/02	Filename	0003Report MS I3 27-11-02.doc		
		Description	Issue 3 – Under Concession design Development.		
			Prepared by	Checked by	Approved by
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		Signature			
Issue 4	07/01/03	Filename	04MS FSE I4 8-01-03		
		Description	ECD issue. Please note performance based engineering including Apartment Type 9 means of escape, refuse room sprinkler protection and compartmentation are subject to approval. Standard solutions should be costed at this stage. See cover note.		
			Prepared by	Checked by	Approved by
		Name	Matthew Salisbury	Pat Connolly	David Charters
		Signature			
Issue 5		Filename	05MS FSE I5 22-06-04		
		Description	Issue 5 – Completion issue. Minor changes incorporated. Fire Strategy Drawings consistent with strategy.		
			Prepared by	Checked by	Approved by
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Issue Document Verification with Document ✓

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QA Rev 1/01 1 November 2001

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1. INTRODUCTION

Arup Fire has been commissioned to provide a detailed fire safety strategy for the proposed new build residential development known as N V Buildings, Salford. This work provides the basis for compliance with Part B of the Building Regulations 2000.

This report will support the Building Regulations application for the project. The report itself does not provide approval and recommendations in this work will require such approval prior to their incorporation in the building.

The strategic information and performance specifications provided herein are based on the recommendations of the approved documents (Part B) to the building regulations, associated British Standards and fire engineering guidance literature. A list of these documents, referenced in this work, can be found at the end of this report.

Where the standard guidance may be unduly onerous or invalid for particular areas of the development the Building Regulations permit a performance based 'building-specific' design to be employed. This design solution is based on fire engineering principles as outlined in the British Standard for fire engineering BS 7974, Application of Fire Safety Engineering principles to the design of buildings – Code of practice. This document provides the outline approach to fire safety engineered solutions with technical information supporting the findings of this work. Where fire safety engineering is applicable, the framework of the approach shall follow the British Standard.

This work addresses fire safety only and has not been drafted for other life safety events.

It should be noted this work provides support to compliance with the Building Regulations, which are intended to ensure that a reasonable standard of life safety is provided in case of fire. The protection of property including the building itself may require additional measures, and insurers therefore should be consulted with respect to the recommendations of this report.

This report is based on the information currently available provided by Broadway Malyan and the following drawings; BLK-A(68)100 to BLK-A(68)117.

It should be noted that this report and the analyses herein apply only to the N V Buildings scheme, and are based on the information currently available. The conclusions of the report should not be applied to any other project and may be invalidated if aspects of the building design are subject to variation.

This report has been prepared and is intended for the sole use of Countryside Properties. The information contained herein shall not be relied upon by a third party and Ove Arup International Ltd will not accept any responsibility for matters arising as a result of a third party use.

This report has the following sections briefly summarised as follows:

- **Main report** – summarises the fire safety strategy, provides qualitative fire safety recommendations and provides system specifications.
- **Appendix A** – provides specifications referred to within main report
- **Appendix B** – provides a quantified fire safety assessment to support the reduction in fire compartmentation requirements

2. DESCRIPTION OF BUILDING

The following summarises features of the scheme:

- Residential apartments and ancillary car parking are to be provided within three new build towers;
- The buildings encompass apartments on 17 floors including a penthouse maisonette and 1 car parking level at ground floor;
- The building height is less than 50m from access level to the highest occupied floor level;
- The buildings are single stair type buildings;
- There are no basement levels on the site.
- Typically, each level of the tower will include apartments in a mix of 1, 2 and 3 bedroom accommodation.

3. FIRE SAFETY – GENERAL

The requirements for the building design have been determined using accepted fire safety standards and performance based solutions. The fire safety strategy herein is a coherent combination of these approaches.

It has been assumed that the standard solutions including Approved Document B and the BS 5588 series provide an adequate level of fire safety and where appropriate the recommendations of these approaches have been adopted. Where an alternative design is considered appropriate to reduce cost or improve safety and functionality a detailed assessment has been undertaken. This is referred to as quantified fire risk assessment. This report includes, as part of the BS 7974 approach, a Qualitative Design Review (QDR). The QDR identifies the performance based areas of the design, discusses fire safety alternatives and sets acceptance criteria for assessment. The Fire Safety Engineering techniques address the following:

- The anticipated probability of a fire occurring;
- The anticipated fire severity, fire size and smoke production rates based on the particular building characteristics and prevention measures;
- The ability of the structure to resist the spread of fire and smoke; and
- The consequential danger to people in and around the building.

The methods used to address these factors are as follows and are detailed within the separate appendixes:

- Fire prevention measures including management control;
- Early warning and detection of fire;
- The adequacy of means of escape including travel distances and exit widths;
- The provision of smoke control to protect evacuation routes including residential corridors and fire fighting access routes;
- ;
- ;
- Facilities to assist the fire service; and

- Management controls and associated recommendations.

3.1 Fire safety principles

The strategy is based on the following key principles:

- Occupants at immediate risk from a fire must be able to evacuate, i.e. within the apartments, unhindered to a place of relative safety away from danger before continuing their evacuation to outside.
- A fire in an apartment should not put occupants in separate compartments in danger throughout the duration of the fire.
- Fire Fighters shall not be put at undue risk throughout the duration of a fire anywhere in the building.

The evacuation philosophy is stated as follows:

Upon activation of an alarm the occupants within the apartment of fire origin shall evacuate that apartment only. All other apartments shall be notified of appropriate action by the fire brigade.

3.2 Building Management

The management of a building of this type is important and refuse areas and common escape corridors/ stairs should be maintained free of combustible material or refuse. The building will be provided with a management statement, policy documentation and procedures in accordance with BS 5588 Part 11: 1997 (Section 8) and also a tenant handbook shall be provided to outline the fire safety requirements for tenants.

3.3 Fire detection and alarm

It is proposed to incorporate an automatic fire detection and alarm (AFDA) as follows:

The alarm system is to be designed to meet 1.2 to 1.22 of Approved Document B and BS5839: Part 6. Refer to this reference for detailed requirements.

The installation of smoke alarms within apartments shall be as follows:

- There should be a smoke alarm within the circulation space within 7.5m of the door to every habitable room
- Where the kitchen is not separated from the stairway or circulation space by a door, there should be a compatible interlinked heat detector in the kitchen, in addition to whatever smoke alarms are needed in the circulation space
- The smoke alarms should be ceiling mounted and at least 300mm from walls and light fittings.

Smoke detectors are required in all common corridors to activate the AOVs (Automatic Openable Vents ~1.5m^2). These detectors are not linked to any other system and should not raise a common alarm.

4. MEANS OF ESCAPE

The evacuation process in residential buildings is on an apartment-by-apartment basis. As a result of this, escape routes need to be available for an extended period allowing occupants to escape safely at any period during a fire incident.

This is achieved through substantial compartmentation and automatic ventilation of protected escape routes, reducing the likelihood of a fire affecting more than one apartment and compromising the escape route. The design principle is that occupants are safe in their own apartment and an escape route will be available only if needed.

The key objectives for protecting the vertical and horizontal escape and fire fighting routes are therefore:

a. separation from fire; and,

b. protection from smoke.

4.1 Common areas

4.1.1 Separation from fire

This is achieved through the use of fire resisting construction and compartmentation. The proposed compartmentation in the building is summarised in Appendix A and described in Section 5.1.

4.1.2 Protection from smoke (common areas)

The key aspects for protecting escape routes from smoke are firstly to prevent smoke entering the escape route and then to effectively clear smoke that does enter the escape route.

Fire resisting construction, smoke sealed doors and the use of lobbies within apartments will reduce the likelihood of smoke entering the escape routes. If however smoke did enter the escape route, ventilation is required to allow smoke to clear.

The standard solution, as set out in the AD, for smoke clearance on escape routes with single direction of escape, recommends:

a. Ventilation to the protected corridor using automatic openable vents ($1.5m^2$)

b. The restriction of travel distances from an apartment door to the stair door to a maximum of 7.5m.

The ventilation is achieved through automatic openable ventilation providing $1.5m^2$ vent area at every level direct to outside.

Travel distances are within the 7.5m recommended limit from the furthest apartment entrance doors to the stair door. .

Additional refuge space within the stair is not considered necessary with regard to BS 5588 Part 8 as the common corridor provides the necessary refuge space.

4.1.3 Ventilation to Stairs

Natural ventilation is to be provided at each stair landing level in accordance with fire fighting access requirements.

4.2 Escape Routes within one floor apartments

The layouts of the apartments will be such that they will comply with the recommendations of the AD. Protected hallways are required to each apartment where the travel distances within the apartment to the entrance door are above 9m. Where travel distances are less than 9m protected hallways are not required. Regardless of these minimum requirements all apartments are provided with protected entrance halls.

Protected entrance lobbies/hallways will have a minimum 30 minutes of fire separation between the accommodation and will have FD20 doors to all habitable rooms (except sanitary accommodation, provided the fire resistance encompasses this accommodation. Please see AD B for detail.). These provisions are applicable to both swing doors and sliding doors where used.

4.3 Means of Escape from Duplex Units

The standard design to meet the Approved Document recommendations suggests duplex apartments (i.e. the penthouse levels) should have alternative escapes from the upper level. Alternative exits are not proposed in this scheme at the upper levels direct to the common corridors, however additional precautions are included to achieve a safe design commensurate with the building regulations. These being:

- The fire alarm system shall be upgraded to cover all habitable rooms.
- The apartments will be protected with a domestic type sprinkler system in accordance with NFPA 13D / DD251 and all associated standards required for domestic type applications.
- The main circulation stair shall be fitted with FD30s fire doors, as opposed to the standard FD20 doors provided within standard entrance halls.
- The door separating the entrance hallway from the common corridor will be FD60S as opposed to FD30S as it is on other levels.

These features are considered sufficient to compensate for a fire escape from the upper level and provide a solution safer than the standard. Fire development will be both detected quickly and controlled, limiting its size and potential damage.

4.4 Means of escape from office areas

The office and other ancillary areas of the building located at the ground floor are code compliant with the entrance lobby providing 120 minute fire protection, having FD60S fire doors into the accommodation.

4.5 Stairs

The main stair shall be a fire fighting stair. The stairs terminate at ground level and there is a direct route to outside. The main stair is protected from the car park by a lobby.

The minimum width of the stair shall be 1100mm to meet fire-fighting requirements.

4.6 Escape Routes from Car Parks

There are at least two means of escape from the car park. This escape provision is well within the maximum acceptable travel distance of 25m and 45m where escape is available in either one or two directions respectively.

5. INTERNAL FIRE SPREAD

Generally, the structural frame and floors of the building will be concrete. The performance of the concrete frame during fire has been addressed in detail in Appendix B and the required fire resistance to prevent failure throughout the duration of a fire has been summarised below.

5.1 Compartmentation

On the basis of the Eurocode analysis the following compartmentation is required: -

- Between the apartments 90 minutes fire resistance with respect to integrity, stability and insulation;
- Between residential and car park accommodation a minimum of120 minutes fire resistance with respect to integrity, stability and insulation.
- Fire fighting shafts 120 minutes compartmentation.

The fire protection between the common corridor and the apartments shall meet the design requirements in BS 5588 Part 1, i.e. 60 minutes. The design objective for compartmentation is to separate fire loads. There is no fire load within the corridors, therefore a design resistance of 60 minutes is considered applicable, i.e. at least 60 minutes will be maintained between apartments and fire loads. To give further assurance the corridor is vented with a 1.5m^2 AOV.

Cavity barriers will need to be supplied and fitted in accordance with the recommendations in table 13 of Section 10 of AD B. Please also note the requirements within this reference for fire stopping of rain screen cladding etc.

As would typically be expected in a residential development, there will be small penetrations in the walls for domestic power and light fixings. The design of the inter-apartment walls will typically be a fire rated plasterboard outer face on each side with a Rockwool (or similar) blanket filling. Any penetrations in the walls for domestic power will be off set in adjacent apartments and the insulation will be placed such that it forms a fire barrier. Also, any fittings in the walls will be a thermoset type material. It is considered that the above arrangements should maintain adequate separation between apartments at these small penetrations.

Where ducts penetrate the compartment walls or floors, they will be provided with dampers (appropriately rated). Service penetrations will be fire stopped with a proprietary system to achieve the appropriate level of fire resistance. Where compartment walls are provided they will be continuous from floor to soffit.

Fire stopping and cavity barriers should be in accordance with the recommendations of Approved Document B Section 9, 10 and 11.

With reference to the alternative means of escape from the penthouse apartments, the lower level escape door shall be an FD60s door to maintain the fire compartment line between the walls of the apartment and the common corridor.

5.2 Structural Eurocode 1 ENV 1991 1-2-2: 1995 Results

A time equivalent analysis was carried out using the Eurocode approach (Appendix B) which calculates the fire exposure of elements of structure expressed as an equivalent exposure to the standard fire test (BS 476).

It is necessary to calculate the equivalent exposure for each compartment type (1-9) as the range of fire loads (floor area) and ventilation conditions vary between apartment types.

Therefore, all compartment types were selected for the calculations. The equivalent time of exposure will be greatest for compartments with high fire loads and/ or low ventilation.

The following table provides a summary of the results from the calculations.

Apartment Type	Equivalent time of exposure (minutes)
1	76.9*
2	83.5
3	74.1
4	72.3
5	70.3
6	73.8
7	81.3*
8	70.1
9	75.0**

*After Sensitivity Analysis, ** Duplex

As indicated by the results all apartments have an equivalent time of exposure of less than the 120 minutes; in all cases the level of fire resistance can be reduced to a minimum of 90 minutes. As noted above this performance based recommendation is subject to approval prior to design confirmation.

5.3 Main structure

All structural elements shall provide at least 90 minutes fire protection in accordance with the Eurocode assessment.

It should be noted that where one element of structure supports or carries or gives stability to another, the fire resistance of the supporting element should be no less then the minimum period of fire resistance for the other element (whether that other element is load bearing or not).

5.4 External steel work

The external steel and glass façade located at the front of the building does not support the structure. It's predominate role is to provide a key architectural feature.

It is understood that the steel provides additional support to the balconies if they have a live load, such as people. In the fire case this loading is not anticipated. If the steel were to heat and lose strength the balconies may dip, however the load bearing capacity of the structure will not be affected. The system as a whole should be confirmed by the structural engineers to ensure local loss of strength will not compromise stability.

5.5 Wall and Ceiling Linings

Wall and ceiling linings will be in accordance with the guidance in Table 10 to the AD. Typically this will require Class 0 materials in common areas and Class 1 within in apartments (except small rooms <4m^2 which may be Class 3).

5.6 Refuse chutes and storage

The nature of the development is such that the ad-hoc storage of refuse in lifts and lobby areas would be unacceptable. This is also considered a fire hazard if waste is not appropriately removed. Therefore refuse chutes will be used for the collection of waste.

The refuse chute will be located within a fire protected shaft which will form the access to the chute. This will be provided with an FD30s door. The chute itself will be at least a 120 minutes fire protected concrete shaft, therefore the common corridors will be protected by at least 90 minutes fire protection, the maximum required in this building. To give further reassurance the refuse area surrounding the chute will be permanently ventilated with the required $0.2m^2$ ventilation.

To give further safety the refuse room shall be protected with a domestic type sprinkler system to reduce the likelihood of a large fire developing and affecting means of escape.

An alarm system shall also be installed to detect a fire and raise the alarm at the concierge desk. The concierge desk will then follow procedures and call the Fire Service. It is not considered necessary to use an automatic Redcare system as false alarms may be common.

6. EXTERNAL FIRE SPREAD

Fire spread from residential buildings to neighbouring sites is not typically problematic, due to the relatively low radiation area, i.e. the windows of one apartment. The site boundary map indicates the distance between the building façade and the boundary. The recommended minimum distance is 12.5m, if the building has 100%unprotected area. The actual distance is between 10m and 30m, with the majority of the site above 12.5m. The area to the North East of the site, where boundary distances are measured to the middle of the road are exposed to the lift core/service areas of the site which are regarded as protected. This side of the building is fire resistant and therefore external fire spread overall is considered to meet the requirements of the AD.

The surface spread of flame for the external façade shall be Class 0. This is the standard applicable to buildings over 18m in height.

7. ACCESS AND FACILITIES FOR THE FIRE SERVICE

As the top floor of the buildings is in excess of 18m above ground floor level, a fire fighting shaft incorporating, fire fighting lift and dry riser will be required.

7.1 Access to the Building

The development is accessed from The Quays street. The access point for the fire service is the main reception point of each building. The access point (and dry main inlet connection point) will be within 18m of the nearest point of access for a fire appliance.

7.2 Fire Fighting Lobbies

The protected residential access corridor provided at each level will form the fire fighting lobby (in accordance with the guidance in the AD). Smoke venting in the corridor will be through the use of the natural smoke system with a $1.5m^2$ vent at each access level.

7.3 Fire Fighting Lifts

One lift will be designated a fire fighting access lift. In accordance with BS5588: Part 5, the fire fighting lifts will be used as passenger lifts in the non-fire configuration. The fire fighting and additional passenger lifts will utilise the same shafts and hence, all passenger lifts will meet the following criteria:

a. Constructed in accordance with section 11.2(b) of BS5588 Part 5;

b. Clearly and conspicuously marked 'Do not use for goods or refuse'; and,

c. Accessed only from the protected residential corridor.

7.4 Risers

A dry riser will be provided to the fire fighting shafts. The risers will be located in the protected residential corridor. Inlet connections for the dry risers will be provided at ground floor level.

7.5 Construction of Fire Fighting Shafts

The walls (excluding those on external elevations) of the fire fighting stairs and lift shafts will provide a minimum of 120 minutes fire resistance. Doors onto the fire fighting stairs will be type FD30s, lift doors will be type FD30 and doors from apartments will be type FD30S. Lift landing areas will be designed in accordance with BS5588: Part 5 with respect to drainage / limiting the potential for water ingress during fire fighting operations.

7.6 Stair ventilation

The stair shall be vented in accordance with BS 5588 Part 5 Section 8.

The following is applicable:

- Ventilation equalling 5% plan area of the stair shall be provided at top of the stair with a remote control mechanism located within the stair at ground floor level and be clearly marked. The vent should be able to open and close.

- At each level within the stair, ventilation equalling 15% of the horizontal stair area is to be provided for smoke ventilation. This shall be provided within a smoke shaft adjacent to the stair. The minimum free area of the smoke vent is to be 1.5m^2 with a minimum edge dimension of 0.75m. The shaft will open to outside at the top and bottom. There is no requirement to fire rate the inlet covers into the smoke shaft from the stair.

  The smoke shaft will have a fire damper to protect it from a fire in the car park. The vent will close on activation of fusible link.

All fire fighting facilities should meet the recommendations of BS5588 part 5.

7.7 Emergency Power

The power supplies for the emergency systems will be provided via two separate intakes into the buildings from the same external substation. This will provide two separate routes for power to the fire-fighting shaft.

8. CONCLUSIONS

N V Buildings Salford has been designed to meet Part B of the Building Regulations as detailed in this document. Where deviation from the standard guidance has been sought, a fire engineered solution has shown the design is considered to meet the functional requirements of the Building Regulations.

APPENDIX A

Fire safety system requirements

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A1. FIRE ALARM SYSTEMS

A2. STAIR WIDTHS

A3. COMPARTMENTATION/ STRUCTURAL FIRE PROTECTION

A4. FIRE DOORS

B1. INTRODUCTION

B2. METHODOLOGY

B3. INPUT DATA
B3.1 General parameters
B3.2 Case specific parameters

B4. RESULTS

A1. FIRE ALARM SYSTEMS

Alarm Description
The alarm system is to be designed to meet 1.2 to 1.22 of Approved Document B and BS5839: Part 6. Refer to this reference for detailed requirements. The installation of smoke alarms within apartments shall be as follows: • There should be a smoke alarm within the circulation space within 7.5m of the door to every habitable room • Where the kitchen is not separated from the stairway or circulation space by a door, there should be a compatible interlinked heat detector in the kitchen, in addition to whatever smoke alarms are needed in the circulation space • The smoke alarms should be ceiling mounted and at least 300mm from walls and light fittings. • The alarm system within the Duplex units shall be upgraded to cover all habitable rooms. Smoke detectors are required in all common corridors to activate the AOV system. These detectors are not linked to any other system and should not raise a common alarm.

A2. STAIR WIDTHS

Stair widths
The stair widths in residential apartments is not a critical factor as the numbers of persons anticipated to use the stair is considered relatively low, in light of the evacuation procedure. Therefore, the minimum width of the stairs is therefore 1100mm to meet fire fighting access requirements.

A3. COMPARTMENTATION/ STRUCTURAL FIRE PROTECTION

Compartmentation requirement
90 minute walls bounding apartments and 120 minutes between floors (concrete slab).
60 minute walls between apartments and residential corridor.
120 minute walls separating residential and car park accommodation.
30 minute compartment walls enclosing all entrance hallways in apartments.

A4. FIRE DOORS

Apartment entrance doors	FD30S (30 minute fire door with smoke seals) (Self closing)
Apartment entrance lobby doors	FD20 (Self closing) FD30S (Self closing) for Apartment type 9
Doors into fire fighting 'lobbies' from ground floor level	FD60S (Self closing)
Doors into escape stairs	FD30S(Self closing)
Doors into COSHH store and kitchen at ground floor	FD60 (self closing)
Doors to outside or not on evacuation route	No specification required.

APPENDIX B

Fire Safety Assessment of residential fire compartmentation

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A1. **FIRE ALARM SYSTEMS**

A2. **STAIR WIDTHS**

A3. **COMPARTMENTATION/ STRUCTURAL FIRE PROTECTION**

A4. **FIRE DOORS**

B1. **INTRODUCTION**

B2. **METHODOLOGY**

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B4. **RESULTS**

B1. INTRODUCTION

The Structural Eurocode 1 ENV 1991-2-2: 1995 provides a method for evaluating the effect of ventilation on structural fire resistance. This approach is known as the "Equivalent time of fire exposure" and is described in Annex E of the Eurocode.

When the Eurocode was published in the UK a National Application Document was included. The NAD gives UK values for parameters in the time-equivalent analysis, so that use of the analysis method generally results in reductions in the structural fire resistance compared to the recommendations in the AD.

Time-equivalent analysis is used to calculate the fire exposure of structural members in a fire compartment, expressed as an equivalent exposure to the standard fire test.

For compartments with typical fire loads such as apartments, that have relatively large window openings in relation to the floor area, time-equivalent analysis shows that the guidance on fire resistance in the AD may be conservative.

The key factor in assessing the applicability of the time-equivalent analysis method to a particular compartment is the compartment geometry, the fire load and the area of natural ventilation. The natural ventilation is usually taken to be openings such as glazing that could fail in a fire. If very limited ventilation is available then a significant fire –such that might threaten the compartmentation- could not occur. Therefore it is assumed that windows glazed with non-fire resisting glass are open or will break when the fire becomes large and will provide sufficient ventilation to support a large fire.

B2. METHODOLOGY

The equivalent time of fire exposure is defined in the Eurocode as follows:

$$t_{ed} = q_{ed} \cdot \gamma_{q1} \cdot \gamma_{q2} \cdot \gamma_n \cdot k_b \cdot w_f \quad \text{(minutes)}$$

Where:

q_{ed}	=	base fire load density
γ_{q1}	=	factor for consequence of structural failure
γ_{q2}	=	factor for risk of fire starting
γ_n	=	factor for effect of sprinklers
k_b	=	conversion factor to account for the thermal properties of the compartment enclosure
w_f	=	ventilation factor [Pettersson formula]

To take account of the varying compartment designs in the scheme, a wide range of cases were considered in the analysis.

B3. INPUT DATA

B3.1 General parameters

The following parameters apply to all of the cases analysed and relate to fuel load, building material characteristics and other factors that are applicable equally to all cases.

Input	Value	Reference
γ_{q1}	2.2	NAD Table 4
γ_{q2}	1.2	NAD Table 5
γ_n	1	NAD Table 6
q_{ed}	500 MJ/m^2	NAD Table 7
k_b	0.07	NAD Table 8

Please note the value of k_b is not applicable for wood walls or vermiculite type plaster.

The design fire load density is therefore: **1320MJ/m^2.**

B3.2 Case specific parameters

In order to assess equivalent fire resistance times for the design of compartmentation, it is therefore necessary to assess a range of different apartment sizes and associated window openings.

Each apartment is assumed to be fully involved in a fully developed fire. The areas used to calculate fire load, are assumed to be the total floor area of the apartment, detailed within the plans. However, where it is understood there is no fire load, such as hallways and bathrooms, this floor area may be deducted from the total apartment floor area. The apartments will be modelled as though they are rectangular in shape. The depth will be measured and the width adjusted by calculation from the floor area and the depth.

The following apartment/room dimensions have been assessed.

Apartment Type	1	2	3	4	5	6	7	8	9
Width of compartment (m)	7.39	7.09	9.14	9.15	9.17	8.31	11.52	17.80	16.02
Height of compartment (m)	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Depth of compartment (m)	6.60	9.00	11.80	8.25	9.20	11.80	8.10	9.30	17.85
Window height (m)	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Window width (m)	4.0	6.50	15.30	1.4	12.80	13.80	8.50	27.70	45.4

In each case, the whole apartment is assumed to be involved in the fire. Apartment Type 9 is a duplex apartment and in this case both levels will be assumed to be involved in the fire. Therefore the total floor area of both levels will used to calculate the fire load. The two levels will also be modelled separately.

B4. RESULTS

The table below summarises the results of the cases analysed.

Case number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Equivalent time of fire exposure (min)	76.9	83.5	74.1	72.3	70.3	73.8	81.3	70.1	75.0

The results indicate that for wide range of apartment and room sizes, the worst case equivalent time of fire exposure is 83.5 minutes. It is therefore concluded that the walls bounding the apartments may have a fire resistance of 90 minutes, and the analysis indicates that a fire in an apartment would be contained within the apartment of origin by the bounding walls.

The two levels of Apartment Type 9 were also modelled as single levels. The equivalent time of fire exposure for each level was no worse than the value when the floors were modelled together.