Project Report
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Fire Resistance and Non-Combustibility

Objectives & Performance Levels for Fire Resistance

FCRC Project 3 Part 1
Fire Resistance and Non-Combustibility

Fire Code Research Reform Program
October1996

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Background

The Fire Code Reform Research Program is funded by voluntary contributions from regulatory authorities, research organisations and industry participants.

Project 3 of the Program involved investigation into aspects of, and the need for, regulatory control of Fire Resistance Levels and specification of Non-Combustibility in certain applications.

This Final Report of Part 1 of the Project examines the historical bases of the fire resistance provisions within the Building Code of Australia; includes an analysis based on statistical information of specific BCA 90 requirements and identifies the derivation of a performance-based framework recommended for development in the ongoing stages of this project

At completion of Part 1 of the work , this Report was prepared by CSIRO - Division of Building, Construction and Engineering jointly by staff located at its establishments at Graham Road, HIGHETT, (PO Box 56), Victoria 3190 and at Riverside Corporate Park, Delhi Road (PO Box 310), NORTH RYDE, New South Wales 1670.

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Comments

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Project 3

FIRE RESISTANCE & NON-COMBUSTIBILITY

PART 1
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CSIRO

EXECUTIVE SUMMARY

Fire Code Reform Project 3 is one of a series of projects designed to introduce flexibility and modern technology into the "deemed to satisfy" prescriptions of the BCA. This report describes Part 1 of the Project 3 study. The purpose of this part of the study was to examine the basis and status of current requirements pertaining to fire resistance, and to establish a rational approach upon which any proposed change may be founded.

The report begins by examining the historical basis for the current BCA requirements in some detail. The review traces the BCA back to its predecessors and shows how the amalgamation of different earlier codes has given rise to a lack of clarity in the goals to be achieved by the requirements as they stand. Inconsistencies were identified. The changes introduced in bringing about the performance BCA have not altered the deemed-to-satisfy provisions, and have not removed anomalies. A review of the current requirements confirmed this assessment, noting that the BCA is very complex in the area of fire resistance, and fails to give due weight to the other fire safety systems in a building when considering FRL's. A survey of industry showed that whilst there is not widespread dissatisfaction with fire resistance levels generally, there is a view that the regulations show inconsistencies and that certain requirements are unduly onerous.

A survey of Australian fire incident statistics has provided valuable information on fire casualties, fire spread and property losses. The data appears to indicate that the fire-related compartment of fire origin has little effect in limiting casualties, fire spread and property damage. Spread of fire beyond the room of origin signifies a considerable increase in the likelihood of casualties and the cost of damage. The proportion of fires with a flame damage extending beyond the room of origin is increased fourfold in the absence of sprinklers.

In order to satisfy the identified need for a rational and consistent approach to fire resistance levels in buildings, the project team sought to determine the objectives for fire safety systems in buildings. These were related to the protection of life and property, and were interpreted into moire specific aims to which fire resistance contributes. These aims are to do with the protection of escape routes, the protection of firefighting access, the containment of fire within and between buildings and the maintenance of structural stability. A set of performance levels were defined which would have to be met by fire resisting building elements in order for them to function as intended in meeting these aims. Modified definitions of fire compartment and critical structure were found to be useful.

Once the performance levels have been defined a methodology is developed to show how building elements could achieve them. In the final chapters of the report it is shown how these performance levels could be applied to building elements as they appear within the BCA, giving a procedure whereby the fire resistance levels can be reappraised.

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1. INTRODUCTION

Fire Code Reform Project 3 is one of a series of projects designed to introduce flexibility and modern technology into the "deemed to satisfy" prescriptions of the BCA and to develop a fully engineered risk-assessment approach to building fire safety.

The objectives of Project 3 are:

- To examine the basis of existing requirements for non-combustibility and fire resistance in the BCA.
- By considering likely fire severities, to establish the basis on which fire resistance levels should be specified to achieve the regulatory intent and objectives of the BCA.
- To establish the levels of performance required for different methods of construction and occupancy categories.
- To establish the role of non-combustibility in delivering the fire-safety objectives.

Part 1 examines the basis for requirements for fire resistance. By reviewing the objectives - first the global objectives and then the required performance of fire resistance of systems (namely the system of barriers that are intended to control the spread of fire and smoke and the structural system that is intended to control the building's stability in a fire), a set of performance levels has been derived that can be applied to all building elements that are currently required to have a fire resistance level. Considering the objectives as part of a coherent whole, rather than as specific goals, has assisted in the development of a sound framework for analysing the issues of fire resistance and non-combustibility.

A significant part of this effort has been a review of the current requirements, how they were derived, and what they are thought to achieve. This work is described in detail in the Sections which follow. The Project goes on to look at how fire resistance levels might better be derived in such a way as to be rational and consistent. A set of calculation procedures are derived from this process which will be implemented, coupled with an experimental program in Parts 2 and 3. Part 4 will deal with non-combustibility in the context of the studies carried out to date.

2. HISTORY OF PASSIVE FIRE PROTECTION IN AUSTRALIA

2.1 INTRODUCTION

To determine the approach taken by succeeding generations of building regulators to the fire-protection of buildings is largely a matter of deduction from the regulations themselves. The Building Code of Australia (BCA) presently being developed as a performance code has its roots firmly planted in the prescriptive regulations of its predecessors - the building regulations of the various states that preceded (and formed) the Australian Model Uniform Building Code (AMUBC), successive amendations of the AMUBC and the various draft and final editions of the BCA itself. But even the predecessors to the AMUBC were not written from first principles. They accommodated the building technology of their day as it developed in response to community expectations and that had, in the opinions of community and regulators, performed reasonably satisfactorily. As what came to be regarded as deficiencies were identified, as technology developed and as economic conditions changed, the regulators of the time fulfilled their *raison d'etre* by amending the regulations. But what was done was by and large no more than progressive amendment so that the origins, founded as they were on their original objectives, were still seminal. For this reason, an historical analysis of objectives is not just a matter of interest but is relevant to the present projects.

In analysing the BCA, we have the work of three committees to examine, the Interstate Standing Committee for Uniform Building Regulations (ISCUBR), the Australian Uniform Building Regulations Co-ordinating Council (AUBRCC) and the Australian Building Codes Board (ABCB). In the first push towards uniformity among Australian building regulations over thirty years ago, ISCUBR did examine basic questions of policy and documented its approach to the fire-protection of buildings and their occupants, but the personnel of ISCUBR changed during its lifetime and then ISCUBR itself was succeeded first by AUBRCC (whose personnel also progressively changed) and presently by the ABCB. There is substantial evidence of changes of approach over the last thirty years but no parallel documentation.

The present chapter is confined to the regulators' objectives in setting fire-resistance levels and their development from their beginnings in ISCUBR Regulation Document No. 1[1] in 1965 through major amendments to the present. For the former we have the explanations in the "philosophical" documents mentioned above. For successive developments all we have is what can be deduced from the arguments put for and against proposed amendments, the amendments themselves and the "objectives" stated in the BCA.

With regard to ISCUBR, we are lucky that its secretariat and technical advice were provided by the Commonwealth Experimental Building Station which undertook also research and development on ISCUBR's behalf. The development of the regulations throughout the ISCUBR era is therefore documented in various CEBS publications.

2.2 HOW THIS CHAPTER IS SET OUT

Fire-resistance levels provide the passive control of the spread of fire from room to room, from floor to floor and from building to building. In regulatory terms, they determine the extent of internal and external compartmentation and of exposure control. The approaches of the regulators in setting the levels for these three aspects of passive fire protection - the fire-resistance levels for internal walls and floors, for external walls and for the protection of openings - differ from one to the other. They are, however, inextricably linked. It has therefore been found best in this chapter to deal first with what can be discovered or deduced about the general approach to passive fire-protection and then to deal separately with the regulators' approach to compartmentation by means of internal walls and floors and external walls, the approach to the preservation of compartmentation by the protection of openings and the approach to exposure control.

2.3 ISCUBR - 1965 TO 1980

2.3.1 The Bases of Fire-protection Regulations -The Documents of 1965 and 1966.

In Regulation Document 4[2], Isaacs lists the bases of fire-protection regulation as follows:

1. Absolute safety, within all the possibilities of a building fire, is economically out of reach. Reasonable safety, to the degree the community seems to expect reasonableness in matters of safety, must therefore be the aim.
2. Personal and community habits vary from one country to another; so also do the common modes of building. The fire risks and the incidence of fire must vary correspondingly.
3. 'Reasonable' must therefore be interpreted to suit our local way of life and our local sense of values.
4. In endeavouring to achieve 'reasonable' safety we must proceed on the basis of a system of priorities.
5. From a safety point of view these priorities must be -

   First, safety against loss of human life and against human injury.

   Second, protection of a building from the effects of fire in adjacent individual properties and, within one building, protection of tenancies from the effects of fire in other tenancies in the building

   Third, protection of the community against degradation of its civic and material standards through the ravages of fire.

6. A possible fourth priority, protection of the community against the material loss of a large building and the consequent unemployment this may cause, is normally irrelevant.

[Note the distinction from item 5. Victoria apparently did not, at least initially, agree with item 6 and alternative clauses were written into Regulation Document 1 to accommodate them. These clauses could well have been the basis for the specification of sprinkler protection in large, isolated buildings which is today in BCA C2.3(a)(ii). See the last dot point on page 4 - Ed.].

7. Protection of the building owner, as such, against the possibilities of damage due to fire within his building is *not* a function of building regulations.

8. Protection of building contents, as such, against the possibilities of fire damage is *not* a function of building regulations.

9. In endeavouring to achieve 'reasonable' safety we must refrain from requiring safety measures which are financially costly relative to the potential benefit they could bring.

10. In the context of item 9, we must refrain from requiring items simply because they aid the fire-fighting services; the test of 'reasonable' should be whether the relevant items aid the fire-fighting services to achieve the degree of safety decided upon for the regulations.

11. At any point of time, the rights and obligations of the owners of adjoining or adjacent allotments should be mutual, and be independent of the chronological order in which the owners may build on their respective allotments.

12. The regulations should be flexible enough to provide readily for the use of all sound new materials and ideas; they therefore should flow as far as possible from defined standards of performance.

13. The regulations should be flexible enough also to provide for the exercise of discretion by the local council or its senior officials, within limits properly defined, where local considerations can have a logical bearing on a general issue, or for such exercise of discretion even on a specific issue where, in affording justice to the community, the issue may and should be resolvable at the local council level.

14. As far as possible, only the most trivial matters as to necessary standards should be left to the decision of a building official; the official's duty should be to administer, not regulate.

[Item 14 suggests that the flexibility promoted in item 13 is not to affect standards (one way or the other). One example of the flexibility intended in item 13 would be, presumably, a flexibility on the part of the administrators to respond to the flexibility afforded the industry in item 12 - Ed.].

15. In absolute terms, and also as a corollary to items 11, 12, 13 and 14 in particular, the building public is entitled to know, as far as possible in advance, exactly what is expected of it.

16. The requirements for simple buildings such as dwellings and small blocks of flats should flow from, not precede, the laying down of the requirements for the more complex buildings.

On these bases, Regulation Document 4 reasoned that the three priorities of item 5 lead to the conclusion that buildings "however and wherever - with minor exceptions - they may be built, should necessarily provide fire safety for the occupants and also, as structures, conform to some pattern of minimal fire-behaviour characteristics." It further concluded that "stated differently, the second part of this conclusion is that building regulations should require, State-wide, a general pattern of fire protection based on building size and type of building structure."

2.3.2 The Five Types of Construction of the AMUBC

ISCUBR decided upon five types of construction for eight of the ten classes of building (with some further division into subclasses). We are interested in what ISCUBR saw as the capability of each of the five types of construction to provide a degree of fire-protection. In examining this question, we must be conscious of major components of the context in which ISCUBR made its decision:

- The regulations were not intended to provide any "absolute" level of safety.

- The types of construction were not theoretically determined. To quote Regulation Document 15[4] "This principle [to aim for a reasonable level of safety - Ed.] has led to the definition of five types of construction that a keen observer would find have been built in Australia over recent decades. RD No. 1 and subsequent documents define these types in precise terms, not as an academic exercise, but to classify into convenient groups all of the types of construction that we find about us." Despite Isaacs' overtones of happy coincidence, one sees the operation of the tradition of tempering the regulations to the industry lamb. What is even more significant is that the endorsement of the traditional types of construction gave us the lateral compartmentation (walls rather than floors as fire-barriers) that is a feature of Section C of the BCA. This obviously arose from the fact that, before the advent of reinforced-concrete construction, major multistorey buildings were of loadbearing brickwork with timber floors. Isaacs knew of, and referred to, the dependence of the walls on lateral support from the floors, particularly in a fire - in Regulation Document 4[2] he refers to a "tall building which could collapse because some of its floors burnt through" - and this was taken into account, along with egress and the capabilities of the fire-fighting authorities, in setting limits to height-in-storeys (and in defining it?).

- With the [qualified ?] exception of type-1 construction, the fire-fighting services were an essential component of a building's fire-protection system. To quote Isaacs again from Regulation Document 15[4] "The situation, therefore, is that just as we have come to use the five basic types of building, so have we come, with fire-brigade help, to live with them, fire-vulnerable as some of them happen to be. Also, for economic reasons, we wish to continue to use these basic types of building as freely as we may -

(a) so long as we do not unduly risk a spread of fire from building to building, and

(b) as a refinement of (a), so long as we take especial 'fire' care of city and suburban areas that are to be nurtured on a town-planning basis."
[Here Isaacs was anticipating fire-zoning - Ed.].

- The 1965 documents contain no discussion of the limits on the degree to which windows (in particular) could be fire-protected and the effect of this on compartmentation. Nor was there any discussion of a possible role for active systems other than the fire-brigades, except in two so-called 'Victorian proposals' (the earliest example of a potential state variation). These were a requirement for sprinklers in what we would call large, isolated, single-storey buildings and a requirement for sprinklers and/or smoke-and-heat venting in large, single-storey buildings that weren't isolated.

Descriptions of the capabilities of the types of construction are in Regulation Documents 4[2], 8[3] and 15[4] and in Bulletin No 9 [13].

Type 1. Fully protected construction - "structurally capable of resisting fire until the fire exhausts itself in the absence of fire-fighting help, or, in technical jargon, ... capable of resisting 'burnout' of the contents".

Type 2. Partially protected construction - " .... the internal construction is not intended to survive a fire unless the fire brigade can quell it at an early stage". [Note "internal"].

Type 3. Externally protected construction - " .... only the external walls are likely to survive any but a mild and short-lived fire, and .... even the external walls may topple in a protracted fire".

Type 4. Non-combustible construction - " .... the only virtue of the construction is that, unlike Type 5 construction, the material of the building will not itself burn, but that otherwise it is not intended to offer much resistance to a fire".

Type 5. Combustible construction - " .... both the contents of the building and the building fabric itself can burn as one".

A "reasonable" level of fire safety was afforded people and property in, and in the vicinity of, buildings by considering the significant, likely characteristics of buildings of each regulatory classification and of the people in and around them. The draft regulations of Regulation Document 1[1] then imposed -

- limitations on the number of storeys above street level,

• degrees of exposure control and external compartmentation (enclosure by fire-resisting external walls),

• degrees of internal compartmentation,

• limitations on the sizes of compartments, and

• restrictions on the combustibility and even the materials of construction of certain components of buildings.

Only for type-1 construction were limitations on compartment size and storey-height considered to be unnecessary (and even this absence of limitation was qualified).

These restrictions cut across the simple descriptions of the types of construction to some extent. For example, "externally protected construction" was also internally compartmented while the external walls, fire walls and internal bounding walls of "combustible construction" were to be, in certain circumstances, not only fire-rated but also clad with non-combustible sheeting and even specifically of masonry or concrete.

Regulation Document 1[1] listed, not the 'minimum' type of construction to be adopted for buildings of various classes and rises in storeys, but the rises in storeys to which types of construction 2 to 5 could be taken. There was no restriction on type 1. Putting these in the form of table we are now used to, we get Table 1 (with an apparent anomaly for class-III buildings of one and two storeys which disappeared when Regulation Document 30[6] was issued). Class-VIIIa buildings were class-VIII buildings with abnormally high fire hazard - VIII and VIIIa were to become VIIIa and VIIIb in the AMUBC. Classes IXa and IXb were the same as classes 9a and 9b of the BCA, not quite the same as IXa and IXb of the AMUBC.

TABLE 1 - RD 1: RISE IN STOREYS TO WHICH PARTICULAR TYPES OF CONSTRUCTION 2 TO 5 CAN BE TAKEN

CLASS/ NO OF STOREYS	II	III	V	VI	VII	VIIIa	VIIIb	IXa	IXb
6 or more									
5									
4			2	2		2			
3			3/4	3	2/3	3	3		
2	2	2/3/5	5	4/5	4/5	4/5	4/5	2	2

1	4	4						3/4/5	3/4/5

If Table 1 is put into the form of Tables 17.2 of the AMUBC, we get Table 2:

TABLE 2 - RD 1 :'MINIMUM' TYPE OF CONSTRUCTION FOR A PARTICULAR RISE IN STOREYS

CLASS/ NO OF STOREYS	II	III	V	VI	VII	VIIIa	VIIIb	IXa	IXb
6 or more	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1
4	1	1	2	2	1	2	1	1	1
3	1	1	4	3	3	3	3	1	1
2	2	5	5	5	5	5	5	2	2
1	4	4	5	5	5	5	5	5	5

2.3.3 The Consolidations of 1967 and 1970

In 1967 those parts of the model code that the members of ISCUBR had agreed to (always subject to future amendment) were issued as Regulation Document 30 "The Australian Model Uniform Building Code - Series 1" [6]. Numbering was now as in the AMUBC as we know it. The effect of classification and height-in-storeys outside a fire-zone was summarised in Table 17.2 and were as follows in Table 3. Note that Table 17.2 of Regulation Document 30 did not include class-IX buildings.

TABLE 3 - RD 30: 'MINIMUM' TYPE OF CONSTRUCTION FOR A PARTICULAR RISE IN STOREYS (TABLE 17.2)

CLASS/ NO OF STOREYS	II	III	V	VI	VII	VIIIa	VIIIb
6 or more	1	1	1	1	1	1	1
5	1	1	2	1	1	1	1
4	1	1	2	1	2	2	1
3	1	2	3	2	3	3	3
2	3	5	5	5	5	5	5
1	5	5	5	5	5	5	5

There was therefore a general relaxation of requirements except for class-VI buildings for which there was some tightening while class-VIII buildings remained unchanged.

When this table was revised "to 1970" in Regulation Document 47 [10] it became Table 4. This represented no change except for the retightening of limitations on class-III buildings while avoiding the earlier anomaly.

Table 17.2 was to remain unchanged for the rest of its regulatory existence except for the re-introduction of buildings of classes IXa and IXb via Regulation Document 67 in 1971 (originally in Part 26).

TABLE 4 - RD 47: 'MINIMUM' TYPE OF CONSTRUCTION FOR A PARTICULAR RISE IN STOREYS (TABLE 17.2)

CLASS/ NO OF STOREYS	II	III	V	VI	VII	VIIIa	VIIIb
6 or more	1	1	1	1	1	1	1
5	1	1	2	1	1	1	1
4	1	1	2	1	2	2	1
3	1	1	3	2	3	3	3
2	3	3	5	5	5	5	5
1	5	5	5	5	5	5	5

2.3.4 Walls and Floors as the Major Components of External and Internal Compartmentation

With one exception, the minimum fire-resistance ratings prescribed for external loadbearing walls, fire walls, internal loadbearing walls and floors in type-1 construction are identical in Regulation Document 1 and in the AMUBC (and from one document to the other). In fact, because of the interdependence of bearing walls and floors, equality of rating is essential to the structural survival of fully protected construction. From this equality we can argue further. Since a structural rating is intended to ensure that the structure will survive the burn-out of the entire contents of a compartment and the ratings for integrity and insulation, determined by means of the standard fire test when single-figure ratings were the norm, would not be inferior to that for structural stability, we can deduce that there was an intention that fire would not be transmitted through either a loadbearing wall or a floor. In other words there was an intention that 'fully protected construction' was fully compartmented at least by its loadbearing walls and floors.

2.3.5 Apparent Anomalies in RD 1 and later Versions of the AMUBC

The exception referred to above is in equating the lowest fire-rating for an external wall with that for a fire-wall. This could reasonably be expected to be the cross-over point from design of the external wall to resist an external fire to design to resist an internal fire. (Fire-resistance requirements for external-wall compartmentation - and for exposure control - are set out in Appendix A2.4). In Regulation Document 1, a rating of $1^1/_2$ hours is accepted for the external wall of a class-III building and this is consistent with the rating required of an internal wall and a fire wall in type-3 construction. But in type-1 construction a rating of 2 hours is required for internal walls and fire walls.

There are other apparent anomalies. Most have to do with exposure control and will be discussed under that head but two of them affect storey-to-storey compartmentation.

Regulation Document 1 did not distinguish between loadbearing and non-loadbearing construction. This is consistent with the policies discussed in Regulation Document 4. It makes no difference whether an external wall is loadbearing or not, it must protect the building from external fire sources and from the transmission of fire from storey to storey. The AMUBC did distinguish between them and subsequent consolidations of the AMUBC introduced further subdivisions of the proximity of the building to a fire-source feature. One result was that the ratings of non-loadbearing external walls in both type-1 and type-3 construction in the AMUBC fell below those for fire-walls once the proximity to a fire-source feature reached 7.5 m or more. But in type-1 construction they are never less than half so that, for storey-to-storey compartmentation, there is a 'cumulative' requirement equating or exceeding that of a fire wall. But the reductions are more precipitous in type 3 than in type 1. The question arises whether the compartmentation was compromised in those cases where, in type-3 construction, floors were required to offer resistance to fire spread (clause 16.9(8) for example). Whether, to continue the example, a fire from a $1^1/_2$-hour fire-load, breaking out through a $^1/_2$-hour external wall would be likely to break back through the $^1/_2$-hour wall above.

There is a similar situation with regard to lift and stair shafts. The fire-ratings required in Regulation Document 1 and the AMUBC for non-loadbearing shafts in buildings of classes II, III, V and IX are the same as those for fire walls but this is not the case for non-loadbearing shafts in buildings of classes VI, VII and VIII. It could be argued that lower ratings are appropriate for room-to-shaft compartmentation at storey level because the shaft will not be long occupied while for storey-to-storey compartmentation the situation is similar to that of an external wall. Fire would have to break into the shaft and then out of it again at the higher levels.

2.4 AUBRCC - 1980 TO 1994

2.4.1 The Transition from AMUBC to BCA

The Australian Uniform Building Regulations Co-ordinating Council continued the amendment of the Australian Model Uniform Building Code until June 1986 (the

AMUBC remained operative until 1990) while it developed the Building Code of Australia, initially as the Uniform Building Code.

Since AUBRCC inherited the ISCUBR regulations it might be argued that it inherited ISCUBR's objectives but such an argument would not be valid. What AUBRCC inherited was the ostensible control of certain aspects of a well established building industry but its expectations of the built-environment that that industry produces could well have differed from those of ISCUBR. In fact there is substantial evidence in its progressive amendment of the regulations of a change in expectations.

Even the differences in compartmentation requirements between type-1 and type-5 or type-A and type-C construction do not necessarily mean that in the case of type-A construction the compartmentation is expected (by AUBRCC) to completely contain the fire and in the case of type-C construction to contain it only so long as it takes to get the people out and the fire-fighters in. Type 1 and type-A generally mean bigger and taller buildings and therefore first, greater risk of fire (more people, more activity, more electrical circuits) and a greater need to inhibit its development, secondly, more difficulty and a greater resource demand in fighting fire, thirdly, greater potential economic loss and fourthly, and this brings us back to the earlier point, it takes longer to get people out and fire-fighters in.

The elimination of fire zones (which will be discussed under exposure control) and the conversions from five types of construction to three and from single-figure fire-resistance ratings to three-component fire-resistance levels were the responsibilities of AUBRCC.

2.4.2 The Three Types of Construction of the BCA

When, for the purposes of the BCA, the types of construction were reduced from five to three (Regulation Document 192 [19]) Table 17.2 was effectively replaced by Table C1.1. The original proposal was for the retention of types 1, 2 and 5. New South Wales argued against this on the basis of the lack of "incremental balance" among the types and in favour of types 1, 3 and 5 (but with the insertion of fire-rating requirements for the floors of what had been type-3). The only documentation available to CSIRO suggests that the ensuing discussion centred on the type of construction that should be required of two-storey buildings of class 2 and two-storey buildings of class 3 although it contains no arguments one way or another. New South Wales proposed that they both could be of type-B, Victoria proposed that they both should be of type-A while the Commonwealth suggested type-A for class 2 and type-B for class 3. In the event, they both became type-B and no general requirement for the fire-rating of floors was introduced into type-B. Buildings that had been required to be of type 1 were required to be of type A, type 3 became type B and type 5 became type C. Type 2 also became type A except for three-storey, class-6 buildings and two-storey, class-9a buildings. These became type B (but what was perhaps the most significant effect of this 'rationalisation' on a class-9a building was countered by clause C2.5(b)(iv)(B) which required the floors of fire-compartments to be fire rated). Fire zones disappeared. Type 4 construction had been essentially a concessional type of construction and although concessions remained the type of construction disappeared. The following table compares AMUBC and BCA:

TABLE 5 - AMUBC AND BCA: TYPES OF CONSTRUCTION

CLASS/ NO OF STOREYS	II/2	III/3	V/5	VI/6	VII/7	VIIIa/ 8	VIIIb/ 8	IXa /9a*	IXb /9b*
6 or more	1/A	1/A	1/A	1/A	1/A	1/A	1/A	1/A	1/A
5	1/A	1/A	2/A	1/A	1/A	1/A	1/A	1/A	1/A
4	1/A	1/A	2/A	1/A	2/A	2/A	1/A	1/A	1/A
3	1/A	1/A	3/B	2/B	3/B	3/B	3/B	1/A	1/A
2	3/B	3/B	5/C	5/C	5/C	5/C	5/C	2/B	3/B
1	5/C	5/C	5/C	5/C	5/C	5/C	5/C	5/C	5/C

* IXa- and IXb-buildings are not quite the same as 9a- and 9b-buildings. See AppendixA2.1 for the differences (which don't affect this table).

2.4.3 The Keough Report - Three-component Fire-resistance Levels

For the fire-resistance-level conversion the executive committee of AUBRCC engaged the expert services of Mr J. J. Keough [15]. Keough had substantial influence on AUBRCC although it may be said that, in certain instances, he had insufficient influence. The conversion was first proposed as amendments to Tables 16.7, 16.9 and 16.11 of the AMUBC but subsequently adapted to the UBC and the BCA (Regulation Documents 226 [20] and 271 [21]). AUBRCC did not adopt Keough's recommendations *in toto* but "while the proposals [the Fire Committee's proposals for the conversion] .... are largely based on the results .... as submitted by Mr Keough .... those proposals attempt to rationalise the aforementioned results with the existing Tables of the BCA having recognition of the practical application of the BCA and the need for consistency of requirements."[21]

A comparison of the AUBRCC "proposals" with Keough's recommendations fails to reveal any superiority in "practical application" or "consistency". The proposals do not indicate the application of any consistent policy or approach (other than to make the tables look neater). In fact they suggest in one or two instances a lack of technical expertise in fire-spread and in the physics of fire. Luckily, successive sets of proposals were submitted to Keough who was able to correct many of the adaptations.

2.4.4 The Keough Report - Common Walls and Party Walls

The Keough report argued also for reductions in requirements for common walls and party walls on the logical grounds that the FRL should be commensurate with the heavier of the two adjacent fire-loads. This was at first rejected by AUBRCC but eventually common walls were equated with fire walls.

2.4.5 Walls and Floors as the Major Components of External and Internal Compartmentation

The impression presented by the FRLs, taken in isolation, is that the BCA position with regard to compartmentation is similar to that of the AMUBC. The original intention appeared to be that, in type-A construction, compartmentation should be complete at loadbearing boundaries (floors, loadbearing walls and loadbearing shafts) and at external walls.

With the BCA, however, non-loadbearing external walls are not required to be fire-resistant once the set-back reaches 3 m in type-A construction. This must compromise the storey-to-storey compartmentation. In type-B construction, requirements for exposure-control cease at 18 m for loadbearing walls and 3 m for non-loadbearing walls. This would compromise the storey-to-storey compartmentation of those type-B buildings that are required to have fire-rated floors.

The reductions caused by the deletion of FRLs for structural adequacy from non-loadbearing external walls are not so dramatic. While, for example, the FRL for a non-loadbearing external wall of a building of class 2, 3 or 4 became 60 minutes rather than 90 minutes, it can be argued that there is a cumulative FRL of at least 120 minutes against storey-to-storey transmission of fire via the facade of the building.

The situation with regard to lift and stair shafts noted among the apparent anomalies in Section 5 persisted in the BCA. The fire-ratings required in the BCA for non-loadbearing shafts in buildings of classes 2, 3, 5 and 9 are the same as those for fire walls but this is not the case for non-loadbearing shafts in buildings of classes 6, 7 and 8. To repeat the argument of Section 5, the lower ratings could be appropriate for room-to-shaft compartmentation at storey level because the shaft will not be long occupied while for storey-to-storey compartmentation the situation is similar to that of an external wall. Fire would have to break into the shaft and then out of it again at the higher levels.

AUBRCC's intentions and expectations with regard to compartmentation are, however, overtly indicated by the "Objectives" that introduce each section of the code.

2.4.6 The Objectives set out in the BCA

The AUBRCC regulation documents are generally lacking in discussion of the regulatory objectives intended to be achieved by the proposals for amendment they contain. Documentation of endorsement or modification of ISCUBR objectives tends also to be lacking. The exceptions would be the arguments for the deletion of fire zones in Regulation Document 192 [19], discussed under exposure control, and the tacit acceptance of Keough's justifications for his recommendations where such recommendations are accepted

For documentation we must therefore turn to the "objectives" set out at the beginning of each section of the BCA. Of these the following are relevant to compartmentation:

Section C - Part C1 Fire Resistance and Stability

(a) ....

(b) Materials used in the construction must be such that if there is a fire in the building -

(i) the spread of fire .... will be minimised;

(ii) stability will be maintained for a period at least sufficient for the occupants to escape and to ensure the safety of fire-fighters; and

(iii) ....

Section C - Part C2 Compartmentation and Separation

Building compartment size and separating construction must be such that the potential size of a fire and the spread of fire and smoke are limited in order to -

(a) protect the occupants of one part of a building from the effects of fire elsewhere in the building,

(b) control the spread of fire to adjoining buildings; and

(c) facilitate access to the building by fire-fighters.

Section D - Part D1 Provision for Escape

There must be adequate means of escape in the case of fire or other emergency from all parts of the building to a place of safety.

Section E - Part E1 Fire Fighting Equipment

Having regard to the size and use of the building and its Type of construction, adequate inbuilt and external fire protection services must be provided to -

(a) restrict fire growth to the compartment of origin;

(b) ....

(c) ....

Section G - Part G3 Atrium Construction

The construction of an atrium must not unduly increase the danger to occupants from fire or smoke.

Section H - Part H1 Theatres, Stages and Public Halls

The audience seating area and egress routes of a Class 9b building used as a theatre, public hall, or the like, must be protected against fire and smoke from any fire occurring on stage, in backstage areas or in rigging lofts.

In summary, the objectives of Section C indicate that the regulations were written in the overall expectation that, if fire develops, occupants would be evacuated and the fire-brigades would fight the fire. The implications of the objectives of Section E are that fire-fighters will be on hand and their use of the inbuilt active fire-protection facilities will be necessary to "restrict fire growth to the compartment of origin". It should be noted also that in (b) of Part C2, one objective of compartmentation is exposure control.

Although the requirements of these sections are, by and large, prescriptive, implications as to objectives can be deduced also from the clauses themselves. Where a requirement has been put into the shape of a performance requirement, the trend is for the prime requirement to be merely rewritten in a generalized (unqualified) form so that any regulatory intention or "objective" must be derived, if it is derivable, from the construction deemed to comply. Throughout Section C, for example, there is the implication that the fire-wall of type-A and type-B construction and its FRL represents the construction required to provide compartmentation unqualified by other considerations. Also in Section C, the requirements governing multistorey, timber-framed buildings in Specification C1.1, are obviously predicated on evacuation of the occupants. The concessions for balconies similarly imply the FRLs of Tables 3, 4 and 5 are for the purposes of escape. In clause 4.1(c) of the same specification, if the fire-resistance required of shafts is valid, then the survival of the floor is limited. The only presumption is that the floor is expected to stay in place only so long as it takes to get the people into and then out of the shaft.

In subclause (f) of D1.4 - Exit Travel Distance, subclause (c) of D1.7 - Travel via Fire-isolated Exits and D2.6 - Smoke Lobbies there are examples of the use of a nominal FRL (of 60/60/60) for the protection of areas where the occupation will be transient. Similarly, in the specification of 60/60/60 for the subdivision of ward areas within patient-care areas, the emphasis appears to be primarily on smoke-control and secondarily on fire-control during evacuation. The FRL required of a proscenium wall in clause 3 of Specification H1.3 similarly suggests containment of the fire and smoke until the audience is evacuated. In contrast, the requirements for fire-control centres in Specification E1.8 combine provision for ready escape with substantial FRLs which therefore envisage protracted occupation by fire-brigade personnel. (Project 1 has identified requirements of the BCA as requirements for fire-compartmentation or for smoke-compartmentation or for both).

The written objectives and their reflections in individual clauses therefore suggest the following expectations on the part of AUBRCC:

- an expectation that the building will be evacuated; and
- an expectation that the fire-brigades will fight and, at least, control the fire and will supervise the evacuation.

On the basis of these expectations we can deduce objectives for the setting of FRLs at two levels. Outside the fire-compartmentation system, FRLs are nominal and expected to inhibit the spread of fire and of smoke only until such time as the areas are evacuated. Within the fire-compartmentation system, the FRLs are so set as to inhibit the spread of fire in the expectation that passive fire-resistance will be overtaken by the active systems brought into play by the fire-brigades. In neither of these cases is it implicit that there is an objective of absolute prevention of the spread of fire by means of passive fire-resistance alone.

The question remains as to whether or not there was a third expectation on the part of AUBRCC. That the structure and compartment boundaries of a building (including the external walls when the external walls constitute compartment boundaries) would survive a protracted or even an uncontrolled fire. It seems likely that there was such an expectation, at least for buildings of type A and type B and some of type C. There is the tacit acceptance (through the acceptance of recommended FRLs) of Keough's argument that "structures having these levels of fire-resistance [the levels of Table B3 of AS 1480 - 1974] do not suffer collapse in fires". Admittedly this would be restricted to those cases where the external walls, fire walls and internal walls had the fire-resistances listed by Keough. As against this, we have the general tenor of the argument in Regulation Document 192 and, at the level of detail, the objective "there will be little risk of collapse" is qualified by the additional phrase "onto adjoining property" and would appear to be confined to the application of C1.11. These would indicate a more general expectation. The question is somewhat academic, given the indications that fires are not expected to be uncontrolled, but is discussed under exposure control.

2.5 THE ABCB - 1994 ONWARDS

2.5.1 The Performance Conversion of the BCA

With the advent of the Australian Buildings Code Board in 1994, we have the production of the draft Building Code of Australia - Performance Conversion. This presents the same 'requirements' as the BCA - the technicalities have not been changed - but more extensive attention to regulatory expectations in the form of "Objectives", "Functional Statements" and "Performance Requirements" as introductions to the regulations of the BCA. All of the previous requirements became descriptions of materials and construction that are deemed to fulfil the objectives. The functional statements are somewhat the more informative. The functional statements for Section C and Section E that are relevant to FRLs are as follows. (The objectives, functional statements and performance requirements of Sections C and E apply also to Part G3 and Section H).

2.5.2 The Functional Statements of the Performance Conversion

CF1 - A building is to be constructed to maintain structural stability during fire to -

(a) allow people adequate time to evacuate safely; and

(b) allow emergency service personnel adequate time to undertake search, rescue and fire-fighting operations; and

(c) ....

CF2 - A building is to be provided with safeguards to prevent fire spread -

(a) so that occupants have time to evacuate to a safe place without being overcome by the effects of fire; and

(b) so that fire brigade personnel have adequate time to undertake search and rescue operations and fire-fighting operations; and

(c) to adjoining sole-occupancy units providing sleeping accommodation; and

(d) to rooms not in a sole-occupancy unit in a Class 2 or 3 building or Class 4 part; and

(e) to adjoining fire compartments; and

(f) to, or from, other property.

EF1.1 - A building is to be provided with fire fighting equipment to safeguard against fire spread

(a) so that occupants have time to evacuate to a safe place without being overcome by the effects of fire; and

(b) so that people may undertake initial attack on a fire; and

(c) so that fire brigade personnel may undertake search and rescue operations and fire-fighting operations; and

(d) to adjoining sole-occupancy units providing sleeping accommodation; and

(e) to rooms not in a sole-occupancy unit in a Class 2 or 3 building or Class 4 part; and

(f) to adjoining fire compartments; and

(g) to other property.

These indicate that the expectations of the ABCB are similar to those of AUBRCC:

- if a fire breaks out, the building will be evacuated; and
- the fire-brigades will attend to fight the fire, to supervise the evacuation and to search and rescue.

The control on the spread of fire provided by compartmentation is, by implication, for the purpose of providing time for evacuation plus search and rescue.

That Sections C and E have objectives in common suggests an expectation of interaction between passive and active fire-containment; that an element of trade-off is already built into the BCA. Certainly the potential for trade-offs is a characteristic of performance codes and must therefore be envisaged in the draft performance conversion of the BCA.

2.5.3 Barriers v Openings

BCA clauses to do with the protection of openings in fire-rated construction and their protection together with their AMUBC antecedents are listed in Appendix A2.2.

If the earliest ISCUBR approaches to openings through fire-rated walls and floors are compared with those to the walls and floors themselves, the papers do not show the same confident directness in defining objectives. The apparent diffidence could well have arisen from the entrenchment of planning and building traditions about which ISCUBR's advisers were dubious.

With regard to doors and windows, part of the difficulty was evidently the state of development of the industry and the influence of the industry on the regulators. Second was the prime necessity that openings fulfil their functions - that doors and shutters facilitate escape and that windows, even unopenable windows, admit light. This consideration gave rise to a third, which was the need to modify the criteria of failure in the standard fire test. (If doors, shutters and windows were to perform their primary functions and be manageable, they had difficulty in acting as insulators. The single-figure fire-resistance-rating was determined by the lowest of the three criteria but a door, window or shutter was unlikely to transmit fire by a failure of insulation. If the insulation criterion was not applied, however, a door and particularly a shutter could become dangerous to people by radiation or by accidental contact while a window was always a potentially dangerous radiator).

The way in which the regulations on the protection of openings developed and the commentaries on the successive instalments of the regulations suggest, however, that the prime cause of the diffidence was a lack of familiarity on the part of the researchers who were developing the model code with the commercially available products, their properties and their fire-behaviour.

As CEBS studies of the products progressed, so did commercial development. CEBS was eventually able to write specifications for doors, shutters and windows which it was confident would control the spread of fire and specifications for test methods that would identify and rate potentially successful products and, for its part, industry was able to produce them.

The problems of specification were to be solved eventually by the introduction of three-component FRLs and the comprehensive development of Australian standards for the testing of the whole range of passive fire-protection products. The limitations, particularly of windows, were to be alleviated also by combining active with passive protection.

2.5.4 General Expectations with regard to the Protection of Openings

In general, with the exceptions noted later in this chapter, regulations governing the protection of openings against penetration by fire have been subjected to less significant amendment than those governing fire-compartmentation by walls, floors and roofs. All the clauses of Sections C and D on this subject have precedents in the earliest versions of the AMUBC that are technically almost identical and, while the change from five types of construction to three and the elimination of fire zones have significantly changed the application of the regulations, the stringency of the regulations and the intentions behind them remain much the same. For this reason, such development as has taken place is best appreciated by considering all three codes - AMUBC, BCA and Draft Performance BCA - together.

By and large the general trend of such amendment as has been made has been to take advantage of advances in technology to facilitate detection, warning and evacuation. This accords with the present approach of the regulators that we saw in the trend of development in fire-compartmentation with its emphasis on evacuation:

- if fire breaks out and is not immediately extinguished by the occupants, buildings will be evacuated irrespective of class and type of construction; and
- fire-brigades will attend all building fires to control and then extinguish them but also to conduct or supervise evacuation and to search and to rescue.

And, as pointed out in the discussion of fire-compartmentation, this implies that compartmentation need not be complete; that its role need no longer be (except in the unlikely case) to contain the fire until self-extinguishment by complete burn-out.

2.5.5 Regulatory Requirements v Actual Practice

Although the degree of fire-compartmentation that the protection of openings should confer is expressly stated in the early regulation documents the explicitness is more apparent than real. It stems from the adoption of single-figure fire-resistence ratings while the actual practices in testing and in local-government control were not to become part of the regulations until the introduction of three-component FRLs.

These practices are revealed by a variety of CEBS and other publications. As early as 1960, before the days of ISCUBR, Notes on the Science of Building No 60 [16] states:

> "4.01 Any opening in a wall of a building is a potential fire hazard, unless it is fitted with a fire door or fire shutter, or effective like device. However, it is not

practicable to protect all openings thus, especially windows in the external walls of a building, hence the associated hazard must be accepted as a considered risk."

and

"4.05 Where openings of normal door and window sizes in, say, internal walls are required to be fire protected, it is desirable to limit also the aggregate area of the openings. It is appropriate to do so in recognition of the common inability to protect an opening so as to afford the same level of protection as that provided by the construction in which the opening occurs.

"4.06 Unavoidable openings in fire walls and other fire barriers, for the passage of ventilating ducts, are customarily protected by automatic fire dampers fixed in the ductwork within the thickness of the wall or barrier. Clearly, the ductwork passing through the opening, along with its lining, should be non-combustible, and the duct-work of material capable of maintaining its form at high temperatures. Metals with relatively low melting points will therefore be inadmissible."

Notes on the Science of Building No 90 [17] of May 1966 states in a discussion of the standard fire test:

"1.01 Section 4 of Australian Standard No. A30 - 1950, Fire Tests on Building Materials and Structures, specifies the method for determining the fire resistance of structural elements. This test requires that a member be failed in a fire-resistance test when

(a) It collapses under its design load, or

(b) It develops cracks through which flames can pass, or

(c) The face of the element remote from the furnace reaches an average temperature of 250^{O}F above the initial temperature or the maximum temperature at any point rises 325^{O}F above the initial temperature.

"1.02 In the case of doors, shutters or windows, which are required to protect openings in fire-resisting walls, it is presumed that combustible contents will not be in direct physical contact with such units and accordingly the third criterion of failure is waived."

With regard to lift-landing doors (about which there appears a complete absence of discussion in the regulation documents) Nassau and Hendry [18] explain the requirements of the present C3.10 of the BCA as follows:

"The FRL of -/60/- for the doors indicates that no requirement for structural adequacy and insulation resistance is necessary and is a reflection of the current nature of these doors. Further, insulation in these installations is not a major concern because lift shafts and lift cars are constructed of non-combustible materials and persons would not use the lifts in the event of fire.

"Fire brigade personnel using the emergency lifts also do not need to pass the lift landing doors of the fire-affected floor(s) as their normal practice is to stop at the floor below and then ascend via the fire stairs."

2.5.6 Doors, windows and shutters

Regulation Document No. 1[1] of January 1965 has references to the protection of openings at clauses 412 and 607, 608 and 609. Clause 412 requires the "framing of external doors, windows, and the like in buildings required to be of Type 1 or Type 2 Construction" to be non-combustible. Part 6 is the precursor of the specifications in Section A of the BCA. Clause 607 covers fire doors and while requiring correspondence with a tested prototype specifies what comprises a fire door and limits glazing and variations from the prototype. Clauses 608 and 609 are (incomplete) construction specifications for nominally 1-hour fire-windows and skylights and, apparently 1-hour, fire-shutters. They are incomplete in so far as they anticipate the writing of "Standard Specifications" presumably to include and complete what we have here. Regulation Document No. 4[2] of June 1965 does not comment on 412 but has the following to say about the other clauses:

> "Clause 607, on pages 76 and 77 of RD No. 1, is based upon the considerable experience of the Building Station in fire-testing 'fire doors' of many types. The intention is to provide a flexible basis for the acceptance of soundly designed fire doors, irrespective of what the fire and accident underwriters may have to say. ....
>
> "Clause 608, on pages 77 and 78 of RD No. 1, presents a 'practical' approach to the relevant situation. It is thought to be improper to specify that all types of fire windows and fire skylights should be fire-tested; the cost of testing would be inordinately high. The use of 'standard specifications' to cover common types of construction is thought to be the sensible way; the Building Station would supply the draft specification, as noted earlier for paragraph (4) on page 68 of RD No. 1.
>
> "Clause 609 and Table 609, on pages 78 to 80 of RD No. 1, embody the results of researches by the Building Station specifically directed to evolving a suitable specification for fire shutters. The researches showed up weaknesses in the present installation practices, but otherwise showed that fire shutters built according to the requirements set out in the clause and table are capable of acting as proper fire barriers for at least one hour under the conditions of the Standard Fire Test (page 13 of RD No. 1)".

RD 1 did not, however, specify where the doors, windows and shutters were to be used. But RD 1 was not a complete code, merely a first instalment.

Progressive "consolidations" and developments (RDs 8, 16 and 19) of the draft regulations did not affect the material on the protection of openings until the issue of

Regulation Document 24[5] in February 1967 which was a "first presentation of provisions on the location and fire protection of openings in various parts of buildings." RD 24 regulated external and internal openings and their protection in terms of location, individual area, proportional area (vis-a-vis the walls in which they occurred) and fire-resistance rating and anticipated almost all of the requirements of the AMUBC and the BCA.

Regulation Document No. 40[7] - "Fire doors, smoke doors, fire windows and fire shutters - Construction requirements", June 1968, was a development of the specification material in RD 1 but still anticipates the writing of "standard specifications" except in the case of fire-doors for which Australian Standard CA.57-1968 was cited. The state-of-the-art, which largely directed the approach of the regulators, is summed up in the commentary that accompanied RD 40:

> "As for walls, floors, and other structural members in buildings, the Standard Fire Test is the basic test in which the 'fire' performance of a fire door, fire window, or fire shutter must in the first place be measured. However, the criteria for passing the test are in some ways different from those for the structural members. Thus:
>
> (a) A fire door should not allow any significant passage of fire during its test period. Depending on its intended use, its face remote from the fire should in many cases not suffer a rise of temperature in excess of 250 degrees (on the Fahrenheit scale) at 30 minutes from the commencement of the test; this is so that heat radiation may be suitably controlled.
>
> (b) A fire window should not allow any passage of fire during the test period, but it cannot be expected to prevent heat radiation.
>
> (c) A fire shutter should not allow any significant passage of fire during its test period, but it cannot be expected to prevent heat radiation.
>
> "Fire Doors
>
> "The Commonwealth Experimental Building Station has had considerable experience in the fire-testing of fire doors. It has accordingly been possible for the Station to make many specific recommendations to the SAA regarding the text of a proposed new Australian Standard, to be entitled Fire Doors in Buildings. The Station is confident that its recommendations will be accepted, and on the assumption that this will be so it becomes possible to curtail very considerably the text of that part of Part 21 of the AMUBC that deals with fire doors. (The new Standard will detail all the special aspects of the Standard Fire Test that must be attended to, according to the precise function to be served by the particular fire door represented in the test.)
>
> "Part 22 will call for fire doors classified variously as 30-minute, 1-hour, 2-hour, and 3-hour fire doors. For most internal fire doors a temperature-rise criterion as mentioned above will also apply (in accordance with the accompanying draft subclause 21.3 - (2)); the internal doors exempted from this requirement are

those in which as a matter of expediency glazing must be permitted, e.g. those leading from public corridors to office tenancies, and those at lift landings.

"There is no doubt that the market can provide a great variety of fire doors to meet the combinations of requirements arising from what the building designer may need as to sizes and aesthetics and what the accompanying draft provisions require at the building-regulations end. The fire-door market is a highly competitive one, and the provisions are intended to allow the market to supply the cheapest door that can be soundly used for each separate set of circumstances.

"Smoke Doors

"Parts 22 and 24 will in certain provisions call for smoke doors. Smoke is frequently a major psychological hazard in a fire, and can also be a real personal one.

"There is no need to specify any form of fire test for a smoke door; all that is needed at the regulations end is a specification clearly calling for a door that will be virtually smoke-tight during the earlier stages of a fire nearby.

"Fire Windows

"Fire windows can fulfil only a limited number of purposes, and they are available only in a limited number of forms. The accompanying draft provisions as to fire windows are therefore intentionally simple, and although they permit fire windows to be accepted on the basis of the Standard Fire Test, it is likely that the very great majority of such windows will be those that merely comply with a departmental specification such as cited in the draf't provisions.

"Fire Shutters

"Little is known from overseas sources regarding actual fire tests on fire shutters. However, such shutters have a very good record of performance in real fires, both overseas and in Australia, and a particular research project at the CEBS to discover likely weaknesses in their fire behaviour showed that, properly made and installed, they can readily stand for at least 3 hours in the Standard Fire Test.

"The accompanying draft provisions have been prepared against this background, and although they permit shutters to be accepted on the basis of the Standard Fire Test, it is likely that virtually all fire shutters will be those complying with a departmental specification such as cited in the draft provisions."

Regulation Document No. 42[8] of September 1968 was the draft of the promised standard specification for fire shutters. The commentary that accompanied it stated:

> "The proposed uses of fire shutters will be governed by what is later drafted for Part 22, Location and Protection of Openings, but it is worth noting that -
>
> "(a) for a shutter-protected opening in an external wall, a single shutter mounted on the inside of the wall may be considered in order on walls required to have fire-resistance ratings of up to 3 hours;
>
> "(b) for a shutter-protected opening in an internal wall, radiation from a hot shutter can be an acute hazard, and shutters should therefore not be used on walls required to have fire-resistance ratings exceeding 2 hours; sliding doors - which are in any case gaining popularity over shutters - should be used instead on the walls required to have ratings exceeding 2 hours; and
>
> "(c) in the case of an internal wall, it may need to be a Council's prerogative - having in mind the particular circumstances - to nominate the side of the wall to have the shutter.
>
> "As to item (c), if it is later found possible to set down principles that will allow the designer rather than the Council to make the relevant determination, this will be done."

The proposed standard specification for fire-windows was to appear in Regulation Document No. 53[12] - "The Australian Model Uniform Building Code - Series 2 - 1970". It remained a 1-hour window whether it depended on a successful fire test or on compliance with the standard specification. There was no commentary.

RD 53 also reproduced the standard specification of RD 42 for fire shutters. A fire-resistance rating was not assigned to the standard shutter. A fire-resistance rating was required to be determined by test. The implication of RD 40 and RD 42 is that it is a 3-hour fire-shutter (except for the insulation criterion) but the material and dimensional details, although a refinement of RD 1, are technically the same. Presumably this is evidence of the researchers growing knowledge of and confidence in fire shutters. The eventual amendment of the AMUBC (in 1985) was to require fire-resistance rating to be always determined by test and to superimpose conformity with AS 1905 Part 2 over and above this on "metallic" shutters. Amendment 5 removed the embargo on metal shutters from C3.5 (it is sufficient for the shutter to conform to the three-component FRL) although Specification C3.5 was not amended in parallel. (It is notable that although C3.5 accepts shutters for the protection of horizontal openings - provided they are not part of a horizontal exit - C3.4 recognizes them only as protection for window openings. C3.4 is invoked by those clauses of the BCA concerned with the protection of openings in external walls - C3.2, C3.3, C3.8(b) and D1.7(c)(ii)(B) - and in this context the shutter is seen as closing off the window opening in the event of fire or supplementing the window if the window has fire-protective properties).

2.5.7 Floor-to-floor Compartmentation - Openings in the External Wall

The spread of fire by its breaking out through an opening in a lower floor and impinging on or radiating through an opening in an upper floor is controlled through passive construction to divert the fire-plume away from the wall. The only significant BCA modification of the latter requirement was to negate it if the building was internally sprinklered - had sprinkler protection on the same side as the potential fire. If the openings were "exposed to a fire-source feature" then the spandrels and slab projections were supplemented by the exposure-control measures imposed on the openings but this was not their prime purpose.

2.5.8 Floor-to-floor Compartmentation - Penetration by Non-fire-isolated Stairs

Such development as has occurred in clauses D1.3 and D1.12 is best demonstrated by quoting the version of 1969 in Regulation Document No. 43[9]. (As the commentary in RD 43 indicates, there were earlier precedents):

> "24.30 - (1) In a Class III, V, or VI building, one stairway that is not required by this Part, and not within a fire-resisting shaft, may be provided between -
>
> (a) a floor from which there is a required doorway leading directly out of the building; and
>
> (b) (i) the floors next and next-but-one above, if the building is of Type 1 construction; or
>
> (ii) the floor next above only, if the building is of Type 2 or Type 3 construction,
>
> subject to subclause (2)."

And subclause (2) says

> "(2) An approved sprinkler system shall be fitted throughout each -
>
> (a) storey; or
>
> (b) section thereof, if the storey is divided into sections by fire walls, served from above or below by a stairway referred to in subclause (1)."

The commentary in RD 43 has this to say:

> "Subclause 24.30 - (1) is a restatement of a principle that appears in the NSW consolidation referred to on page 3 of the present document (RD 43 - Editor). A somewhat similar principle appears in paragraph (f) of clause 2707 (should be 2706 - Editor) in RD No. 33, along with that part of paragraph (c) that is on page

11 of RD No. 33, but is extended to a degree that is inconsistent with overseas practices.

> "It must be realized in this context that it is very undesirable that there should be any open stairways such as permitted by subclause 24.30 - (1); they are permitted only as a matter of commercial expediency, and even then only under conditions where egress can be well assured and the principle of using floors to establish fire compartments is not unduly diluted.
>
> "The approved sprinkler system referred to in subclause 24.30 - (2) is needed to reduce the chance that a fire may break out (and make egress necessary), and to reduce the chance that if the fire breaks out it may spread from one storey to another by way of the openings through the floors for the non-required stairway."

The restrictions put on the implementation of this clause in buildings of class 9a indicate that the authors of the BCA recognize that it represents a significant increase in risk. The same recognition is indicated by the stringency of Specification D1.12 which applies when more than two or three floors are to be connected by non-required, non-fire-isolated stairs, escalators, walkways or ramps in fully sprinklered buildings of class 5 or class 6.

2.5.9 Openings for Services and Construction Joints - Fire Stopping

The intention behind clauses C3.12, C3.14, C3.15 and C3.16 which regulate the fire-stopping of openings for services and construction joints is quite unequivocal. Fire-compartmentation must be maintained. The same intention is behind clause C3.17 which governs fire-stopping around column-penetrations of floors. That C3.17 limits the requirement to columns protected with lightweight construction is an indication of the origins of the clause rather an intentional limitation of application.

2.5.10 The Atrium as an Opening

An atrium can represent a dangerous risk of fire-spread in that it could be a flue (or even a blast furnace) penetrating a building from bottom to top. It is commonly meant to accommodate a variety of activities - and therefore a variety of fire-loads - and a high degree of glazing is also common. In terms of apparent intentions, there is no compromise in the BCA on compartmentation through combinations of prescriptive active and passive measures but the primary safety measures are detection, warning, smoke-control, evacuation and automatic suppression. The policy to be inferred from the regulations is

- penetration of fire from the rest of the building into the atrium (and in the other direction) must be prevented;
- if fire occurs in the atrium it must be confined, not just to the atrium, but to its location of occurrence;

- detection to initiate warning, smoke-control and automatic suppression must be comprehensive and at the most sensitive practicable level;
- evacuation must be a matter of course and promptly initiated and facilitated.

The requirements for the protection of openings serving the atrium are in accord with this policy.

2.5.11 The Proscenium as an Opening

The regulatory approach to fire-protection in theatres, stages and public halls reflects the current trend of Australian building regulation noted earlier in that the emphasis appears to be on evacuation - in particular, on evacuation of the audience. Given appropriate smoke-control and sprinkler systems the principal opening between stage, backstage and under-stage and the auditorium need not be fire-protected. Specifications for smoke-control, active fire-protection and separation are comprehensive but while the former are stringent the latter is no more than nominal - the FRL required of the proscenium wall is no more than 60/60/60 (which might be sufficient in the circumstances but there is no evidence of this and research would be required to answer the question) and the curtain can be either non-combustible and smoke-tight (under pressure) or otherwise conform to specific early-fire-hazard limitations and be protected by a deluging system. In short, the intention appears to be to provide sufficient compartmentation to contain the fire until the audience has escaped and, presumably, the fire-brigades have taken over.

2.5.12 Nominal Compartmentation

The approach to compartmentation suggested by Part H1 is an example of a feature that appears to pervade the current BCA - the acceptance of nominal FRLs in situations where evacuation would be underway and imminent. Other examples are D2.6 - Smoke Lobbies which requires the walls of smoke lobbies to have an FRL of 60/60/60 and the doorways to be protected only by smoke-doors and D2.11 - Fire-isolated Passageways which, again, will accept an FRL for the "enclosing construction" of 60/60/60 in certain circumstances.

2.5.13 The Objectives set out in the BCA

Of the objectives set out at the beginning of each section of the BCA, those relevant to the protection of openings are as follows:

> **Section C - Part C1 Fire Resistance and Stability**
>
> (a) A building must be constructed so that it is protected from fire in any other building.
>
> (b) ....
>
> **Section C - Part C2 Compartmentation and Separation**

Building compartment size and separating construction must be such that the potential size of a fire and the spread of fire and smoke are limited in order to -

(a) protect the occupants of one part of a building from the effects of fire elsewhere in the building,

(b) control the spread of fire to adjoining buildings;

(c) ....

2.5.14 The Draft Performance Conversion of the BCA

As pointed out earlier, of the "Objectives", "Functional Statements" and "Performance Requirements" which are placed as introductions to the regulations of the draft performance conversion of the BCA, the functional statements are somewhat the more informative. The functional statements for Section C that are relevant to the protection of openings are as follows:

CF1 - A building is to be constructed to maintain structural stability during fire to -

(a) ....

(b) ....

(c) avoid damage to other property.

CF2 - A building is to be provided with safeguards to prevent fire spread -

(a) so that occupants have time to evacuate to a safe place without being overcome by the effects of fire; and

(b) ....

(c) to adjoining sole-occupancy units providing sleeping accommodation; and

(d) to rooms not in a sole-occupancy unit in a Class 2 or 3 building or Class 4 part; and

(e) to adjoining fire compartments; and

(f) to, or from, other property.

In summary, both the BCA and its draft performance conversion require compartmentation to be maintained and exposure-control to be two-directional.

2.6 EXPOSURE CONTROL UNDER ISCUBR - 1965 TO 1980

2.6.1 Protection from Fire in Adjacent Buildings

Regulation Document 4[2] defines the purpose of exposure control as the "protection of a building **from** the effects of fire in adjacent individual properties". In this it parallelled the purpose of compartmentation between tenancies - "protection of tenancies **from** the effects of fire in other tenancies in the building". (See item 5 of the Bases of Fire Protection Regulations on page 2 of this chapter). The authors of Regulation Document 1 did not envisage that a "protracted" fire could be confined within a building of other than type 1 and there was no knowing what might be built next door as a potential fire-source. Therefore every building must be designed on the assumption that a much more hazardous building might be built next door.

There was, however, already a couple of chinks in the armour. First there was the linking of exemption from floor-area limitations with isolation of the building. Second, Victoria went much further by proposing that single-storey buildings from which the limitations on floor area were removed were variously to be isolated, to be sprinklered, to have roof curtains with smoke-and-heat vents, to have parapets and/or to have limited window areas (Regulation Document 1[1]). The intention was, presumably, to impose a responsibility on the owner of this potentially huge fire-source feature to isolate it, control it or to confine it to some extent. In addition, as the AMUBC was progressively amended, further anomalous fire-resistance requirements were introduced.

2.6.2 Apparent Anomalies in RD 1 and later Versions of the AMUBC

In neither Regulation Document 1 nor the AMUBC is it clear that the worst exposure to a fire-source feature is being provided for in all cases. Tables 6 and 7 in Appendix A2.4 immediately raise the question of why not the highest figure along each row. A number of answers could be offered including

- high-hazard factories and warehouses are not built in association with flats, hotels, office buildings and department stores (Isaacs actually advocated their zoning);
- less risk should be taken with high-hazard factories and warehouses so we increase the protection we afford them and their contents (but neither of these arguments would explain the differences between IIs, IIIs, Vs and VIs as the proximities increase);
- there is always that policy of tempering the wind to the shorn lamb.

There is also an exception to equating the lowest fire-rating for an external wall with that for a fire-wall - the cross-over point from design of the external wall to resist an external fire to design to resist an internal fire. In Regulation Document 1, a rating of $1^1/_2$ hours is accepted for the external wall of a class-III building and this is consistent with the rating required of an internal wall and a fire wall in type-3 construction. But in type-1 construction a rating of 2 hours is required for internal walls and fire walls

Regulation Document 1 did not distinguish between loadbearing and non-loadbearing construction. This is consistent with the policies discussed in Regulation Document 4. It makes no difference whether an external wall is loadbearing or not, it must protect the building from external fire sources and from the transmission of fire from storey to storey. The AMUBC did distinguish between them without justificatioin.

There is a further anomaly in this regard. Subsequent consolidations of the AMUBC introduced further subdivisions of the proximity of the building to a fire-source feature. At the greater distances, fire-resistances less than those for fire-walls were sufficient for exposure control but the question arises, if type-3 construction is meant to be "externally protected construction", why do the ratings required of external walls at 7.5 m and more fall below those required of type-1 construction.

2.6.3 Exposure Control and the Protection of Openings

The commentaries on the earliest regulation documents indicate that the limitations imposed on openings in external walls are for exposure control. Their effectiveness in floor-to-floor compartmentation is incidental. The general tenor of the exposure-control regulations and the commentaries on them suggest that the objective was protection commensurate with that afforded by the walls themselves. But ISCUBR recognized the danger of, particularly, shutters and windows as radiators and introduced the limits on the proportion of the wall area they could occupy.

A substantial part of Regulation Document No. 24[5] in February 1967 which was a "first presentation of provisions on the location and fire protection of openings in various parts of buildings" was taken up by a discussion of clause 802 which is concerned with size limits and fire protection of openings in external walls that "represent a fire-spread hazard" - in later parlance 'are exposed to a fire-source feature'. The commentary makes it clear that the purpose of the controls is to protect the building from sources of fire outside the openings:

> "The fire-spread hazard mentioned in the opening phrases of clause 802 is one due to heat radiation supplemented, in some cases, by possible flame contact. The heat radiation may come from a fire in another building, or, in some cases, it may come (along with the flame) from another part of the building which has the opening."

Regulation Document No. 42[8] of September 1968 was the draft of the promised standard specification for fire shutters. The commentary that accompanied it stated:

> "The proposed uses of fire shutters will be governed by what is later drafted for Part 22, Location and Protection of Openings, but it is worth noting that -
>
> "(a) for a shutter-protected opening in an external wall, a single shutter mounted on the <u>inside</u> of the wall may be considered in order on walls required to have fire-resistance ratings of up to 3 hours;

In contrast, Regulation Document No. 49[11], prepared by "the initiating panel of ISCUBR" and undated but apparently early 1970, states

> "The purpose of protecting openings in external walls is to limit the spread of fire by radiation to adjoining premises. The effect of community fire-spread in

> fire zones is such that openings close to boundaries etc., should be protected in certain circumstances."

and

> "One hour fire windows, which are usually wired glass will not significantly affect the degree of fire radiation through the glazed area and their main function is to prevent the flames from a fire within a building from breaking out within the specified period and thereby increasing the intensity of the radiation.
>
> "The purpose of clause 22.5 is to limit the extent of openings and the amount of radiated heat passing through them."

There was therefore a confusion of purpose which was to be formalised, but not really resolved, with the advent of the BCA. (see Sections 26 and 27).

2.7 EXPOSURE CONTROL UNDER AUBRCC - 1980 TO 1994

2.7.1 The Elimination of Fire Zones

The elimination of fire zones - the administrative power to create them and the regulatory provisions with regard to them - was seen by AUBRCC as part and parcel of the conversion from five types of construction to three. In fact, the proposals for three types of construction were put forward in Regulation Document 192 [19] which is entitled "Deletion of Fire Zones". The deletion is significant of AUBRCC's regulatory objectives. In this case there is some discussion of regulatory expectations in Regulation Document 192. While basing arguments on "anomalies" between requirements inside and outside fire zones, "unnecessary complication of the regulations", "non uniformity of adoption" and "difficulties in explaining the concept to the industry", Regulation Document 192 did discuss the objective behind the original introduction of fire zones in the following terms:

" 'Old-fashioned' Concept of Control

"The fire zone concept has become outdated. Modern building controls such as the British and Canadian Building Regulations based on British and Canadian Fire Research Establishment findings have moved away from the fire zone concept. Fire zones are still in use in California and some other parts of the USA because permissible window areas in external walls are not limited. The fire zone concept is understood to be based on the "fuel content" of a building area, i.e., large commercial areas would have more "building bulk". The "building bulk" in modern times is, however, composed mainly of concrete and steel rather than timber and other combustible materials, and there appears to be little reason to consider any more than the possibility of spread of fire to the adjacent property rather than envisaging a 'fire storm' over a whole city or suburban block."

This argument does not quite represent the position of ISCUBR which led it to introduce fire zones. The earlier position of ISCUBR can be summarized in the following statements from Regulation Document 4[2]:

"Absolute safety, within all the possibilities of a building fire, is economically out of reach. Reasonable safety, to the degree the community seems to expect reasonableness in matters of safety, must therefore be the aim."

"The situation, therefore, is that just as we have come to use the five basic types of building, so have we come, with fire-brigade help, to live with them, fire-vulnerable as some of them happen to be. Also, for economic reasons, we wish to continue to use these basic types of building as freely as we may". and

"..... it is pertinent to note that <u>all</u> Australian capital cities and many towns must, on availiable information, be assumed to contain important areas where a fire, once taking hold, could develop sufficiently to over-tax the fire-fighting forces. The situation would be one in which only buildings of fully fire-resisting construction could be expected to survive; less fire-resisting construction would add to the burden on the fire-fighting services, water from the mains would not be sufficient to maintain the security of buildings depending on sprinklers, and all such less fire-resisting buildings would in all probability collapse, thus adding to the confusion and calamity.

"This is a peace-time consideration. So also is it a peace-time consideration that our cities and towns are growing.

"In such circumstances there is a need for certain buildings to be fully fire-resisting i.e., to be structurally capable of resisting fire until the fire exhausts itself in the absence of fire-fighting help, or, in technical jargon, to be capable of resisting 'burnout' of the contents."

But, it is this argument that AUBRCC is rejecting. The situations for which fire zones were conceived by ISCUBR were no longer seen by AUBRCC as likely to occur; that the probability was not such as to require regulatory provision. In other words, the elimination of fire zones meant that AUBRCC based its amendments to the AMUBC on the presumption that the fire-brigades would always attend a building fire and would always control it before it could lead to the collapse of the building irrespective of type of construction.

The reference in Regulation Document 192 to the control of the areas of windows (with its implication of control of the fire-source feature) should also be noted.

2.7.2 The Keough Report - Exposure Control

In contrast to its approach to three-component fire-resistance ratings, one area in which AUBRCC did accept the Keough report [15] and departed from the bases of the

AMUBC was in reductions in fire-resistance requirements for external walls in "fully protected" and "externally protected" construction - type-A (type-1) and type-B (type-3) construction. This departure was based on the contention that buildings designed for their own fire-loads do not collapse even in an uncontrolled fire. It was accompanied by a further change in concept - that the building under design is the fire-source feature which can be controlled by regulation of its external walls.

The elimination of fire zones, the conversion from five types of construction of the AMUBC to the three types of the BCA and the conversion to three-component fire-resistance levels were therefore accompanied by what could not be otherwise than a radical change in the approach of the regulators to structural fire-protection. Basic to the AMUBC were the concepts:

- Only a building of type-1 construction could survive the burn-out of its contents. Fire in a multistorey building of any other type, if uncontrolled by the fire-fighting services, would cause its collapse.
- A potential fire-source feature could be another building with a high fire-load so external walls must be rated accordingly. For example, a class-VI building (3-hour fire-load) might be built on the boundary adjoining a class-II ($1^1/_2$-hour fire-load) so the class-II must be built with a 3-hour external wall.
- The role of the fire-rated external wall was (predominantly) to protect *against* external hazards.

The FRLs required of external walls in the BCA indicate a new approach:

- Buildings constructed to the BCA will not collapse even if gutted by fire.
- Provided openings are regulated, it is sufficient for external walls to be rated according to the fire-load *within* the building.
- External walls and the openings in them are regulated to protect the neighbours.

The evidence for this change in approach is presented in detail in Appendix A2.3.

The assumption of survival of external walls in which the size and disposition of openings are controlled as a basis for regulation is a radical departure from the bases of Regulation Document 1 on two counts:

- the assumption itself - that in a burning building, external walls, limited in height and fire-rated to the levels of the AMUBC, can survive the loss of lateral support from the floors; and
- the suggestion that the external construction of a building is regulated to protect adjacent property from the building as a "fire-source feature".

Although the first of these points might constitute an expectation rather than an intention, that there was such an expectation is borne out by the changes to the requirements imposed on external walls for exposure control. See Tables 7 and 8 in Appendix A2.4.

2.7.3 The FRLs required of External Walls

Appendix A2.5 Tables 7 and 8 summarize the fire-resistance ratings required of external walls for exposure-control and storey-to-storey compartmentation in Regulation Document 1, in the final edition of the AMUBC and in the 1990 edition of the BCA as amended. The fire-resistance ratings required of a fire wall are included as indicative of the fire-resistances required to prevent the lateral transmission of an *internal* fire

The tables indicate that Regulation Document 1 and the AMUBC expected buildings of fully protected and externally protected construction to resist exposure to fires considerably more severe than those represented by their own fire loads (except when they themselves contained the highest fire loads). See Section 23 for a discussion of some apparent anomalies.

The exposure-control FRLs of the BCA on the other hand are, as Technical Record 91/1[14] reported, no more than the FRLs required to resist the individual internal fire-loads. With the amendment of the BCA, the passive exposure-control presented by non-loadbearing external construction was even further reduced to the "integrity" levels of the three-part FRLs.

In spite of Keough's arguments, the anomalous differences in requirements between loadbearing and non-loadbearing external walls persist.

2.7.4 Inconsistencies in Application

The change in approach to exposure control - the requirement that the external walls and the openings in them protect the neighbours - was not consistently followed up in amendment to the AMUBC and inconsistences persist into the BCA.

1. Subclause C3.2(b) calls for external wall-wetting sprinklers which means the fire is outside.

2. Up until Amendment 5 which introduced the new D1.7(c), clause C3.4 called for external wall-wetting sprinklers.

3. Clause 5.1(b) of Specification C1.1 states that "an external wall required by Table 5 to have an FRL need only be tested from the outside to satisfy the requirement". The BCA requires protection only from the external fire-source feature and then only pretty nominal protection. It is not apparently concerned with the type-C building becoming a fire-source feature.

4. Clause 4 of Specification C1.9 requires a wall within the critical distance of a boundary or of another building to have a specific FRL only "when tested from the outside".

5. The exposure-control requirements for type-C construction are less stringent than those for types A and B. If the exposure-control requirements are to prevent fire-spread to adjoining premises, there appears to be no justification for permitting a type-C building to be a greater danger to its neighbours than buildings of other types of construction; the neighbours must revert to reliance on their own exposure-control measures to protect them from fire from outside.

6. On a less particular level, the traditional phraseology - "exposure *to* a fire-source feature", "protection *from* a fire-source feature" persists in the regulations and in commentaries on them.

It is noted, however, that the requirements of C3.2 represent a tightening of the regulations in the transition from AMUBC to BCA. Originally they applied within a fire zone. With the deletion of fire zones they became more generally applicable while the embargo on openings within 1.5 m or 1 m of a fire-source-feature was unprecedented in the AMUBC.

2.7.5 The Objectives set out in the BCA

As pointed out with regard to compartmentation, the AUBRCC regulation documents are generally lacking in discussion of the regulatory objectives intended to be achieved by the proposals for amendment they contain. Documentation of endorsement or modification of ISCUBR objectives tends also to be lacking. The exceptions are the arguments for the deletion of fire zones in Regulation Document 192 [19] and the tacit acceptance of Keough's justifications for his recommendations where such recommendations are accepted. Otherwise we have arguments such as that for the change in setback (of a fire-source feature) from 1.2 m to 1.5 m: "the dimension of 1.2 m had no strong justification for its use and was inconsistent with the dimension progression within the remainder of the Table. The increase of 300 m is not considered to impose any financial or practical burden." The New South Wales argument for incremental balance is fair enough but what is significant is that the proposals are not argued in terms of regulatory objectives with regard to the safety of people or property.

For documentation we must therefore turn to the "objectives" set out at the beginning of each section of the BCA. Of these the following are relevant to exposure control:

Section C - Part C1 Fire Resistance and Stability

(a) A building must be constructed so that it is protected from fire in any other building.

(b) Materials used in the construction must be such that if there is a fire in the building -

(i) ....

(ii) ....

(iii) there will be little risk of collapse onto adjoining property.

Section C - Part C2 Compartmentation and Separation

Building compartment size and separating construction must be such that the potential size of a fire and the spread of fire and smoke are limited in order to -

(a) ....

(b) control the spread of fire to adjoining buildings; and

(c) ....

It is to be noted that the objective of preventing collapse [(b)(iii) of Part C1] is confined to ensuring "little risk of collapse ***onto adjoining property***" [my italics - Ed.] and that one objective of compartmentation [(b) of Part C2] is exposure control.

2.8 EXPOSURE CONTROL UNDER THE ABCB - 1994 ONWARDS

2.8.1 The Functional Statements of the Performance Conversion

The superficial differences between the BCA and the draft Building Code of Australia - Performance Conversion are described earlier. The following functional statements for Section C and Section E are relevant to exposure control. (The objectives, functional statements and performance requirements of Sections C and E apply also to Part G3 and Section H).

CF1 - A building is to be constructed to maintain structural stability during fire to -

(a) ....

(b) ....

(c) avoid damage to other property.

CF2 - A building is to be provided with safeguards to prevent fire spread -

....

....

(f) to, or from, other property.

EF1.1 - A building is to be provided with fire fighting equipment to safeguard against fire spread

....

....

(g) to other property.

There is, again, the objective of protecting other property and the prevention of fire-spread “to” or “from” other property. “From” requires exposure control of the building under design. “To” requires the building under design to be designed as a potential fire-source feature.

The carry-over of the FRLs from the BCA implies also a carry-over of the expectation that the structure of the building will not collapse even if a fire is uncontrolled.

2.9 CONCLUSIONS

2.9.1 Primary Compartmentation

1. The bases on which the fire provisions of the AMUBC were first drafted are itemised as sixteen points in Regulation Document 1[1] and reproduced at the beginning of this chapter. They include the three priorities of fire protection:

> First, safety against loss of human life and against human injury.
>
> Second, protection of a building from the effects of fire in adjacent individual properties and, within one building, protection of tenancies from the effects of fire in other tenancies in the building.
>
> Third, protection of the community against degradation of its civic and material standards through the ravages of fire.

2. The provisions of the AMUBC were written in the context that the fire-fighting services would, except in exceptional circumstances, be available to supplement in-house systems. In this context, only type-1 construction was expected to survive a fire structurally; all other types would need the services of the fire-brigades to progressively increasing extents if fire were not to lead to the collapse of the building.

3. The writers of the BCA replaced type-1 construction with type A, type 3 with type B and type 5 with type C and absorbed types 2 and 4 into the three-tier structure. Buildings of type-A construction were expected to survive the burn-out of the contents as were their predecessors but there was a change in the approach to the regulation of type-B buildings, the old type-3, (and even type-C buildings, the old type 5, or at least those of classes 2 and 3).

4. With the advent of the BCA, the FRLs required of external walls and the revision of Bulletin 9 that followed publication of the BCA, indicate a change in the expectations of the regulation writers: provided walls have FRLs commensurate with the contents of the building, they will remain standing. Even if the contents burn out (in the absence of any fire-fighting) a building will be gutted but will not collapse. This meant that the FRLs required of external walls need be no more than those necessary to compartment the building internally. The FRLs for integrity and insulation could, of course, be less. With the deletion of structural-

adequacy levels from the FRLs required of non-loadbearing walls, the fire-resistances of the external walls of certain buildings were further reduced.

5. Regulation Document 1[1] envisaged also that compartmentation in type-1 construction, at least within loadbearing boundaries and within external walls, would be complete - that an uncontrolled fire would be contained until it ceased for lack of fuel. This principle appears to have been compromised in the BCA by the elimination of FRL-requirements for certain external non-loadbearing walls. The same situation has arisen in the case of those buildings of type-B construction that are required to be compartmented at floor level.

6. The BCA indicates also a modification of approach to compartmentation. This is indicated by the elimination of fire zones and the general tenor of the objectives stated in the BCA 1988 - 1990 and the draft BCA Performance Conversion:

- if fire breaks out and is not immediately extinguished by the occupants, buildings will be evacuated irrespective of class and type of construction; and
- fire-brigades will attend all building fires to control and then extinguish them but also to conduct or supervise evacuation and to search and to rescue.

This implies that compartmentation need not be complete; that its role need no longer be (except in the unlikely event of the fire-brigade's non-arrival) to contain the fire until self-extinguishment by complete burn-out.

7. There is evidence also of the use of nominal FRLs to specify construction for smoke-compartmentation.

8. Comparison of the FRLs required of type-C construction with those of types A and B shows that

evacuation is a matter of course;

attendance of the fire-brigades would be necessary to ensure that the building did not reach its potential as a fire-source feature.

9. As against all this, the suggestions that presently specified FRLs are based on significantly conservative estimates of fire load for the various classes should be noted; that, with the present FRLs, compartmentation will survive longer than is necessary for evacuation and fire-fighting purposes.

2.9.2 The Protection of Openings

10. Although the ostensible intention behind the original regulations that governed the protection of openings in fire-rated construction was that fire-compartmentation must be complete and must be preserved, in practice the fire-resistances required of doors, shutters and windows were significantly less stringent than those required of the main fabric of the building. The writers of the model regulations acknowledged that if

doors and windows were to fulfil their functions, their fire-ratings would be prejudiced by difficulties with insulation and radiation-control. At the same time, they recognized that shortcomings in insulation were not so critical as with walls and floors because combustibles are not (certainly should not) be placed in contact with doors and windows.

11. The ideal is insisted on with fire-walls (which reproduce the function of external walls by separating buildings); windows are out altogether and, even for openings that are not part of a horizontal exit (C3.5), the adoption of two doors or two shutters is envisaged. For doorways that are part of a horizontal exit (C3.7) shutters are also out and, until 1990, the door (or pair of doors in buildings of class 7 and class 8) was required to reproduce the FRL of the fire wall.

12. Otherwise the problem with door and window openings was solved by liberalizing the insulation criterion (ultimately facilitated by the adoption of three-component FRLs), limiting the proportional areas of openings in fire-rated construction, limiting the areas of glazing in doors, requiring separate fire-protection for structural elements exposed to radiation through windows, the combination of active with passive protection and restrictions and even embargoes on fire-windows and fire-shutters where fire-compartmentation was seen to be more critical than the norm.

13. The connection of two and three storeys by unprotected openings in floors (by non-fire-isolated stairs, escalators, ramps and walkways) was accepted in the earliest drafts under pressure from traditional practices. ISCUBR recognized the increase in risk of fire and smoke-spread and mitigated it by limiting the situations in which the practice could be adopted and by requirements for active fire-protection. The original model regulations were somewhat more stringent than the present regulations.

14. The change in approach to exposure-control is explicit in the commentaries on AMUBC regulations for the protection of openings in external walls. Up until September 1968 (or even later) the protection of openings in external walls was to protect the building from external fire-source features. From the beginning of 1970, it was to protect the neighbours. In the BCA and the draft performance conversion of the BCA the protection is to be two-directional. The regulations, however, were not comprehensively amended for consistency with these changes of approach.

15. The original attitude to fire-source features and protection against them could explain why protection of openings in external walls was not adopted for the purposes of storey-to-storey compartmentation. The approach was to require construction that would divert the fire-plume away from the upper storeys (and towards the neighbours).

16. Such progressive amendment as has been made to the rules on the protection of openings reflects the change in the general approach to fire-protection already noted; the emphasis on evacuation, automatic suppression and fire-authority intervention. Advantage has been taken of progress in technology to augment the requirements for detection, warning, smoke-control, automatic alerting of the fire authorities and

automatic suppression. Recognition of (and encouragement of) advances in technology do not appear to extend to passive systems.

17. Consistent with the emphasis on evacuation and active systems is the adoption of what appear to be no more than nominal compartmentational FRLs - FRLs that appear to be intended to do no more than contain the fire while evacuation is accomplished.

2.9.3 Exposure Control

18. The original objective of exposure control was to protect the building under design from the effects of fire in adjacent, individual properties.

19. Since "the rights and obligations of the owners of adjoining or adjacent allotments should be mutual, and be independent of the chronological order in which the owners may build on their respective allotments" the regulations required the building owner to anticipate (baring some noted anomalies) the potential proximity of a fire-source feature incorporating the highest fire load envisaged by the regulations.

20. The protection of openings in the external walls was for the protection of the building containing them from external fires.

21. With the advent of the BCA, the FRLs required of external walls and the revision of Bulletin 9 that followed publication of the BCA, indicate a change in the expectations of the regulation writers: provided walls have FRLs commensurate with the contents of the building, they will remain standing. Even if the contents burn out (in the absence of any fire-fighting) a building will be gutted but will not collapse. This meant that the FRLs required of external walls need be no more than those necessary to compartment the building internally. The FRLs for integrity and insulation could, of course, be less. With the deletion of structural-adequacy levels from the FRLs required of non-loadbearing walls, exposure-control in certain buildings was further reduced.

22. This change in expectation led to further changes in the approach to exposure control. If a burning building does not collapse, the danger it represents to its neighbours is reduced to radiation from the windows and from any fire-plume issuing from them. Therefore, a building can be controlled as a potential fire-source feature by regulating the sizes and dispositions of openings in its external walls. This concept led to two progressive changes in approach. First, the purpose of the regulation of the external walls of a building became the protection of adjacent property from fire *in* the building. Second, in the present BCA and in the draft performance conversion of the BCA, the protection is ostensibly intended to be two-directional. These changes were not, however, consistently followed up by comprehensive amendment.

2.10 REFERENCES

1. ISCUBR RD 1 - FIRE PROTECTION : PART 1 (Draft regulations), D.V.Isaacs, January 1965.

2. ISCUBR RD 4 - FIRE PROTECTION : A DISCUSSION OF PRINCIPLES, D.V.Isaacs, May 1965.

3. ISCUBR RD 8 - FIRE PROTECTION : PART 1 (Redraft of RD1), D.V.Isaacs, September 1965.

4. ISCUBR RD 15 - FIRE ZONING (The principles of fire-zoning and draft regulations), D.V.Isaacs, May 1966.

5. ISCUBR RD 24 - FIRE-PROTECTION REGULATIONS: PART 8, D.V.Isaacs, February 1967

6. ISCUBR RD 30 - THE AUSTRALIAN MODEL UNIFORM BUILDING CODE - SERIES 1 (A consolidation of the code as drafted to the time of publication), undated but evidently 1967.

7. ISCUBR RD 4O - FIRE DOORS, SMOKE DOORS, FIRE WINDOWS AND FIRE SHUTTERS - CONSTRUCTION REQUIREMENTS, D.V.Isaacs (CEBS) and N.A.Steed (NSW), June 1968

8. ISCUBR RD 42 - FIRE-RESISTANT ROLLER SHUTTERS, D.V.Isaacs (CEBS), September 1968

9. ISCUBR RD 43 - MEANS OF EGRESS AND INTERNAL MOVEMENT, D.V.Isaacs (CEBS), January 1969.

10. ISCUBR RD 47 - THE AUSTRALIAN MODEL UNIFORM BUILDING CODE - SERIES 1 REVISED TO 1970, undated but, although the revision was "to 1970", the number 47 would suggest 1972.

11. ISCUBR RD 49 - LOCATION AND PROTECTION OF OPENINGS, Prepared by "the initiating panel of ISCUBR", undated but apparently early 1970.

12. ISCUBR RD 53 - THE AUSTRALIAN MODEL UNIFORM BUILDING CODE - SERIES 2, 1970.

13. CEBS BULLETIN No 9 - FIRE PROTECTION IN BUILDINGS, J.W.Drysdale, October 1965.

14. CSIRO DBCE TR91/1 - FIRE PROTECTION IN BUILDINGS, J.J.Keough, 1991, a revision of CEBS Bulletin No. 9.

15. KEOUGH CONSULTANTS - REPORT ON A RESEARCH PROJECT - Reviewing the Australian Model Uniform Building Code as to its regulation of fire resistance of elements of construction in terms of structural adequacy,

integrity and insulation in terms of AS 1530, Part 4 - 1985, J.J.Keough, undated but evidently 1986.

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18. BUILDING CONTROL IN VICTORIA, Nassau and Hendry, Second Edition, 7 July 1994.

19. AUBRCC RD 192 - DELETION OF FIRE ZONES - Proposed Amendments to the UBC based on the Report of AUBRCC Fire Committee No 1 and developed by the Editorial Committee, July, 1986.

20. AUBRCC RD 226 - FIRE-RESISTANCE LEVELS - Proposed Amendments to the UBC based on the Report of Keough Consultants, July, 1986.

21. AUBRCC RD 271 (AF 199) - TYPES OF CONSTRUCTION - BCA PART C3, Chairman, AUBRCC Fire Committee, January, 1988.

APPENDIX A2.1

DEFINITIONS OF BUILDINGS OF CLASS IX (AMUBC) AND CLASS 9 (BCA)

The AMUBC defines class-IX buildings as follows:

"**Class IX:** Buildings of a public nature comprising -

(i) *Institutional buildings* as defined in clause 1.3 being of Class IXa; and

(ii) *schools* and other *assembly buildings* as defined in clause 1.3 being of Class IXb,

but excluding *portions* of such buildings that are of Class III or used as labaratories."

and defines institutional, school and assembly buildings as below:

" **'Institutional building'** means a building designed, *constructed*, or adapted as a clinic, convalescent home, hospital, infirmary, nursing home, sanatorium, asylum, pre-school centre, home or institute for orphans, poor, aged, sick, or physically or mentally handicapped persons, or similar institution.

" **'school'** includes a university, agricultural college, teachers' training college, school of mines, theological college, or similar establishment designed, *constructed,* or adapted for tertiary education;

" **'assembly building'** means a building designed, *constructed*, or adapted for the assembly of persons for -

(a) civic, political, educational, transit, religious, social, or recreational purposes; or

(b) entertainment or amusement; or

(c) the consumption of food or drink."

BCA defines class-9 buildings as follows:

"**Class 9:** a building of a public nature -

(a) **Class 9a** - a *health-care building;* including those parts of the building set aside as a laboratory; or

(b) **Class 9b** - an *assembly building,* including a trade workshop, laboratory or the like in a primary or secondary *school* but excluding any other parts of the building that are of another Class."

and defines health-care, assembly and school buildings as below:

> **"Health-care building means** a building whose occupants or patients undergoing medical treatment generally need physical assistance to evacuate the building during an emergency and includes -
>
> (a) a public or private hospital; or
>
> (b) a nursing home or similar facility for sick or disabled persons needing full-time nursing care; or
>
> (c) a clinic, day surgery or procedure unit where the effects of the predominant treatment administered involves patients becoming non-ambulatory and requiring supervised medical care on the premises for some time after the treatment.
>
> **"Assembly building means** a building where people may assemble for -
>
> (a) civic, theatrical, social, political or religious purposes;
>
> (b) educational purposes in a *school, early childhood centre,* pre*school*, or the like;
>
> (c) entertainment, recreational or sporting purposes; or
>
> (d) transit purposes.
>
> **"School** includes a primary or secondary *school* college, university or similar educational establishment."

APPENDIX A2.2

BCA CLAUSES THAT GOVERN OPENINGS IN FIRE-RATED CONSTRUCTION

The clauses of the BCA that deal with openings in compartment boundaries and their fire-protection are listed together with, where appropriate, comment and the clause numbers of their AMUBC predecessors. They can be subdivided according to function as follows (some clauses are directed at more than one function):

Application Clauses

C2.1 Application	Application of C2 on Compartmentation and Separation. Buildings of class 1 and class 10 are excluded. Other exclusions are not relevant to the protection of openings.	
C3.1 Application of Part	Application of C3 on Protection of Openings. Exclusions are Class-1 and class-10 buildings; 'Small' control joints and weep holes in external walls of masonry; 'Small' construction joints in external walls of pre-cast concrete panels; Non-combustible subfloor and cavity ventilators of specific size and spacing	
D1.1 Application	Application of D1 on Provision for Escape. Exclusions are Class-1 and class-10 buildings; The internal parts of a sole-occupancy unit in a building of class 2 or class 3.	

Lateral Fire Compartmentation

C2.7(b) Separation by fire walls	Openings to comply with Part C3 if parts are to be treated as separate buildings	23.1(7)

C2.10(c) Separation of lift shafts	Openings for lift-landing doors and services to be protected according to Part C3.	23.5(1)(b)
C2.12(d)(ii) Separation of equipment	Doors in separating construction (120/120/120) to be self-closing and -/120/30 or more.	New subclause.
C2.13(d)(ii) Electricity supply system - electricity substations	Doors in separating construction (120/120/120) to be self-closing and -/120/30 or more.	New subclause.
C2.13(e)(ii) Electricity supply system - main switchboard (which supports emergency equipment)	Doors in separating construction (120/120/120) to be self-closing and -/120/30 or more.	New subclause.
C3.4 Acceptable methods of protection	Called up in C3.2, C3.3, C3.8(b), D1.7(c)(ii)(B). Prescriptive but invokes Spec. C3.4.	22.4(2)
C3.5 Doorways in fire walls - "which are not part of a horizontal exit"	Limits on proportional area and requirements for FRL	22.6
C3.6 Sliding fire doors	Automatic closure and warning.	New.
C3.7 Protection of doorways in horizontal exits	cf C3.5	New
C3.8 Openings in fire-isolated exits	Requirements for doorways (internal) and windows (external).	22.7
C3.9 Service penetrations in fire-isolated exits	Electricity to lighting, intercommunication systems and pressurisation systems, water supply to fire-fighting services, ducting for	New

	pressurisation systems. Minimisation of penetrations.	
C3.10 Openings in fire-isolated lift shafts	Doorways to a fire-isolated lift shaft and lift-indicator panels only.	22.8
C3.11 Bounding construction: Class 2, 3 and 4 buildings	Doorways in class 2 or 3 from SOU to anywhere Doorways in class 2 or 3 from other than a SOU to exitway Doorways from class 4 to another part of the building Protection required for the doorway in type-A and type-B construction Other openings Detection, warning and automatic closure; not compartmentation Egress across an open balcony exposed to	22.9 & 22.10 in part.
C3.11 continued	doors or windows; not compartmentation.	
C3.14 Openings for service installations	This is the general requirement for fire-stopping of service penetrations through internal construction required to have an FRL - cf C3.12/C2.5(b)(iv)(B).	22.13
C3.15 Openings for service installations	Installations deemed to satisfy C3.14.	22.13
C3.16 Construction joints	A requirement to maintain the fire-resistance - cf C3.1 and note the implied requirement for testing.	New
D1.7 Travel via fire-isolated exits	Does have implications for compartmentation.	New
D1.8 External stairways		24.11
D2.2 Fire-isolated stairways and ramps	Internal construction to be non-combustible and non-damaging.	16.13(1)

D2.7 Installations in exits and paths of travel	Subclause (d) is probably the most relevant; very nominal fire-compartmentation with emphasis on smoke enclosure (which would prevent it reaching detectors).	24.17 & 24.18
D2.8(b)(ii) Enclosure of space under stairs and ramps	Nominal compartmentation?	24.19(2)(b)
D2.11 Fire-isolated passageways	Enclosing construction - not 'openings' but evidence of nominal fire-compartmentation.	24.9 & 24.10

Floor-to-floor Fire Compartmentation

C2.10(c) Separation of lift shafts	Openings for lift-landing doors and services to be protected according to Part C3.	23.5(1)(b)
C3.9 Service penetrations in fire-isolated exits	Electricity to lighting, intercommunication systems and pressurisation systems, water supply to fire-fighting services, ducting for pressurisation systems.	New. Minimisation of penetrations.
C3.10 Openings in fire-isolated lift shafts	Doorways to a fire-isolated lift shaft and lift-indicator panels only.	22.8
C3.12 Openings in floors for services	Type-A construction - in shafts or compliance with C3.14.	22.11
C3.13 Openings in shafts - type-A construction	Protection of openings in service shafts	22.12
C3.14 Openings for service installations	This is the general requirement for fire-stopping of service penetrations through internal construction required to have an FRL - cf C3.12/C2.5(b)(iv)(B).	22.13 in part

C3.15 Openings for service installations	Installations deemed to satisfy C3.14.	22.13 in part
C3.16 Construction joints	A requirement to maintain the fire-resistance - cf C3.1 and note the implied requirement for testing.	New
C3.17 Columns protected with lightweight construction to achieve an FRL	Note the restriction to lightweight construction (and columns) - due to its ancestry.	20.9(3)
D1.3 When fire-isolated exits are required -	Connection of storeys by non-fire-isolated exits in 2s & 3s and 5s to 9s with and without sprinklers. Special mentions of 9a's and open spectator stands.	24.36,24.37 & 24.45 but not class 9s
D1.7 Travel via fire-isolated exits	Does have implications for compartmentation.	24.8, 24.14 in part
D1.8 External stairways		24.11
D1.12 Non-required stairways, ramps and escalators	Connection of storeys - cf D1.3. Spec. D1.12 has stringent requirements if connection of storeys is to be unlimited.	24.12 but not class 9s
D2.2 Fire-isolated stairways and ramps	Internal construction to be non-combustible and non-damaging.	16.13(1)
D2.7 Installations in exits and paths of travel	See notes under lateral fire-compartmentation.	24.17, 24.18
D2.8(b)(ii) Enclosure of space under stairs and ramps	Nominal compartmentation?	24.19(2)(b)

Floor-to-floor External-wall Fire Compartmentation

C2.6 Vertical separation of openings in external walls in type-A construction	Spandrels etc.	22.3
C2.7(d)(ii) Separation by fire walls	Openings in the lower roof to be 3 m or more from the upper wall if parts are to be treated as separate buildings.	23.1(4)(c)(ii)
C3.2(b) Protection of openings in external walls	Upper limits on requirement for protection.	22.4

Exposure Control

C3.2(a) Protection of openings in external walls	Lower limit on distance from fire-source feature.	New
C3.2(b) Protection of openings in external walls	Upper limits on requirement for protection.	22.4
C3.2(c) Protection of openings in external walls	Limit on proportional area.	22.5

Lateral Smoke Compartmentation

C2.5(b)(iii) (C) Class 9a buildings		New
C2.5(b)(iii) (D) Class 9a buildings		New
C2.5(b)(iii) (E) Class 9a buildings		New
C2.5(b)(v) Class 9a buildings		New
D2.6 Smoke lobbies		Not found

D2.7 Installations in exits and paths of travel	See notes under lateral fire-compartmentation.	24.17, 24.18
D2.8(b)(ii) Enclosure of space under stairs and ramps		24.19(2)(b)
D2.11 Fire-isolated passageways.	See notes under lateral fire-compartmentation.	24.9, 24.10

Floor-to-floor Smoke Compartmentation

C2.5(b)(iii) (E) Class 9a buildings		New
D1.12 Non-required stairways, ramps and escalators		24.12 but not class 9s
D2.7 Installations in exits and paths of travel.	See notes under lateral fire-compartmentation.	24.17, 24.18
D2.8(b)(ii) Enclosure of space under stairs and ramps		24.19(2)(b)

Escape

The following clauses, although referring to openings, appear to be primarily intended to ensure speed, efficiency and/or safety of evacuation.

C2.5(b)(v) Class 9a buildings	Smoke control rather than compartmentation	New
D1.2 Number of exits required		24.31, 24.41 but not class 9s
D1.5 Distance between alternative exits		24.33, 24.35, 24.43 but not class 9s
D2.5 Open access ramps and balconies	Smoke control rather than compartmentation	55.8(4)

APPENDIX A2.3

STRUCTURAL FIRE PROTECTION IN THE AMUBC AND THE BCA

A Change of Approach

The supersession of the AMUBC by the BCA was accompanied by a radical change in the approach of the regulators to structural fire-protection. Regulation Document 4[2] shows a very clear appreciation of the capabilities of the various types of construction of which only type-1 was expected to survive the burn-out of the contents. For example, type-3 - "externally protected construction" was just that. It was protected from fire from outside. There was no suggestion of confining a 'protracted' fire within the building. Once the floors burnt out the collapse of the walls was likely and the ruin would become an unconfined fire-source feature. In the discussion of fire-zoning (Regulation Document 15[4]), types of construction 4 and 5 were out because "the fire-resistance called for is only elementary". Only fully externally-protected construction was to be adopted and even so, in a primary fire zone, type-3 construction was to be confined to single-storey buildings because "a three-storey building of Type-3 construction, once on fire, is likely to have three storeys burning and radiating strongly towards nearby buildings and finally collapsing to form a concentration of burning material." The only suggestion that the external walls might have a role in protecting adjacent property from radiation (although they might do so incidentally during a "short-lived" fire) was in one of the Victorian proposals mentioned on page 4 and in somewhat more detail on page 25. A large, single storey building of type-3 construction not isolated from its boundaries but exempted from the more stringent floor-area restrictions by virtue of draught curtains and roof-venting was to have parapets and the areas of openings in the external walls of such buildings were restricted. (These controls on the building as a potential fire-source feature were adopted into the AMUBC with some modification as to floor area, type of construction and isolation). Otherwise, at least until 1970, the danger of radiation was discussed only as radiation *from* outside *onto* contents. Note that the second priority of item 5 of Regulation Document 4[2] is the protection of a building *from* the effects of fire in adjacent properties.

The Keough Report

The Keough report[15] reproduced Table B3 of Appendix B of AS 1480 - 1974 as follows:

Class II and Class III	$1^1/_2$ hour
Class V	2 hour
Class VI	3 hour

Class VII	4 hour
Class VIIIa	3 hour
Class VIIIb	4 hour
Class IX	2 hour

These ratings indicated "the fire resistance required of structural members if they were to survive an *uncontrolled* fire". Keough goes on to say: "Experience with actual building fires has shown that structures having those levels of fire resistance do not suffer collapse in fires. Indeed experience in Great Britain has been that 1 hour is adequate for Class II and more recently that $1^1/_2$ hour is adequate for Class V".

The conclusions drawn from this experience could be questioned. The fire-resistances required of external walls by the AMUBC combined with limitations on height-in-storeys (even outside fire-zones) must have given them a degree of robustness they might not otherwise have had. In addition, fires are almost invariably attended by the fire-fighting services and extinguished or at least brought under control. These would explain why such statistics as we have might indicate a capacity among buildings that were not 'fully protected' to survive and promote the change in the regulators' expectations. As against this, there is a history of the collapse of factory walling - lateral support tends to be significantly less than in other buildings - but then the BCA requirements for factories are at the top end of the scale anyway. This is an issue that would bear a re-examination from a structural point of view.

The other question that needs to be put is whether there were buildings designed to the ratings listed in AS 1480 - 1974 that were subjected to "uncontrolled" fires or whether the ratings arise from fire-load surveys in buildings designed to the older requirements and therefore so robust that they were able to survive burn-out of the contents. This is not to say that a building should be designed for other than its own fire load. It is a question of the limitation on the height of buildings with unrated (even combustible) floors and design for exposure control.

If a building will not collapse even when a fire is uncontrolled, then the danger it presents as a fire-source feature is, for practical purposes, limited to flames issuing from openings. The 'severity' of the fire is a matter of duration not temperature and the latter is reduced by the entrainment of cool air and by distance. Keough therefore goes on to argue that exposure control should require no more of external walls than does a building's own fire load. He also questions whether a tall class-II or class-III building should, or would, be allowed to be built against a class-VII building of type-4 or type-5 construction.

The manner in which these recommendations were taken up by AUBRCC and the correspondence between AUBRCC and Keough as they were developed raises the question as to whether the building with whose external walls the regulations are concerned is the fire-source feature and is to be controlled by regulation of its external walls.

The following AUBRCC proposals for progressive reductions in the integrity and insulation levels of the external walls of buildings of classes 2, 3 and 4 in type-A construction are typical:

Distance from a Fire-source feature	**Fire-resistance levels for structural stability, integrity and insulation**	
	RD 226	**BCA (unamended)**
For loadbearing parts -		
Less than 1.2 m	90/90/90	
1.2 to less than 4.5 m	90/60/60	
4.5 m or more	90/60/30	
Less than 1.5 m		90/90/90
1.5 to less than 3 m		90/60/60
3 m or more		90/60/30
For non-loadbearing parts -		
Less than 1.2 m	90/90/90	
1.2 to less than 3.0 m	-/-/-	
Less than 1.5 m		90/90/90
1.5 to less than 3 m		90/60/60
3 m or more		-/-/-

The argument could have been after this style. With a fire in a building, the danger to other buildings is increased if the external walls collapse - the debris would become an unconfined fire-source feature. Hence the logic of conservative levels for structural adequacy. Failures in integrity or insulation, on the other hand, don't prejudice the fate of the burning building itself. In fact, the closer the temperature of the outer surface is to that of the inner surface, the more uniform will be the thermal gradient through the wall and its thermal curvature is reduced. The wall is stabilised. And although the radiation from the hotter outer surface will be greater, its effect will be reduced by distance. Hence the logic of FRLs that reduce from 90/90/90 at separations of 1.2 m to 90/60/30 at separations of 4.5 m or more.

In Keough's comments on AUBRCC's proposals there are two that indicate he is regarding the building being designed as the fire-source feature. First, in trying to correct AUBRCC's differentiation between loadbearing and non-loadbearing walls (in the FRLs for exposure control) Keough writes as follows: "As far as fire damage from building to building or from storey to storey by flame impingement or radiant heat is concerned the element being damaged cannot distinguish whether or not the ***source*** [my italics - Editor] is a loadbearing element. Accordingly, the requirements for integrity and insulation of exterior walls should be the same for both loadbearing and non-loadbearing walls." He later goes on to say: "I have reworked the treatment of exterior walls to what used to be the basic AUBRCC philosophy and have suggested a considerable reduction at setbacks where ***other*** [my italics - Editor] buildings are obviously safe."

Regulation Document No. 24

In fact, the change had been made explicit in 1970 in Regulation Document No. 49 [11]. The original position had been made clear in Regulation Document No. 24 [5]:

> "The fire-spread hazard [in later parlance "exposure to a fire-source feature" - Editor] mentioned in the opening phrases of clause 802 is one due to heat radiation supplemented, in some cases, by possible flame contact. The heat radiation may come from a fire in another building, or, in some cases, it may come (along with the flame) from another part of the building which has the opening."

And Regulation Document No. 42 [8] of September 1968 says

> "The proposed uses of fire shutters will be governed by what is later drafted for Part 22, Location and Protection of Openings, but it is worth noting that ..... for a shutter-protected opening in an external wall, a single shutter mounted on the inside of the wall may be considered in order on walls required to have fire-resistance ratings of up to 3 hours". ("Inside" because the fire was on the outside - Editor).

In contrast, Regulation Document No. 49 [11], prepared by "the initiating panel of ISCUBR" and undated but apparently early 1970, states

> "The purpose of protecting openings in external walls is to limit the spread of fire by radiation to adjoining premises. The effect of community fire-spread in fire zones is such that openings close to boundaries etc., should be protected in certain circumstances."

and

"One hour fire windows, which are usually wired glass will not significantly affect the degree of fire radiation through the glazed area and their main function is to prevent the flames from a fire within a building from breaking out within the specified period and thereby increasing the intensity of the radiation.

"The purpose of clause 22.5 is to limit the extent of openings and the amount of radiated heat passing through them."

Bulletin No 9 and Technical Record 91/1

The first two editions of Bulletin 9 [13], which has always been an exposition of the Australian regulators' approach to the fire-protection of buildings, discuss exposure hazard in the following terms:

"A building that abuts the boundaries of its site may be subjected at different times to fires of two severities. An internal fire may attain the severity characteristics of the class of occupancy that is housed. Construction of the external wall of the building may alternatively be subjected to fire of a severity approaching that possible in the adjoining class of occupancy. Either of the potential fires may dictate what fire resistance the construction must have to withstand both contingencies.

"Different classes of occupancy are not segregated within built-up areas. The exposure hazard between buildings can therefore range from low to high, depending on the distribution of occupancies in the community. It is too complex, administratively, to give individual attention to the fire hazard between pairs of buildings. Where external walls abut common boundaries, their construction is required to resist the normal maximum level of fire severity".

Despite the vagueness of the last phrase, the implication seems clear; that, at least for types 1, 2 and 3, you construct the external walls to resist either an internal fire or impingement and radiation from an adjacent building of high fire-load whichever demands the greater fire-resistance. Bulletin 9 then goes on to point out that the severity of the exposure diminishes as the distance between buildings increases. The fire-resistance levels of Regulation Document 1 [1] and the AMUBC indicate that the cross-over point from design for external exposure to design for an internal fire was considered to be at 20 ft (6 m). At this point the requirements for external walls equate with those for fire-walls. (There are departures from these two principles in Regulation Document 1 [1]. See Section 5).

In contrast, the 1991 revision of Bulletin 9 (Technical Record 91/1 [14]) saw the danger from a burning building in terms of impingement and radiation from window and door openings. In its discussion of exposure hazard, Technical Record 91/1 states:

"A feature of postwar building regulations was a requirement of buildings to have a high level of fire resistance for their exterior walls. Because of wartime experience with the spread of uncontrolled fires from building to building and the fact that neighbouring buildings can house very different fire loads it was presumed that all buildings should have external walls capable of withstanding the potential severity of a fire in a neighbouring building. Experience has shown that this was not justified and is unduly costly.

"Provided that the external walls of a building have a fire resistance sufficient to survive the burn-out of the contents, the mechanism of the heat transfer to a neighbour will be by radiation from openings in the exterior walls and from plumes of flames issuing from those openings. Studies of radiation exposure hazards have established that provided the area of openings and their proximities to neighbouring buildings are controlled, both the radiation and the convective heating from the plumes of flames can be maintained within acceptable limits. It is now recognized that, provided openings are regulated, the exterior walls of buildings need only have a fire resistance related to their individual fire loads."

These statements were not qualified in terms of type of construction and there is the unstated assumption that "a fire resistance related to their individual fire loads" is sufficient to ensure that the walls survive "the burn-out of the contents", i.e. will not collapse.

APPENDIX A2.4

FRLs FOR EXPOSURE CONTROL AND EXTERNAL COMPARTMENTATION

The proximities to the fire-source feature in terms of which the various versions of the regulations specified exposure control are set out in Table 6. Because of the differences between RD 1, the AMUBC and the BCA, not all rows in Tables 7 and 8 can be filled in for all three documents.

TABLE 6 - PROXIMITIES TO THE FIRE-SOURCE FEATURE

RD 1 1965	RD 30 - RD 47 1967(?) - 1972(?)	AMUBC 1989	BCA 1990
Type 1/Type A Construction - Loadbearing			
			Less than 1.5 m
			1.5 to less than 3 m
			3 m and more
Less than 4.5 m	Less than 4.5 m	Less than 4.5 m	
4.5 to less than 6 m	4.5 to less than 6 m	4.5 to less than 6 m	
6 m and more	6 m and more	6 m and more	
Type 1/Type A Construction - Non-loadbearing			
			Less than 1.5 m
			1.5 to less than 3 m
			3 m and more
Less than 4.5 m	Less than 4.5 m	Less than 4.5 m	
4.5 to less than 6 m	4.5 to less than 6 m	4.5 to less than 6 m	
6 m and more	6 to less than 7.5 m	6 to less than 7.5 m	
	7.5 to less than 9 m	7.5 to less than 9 m	
	9 m and more	9 m and more	

Type 3/Type B Construction - Loadbearing			
			Less than 1.5 m
			1.5 to less than 3 m
			3 to less than 9 m
			9 to less than 18 m
			18 m and more
Less than 4.5 m	Less than 4.5 m	Less than 4.5 m	
4.5 to less than 6 m	4.5 to less than 6 m	4.5 to less than 6 m	
6 m and more	6 m and more	6 m and more	
Type 3/Type B Construction - Non-loadbearing			
			Less than 1.5 m
			1.5 to less than 3 m
			3 m and more
Less than 4.5 m	Less than 4.5 m	Less than 4.5 m	
4.5 to less than 6 m	4.5 to less than 6 m	4.5 to less than 6 m	
6 m and more	6 to less than 7.5 m	6 to less than 7.5 m	
	7.5 to less than 9 m	7.5 to less than 9 m	
	9 m and more	9 m and more	

TABLE 7 - FRLs for Exposure Control and External (Storey-to-storey) Compartmentation

TYPE 1 / TYPE A CONSTRUCTION - RD 1, AMUBC and the BCA

Building Element	II / 2	III / 3	V / 5	VI / 6	VII / 7	VIIIb / 8	IX / 9
External Walls Loadbearing							RD 1 did not include class-IXs.
less than 1.5 m	3/3/90	3/3/90	3/3/120	3/3/180	4/4/240	4/4/240	-/3/120
1.5 to < 3 m	3/3/90	3/3/90	3/3/120	3/3/180	4/4/240	4/4/240	-/3/120
3 m and more	90	90	120	180	240	240	120
less than 4.5 m	3/3	3/3	3/3	3/3	4/4	4/4	-/3
4.5 m to < 6 m	2/2/90	2/2/90	2/2/120	3/3/180	4/4/240	4/4/240	-/2/120
6 m and more	1½/1½/90	1½/1½/90	2/2/120	3/3/180	4/4/240	4/4/240	-/2/120
External Walls Non-loadbearing	RD 1 did not distinguish						

less than 1.5 m	3/3/90	3/3/90	3/3/120	3/3/180	4/4/240	4/4/240	-/3/120
1.5 to < 3 m	3/3/60	3/3/60	3/3/90	3/3/180	4/4/240	4/4/240	-/3/90
3 m and more	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)
less than 4.5 m	3/3	3/3	3/3	3/3	4/4	4/4	-/3
4.5 m to < 6 m	2/2/0	2/2/0	2/2/0	3/3/0	4/4/0	4/4/0	-/2/0
6 m to < 7.5 m	1½ /1½ /0	1 ½ /1½/0	2/2/0	3/3/0	4/4/0	4/4/0	-/2/0
7.5 m to < 9 m	1½ /1 /0	1½ /1/0	2/1½/0	3/2/0	4/3/0	4/3/0	-/1½/0
9 m and more	1½ /1 /0	1½ /1/0	2/1/0	3/1½/0	4/2/0	4/2/0	-/1/0

Fire Walls	1½ /1½ /90	2/1½ /90	2/2/120	3/3/180	4/4/240	4/4/240	-/2/90

The BCA FRLs for loadbearing walls are for ‘structural adequacy’ and for non-loadbearing walls are for ‘integrity’.

RD 1 and AMUBC ratings are in hours, BCA ratings are in minutes.

TABLE 8 - FRLs for Exposure Control and External (Storey-to-storey) Compartmentation

TYPE 3 / TYPE B CONSTRUCTION - RD 1, AMUBC and the BCA

Building Element	II / 2	III / 3	V / 5	VI / 6	VII / 7	VIIIb / 8	IX / 9
External Walls Loadbearing	RD 1 did not provide for class-IIs in Type 3 construction						RD 1 did not include class-IXs.
less than 1.5 m	-/3/90	3/3/90	3/3/120	3/3/180	4/4/240	4/4/240	-/3/120
1.5 m to < 3 m	-/3/90	3/3/90	3/3/120	3/3/180	4/4/240	4/4/240	-/3/120
3 m to < 9 m	90	90	120	180	240	240	120
less than 4.5 m	-/3	3/3	3/3	3/3	4/4	4/4	-/3
4.5 m to < 6 m	-/2/90	2/2/90	2/2/120	3/3/180	4/4/240	4/4/240	-/2/120
6 m and more	-/1½	1½/1½	2/2	3/3	4/4	4/4	-/2
9 m to < 18 m	-/1½/90	1½/1½/90	2/2/120	3/3/180	4/4/240	4/4/240	-/2/120
18 m and more	-/1½/0	1½/1½/0	2/2/0	3/3/0	4/4/0	4/4/0	-/2/0
External Walls Non-loadbearing		RD 1 did not distinguish					

less than 1.5 m	-/3/90	*3*/3/90	*3*/3/120	*3*/3/180	*4*/4/240	*4*/4/240	-/3/120
1.5 to < 3 m	-/3/60	*3*/3/60	*3*/3/90	*3*/3/120	*4*/4/180	*4*/4/180	-/3/90
3 m and more	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)	0 (BCA)
less than 4.5 m	*3*/3	*3*/3	*3*/3	*3*/3	*4*/4	*4*/4	-/3
4.5 m to < 6 m	-/2/0	*2*/2/0	*2*/2/0	*3*/3/0	*4*/4/0	*4*/4/0	-/2/0
6 m to < 7.5 m	-/1½/0	*1½*/1½/0	*2*/2/0	*3*/3/0	*4*/4/0	*4*/4/0	-/2/0
7.5 m to < 9 m	-/1 /0	*1½*/1 /0	*2*/1 /0	*3*/1½/0	*4*/2/0	*4*/2/0	-/1/0
9 m and more	-/ ½/0	*1½*/ ½/0	*2*/ ½/0	*3*/1/0	*4*/1/0	*4*/*1*/0	-/ ½/0

Fire Walls	-/1½/90	*1½*/1½/90	*2*/2/120	*3*/3/180	*4*/4/240	*4*/4/240	-/2/120

The BCA FRLs for loadbearing walls are for 'structural adequacy' and for non-loadbearing walls are for 'integrity'.

RD 1 and AMUBC ratings are in hours, BCA ratings are in minutes. [Table6.doc]

3. CURRENT REQUIREMENTS

3.1 FRL REQUIREMENTS IN THE BCA

3.1.1 Fire Resistance Levels

Current requirements for fire resistance are expressed in terms of Fire Resistance Levels (FRLs) in the Building Code of Australia (BCA). Each FRL is a grading period in minutes and has three parts relating to structural adequacy, integrity and insulation of the building element when subjected to the standard fire resistance test. Details of the test are given in Specification A2.3 of the BCA.

3.1.2 Types of Construction

Fire resistance requirements are, to a large extent, dependent upon the "Type of construction" required for the building. In the BCA three "Types of construction" are specified, with Type A as the most fire-resisting and Type C as the least. Type of construction is first determined by building use ("building class" in BCA terms) and rise in storeys (note that rise in storeys is defined in the BCA), and next by floor area or volume of fire compartments.

3.1.3 Fire Compartments

Fire compartments are defined as:

a) the total space of a building; or
b) any part thereof separated from the remainder by walls and/or floors each having an *FRL* not less than that *required* for a *fire wall* for that type of construction and where all openings in the separating construction are protected in accordance with the relevant Part.

Since fire walls are required to have the highest FRL of any element within a building, it can be assumed that they will only be built where necessary to meet the floor area or volume limits of the BCA.

3.1.4 FRLs in Specification C1.1

Fire Resistance Levels for most building elements are listed under Types of construction in Specification C1.1. Certain classes of building have the same FRL requirements, and these are grouped together in the tables. The groups are:

Class 2, 3 and 4 (residential buildings);
Class 5 and 9 (offices, public assembly buildings and health-care buildings);
Class 6 (shops); and
Class 7 and 8 (carparks, warehouses and factories).
Open deck carparks and those with sprinklers have a separate table.

Details of building classifications are given in BCA Part A3.

3.1.5 Concessions

In addition to the requirements listed in the tables, there are a number of concessions and special requirements. Concessions are granted for a variety of reasons, sometimes related to the class of building and sometimes related to the nature of the construction, and can be found throughout the sections of the BCA that relate to design for fire safety. Special requirements apply to specialised construction, such as tilt-up panels, atriums and proscenium walls in theatres. Again, these are scattered throughout the requirements for design for fire safety.

3.2 FIRE CODE REFORM PROJECT 1

3.2.1 Regrouping BCA Requirements

Fire Code Reform Project 1 regrouped the BCA requirements for particular buildings in terms of levels of performance of building system elements. Fire resistance levels were considered to be part of one of five system elements, namely:

Structure;
Smoke compartmentation;
Flame compartmentation;
Flame and smoke compartmentation; and
Exposure control.

FRLs (including concessions), extent of construction, protection of openings and all the attributes required of each building element were grouped together in terms of levels of performance of the relevant system element. The regrouping allows the researchers to study all the prescriptive requirements which together achieve the required system element performance.

3.2.2 Levels of Performance and Performance Descriptors

The aim of Project 1 was to assign levels of performance to the existing requirements, and to find ways to describe the performance required by these levels. During the course of the project, a detailed study was made of FRL requirements for the system elements listed above. FRLs for structural adequacy were considered to provide the acceptable solutions for the structural system elements, while those for integrity and insulation provided solutions for the compartmentation system elements. Exposure control was considered to be a function of both structure and compartmentation. Within the restraints of the project (time and budget) it was found to be almost impossible to assign levels of performance based on the FRLs. In the end the researchers resorted to the existing groupings, and Types of construction were taken as primary levels. Attempts were made to specify the intent of each Type of construction. Although the original intents had been clearly specified, technical changes have muddied the waters and the intent is no longer clear. An appreciation of the original intent can be gleaned from the historical review given in Chapter 2.

In most cases special requirements were regarded as forming separate levels of performance. These include support of external walls in a building with concrete external walls that could collapse as complete panels, atriums, the stage area of a theatre and patient care areas in health care buildings.

The levels of performance and their associated acceptable solutions are given in the FCRC report on Project 1, BCA Fire Provisions Restructured.

3.2.3 Fire Resistance Levels for Specific Building Elements

The rearrangement of requirements achieved in Project 1 can be further refined. It is possible to present all the current BCA attributes required to ensure that elements perform as barriers or supports in the form of a series of tables. Entries in the tables correspond to the required performance of each system element. The left-hand column is a list of all building elements required to have an FRL (including special construction and elements that are subject to concessions), while subsequent columns contain requirements for each unique set of buildings. For any building the requirements for any element can then be found with ease.

The tabulation has been completed for flame and smoke compartmentation for all buildings of Type A construction, and the resulting table is given in Appendix A3.1. Fire resistance levels for integrity and insulation are shown within the table. Additional BCA requirements are shown as a number, which corresponds to the list following the table. Note that elements related to exposure control are not included.

The table is extensive but it presents a comprehensive picture of FRLs for analysis and draws attention to the (sometimes unnecessary) complexities of current requirements. It was not considered necessary to complete the tabulation exercise for each level of each system element for this project, as the required information is available, in a less easily accessible form, in the acceptable solutions derived for Project 1.

Tabulation of BCA Requirements for Internal Compartmentation for Buildings of Type A Construction

Building description / **Building element**	**class 9a pat'nt care <25m <4st'y**	**class 9a pat'nt care <25m >3st'y**	**class 9a pat'nt care >25m**	**class 9a not pat'nt care <25m <4st'y**	**class 9a not pat'nt care <25m >3st'y**	**class 9a not pat'nt care >25m**	**class 9b no sub-class <25m <4st'y**	**class 9b no sub-class <25m >3st'y**	**class 9b no sub-class >25m**	**class 9b th'tre <25m <4st'y**	**class 9b th'tre <25m >3st'y**	**class 9b th'tre >25m**	**class 9b indoor sports <25m <4st'y**	**class 9b indoor sports <25m >3st'y**	**class 9b indoor sports >25m**	**class 9b open spec'r stand**	**class 9b school or e c <25m <4st'y**	**class 9b school or e. c <25m >3st'y**	**Class 9b school or e. c >25m**
COMMON WALLS AND FIRE WALLS																			
FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*1,2,3,4,5, 18,39*	*1,2,3,4,5, 18,39*	*1,2,3,4,5, 18,39*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*
INTERNAL WALLS																			
Fire-resisting lift and stair shafts																			
FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*6,7,8,25*	*6,7,8,25*	*6,7,8,25*	*6,7,8,25*	*6,7,8,25*	*6,7,8,25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*
Bounding public corridors, public hallways and the like - loadbearing																			
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*
Bounding public corridors, public hallways and the like - non-loadbearing																			
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*
Between or bounding sole-occupancy units - loadbearing																			
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*

Between or bounding sole-occupancy units-non-loadbearing																			
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*
Ventilating, pipe, garbage, and like shafts not used for the discharge of hot products of combustion																			
FRL:	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90
Requirements:	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*
bounding an atrium																			
FRL:	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Requirements:	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*
in the storey immediately below the roof, in buildings where the roof does not have an FRL and is non-combustible [see requirement 14]: loadbearing internal walls other than fire walls.																			
FRL:	-/-	60/60		-/-	60/60		-/-	60/60		-/-	60/60		-/-	60/60			-/-	60/60	
between a room not within a sole-occupancy unit and the landing of an internal non-fire-isolated stairway that serves as a required exit.																			
Requirement:																			
separating a room from circulation space																			
FRL:							60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60			
Requirement:							*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*			
dividing ward areas in health care buildings																			
Requirement:	*40*	*40*	*40*																

separating ancillary use areas from patient care areas: FRL:	60/60	60/60	60/60																
Requirement:	*41*	*41*	*41*																
proscenium wall separating a stage from an audience seating area FRL:										60/60	60/60	60/60							
Requirement:										*42*	*42*	*42*							
CONSTRUCTION separating equipment installed in or near a building FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*
FLOORS separating fire compartments FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*
within sole-occupancy units FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*
a) laid directly on the ground b) open access floors above a floor with the required FRL c) timber stage floors laid over a floor having the required FRL, where the space below the stage is not used as a dressing room, store room or the like FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:																			

Where the space below is not a storey, does not accommodate motor vehicles, is not a storage or work area and is not used for any other ancillary purpose																			
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Requirements:																			
above a floor designed for a live load not exceeding 3kPa																			
FRL:							90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90
Requirements:																			
Floor slab or vehicle ramp																			
FRL:																			
Requirement:																			
Floors in sanitary compartments																			
FRL:																			
Requirement:							*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*
Other																			
FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*
ROOFS																			
where the covering is non-combustible																			
FRL:	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30
Requirements:	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*
above a floor designed for a live load not exceeding 3kPa																			
FRL:							60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30
Requirements:																			
other																			
FRL:	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30
Requirements:	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*

FIRE-ISOLATED EXITS																			
Requirements:	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 38*	*15,16,17*	*15,16,17*	*15,16,17*
enclosing construction of a fire-isolated passageway:																			
a) if the passageway discharges from a fire-isolated stairway or ramp																			
FRL when tested for a fire outside the passageway:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*
b) in any other case																			
FRL when tested for a fire outside the passageway:	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60
Requirements:	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*
ESCALATORS, MOVING WALKWAYS AND NON-REQUIRED NON-FIRE-ISOLATED STAIRWAYS AND PEDESTRIAN RAMPS																			
Requirement:	*30*	*30*	*30*	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*27*	*27*	*27*	*27,38*	*31,32*	*31,32*	*31,32*

Building description Building element	class 2 <25m	class 2 >25m	class 3 <25m	class 3 >25m	class 4 part	class 5 <25m <4storey	class 5 <25m >3storey	class 5 >25m	class 6 <25m <4storey	class 6 <25m >3storey	class 6 >25m	class 7 - od or sp carpark <25m <4storey	class 7 - od or sp carpark <25m >3storey	class 7 - od or sp carpark >25m	class 7 other than od or sp carpark and class 8 <25m <4storey	class 7 other than carpark and class 8 <25m >3storey	class 7 other than carpark and class 8 >25m
COMMON WALLS AND FIRE WALLS																	
FRL:	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120	180/180	180/180	180/180	120/120	120/120	120/120	240/240	240/240	240/240
Requirements:	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*1,2,3,4,5, 18*	*19*	*19*	*19*	*1,2,3,4,5, 19*	*1,2,3,4,5, 19*	*1,2,3,4,5, 19*
INTERNAL WALLS																	
Fire-resisting lift and stair shafts																	
FRL:	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120
Requirements:	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*				*4,5,6,7,8, 25*	*4,5,6,7,8, 25*	*4,5,6,7,8, 25*
Bounding public corridors, public hallways and the like - loadbearing																	
FRL:	90/90	90/90	90/90	90/90	90/90	-/-	-/-	-/-	-/-	-/-	-/-				-/-	-/-	-/-
Requirements:	*4,5,22*	*4,5,22*	*4,5,22*	*4,5,22*	*4,5,22*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*				*4,5*	*4,5*	*4,5*
Bounding public corridors, public hallways and the like - non-loadbearing																	
FRL:	60/60	60/60	60/60	60/60	60/60	-/-	-/-	-/-	-/-	-/-	-/-				-/-	-/-	-/-
Requirements:	*4,5,22*	*4,5,22*	*4,5,22*	*4,5,22*	*4,5,22*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*				*4,5*	*4,5*	*4,5*
Between or bounding sole-occupancy units - loadbearing																	
FRL:	90/90	90/90	90/90	90/90	90/90	-/-	-/-	-/-	-/-	-/-	-/-				-/-	-/-	-/-
Requirements:	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21,37*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*				*4,5*	*4,5*	*4,5*

Between or bounding sole-occupancy units - non-loadbearing																	
FRL:	60/60	60/60	60/60	60/60	60/60	-/-	-/-	-/-	-/-	-/-	-/-				-/-	-/-	-/-
Requirements:	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21*	*4,5,9,10, 21,37*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*	*4,5*				*4,5*	*4,5*	*4,5*
Ventilating, pipe, garbage, and like shafts not used for the discharge of hot products of combustion																	
FRL:	90/90	90/90	90/90	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120				120/120	120/120	120/120
Requirements:	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*	*4,5,7*				*4,5,7*	*4,5,7*	*4,5,7*
bounding an atrium																	
FRL:	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Requirements:	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*	*43,44,45, 46,47*
in the storey immediately below that roof, in buildings where the roof does not have an FRL and is non-combustible [See requirement 14]: loadbearing internal walls other than fire walls.																	
FRL:	60/60		60/60			-/-	60/60		-/-	60/60		-/-	60/60		-/-	60/60	
between a room not within a sole-occupancy unit and the landing of an internal non-fire-isolated stairway that serves as a required exit.																	
Requirement:	*23*	*23*	*23*	*23*	*23*												
separating a room from circulation space																	
FRL:																	
Requirement:																	

CONSTRUCTION separating equipment installed in or near a building																	
FRL:	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120	120/120				120/120	120/120	120/120
Requirements:	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*	*11,12*				*11,12*	*11,12*	*11,12*
FLOORS separating fire compartments																	
FRL:	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120	180/180	180/180	180/180				240/240	240/240	240/240
Requirements:	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*				*13*	*13*	*13*
within sole-occupancy units																	
FRL:	-/-	-/-	-/-	-/-	-/-	120/120	120/120	120/120	180/180	180/180	180/180				240/240	240/240	240/240
Requirements:						*13*	*13*	*13*	*13*	*13*	*13*				*13*	*13*	*13*
a) laid directly on the ground b) open access floors above a floor with the required FRL c) timber stage floors laid over a floor having the required FRL, where the space below the stage is not used as a dressing room, store room or the like																	
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-				-/-	-/-	-/-
Requirements:																	
Where the space below is not a storey, does not accommodate motor vehicles, is not a storage or work area and is not used for any other ancillary purpose																	
FRL:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	180/180	180/180	180/180				240/240	240/240	240/240
Requirements:									*13*	*13*	*13*				*13*	*13*	*13*
above a floor designed for a live load not exceeding 3kPa																	
FRL:						90/90	90/90	90/90									
Requirements:																	

Floor slab or vehicle ramp FRL: *Requirement:*												60/60	60/60	60/60			
Floors in sanitary compartments FRL: *Requirement:*						*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*
Other FRL:	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120	180/180	180/180	180/180				240/240	240/240	240/240
Requirements:	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*				*13*	*13*	*13*
ROOFS where the covering is non-combustible FRL:	-/-	-/-	-/-	-/-	-/-	60/30	60/30	60/30	60/30	60/30	60/30				90/60	90/60	90/60
Requirements:	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*				*14*	*14*	*14*
above a floor designed for a live load not exceeding 3kPa FRL: *Requirements:*						60/30	60/30	60/30									
other FRL:	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30	60/30				90/60	90/60	90/60
Requirements:	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*	*14*				*14*	*14*	*14*
FIRE-ISOLATED EXITS *Requirements:*	*15,16,17, 34*	*15,16,17, 34*	*15,16,17, 35*	*15,16,17, 35*	*15,16,17*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*	*33*	*33*	*33*	*15,16,17, 33*	*15,16,17, 33*	*15,16,17, 33*
enclosing construction of a fire-isolated passageway: a) if the passageway discharges from a fire-isolated stairway or ramp FRL when tested for a fire outside the passageway:	90/90	90/90	90/90	90/90	90/90	120/120	120/120	120/120	120/120	120/120	120/120				120/120	120/120	120/120

Requirements:	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*				*15,16,17*	*15,16,17*	*15,16,17*
b) in any other case																	
FRL when tested for a fire outside the passageway:	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60	60/60/60				60/60/60	60/60/60	60/60/60
Requirements:	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*	*15,16,17*				*15,16,17*	*15,16,17*	*15,16,17*
ESCALATORS, MOVING WALKWAYS AND NON-REQUIRED NON-FIRE-ISOLATED STAIRWAYS AND PEDESTRIAN RAMPS																	
Requirement:	*31,32*	*31,32*	*31,32*	*31,32*	*31,32*	*28,29,31*	*28,29,31*	*28,29,31*	*28,29,31*	*28,29,31*	*28,29,31*	*24,27*	*24,27*	*24,27*	*31,32*	*31,32*	*31,32*

BCA REQUIREMENTS

1. Walls separating fire compartments or buildings

(a) An internal wall that is the boundary of a fire compartment must be a fire wall.

(b) A wall that separates two buildings must be a fire wall and:

(i) extend through all storeys and spaces in the nature of storeys that are common to that part and any adjoining part of the building; and

(ii) be carried through to the underside of the roof covering; and

(iii) have the relevant FRL for each of the adjoining parts, and if these are different, the greater FRL; and

(iv) have no combustible building elements passing through it or crossing it, except for roof battens with dimensions of 75 mm x 50 mm or less.

(v) where the roof of one of the adjoining parts is lower than the roof of the other part, extend to the underside of:

- (A) the covering of the higher roof, or not less than 6 m above the covering of the lower roof; or
- (B) the lower roof if it has an FRL not less than that of the fire wall and no openings closer than 3 m to any wall above the lower roof; or
- (C) the lower roof if its covering is non-combustible and the lower part has a sprinkler system.

2. Doorways in fire walls

(a) The aggregate width of openings for doorways in a fire wall, which are not part of a horizontal exit, must not exceed 1/2 of the length of the fire wall, and each doorway must be protected by:

- (i) 2 fire doors or fire shutters, one on each side of the doorway, each of which has an FRL of not less than 1/2 that of the fire wall except that each door or shutter must have an insulation level of at least 30; or
- (ii) a fire door on one side and a fire shutter on the other side of the doorway, each of which complies with (i); or
- (iii) a single fire door or fire shutter which has an FRL of not less than that of the fire wall except that each door or shutter must have an insulation level of at least 30.

(b)

- (i) A fire door or fire shutter required by (a)(i), (a)(ii) or (a)(iii) must be self-closing, or automatic closing in accordance with (ii) and (iii).
- (ii) The automatic closing operation must be initiated by the activation of a smoke detector, or a heat detector if smoke detectors are unsuitable in the atmosphere, installed in accordance with the relevant provisions of AS 1670 and located on each side of the fire wall not more than 1.5 m horizontal distance from the opening.
- (iii) Where any other required suitable fire alarm system, including a sprinkler system, is installed in the building, activation of the

system in either fire compartment separated by the fire wall must also initiate the automatic closing operation.

3. Sliding fire doors

(a) If a doorway in a fire wall is fitted with a sliding fire door which is open when the building is in use:

(i) it must be held open with an electromagnetic device, which when de-activated in accordance with (b), allows the door to be fully closed not less than 20 seconds, and not more than 30 seconds, after release; and

(ii) in the event of power failure to the door - the door must fail safe in the closed position in accordance with (i); and

(iii) an audible warning device must be located near the doorway and a red flashing warning light of a suitable intensity on each side of the doorway must be activated in accordance with (b); and

(iv) signs must be installed on each side of the doorway located directly over the opening stating:
WARNING- SLIDING FIRE DOOR
in capital letters not less than 50 mm high in a colour contrasting with the background.

(b) (i) The electromagnetic device must be de-activated and the warning system activated by heat or smoke detectors, as appropriate, installed in accordance with AS 1905.1 and the relevant provisions of AS 1670.

(ii) Where any other required suitable fire alarm system, including a sprinkler system, is installed in the building, activation in either fire compartment separated by the fire wall must also de-activate the electromagnetic device and activate the warning system.

4. Internal walls required to have an FRL

The internal wall must extend to:

(a) the underside of the floor next above; or

(b) if the roof has an FRL, the underside of the roof; or

(c) if the roof does not have an FRL, the underside of the non-combustible roof covering and, except for roof battens with dimensions of 75 mm x 50 mm or less, must not be crossed by timber or other combustible building elements; or

(d) a ceiling that is immediately below the roof and has a resistance to the incipient spread of fire to the roof space between the ceiling and the roof of not less than 60 minutes.

5. Openings in walls providing access to a ventilating, pipe, garbage or other service shaft.

The opening must be protected by:

(a) if it is in a sanitary compartment - a door or panel which, together with its frame, is non-combustible or has an FRL of not less than - /30/30; or
(b) a self-closing - /60/30 fire door or hopper; or
(c) an access panel having an FRL of not less than - /60/30; or
(d) if the shaft is a garbage shaft, a door or hopper of non-combustble construction.

6. Lifts (other than lifts which are wholly within an atrium), connecting more than:
(a) 2 storeys; or
(b) 3 storeys if the building is sprinklered.

(a) The lift must be separated from the remainder of the building by enclosure in a shaft in which the walls have the FRL prescribed by the table above.
(b) Openings for lift landing doors and services must be protected as follows:(i) Doorways - an entrance doorway to the shaft must be protected by - /60/ - fire doors that:
(A) comply with AS 1735.11; and
(B) are set to remain closed except when discharging or receiving passengers, goods or vehicles.
(ii) Lift indicator panels - A lift call panel, indicator panel or other panel in the wall of the lift shaft must be backed by construction having an FRL of not less than - /60/60 if it exceeds 35 000 mm² in area.

7. Enclosure of shafts required to have an FRL

Shafts must be enclosed at the top and bottom by construction having an FRL not less than that required for the walls of a non-loadbearing shaft in the same building, except that these provisions need not apply to:
(a) the top of a shaft extending beyond the roof covering, other than one enclosing a fire-isolated stairway or ramp; or
(b) the bottom of a shaft if it is non-combustible and laid directly on the ground.

8. Stairways and lifts in one shaft

A stairway and lift must not be in the same shaft if either the stairway or the lift is required to be in a fire-resisting shaft.

9. Openings in internal walls which are required to have an FRL with respect to integrity and insulation

The construction must not reduce the fire-resisting performance of the wall.

10.Doorways in bounding construction

(a) Protection for a doorway must be at least a self-closing - /60/30 fire door.
(b) The door may be automatic-closing; and
(i) The automatic-closing operation must be initiated by the activation of a smoke detector, or a heat detector if smoke

detectors are unsuitable in the atmosphere, installed in accordance with the relevant provisions of AS 1670 and located not more than 1.5 m horizontal distance from the approach side of the opening; and

(ii) Where any other required suitable fire alarm system, including a sprinkler system, is installed in the building, activation of the system must also initiate the automatic- closing operation.

11.Equipment comprising:

(a) Lift motors and lift control panels, except separating construction between the lift shaft and the lift motor room; or

(b) emergency generators or central smoke control plant; or

(c) boilers; or

(d) batteries; but not:

(e) smoke control exhaust fans located in the air stream which are constructed for high temperature operation in accordance with AS6; or

(f) stair pressurising equipment installed in compliance with the relevant provisions of AS 1668.1; or

(g) on-site fire pumps.

(a) The equipment must be suitably separated from the remainder of the building.

(b) The separating construction must have any doorway protected with a self-closing fire door having an FRL of not less than -/120/30.

12.On-site fire pumps.

On-site fire pumps must:

(a) if within a building that is not protected throughout with a *sprinkler system*, be separated from the remainder of the building by construction having an FRL of not less than that *required* for a *fire wall* for the particular building; and

(b) if fixed externally to the building within an enclosure and within 6 m of the building, be separated from the building by construction with an FRL of not less than that *required* for a *fire wall* for the particular building. The separating construction must be:

(i) each wall of the enclosure exposed to the building; or

(ii) that part of the external wall of the building which extends 2 m each side of the enclosure and 3 m above the enclosure; or

(iii) a wall between the building and the enclosure which extends 2 m each side of the enclosure and 3 m above the enclosure.

13.Openings in floors for services

Services passing through a floor must either be installed in shafts complying with the table above or protected in accordance with Specification FS1.

14.Roofs

(a) A roof need not have an FRL if its covering is non-combustible and the building:

- (i) has a sprinkler system installed throughout; or
- (ii) has a rise in storeys of 3 or less; or
- (iii) has an effective height of not more than 25m and the ceiling immediately below the roof has a resistance to the incipient spread of fire to the roof space below it of not less than 60 minutes.(b) A roof superimposed on a concrete slab roof need not have an FRL or comply with (a) if:

(i) the superimposed roof and any construction between it and the concrete slab roof are non-combustible throughout; and

(ii) the concrete slab roof complies with the table above.

15.Service penetrations

Fire-isolated *exits* must not be penetrated by any services other than:

(a) electrical wiring associated with a lighting or pressurisation system serving the *exit* or an intercommunication system in accordance with **[BCA clause D2.22];** or

(b) ducting associated with the pressurisation system if it:

- (i) is constructed of material having an FRL of not less than 120/120/60 where it passes through any other part of the building; and
- (ii) does not open into any other part of the building; or

(c) water supply pipes for fire services.

16.Openings

(a)

- (i) Doorways that open to fire-isolated stairways, fire-isolated passageways or fire-isolated ramps, and are not doorways opening to a road or open space, must be protected by - /60/30 fire doors that are self-closing, or automatic-closing in accordance with (ii) and (iii).
- (ii) The automatic closing operation must be initiated by the activation of a smoke detector, or a heat detector if smoke detectors are unsuitable in the atmosphere, installed in accordance with the relevant provisions of AS 1670 and located not more than 1.5 m horizontal distance from the approach side of the opening.
- (iii) Where any other required suitable fire alarm system, including a sprinkler system, is installed in the building, activation of the system must also initiate the automatic- closing operation.

(b) A window in an external wall of a fire-isolated stairway, fire-isolated passageway or fire-isolated ramp must be protected in accordance with [**C3.4**] if it is within 6 m of, and exposed to:

- (i) a fire-source feature; or
- (ii) a window or other opening in a wall of the same building, other than in the same fire-isolated enclosure.

17. Enclosing construction of a fire-isolated passageway. The construction must be non-combustible

18. A doorway that is part of a horizontal exit

(a) The doorway must be protected by a single fire door that has an FRL of not less than that of the fire wall except that the door must have an insulation level of at least 30.

(b) Each door in a horizontal exit must be self-closing, or automatic-closing with:

- (i) the automatic-closing operation initiated by the activation of a smoke detector, or a heat detector if smoke detectors are unsuitable in the atmosphere, installed in accordance with the relevant provisions of AS 1670 and located on each side of the fire wall not more than 1.5 m horizontal distance from the opening; and
- (ii) where any other suitable fire alarm system, including a sprinkler system, is installed in the building, activation of the system in either fire compartment separated by the fire wall must also initiate the automatic-closing operation.

19. A doorway that is part of a horizontal exit

(a) The doorway must be protected by either:

- (i) a single fire door that has an FRL of not less than that of the fire wall except that the door must have an insulation level of at least 30; or
- (ii) 2 fire doors, one on each side of the doorway, each with an FRL of not less than 1/2 that of the fire wall except that each door must have an insulation level of at least 30.

(b) Each door in a horizontal exit must be self-closing, or automatic-closing with:

- (i) the automatic-closing operation initiated by the activation of a smoke detector, or a heat detector if smoke detectors are unsuitable in the atmosphere, installed in accordance with the relevant provisions of AS 1670 and located on each side of the fire wall not more than 1.5 m horizontal distance from the opening; and
- (ii) where any other suitable fire alarm system, including a sprinkler system, is installed in the building, activation of the system in either fire compartment separated by the fire wall must also initiate the automatic-closing operation.

20. In a building having a roof without an FRL, in the storey immediately below that roof:

(a) internal columns, other than those that face and are within 1.5 m of a window and are exposed through that window to a fire-source feature; and

(b) loadbearing internal walls other than fire walls.

The columns and walls may have:
(a) [an FRL for integrity and insulation of 60.
(b) no FRL

21.(a) A doorway that provides access from a sole-occupancy unit to:
(i) a public corridor, public hallway, or the like; or
(ii) a room not within a sole-occupancy unit; or
(iii) the landing of an internal non-fire-isolated stairway that serves as a required exit; or
(iv) another sole-occupancy unit.

The doorway must be protected by internal or *external wall*-wetting sprinklers as appropriate or - /60/30 fire doors (*se.f-closing* or *automatic* closing).

22.A doorway that provides access from a room not within a sole-occupancy unit to a public corridor, public hallway, or the like

The doorway must be protected by internal or *external wall*-wetting sprinklers as appropriate or - /60/30 fire doors (*se.f-closing* or *automatic* closing).

23.A doorway that provides access from a room not within a sole-occupancy unit to the landing of an internal non-fire-isolated stairway that serves as a required exit.

The doorway must be protected by internal or *external wall*-wetting sprinklers as appropriate or - /60/30 fire doors (*se.f-closing* or *automatic* closing).

24.An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp

The stairway, ramp or escalator may connect any number of storeys.

25.A stairway or ramp (including any landings) that is required to be within a fire-resisting shaft

The stairway or ramp must be constructed so that if there is local failure, it will not cause structural damage to, or impair the fire-resistance of, the shaft.

26.Pipes that penetrate the floor of a sanitary compartment, where the sanitary compartment is separated from other parts of the building by walls with the FRL required by the table above for a stair shaft, and a self-closing - /60/30 fire door.

The pipe need not comply with Specification FS1 if it:
(a) is of metal or UPVC; and
(b) has a neatly-formed opening no larger than is necessary to accommodate the pipe or fitting; and
(c) has the gap between pipe and floor fire-stopped in accordance with Specification FS1, *fire stcpping*.

27.An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp.

The stairway, ramp or escalator may connect any number of storeys.

28. An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp that is in a building that is sprinklered throughout.

The stairway, ramp or escalator may connect any number of storeys if it is protected in accordance with Specification FS28.

29. An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp that:

(a) is in a building that is not sprinklered throughout; or

(b) is not protected in accordance with Specification FS28

The escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp must not connect more than:

(a) 3 storeys if each of those storeys is provided with a sprinkler system throughout; or

(b) 2 storeys,

and those storeys must be consecutive, and one of those storeys must be situated at a level at which there is direct egress to a road or open space

30. An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp.

An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp must not be used.

31. An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp that is:

(a) in an atrium; or

(b) outside a building.

The stairway, ramp or escalator may connect any number of storeys.

32. An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp that is not:

(a) in an atrium; or

(b) outside a building.

The escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp must not connect more than:

(a) 3 storeys if each of those storeys is provided with a sprinkler system throughout; or

(b) 2 storeys,

and those storeys must be consecutive, and one of those storeys must be situated at a level at which there is direct egress to a road or open space

33. A required exit that connects or passes through more than 2 consecutive storeys or 3 consecutive storeys if the building has a sprinkler system installed throughout

The exit must be fire-isolated.

34. Exits that connect more than 3 consecutive storeys or 4 if the additional storey is only for the accommodation of motor vehicles or for other ancillary purposes.

The required exit must be fire-isolated

35. Exits that connect more than 2 consecutive storeys or 3 if the additional storey is only for the accommodation of motor vehicles or for other ancillary purposes..

The required exit must be fire-isolated

36. Where the distance to one of the exits is between 40 and 60 m in accordance with EP?.

Every doorway in the wall must be protected by a tight fitting self-closing solid-core door not less than 35 mm thick.

37. Doorways that provide access to any other internal part of the building

The doorway must be protected by a self-closing -/60/30 fire door.

38. Exits

(a) Required exits need not be fire-isolated.

(b) An escalator, moving walkway or non-required non-fire-isolated stairway or pedestrian ramp may connect any number of storeys.

39. Patient care areas.

Patient care areas must be divided into fire compartments not exceeding 2000m².

40. Ward areas.

(a) Ward areas:

- (i) where the floor area exceeds 1000 m², must be divided into areas not more than 1000 m² by walls with an FRL of not less than 60/60/60; and
- (ii) where the floor area exceeds 500 m², must be divided into areas not more than 500 m² by smoke proof walls complying with (c); and
- (iii) where division of ward areas by fire-resisting walls under 39 and (a)(i) is not required, any smoke proof walls required under (a)(ii) must have an FRL of not less than 60/60/60.

(b) A wall required to be smoke-proof must:

- (i) be non-combustible and extend to the underside of the floor above, to the underside of a non-combustible roof covering or to the underside of a ceiling having a resistance to the incipient spread of fire to the space above itself of not less than 60 minutes; and
- (ii) not incorporate any glazed areas unless the glass is safety glass as defined in AS 1288; and
- (iii) have all doorways fitted with smoke doors complying with **[Specification C3.4]**; and
- (iv) have the openings around any penetrations adequately stopped to prevent the free passage of smoke; and
- (v) incorporate smoke dampers where air-handling ducts penetrate the wall, except where the air-handling system forms part of a smoke control system or is required to continue operating during a fire.

(c) A door required to be smoke proof or have an FRL, other than one that serves a fire compartment provided with a zone smoke control system in accordance with AS 1668.1, must provide a smoke reservoir by not extending within 400 mm of the underside of:
   (i) a roof covering; or
   (ii) the floor above; or
   (iii) an imperforate false ceiling that will prevent the free passage of smoke.

41.Located within a patient care area:

(i) A kitchen and related food preparation areas having a combined floor area of more than 30 m².
(ii) A room containing a hyperbaric facility (pressure chamber).
(iii) A room used predominantly for the storage of medical records having a floor area of more than 10 m².
(iv) A laundry, where items of equipment are of the type that are potential fire sources (eg gas fire dryers).

The ancillary use area must be separated from the patient care area by walls that extend to a non-combustible roof covering, the floor above or a ceiling with a resistance to the incipient spread of fire, the doorway being protected with fire doors having an FRL of not less than - /60/30 :

42.A building which:

(a) has a stage and any back stage area with a total floor area of more than 200m²; or
(b) has a stage with an associated rigging loft.

A theatre, public hall or the like must have the stage, backstage area and accessible under-stage area separated from the audience by a proscenium wall complying with Specification AS42 and have a mechanical exhaust system in accordance with AS9b.

43.Walls bounding an atrium.

Separation cf atrium by bounding walls

An atrium must be separated from the remainder of the building at each storey by bounding walls set back not more than 3.5 m from the perimeter of the atrium well except in the case of the walls at no more than 3 consecutive storeys if-

(a) one of those storeys is at a level at which direct egress to a road or open space is provided; and
(b) the sum of the floor areas of those storeys that are contained within the atrium is not more than the maximum area of the fire compartment under consideration.

Construction cf bounding walls

Bounding walls must:

(a) have an FRL of not less than 60/60/60, and:
   (i) extend from the floor of the storey to the underside of the floor next above or to the underside of the roof; and
   (ii) have any door openings protected with self-closing or automatic - /60/30 fire doors; or

(b) be constructed of fixed toughened safety glass, or wired safety glass in non-combustible frames, with:
  - (i) any door openings fitted with a self-closing smoke door complying with [**BCA Specification C3.4**]; and
  - (ii) the walls and doors protected with wall-wetting systems in accordance with **[BCA Specification G3.8]**; and
  - (iii) a fire barrier with an FRL of not less than - /60/30 installed in any ceiling spaces above the wall.

Location of protection

Where an atrium is separated from the remainder of the building by walls or doors incorporating glazing, a wall wetting system with suitable non-combustible heat collector plates of 200 mm diameter must be provided to protect the glazing as follows:

(a) On the atrium side of the glazing - to all glazed walls which are set back more than 3.5 m from the atrium well.

(b) On the side of the glazing away from the atrium well - to all glazing forming part of bounding wall at each storey.

Wall-wetting sprinklers - Sprinkler head location

Sprinklers must be located in positions allowing full wetting of the glazing surfaces without wetting adjacent sprinkler heads.

Head rating and response time

Sprinkler heads must be of the fast response type and have a maximum temperature rating of 74°C.

Water discharge rate

The rate of water discharge to protect glazing must be not less than:

(a) on the atrium side of the glazing:
  - (i) 0.25 L/s.m2 where glazing is not set back from the atrium well; or
  - (ii) 0.167 L/s.m2 where glazing is set back from the atrium well ; and

(b) on the side away from the atrium well - 0.167 L/s.m2.

Water supply

In addition to the water supply to the basic sprinkler protection for the building, where the walls are set back 3.5 m or more from the atrium well, the water supply to required wall wetting systems must be of adequate capacity to accommodate wetting of a part not less than 12 m long on one storey on the atrium side of the glazing.

Stop valves

(a) Basic sprinkler and wall wetting systems protecting a building containing an atrium must be provided with easily accessible and identified stop valves.

(b) Sprinkler and wall wetting systems must be provided with independent stop valves.

(c) Sprinkler heads protecting the roof of the atrium must be provided with a stop valve.

(d) Stop valve to wall wetting and roof sprinklers may be of the gate type.

(e) All sprinkler and wall wetting stop valves must be monitored to detect unauthorised closure.

44. Walls bounding the atrium if:

- **(a) a Class 2, 3, 5 or 9 part of the building is open to the atrium; and**
- **(b) the atrium is separated from the remainder of the building by walls or doors incorporating glazing; and**
- **(c) the glazed walls are not set back, or are set back 3.5 m or less, from the atrium well,**

at all levels which are less 12 m above the floor of an atrium or the floor of the highest storey where the bounding wall is set back more than 3.5 m from the atrium well.

Acceptable solution

A wall wetting system with suitable non-combustible heat collector plates of 200 mm diameter must be provided to protect the glazing on the atrium side of the glazing.

45. Where:

- **(a) a Class 2, 3, 5 or 9 part of the building is open to the atrium; and**
- **(b) the bounding walls are set back less than 3.5 m from the atrium well**

Acceptable solution

In addition to the water supply to the basic sprinkler protection for the building, the water supply to required wall wetting systems must be of adequate capacity to accommodate wetting of a part not less than 6 m long, for a height of not less than 12 m above the floor of the atrium or the floor of the highest storey with bounding walls set back less than 3.5 m from the atrium well.

46. Walls bounding the atrium if:

- **(a) a Class 6, 7 or 8 part of the building is open to the atrium; and**
- **(b) the atrium is separated from the remainder of the building by walls or doors incorporating glazing; and**
- **(c) the glazed walls are not set back, or are set back 3.5 m or less, from the atrium well,**

at all levels which are less 20 m above the floor of an atrium or the floor of the highest storey where the bounding wall is set back more than 3.5 m from the atrium well.

A wall wetting system with suitable non-combustible heat collector plates of 200 mm diameter must be provided to protect the glazing on the atrium side of the glazing.

47. Where:

- **(a) a Class 6, 7 or 8 part of the building is open to the atrium; and**
- **(b) the bounding walls are set back less than 3.5 m from the atrium well**

In addition to the water supply to the basic sprinkler protection for the building, the water supply to required wall wetting systems must be of adequate capacity to accommodate wetting of a part not less than 6 m long, for a height of not less than 20 m above the floor of the atrium or the floor of the highest storey with bounding walls set back less than 3.5 m from the atrium well.

Specification FS1

The service must be installed so that:

(b) the method and materials used are identical with a prototype assembly of the service and building element which has been tested in accordance with AS 4072.1 and AS 1530.4 and has achieved the required FRL or resistance to the incipient spread of fire; or

(c) it complies with (b) except for the insulation criteria relating to the service and:

  (i) the service is protected so that combustible material cannot be located within 100 mm of it; and

  (ii) it is not located in a required exit; or

(d) in the case of ventilating or air-conditioning ducts or equipment the installation is in accordance with AS 1668.1; or

(e) the service is a metal pipe installed in accordance with [**Specification C3.15]** and it:

  (i) penetrates a wall, floor or ceiling, but not a ceiling required to have a resistance to the incipient spread of fire; and

  (ii) connects not more than 2 fire compartments in addition to any fire-resisting service shafts; and

  (iii) does not contain a flammable or combustible liquid or gas; or

(f) the service is a wire or cable, or a cluster of wires or cables installed in accordance with *wires and cables* (below) and it:

  (i) penetrates a wall, floor or ceiling, but not a ceiling required to have a resistance to the incipient spread of fire; and

  (ii) connects not more than 2 fire compartments in addition to any fire-resisting service shafts; or

(g) the service is an electrical switch, outlet, or the like, and it is installed in accordance with e*lectrical switches and outlets* (below).

Wires and cables

If a wire or cable or cluster of wires or cables penetrates a floor, wall or ceiling:

(a) the opening must be neatly formed, cut or drilled and no closer than 50 mm to any other service opening; and

(b) the opening must be no larger in cross-sectional area than:

  (i) 2000 mm2 if only a single cable is accommodated and the gap between cable and wall, floor or ceiling is no wider than 15 mm; or

  (ii) 500 mm2 in any other case; and

(c) the gap between the service and the wall, floor or ceiling must be fire-stopped as detailed below.

Electrical switches and outlets

If an electrical switch, outlet, socket or the like is accommodated in an opening or recess in a wall, floor or ceiling:

(a) the opening or recess must not:

  (i) be located opposite any point within 300 mm horizontally or 600 mm vertically of any opening or recess on the opposite side of the wall; or

  (ii) extend beyond half the thickness of the wall; and

(b) the gap between the service and the wall, floor or ceiling must be fire-stopped as detailed below.

Metal pipes

(a) A metal pipe that is not normally filled with liquid must not penetrate a wall, floor or ceiling within 100 mm of any *combustible* material, and must be constructed of:

  (i) copper alloy or stainless steel with a wall thickness of at least 1 mm; or
  (ii) cast iron or steel (other than stainless steel) with a wall thickness of at least 2 mm.

(b) An opening for a metal pipe must-

  (i) be neatly formed, cut or drilled; and
  (ii) be no closer than 200 mm to any other service penetration; and
  (iii) accommodate only one pipe.

(c) A metal pipe must be wrapped but must not be lagged or enclosed in thermal *insulation* over the length of its penetration of a wall, floor or ceiling unless the lagging or thermal *insulation* fulfils the requirements of Clause 7.

(d) The gap between a metal pipe and the wall, floor or ceiling it penetrates must be fire-stopped as detailed below.

Fire-stopping

(a) **Material:** The material used for the fire-stopping of service penetrations must be concrete, high-temperature mineral fibre, high-temperature ceramic fibre or other material that does not flow at a temperature below 1120ºC when tested in accordance with AS 1038.15, and must have:

  (i) demonstrated in a system tested in accordance with [**C3.15(a)** of the BCA]that it does not impair the fire-resisting performance of the building element in which it is installed; or
  (ii) demonstrated in a test in accordance with (e) that it does not impair the fire-resisting performance of the test slab.

(b) **Installation:** Fire-stopping material must be packed into the gap between the service and wall, floor or ceiling in a manner, and compressed to the same degree, as adopted for testing under (a)(i) or (a)(ii).

(c) **Hollow construction:** If a pipe penetrates a hollow wall (such as a stud wall, a cavity wall or a wall of hollow blockwork) or a hollow floor/ceiling system, the cavity must be so framed and packed with fire-stopping material that the material is-

  (i) installed in accordance with (b) to a thickness of 25 mm all round the service for the full length of the penetration; and
  (ii) restrained, independently of the service, from moving or parting from the surfaces of the service and of the wall, floor or ceiling.

(d) **Recesses:** If an electrical switch, socket, outlet or the like is accommodated in a recess in a hollow wall or hollow floor/ceiling system-

  (i) the cavity immediately behind the service must be framed and packed with fire-stopping material in accordance with Clause 7(c); or

(ii) the back and sides of the service must be protected with refractory lining board identical with and to the same thickness as that in which the service is installed.

(e) **Test:** The test to demonstrate compliance of a fire-stopping material with this Specification must be conducted as follows:

  (i) The test specimen must comprise a concrete slab not less than 1 m square and not more than 100 mm thick, and appropriately reinforced if necessary for *structural adequacy* during manufacture, transport and testing.

(ii) The slab must have a hole 50 mm in diameter through the centre and the hole must be packed with the fire-stopping material.

(iii) The slab must be conditioned in accordance with AS 1530.4.

(iv) Two thermocouples complying with AS 1530.4 must be attached to the upper surface of the packing each about 5 mm from its centre.

(v) The slab must be tested on flat generally in accordance with Section 10 of AS 1530.4 and must achieve an FRL of 60/60/60 or as otherwise *required.*

Specification FS28

(a) The escalator, walkway, stairway or ramp must be bounded by a shaft of:

(i) construction with an FRL of not less than 120/120/120 if loadbearing or -/120/120 if non-loadbearing

(ii) glazed construction with an FRL of not less than - /60/30 and protected by a wall wetting system in accordance with

(b) the void of each non-required stairway, ramp or escalator must not connect more than 2 storeys.

(c) rising and descending escalators, walkways, stairways and ramps within one shaft must be separated by construction with an FRL of not less than - /60/30.

(d) openings into the shaft must be protected by fire doors with an FRL not less than - /60/30.

(e) when a fire door is closed the floor or any covering over the floor beneath the fire door must not be combustible.

(f) fire doors must be fitted with smoke seals and the assembly must be tested in accordance with AS 1530.4.

Specification FS42

Proscenium walls and curtains

Exits from theatre stages

The path of travel to an exit from a stage or performing area must not pass through the proscenium wall if the stage area is separated from the audience area with a proscenium wall.

Separation of stage areas, etc

(a) Dressing rooms, scene docks, property rooms, workshops, associated store rooms and other ancillary areas must be:

(i) located on the stage side of the proscenium wall; and

(ii) separated from corridors and the like by construction having an FRL of not less than 60/60/60, and if of lightweight construction, complying with M15.

(b) The stage and backstage must be separated from other parts of the building other than the audience seating area by construction having an FRL of not less than 60/60/60

(c) Any doorway in the construction referred to in (a) and (b) must be protected by a self-closing - /60/30 fire door.

Proscenium wall construction

(a) A proscenium wall must:

(i) extend to the underside of the roof covering or the underside of the structural floor next above; and

(ii) have an FRL of not less than 60/60/60.

(b) Timber purlins or other combustible material must not pass through or cross any proscenium wall.

Protection of openings in proscenium wall

Every opening in a proscenium wall must be protected:

(a) at the principal opening, by a curtain as described below which is:
   (i) capable of closing the proscenium opening within 35 seconds either by gravity slide or motor assisted mechanisms; and
   (ii) operated by a system of automatic heat activated devices, manually operated devices or push button emergency devices; and
   (iii) able to be operated from either the stage side or the audience side of the curtain; and

(b) at any doorway in the wall, by a self-closing - /60/30 fire door.

Proscenium curtains

A curtain required by (a) above must be:

(a) a fire safety curtain:
   (i) made of non-combustible material; and
   (ii) capable of withstanding a pressure differential of 0.5 kPa over its entire surface area; and
   (iii) so fitted that when fully lowered it inhibits the penetration of smoke around the perimeter of the opening, from the stage; or

(b) a curtain:
   (i) having a Spread-of-Flame Index not greater than 0 and a Smoke-Developed Index not greater than 3; and
   (ii) protected by a deluge system of open sprinklers installed along the full width of the curtain.

4. PERFORMANCE OF EXISTING PROVISIONS

4.1 STATISTICAL EVIDENCE

4.1.1 Introduction

This report is based on data obtained from CSIRO and represents fires in *buildings* (*structures* in the terminology used in AS 2577 - 1983 Collection of Data on Fire Incidents[1]) in Australia during the years 1989 to 1993. The data supplied by CSIRO are obtained from records supplied through the Australian Fire Authorities Council by the following organisations: NSW Fire Brigades, Melbourne Metropolitan Fire Brigades, Country Fire Authority, Victoria, South Australian Metropolitan Fire Service, Western Australia Fire Brigades, Tasmania Fire Service, and Queensland Fire Service (some years).

The data represent fires that are notified to the fire brigade. An unknown number of fires are not notified to the fire brigade and are therefore not included in the data. It is to be expected that a large proportion of fire starts fail to grow significantly or are extinguished while still very small by the building occupants. Information obtained from a Swiss insurance company indicates that in the Canton of Berne (Switzerland) while the fire brigade are called to about 1500 fires each year, over 5000 claims are made for fire damage to buildings. Thus the number of fire starts is at least three times the number notified to the fire brigade. It is reasonable to assume that the actual number of fire starts is significantly larger again, because a further group of fires would do no damage or sufficiently little damage that placing an insurance claim would be unwarranted.

The data are for building fires only and are presented herein in two categories of buildings: *Residential* and *Commercial*. In this context *residential* means buildings classified as residential in the field *Fixed Prcperty Use* (FPU) of AS 2577 - 1983[1]. *Commercial* means all other buildings, thus including Public Assembly property; Educational property; Shop/Store, Office property; Basic Industry, Utility, Defence property; Manufacturing property; and Storage property. A third category (*unknown*) is included for the balance of fires specified in the data as being fires in buildings in which the FPU was not identified or the data omitted.

In the following sections the data are presented as absolute numbers (the actual number of fires, fatalities, injuries and estimated $ losses in each category examined) and as rates (the number of fatalities and injuries per 1000 fires and the estimated $ loss per fire in each category examined). This allows an appreciation to be obtained of both the importance of each category in terms of the casualties and losses associated with fires in that category (the absolute numbers for each category) and the "risk" associated with fires in each category (the rates for each category). These rates might be expected to be presented on the basis of the average outcome per fire and this is indeed the case for the estimated $ losses, but the casualty rates are presented per 1000 fires so as to generally result in easily understood numbers with one or two digits before the decimal point (rather than numbers with many zeros after the decimal point: thus 1.2 fatalities per 1000 fires rather than 0.0012 fatalities per fire).

The data are summarised in Table 4.1.

TABLE 4.1 AUSTRALIAN STRUCTURE FIRES 1989 TO 1993

Building Use	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Commercial	24497	745	461	30	1	1.3253e9
Residential	35303	2192	382	250	4	4.8346e8
Unknown	570	11	1	1	0	6.2327e6

It can be seen in Table 4.1 that there are major differences in the casualties and losses between the two *building use* categories. In summary there were:

- 7.1 civilian fatalities per 1000 fires in *residential* buildings
- 1.2 civilian fatalities per 1000 fires in *commercial* buildings
- 62.1 civilian injuries per 1000 fires in *residential* buildings
- 30.4 civilian injuries per 1000 fires in *commercial* buildings
- 0.11 fire fighter fatalities per 1000 fires in *residential* buildings
- 0.04 fire fighter fatalities per 1000 fires in *commercial* buildings
- 10.8 fire fighter injuries per 1000 fires in *residential* buildings
- 18.8 fire fighter injuries per 1000 fires in *commercial* buildings
- $13,700 losses per fire (estimated by the fire fighters) in *residential* buildings
- $54,100 losses per fire (estimated by the fire fighters) in *commercial* buildings

It can be seen from these figures that there are major differences in the rates of human casualties and property damage resulting from fires in the two building use categories.

Nearly six times as many civilians are killed per 1000 fires in *residential* buildings compared with *commercial* buildings, while the comparable rate for fire fighters was just under three.

The figures were closer for civilian injuries - about twice as many civilians were injured per 1000 fires in *residential* compared with *commercia*l buildings. However for fire fighters the ratio was reversed - about twice as many firefighters were injured per 1000 fires in *commercial* compared with *residential* buildings.

The estimated property losses were about four times higher per fire for *commercial* than for *residential* buildings.

It is noteworthy that these figures for *commercial* building fires are similar to those for *çfice* fires in the USA for the period 1983 to 1991 that have previously been analysed. Coincidently the number of fires is similar (27,669) and they resulted in 31 civilian and one fire fighter fatality, 539 civilian and 1417 fire fighter injuries and total estimated losses of $676 million. Thus there were:

- 1.1 civilian fatalities per 1000 fires (compared with 1.2 above)
- 0.04 fire fighter fatalities per 1000 fires (compared with 0.04 above)
- 19.5 civilian injuries per 1000 fires (compared with 30.4 above)
- 51.2 fire fighter injuries per 1000 fires (compared with 18.8 above)
- US$24,500 per fire (compared with A$54,100 above)

Similarly, from an analysis of USA *retail* building fires 1983 to1993 (excluding 1986), in the 77,996 fires included in the database a total of 87 civilian and 14 fire fighter fatalities and 2,118 civilian and 4,580 fire fighter injuries were recorded. Thus there were:

- 1.1 civilian fatalities per 1000 fires (compared with 1.2 above)
- 0.18 fire fighter fatalities per 1000 fires (compared with 0.04 above)
- 27.2 civilian injuries per 1000 fires (compared with 30.4 above)
- 58.7 fire fighter injuries per 1000 fires (compared with 18.8 above)
- US$24,500 per fire (compared with A$54,100 above)

It is clear from a comparison of the Australian figures presented above (both the absolute numbers and rates) that for civilians fires in *residential building*s are much more likely to result in death and injury than fires in *commercial buildings*. This may, in part, be due to some characteristics of the construction of *residential* compared with *commercia*l buildings, but it is thought to be much more significantly influenced by the activities of the people in the buildings and by their characteristics such as age, sex, physical condition and whether they are under the influence of alcohol or drugs.

It appears for fire fighters that fires in *residential* buildings on average result in more fatalities than those in *commercial* buildings, but with the reverse being true for injuries. No explanation is offered as to why this is the case. On average fires in *commercial* buildings are estimated to result in substantially greater property loss per fire than those in *residential* buildings.

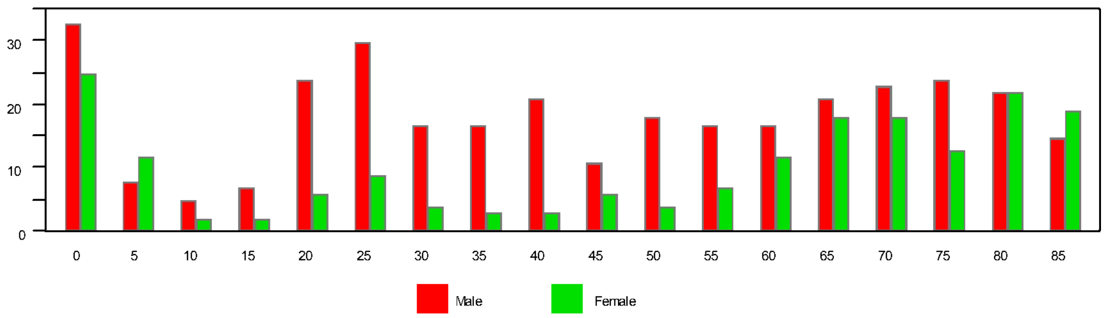
The investigations below indicate some possible reasons for these differences, as well as the effect of sprinklers, building storey height and construction type on the effect of fires.

4.1.2 Australian Fire Fatalities

Before examining the fire data in more detail it is appropriate to concentrate first on fatalities due to fires in buildings as the first and best accepted objective of the building regulations is minimisation of fatalities due to fires in buildings.

Figure 4.1 shows the variation with age and sex of the deaths in fires during the period 1989 to 1993 abstracted from References 2, 3 and 4. Unfortunately, although stated in References 2 to 4 to be fatalities in building (structure) fires it appears that they are actually due to all accidental fires (as opposed to fires related to suicide and murder) during that period. Data recently supplied by CSIRO indicate that it is likely that about 55% of them are due to building fires and about 35% due to vehicle fires, with the remaining fires in a wide variety of circumstances. It is not possible at this stage to obtain age and sex data for fatalities specific to building fires.

It is obvious from Figure 4.1 that males are very over-represented in the fire fatalities: about 64% of the total are males. Thus there are nearly two male fire fatalities for each female fire fatality. However, this situation does not exist uniformly through the entire age range. Up to age 15 years and above age 65 years it is much more even: in both of these age ranges about 54% of fatalities are males. In the intervening period (age 15 to 64 years) 77% of fatalities are males, a more than three to one ratio over female fatalities. The male deaths during this age range make up about 35% of the total fire fatalities. Thus it appears that any improvement in fire safety will need to address the causes and other gender specific details of these fatalities.



Age Range (0-4, 5-9, etc years)

The vertical axis is the number of fatalities.

Figure 4.1 Structure fire fatalities for period 1989-1993 by Age and Sex

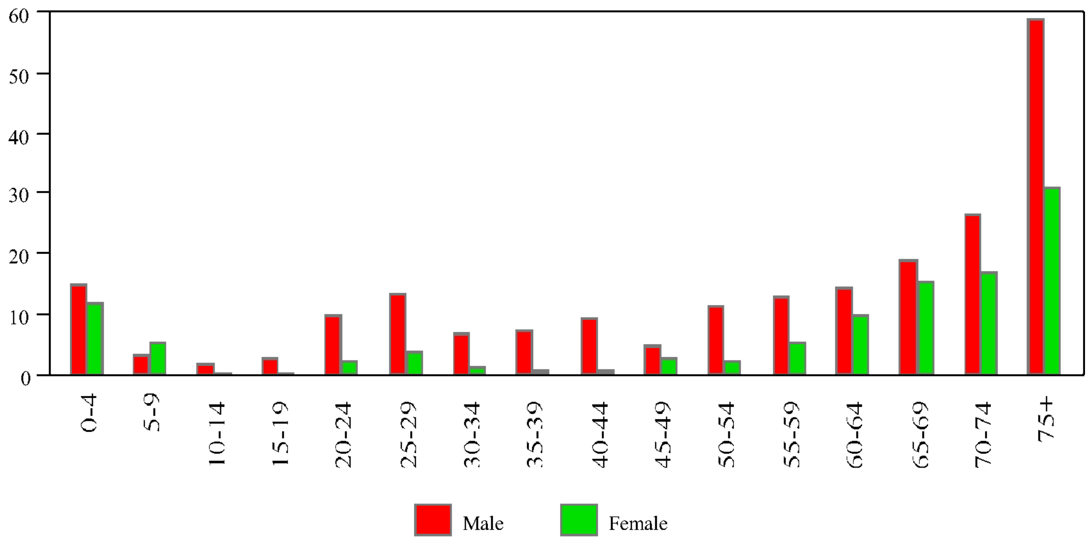
Children age between 0 and 4 years represent about 11% of the fatalities but only about 7% of the population[5], thus they are significantly over represented. Even more so are people aged 65 and above forming about 38% of the fatalities but only about 12% of the population.

Figure 4.2 represents the same fire data as Figure 4.1 but the fatalities for each age and sex group have been divided by the number of people in that category in the Australian population in the 1991 census[5] and the resulting relative risk of death in fire has been standardised by dividing by the value for the lowest risk group which is females aged 10 to 19 years. Thus the vertical axis represents the risk for each age and sex group relative to females aged 10 to 19 years.

By reference to Figure 4.2 it can be seen that females aged 35 to 44 years also have a very low risk. Children under five have risks about twelve (for females) to fifteen (for males) times females aged ten to nineteen. Males from twenty to about forty-four have a risk averaging about ten times females aged ten to nineteen. However, the highest factors come as a result of age: both male and female risk factors rise continually from age about forty-five to a maximum of almost sixty (60) for males aged seventy-five and over and about thirty (30) for females in the same age range.

It is noteworthy that the annual number of deaths by fire would fall by a factor of about nine (9) if all sex and age groups were to have the same risk factor as females aged ten to nineteen.

It has been observed from other studies that people who are vulnerable are those most at risk from fire - the very young, the very old, people who are asleep, people who are severely affected by alcohol or drugs, and people who are unable to react appropriately when fire occurs (bedridden, etc). It is thus no surprise that increasing age is a significant risk factor - the percentage of the population that is disabled (that is, is more unlikely to be able to react appropriately) increases both in quantity and in severity with increasing age.



Vertical axis is fire fatalities per head of population standardised to female age 10 to 19 years = 1

Figure 4.2 Standardised Rate of Structure Fire Fatalities

This analysis makes it very obvious that any attempt to improve fire safety will need to address the age and sex specific factors that lead to such a great range of risk factors. It may be that the means of improving fire safety available through engineering and building regulations are inappropriate for this task and other methods may have to be employed if any improvement of the situation is sought, or even possible.

4.1.3 Effect of Fire Brigade Arrival Time and Presence of Sprinklers on Extent of Flame Damage

It is shown in Section 4.1.4 that the *extent of flame damage* recorded by the fire brigade represents a good indicator of the degree of risk of death or injury for building occupants (civilians in terms of the headings on the tables below), fire fighters and the degree of property damage ($ Loss in terms of the headings on the tables below).

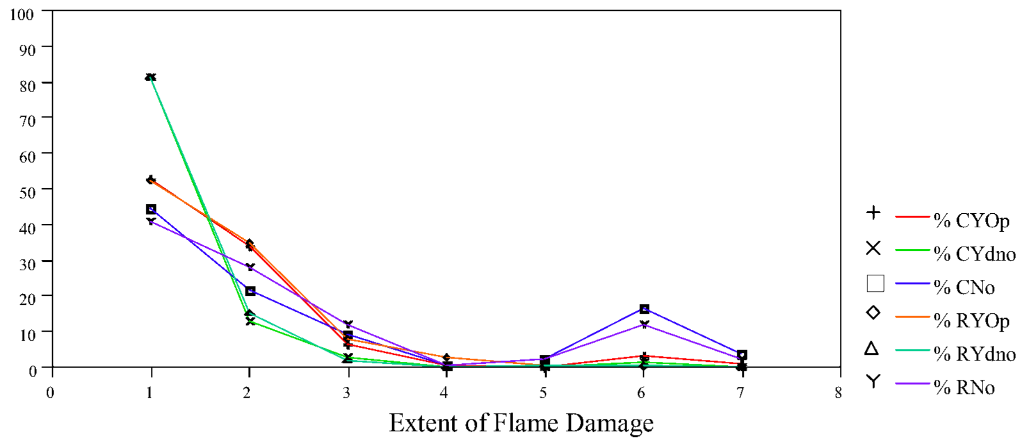
Generally, as the flame damage becomes more extensive, the risk to people and property increases.

The extent of flame damage is categorised in AS 2577 - 1983[1] in seven categories representing progressively greater spread of flame damage through the building. Flame damage is the area that was actually burned or charred. The *extent of flame damage* categories are:

- EFD 1 Confined to object of origin
- EFD 2 Confined to part of room or area of origin
- EFD 3 Confined to room of origin
- EFD 4 Confined to fire-rated compartment of origin
- EFD 5 Confined to floor of origin
- EFD 6 Confined to structure of origin
- EFD 7 Extended beyond structure of origin

Figure 4.3 shows a comparison of the percentages of fires in each of the extent of flame damage categories for residential (R) and commercial (C) buildings for each of three sprinkler cases:

- automatic sprinkler system not present in the room of fire origin (No)
- sprinkler system present and operated (YOp)
- sprinkler system present but did not operate (Ydno) (for whatever reason, including the fire being too small to trigger sprinkler operation)



The vertical axis represents the % of fires

Figure 4.3: Extent of Flame Damage by Building Use and Sprinkler Presence and Operation

It can be seen in Figure 4.3 that the percentages for the *residential* building and *commercial* building cases are very close, particularly when sprinklers are present (but whether the sprinklers operated or not).

It is also notable in Figure 4.3 that the overwhelming majority of fires notified to the fire brigade are in the categories EFD 1, EFD 2 and EFD 3 and are therefore confined to the room of origin. The cumulative percentages (%EFD 1 + %EFD 2 + %EFD 3) are:

- residential buildings with
    - sprinklers present and operated 96%
    - sprinklers present but did not operate 99%
    - sprinklers not present 82%
- commercial buildings with
    - sprinklers present and operated 94%
    - sprinklers present but did not operate 98%
    - sprinklers not present 76%

Clearly the presence of sprinklers is beneficial in reducing very substantially the likelihood of fire spread beyond the room of origin. It is notable in Figure 4.3 that virtually all of the fires that spread beyond the room of origin, in both residential and commercial buildings, spread through the building and a small but significant proportion of these spread beyond the building of origin.

There is no indication in the data represented by Figure 4.3 that the *fire-rated compartment of fire origin* (EFD = 4) has any significant effect in limiting the spread of fire.

In Figures 4.4 to 4.7 the percentage of fires by the time from alarm to fire brigade arrival (*fire brigade arrival time*) is presented along with the cumulative percentage. On each graph there is a reference line at 50% to enable the median value of fire brigade arrival time to be more easily observed. Figures 4.4 and 4.5 are for *commercial* buildings and Figures 4.6 and 4.7 for *residential* buildings. Figures 4.4 and 4.6 are for *sprinklers not present* and Figures 4.5 and 4.7 are for *sprinklers present*, whether they operated or not.

There is some variation in the median values of *fire brigade arrival time* between the different cases represented by the Figures 4.4 to 4.7. The median value of *fire brigade arrival time* is:

- between four and five minutes in the *sprinklers present* cases
- between five and six minutes in the *sprinklers not present* cases

No explanation of the difference is offered.

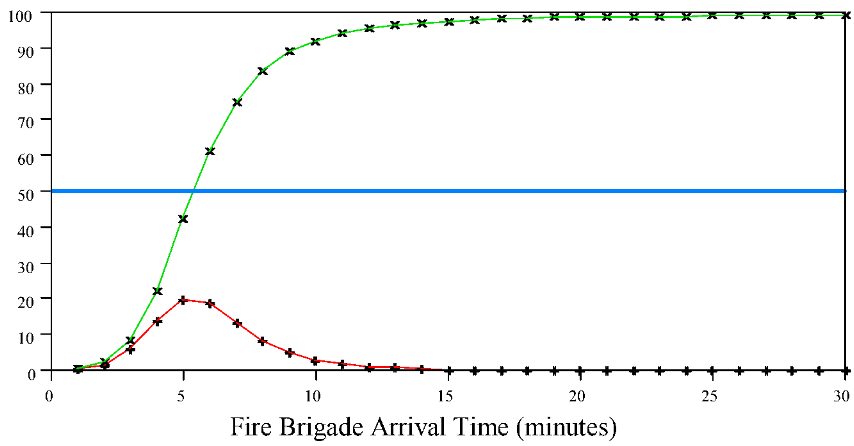
In 95% of fires the fire brigades had arrived in:

- between eleven and twelve minutes for *commercial* buildings with *sprinklers not present*
- between ten and eleven minutes for *commercial* buildings with *sprinklers present*

- between twelve and thirteen minutes for *residential* buildings with *sprinklers not present*
- at about seven minutes for *residential* buildings with *sprinklers present*

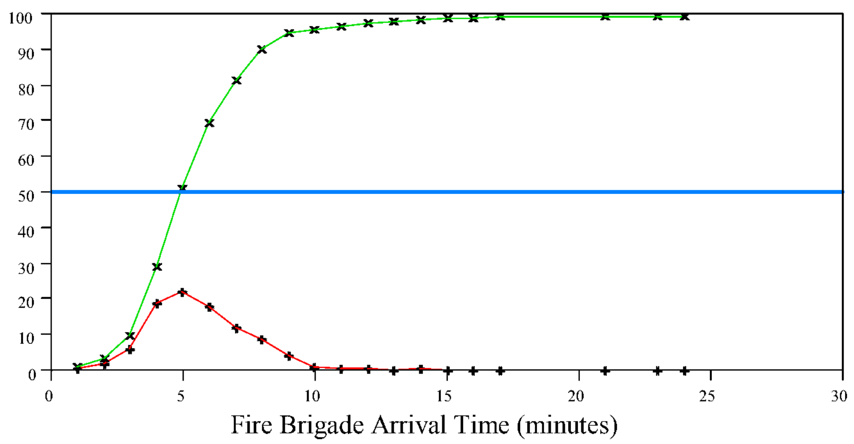
(Note the different scales on the time axes of these graphs.)

The effect of the fire brigade arrival time on extent of flame spread is illustrated in Figures 4.8 to 4.13. Figures 4.8 to 4.10 are for *commercial* buildings and Figures 4.11 to 4.13 for *residential* buildings. In Figures 4.8 to 4.13 the percentage of fires for each extent of flame damage category (see Figure 4.3 for details) is plotted for each five minute time period (1 to 5 minutes, 6 to 10 minutes, 11 to 15 minutes, etc) for which there is a large enough number of fires to make the analysis meaningful. Figures 4.8 and 4.11 are for *sprinklers not present*, Figures 4.9 and 4.12 for *sprinklers present and operated* and Figures 4.10 and 4.13 for *sprinklers present but did not operate*.



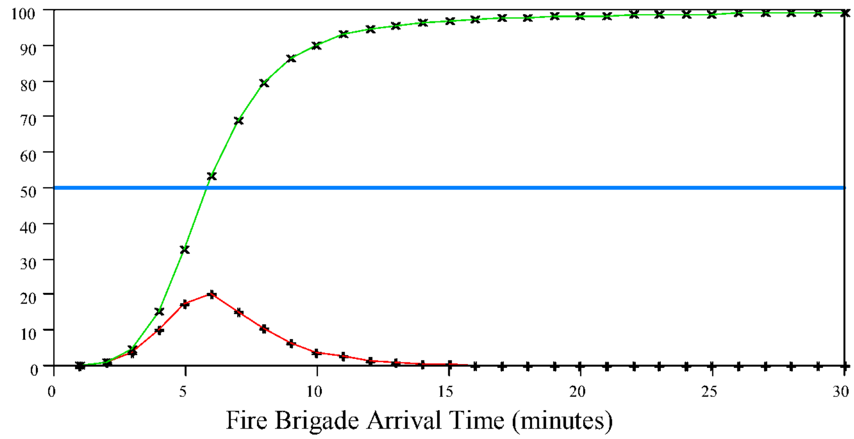
Vertical axis is % of Fires

Figure 4.4: Time from Alarm to Fire Brigade Arrival for Commercial Buildings with Sprinklers Not Present



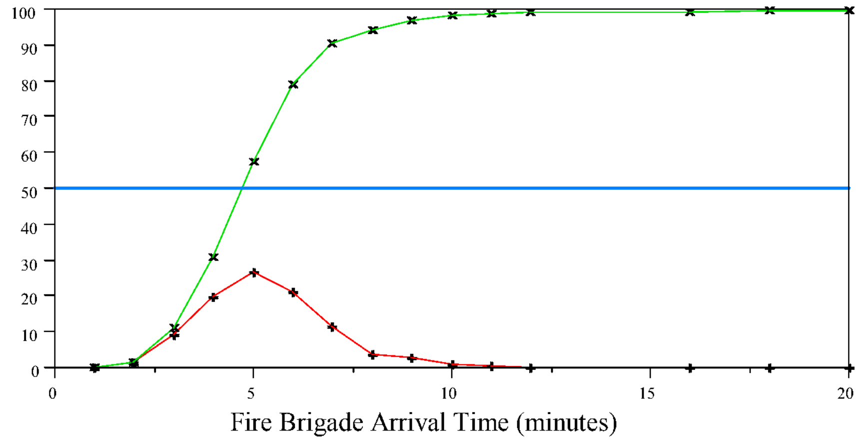
Vertical axis is % of Fires

Figure 4.5: Time from Alarm to Fire Brigade Arrival for Commercial Buildings with Sprinklers Present



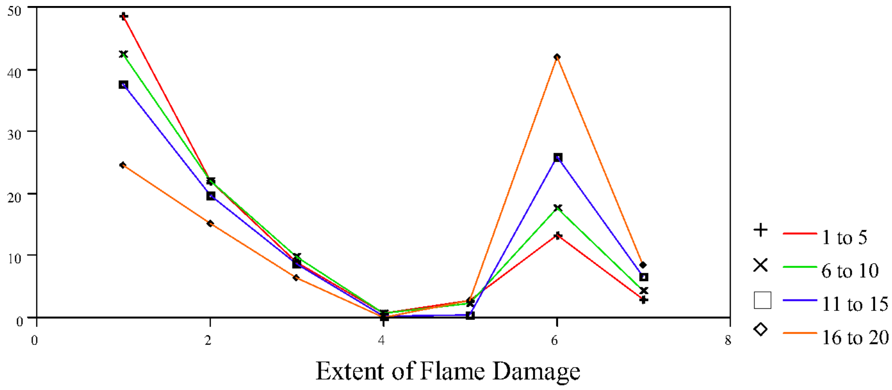
Vertical axis is % of Fires

Figure 4.6: Time from Alarm to Fire Brigade Arrival for Residential Buildings with Sprinklers Not Present



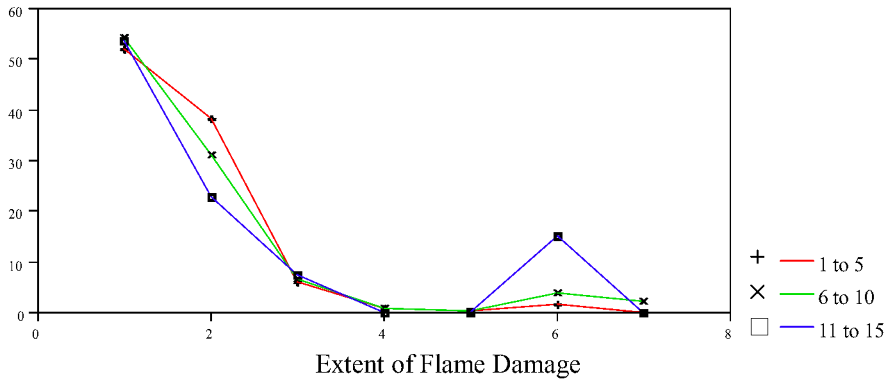
Vertical axis is % of Fires

Figure 4.7: Time from Alarm to Fire Brigade Arrival for Residential Buildings with Sprinklers Present



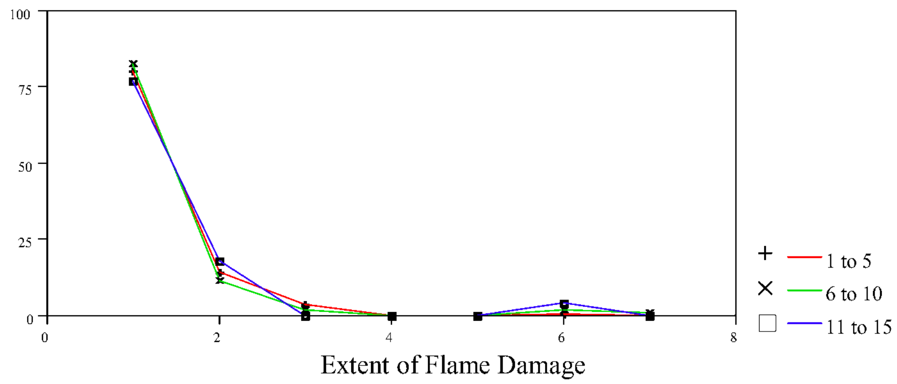
Vertical axis is % of Fires

Figure 4.8: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Commercial Buildings with Sprinklers Not Present



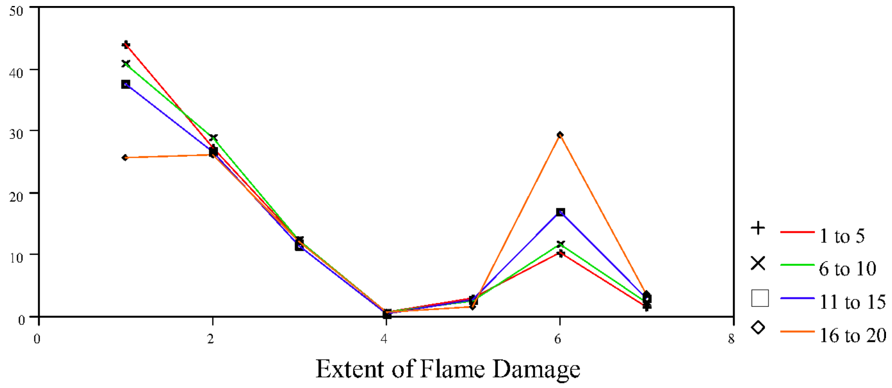
Vertical axis is % of Fires

Figure 4.9: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Commercial Buildings with Sprinklers Present and Operated



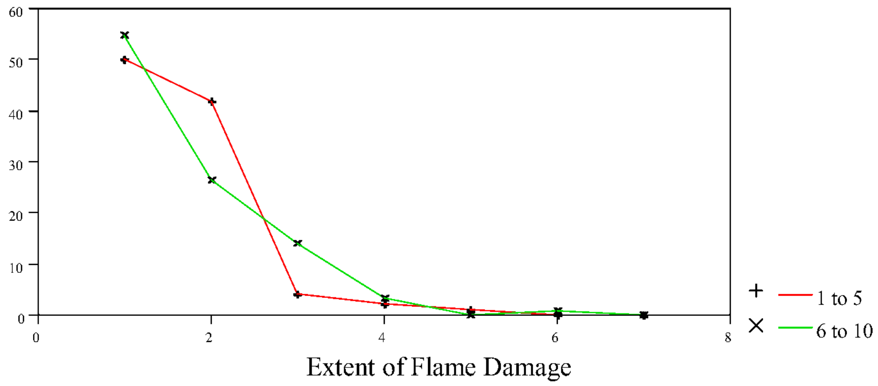
Vertical axis is % of Fires

Figure 4.10: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Commercial Buildings with Sprinklers Present But Did Not Operate



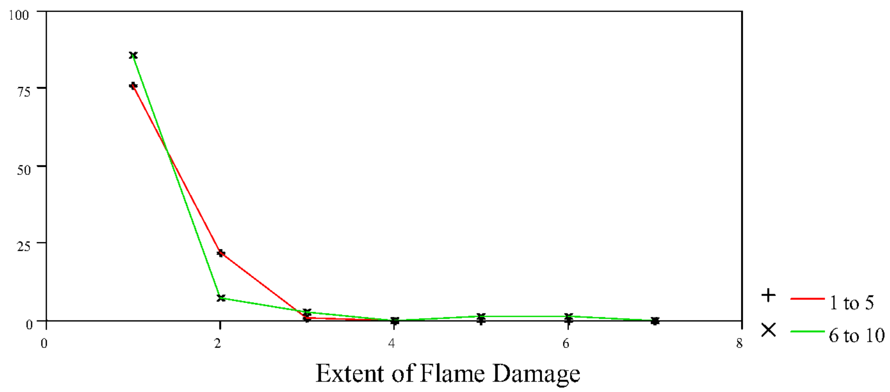
Vertical axis is % of Fires

Figure 4.11: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Residential Buildings with Sprinklers Not Present



Vertical axis is % of Fires

Figure 4.12: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Residential Buildings with Sprinklers Present and Operated



Vertical axis is % of Fires

Figure 4.13: Effect of Fire Brigade Arrival Time on Extent of Flame Damage for Residential Buildings with Sprinklers Present But Did Not Operate

It can be seen in Figure 4.8 that for *commercial* buildings with *sprinklers not present*, as the *fire brigade arrival time* increases, the percentage of fires *confined to the object of origin* reduces:

- nearly 50% are *confined to the object of origin* for the 1 to 5 minute interval
- about 25% are *confined to the object of origin* for 16 to 20 minute interval

The proportion remaining *confined to the part of room or area of fire origin* also reduces but to a lesser extent (from about 22% to about 15 %).

Only minor changes occur in the proportions *confined to the room, fire-rated compartment and floor of origin*. Virtually all of the increases compensating for the reductions mentioned above occur by way of fires with flame damage *confined to the structure of origin* and to a much lesser extent fires resulting in flame damage *extending beyond the structure of origin*.

Thus, as the *fire brigade arrival time* increases, the percentage of fires *confined to the structure of origin* increases:

- about 15% are *confined to the structure of origin* for the 1 to 5 minute interval
- about 45% are *confined to the structure of origin* for the 16 to 20 minute interval

It is also notable in Figure 4.8 that the overwhelming majority of fires notified to the fire brigade are in the categories EFD 1, EFD 2 and EFD 3 and are therefore confined to the room of origin during the 1 to 5 minute interval but that this reduces substantially as the *fire brigade arrival time* increases. The cumulative percentages (%EFD 1 + %EFD 2 + %EFD 3) are:

- about 80% of fires are *confined to the room of origin* for the 1 to 5 minute interval
- about 46% of fires are *confined to the room of origin* for the 16 to 20 minute interval

In fires in *commercial* buildings in which the *sprinklers were present and operated* (Figure 4.9) there was little change in the percentage of fires *confined to the object of origin* (between about 50 and 55%), with the largest decrease occurring in the percentage *confined to the part of room or area of origin* (from about 40% with *fire brigade arrival* during the 1 to 5 minute interval to just less than 25% for arrival during the 11 to 15 minute interval). The majority of the compensating increase occurred in fires *confined to the structure of origin* (from about 1% to about 15%).

Thus in *commercial* buildings in which the *sprinklers were present and operated* with the *fire brigade arrival time* in the interval 1 to 5 minutes only about 3% of fires were **not** *confined to the room of origin*, whereas at the 11 to 15 minute interval the percentage was about 11%, a fourfold increase.

It is obvious from Figure 4.10 that there was very little effect of the *fire brigade arrival time* on the proportions of fires in the various extent of flame damage categories for *commercial* buildings in which the *sprinklers were present but did not* *operate*. The reason for this is obviously that the overwhelming reason for the sprinklers not operating was that the fire did not grow sufficiently to trigger their operation.

The pattern with increasing *fire brigade arrival time* was similar for residential buildings.

It is obvious in Figure 4.11 that for *residential* buildings with *sprinklers not present* the major changes that occur between the 1 to 5 minute and 16 to 20 minute *fire brigade arrival time* intervals are a decrease in the proportion of fires *confined to the object of origin* from about 45% to about 25%. There is a compensating increase in those *confined to the structure of origin* from about 10% to 30%.

Thus for *residential* buildings with *sprinklers not present* the total proportion of fires **not** *confined to the room of origin* changed from about 18% to about 38% over this time interval.

There was a little more variability with increases in *fire brigade arrival time* in the case of *residential* buildings in which *sprinklers* were *present and operated* than for *commercial* buildings, but the overall effect was similar: the total proportion of fires **not** *confined to the room of origin* remained about 4% over the reduced (compared with the preceding figures) range of *fire brigade arrival times* covered in Figure 4.12.

There was no significant change in the total percentage of fires for which flame damage remained *confined to the room of origin* for *residential* buildings with *sprinklers present but did not operate*, whatever the reason (Figure 4.13).

Overall, it is obvious that increased *fire brigade arrival times* resulted in greater flame damage (increased fire spread) in both sprinklered and unsprinklered *commercial* buildings, but in *residential* buildings the sensitivity (that is, degree of change between categories) to *time of fire brigade arrival* was very much greater in unsprinklered buildings.

4.1.4 Variation of Civilian Fatalities with Extent of Flame Spread

The variation in the number and rate of *civilian* fatalities with *extent of flame damage* will be investigated for *residential* and *commercial* buildings and each of the three sprinkler cases (*sprinklers not present, sprinklers present and operated*, and *sprinklers present but did not operate*) below, but it is worthwhile at this stage to present an overall perspective.

(The number of *fire fighter* fatalities is so low that no meaningful analysis of this sort can be undertaken.)

The variation in the number and rate (fatalities per 1000 fires) of *civilian* fatalities with *extent of flame damage* is shown in Table 4.2. Also shown in Table 4.2 and graphed in Figure 4.14 is the standardised fatality rate (obtained by dividing the fatality rate for each *extent of flame damage* category by the fatality rate for fires with *flame damage confined to the object of origin*).

In Table 4.2 it is apparent that in both *residential* and *commercial* buildings by far the largest number of *civilian* fatalities occurred in fires where the *extent of flame damage* was classified as *confined to the structure of origin*. In both building uses the next highest number of *civilian* and *fire fighter* fatalities occurred in fires *confined to the room of origin*. In *residential* buildings significant numbers of *civilian* fatalities also occurred in fires *confined to the part of room or area of origin* and *confined to the floor of origin*, and fires in which flame damage *extended beyond the structure of origin*.

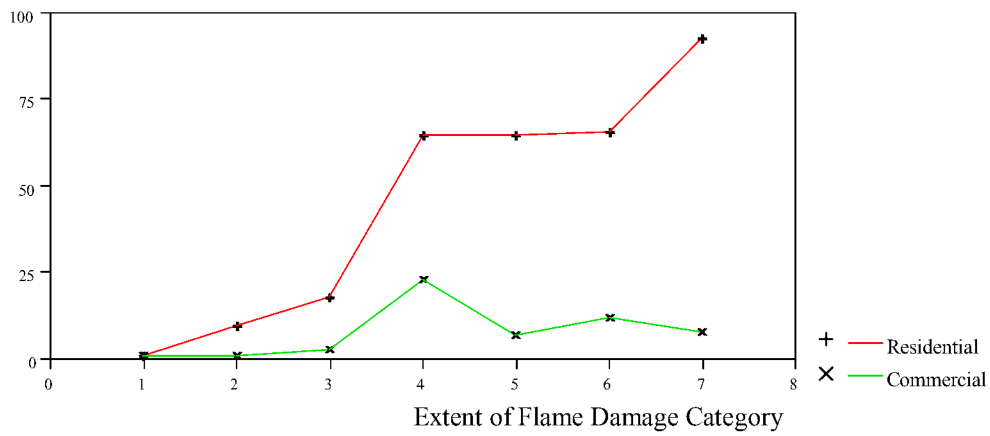
Table 4.2 Variation of Number of Fires, Civilian Fatalities and Fatality Rates with Extent of Flame Damage

Extent of Flame Damage	Fires	Fatal-ities	Fatality Rate (fatal-ities/ 1000 fires)	Stand-ardised Fatality Rate	Fires	Fatal-ities	Fatality Rate (fatal-ities/ 1000 files)	Stand-ardised Fatality Rate
	Residential Buildings				Commercial Buildings			
Confined to the object of origin	9945	4	0.40	1	7381	3	0.41	1
Confined to the part of room or area of origin	6930	28	4.04	10	3546	1	0.28	1
Confined to the room of origin	4951	35	7.07	18	2516	3	1.19	3
Confined to the fire-rated compartment of origin	191	5	26.2	65	106	1	9.43	-
Confined to the floor of origin	652	17	26.1	65	369	1	2.71	7
Confined to the structure of origin	4130	109	26.4	66	3580	17	4.75	12
Extended beyond the structure of origin	537	20	37.2	93	583	2	3.43	8

A clear trend of increasing *standardised rate of civilian fatalities* with increasing *extent of flame damage* is obvious for *residential* buildings (Figure 4.14) and to a lesser degree also for *commercial* buildings. (The "blip" in the rate for *commercial* buildings for fires with flame damage *confined to the fire-rated compartment of origin* may not be significant, merely a function of the comparatively small number of fires *confined to the fire-rated compartment of origin*.)

The standardised fatality rates make it obvious that there is a great increase in the risk to civilians as the *extent of flame damage* increases, particularly in *residential* buildings. Thus it appears reasonable to conclude that confining fires to the room of origin, or even better, the object of origin, is a laudable objective to achieve minimisation (or even a reduction) of the number of civilian fatalities.

If all fire starts reported in the data base had been *confined to the object of origin* and the rate of civilian fatalities for fires *confined to the object of origin* remained the same, the number of civilian fatalities would be reduced from 251 to 14 for *residential* buildings (a factor of 18) and from 30 to 10 for *commercial* buildings. Note however, that it is by no means certain that the rate would remain the same if the *extent of flame damage* in all fires was *confined to the object of origin*.



Vertical axis is Standardised Rate of Civilian Fatalities (EFD 1 = 1)

Figure 4.14 Variation of Standardised Rate of Civilian Fatalities with Extent of Flame Damage Categories

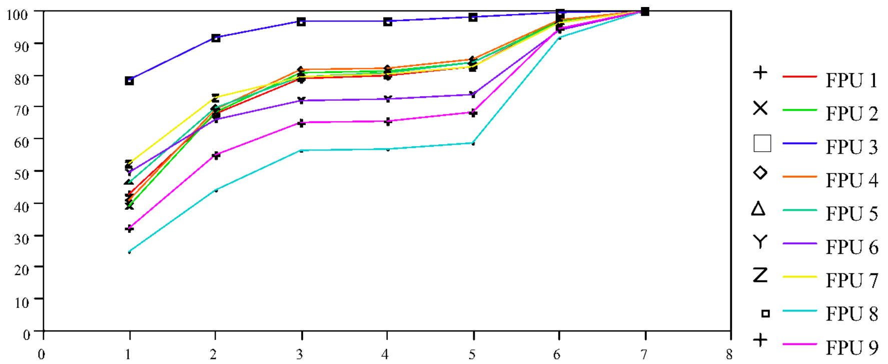
4.1.5 Effect of Fixed Property Use on Extent of Flame Spread

Although this analysis concentrates in the main on only the two building use categories mentioned above (*residential* and *commercial*) it is worthwhile mentioning some data that is available that reveals significant differences between the various categories of buildings grouped together in the category *commercial* elsewhere in this analysis.

Figures 4.15 to 4.17 show the variation in the cumulative percentage of fires by extent of flame damage for the Fixed Property Use (FPU)[1] categories as follows:

- FPU 1 Public Assembly
- FPU 2 Educational
- FPU 3 Institutional
- FPU 4 Residential
- FPU 5 Shop, Office, etc
- FPU 6 Basic Industry
- FPU 7 Manufacturing
- FPU 8 Storage
- FPU 9 Special
- FPU 0 Unclassified, unknown, etc

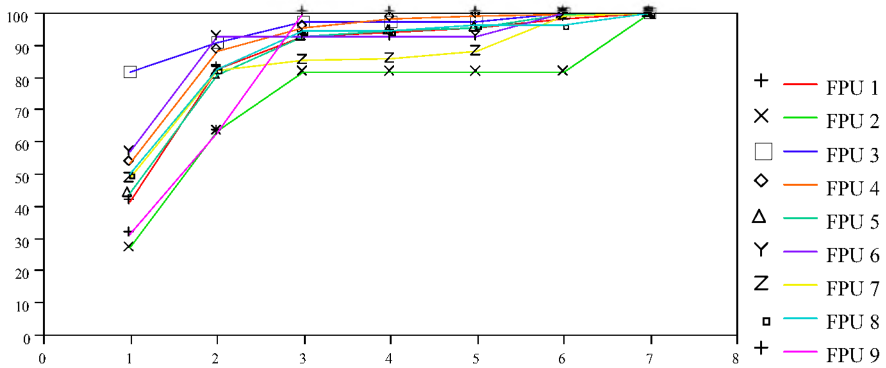
It is clear from Figure 4.15 that with *sprinklers not present* in the room of fire origin, fires in *institutional* buildings (these include care of aged, young, sick, injured, physically restrained, physically inconvenienced (handicapped), mentally handicapped, etc) are much more likely to have *flame damage confined to the object of fire origin* than fires in other buildings. In *institutional* buildings 79% of fires had the *flame damage confined to the object of origin*, whereas for the other categories the percentage ranged from a low of 25% for *storage* buildings (these include storage of agricultural products, textiles, processed food, tobacco, petroleum products, alcoholic beverages, wood, paper, chemicals, plastics, metal, metal products, vehicles, general, etc), 33% for *special* buildings (these include buildings under construction, unoccupied, special structures, etc), to a high of 52% for *manufacturing* buildings.



Extent of Flame Damage Category

Vertical axis is Cumulative % of Fires

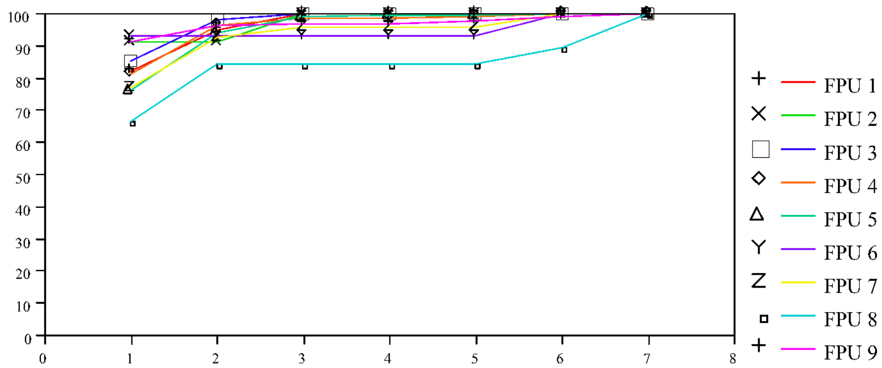
Figure 4.15 Cumulative Extent of Flame Damage by Fixed Property Use, Sprinklers Not Present



Extent of Flame Damage Category

Vertical axis is Cumulative % of Fires

Figure 4.16 Cumulative Extent of Flame Damage by Fixed Property Use Sprinklers Present and Operated



Extent of Flame Damage Category

Vertical axis is Cumulative % of Fires

Figure 4.17 Cumulative Extent of Flame Damage by Fixed Property Use Sprinklers Present But Did Not Operate

The increase in the percentage of fires with *flame damage confined to the room of origin* compared with those *confined to the object of origin* can be seen in Figure 4.15 to be very similar for all of the FPU categories except *basic industry* buildings (these include utility, defence, nucleonics, energy production, laboratories, communications, defence, document facilities, utility, energy distribution systems, sanitary services, agriculture, forests, mining, etc). The increase in percentage for *basic industry* buildings is about half that for buildings in the other FPU categories.

The percentage of fires with *flame damage confined to the room of origin* ranges from a high of 97% for *institutional* buildings, to a low of 56% for *storage* buildings with buildings in the other FPU categories in the range 65% to 82% with the majority being about 80%.

In none of the FPU categories is there any significant increase in the percentage of fires with *flame damage confined to the fire-rated compartment of origin* compared with the percentages of fires with *flame damage confined to the room of origin*.

Comparison of Figure 4.15 (*sprinklers not present)* with Figures 4.16 (*sprinklers present and operated*) and 4.17 (*sprinklers present but did not operate*) indicates that for every FPU category the presence of sprinklers, whether they operate or not, results in greater percentages of fires with flame damage *confined to the object of origin and the room of origin* than for fires with *sprinklers not present*.

Comparison of Figures 4.16 and 4.17 reveals a fact that may seem surprising at first glance - for all FPU categories the percentage of fires with flame damage *confined to the object of origin* is greater when the *sprinklers were present but did* ***not*** *operate* than when they *did operate*. However, this can be satisfactorily explained when it is realised that the most common reason for sprinklers not operating is because the fire did not become large enough to trigger them.

A comparison of Figures 4.16 (*sprinklers present and operated*) and 4.17 (*sprinklers present but did not operate*) in terms of the cumulative percentage of fires with flame damage *confined to the room of origin* for each FPU category is not so clear cut - for five of the nine FPU categories the cumulative percentage was higher when the *sprinklers were present but did not operate*, for one it was equal, and for the remaining three it was lower.

In Figures 4.16 and 4.17 three FPU categories particularly stand out in comparison with the others:

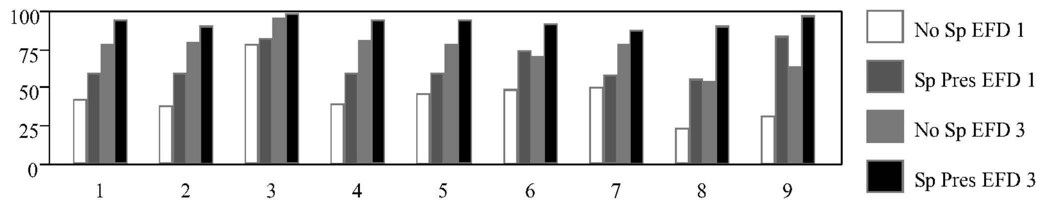
- for the *sprinklers present and operated* case (Figure 4.16) *educational* buildings remain substantially lower than the other buildings for all *extent of flame damage* categories
- again for the *sprinklers present and operated* case, the increase in percentage for *special* buildings continues to the *confined to the room of origin* category to the extent that for these buildings no flame damage is recorded as having occurred beyond the room of fire origin when the *sprinklers were present and operated*

- for the *sprinklers present but did not operate* case (Figure 4.17) *storage* buildings had a significantly lower percentage of fires *confined to each extent of flame damage category* than any of the other FPU categories

The overall effect of the presence of sprinklers may be observed in Figure 4.18. In this figure the cumulative percentages for *sprinklers present* (*whether they operated or not*) are compared with those for *sprinklers not present* for fires in which flame damage was *confined to the object of origin* (EFD 1) and *confined to the room of origin* (EFD 3) for each FPU category.

In all FPU categories there was some benefit associated with the *presence of sprinklers* in terms of fires with flame damage *confined to the object of origin*. In the cases of *institutional* buildings and *manufacturing* buildings, the benefit appears to be only marginal, but for the other building categories the benefit was substantial - generally an increase of more than 20%, with a maximum increase of 52% for *special* buildings.

Cumulative Percentage



Extent of Flame Damage Category

Vertical axis is Cumulative % of Fires

Figure 4.18 Comparison of Effect of Sprinkler Presence by FPU

In terms of fires with the extent of flame damage *confined to the room of fire origin* there was also some benefit associated with the presence of sprinklers for all FPU categories. The smallest increase in cumulative percentage was for *institutional* buildings, but this was because the increase was from 97% to 99%. The remaining increases ranged between 80% to 89% (that is, 9%) for *manufacturing* buildings and 56% to 91%(that is, 35%) for *storage* buildings.

(As there was virtually no difference between the cumulative percentage of fires recorded as having the extent of flame damage *confined to the room of origin* and *confined to the fire-rated compartment of origin* it may be said that the presence of sprinklers had very similar effects in increasing the cumulative percentages of fires with flame damage *confined to the fire-rated compartment of origin*.)

The cumulative percentages of fires with flame damage *confined to the room of origin* was: FPU 1 - 96%, FPU 2 - 91%, FPU 3 - 99%, FPU 4 - 96%, FPU 5 - 96%, FPU 6 - 93%, FPU 7 - 89%, FPU 8 - 91% and FPU 9 - 98%.

However, this way of looking at the benefits associated with the presence of sprinklers under-rates the **improvement** in limiting the *extent of flame damage*.

The relevant objective here is **to minimise the number of fires for which flame damage is not confined**. For example, the percentage of fires where the fire was **not** *confined to the room of origin* was reduced from 3% to 1% for *institutional* buildings: thus the number of fires where the *extent of flame damage* was **not** *confined to the room of origin* was reduced by a factor of three (3).

Similarly, for *storage* buildings the percentage of fires with *extent of flame damage* **not** *confined to the room of origin* was reduced from 44% to 9%, a factor of about five (5).

Thus the effect of the presence of sprinklers was to reduce the occurrence of failures (with failure defined as the *flame damage extending beyond the room of origin*) by factors of three and five for these cases. Analysis of the figures for all FPU categories shows a minimum reduction of a factor of just under two to a maximum of about 17, with the majority being in the range three to five.

4.1.6 Residential Buildings

In this section some of the data available for residential buildings will be examined. This will be done in terms of some of the fields available in the fire data, such as area of fire origin, form of heat of ignition, ignition factor, etc. Including in this document full details of these fields would require too much space so that, if further details are required, Reference 1 should be consulted.

The concentration in this section will mainly be on fires causing civilian fatalities. Similar analysis is possible in relation to civilian and fire fighter injuries and property damage, but these will not be covered in detail in this report.

Area of Fire Origin (AFO)

The AFO specifies the area within a building where a fire originated and is recorded in terms of nine major categories:

- means of egress
- assembly, sales areas (groups of people)
- functional areas
- storage areas
- service facilities
- service, equipment areas
- structural areas
- transportation, vehicle areas
- other area of origin

There are many sub-categories within each of these categories. A quirk in the classification that is rather incongruous for *residential* buildings is that *lounge* areas are included in the *assembly, sales areas* category.

The AFO is known for fires resulting in 201 of the 250 civilian fatalities. Of the 201 fatalities 118 (or 59%) were from fires starting in a *residential* area and sixty-two

(31%) from fires in an *assembly, sales* area, thus these two categories account for 90% of all civilian fatalities.

Sixty-one of the sixty-two civilian fatalities in the fires originating in *assembly, sales* areas were from *lounge* areas. The resulting rate of fatalities was 14 per 1000 fires.

Of the civilian deaths resulting from fires originating in *residential* areas seventy-four were from sleeping rooms (14 fatalities per 1000 fires) and thirty-five were from a much larger number of fires originating in dining and kitchen areas (2.9 fatalities per 1000 fires). Further details of these fires are shown in Table 4.3.

Table 4.3 Area of Fire Origin of Selected Fires in Residential Buildings

Area of fire origin	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatal-ities	Fire Brigade Fatal-ities	$ Loss
Lounge Area	4441	397	75	61	1	93763400
Sleeping Rooms	5293	714	88	74	1	127805996
Dining and Kitchen	12226	653	60	35	0	90683746

Fires starting in *assembly, sales* and *residential* areas accounted for 24,488 (74%) of the fires with known AFO. The fires represented in Table 4.3 amount to the majority of these (21,960 fires or 66% of fires with known AFO) and also account for 85% of civilian injuries, 66% fire fighter injuries, 50% fire fighter fatalities and 73% of the estimated property damage in fires with known AFO.

Form of Heat of Ignition (FHI)

The FHI specifies the form of heat energy that ignited the fire and is classified in nine major categories as follows:

- heat from fuel-fired, fuel-powered object
- heat from electrical equipment arcing, overloaded
- heat from smoking material
- heat from open flame, spark
- heat from hot object
- heat from explosive, fireworks
- heat from natural source
- heat spreading from another hostile fire (exposure)
- other form of heat of ignition

There are many sub-categories within each of these categories, but these will not be discussed in this report. As may be intuitively expected the FHI is unknown for many of the fires in the database.

The FHI of the fire is unknown for 117 of the fires involving the 250 civilian fatalities. Of the remaining 133 civilian fatalities the largest group (41 or 31%) were initiated by *heat from hot objects*, which was also the FHI resulting in the largest number of fires overall (9943 or 33% of the fires with known FHI), resulting in a civilian fatality rate of 4.1 civilian fatalities per 1000 fires. Details of the fires with known FHI that resulted in more than ten civilian fatalities per FHI category are shown in Table 4.4.

Table 4.4 Form of Heat of Ignition of Selected Fires in Residential Buildings

Form of Heat of Ignition	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatal-ities	Fire Brigade Fatalities	$ Loss
Heat from Hot Object	9943	551	78	41	0	59571250
Smoking Material, etc	1955	213	34	29	0	20530800
Heat from Open Flame	5559	480	67	27	0	111117496
Electrical equipment arcing, overloaded	6491	240	49	22	1	77084600

The FHI category with the highest rate of civilian fatalities was *smoking material* with a rate of 15 civilian fatalities per 1000 fires. The rates for the other significant FHI categories were: *heat from open flame, spark* 4.9 civilian fatalities per 1000 fires and *electrical equipment arcing, overloaded* 3.4 civilian fatalities per 1000 fires.

Ignition Factor (IF)

The IF is the situation that permitted the heat source and combustible material to combine and start a fire. It is classified in terms of the following major categories:

- incendiary
- suspicious
- misuse of heat of ignition
- misuse of material ignited
- mechanical failure, malfunction
- design, construction, installation deficiency
- operational deficiency
- natural condition
- other ignition factor

The IF is unknown for the fires that resulted in ninety-one out of the 250 civilian fatalities. Of the fires resulting in the 161 civilian fatalities with known IF the fires resulting in sixty-one (38%) of the civilian fatalities were due to *misuse of heat of ignition*, and twenty-eight (17%) were due to *misuse of material ignited*. Further details of the fires with known IF that resulted in more than ten civilian fatalities per IF category are shown in Table 4.5.

Unfortunately, the rate of highest rate of civilian fatalities occurs for fires with IF category *unknown*. The IF categories with the highest rate of civilian fatalities are *misuse cf heat cf ignition* and *misuse cf material ignited*, both with 11 civilian fatalities per 1000 fires, *natural conditions* and *suspicious* with 10 civilian fatalities per 1000 fires and *incendiary* with 8.1 civilian fatalities per 1000 fires.

A high rate of civilian injuries also occurred in fires with IF category *unknown*, but the highest rate occurred in fires due to *misuse cf heat cf ignition* (96 civilian injuries per 1000 fires). High civilian injury rates also occurred in fires due to *incendiary* (86 civilian injuries per 1000 fires) and *misuse cf material ignited* (81 civilian injuries per 1000 fires).

Table 4.5 Ignition Factor for Selected Fires in Residential Buildings

Ignition Factor	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatal-ities	Fire Brigade Fatalities	$ Loss
Misuse of Heat of Ignition	5799	554	59	61	0	62684300
Misuse of Material Ignited	2575	209	29	28	1	30736800
Suspicious	2250	142	39	22	1	62320750
Mechanical Failure	7889	268	63	21	0	80298650
Operational Deficiency	8568	489	24	13	0	57087500
Incendiary	1361	117	25	11	0	58543648

The highest rates of fire fighter injuries occurred in fires with *unknown* IF category Of the remainder, *incendiary* with a rate of 18 fire fighter injuries per 1000 fires, was highest.

Detector Performance (DP)

The detector performance effectively records whether fire detectors are installed in the building and, if so, their effectiveness. The possible entries in this field are:

- detector(s) in the room or space of fire origin and they operated
- detector(s) not in the room or space of fire origin and they operated
- detector(s) in the room or space of fire origin and they failed to operate
- detector(s) not in the room or space of fire origin and they did not operate
- detector(s) in the room or space of fire origin failed to operate due to low severity of fire
- no detectors present
- performance of detection equipment not classified above, undetermined or unreported (unknown)

Table 4.6 shows the performance of detectors in fires in residential buildings, and the fatality, injury and property loss outcomes of those fires.

The fires with *no detectors present* and with *unknown* detectors both resulted in 7.1 civilian fatalities per 1000 fires. The 562 fires with *detectors in the room of origin and they operated* resulted in 11 civilian fatalities per 1000 fires. In all there were 875 fires with detectors present (whether they operated or not) and in those fires there were 6 civilian fatalities - a rate of 7 civilian fatalities per 1000 fires.

The fires with *detectors in the room of origin and they operated* resulted in a civilian injury rate of 110 civilian injuries per 1000 fires - well above average, as was the rate for civilian fatalities (above) in this DP category.

Table 4.6 Detector Performance for Fires in Residential Buildings

Detector Performance	Fires	Civilian Injury	Fire Brigade Injury	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Detectors in the room or space of fire origin and they operated	562	62	10	6	0	1920150
Detectors not in room of fire origin and they operated	142	3	9	0	0	1073100
Detectors in room of fire origin - failed to operate	69	2	0	0	0	138950
Detectors not in room of fire origin - did not operate	40	0	0	0	0	45200
Detectors in room of fire origin failed to operate due low fire severity	62	1	0	0	0	272000
No detectors present	21058	1348	168	149	1	271588544
Unknown	13370	776	195	95	3	208417990

The fire fighter injury rate was particularly high (110 injuries per 1000 fires) for *detectors not in the room or space of fire origin and they operated* but was also above average for *detectors in the room of origin and they operated* (18 injuries per 1000 fires).

However, the estimated $ loss per fire was lower than average in both *detectors not in the room or space of fire origin and they operated* ($3400 per fire) and *detectors in the room of origin and they operated* ($7600 per fire). The highest rate was $16,000 per fire for detectors *unknown*.

Major Method of Extinguishment (MME)

The MME identifies the method that had the major effect in extinguishing the fire, and uses the following major categories:

- self-extinguished
- makeshift aids (garden hoses, etc)
- portable fire extinguisher
- automatic extinguishing system
- appliance hose line or reel with water carried in apparatus tanks

- hoseline(s) with water direct from hydrant, standpipe
- hoseline(s) with water from pump (from reticulated or static supplies)
- master stream device(s) with or without hand line(s)
- unknown, etc

As shown in Table 4.6 the largest number of fires was extinguished using an *appliance hose line or reel with water carried in apparatus tanks*, but a very large number of fires was extinguished using a *portable fire extinguisher*. The number of *self-extinguished* fires was also very significant.

The MME was *unknown* for 5400 fires.

Table 4.6 Major Method of Extinguishment for Fires in Residential Buildings

Major Method of Extinguishment	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$Loss
Self Extinguished	4795	93	8	20	0	8630600
Makeshift Aids	8438	467	52	7	0	28593050
Portable Fire Extinguisher	3229	124	6	3	1	9476250
Automatic Extinguishers	290	6	0	0	0	445850
Hose Line/Reel	10735	909	165	123	1	287419082
Hose Line from Hydrant	628	69	18	9	0	23172900
Hose Line from Pump, etc	1759	266	82	73	0	119275044
Master Stream Device	29	0	0	0	0	182750

Extent of Smoke Damage (ESD)

The extent of smoke damage is categorised in AS 2577 - 1983[1] in seven categories representing progressively greater spread of smoke damage through the building. Smoke damage includes heat scorching (but not actual burning or charring). The *extent of smoke damage* categories are:

- ESD 9 No damage of this type
- ESD 1 Confined to the object of origin
- ESD 2 Confined to part of room or area of origin
- EFD 3 Confined to room of origin
- EFD 4 Confined to fire-rated compartment of origin
- EFD 5 Confined to floor of origin
- EFD 6 Confined to structure of origin
- EFD 7 Extended beyond structure of origin

The extent of smoke damage and the occurrence of fatalities, injuries and (estimated) property loss is given in Tables 4.7, 4.8 and 4.9 for the *sprinklers not present*, *sprinklers present* and *sprinkler presence unknown* cases respectively.

In the case of *sprinklers not present* smoke damage was *confined to the room of origin* in 56% of the fires and smoke damage *extended throughout or beyond the structure of origin* in 30% of fires (Table 4.7).

Table 4.7 Extent of Smoke Damage for Fires in Residential Buildings Sprinklers Not Present

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	2603	46	2	1	0	7601700
Confined to object of origin	2640	31	6	2	0	3763800
Confined to part of room or area of origin	2504	83	6	2	0	4527750
Confined to room of origin	2972	150	8	5	0	11631650
Confined to fire rated compartment of origin	714	86	3	5	0	3827950
Confined to floor of origin	1422	163	11	5	0	18454350
Confined to structure of origin	4951	599	118	75	1	1.729e8
Extended beyond structure of origin	471	79	11	29	0	23642300

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinklers not present* where the smoke damage *extended beyond the room of origin*:

- the civilian fatality rate was 0.9 fatalities per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 15.1 fatalities per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the civilian injury rate was 28.9 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 122 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 2.1 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 19 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinklers not present* with smoke damage that **did not** *extend beyond the room of origin* on average resulted in 6% of the civilian fatalities, 25% of the civilian injuries and 11% of the fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

In the case of fires with *sprinklers present* smoke damage was *confined to the room of origin* in a total of 89% of the fires and smoke damage *extended throughout or beyond the structure of origin* in only 3.4% of fires (Table 4.8).

Table 4.8 Extent of Smoke Damage for Fires in Residential Buildings Sprinklers Present

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	160	0	0	0	0	53350
Confined to object of origin	139	0	0	0	0	180700
Confined to part of room or area of origin	112	1	0	0	0	160700
Confined to room of origin	105	3	5	0	0	577200
Confined to fire rated compartment of origin	15	1	0	0	0	41200
Confined to floor of origin	29	2	0	0	0	77600
Confined to structure of origin	17	1	1	0	0	359850
Extended beyond structure of origin	3	0	0	0	0	10050

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires where the smoke damage *extended beyond the room of origin*:

- there were no civilian fatalities in fires with smoke damage that **did not** *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- there were no civilian fatalities in fires with smoke damage that did *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the civilian injury rate was 8 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 50 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin* (but the number of fires and the number of injuries were both very low so this must be treated with great caution)
- the fire fighter injury rate was 8 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 50 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin* (but again the number of fires and the number of injuries were both very low so this must be treated with great caution)

As the number of fires and the number of injuries were both very low great caution must be exercised in drawing conclusions from this data. However it appears likely from these figures that fires with *sprinklers present* with smoke damage that **did not** *extend beyond the room of origin* would on average result in about 16% of the civilian and fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

Comparing the *sprinklers not present* and *sprinklers present* cases it appears that the *sprinklers present* case is clearly better in terms of civilian injuries (29 compared with 8 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin* and 122 compared with 50 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*). However, perhaps surprisingly, it appears worse in terms of fire fighter injuries (2.1 compared with 8 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin* and 19 compared with 50 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*).

In the case of *sprinkler presence unknown* smoke damage was *confined to the room of origin* in a total of 47% of the fires and smoke damage *extended throughout or beyond the structure of origin* in 48% of fires (Table 4.9).

Table 4.9 Extent of Smoke Damage for Fires in Residential Buildings Sprinklers Presence Unknown

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	1061	35	1	3	0	6199300
Confined to object of origin	830	27	2	4	0	3153600
Confined to part of room or area of origin	860	55	5	5	0	3329750
Confined to room of origin	1457	80	13	2	0	7635400
Confined to fire rated compartment of origin	120	19	1	2	0	844550
Confined to floor of origin	373	34	7	2	0	6442800
Confined to structure of origin	4157	490	98	79	2	1.7109e8
Extended beyond structure of origin	172	18	12	1	0	5257150

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinkler presence unknown* where the smoke damage *extended beyond the room of origin*:

- the civilian fatality rate was 3.3 fatalities per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 18 fatalities per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the civilian injury rate was 46.7 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 117 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*

- the fire fighter injury rate was 5.0 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 25.4 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinkler presence unknown* with smoke damage that **did not** *extend beyond the room of origin* on average resulted in 18% of the civilian fatalities, 40% of the civilian injuries and 20% of the fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

There are significant differences between the *sprinkler presence unknown* case and the *sprinklers not present* and *sprinkler present* cases. It does not represent a weighted average of the two other cases and therefore there may be some other influence effecting the statistics for these fires. No explanation of these differences is offered.

Extent of Flame Damage (EFD)

The categories for *extent of flame damage* are given in Section 4.1.3.

The extent of flame damage and the occurrence of fatalities, injuries and (estimated) property loss is given in Tables 4.10, 4.11 and 4.12 for the *sprinklers not present, sprinklers present* and *sprinkler presence unknown* cases respectively.

In the case of *sprinklers not present* flame damage was *confined to the room of origin* in a total of 82% of fires and flame damage *extended throughout or beyond the structure of origin* in 15% of fires (Table 4.10).

Table 4.10 Extent of Flame Damage for Fires in Residential Buildings Sprinklers Not Present

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	7422	165	10	2	0	10598000
Confined to part of room or area of origin	5055	334	22	12	0	24593400
Confined to room of origin	2227	270	18	13	1	28135700
Confined to fire rated compartment of origin	146	40	6	4	0	3665600
Confined to floor of origin	493	92	11	12	0	22342950
Confined to structure of origin	2229	274	87	60	0	1.2656e8
Extended beyond structure of origin	414	49	9	19	0	26367350

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinklers not present* where the flame damage *extended beyond the room of origin*:

- the civilian fatality rate was 1.8 fatalities per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 29.9 fatalities per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the civilian injury rate was 52.3 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 122 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 3.4 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 36.3 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the estimated loss averaged $4300 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the estimated loss averaged $58,000 per fire for all of the fires with flame damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinklers not present* with flame damage that **did not** *extend beyond the room of origin* on average resulted in 6% of the civilian fatalities, 43% of the civilian injuries, 9% of the fire fighter injuries and 7% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

In the case of fires with *sprinklers present* flame damage was *confined to the room of origin* in a total of 96% of the fires and *flame damage extended throughout or beyond the structure of origin* in only 0.7% of fires (Table 4.11).

Table 4.11 Extent of Flame Damage for Fires in Residential Buildings Sprinklers Present

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	347	3	5	0	0	757800
Confined to part of room or area of origin	168	4	1	0	0	286900
Confined to room of origin	33	1	0	0	0	65150
Confined to fire rated compartment of origin	13	0	0	0	0	2000
Confined to floor of origin	4	0	0	0	0	38000
Confined to structure of origin	3	0	0	0	0	300050
Extended beyond structure of origin	1	0	0	0	0	5000

The civilian and fire fighter injuries occurred only in fires where the flame damage was confined to the room of origin, but it must be noted that the number of fires where flame damage extended beyond the room of origin was extremely small (and no injuries or fatalities would have been expected in such a small number of fires in fires where flame damage was *confined to the room of origin*):

- there were no civilian fatalities in fires with flame damage that **did not** *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- there were no civilian fatalities in fires with flame damage that did *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the civilian injury rate was 15 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- there were no civilian injuries in fires with flame damage that did *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the fire fighter injury rate was 11 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- there were no fire fighter injuries in fires with flame damage that did *extend beyond the room of origin* (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the estimated loss averaged $2000 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the estimated loss averaged $76,000 per fire for all of the fires with flame damage that did *extend beyond the room of origin*

As the number of fires and the number of injuries were both very low, great caution must be exercised in drawing conclusions from this data. However it appears likely from these figures that fires with *sprinklers present* with flame damage that **did not** *extend beyond the room of origin* would on average result in about 3% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

Comparing the *sprinklers not present* and *sprinklers present* cases it appears that the *sprinklers present* case is clearly better in terms of civilian injuries (15 compared with 52 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*) and also in terms of estimated $ loss ($2000 compared with $4300 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin* but $76,000 compared with $43,000 per fire for the very few fires with flame damage that did *extend beyond the room of origin*). However, perhaps surprisingly, it appears worse in terms of fire fighter injuries (11 compared with 3.4 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*).

In the case of fires with *sprinkler presence unknown* flame damage was *confined to the room of origin* in a total of 75% of the fires and flame damage *extended throughout or beyond the structure of origin* in 23% of fires (Table 4.12).

Table 4.12 Extent of Flame Damage for Fires in Residential Buildings Sprinklers Presence Unknown

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	2176	94	8	2	0	9545700
Confined to part of room or area of origin	1707	134	4	16	0	13286500
Confined to room of origin	2691	266	21	22	0	44712550
Confined to fire rated compartment of origin	32	12	1	1	0	973100
Confined to floor of origin	155	20	14	5	0	8256200
Confined to structure of origin	1898	246	78	49	2	1.343e8
Extended beyond structure of origin	122	14	14	1	0	6198950

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinkler presence unknown* where the flame damage *extended beyond the room of origin*:

- the civilian fatality rate was 6.1 fatalities per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 25 fatalities per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the civilian injury rate was 75.1 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 129 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 5.0 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 45.4 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the estimated loss averaged $10,000 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the estimated loss averaged $70,000 per fire for all of the fires with flame damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinkler presence unknown* with flame damage that **did not** *extend beyond the room of origin* on average resulted in 25% of the civilian fatalities, 58% of the civilian injuries, 11% of the fire fighter injuries and

14% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

There are significant differences between the *sprinkler presence unknown* case and the *sprinklers not present* and *sprinkler present* cases but it seems to be reasonably close to the *sprinklers not present* case.

Number of Storeys

The data available on the number of fires and the resulting casualties and property losses contains errors in the number of storeys field. It appears that many of the entries showing storey height as 10, 20, 30, 40, etc are actually for 1, 2, 3, 4, etc storeys respectively due to errors in coding the data.

In what follows relating to number of storeys entries that have 10, 20, 30, 40, etc have been excluded. Thus the following relates to 1 to 9, 11 to 19, 21 to 29, 31 to 39, etc storeys only.

Table 4.13 is for fires with *sprinklers not present* and includes both the actual number of fires, casualties and estimated $ loss and (in brackets) the relevant rates.

Table 4.13 Effect of Storeys on Fires in Residential Buildings Sprinklers Not Present

Storeys	Fires	Civilian Injuries (Rate*)	Fire Fighter Injuries (Rate*)	Civilian Fatalities (Rate*)	Fire Fighter Fatalities (Rate*)	$ Loss (Rate*)
1	11316	678	99	69	1	1.55E+08
		(59.9)	(8.8)	(6.1)	(0.1)	(14,000)
2	3053	222	35	18	0	54674650
		(72.7)	(12)	(5.9)	(-)	(18,000)
3	1313	118	8	11	0	6760950
		(89.9)	(6)	(8.4)	(-)	(5000)
4	439	44	1	4	0	2249300
		(100)	(2)	(9)	(-)	(5000)
5 to 9	326	31	5	3	0	2289050
		(95)	(15)	(9)	(-)	(7000)
11 to 19	251	19	0	0	0	862900
		(76)	(-)	(-)	(-)	(3000)
21 to 39	43	1	0	0	0	58600
		(20)	(-)	(-)	(-)	(1000)
41+	13	0	1	0	0	46750
		(-)	(80)	(-)	(-)	(4000)

Note: * Rate is casualties per 1000 fires, except estimated $ loss which is per fire.

It shows that the largest number of fires, casualties and estimated $ losses occurred in one storey buildings, with the number of fires and resulting casualties and estimated $ losses falling rapidly with increasing storeys. There is insufficient data for a similar analysis for buildings with *sprinkler present* to be meaningful, and thus there is no table for this case.

Based on the data in Table 4.13 there is a fairly consistent trend in the civilian fatality rates from 6.1 civilian fatalities per 1000 fires for one storey to 9.2 civilian fatalities per 1000 fires for 5 to 9 storeys respectively. There were no civilian fatalities in buildings above eleven storeys, but the number of fires was also very small and thus no conclusion should be drawn based on this fact.

The civilian injury rates rise consistently between one and four storeys and then fall with increasing storeys while the fire fighter injury rates seem quite variable with no consistent trend.

The estimated $ loss rates fall quite considerably from highs for one and two storeys to a fraction of these rates for more storeys.

Construction Type

The construction types considered in AS 2577-1983[1] are summarised reasonably comprehensively in Table 4.14, but more complete descriptions are available in the standard.

It is generally accepted that the construction type varies from *most fire resistive* to *least fire resistive* in the order in which they are presented in the Table (and AS 2577-1983), although it is not entirely clear that this is a consistent trend from the descriptions in the standard.

Table 4.14 Effect of Construction Type: Sprinklers Not Present

Construction Type	Cumulative % of Fires Confined to Room of Origin	% of Fires Confined to Fire-rated Compartment of Origin	% Fires Confined to or Extended Beyond Structure of Origin
Fire Resistive: Totally non-combustible, no unprotected steel, steel protection "heavy"	92%	1.2%	4.3%
Heavy Timber: Mill-construction building, load bearing walls or columns masonry or heavy timber	74%	0.6%	23%
Protected non-combustible: Totally non-combustible, no exposed structural steel, steel protection "light"	92.4%	1.3%	5.2%
Unprotected non-combustible: Totally non-combustible, exposed structural steel	67%	1.3%	31%
Protected Ordinary: Load bearing walls masonry, columns fire protected, underside of all wood floor and roof decks protected by fire-resisting covering	89%	0.9%	6.9%
Unprotected Ordinary: load bearing walls masonry,	82%	0.7%	13%

columns, wood floor and roof decks exposed and unprotected			
Protected Wood Frame: Walls, floors and roof structure wood framing, Interior walls and ceilings of habitable spaces protected by fire resistive covering, "brick veneer"	81%	0.8%	15%
Unprotected wood frame: Walls, floors and roof structure are wood framing, no fire-resistive covering protecting wood frame.	63.4%	0.6%	33.8%
Unknown, etc	55.6%	0.3%	39.5%

Table 4.14 differs from the preceding tables by presenting the fire spread information in three only categories in an attempt to focus on the effectiveness or otherwise of the methods of construction. The data is presented only for those fires with *sprinklers not present* for two reasons: firstly, there are insufficient numbers of fires in each of the *construction types* for the *sprinklers present* case; secondly, the absence of sprinklers is expected to most clearly delineate any effects associated with *construction type*.

It is obvious in the table that the *percentage of fires confined to the fire-rated compartment of origin* represents only a very small percentage of fires for all *construction types*.

However, the *cumulative percentage of fires confined to the room of origin* does vary considerably but not in a way that indicates the construction type has any consistent effect on it.

Table 4.15 Effect of Construction Type (Sprinklers Not Present)

Construction Type	Civilian Injury Rate (per 1000 fires)	Fire Fighter Injury Rate (per 1000 fires)	Civilian Fatality Rate (per 1000 fires)	$ Loss Rate (per fire)
Fire Resistive: Totally non-combustible, no unprotected steel, steel protection "heavy"	82	6.4	4.3	5700
Heavy Timber: Mill-construction building, load bearing walls or columns masonry or heavy timber	83	15	32	23,000
Protected non-combustible: Totally non-combustible, no exposed structural steel, steel protection "light"	96	11	4.3	7000
Unprotected non-combustible: Totally non-combustible, exposed structural steel	28	12	4.0	10,000
Protected Ordinary: Load bearing walls masonry, columns fire protected, underside of all wood floor and roof decks protected by fire-resisting covering	60	6.6	6.2	7900
Unprotected Ordinary: load bearing walls masonry, columns, wood floor and roof decks exposed and unprotected	72	9.4	4.5	14,000
Protected Wood Frame: Walls, floors and roof structure wood framing, Interior walls and	65	6.3	6.6	15,000

ceilings of habitable spaces protected by fire resistive covering, "brick veneer"				
Unprotected wood frame: Walls, floors and roof structure are wood framing, no fire-resistive covering protecting wood frame.	42	13	8.2	20,000
Unknown, etc	102	39	4.5	2900

The variation of the casualty rates and property losses with *construction type* for *residential* buildings with *sprinklers not present* is shown in Table 4.15. (There is no column in the table for *fire brigade injuries* because all of the entries were zero.)

Apart from *heavy timber* (and ignoring the row for *unknown, etc*) there appears to be a moderately consistent trend down the table for *civilian fatality rate* (increasing down the table), *civilian injury rate* (decreasing down the table) and *$ loss rate* (increasing down the table), but no apparent trend for *fire fighter injury rate*.

The construction type *heavy timber* stands apart from these trends having the highest *civilian fatality rate* and *$ loss rate* by far, the latter only being almost matched by the *$ loss rate* for *unprotected wood frame*.

Time of Alarm

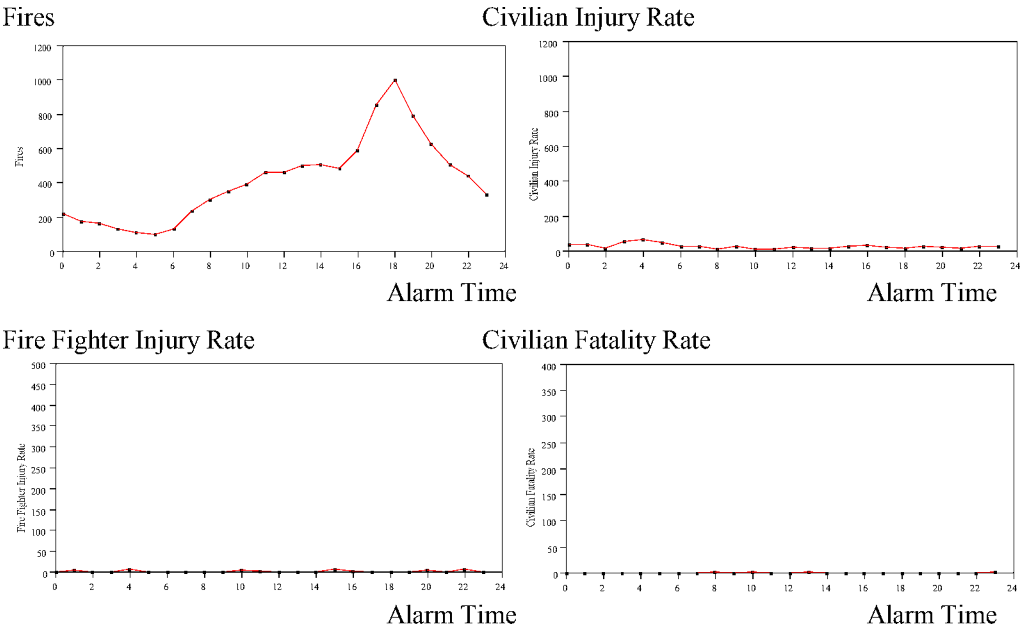
The graphs in Figure 4.19 show the variation in the number of fires and rates of civilian fatalities and injuries and fire fighter injuries by the alarm time on a 24 hour clock.

Comparison of the graphs showing the variation in the number of fires with alarm time indicates that the number of alarms per hour is a minimum at about 6 am (0600 hours), rises through the day to a peak at about 6 pm (1800 hours) and then decreases rapidly until about 11 pm (2300 hours) and then more slowly until 6 am. About 80% of the increase during the day takes place in fires that are *confined to the object of origin* and *confined to the area or part of room of origin*. In the *confined to the object of origin* category the maximum is over ten times the minimum while in the *confined to the area or part of room of origin* category the maximum is nearly seven times the minimum.

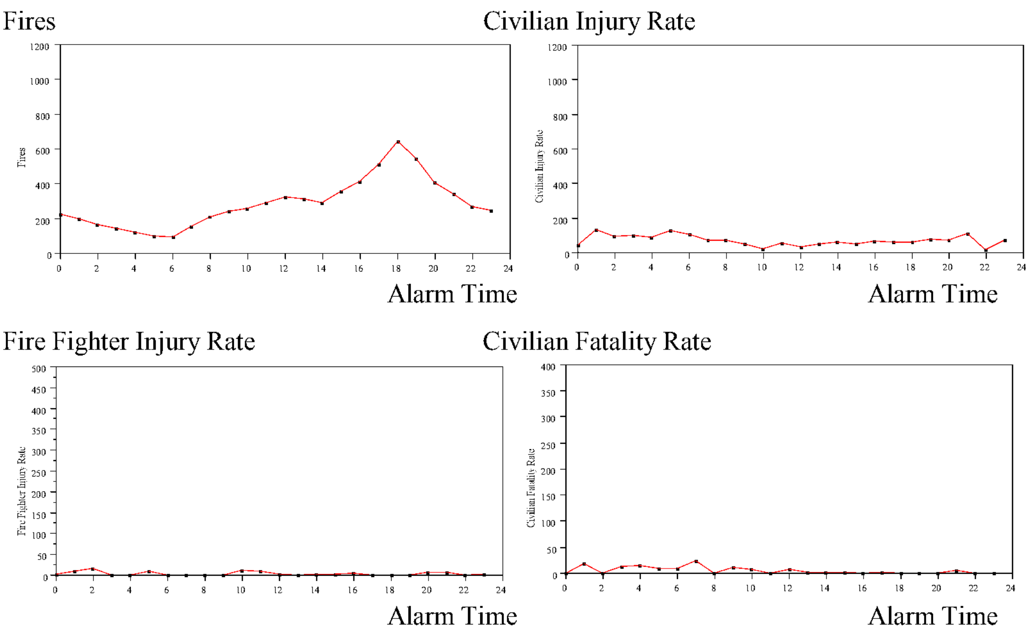
Thus, it appears that while people are active (during daylight) there are significantly more fire starts but the resulting fires are almost totally *confined to the object or part of room of origin*.

Comparison of the civilian injury rate graphs shows this rate is reasonably constant and quite low until fires are such that the flame damage spreads beyond the room of origin. It is then very variable and sometimes very high as the flame damage spread increases. (It must be understood that the number of fires in some of these flame spread categories is very low.) It is notable though, that the peaks generally occur between midnight and 8 am (0800 hours).

The fire fighter injury rate is reasonably constant and very low until the fire spreads such that flame damage extends beyond the room of origin. The fire fighter injury rate generally increases but also becomes more variable for flame damage beyond the room of origin. The peaks generally occur during the night, mostly between 7 pm (1900 hours) and midnight.

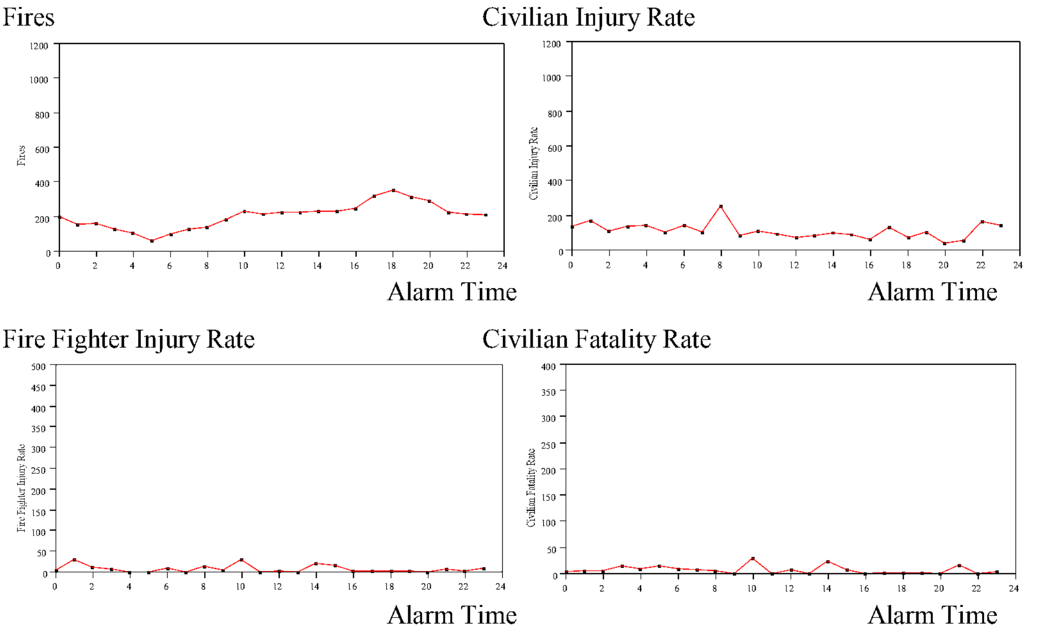


(a) Extent of Flame Damage Confined to Object of Fire Origin

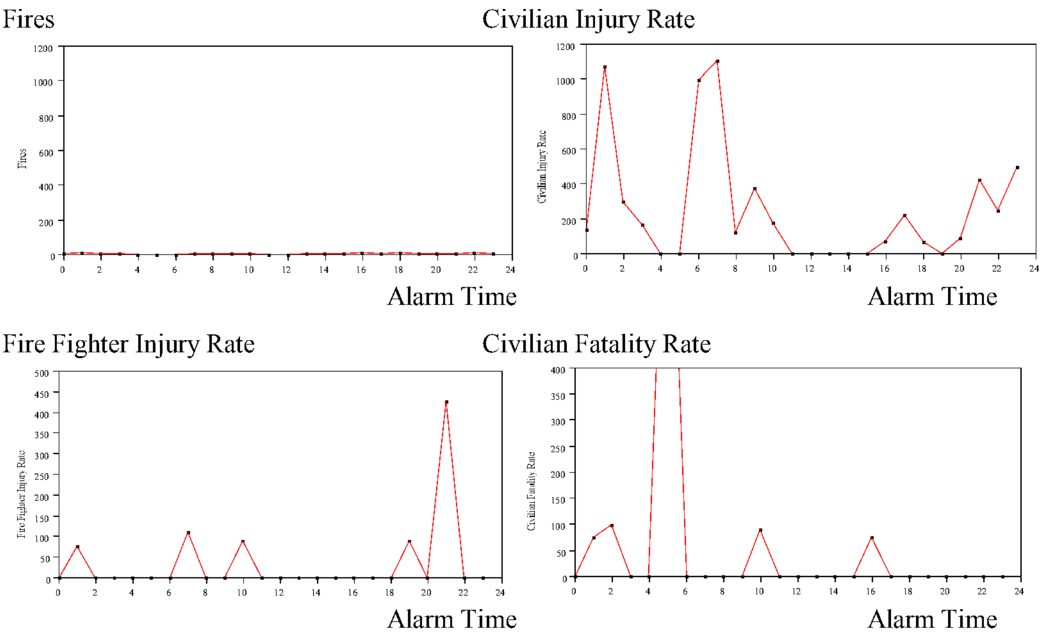


(b) Extent of Flame Damage Confined to Part of Room or Area of Fire Origin

Figure 4.19 Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Residential Buildings

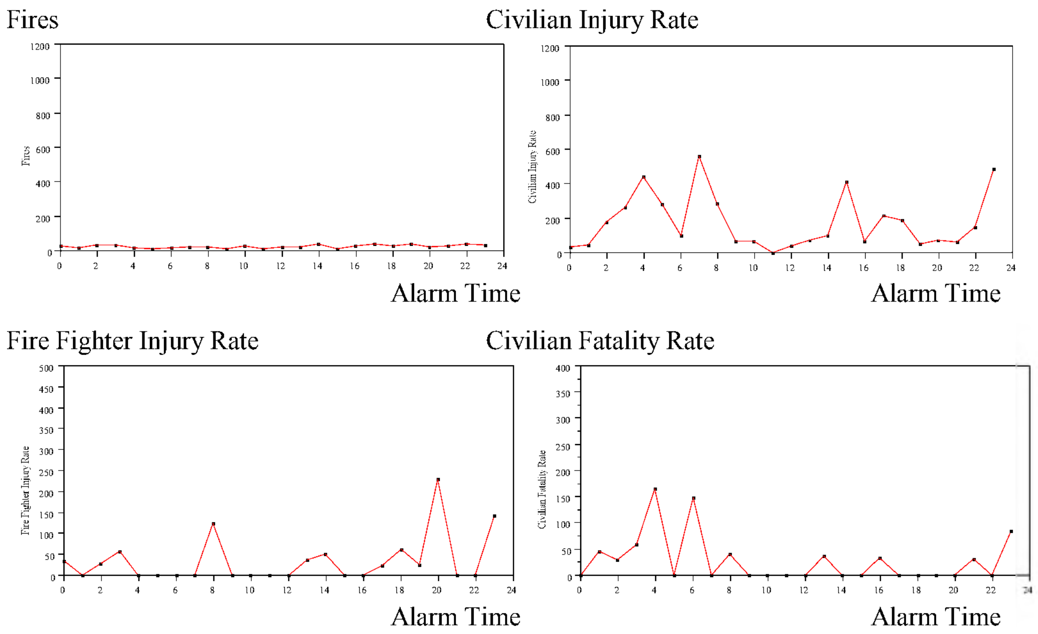


(c) Extent of Flame Damage Confined to Room of Fire Origin

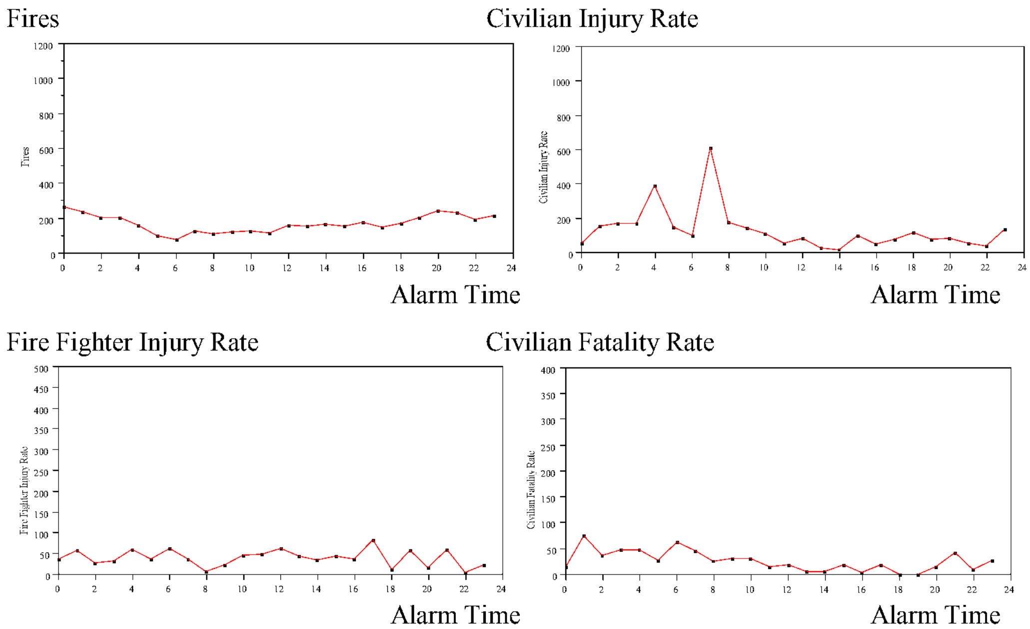


(d) Extent of Flame Damage Confined to Fire-rated Compartment of Fire Origin

Figure 4.19 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Residential Buildings



(e) Extent of Flame Damage Confined to Floor of Fire Origin

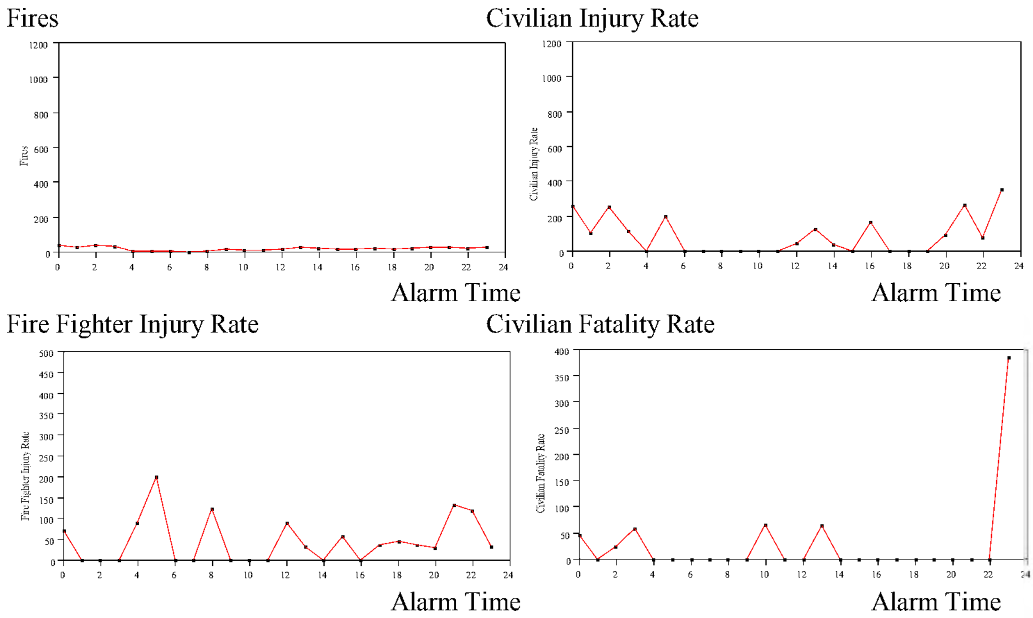


(f) Extent of Flame Damage Confined to Structure of Fire Origin

Figure 4.19 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Residential Buildings

The civilian fatality rate is generally low and moderately constant for fires with flame damage confined to the room of origin. The remaining fires are again more "peaky" and the major peaks generally appear to be confined to the hours of darkness, mostly from midnight to 6 am.

Thus it appears that generally the more dangerous fires in terms of civilian and fire fighter casualties occur during darkness.



(g) Extent of Flame Damage Extended Beyond Structure of Fire Origin

Figure 4.19 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Residential Buildings

4.1.7 Commercial Buildings

In this section some of the data available for commercial buildings will be examined in the same way that data for residential buildings was examined in Section 4.1.6. Unless noted otherwise the definitions used in Section 4.1.6 apply.

Area of Fire Origin (AFO)

The AFO specifies the area within a building where a fire originated.

The AFO is known for fires resulting in 23 of the 30 civilian fatalities. Of the 23 fatalities eight (or 35%) were from fires starting in a *residential* area and seven (30%) from fires in an *assembly, sales* area, thus these two categories account for 65% of all civilian fatalities.

There are great similarities here with fires in *residential* buildings because of the seven civilian fatalities in the fires originating in *assembly, sales* areas six were from *lounge* areas and the remaining fatality was in a *small assembly area*. The rate of fatalities in *assembly, sales* areas was 4 per 1000 fires.

Table 4.16 Area of Fire Origin of Selected Fires in Commercial Buildings

Area of fire origin	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Assembly, Sales Area	1952	76	44	7	0	166564650
Residential Area	5420	143	50	8	1	145199296
Storage Area	5220	148	116	5	0	320329736
Unknown, etc	3715	89	110	7	0	243126192

Of the civilian deaths resulting from fires originating in *residential* areas five were from *sleeping rooms* (7 fatalities per 1000 fires) and two were from a much larger number of fires originating in *dining and kitchen* areas (1 fatality per 1000 fires). Further details of these fires are shown in Table 4.16.

Most of the remaining civilian fatalities (four, at a rate of 4 fatalities per 1000 fires) were due to fires in *storage* areas, specifically *garage or carport* areas.

The fires in *storage* and *assembly, sales* areas averaged much greater property damage ($61,000 and $85,000 per fire) than those in *residential* areas ($27,000 per fire).

Form of Heat of Ignition (FHI)

The FHI specifies the form of heat energy that ignited the fire.

The FHI of the fire is unknown for 10 of the fires involving the 30 civilian fatalities. Of the remaining 20 civilian fatalities the largest group (9 or 45%) were initiated by *smoking material, etc*. The FHI resulting in the largest number of fires overall (7001 or 37% of the fires with known FHI) was *heat from open flame, spark*. Details of the fires with known FHI that resulted in more than one civilian fatality per FHI category are shown in Table 4.17.

Table 4.17 Form of Heat of Ignition of Selected Fires in Commercial Buildings

Form of Heat of Ignition	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Smoking Material, etc	1328	32	8	9	0	20022800
Heat from Open Flame	7001	150	78	7	0	367232496
Heat from Hot Object	3059	73	20	2	0	69414550
Unknown, etc	3973	253	272	10	1	765624272

The FHI category with the highest rate of civilian fatalities was *smoking material* with a rate of 7 civilian fatalities per 1000 fires. The rates for the other significant FHI categories were: *heat from open flame, spark* 1 civilian fatalities per 1000 fires and *heat from hot object* 0.7 civilian fatalities per 1000 fires.

The greatest property damage was for fires with FHI *unknown* (an average of $193,000 per fire) and *heat from open flame* ($52,000 per fire).

Ignition Factor (IF)

The IF is the situation that permitted the heat source and combustible material to combine and start a fire.

The IF is unknown for the fires that resulted in nine out of the thirty civilian fatalities. Of the fires resulting in the twenty-one civilian fatalities with known IF the fires resulting in 10 (48%) of the civilian fatalities were due to *misuse of heat of ignition*, and four (19%) were due to *misuse of material ignited*. Further details of the fires with known IF that resulted in civilian fatalities are shown in Table 4.18.

The IF categories with the highest rate of civilian fatalities are *misuse of material ignited*, with 3 civilian fatalities per 1000 fires and *misuse of heat of ignition* with 2.5 civilian fatalities per 1000 fires. These rates are much lower than for *residential* buildings but the IF categories are similar.

A high rate of civilian injuries also occurred in fires with IF category unknown, but the highest rate occurred in fires due to *misuse of material ignited* (59 civilian injuries per 1000 fires) with *suspicious* (32 civilian injuries per 1000 fires) also high.

Table 4.18 Ignition Factor for Selected Fires in Commercial Buildings

Ignition Factor	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Unknown, etc	4338	183	182	9	1	400901536
Incendiary	2495	49	61	2	0	292930150
Suspicious	3693	120	78	3	0	288939926
Misuse of Heat of Ignition	4045	95	39	10	0	79983350
Misuse of Material Ignited	1211	72	19	4	0	18526500
Mechanical Failure	5270	136	47	0	0	128058348
Operational Deficiency	2755	63	25	2	0	57336700

The highest rates of fire fighter injuries occurred in fires with unknown IF category (42 fire fighter injuries per 1000 fires), of the remainder *incendiary* with a rate of 24 fire fighter injuries per 1000 fires was highest.

The highest average property loss per fire was $117,000 per fire for IF *incendiary*.

Detector Performance (DP)

The detector performance effectively records whether fire detectors are installed in the building and, if so, their effectiveness.

Table 4.19 shows the performance of detectors in fires in commercial buildings, and the fatality, injury and property loss outcomes of those fires.

The only fatalities occurred in fires with no detectors present. The civilian injury rate was higher for fires with *detectors in the room or space of origin and they operated* (41 civilian injuries per 1000 fires) than in the fires with *no detectors present* (29 civilian injuries per 1000 fires). Taking together all of the fires with *detectors present* (whether they operated or not) the rates were much closer (33 civilian injuries per 1000 fires).

The fire fighter injuries were largely concentrated in the fires with *no detectors present*.

The estimated $ loss per fire was on average much higher for fires with detectors *unknown* ($76,000 per fire) or *no detectors present* ($47,000 per fire) than for fires with *detectors in the room or space of origin and they operated* ($17,000 per fire) or taking together all of the fires with *detectors present* (whether they operated or not) ($15,000 per fire).

Table 4.19 Detector Performance for Fires in Commercial Buildings

Detector Performance	Fires	Civilian Injury	Fire Brigade Injury	Civilian Fatalities	Fire Brigade Fatalities	$ Loss
Detectors in the room or space of fire origin and they operated	1647	68	8	0	0	28328800
Detectors not in room of fire origin and they operated	278	2	0	0	0	4700850
Detectors in room of fire origin - failed to operate	204	11	0	0	0	1512950
Detectors not in room of fire origin - did not operate	108	1	3	0	0	3497900
Detectors in room of fire origin failed to operate due low fire severity	392	4	0	1	0	942800
No detectors present	12853	372	258	15	0	604463104
Unknown	9015	287	192	14	1	681880694

Major Method of Extinguishment (MME)

The MME identifies the method that had the major effect in extinguishing the fire.

The largest number of fires was extinguished using an *appliance hose line or reel with water carried in apparatus tanks*, but a very large number of fires was extinguished using a *portable fire extinguisher*. The number of *self-extinguished* fires was also very significant.

The MME was *unknown* for 2977 fires.

Table 4.20 Major Method of Extinguishment for Fires in Commercial Buildings

Major Method of Extinguishment	Fires	Civilian Injuries	Fire Brigade Injuries	Civilian Fatalities	Fire Brigade Fatalities	$Loss
Self Extinguished	2794	55	1	0	0	8399950
Makeshift Aids	1920	51	0	2	0	3450300
Portable Fire Extinguisher	3396	115	12	2	0	26517700
Automatic Extinguishers	565	11	2	0	0	8321100
Hose Line/Reel	10001	208	202	12	0	7.89E+08
Hose Line from Hydrant	1057	57	30	1	0	1.13E+08
Hose Line from Pump, etc	1740	164	124	10	0	3.37E+08
Master Stream Device	47	1	5	0	0	21745300

Extent of Smoke Damage (ESD)

The extent of smoke damage and the occurrence of fatalities, injuries and (estimated) property loss is given in Tables 4.21, 4.22 and 4.23 for the *sprinklers not present*, *sprinklers present* and *sprinkler presence unknown* cases respectively.

In the case of *sprinklers not present* smoke damage was *confined to the room of origin* in a total of 53% of the fires with known extent of smoke damage and smoke damage *extended throughout or beyond the structure of origin* in 26.3% of fires (Table 4.21).

Table 4.21 Extent of Smoke Damage for Fires in Commercial Buildings Sprinklers Not Present

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	2531	63	10	0	0	44083750
Confined to object of origin	2044	28	3	2	0	10557500
Confined to part of room or area of origin	1456	36	6	0	0	14726600
Confined to room of origin	1592	29	8	0	0	20684200
Confined to fire rated compartment of origin	143	2	6	1	0	3226900
Confined to floor of origin	646	37	5	0	0	26091000
Confined to structure of origin	2511	105	103	11	0	3.207e+8
Extended beyond structure of origin	498	32	42	1	0	73595600

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinklers not present* where the smoke damage *extended beyond the room of origin*:

- the civilian fatality rate was 0.3 fatalities per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 4.0 fatalities per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the civilian injury rate was 20.5 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 45.5 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 3.5 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 48.2 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinklers not present* with smoke damage that **did not** *extend beyond the room of origin* on average resulted in 7% of the civilian fatalities, 46% of the civilian injuries and 7% of the fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

In the case of fires with *sprinklers present* smoke damage was *confined to the room of origin* in a total of 82% of the fires and smoke damage *extended throughout or beyond the structure of origin* in only 8.9% of fires (Table 4.22).

The civilian and fire fighter injuries clearly occurred disproportionately in fires where the smoke damage *extended beyond the room of origin*:

- there were no civilian or fire fighter fatalities (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the civilian injury rate was 19 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 82 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin* (but the number of fires and the number of injuries were both very low so this must be treated with great caution)
- the fire fighter injury rate was 4 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 44 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin* (but again the number of fires and the number of injuries were both very low so this must be treated with great caution)

Table 4.22 Extent of Smoke Damage for Fires in Commercial Buildings Sprinklers Present

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	341	3	2	0	0	2310700
Confined to object of origin	299	7	2	0	0	4612700
Confined to part of room or area of origin	236	11	0	0	0	2405500
Confined to room of origin	366	2	1	0	0	6251300
Confined to fire rated compartment of origin	30	18	0	0	0	384150
Confined to floor of origin	104	2	3	0	0	7971800
Confined to structure of origin	112	11	3	0	0	1327845 0
Extended beyond structure of origin	23	0	3	0	0	5134100

As the number of fires and the number of injuries were both very low, great caution must be exercised in drawing conclusions from this data. However it appears likely from these figures that fires with *sprinklers present* with smoke damage that **did not** *extend beyond the room of origin* would on average result in about 23% of the civilian and 9.1% of the fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

Comparing the *sprinklers not present* and *sprinklers present* cases it appears that the *sprinklers present* and *sprinklers not present* cases are somewhat mixed in terms of civilian injuries (18.5 compared with 20.5 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin* and 82 compared with 45.5 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*) and very similar in terms of fire fighter injuries (4.0 compared with 3.5 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin* and 44 compared with 48 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*).

In the case of *sprinkler presence unknown* smoke damage was *confined to the room of origin* in a total of 54% of the fires and smoke damage *extended throughout or beyond the structure of origin* in 41% of fires (Figure 4.23).

Table 4.23 Extent of Smoke Damage for Fires in Commercial Buildings Sprinklers Presence Unknown

Extent of Smoke Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
No damage of this type	1122	23	10	0	0	25787600
Confined to object of origin	570	14	26	0	0	5698750
Confined to part of room or area of origin	474	13	7	1	0	9708750
Confined to room of origin	882	42	29	2	0	27868300
Confined to fire rated compartment of origin	35	0	2	0	0	408950
Confined to floor of origin	121	4	3	0	0	8395300
Confined to structure of origin	2086	49	100	7	0	4.8708e8
Extended beyond structure of origin	112	71	10	0	0	16880200

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinkler presence unknown* where the smoke damage *extended beyond the room of origin*:

- the civilian fatality rate was 1 fatality per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 3 fatalities per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the civilian injury rate was 30 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*

- the civilian injury rate was 55 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 24 injuries per 1000 fires for all of the fires with smoke damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 50 injuries per 1000 fires for all of the fires with smoke damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinkler presence unknown* with smoke damage that **did not** *extend beyond the room of origin* on average resulted in 31% of the civilian fatalities, 55% of the civilian injuries and 47% of the fire fighter injuries of fires with smoke damage that did *extend beyond the room of origin*.

There are some quite significant differences between the *sprinkler presence unknown* case and the *sprinklers not present* and *sprinkler present* cases. It does not represent a weighted average of the two other cases for all casualty cases and therefore there may be some other influence effecting the statistics for these cases. No explanation of these differences is offered.

Extent of Flame Damage (EFD)

The categories for *extent of flame damage* are given in Section 4.1.3.

The extent of flame damage and the occurrence of fatalities, injuries and (estimated) property loss is given in Tables 4.24, 4.25 and 4.26 for the *sprinklers not present, sprinklers present* and *sprinkler presence unknown* cases respectively.

In the case of *sprinklers not present* flame damage was *confined to the room of origin* in a total of 76% of fires and flame damage *extended throughout or beyond the structure of origin* in 21% of fires (Table 4.24).

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinklers not present* where the flame damage *extended beyond the room of origin*:

- the civilian fatality rate was 0.5 fatalities per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 4.3 fatalities per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the civilian injury rate was 26 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 37 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 6.2 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 52 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*

- the estimated loss averaged $12,000 per fire for all of the fires with flame damage that **did not** *extend beyond the room cf origin*
- the estimated loss averaged $151,00 per fire for all of the fires with flame damage that did *extend beyond the room cf origin*

Table 4.24 Extent of Flame Damage for Fires in Commercial Buildings Sprinklers Not Present

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	4983	116	10	3	0	24546850
Confined to part of room or area of origin	2442	66	17	0	0	43551050
Confined to room of origin	1061	40	26	1	0	36977800
Confined to fire rated compartment of origin	79	1	0	1	0	10651900
Confined to floor of origin	277	20	9	0	0	45628800
Confined to structure of origin	1879	63	109	8	0	2.7085e8
Extended beyond structure of origin	459	23	13	2	0	82027150

Table 4.25 Extent of Flame Damage for Fires in Commercial Buildings Sprinklers Present

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	964	20	4	0	0	13206050
Confined to part of room or area of origin	356	25	3	0	0	4470450
Confined to room of origin	91	8	0	0	0	1693400
Confined to fire rated compartment of origin	7	0	0	0	0	1277500
Confined to floor of origin	12	1	3	0	0	6076000
Confined to structure of origin	52	1	4	0	0	11350000
Extended beyond structure of origin	13	0	0	0	0	4303000

Table 4.26 Extent of Flame Damage for Fires in Commercial Buildings Sprinklers Presence Unknown

Extent of Flame Damage	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
Confined to object of origin	1434	27	13	0	0	13206050
Confined to part of room or area of origin	748	28	14	1	0	4470450
Confined to room of origin	1364	38	40	2	0	1693400
Confined to fire rated compartment of origin	20	2	0	0	0	1277500
Confined to floor of origin	80	2	2	1	0	6076000
Confined to structure of origin	1649	34	110	9	0	11350000
Extended beyond structure of origin	111	72	7	0	0	4303000

It is clear from these figures that fires with *sprinklers not present* with flame damage that **did not** *extend beyond the room of origin* on average resulted in 11% of the civilian fatalities, 71% of the civilian injuries, 12% of the fire fighter injuries and 8% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

In the case of fires with *sprinklers present* flame damage was *confined to the room of origin* in a total of 94% of the fires and *flame damage extended throughout or beyond the structure of origin* in only 4.3% of fires (Table 4.25).There were no civilian or fire fighter fatalities.

The rates for the civilian and fire fighter and injuries were mixed:

- there were no civilian or firefighter fatalities (but the number of fires is so low that even in the *sprinklers not present* case no fatalities would be expected)
- the civilian injury rate was 38 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 15 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin* (but this is based on only one injury and a very low number of fires)
- the fire fighter injury rate was 5 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 62 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin* (but this is based on only four injuries and a very low number of fires)
- the estimated loss averaged $14,000 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the estimated loss averaged $241,000 per fire for all of the fires with flame damage that did *extend beyond the room of origin*

As the number of fires and the number of injuries were both very low great caution must be exercised in drawing conclusions from this data. However it appears likely from these figures that fires with *sprinklers present* with flame damage that **did not** *extend beyond the room of origin* would, on average, result in about 6% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

Comparing the *sprinklers not present* and *sprinklers present* cases it appears that the *sprinklers present* case is somewhat better in terms of civilian injuries (38 compared with 26 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*), fire fighter injuries (6 compared with 5 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*) and also in terms of estimated $ loss ($14,000 compared with $12,000 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin* but $241,000 compared with $151,000 per fire for the very few fires with flame damage that did *extend beyond the room of origin*).

In the case of fires with *sprinkler presence unknown* flame damage was *confined to the room of origin* in a total of 66% of the fires and flame damage *extended throughout or beyond the structure of origin* in 33% of fires (Table 4.26).

The civilian and fire fighter fatalities and injuries clearly occurred disproportionately in fires with *sprinkler presence unknown* where the flame damage *extended beyond the room of origin*:

- the civilian fatality rate was 0.8 fatalities per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian fatality rate was 5.1 fatalities per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the civilian injury rate was 26 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the civilian injury rate was 60 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the fire fighter injury rate was 19 injuries per 1000 fires for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the fire fighter injury rate was 67 injuries per 1000 fires for all of the fires with flame damage that did *extend beyond the room of origin*
- the estimated loss averaged $5500 per fire for all of the fires with flame damage that **did not** *extend beyond the room of origin*
- the estimated loss averaged $8900 per fire for all of the fires with flame damage that did *extend beyond the room of origin*

It is clear from these figures that fires with *sprinkler presence unknown* with flame damage that **did not** *extend beyond the room of origin* on average resulted in 17% of the civilian fatalities, 44% of the civilian injuries, 28% of the fire fighter injuries and 66% of the estimated $ loss of fires with flame damage that did *extend beyond the room of origin*.

There are significant differences between the *sprinkler presence unknown* case and the *sprinklers not present* and *sprinkler present* cases but it seems to be reasonably close to the *sprinklers not present* case.

Storey Height

As with the residential data the there are errors in the number of storeys field. It appears that many of the entries showing storey height as 10, 20, 30, 40, etc are actually for 1, 2, 3, 4, etc storeys respectively due to errors in coding the data.

In what follows relating to number of storeys entries that have 10, 20, 30, 40, etc have been excluded. Thus the following relates to 1 to 9, 11 to 19, 21 to 29, 31 to 39, etc storeys only.

Table 4.27 is for fires with *sprinklers not present* and includes both the actual number of fires, casualties and estimated $ loss and (in brackets) the relevant rates.

Table 4.27 Effect of Storeys on Fires in Commercial Buildings Sprinklers Not Present

Storeys	Fires	Civilian Injuries	Fire Fighter Injuries	Civilian Fatalities	Fire Fighter Fatalities	$ Loss
1	6150	151	116	7	0	2 66E+08
		(25)	(19)	(1)	(-)	(43,000)
2	2375	106	51	3	0	1 15E+08
		(45)	(21)	(1)	(-)	(48,000)
3	528	15	5	0	0	23486950
		(28)	(9)	(-)	(-)	(44,000)
4	275	5	3	0	0	3690600
		(18)	(11)	(-)	(-)	(13,000)
5 to 9	402	9	6	1	0	18017350
		(22)	(15)	(2)	(-)	(45,000)
11 to 19	189	4	0	0	0	1264500
		(21)	(-)	(-)	(-)	(6700)
21 to 39	27	1	0	0	0	84750
		(40)	(-)	(-)	(-)	(3100)
41+	15	0	0	0	0	245650
		(-)	(-)	(-)	(-)	(16,000)

Note: * Rate is casualties per 1000 fires, except estimated $ loss which is per fire.

It shows that the largest number of fires, casualties and estimated $ losses occurred in one storey buildings, with the number of fires and resulting casualties and estimated $ losses falling rapidly with increasing storeys. There is insufficient data for a similar analysis for buildings with *sprinkler present* to be meaningful, and thus there is no table for this case.

These does not seem to be any significant consistent variation in these parameters with storey height.

Construction Type

Table 4.28 presents fire spread information focusing on the effectiveness or otherwise of the methods of construction. The data is presented only for those fires with *sprinklers not present.*

It is obvious in the table that the *percentage of fires confined to the fire-rated compartment of origin* represents only a very small percentage of fires for all *construction types*.

However, the *cumulative percentage of fires confined to the room of origin* does vary considerably but not in a way that indicates that the construction type has a consistent effect on it. It may be that the use to which buildings are put varies in some way with the *construction type* and that this has a significant effect on the *extent of flame spread* characteristics for fires in those buildings.

The variation of the casualty rates and property losses with *construction type* for *residential* buildings with *sprinklers not present* is shown in Table 4.29.

It is difficult to see any meaningful trends in this data.

Time of Alarm

The graphs in Figure 4.20 show the variation in the number of fires and rates of civilian fatalities and injuries and fire fighter injuries by the alarm time on a 24 hour clock. The shapes of many of the curves on these graphs are significantly different from the respective graphs for *residential* buildings (Figure 4.19).

Comparison of the graphs in Figure 4.20 showing the variation in the number of *fires* with *alarm time* indicates that the number of alarms per hour is a minimum at about 6 am (0600 hours), rises rapidly in the morning and plateaus through the day and then decreases after about 10 pm (2200 hours). Most of the increase during the day takes place in fires that are *confined to the object of origin*, *confined to the area or part of room of origin and confined to the room of origin*, although there is some increase in fires *confined to the structure of origin* throughout the day until about 1 am (0100 hours). There are clearly different shapes to the graphs for each *extent of flame damage* category.

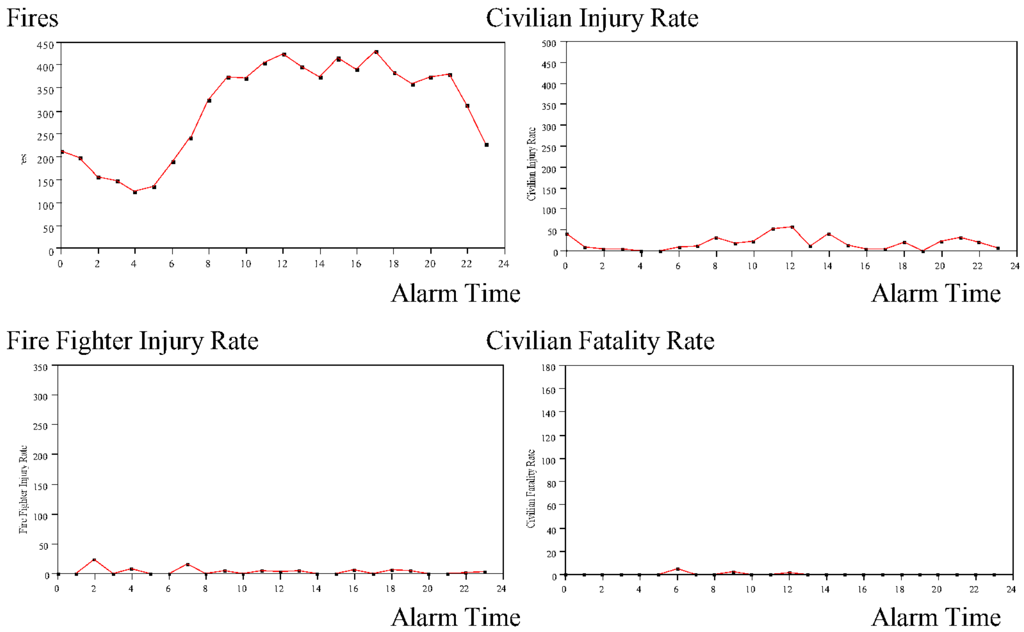
Thus, it appears that while people are active (during daylight) there are significantly more fire starts but the resulting fires are largely *confined to the object and part of room of origin*. The civilian injury rate is reasonably constant and quite low until fires are such that the flame damage spreads beyond the room of origin. It is then very variable and sometimes very high as the flame damage spread increases. (It must be understood that the number of fires in some of these flame spread categories is very low.) It is notable though, that the peaks generally occur during daylight hours.

Table 4.28 Effect of Construction Type on Extent of Flame Damage (Sprinklers Not Present)

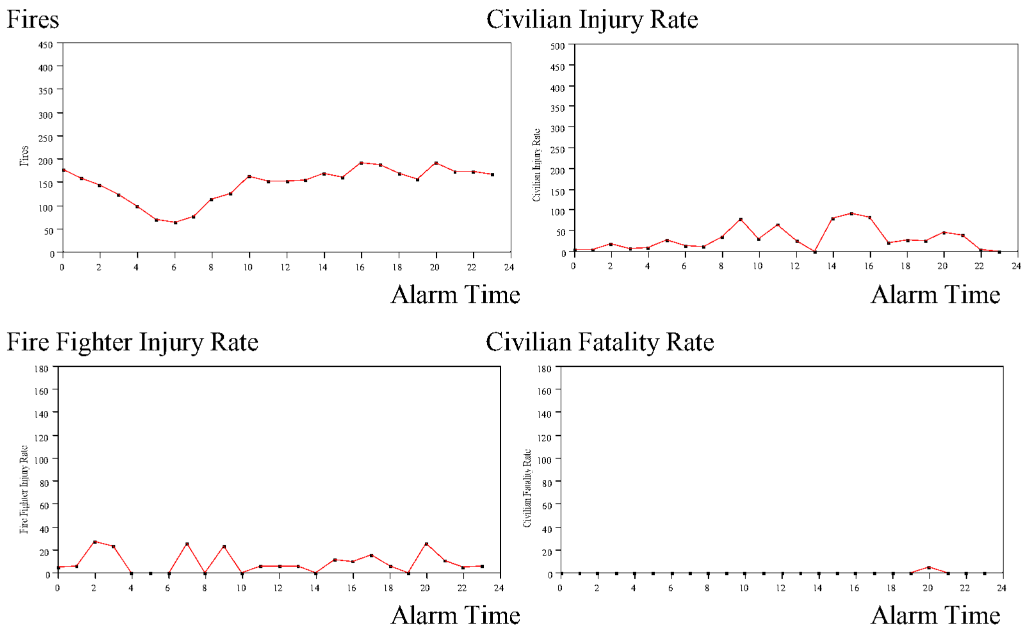
Construction Type	Cumulative % of Fires Confined to Room of Origin	% of Fires Confined to Fire-rated Compartment of Origin	% Fires Confined to or Extended Beyond Structure of Origin
Fire Resistive: Totally non-combustible, no unprotected steel, steel protection "heavy"	91.7	0.5	5.5
Heavy Timber: Mill-construction building, load bearing walls or columns masonry or heavy timber	72.2	1.3	23.9
Protected non-combustible: Totally non-combustible, no exposed structural steel, steel protection "light"	89.0	0.9	8.0
Unprotected non-combustible: Totally non-combustible, exposed structural steel	72.6	0.9	23.8
Protected Ordinary: Load bearing walls masonry, columns fire protected, underside of all wood floor and roof decks protected by fire-resisting covering	86.4	1.1	9.4
Unprotected Ordinary: load bearing walls masonry, columns, wood floor and roof decks exposed and unprotected	71.3	1.1	24.4
Protected Wood Frame: Walls, floors and roof structure wood framing, Interior walls and ceilings of habitable spaces protected by fire resistive covering, "brick veneer"	71.7	0.5	25.0
Unprotected wood frame: Walls, floors and roof structure are wood framing, no fire-resistive covering protecting wood frame.	47.1	0.3	50.6
Unknown, etc	68.5	0.2	30.6

Table 4.29 Effect of Construction Type (Sprinklers Not Present)

Construction Type	Civilian Injury Rate (per 1000 fires)	Fire Fighter Injury Rate (per 1000 fires)	Civilian Fatality Rate (per 1000 fires)	$ Loss Rate (per fire)
Fire Resistive: Totally non-combustible, no unprotected steel, steel protection "heavy"	46	7.7	0.8	29,000
Heavy Timber: Mill-construction building, load bearing walls or columns masonry or heavy timber	10	40	3	42,000
Protected non-combustible: Totally non-combustible, no exposed structural steel, steel protection "light"	7	0	0	32,000
Unprotected non-combustible: Totally non-combustible, exposed structural steel	32	23	0.8	100,000
Protected Ordinary: Load bearing walls masonry, columns fire protected, underside of all wood floor and roof decks protected by fire-resisting covering	26	7.8	1	24,000
Unprotected Ordinary: load bearing walls masonry, columns, wood floor and roof decks exposed and unprotected	34	18	1	61,000
Protected Wood Frame: Walls, floors and roof structure wood framing, Interior walls and ceilings of habitable spaces protected by fire resistive covering, "brick veneer"	19	20	2	38,000
Unprotected wood frame: Walls, floors and roof structure are wood framing, no fire-resistive covering protecting wood frame.	24	30	3	45,000
Unknown, etc	13	35	0	30,000

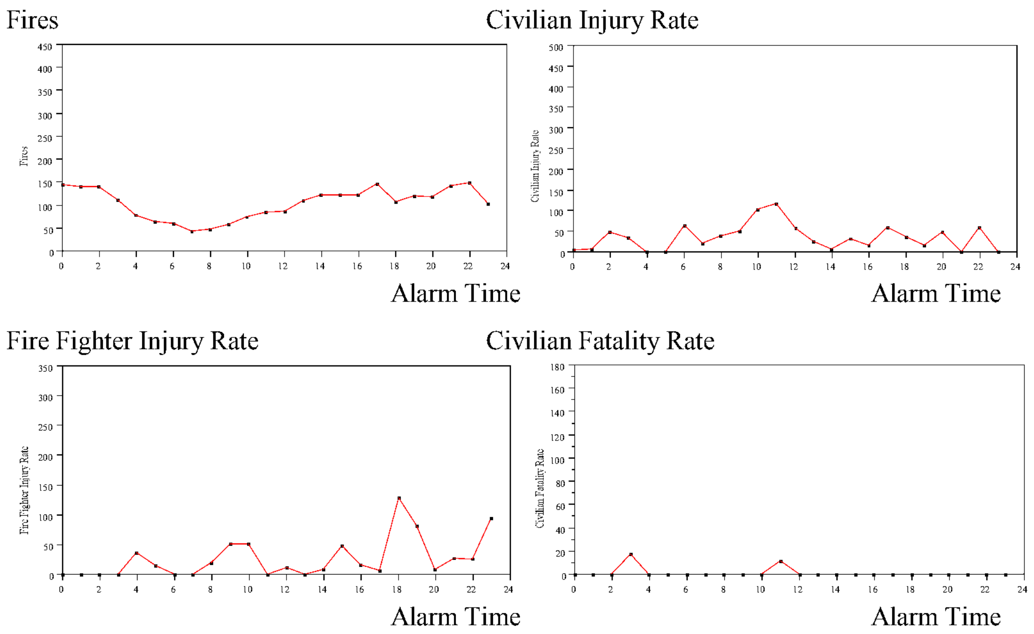


(a) Extent of Flame Damage Confined to Object of Fire Origin

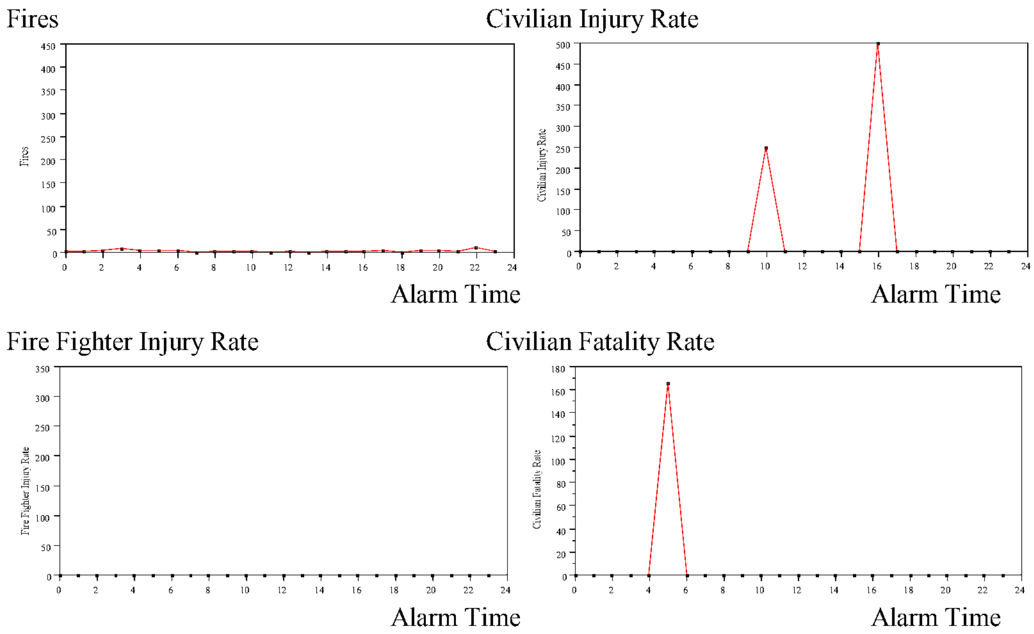


(b) Extent of Flame Damage Confined to Part of Room or Area of Fire Origin

Figure 4.20 Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Commercial Buildings

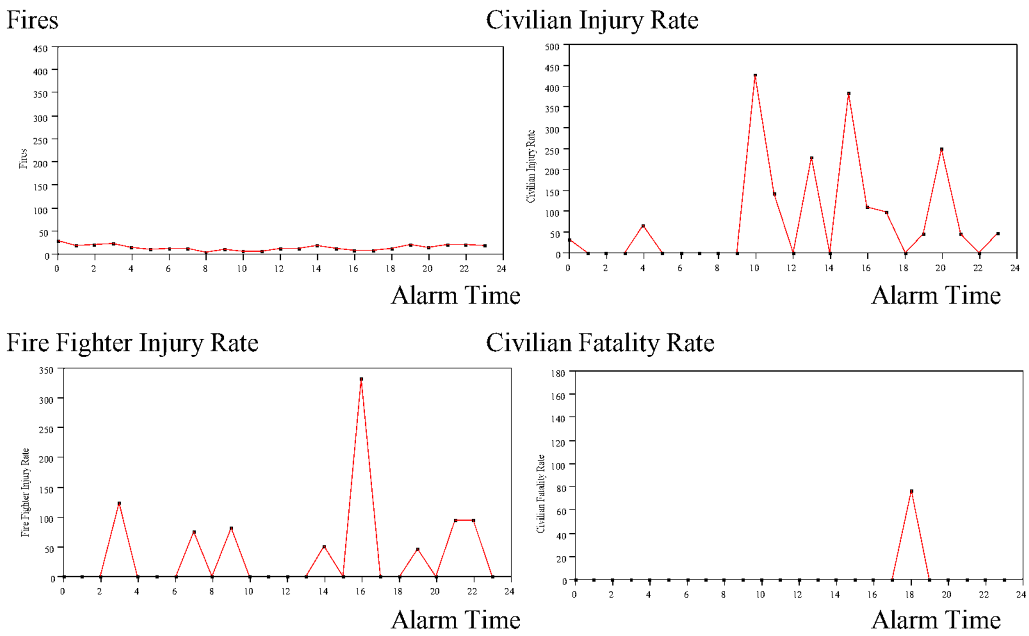


(c) Extent of Flame Damage Confined to Room of Fire Origin

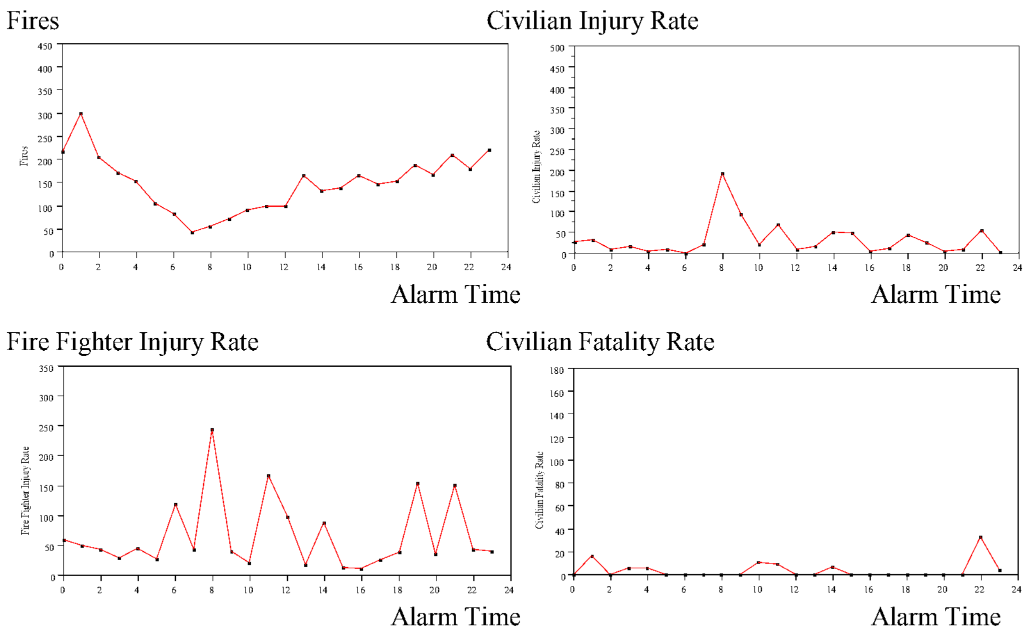


(d) Extent of Flame Damage Confined to Fire-rated Compartment of Fire Origin

Figure 4.20 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Commercial Buildings

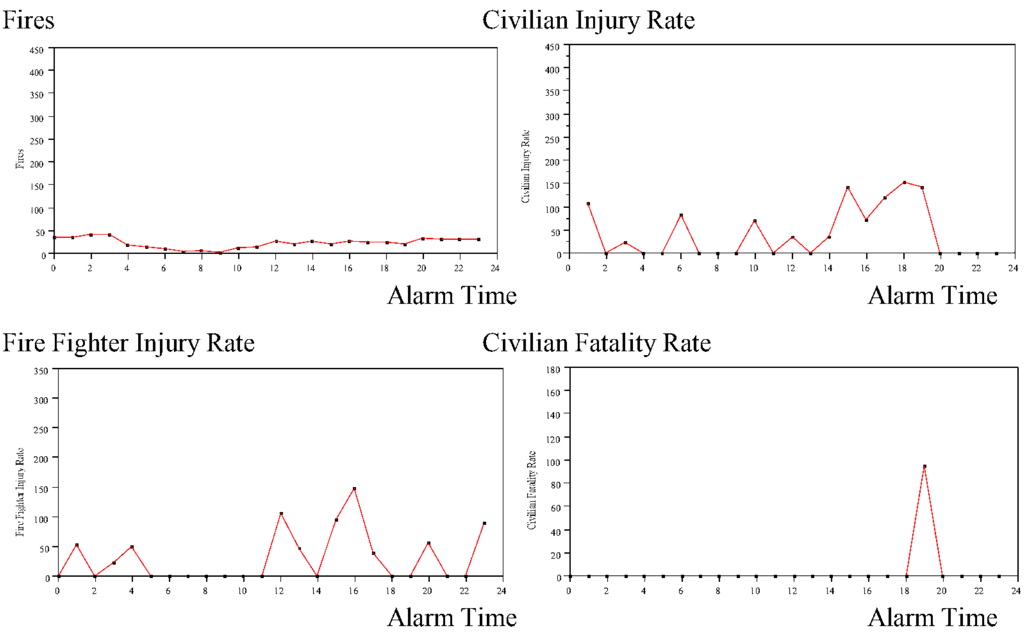


(e) Extent of Flame Damage Confined to Floor of Fire Origin



(f) Extent of Flame Damage Confined to Structure of Fire Origin

Figure 4.20 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Commercial Buildings



(g) Extent of Flame Damage Extended Beyond Structure of Fire Origin

Figure 4.20 (cont) Variation of Number of Fires, Rate of Civilian Injuries, Rate of Fire Fighter Injuries and Rate of Civilian Fatalities with Alarm Time for Commercial Buildings

The fire fighter injury rate is also reasonably low until the fire spreads such that flame damage *extends* ***beyond*** *the room of origin*. The fire fighter injury rate generally increases but also becomes more variable for flame damage *beyond the room of origin*. The peaks occur throughout the twenty-four hours.

The civilian fatality rate is generally low and moderately constant for fires with flame damage *confined to the room of origin*. The remaining fires are again very "peaky" with peaks occurring at odd hours of the day and night.

While there is a substantial increase in the number of fires during the day and evening they do not seem to be accompanied by increases in fire fighter or civilian casualty rates.

4.1.8 Conclusion

Before drawing conclusions based on the data presented it is appropriate to mention some considerations that should be borne in mind when attempting to reach conclusions using such data. The data presented covers all classes of buildings and all occupancies. It may be that for some particular classes of buildings or some particular occupancies there is a high degree of dependence or correlation between certain of the fields contained in the data. For example, in some (or indeed all) occupancies there may be a strong correlation between the *construction type* and *presence of sprinklers*. Therefore it is impossible to be sure that variation of say, casualty rates, is dependent on one or other (or indeed, either) of the fields under examination.

It must be understood that such dependencies or correlations observed in statistical data **do not** indicate a cause-and-effect relationship between the variables and no such relationship should be taken to exist between variables just because they correlate closely or appear to vary sympathetically. Observed dependencies or correlations require specific and detailed investigation to establish the existence (or otherwise) of cause-and-effect relationships.

Nevertheless, some observations can reasonably be made:

- the rate of *civilian fatalities* is about six times higher in fires in *residential* buildings than *commercial* buildings, but the *civilian injury rate* is only about twice as high
- the rate of *fire fighter fatalities* is about three times higher in fires in *residential* buildings than *commercial* buildings, but the *fire fighter injury rate* is nearly twice as high in *commercial* building fires than *residential* building fires
- the *$ losses* per fire average about four times higher for fires in *commercial* buildings than *residential* buildings
- males are more likely to be fire fatalities than females, and the very young and very old of both sexes have much higher than average fatality rates
- particularly in residential buildings (also in commercial buildings, but to a lesser extent) increasing *extent of flame damage* increases the likelihood of civilian fatalities - by over ninety times for fires in *residential* buildings with flame damage *extending beyond the structure of origin* compared with fires with flame damage *confined to the object of origin*
- *fire brigade arrival time* has a significant effect on the *extent of flame damage*, the shorter the time the less the extent of damage
- the *presence* of *sprinklers* in the *room of fire origin* has a very significant effect on the likelihood of fire spread beyond the room of origin and therefore might be expected to have a significant influence on the overall *rate of civilian fatalities* in fires in buildings (but there are too few fires in sprinklered buildings to confirm this with confidence)
- there are significant differences in the likelihood of *flame spread beyond the object of origin* (and similarly *beyond the room of origin*) in buildings with different *fixed property uses*
- *civilian fatalities* occur most frequently in both *residential* and *commercial* buildings in fires originating in *lounge and sleeping rooms*
- *smoke damage* is much less likely (by a factor of four in *residential* and over two in *commercial*) to *extend beyond the room of origin* in fires with *sprinklers present* in the room of origin compared with fires originating in rooms *without sprinklers*
- *flame damage* is much less likely (by a factor of over four in *residential* and four in *commercial*) to *extend beyond the room of origin* in fires with *sprinklers present* in the room of origin compared with fires originating in rooms *without sprinklers*
- there is no indication in the data that the *fire-rated compartment (of fire origin)* has any significant effect in limiting smoke or flame spread

Many further useful observations may be obtained by detailed examination of the data presented.

4.2 INDUSTRY EXPERIENCE

4.2.1 Responses to Industry Circular

A questionnaire concerning perceptions of aspects of fire resistance and non-combustibility in the BCA was circulated to 18 industry organisations in March 1996 (see Appendix A 4.3.1). A reminder was sent in August, stating that no response was received, it would be assumed that the recipient was happy with existing BCA requirements. 10 responses were received and comment was also submitted by David Mumford of Waverley Council.

Number circulated: 18

Number of responses received: 10 + 1 additional comment

No	*Organisation*	*Response received*	*General comment*
1	Australian Building Codes Board	No	Participating in Fire Code Reform
2	Fire Protection Industry Association of Australia	No	
3	Cement and Concrete Association (& Concrete Masonry Association of Australia)	Yes	
4	Australian Institute of Steel Construction	Yes	
5	Commonwealth Fire Board	No	
6	Brick and Paver Institute	No	
7	Steel Institute of Australia	No	Questionnaire forwarded to AISC
8	National Association of Forest Industries	Yes	

9	Master Builders Association	No	
10	BOMA National	No	
11	AFPA	Yes	
12	Fire Prevention, NSW Fire Brigade	Yes	Unable to allocate staff to compile response. Neither support nor disagree with BCA provisions
13	Royal Australian Institute of Architects	Yes	
14	Farima	Yes	General comment on AS1530. Specific comment applies to early fire hazard and has been referred to Project 2
15	Australian Fire Authorities Council	Yes	
16	Standards Australia	Yes	
17	AMCA National	Yes	
18	Assoc of Consulting Engineers of Australia	No	
	Additional comment from David Mumford, Waverley Council	-	Comment on solid core doors

Q1: Do you consider the existing fire resistance levels in the BCA to be inadequate/appropriate/excessive and why?

No	***Comment Summary***
3	Appropriate - supported by enviable national safety record and community acceptance of current level of protection. Reductions based on computer simulation, experiment and overseas experience must take local factors into account - hasten slowly
4	Excessive - compared with other countries with similar or better levels of fire

	safety with higher usage of sprinklers
8	Excessive - historic evidence (Keough report, Great Britain, others world wide) shows excesses. Performance-based codes currently reducing FRLs. Reductions must be rational.
11	Adequate - given our fire losses compared to other countries. Need better and longer term statistics to verify answer.
13	Excessive - 2 hr requirement for new single buildings - must be based on building preservation, not occupant evacuation. Also concessions obtainable for heritage buildings indicate built-in excesses Adequate - requirements for separation of different buildings as adjacent buildings may not be protected
14	AS 1530 tests no longer suitable as tests for insulation materials
15	Inadequate - do not reflect fire load in a particular building. Based on class, not specific use
16	Unable to evaluate as committee process does not appear to have provided us with an awareness of this issue
17	No expertise

Summary and discussion

The majority of respondents felt current FRLs were adequate (2) or excessive (3). One respondent (the only fire-fighting group to offer detailed response) believed them to be inadequate.

Q2: Do you believe the existing provisions provide a rational framework for fire resistance that permits a consistent approach to attaining the BCA objectives?

No	***Comment Summary***
3	No - rules are widely acknowledged to be empirical, at times conflicting (ambiguous) and confusing to the specifier
4	Cannot answer question without detailed analysis
8	No - the BCA has massive passive protection requirements which are onerous on cost. Barrier provisions are inconsistent - FRLs for external walls distant from boundaries are inadequate to protect against spread of fire from a lower storey.

11	Sceptical, although familiarity with the regulations leads to an acceptance of a degree of consistency.
13	No - different interpretations of detail by different authorities lead to problems eg (i) definition of s.o.u v dormitory unit (ii) finishes to corridors leading to fire stairs
14	AS 1530 tests no longer suitable as tests by themselves for insulation materials
15	With the imminent introduction of performance provisions, buildings will be assessed on specific use. It is to be hoped that BCA objectives will be met.
16	Not an issue that we can readily address
17	Yes - but there are anomalies which confuse the building service designers and contractors, especially FRLs for plant rooms and fire control rooms.

Summary and discussion

The majority of respondents believed that the existing provisions do not provide a rational framework for fire resistance. The only respondent who felt there was a rational framework believed that it contained anomalies.

Q3: Do you agree with the present concept of three basic types of construction?

What do you understand the objectives for the three types of construction (Type A, Type B, Type C) to be?

No	***Comment Summary***
3	3 Types reasonable but need rational design approach Type A - confine fire to compartment of origin and protect building from external fire Type B - intermediate Type C - protect building from external fire
4	Three types appear to be adequate, but: (a) Lower FRLs should apply to Type B construction, and

	(b) Type A construction should start above 4 storeys Objectives for Types of construction should be same as BCA objectives.
8	Three levels too limiting; need more (5), with sensible grading of performance that does not include combustibility of barriers Type A - in uncontrolled fire, building or compartment of fire origin should survive burnout and occupants escape to a place of safety Type B - in uncontrolled fire, building of fire origin can be "gutted" provided external walls do not collapse Type C - in uncontrolled fire, building can end up as pile of ashes
11	Three Types of construction is restrictive - why not 6 or 10? Understanding of objectives of "types" not assisted by Part C - need commentary to provide rationale, aims, objectives.
13	Yes, 3 types Type A - large complex multi-level buildings with limited egress possibilities Type B - Medium sized buildings with good egress possibilities Type C - Small combustible buildings where egress is easy and quick
14	No relevant comment
15	Type A, B or C academic Possible to have Type A building with no FRL (large single storey class 5-9 (ed)), therefore Type A not always "most fire resistant". Large isolated buildings no specific type of construction
16	The current Types of construction do not coincide with performance objectives and therefore do not provide desired flexibility. Type A - effectively provides full compartmentation through fire resistant construction where the structure should be capable of surviving a fire, provided the contents are typical of the building classification Type B - less than full compartmentation and fire resistant construction affords external protection only Type C - may be of combustible construction with no fire resistant capability and therefore no compartmentation

	Objectives - Type A - maximum time afforded for occupants to egress Type B - limited time afforded for occupants to egress Type C - minimal time afforded for occupants to egress
17	Agree with concept of three Types of construction. Type A - whole construction can resist complete burnout and building resistant to adjacent fire source Type B - all structural elements other than floors and roofs can resist fire. Stair and lift shafts can resist fire. Building resistant to adjacent fire source. Type C - Building resistant to adjacent fire source, but to a lesser extent than Type A or B

Summary and discussion

Four respondents agreed that three Types of construction were reasonable although the number was seen to be somewhat arbitrary. Three respondents felt that three Types was limiting, and one that Types were academic. It was generally felt that a more rational design approach was needed as there were inconsistencies in the use of the Types.

Perception of the objectives of "Types of construction" varied. Most viewed Types of construction in relation to the degree of compartmentation, with Type A restricting the fire to the compartment of fire origin and Type C offering protection from fire in an adjacent building or no protection at all. Type A was seen as being appropriate for buildings where egress times were long or choices limited, while Type C would apply to buildings where egress times were short and egress easy. The variety of perception of the objectives indicates a lack of clear division between the Types of construction.

Q4: What are your views with regard to the present provisions for "support of another part"?

No	***Comment Summary***
3	Intent and objective unclear. Make sense within one compartment, but irrational where column passes

	through several compartments, where FRL should be related to fire load within the compartment.
4	Issue has been resolved with ABCB
8	"lateral support" (Spec C1.1 clause 2.2) causes many members to be unnecessarily fire-rated. Recommend Queensland and Victorian variations.
11	Treatment in BCA is simplistic. Does not satisfactorily address the interconnection or inter-reliance of the two elements and their effect on either the FRL of the components or of the material characteristics and compatibility
13	Not appropriate for "inner city" type residences where timber floors are stabilising party walls. If floor burns then wall is deemed unstable.
14	No relevant comment
15	Appears logical in principle but not so in practice. Eg 4th floor warehouse requires 240/240/240 FRLs on external facade columns; fire load in offices below requires only 120/120/120 columns, but 240/240/240 required for support. But, if calculations correct, office storey will not burn for more than 2 hours. Support should ensure structural stability irrespective of use of storey
16	Unable to provide a view
17	No expertise on building elements, but anomalies in support of fire resisting ductwork. BCA Part E2 requires compliance with AS1668.1 - 1991, but Standard does not address adequacy of roof or floor to support ductwork - could be significant in Type B construction.

Summary and discussion

Generally it was felt that this requirement was onerous, leading to unnecessarily high FRLs especially where two or more fire compartments were involved. The BCA does not clarify whether the requirement for support of another part extends to building components required to have an FRL by Standards called up in the BCA (eg ductwork).

Q5: What are your views with regard to the present provisions for "tilt-up" and panalised construction?

No	***Comment summary***

3	Current rules empirical and address wide range of scenarios with simple rules - should be reviewed when evidence available to confirm satisfactory performance. Need set of performance criteria for all external walls.
4	Present provisions appear to be adequate
8	No comment
11	Use of tilt-up panels leads to sub-standard construction. Objectives of Part C1(b)(i) and (ii) are often ignored in regard to adjoining property. Load-carrying performance of connectors in Clause C1.11 do not take account of elevated temperatures. Base slippage could be addressed by cast floor seating channel. Whole area needs expansion.
13	No comment
14	No comment
15	Tilt-up walls should not fall inwards as fire-fighters may need to search and rescue within the building. FRL for support of tilt-up wall is in practice less than the wall, so tilt-up wall will not perform to required FRL. Therefore all buildings with tilt-up construction should be sprinkler protected - the direction of fall might then become irrelevant.
16	Unable to provide a view
17	No comment

Summary and discussion

Few respondents had expertise in this area. It was suggested that the requirements were limited and should address a wider range of possible construction methods, possibly providing performance requirements for all external walls. Fire fighters were concerned that walls would fall inwards (note that Clause C1.11 applies in addition to requirements for FRL for the appropriate Type of construction and the requirement for support of another part, which should ensure that the wall stays up for long enough to evacuate the building).

Q6: What are your views with regard to the present provisions for carparks?

No	***Comment Summary***
3	Adequate, but standard of protection required for various building elements

	conflict for different construction materials. Intensity of fire will remain the same for all non-combustible materials, so allowing some steel columns to have FRP of 30mins and others 60mins seems irrational
4	They are adequate and supported in practice in other countries
8	No comment
11	No problems encountered
13	Concessions are acceptable. Modern cars are a low fire hazard in buildings
14	No relevant comment
15	Requirements for enclosed carparks reasonable. Open carparks have no floor area limits and BCA cross-ventilation might not be adequate for control of smoke spread
16	Unable to provide a view
17	No expertise

Summary and discussion

Again, few respondents had expertise in this area. There was general agreement that FRLs for carparks were adequate if inconsistent. One respondent felt that cross-ventilation was inadequate for smoke control in large carparks.

Q7: What are your views with regard to the need for provisions for timber-framed and other combustible construction?

No	***Comment Summary***
3	Previous rules were irrational. Current relaxation need to be evaluated in practice before they are embraced without reservation. Current process of permitting timber frames for a limited range of multi-storey residential buildings is a sensible way of evaluating performance in Australian conditions.
4	No comment
8	Control of timber-framed construction should be within limitations of its structural ability, as any other material, and the fire-rated performance of its assemblies, regardless of whether it is loadbearing. Whole use of combustibility in BCA needs review

11	Present BCA is limiting, particularly looking at NZ and USA. With current methods of protection (smoke detectors, fast response sprinklers) there is no doubt that larger safe structures could be built.
13	Changes are required as timber provides an important alternative method of construction for medium sized buildings
14	No relevant comment
15	Matter too complex to give a general answer.
16	Timber-framed and combustible construction should be treated as two issues: (a) there is a legitimate need to provide for timber-framed construction on the ground of choice, popularity, availability and economy (b) fire resistance and fire hazards associated with combustible construction should be separated, the latter needs to allow for maximum flexibility on the choice of building materials.
17	Have problems installing air conditioning in existing buildings with timber construction. No problems with new buildings

Summary and discussion

Respondents' views varied but generally agreed that recent concessions were a step in the right direction and should be extended to other occupancies if experience shows this is appropriate. The use of combustible construction in the BCA should be the subject of a separate review.

Q8: Are there any areas where the existing provisions for fire resistance are inadequate?

No	***Comment Summary***
3	Property protection is being overlooked in the concentration on life safety. Loss of personal property can be traumatic.
4	No comment
8	No comment
11	Can only be addressed in the light of better information

13	Not known
14	No comment
15	See previous answers
16	Unable to provide a view
17	(a) Spec E1.8 for Fire Control Centres is inadequate in the following areas with respect to fire resistance: Clauses 4(d) and 5(d)(ii) require ventilation duct openings to be protected with fire dampers. The activation of such dampers during a fire would render the fire control centre ventilation inoperable. Clause 8(b)(i) does not define airflow velocity criteria across the exit doors (b) There is no requirement in the BCA to enclose emergency generating plant in a fire resistant enclosure. This is self-evident under a performance-based regime, but should be defined for "deemed to comply" systems.

Summary and discussion

In addition to the areas previously discussed, existing provisions for fire resistance were considered inadequate in the following areas:

(a) for property protection;

(b) fire control centres (see comment 17); and

(c) structure surrounding emergency generating plant. (Note that this is addressed in BCA clause C2.12(a)(ii).)

Q9: Are there any areas where the existing provisions for fire resistance are unduly onerous?

No	***Comment Summary***
3	"unduly" is difficult. Obviously, support of another part can be so. A more rational approach would solve these problems
4	See answer to Q1

8	See answers to Q1 and Q7
11	Can only be addressed in the light of better information
13	Refer Q4. Progressive collapse and lateral support of another part seem to be areas that could be revised
14	No relevant comment
15	See above answers
16	Unable to provide a view
17	No knowledge of unduly onerous provisions.

Summary and discussion

The only area where existing fire resistance provisions are unduly onerous mentioned in addition to those discussed above is progressive collapse.

4.2.2 Additional Comment

Additional comment concerning the performance of solid core doors of various construction and their fitting was received from David Mumford of Waverley Council. This comment, which provides technical detail of current construction practice, will be taken into account in later parts of Project 3.

4.2.3 Conclusions

Of the 18 organisations contacted, six did not respond. The responses received indicated that, although FRLs were generally considered adequate or excessive, any rational framework was not clearly apparent and requirements contain anomalies and inconsistencies. The perception of the objectives of "Types of construction" was inconsistent and the number of Types was considered arbitrary.

Requirements for support of another part were considered onerous and excessive, while those for tilt-up construction could be extended to include a wider range of construction methods; it was suggested that the objective of these requirements might also need to be reconsidered. Requirements for carparks were considered to be adequate but inconsistent. Concessions for multi-storey timber framed construction in Class 2 buildings were welcomed, and it was suggested that these could be extended to other classes. It was suggested that the issue of non-combustibility required a separate review (this is the subject of part 4 of Project 3).

APPENDIX A4.3.1

21 March 1996

Dear

FIRE CODE REFORM PROGRAM PROJECT 3:
FIRE RESISTANCE and NON-COMBUSTIBILITY

I am writing to you on behalf of the research team undertaking the above project to seek your assistance. As you may be aware the project is to review the existing Building Code of Australia (BCA) provisions for fire resistance (FRLs) and non-combustibility. The outcome from this project will be recommendations for changes in the BCA with regard to fire resistance levels and non-combustible construction. It is intended to develop a rational framework for determining fire resistance levels and the evaluation of appropriate fire resistance levels taking into account building and occupancy characteristics, other fire safety systems that may be present and regulatory objectives.

Part one of the project is concerned with a historical perspective on the existing provisions. It is intended to establish how well the existing provisions have served us and what are its merits and shortcomings. One of the activities of the project involve the identification of issues, problems and concerns that you, or your industry colleagues, may have with the present provisions for fire resistance and non-combustibility.

The research team would value any contribution you care to make on this topic. In particular we would appreciate if you could provide answers to the following questions.

Q1: Do you consider the existing fire resistance levels in the BCA to be inadequate/appropriate/excessive and why?

Q2: Do you believe the existing provisions provide a rational framework for fire resistance that permits a consistent approach to attaining the BCA objectives?

Q3: Do you agree with the present concept of three basic types of construction? What do you understand the objectives for the three types of construction to be?
Type A:
Type B:
Type C:

Q4: What are your views with regard to the present provisions for "support of another part"?

Q5: What are your views with regard to the present provisions for "tilt-up" and panalised construction?

Q6: What are your views with regard to the present provisions for carparks?

Q7: What are your views with regard to the need for provisions for timber-framed and other combustible construction?

Q8: Are there any areas where the existing provisions for fire resistance are inadequate?

Q9: Are there any areas where the existing provisions for fire resistance are unduly onerous?

We would appreciate any other views you may have with regard to the existing provisions for fire resistance and non-combustibility or future regulatory provisions.

I hope that you will be able to spare a little time to assist us and look forward to your reply.

Yours sincerely
Stephen J Grubits
Principal Research Consultant
FCRC Project 3.

Dear

FIRE CODE REFORM PROGRAM PROJECT 3:
FIRE RESISTANCE AND NON-COMBUSTIBILITY

You may recall that in March we sent you a questionnaire concerning your perception of existing provisions for fire resistance levels and non-combustibility in the Building Code of Australia (BCA). We are now ready to finalise our report on industry's concerns, but do not appear to have received your response.

Your contribution is of value to us and we would appreciate your participation in our survey, however brief your answers. For your convenience, a copy of the questionnaire is attached.

If we have not heard from you by 31st August we will assume that you are satisfied with the current BCA requirements and feel that no change is warranted.

Yours sincerely
Jane Blackmore
CSIRO Project Leader
FCRC Project 3

4.2.4 Specific Issues

Issues that have been raised or considered recently regarding the fire resistance requirements of the BCA are briefly mentioned in this section.

There has been fairly widespread concern over the level of FRL's among certain interest groups for many years, the level of some or all FLR's being stated to be excessive. Another aspect of this general concern has been perceived inconsistencies in the level of FRL's for certain members and building classes. Many would argue that the current provisions are an inconsistent and irrational collection of often specific and detailed requirements rather than well structured and rational requirements appropriate for the building methods and operating conditions currently expected by the community.

The lack of reduced FRL's when sprinklers are fitted in the building has been a major issue for many years. It is argued by many designers and fire engineers that it is appropriate to have reduced FRL's when sprinklers are fitted compared with the no sprinkler case. Less of an issue, but also of concern is the question of whether reduction of FRL's is appropriate when detectors are fitted, it again being advocated that it is appropriate to lessen FRL's when detectors are required.

Specific issues have been raised (and to a large extent dealt with over the last few years) regarding requirements for tilt-slab and precast concrete wall panels. With the introduction to common usage of this form of construction several years ago concern was raised about of panels falling outwards during fires - representing a danger to fire fighters in particular. This issue has largely been dealt with by requiring adequate and suitable connection of the panels to the remainder of the building, so that detachment was prevented.

The requirements for support of another part have been changed in the latest amendment after several years of submissions and discussion. The gist of the argument for change has been that the requirements for the same FRL to be provided to supporting members as the members they support applies sensibly within fire-rated compartments, but not when they are in different compartments with different occupancies. Provided there is appropriate fire separation the FRL's should relate to the occupancy of the compartment and not of compartments remote from it.

The lesser requirements for FRL's for fire doors have been seen as inconsistent with the FRL's for the walls they are incorporated in and have been of some concern. The less stringent requirements in the standard fire test for doors and other opening treatments have also been raised.

Inconsistencies in the requirements for construction Types B and C are also of some concern.

5. NEED FOR CHANGE

5.1 PERSPECTIVE

The preceding sections of this report have involved detailed studies in the different areas which relate to the current position on fire resistance and non-combustibility requirements for buildings. It is now necessary to summarise and draw together these different strands with a view to establishing the basis upon which any changes proposed need to be founded.

5.2 HISTORICAL REVIEW

The review of the historical basis of requirements for passive fire protection has shown that the BCA has its roots in a system of regulations reflecting the building technology of the day, rather than in an approach which identifies goals and deduces a regulatory framework from them. It has evolved though a series of changes and amalgamations of different documents, many of which have been the result of political rather than technical pressure. Attempts have been made by the regulators to try to identify the role of the requirements in contributing to fire safety, but these attempts have been after the event, rather than being stated objectives which then lead to the requirements which follow. As a result the introduction of 'objectives', 'functional statements' and 'performance requirements' has not led to a change in the BCA provisions for fire resistance.

5.3 CURRENT REQUIREMENTS

Neither the review contained herein, nor the final report on FCRC Project 1 has been able unambiguously to determine the role of fire resistance requirements when considered in the context of overall building fire safety systems. There is no suggestion that the requirements have turned out to be inadequate as a consequence of the process by which the existing BCA has developed. But the result is that a lack of consistency may be identified and a lack of a rational basis for some of the measures which are currently required. This in itself makes improvement difficult, and would suggest that a analysis of the various measures to see if consistency and rationality can be introduced would be beneficial.

5.4 STATISTICAL EVIDENCE

Statistics, because of the way they are collected, cannot be used to show whether failure of fire resisting barriers is a significant contributor to fire spread in buildings. Because very many fire barriers are breached by doors, windows, shafts and other penetrations, which may or may not maintain the integrity of the barrier, it is not possible to conclude that spread of fire beyond the compartment of fire origin represents failure of the fire resistant barrier as such. Evidence suggests that failure of fire protected structural elements is almost unknown.

5.5 INDUSTRY VIEW

The industry survey indicated that the industry generally found the BCA requirements to be adequate or excessive. It was noted by those who responded however, that there was an absence of a rational framework, and that anomalies and inconsistencies exist, which agrees with the observations of the present study, noted above. Six organisations did not respond, indicating by default that they were happy with the existing BCA fire resistance levels. Because of the way in which the questionnaire was structured, it was not possible to deduce the extent to which change would be welcomed, if reduction in fire resistance requirements could be achieved consistent with maintaining adequate safety levels. Presumably it would, at least in the commercial sector.

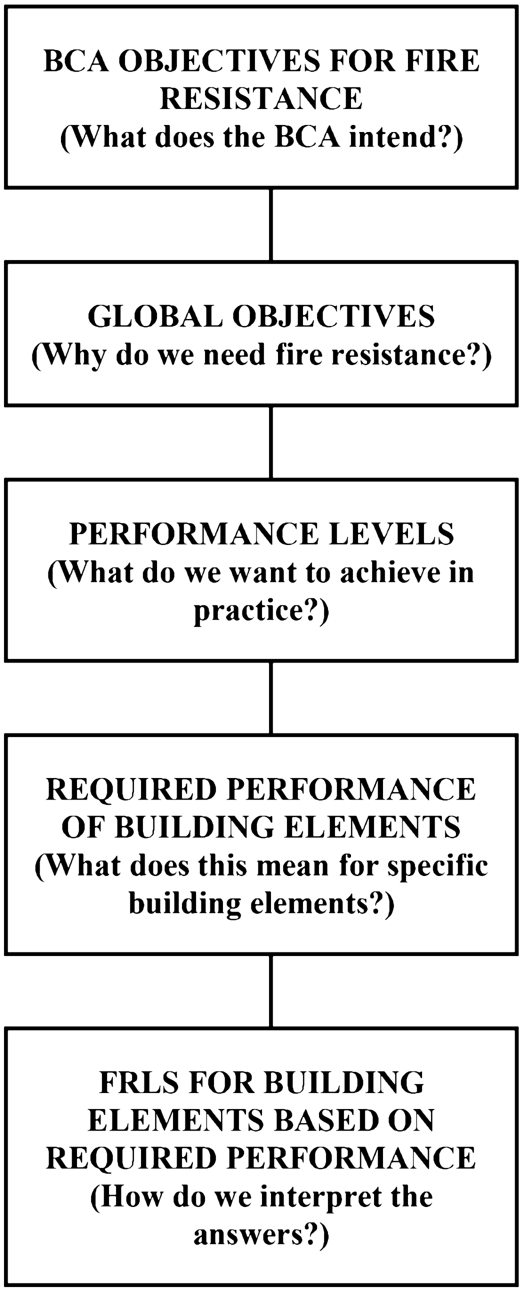
5.6 SUMMARY

The strongest theme to emerge from the studies undertaken and outlined above is that there is a need for a rational and consistent approach to be introduced into the BCA requirements for fire resistance and non-combustibility. The statistics do not show that there are unexplained failures of the existing buildings which need to be addressed. Therefore it is possible to build on this confidence to undertake an analysis which would address the concern of building regulators and designers. Because change in the past has always relied on an unquantified degree of conservatism, it is to be expected that at least some of the recommended changes which would emerge from the analysis would have the effect of reducing the passive fire protection requirements, thereby improving cost-effectiveness of building designs.

6. A PERFORMANCE FRAMEWORK FOR FIRE RESISTANCE LEVELS IN THE BCA

6.1 STEPS IN DERIVING FRLS

The following chart summarises the steps that need to be taken to derive a rational set of FRLs for building elements:



6.2 OBJECTIVES

6.2.1 Global objectives

It is part of the aim of this project to review the objectives of the building regulations for fire resistance and derive a more rational set upon which quantified design options can be based. To ensure that the final set of objectives is comprehensive, it is helpful to consider both the global objectives of fire safety (a "top down" approach) and the intent of the detailed requirements (a "bottom up" approach - see Fire Code Reform Project 1).

In broad terms the objectives will address the control of injury and loss of life in fire at acceptably low levels. It is debatable whether property loss is a regulatory or an insurance matter but a degree of property protection may be achieved in preventing injury, loss of life and fire spread. A decision on the extent of such protection is a matter of public policy to be addressed by the ABCB and is outside the scope of Fire Code Reform.

The following global objectives have been identified as the intentions behind the provisions of the BCA:

- to keep loss of life in building fires to a very low level (it is assumed that there is a relationship between injury and loss of life in fire, such that the reduction in risk to life automatically implies a reduction in risk of injury)

- to limit property damage by introducing measures to control fire size and to prevent fire spread from premises on fire to neighbouring premises

- to provide protection to firefighters in the execution of their duty.

6.2.2 Context

As building designs have become more complex and active systems more sophisticated and reliable, the role of any component or aspect of a building which contributes to fire safety cannot be studied in isolation. It is important therefore that any review of FRL requirements is sufficiently comprehensive to analyse the objectives in the context of all relevant building and occupant characteristics.

6.2.3 Building systems

Having determined global objectives it is possible to see how they might be achieved by establishing a set of more precise aims to which specific fire safety systems contribute directly. In this way the objectives and the context may be brought together in a matrix such as that in Table 6.2.3. A filled box indicates that the identified system contributes significantly to the proposed aim.

TABLE 6.2.3 FIRE SAFETY AIMS AND THE CONTRIBUTION OF BUILDING SYSTEMS

Matrix showing some possible building systems that could contribute to achieving the fire safety aims

Fire Safety Aims / Building Systems		Detection	Alarms	Escape Routes	Management	Control of materials	Occupant fire fighting	Smoke control	Sprinklers	Communications	Internal fire barriers	Brigade fire fighting	Structure	Boundary fire barriers
Reduce risk of ignition					■	■								
Alert people		■	■		■				■	■				
Keep fire small		■				■	■		■					
Provide escape routes				■										
Protect escape routes	from smoke							■	■		■			
	from fire					■			■		■			
	from collapse								■				■	
Limit fire spread						■			■		■	■		
Protect fire fighters	from smoke							■	■					
	from fire								■		■	■		
	from collapse								■			■	■	
Protect neighbours	from fire								■			■		■
	from collapse								■			■	■	

Table 6.2.3 also clarifies interactions between systems. It can be seen that one of the suggested purposes of fire resistant barriers is to achieve the aim of limiting fire spread, but that this aim is also met by the use of sprinklers. Therefore it is clear that the FRL required for barriers may be modified if sprinklers are present, whilst maintaining the same safety level. Another function of fire resistant barriers is to protect escape routes, but these might alternatively be protected by smoke control or use of materials.

6.2.4 Building characteristics

The relative importance of each of the systems in Table 6.2.3 to each of the aims varies very significantly with building type. Variations in the fire load, building height, area, layout and use add a third dimension to the table. Table 6.2.4 clarifies the specific building characteristics which might influence fire resistance requirements in the sense that they have an effect on fire severity.

6.2.5 Occupant characteristics

The risk to life from fire in buildings changes very markedly with parameters which govern the behaviour of occupants. In particular, whether the occupants may be asleep or otherwise slow to respond is of great importance in determining the time which will be taken for evacuation to be completed. This in turn affects the fire resistance requirements of some barriers and structures, or alters the significance of some of the systems which might be installed. These characteristics are included in Table 6.2.4.

6.2.6 Firefighters access

Under Fire Services Acts, firefighters have a duty to protect both life and property. The execution of this duty may require access to a burning building. Firefighters have training in identifying and coping with potentially unsafe buildings, and equipment designed to mitigate the effects of fire. There is a need in certain buildings to provide access routes to enable firefighters to carry out their duties effectively. Principally, this requirement relates to buildings fitted with firefighting hydrants, where protected access to any floor where a hydrant is located may be necessary. Once firefighters have gained access to the floor and hoses are operational, it is assumed that the situation is under control and a decision can be made to fight the fire or to retreat. In buildings where there are no internal hydrants, it may be assumed that firefighting operations are to be conducted from outside the building.

TABLE 6.2.4 FIRE SAFETY AIMS AND THE CONTRIBUTION OF BUILDING CHARACTERISTICS

Matrix showing some building characteristics that could contribute to achieving fire safety aims

Fire Safety Aims	Building Characteristics	Length of Escape Route	Capacity of Escape Route	Alertness of Occupants	Confinement of Occupants	Building height	Fire Load	Ventilation	Compartment Area	Compartment volume	Nature of materials	Building location	Distance to Brigade
Reduce risk of ignition							■				■		
Alert people				■									
Keep fire small							■				■		
Provide escape routes		■	■	■	■	■							
Protect escape routes	from smoke	■		■	■	■	■	■	■	■			
	from fire				■		■	■	■	■			
	from collapse						■	■	■	■			
Limit fire spread						■	■	■	■	■	■		
Protect fire fighters	from smoke	■				■	■	■	■	■	■		■
	from fire						■	■	■	■	■		■
	from collapse					■	■	■	■	■	■		■
Protect neighbours	from fire						■	■	■	■	■	■	■
	from collapse						■	■	■	■	■	■	■

6.3 PERFORMANCE LEVELS

6.3.1 Performance Defined

Fire resistance requirements relate to construction that is required to function either as a barrier to smoke and/or fire, or as a structural element. The performance required of a barrier or structure is the maintenance of necessary attributes while exposed to a fire of a certain intensity for a specified time. For barriers, the necessary attribute is its ability to resist the passage of smoke or fire, which is ultimately reflected in the FRL criteria for integrity and insulation. For structure the necessary attribute is stability under load, which is reflected in the FRL criterion for structural adequacy.

For the purpose of this report, a fire compartment has been defined as follows:

> A fire compartment is intended to limit the fire size to that which can be controlled by available fire fighting resources
>
> *Note: this definition is in performance terms rather than the prescriptive form given in the BCA.*

From the aims given in Table 6.2.3, it is possible to deduce 5 levels of performance that relate to barriers and structure. The functions of the five levels are shown in Table 6.3.1.

6.3.2 Barrier performance

For barriers the performance levels described apply to internal and to external barriers and will influence FRL criteria for integrity and insulation. The barrier system is composed of elements that provide protection from the effects of fire and would typically include walls, doors, floors/ceilings, roofs and windows.

Level 1 relates to barriers in place to limit the passage of smoke early in a fire. The duration for performance is the expected period of time in which people will reach a place of safety.

Level 2 relates to barriers which must survive exposure to fire to provide protection for escape routes. The duration for performance is the expected time in which people will reach a place of safety.

This level of performance applies to fire isolated staircases and corridors but must also apply to all floors, which form part of an escape route. This implies that all floors have to be fire resisting, but in certain buildings the time of exposure would be so short that no FRL would need to be applied.

TABLE 6.3.1-FIRES WHICH CHALLENGE FIRE RESISTANT BARRIERS AND STRUCTURES

		Critical Structure	Non-critical structure	Internal fire barriers	Boundary fire barriers
Protect people in escape routes	from smoke			1	
	from fire			2	
	from collapse	2	2		
Limit fire spread				3	
Protect fire fighters	from smoke				
	from fire			4	
	from collapse	3	3		
Protect neighbours	from fire				5
	from collapse	5			

hot smoke for escape duration	1
room fire for escape duration	2
compartment fire for fire access duration	3
compartment fire for fire access duration	4
burnout	5

Level 3 relates to barriers which must survive exposure to fire to provide access for firefighters. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

Where there are no internal hydrants, it may be assumed that firefighting takes place from outside of the building, and that if firefighters enter they exercise their professional judgement in so doing. For buildings with internal hydrants protection must be provided to allow firefighters to mount firefighting operations from within the building. From the point of view of fire resistance, this implies protection for staircases used for access, and also protection for floors.

Level 4 relates to barriers which limit fire spread to a fire compartment. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

It is assumed for these barriers that when firefighters undertake an operation, whether from inside or outside, their efforts will meet with success and the barriers will not be the sole means for limiting fire spread beyond that time.

Level 5 relates to barriers which are there to prevent fire spread where firefighting operations are significantly delayed or unsuccessful. The barriers are therefore required to survive burnout.

Barriers requiring this level of performance are those which must survive even in the very unlikely event of no or ineffective fire brigade intervention.

In considering the Performance Levels proposed above, it is assumed that a barrier includes all of the structure required to maintain its effectiveness. A barrier also includes all openings through it. Therefore windows, doors, shafts, and shutters must achieve at least the same function as the barrier in which they are located, unless it can be shown that the barrier performance is not adversely affected by alternative arrangements.

The different functions and Performance Levels are indicated in Table 6.3.1.

6.3.3 Structural performance

In undertaking a similar study on performance of the structure expressed in terms of real fire response, it needs to be noted that fire does not simultaneously attack all structural elements, even when it may be said that the whole building became (eventually) involved in fire. Local failure of part of the structure may not lead to significant collapse, as loads may be redistributed through other elements not affected by the fire. Buildings have been seen to perform better than expected judged by simple single - element analysis. Therefore it is necessary to distinguish between critical and non-critical structure.

In this context, the term critical structure is applied to any system of elements where simultaneous failure under fire conditions is foreseeable, and would signal collapse involving the whole or a significant part of the building. Failure of non-critical structure would cause only local collapse, if any. These ideas are summarised in Table 3.1.

Although the necessary attributes of barriers and loadbearing structures are different, performance is defined in terms of the same fire intensities and durations. It is assumed that smoke will have no impact on structure, and Level 1 may therefore be ignored.

Level 2 relates to the stability required of structure contributing to the proper functioning of escape routes, which will include all floors. The duration for performance is the expected time in which people will reach a place of safety.

Level 3 relates to the structural stability of structure required to provide access for firefighting. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

Level 4 is not relevant, since it deals with barriers exclusively.

Level 5 relates to the behaviour and structural stability of critical elements to prevent collapse in the case of burnout.

6.4 DERIVING FRLS FROM PERFORMANCE LEVELS

6.4.1 Quantifying performance

From the above, it can be seen that performance levels can be found for any building element that is required to resist fire. It should not be assumed however, that the FRL for an element that is required to perform to Level 5 will be greater than that of an element that is required to perform to Level 3. The quantification of the FRL from the performance level will depend on the intensity of the fire and the time over which the element must continue to perform. Barriers protecting an escape path in a large building with long escape times might require higher FRLs than fire barriers in a different building that are required to perform to Level 4.

Fire exposure is defined by two quantities: a fire severity and a duration for exposure.

6.4.2 Fire severity

In practice fire severity will probably be most usefully expressed in terms of a temperature-time curve which the element will be required to survive. The most important factors governing fire severity are fire load and ventilation. The nature of the combustibles will vary with occupancy and will provide a mechanism for determining how FRL requirements should vary between different building uses. In addition to ventilation, compartment size may be important, particularly for very large compartments. How these aspects can be incorporated into a general fire severity model remains to be studied.

6.4.3 Duration of exposure

For the purposes of Project 3, it is assumed that crude estimates of expected times of exposure are appropriate, as long as care has been taken to make sure that estimates are conservative. Three different exposure periods have been identified, which may be identified as **escape duration** (the time taken for all building occupants to reach a place of safety), **fire access duration** (the time needed for the fire brigade to arrive, set up firefighting and rescue operations and stop the fire growth) and **burnout duration** (the time taken for the fire to consume all of the combustibles and to go out of its own accord). Each of these durations is dependant on building and occupant characteristics, which may be modified if appropriate fire safety systems are in place.

6.4.4 Tasks to be undertaken

Fire severity curves and exposure durations for different building types will be modified by the existence of building systems such as sprinkler and fire detection systems. It is proposed to use probabilistic analysis to establish equivalent fire severity curves for buildings with and without such systems, on the basis of equal probability of the identified fire severity occurring.

It is also necessary to develop an analytical model which will assess the behaviour of particular barriers or specific barrier types to the fire exposure. Such a model will have to take as input variations in materials and construction methods to generate a barrier failure probability. One of the future tasks of Project 3 will be to identify acceptable failure probabilities and to compare these with the results of the model to determine whether a particular barrier meets the required performance or not. Once the type of barrier which will perform to the required level in a particular building has been established, it is necessary to interpret that value in terms of the FRL which would be achieved by the barrier in a fire resistance test. This task will be undertaken by means of barrier performance modelling, backed up by tests in a fire resistance furnace. The performance levels in Table 4.3 can then be replaced by equivalent FRLs.

6.5 CONCLUSIONS

Fire resistance, as specified for barriers and structural elements in buildings, has for a long time been one of the cornerstones of fire safety provisions as defined in the BCA, and as such is rarely questioned. This document sets out a framework whereby the application of FRLs to building elements may be reviewed on a rational basis. The approach starts by identifying the different purposes of fire resisting elements, showing how these may differ for different parts of the same building and between buildings. The performance required depends on what purpose the element serves, the fire severity to which it might be exposed and for how long it has to perform. Within the framework defined, the use of the building can be taken into account, as can the nature of the occupants, location with respect to firefighting resources, and the existence of other fire safety systems.

Until the calculation procedures outlined herein are undertaken, it is not possible to be clear as to how the recommendations which will emerge from the Project will differ from the existing provisions of the BCA. What is clear is that whatever does emerge will have been generated by a process which is reasonable, defensible and open to scrutiny.

7. APPLICATION OF FRAMEWORK TO BCA

7.1 PERFORMANCE OF BUILDING ELEMENTS

The performance levels derived in Section 3 describe functions that can reasonably be expected of various parts of a building. For example, all protected escape routes can be expected to function to level 2 (to protect the building occupants until they have had time to escape). The combination of elements that surround the escape route - that is, the walls, floor and ceiling - must therefore function as barriers for as long as necessary. Table 7.1 interprets performance levels for parts of buildings.

TABLE 7.1 - INTERPRETATION OF TABLE 6.3.1 IN TERMS OF PARTS OF BUILDINGS

Parts of Building	Performance Level	
	Structural	**Barrier**
Smoke Barriers (including walls, doors, smoke curtains)	none	1
Exit System (including walls, doors, floors, stairs)	2	2
All Structure	2	2
Fire Fighting Access (including exit, floors, structure where hydrants are fitted)	3	3
Compartment Boundaries	none	4
Walls Separating Neighbours	5	5
Critical Structure (where total or substantial collapse is unacceptable)	5	5

Building elements may perform more than one role. A loadbearing internal wall might protect an escape route, separate emergency equipment and support the roof of the building. Each role must be considered separately, and the performance level for each must be met.

7.2 PERFORMANCE LEVELS AND BCA REQUIREMENTS

The required performance levels of building elements is defined in Table 7.1. These levels can be interpreted for all elements in the BCA that are required to have an FRL.

The BCA stipulates fire resistance levels for many building elements. These elements were used to derive Tables 7.2 and 7.3. It is assumed that the list of building elements is comprehensive as it has evolved over many years and in response to many situations.

7.3 BARRIER PERFORMANCE

In allocating performance levels to building elements, each element that is currently required to have an FRL by the BCA was considered. However, the list is extensive and it was agreed that initially less frequently used construction, such as walls separating ancillary areas and equipment, would not be addressed.

The performance required of a barrier will not always be the same from each side. Some barriers may be required to provide protection from only one side. For example, an exit or stair shaft is required to protect the building occupants until they have reached a place of safety. The building does not need to be protected from a fire within the shaft. Protection need only be provided from the outside. It is therefore important to consider the direction of protection in relation to the required performance and to include this information in the final specification of required fire resistance. In Table 7.3 the direction of protection for each building element has been specified.

In deriving Table 7.3, reference was made to construction currently defined within the BCA. In some cases the definitions are unclear or unsuitable for current considerations and need to be reconsidered. It is intended that recommendations will be made later in this project. These definitions include:

sole-occupancy unit
fire wall
fire compartment

It is not within the remit of this project to address the correctness of the BCA floor area limits. Similarly, this project does not consider the correctness of BCA requirements to allow the interconnection of floors by escalators or unprotected stairs. It assumes that a barrier that divides a large space that is penetrated by such an opening, together with existing limits on such interconnections, will limit the spread of fire to a level that is currently acceptable to the regulators.

TABLE 7.3 - BARRIER PERFORMANCE

BARRIERS ***Walls, floor/ceiling & openings*** ***(See 6.3.2)***	***LEVEL***	***DIRECTION OF PROTECTION***	***EXPLANATION***
Exits			
All fire-isolated exits	2	From outside the exit system	1 There is no explicit definition of fire-isolated exit in the BCA, but details of when fire-isolated exits are required are given in clause D1.3 2 All barriers that protect exits must continue to function until the building occupants have reached a place of safety. There is no need for protection from inside the exit.
Fire-isolated exits required by fire brigades to access internal hydrants or fire control centres	3	From outside the exit system	Exits used for fire fighting must offer protection until the firefighters have the fire under control.
Common walls			
	5	From either side	Common walls are walls separating neighbours and so need level 5
Internal barriers bounding sole-occupancy units			
Separate dwellings	4 or 5	From either side	Occupancies in Class 2 buildings are separate dwellings and the responsibility to prevent fire spread is the same as for walls between buildings
Residential accommodation that is not a separate dwelling	4 or 5	From either side	A Class 3 building has one owner, who will take the necessary action to raise the alarm and ensure the safety of

			occupants. It can be assumed that the fire brigade will attend the fire
Walls separating dwellings (in Class 1 buildings)	5	From either side	As for separate dwellings in Class 2 occupancies
Fire compartment barriers (including barriers bounding atriums)	4	From either side	Since these barriers do not separate occupancies, their function is not as critical as common walls. Their function is to limit fire spread, and they need only function until the fire fighters have the fire under control
Barriers for staged evacuation			These barriers must function as exit protection
Areas of safety from smoke	1	From outside the area of safety	
Areas of safety from smoke and fire	2	From outside the area of safety	
Areas required by fire brigades to access internal fire hydrants or fire control centres	3	From outside the area of safety	
Floors that are not laid directly on the ground	2	From below	All floors form part of an escape route and must provide level 2 protection. Floors laid directly on the ground will achieve this performance.
Vertical shafts that			

penetrate fire compartment barriers	4	From outside the shaft	Shafts must not reduce the performance of the barrier
Internal barriers surrounding public corridors	2	From outside the corridor	The corridor is an escape route and must offer protection until building occupants have reached a place of safety.
Proscenium walls	4	From either side	A proscenium wall acts as a fire compartment boundary.
Barriers separating emergency equipment	3	From outside the emergency equipment enclosure	The ability of the emergency equipment to function until the fire is under control must not be jeopardised by fire in the building.
Barriers separating areas of high hazard	4	From either side	Areas of high hazard must not present a risk to the remainder of the building.
External barriers			
between buildings	5	From either side	Barriers between buildings must perform as common walls.
between parts of the same building	4	From either side	These barriers must perform as compartment barriers.

7.4 STRUCTURAL PERFORMANCE

As with barrier performance, a list of elements currently required to have FRLs for structural performance was used to derive Table 7.4. In arriving at performance levels, judgements were made as to the function of the structure in different parts of the building.

All structure, critical or non-critical, clearly must remain standing until people escape and must therefore achieve Level 2. Structure which relates to the support of exits which are used for firefighting access, and for the stability of floors in buildings with internal fire hydrants will achieve Level 3. This level should also be applied to critical structure in buildings with internal fire hydrants.

In some buildings, for example high rise, the risk of significant collapse will be judged to be unacceptable, because of risk to neighbouring properties and to people outside the building. Even in the event that the sprinkler system might have malfunctioned, and the fire brigade failed to arrive sufficiently early to bring the fire under control, such buildings' critical structure will be required to survive the fire, and therefore to perform to Level 5. For other types of building, for example isolated single storey warehouses, traditionally no regulatory requirements have been imposed to avoid collapse in fire.

TABLE 7.4 - STRUCTURAL PERFORMANCE

	Level	Explanation
All loadbearing elements that contribute to the proper functioning of escape routes including exits	2	The structure must continue to function until the building occupants have escaped
Loadbearing members that contribute to the proper functioning of exits used by the fire brigades to access internal hydrants or fire control centres	3	The structure must continue to function until the fire brigades have the fire under control.
Critical structure		
All buildings	2	Critical structure in all buildings must continue to function until the occupants have escaped.
Buildings with internal fire fighting facilities	3	Critical structure must continue to function until the fire fighters have the fire under control
Buildings where total (or substantial) collapse is unacceptable	5	In certain buildings collapse of critical structure as a result of fire is unacceptable under any circumstances.

BARRIER PERFORMANCE LEVELS

Level 1 relates to barriers in place to limit the passage of smoke early in a fire. The duration for performance is the expected period of time in which people will reach a place of safety.

Level 2 relates to barriers which must survive exposure to fire to provide protection for escape routes. The duration for performance is the expected time in which people will reach a place of safety.

Level 3 relates to barriers which must survive exposure to fire to provide access for firefighters. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

Level 4 relates to barriers which limit fire spread to a fire compartment. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

Level 5 relates to barriers which are there to prevent fire spread where firefighting operations are significantly delayed or unsuccessful. The barriers are therefore required to survive burnout.

STRUCTURAL PERFORMANCE LEVELS

Level 1 is not relevant, since smoke does not impact on structural performance.

Level 2 relates to the stability required of structure contributing to the proper functioning of escape routes, which will include all floors. The duration for performance is the expected time in which people will reach a place of safety.

Level 3 relates to the structural stability of structure required to provide access for firefighting. The duration for performance is the expected time of arrival of the fire brigade plus the expected time for them to set up firefighting and rescue operations and stop the fire growth.

Level 4 is not relevant, since it deals with barriers exclusively.

Level 5 relates to the behaviour and structural stability of critical elements to prevent collapse in the case of burnout.

8. CONCLUSIONS

Fire resistance, as specified for barriers and structural elements in buildings, has for a long time been one of the cornerstones of fire safety provisions as defined in the BCA, and as such is rarely questioned. The studies of the historical basis for fire resistance provisions have shown that there is no underlying logic which is being followed: though the current requirements are not in general perceived as being excessive anomalies and inconsistencies have been identified by the project team and by the users of the BCA. There are clearly areas where change would be beneficial. The statistical evidence shows that *fire resistance works well but suggests that other parts of a building's overall fire safety systems are more important in meeting life safety objectives.*

This document sets out a framework whereby the application of FRLs to building elements may be reviewed on a rational basis. The approach starts by identifying the different purposes of fire resisting elements, showing how these may differ for different parts of the same building and between buildings. The performance required depends on what purpose the element serves, the fire severity to which it might be exposed and for how long it has to perform. Within the framework defined, the use of the building can be taken into account, as can the nature of the occupants, location with respect to firefighting resources, and the existence of other fire safety systems.

Until the calculation procedures outlined herein are undertaken, it is not possible to be clear as to how the recommendations which will emerge from the Project will differ from the existing provisions of the BCA. What is clear is that whatever does emerge will have been generated by a process which is reasonable, defensible and open to scrutiny.