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Fire safety engineering — Examples of fire safety objectives, functional requirements and safety criteria

National foreword

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Fire safety engineering — Examples of fire safety objectives, functional requirements and safety criteria

*Ingénierie de la sécurité incendie — Exemples d'objectifs de sécurité
incendie, d'exigences fonctionnelles et de critères de sécurité*



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Foreword

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This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

Introduction

The vast majority of fire safety designs rely on prescriptive specifications written into regional, national, or local regulations. Currently, various engineering approaches are also allowed by these regulations, although information needed for an engineering approach is still generally obtained from conventional test methods. Fire safety engineering (FSE) is a discipline increasingly being used throughout the world in support of performance-based design, i.e. the reliance on engineering methods to determine whether a given design meets stated performance objectives. ISO 23932 provides general principles for a performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is evaluated through an engineered approach based on the quantification of the behaviour of fire and people and based on knowledge of the consequences of such behaviour on life safety, property and the environment.

The difference between prescriptive and performance-based approaches to fire safety design is highlighted in ISO 23932 by emphasizing the development of quantifiable fire safety design objectives and related functional requirements as the first step in a performance-based analysis. According to ISO 23932, the fire safety objectives include, for example, safety of life, conservation of property, continuity of operations, protection of the environment and preservation of heritage.

In ISO 23932, it is also mentioned that explicit performance criteria should be developed for each functional requirement. Performance criteria are engineering metrics that are expressed in deterministic or probabilistic (e.g. measures of fire risk) form to determine if each functional requirement has been satisfied by the fire safety design.

As a preliminary work prior to producing ISO standardized documents for fire safety objectives, functional requirements and safety criteria, ISO/TC 92/SC 4 decides to collect the examples of those from the existing documents that have been developed in different countries in the course of moving towards performance-based fire safety design. So far, three countries have responded to the solicitation for such documents, i.e. Japan, France and New Zealand. The development of these documents, as summarized below, was motivated by the attempts to rationalize the existing fire safety design practices based on prescriptive building by making use of fire safety engineering methods.

Japan: First developed by the Building Research Institute during the Ministry of Construction's project for developing a performance-based fire safety design method, 1981 to 1986, and subsequently improved by the committee on fire safety design in Architectural Institute of Japan, of which the report was published in 2000.

France: Developed in the collaborative research project to establish the bases to introduce fire safety engineering into fire safety design, which was conducted with the sponsorship of French ministry for construction and home office from 2005 to 2011, involving research institutes, fire brigades, practitioners, designers and owners.

New Zealand: Developed by a working group made up of external fire experts and staff from the regulatory agency. The group was set up to research and develop a suitable fire safety design framework, in the course of amending the New Zealand Building Codes corresponding to the introduction of the Building Act 2004.

Fire safety engineering — Examples of fire safety objectives, functional requirements and safety criteria

1 Scope

This document compiles examples of fire safety design objectives, functional requirements and safety criteria from Japan, France and New Zealand.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

functional requirements

statement of the means to achieve specified fire safety objectives, taking into account the features of a built environment

Note 1 to entry: Mandatory functional requirements are required by building codes or national regulations; voluntary functional requirements are expressed by other interested/affected parties.

3.2

mandatory objectives

fire safety objectives, such as life safety and protection of the environment, which are required by building codes or national regulations

3.3

performance criteria

quantitative engineering specifications, which form an agreed basis for assessing the safety of a built environment design

3.4

safety factor

multiplicative adjustment applied to calculated values to compensate for uncertainty in methods, calculations, input data and assumptions

3.5

verification

process of determining that a fire safety design complies with the fire safety requirements by examining the design in the light of safety criteria

3.6

voluntary objectives

fire safety objectives, which are requirements expressed by interested/affected parties, beyond mandatory objectives

4 Examples from France, New Zealand and Japan

[Annexes A](#) to [D](#) contain examples of fire safety objectives, functional requirements and safety criteria from France, New Zealand and Japan.

Annex A (informative)

Example of fire safety design objectives and functional requirements in France

A.1 Introduction

Fire safety design in France for life safety and property protection is mainly prescriptive and managed by regulation. Even if there are already partial openings to fire safety engineering, since only some years ago it has become increasingly obvious that more involvement in fire safety engineering need to be made in French fire safety regulations.

In mid-2005, a collaborative research project was set up, with the sponsorship of French ministry for construction and home office, involving different partners including research institutes, fire brigades, practitioners, designers and owners. The research project, which ended by mid-2011, was divided into 18 main items, clustered in three main parts:

- Development of general principles for FSE assessment:
 - FSE methodology;
 - objectives and performance criteria;
 - fire risk assessment;
 - design fire and behavioural scenarios;
 - verification of the methodology by examples;
 - validation by reconstructions of fire incidents.
- State-of-the-art and research projects regarding:
 - statistical analysis of fuel load density;
 - characterization of burning items;
 - fire development and spread;
 - structural behaviour calculations;
 - fire containment;
 - behaviour at elevated temperature of regular glazing;
 - fire protection;
 - human behaviour.
- Communication and dissemination:
 - teaching of FSE in universities or high schools for engineers;
 - information and awareness of actors involved in FSE;
 - publication of outcomes;

- proposals for regulation improvements.

A translation of the general principles developed within the scope of this collaborative research is given in this document. The performance-based structure consists of the three following levels:

- fire safety objectives;
- functional requirements;
- performance criteria.

Fire safety objectives which are explicitly or implicitly mentioned in French regulations (for public buildings, tall buildings, work places, warehouses, industrial plants, etc.) were identified. Functional requirements were selected mainly by brain storming among the members who joined this research project.

A few examples of vulnerability criteria have been given, involving life safety objectives and requirements, and focusing on what should be “adequate tenability conditions”. Performance criteria proposed were derived from some national or international research works or standards.

A.2 General

A.2.1 Purpose

This document provides examples of fire safety objectives, functional requirements and performance criteria for interested parties involved in a performance-based approach to assess the level of fire safety of a built environment. The development of quantifiable fire safety objectives is the first step in a performance-based analysis. This is an alternative to prescribed regulatory requirements, giving more freedom in the design of built environments, a better cost/benefit within sustainability development, while retaining equal or higher level of safety performance compared with the prescribed approach.

A.2.2 Scope

The examples developed in this document can apply when performing the fire safety engineering process for a whole built environment or part of it, and for new or existing buildings. They can be used when the performance-based approach is considered as an alternative to a prescriptive acceptable solution (in this case, performance criteria are not defined but relative to the performance reached by the acceptable solution when considering the selected fire safety objectives and functional requirements).

These objectives can be used as either mandatory or voluntary fire design objectives, depending on the regulatory requirements which need to be fulfilled.

It is necessary to have an agreement on any assumptions taken for objectives, functional requirements and performance criteria (when they are not explicitly given in the regulation) from authorities having jurisdiction, prior to performing the assessment work as such.

A.2.3 Terms and definitions

A.2.3.1

compartment

enclosed space, which may be subdivided, separated from adjoining spaces by fire barriers

A.2.3.2

media impact

qualitative value of exposure through a given medium

A.2.3.3**safe refuge**

temporary location that is free from immediate danger from effects of fire

A.2.3.4**strategic function**

capacity or resource of an entity or an organization that maintains its ability to achieve future outcomes and determines its long-term performance

A.2.3.5**sudden change**

transition within a few seconds

A.2.3.6**untenable condition**

condition such that people are unable to take effective action to accomplish their own escape to a place of safe refuge

A.2.4 Symbols and abbreviated terms

Shown below are the abbreviated terms that are used in this document.

FNR	functional requirement
FSE	fire safety engineering
OBJ	objective

A.3 Fire safety objectives

The fire safety objectives which need to be addressed in design of a building can be related to the safety of life, property, environment, continuity of operations, or cultural heritage. The different categories of objectives are summarized below.

OBJ 1: Health and life safety

Life safety is often the most important objective of fire safety design. It first involves occupants of the building and may extend to firefighters who are expected to assist in evacuation or prevent extensive uncontrolled spread of fire, and finally to third parties. Thus, three sub-objectives are defined.

OBJ 1-1: Health and life safety of occupants**OBJ 1-2: Health and life safety of firefighters****OBJ 1-3: Health and life safety of third parties****OBJ 2: Environment protection**

Avoiding long-term consequences of the environmental impact of fires is becoming a more apparent goal. The objectives of environmental protection in case of fire may be divided into two main groups as follows:

OBJ 2-1: Ground and water**OBJ 2-2: Atmosphere**

OBJ 3: Property protection

Protection of property from fire damage aims generally at limiting any damage to the contents of the building, to the building itself, or to the vicinity of the building.

In the modern world, the cost of business interruption is also of interest because it may be much higher than the cost of direct damage to the contents and the building itself. In the same way, preservation of the strategic functions may be essential, especially when involving, for example, transportation, power, and other infrastructures necessary to the functioning of a community.

Besides, some buildings with architectural, historical or cultural importance may have values which cannot be measured on a monetary scale. Their protection against the damage caused by fire is considered to be one of the basic moral duties of the society.

Finally, in many fields of industry, a good public image is essential to success in business. A fire loss may damage public image and lead to detrimental long-term consequences.

As a result, the property protection objectives may be divided into the following sub-objectives:

OBJ 3-1: Moveable properties and real estate within the premises

OBJ 3-2: Moveable properties and real estate of third parties

OBJ 3-3: Continuity of operations

OBJ 3-4: Strategic matters

OBJ 3-5: Preservation of heritage

OBJ 3-6: Media impact

A.4 Functional requirements

Functional requirements are necessary to take into account specific conditions related to the built environment to enable the link between fire safety objectives and performance criteria.

OBJ 1-1: Health and life safety of occupants

FNR 1-1-1: No sudden change in the tenability conditions before every occupant left the room of origin

In the room of fire origin, the different factors influencing fire development and spread of fire effluents shall be such that sudden changes in the exposure conditions, which can catch the occupants before they have become aware of the hazard and have left the room, should be prevented. The underlying idea is to delay the occurrence of a flashover in this room, for example, by distancing the different combustible materials present in the room, or by using safety systems such as automatic detection or sprinkler system.

FNR 1-1-2: Adequate tenability conditions in the egress route up to any occupant left

The occupants must be able to totally evacuate the building without being subject to untenable conditions.

FNR 1-1-3: Adequate tenability conditions in space within the building, outside the room of origin, where people are waiting for rescue

The occupants must be able to remain in a safe refuge, waiting to get rescued, without being subject to untenable conditions.

FNR 1-1-4: Adequate tenability conditions for the whole duration of the fire, in space within the building where people have found refuge

The occupants must be able to remain in a safe refuge for the whole duration of the fire without being subjected to untenable conditions. This is the same as the previous functional requirement, except that the possibility to get rescued is not considered. It could lead, for example, to a fire resistance rating for the walls of the refuge more important than in the previous case.

OBJ 1-2: Health and life safety of firefighters

FNR 1-2-1: Adequate tenability conditions during the necessary time for the reconnaissance of the fire area

This mainly concerns the access paths for firefighting vehicles and the egress routes to search for the origin of the fire or to identify specific risks such as storage of gas cylinders.

FNR 1-2-2: Adequate tenability conditions during the necessary time for evacuating people

The firefighters must be able to evacuate people without being subjected to untenable conditions.

FNR 1-2-3: No sudden change in the tenability conditions when fighting the fire

Sufficient time must be available for the firefighters to get out from the room, the floor or the building before conditions have become untenable. They should not be trapped by an extremely rapid fire progress or other flashover-related phenomena that may happen in a room with combustible partition walls.

OBJ 1-3: Health and life safety of third parties

FNR 1-3-1: Adequate tenability conditions within a neighbouring built environment during the whole duration of the fire

The health and life safety of third parties must be ensured during the whole duration of the fire without forcing them to leave the premises.

FNR 1-3-2: Adequate tenability conditions in the surrounding spaces, during the necessary time, as a function of the mobility conditions of the third parties (including traffic roads)

Third parties in surrounding spaces must be able to move away from the fire zone without being subjected to the effects of the fire. Surrounding spaces include sidewalks, public or private areas, and roads for which visibility conditions may be essential.

OBJ 2-1: Ground and water protection

FNR 2-1-1: Reduction of hazardous solid or liquid fire residues

When fighting and extinguishing the fire, there are often serious releases of hazardous solid or liquid fire residues to the ground or to the waste water system, which may consequently damage the ground water or nearby lakes or rivers. Necessary measures such as containment basins must be in place to limit or contain these combustion residues.

FNR 2-1-2: Control of hazardous fire effluent released

Necessary measures must be in place to contain the hazardous, polluting or toxic products released during the fire. Highly hazardous products could be, for example, placed in specifically designated areas with a particular protection and sectioned off from other areas.

OBJ 2-2: Atmosphere protection

FNR 2-2-1: Fire effluent containment

Necessary measures must be in place to contain the smoke and combustion products released during the fire, in order to limit emissions into the atmosphere.

FNR 2-2-2: Control of hazardous fire effluent released and dispersed into the atmosphere

Necessary measures must be in place to limit the hazardous, polluting or toxic products released during the fire and dispersed into the atmosphere.

OBJ 3-1: Moveable properties and real estate within the premises

FNR 3-1-1: Preservation of a specific component within the room of origin

A specific content of the building can be considered of great interest, like a safety-deposit box or a work of art, and specific protection (automatic detection, sprinkler system, etc.) should be used to prevent any degradation.

FNR 3-1-2: Fire restricted to the room of origin

Necessary measures must be in place to avoid the spread of fire outside the room of origin.

FNR 3-1-3: Damages restricted to the room of origin

Even if the fire is restricted to the room of fire origin, the effects of the fire may cause damages to adjacent rooms. It may be necessary to avoid damages outside the room of origin.

FNR 3-1-4: Damages restricted to the compartment of origin/to the floor of origin

It is the same approach as the previous requirement, except that damages are accepted to all the rooms of the compartment or floor of origin.

OBJ 3-2: Moveable properties and real estate of third parties

FNR 3-2-1: No spread of fire to neighbouring constructions

Necessary measures must be taken to avoid the spread of fire to neighbouring constructions. For example, to avoid the spread of fire between adjacent multi-storey buildings, a classical approach is to limit the use of combustible materials in facades.

FNR 3-2-2: No damages to neighbouring constructions

Necessary measures must be in place to avoid damages to neighbouring constructions. It could be by imposing distance between buildings.

OBJ 3-3: Continuity of operations

FNR 3-3-1: Preservation of a given activity

In a company, an organization, or an association, an activity of critical importance might be subjected to specific provisions in case of fire.

FNR 3-3-2: Protection of the production capability

Necessary measures must be in place to maintain the production capability intact in case of fire.

FNR 3-3-3: Preservation of a specific device (and its supplying fittings)

Within a building, a specific device can be deemed to be essential for the good functioning of the building. Necessary measures must be in place to protect the device and its supplying fittings in case of fire.

OBJ 3-4: Strategic matters

FNR 3-4-1: Preservation of the strategic functions

Necessary measures must be in place to ensure the continuity of the strategic functions in case of fire.

FNR 3-4-2: Protection of any devices involved in strategic functions

Necessary measures must be in place to protect from the effects of the fire any devices involved in strategic functions.

OBJ 3-5: Preservation of heritage**FNR 3-5: Protection from attack to any object or construction which could not be replaced**

Necessary measures must be in place to protect from the effects of the fire any objects or buildings with architectural, historical or cultural importance. Any alterations which are unavoidable should be reversible, allowing the objects or building affected to be returned to its original condition. Consequently, in some cases, fire detection would be more appropriate than fire suppression.

OBJ 3-6: Media impact**FNR 3-6: Preservation of the image from any media action**

This is a global rather than an individual protection, and necessary measures must be in place to minimize the visible consequences that may damage public image and lead to detrimental long-term consequences.

A.5 Performance criteria

A few examples of criteria are proposed in this clause, focusing on what should be “adequate tenability conditions”. These criteria, based on both discrete values (which are sometimes associated with a discrete time period) and dose methods (which consider time-dependent exposures and thresholds), are not exhaustive.

OBJ 1-1 and 1-3: Health and life safety of occupants and third parties**FNR 1-1-2, 1-1-3, 1-1-4, 1-3-1 and 1-3-2**

Criteria 1: Maximum gas temperature of 60 °C^{[1][2]}

Criteria 2: Maximum incident heat flux of 2 kW/m² (for an exposure time >10 s) or 2,5 kW/m² (for an exposure time <10 s)^[2]

Criteria 3: Maximum radiative dose of 300 kW^{4/3}m^{-8/3}s (for an exposure time <2 min)^[3]

Criteria 4: Maximum fractional effective dose (FED) of 0,3^[4]

Criteria 5: Minimum visibility of 10 m (as calculated in ISO 13571)^[4]

OBJ 1-2: Health and life safety of firefighters**FNR 1-2-1 and 1-2-2**

Criteria 6: Maximum incident heat flux of 5 kW/m²^[5]

A.6 Bibliography

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[4] ISO 13571, *Life-threatening components of fire — Guidelines for the estimation of time to compromised tenability in fires*

[5] BRAUN E., COBB D., COBBLE V.B., KRASNY J.F., PEACOCK, R.D. Measurement of the protective value of apparel fabrics in a fire environment. *Journal of Consumer Product Flammability*. 1980, 7, No.1, p. 15–25

Annex B (informative)

Example of fire safety design objectives and functional requirements in New Zealand

B.1 Introduction

In New Zealand, building regulations have traditionally been prescriptive. They did not cover emerging technologies and every combination of circumstances. Thus, prescriptive regulations have provided constraints to design that are not always appropriate to the specific building being considered.

In order to free design from such constraints, increase innovation and facilitate trade, New Zealand developed a building code to be performance based. New Zealand first introduced performance-based code in 1992 with the introduction of the Building Regulations 1992. After this time, fire engineering emerged as a specialized field, requiring university-based education and training. New Zealand's first group of locally-trained fire engineers graduated from the University of Canterbury in 1995. Over the years, fire engineering has continued to develop as a recognized, specialist field within New Zealand, playing a critical role in building design.

A review of the Building Code in 2007 recommended reform to improve and streamline the Code and its supporting documents. This review highlighted that performance requirements for fire design are non-specific and insufficiently quantified.

The review found that fire engineers were using a wide diversity of guidance and methods resulting in wide variance in fire safety reports. There was no defined approval process with inconsistent views of each local authority. Assumptions in the calculation input by fire engineers were often different for similar buildings. This was leading to an inefficient consenting process, with costly delays for developers, especially in the construction of large buildings.

In 2012, there were changes made to Building Code Clause C (protection from fire) and the supporting documents. The changes were significant in nature with quantification of performance criteria in the Building Code, new Verification Method and seven Acceptable Solutions.

The new Building Code provides a clear set of performance criteria together with Verification Method to provide a systematic approach to fire engineering design within a legislative compliance document. The Verification Method standardizes fire engineering practice and provides a consistent measure of performance in fire engineering projects across New Zealand to comply with the Building Code.

The fire design scenarios and associated design parameters are set out in Verification Method C/VM2, which applies to complex buildings. Simple buildings are covered by a suite of Acceptable Solutions C/AS1 to C/AS7.

When developing the fire safety design framework, the working group's approach was as follows.

- When there was obvious analysis available to support the chosen values in the existing Compliance Documents, it would first consider those existing Compliance Documents.
- In other cases, it would investigate the approach of overseas building codes.

There was no deliberate intention to significantly change the level of safety that previously existed and implicitly contained within the previous compliance documents. This was a factor that influenced some of the performance criteria adopted.

B.2 General

B.2.1 Purpose

All building work in New Zealand must comply with the Building Code. It is a performance-based code, which means it states how a building must perform in its intended use rather than describing how the building must be designed and constructed. This document describes the fire safety objectives, functional requirements and performance criteria from the New Zealand Building Code.

B.2.2 Scope

The Building Code contains compulsory rules for all new building work. The Building Act 2004 applies to:

- building construction, alteration, demolition or removal;
- maintenance of a building's specified systems, such as lifts and fire protection installations.

It does not cover planning and resource management, occupational safety and health.

B.2.3 Terms and definitions

B.2.3.1

available safe egress time

ASET

time available for escape for an individual occupant

Note 1 to entry: This is the calculated time interval between the time of ignition of a fire and the time at which conditions become such that the occupant is estimated to be incapacitated (i.e. unable to take effective action to escape to a place of safety).

B.2.3.2

burnout

exposure to fire for a time that includes fire growth, full development, and decay in the absence of intervention or automatic suppression, beyond which the fire is no longer a threat to building elements intended to perform loadbearing or fire separation functions, or both

B.2.3.3

evacuation time

time interval between the time of warning of a fire being transmitted to the occupants and the time at which the occupants of a specified part of a building or all of the building are able to enter a place of safety

B.2.3.4

fire load

quantity of heat which can be released by the complete combustion of all the combustible materials in a volume, including the facings of all bounding surfaces

Note 1 to entry: It is expressed in joules (J).

B.2.3.5**fire load energy density****FLED**

fire load (B.2.3.4) per unit floor area

Note 1 to entry: It is expressed in megajoules per square meter (MJ/m²).

B.2.3.6**fractional effective dose****FED**

fraction of the dose [of carbon monoxide (CO) or thermal effects] that would render a person of average susceptibility incapable of escape

B.2.3.7**importance level**

each of the five levels of importance of buildings, as set out in Clause A.3 of the New Zealand Building Code, that can be assigned to a building

Note 1 to entry: See Reference [1].

B.2.3.8**incapacitated**

state of physical inability to accomplish a specific task

B.2.3.9.1**place of safety**

<general> safe place

B.2.3.9.2**place of safety**

<building> place inside a building meeting the following requirements:

- a) the place is constructed with fire separations that have fire resistance sufficient to withstand burnout at the point of the fire source;
- b) the place is in a building that is protected by an automatic fire sprinkler system that complies with NZS 4541 or NZS 4515 as appropriate to the building's use;
- c) the place is designed to accommodate the intended number of persons;
- d) the place is provided with sufficient means of escape to enable the intended number of persons to escape to a safe place that is outside a building

B.2.3.10**safe place**

place, outside of and in the vicinity of a single building unit, from which people may safely disperse after escaping the effects of a fire

Note 1 to entry: It may be a place such as a street, open space, public space or an adjacent building unit.

B.2.3.11

separating element

barrier that exhibits fire integrity, structural adequacy, thermal insulation, or a combination of these for a period of time under specified conditions (in a fire resistance test)

B.2.3.12

structural adequacy

time in minutes for which a prototype specimen has continued to carry its applied load within defined deflection limits, in the context of the standard test for fire resistance

B.2.3.13

visibility

maximum distance at which an object of defined size, brightness and contrast can be seen and recognized

B.2.4 Regulatory framework

The regulation and performance of buildings sit under the following three-part framework.

- The **Building Act**, which contains the provisions for regulating building work.
- The various **Building Regulations**, which contain prescribed forms, list specified systems, define “change the use” and “moderate earthquake”, and set out the rate of levy and fees for determinations.
- The **Building Code**, contained in Schedule 1 of the Building Regulations 1992, which sets performance standards all new building work must meet and covers aspects such as stability, fire safety, access, moisture, safety of users, services and facilities, and energy efficiency.

[Figure B.1](#) illustrates the legislation that forms the building control framework governed by the Building Act.

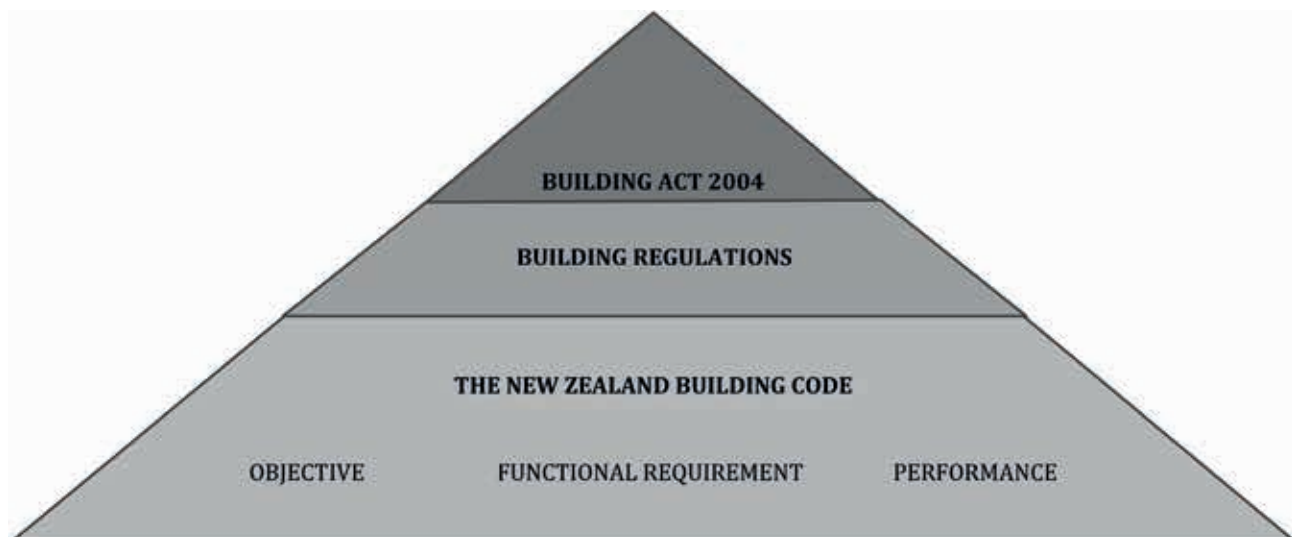


Figure B.1 — New Zealand building control framework

The Building Code sets out performance criteria that building work must meet. It covers aspects such as structural stability, fire safety, access, moisture control, durability, services and facilities, and energy efficiency. The Building Code does not prescribe how work should be done, but states how completed building work and its parts must perform.

An advantage of a performance-based Building Code is flexibility. It contains no prescriptive requirements stipulating that certain products or designs must be used. This flexibility allows developments and innovation in building design, technology and systems.

The Building Code consists of two preliminary clauses and 35 technical clauses. Each technical clause has three levels that describe the requirements for the clause and are listed below.

- Objective: Social objectives the building must achieve.
- Functional requirement: Functions the building must perform to meet the objective.
- Performance: The performance criteria the building must achieve. By meeting the performance criteria, the objective and functional requirement can be achieved.

B.2.5 Symbols and abbreviated terms

NZBC	New Zealand Building Code
FSD	fire safety design
FNR	functional requirement
OBJ	objective
PR	performance requirement

B.3 Fire safety objectives, functional requirements and performance requirements

This clause describes the fire safety objectives (OBJ), functional requirements (FNR) and performance requirements (PR) that were identified from the fire safety provisions of the NZBC.

B.3.1 Fire safety objectives

B.3.1.1 Clause C1 Objectives of Clause C2 to C6 (Protection from Fire)

The objectives of Clause C2 to C6 are to

- a) safeguard people from an unacceptable risk of injury or illness caused by fire,
- b) protect other property from damage caused by fire, and
- c) facilitate firefighting and rescue operations.

B.3.2 Functional and performance requirements

B.3.2.1 Clause C2 Prevention of Fire Occurring

C2.1 Fixed appliances using controlled combustion and other fixed equipment must be designed, constructed, and installed in buildings in a way that reduces the likelihood of illness or injury due to fire occurring (FNR).

C2.2 The maximum surface temperature of combustible building materials close to fixed appliances using controlled combustion and other fixed equipment when operating at their design level must not exceed 90 °C (PR).

C2.3 Fixed appliances using controlled combustion and other fixed equipment must be designed, constructed and installed so that there is a low probability of explosive or hazardous conditions occurring within any spaces in or around the building that contains the appliances (PR).

Subclause C2.2 defines the maximum surface temperature that a combustible surface shall not exceed, based on long-term exposure to elevated temperatures and surface radiation from a heating appliance. The intention of declaring a specific value as opposed to a temperature rise is to reduce any dispute about the appropriate ambient temperature to assume in the application of this clause.

At first, the value of 90 °C may appear to be significantly lower than typical piloted ignition temperatures of around 200 °C. However, a review of the literature shows that wood exposed to constant heating for long periods of time may change chemically and this can result in significantly lower ignition temperatures. The recommended limiting surface temperature for long exposure times accordingly varies from 66 °C to 110 °C.

Subclause C2.3 is intended to ensure that all fixed appliances using controlled combustion and other fixed equipment are constructed and installed according to an appropriate standard. If a designer is not referring to a New Zealand Standard, it is his or her responsibility to demonstrate that the standard used is equivalent to the appropriate New Zealand Standard.

B.3.2.2 Clause C3 Fire Affecting Areas Beyond the Fire Source

C3.1 Buildings must be designed and constructed so that there is a low probability of injury or illness to persons not in close proximity to a fire source (PR).

C3.2 Buildings with a building height greater than 10 m where upper floors contain sleeping uses or other property must be designed and constructed so that there is a low probability of external vertical fire spread to upper floors in the building (PR).

Subclause C3.2 does not apply to importance level 1 buildings.

C3.3 Buildings must be designed and constructed so that there is a low probability of fire spread to other property vertically or horizontally across a relevant boundary (PR).

C3.4(a) Materials used as internal surface linings in the following areas of buildings must meet the performance criteria specified in [Table B.1](#) (PR):

Table B.1

Area of building	Performance determined under conditions described in ISO 9705	
	Buildings not protected with an automatic fire sprinkler system	Buildings protected with an automatic fire sprinkler system
Wall/ceiling materials in sleeping areas where care or detention is provided	Material Group Number 1-S	Material Group Number 1 or 2
Wall/ceiling materials in exitways	Material Group Number 1-S	Material Group Number 1 or 2
Wall/ceiling materials in occupied spaces in importance level 4 buildings	Material Group Number 1-S	Material Group Number 1 or 2
Internal surfaces of ducts for HVAC systems	Material Group Number 1-S	Material Group Number 1 or 2
Ceiling materials in crowd and sleeping uses except household units and where care or detention is provided	Material Group Number 1-S or 2-S	Material Group Number 1, 2 or 3
Wall materials in crowd and sleeping uses except household units and where care or detention is provided	Material Group Number 1-S or 2-S	Material Group Number 1, 2 or 3

Table B.1 (continued)

Area of building	Performance determined under conditions described in ISO 9705	
	Buildings not protected with an automatic fire sprinkler system	Buildings protected with an automatic fire sprinkler system
Wall/ceiling materials in occupied spaces in all other locations in buildings, including household units	Material Group Number 1, 2 or 3	Material Group Number 1, 2 or 3
External surfaces of ducts for HVAC systems	Material Group Number 1, 2 or 3	Material Group Number 1, 2 or 3
Acoustic treatment and pipe insulation within air handling plenums in sleeping uses	Material Group Number 1, 2 or 3	Material Group Number 1, 2 or 3

Subclause C3.4 does not apply to detached dwellings, within household units in multi-unit dwellings, or outbuildings and ancillary buildings.

Subclause C3.4 is intended to reduce the risk of rapid flame spread on walls, floors, and ceilings, so that the fire growth rate does not significantly exceed that given in Verification Method C/VM2. The hazards of rapid flame spread on building surfaces can result in extremely rapid fire growth that can easily exceed the design fires typically used in fire engineering design and, in particular, the design fire values given in Verification Method C/VM2. While it is not possible for the Building Code to control the contents of a building, it is appropriate to place controls on the surface finishes in certain areas of a building. Controlling the surface spread of flame significantly reduces the likelihood that a fire will exceed the growth rate given in Verification Method C/VM2.

The Group Number methodology used in Subclause C3.4(a) has been the subject of significant research in Europe and Australia, and more recently in New Zealand. The current methodology applied in the Building Code of Australia was adopted as a model for the NZBC. This uses the ISO 9705 method as a reference scenario. ISO 5660-1 results have been correlated to the larger scale ISO 9705 room corner fire test and the correlation can be used for most materials. Surface linings are exposed to 100 kW for 10 min and then 300 kW for a further 10 min, and the time to reach flashover (when the heat release rate reaches 1 MW in a 3,6 m × 2,4 m × 2,4 m room) is then determined. Materials are classified from Group Number 1 (best) to Group Number 4 (worst) based on their measured time to flashover in the fire test.

Group Number 1 materials

These include non-combustible materials or those with limited combustibility. Examples are plasterboard and similar, and low-hazard materials (no flashover in 20 min). These materials meet the flashover criteria of the performance requirement of Subclause C3.4(a) for exitways.

Group Number 2 materials

These typically include many fire retardant treated timbers (no flashover in 10 min). These materials meet the flashover criteria of the performance requirement of Subclause C3.4(a) for crowd uses.

Group Number 3 materials

These typically include ordinary timber or similar products (no flashover in 2 min). These materials meet the flashover criteria of the performance requirement of Subclause C3.4(a) for all other areas.

Group Number 4 materials

These typically include exposed polyurethane foams or similar products (flashover within 2 min). Note that these materials are potentially hazardous when installed as room linings and are not acceptable in occupied spaces.

C3.4(b) Floor surface materials in the following areas of buildings must meet the performance criteria specified in [Table B.2](#) (PR).

Table B.2

Area of building	Minimum critical radiant flux when tested to ISO 9239-1	
	Buildings not protected with an automatic fire sprinkler system	Buildings protected with an auto- matic fire sprinkler system
Sleeping areas and exitways in buildings where care or detention is provided	4,5 kW/m ²	2,2 kW/m ²
Exitways in all other buildings	2,2 kW/m ²	2,2 kW/m ²
Firecells accommodating more than 50 persons	2,2 kW/m ²	1,2 kW/m ²
All other occupied spaces except household units	1,2 kW/m ²	1,2 kW/m ²

Subclause C3.4(b) applies to the floor surface or the floor covering if present. A minimum critical radiant flux (CRF) is specified depending on location in the building and whether sprinklers are present. The CRF is measured in the floor radiant panel test (ISO 9239-1). For general use spaces, the level of performance required is low. This reflects previous requirements in New Zealand where controls on floor coverings in spaces other than exitways were minimal or nonexistent.

C3.4(c) Suspended flexible fabrics or membrane structures used in the construction of buildings must have properties resulting in a low probability of injury or illness to persons not in close proximity to a fire source (PR).

C3.5 Buildings must be designed and constructed so that fire does not spread more than 3,5 m vertically from the fire source over the external cladding of multi-level buildings (PR).

Subclause C3.5 applies to:

- a) buildings with upper floors containing sleeping occupancies or other property;
- b) buildings of building height >10 m.

It does not apply to importance level 1 buildings (as specified in Clause A3 of the Building Code).

C3.5 is intended to reduce the risk of flame spread via the external wall surfaces of buildings. The intention is to reduce the likelihood of fire spreading into upper floor levels or creating a hazardous situation for firefighters or occupants while escaping from the building.

C3.6 Buildings must be designed and constructed so that in the event of fire in the building, the received radiation at the relevant boundary of the property does not exceed 30 kW/m² and at a distance of 1 m beyond the relevant boundary of the property, does not exceed 16 kW/m² (PR).

C3.7 External walls of buildings that are located closer than 1 m to the relevant boundary of the property on which the building stands must either (PR):

- a) be constructed from materials which are not combustible building materials;
- b) for buildings in importance levels 3 and 4, be constructed from materials that, when subjected to a radiant flux of 30 kW/m², do not ignite for 30 min;
- c) for buildings in importance levels 1 and 2, be constructed from materials that, when subjected to a radiant flux of 30 kW/m², do not ignite for 15 min.

Subclauses C3.6 and C3.7 work in tandem to limit the probability of fire spread to adjoining property.

C3.6 is a performance requirement that limits the received radiation at the relevant distances, while C3.7 limits the combustibility of building surfaces in order to moderate the radiation requirements from the fire source building.

In C3.6, the maximum allowable received radiation on the boundary of 30 kW/m^2 recognizes that the construction of the external walls within 1,0 m of the relevant boundary must meet the separate criteria for ignitability as required by Subclause C3.7. Therefore, the material can be expected to be able to withstand an exposure of 30 kW/m^2 at least until the fire service has arrived, providing additional resources to prevent fire spread across the boundary. Beyond 1,0 m across the relevant boundary, Subclause C3.7 does not restrict the ignitability of materials that may be used on the external wall. Therefore, the maximum allowable received radiation at these locations is set at a lower value of 16 kW/m^2 . As this value may not necessarily be small enough to prevent ignition or damage to all cladding materials, it is anticipated that the fire service will provide a secondary means of preventing fire spread in these situations, if necessary.

While it is not possible to give 100 % guarantee of timely fire service intervention, the history of past fires indicates that the risk of fire spread to adjacent property is small but not insignificant (approximately 3 % of all structure fires according to NZFS Emergency Incident Statistics 2005–2010).

It should be noted that the design values for radiant flux given in this scenario and other assumptions implicit in the limiting distance method do not guarantee that fire spread will be prevented in all situations. Specifically, assumptions made such as ignoring flame projection from openings, cladding properties representing timber with 15 % moisture content, limited duration of exposure, and fire gas temperatures following a standard time-temperature curve may not be the most conservative cases. For this reason, it is anticipated that, in some instances, the fire service may also be called upon to provide a secondary means of helping to prevent fire spread.

The intention of Subclause C3.7 is to ensure that materials within 1,0 m of the relevant boundary are resistant to the level of radiation that they may be exposed to in that position. If a building is to be constructed closer than 1,0 m to the relevant boundary, then it is the responsibility of the owner to reduce the probability of fire spread by reducing the likelihood of ignition of their property. This is achieved by having more stringent requirements on the ignitability of the exterior cladding for buildings within 1,0 m of the relevant boundary. The combustibility (or non-combustibility) of materials can be assessed using AS 1530 Part 1 or ISO 1182. These test methods are severe and it can be assumed that if a material is classified as non-combustible, then there will be no ignition at heat fluxes up to 30 kW/m^2 . Alternatively, the time to ignition of cladding materials can be determined using ISO 5660-1. As ordinary timber claddings will ignite in less than 15 min when exposed to 30 kW/m^2 , they do not meet the performance criteria of Subclause C3.7.

C3.8 Firecells located within 15 m of a relevant boundary that are not protected by an automatic fire sprinkler system and that contain a fire load greater than 20 TJ or that have a floor area greater than 5,000 m^2 must be designed and constructed so at the time firefighters first apply water to the fire, the maximum radiation flux at 1,5 m above the floor is no greater than $4,5 \text{ kW/m}^2$ and the smoke layer is not less than 2 m above the floor.

C3.8 recognizes that C3.6 and C3.7 may, in some situations, be insufficient to protect other property without fire service intervention. For large, unsprinklered buildings, it is the intention to limit the maximum fire size and maximum allowable total energy level that can occur within a firecell. However, although these limits apply to all buildings, the limits set are only expected to affect large storage areas. There is no direct analytical method to determine the values used in C3.8 and, although they are noticeably larger than the 2 TJ of the previous Acceptable Solution C/AS1 (2011), the conventional explanation for that previous value was not well supported by sound engineering analysis. A number of international codes, including those of the UK, USA and Australia, were reviewed for comparative purposes. The values chosen for New Zealand are considered to be broadly comparable with these codes, even though direct comparison was limited by the differences in fire-resistive construction requirements, separation distances from boundaries, and controls on the total allowable energy. The maximum area limit of 5,000 m^2 was set based on a fire load energy density (FLED) of 800 MJ/m^2 per metre height of storage and a 5,0 m storage height.

C3.9 Buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety system intended to control fire spread (PR).

Subclause C3.9 recognizes that certain fire safety features may not respond as intended. Therefore, the failure of individual fire safety features should be considered in performance-based design. The

engineer is expected to evaluate their design under a specific scenario to address this concern, as well as to specify appropriate installation and maintenance standards for fire safety systems.

B.3.2.3 Clause C4 Movement to a Place of Safety

C4.1 Buildings must be provided with (FNR):

- a) effective means of giving warning of fire;
- b) visibility in escape routes complying with Clause F6.

C4.2 Buildings must be provided with means of escape to ensure that there is a low probability of occupants of those buildings being unreasonably delayed or impeded from moving to a place of safety and that those occupants will not suffer injury or illness as a result (FNR).

C4.3 The evacuation time must allow occupants of a building to move to a place of safety in the event of fire so that occupants are not exposed to any of the following (PR):

- a) a fractional effective dose of carbon monoxide greater than 0,3;
- b) a fractional effective dose of thermal effects greater than 0,3;
- c) conditions where, due to smoke obscuration, visibility is less than 10 m except in rooms of less than 100 m² where visibility may fall to 5 m.

Subclause C4.3 is intended to define the minimum life safety criteria for use in performance-based fire safety design. Specifying values for the fractional effective doses (FEDs) and visibility gives a more consistent level of safety than that given by the previous qualitative description of performance. According to ISO 13571, an FED of 1,0 is taken to be the level which would render occupants of average susceptibility incapable of effecting their own escape. Since the variability of human response to toxicological insults is best represented by a distribution, we can interpret an FED of 1,0 to be the point at which approximately 50 % of occupants might be expected to be incapacitated. The Code clause requires a lower FED threshold of 0,3 and we interpret this level to correspond to the point at which approximately 11 % of the population would be susceptible to less severe exposures. Lower threshold values would reduce that portion of the population. However, there is no threshold criterion so low as to be statistically safe for every exposed occupant.

The above discussion is mainly in relation to the toxicological effects of gases on people, but we have assumed that broadly similar principles apply to the thermal effects and we have accordingly used the same threshold criterion of FED <0,3.

C4.4 Subclauses C4.3(b) and (c) do not apply where it is not possible to expose more than 1 000 occupants in a firecell protected with an automatic fire sprinkler system.

Subclause C4.4 removes the performance criteria for visibility and FED thermal when it is not possible to expose more than 1 000 occupants in a sprinklered firecell. This is intended to promote the use of sprinklers in buildings and to provide closer alignment with the requirements of the Acceptable Solutions. However, it also recognizes the current limitations in accurately modelling sprinkler performance in controlling the fire and reducing the threat to life safety. Although there may be a temporary increase in smoke production when a sprinkler activates, due to the expansion of steam generated from cooling the fire, this is quickly controlled and the threat to the building's occupants is greatly reduced. Therefore, with sprinklers, only the FEDCO needs to be calculated unless there are very large numbers of occupants at risk. This places a practical limit on the maximum evacuation time in the rare cases where the fire may be shielded from the sprinkler or the system does not operate as designed.

C4.5 Means of escape to a place of safety in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems (PR).

Subclause C4.5 recognizes that certain fire safety features may not respond as intended. Therefore, the failure of individual fire safety features should be considered in performance-based design. The

engineer is expected to evaluate their design under a specific scenario to address this concern, as well as to specify appropriate installation and maintenance standards for fire safety systems.

B.3.2.4 Clause C5 Access and Safety for Firefighting Operations

C5.1 Buildings must be designed and constructed so that there is a low probability of firefighters or other emergency services personnel being delayed in or impeded from assisting in rescue operations and performing firefighting operations (FNR).

C5.2 Buildings must be designed and constructed so that there is a low probability of illness or injury to firefighters or other emergency services personnel during rescue and firefighting operations (FNR).

C5.3 Buildings must be provided with access for fire service vehicles to a hard-standing from which there is an unobstructed path to the building within 20 m of (PR):

- a) the firefighter access into the building;
- b) the inlets to automatic fire sprinkler systems or fire hydrant systems, where these are installed.

C5.4 Access for fire service vehicles in accordance with Subclause C5.3 must be provided to more than one side of firecells greater than 5,000 m² in floor area that are not protected by an automatic fire sprinkler system (PR).

Where Subclause C5.4 applies for vehicle access, it is intended that the points should be distributed around the building and not located each side of a corner such that the same hard-standing is utilized. The purpose of this clause is to ensure firefighter vehicle access to very large unsprinklered buildings.

C5.5 Buildings must be provided with the means to deliver water for firefighting to all parts of the building (PR).

C5.6 Buildings must be designed and constructed in a manner that will allow firefighters, taking into account the firefighters' personal protective equipment and standard training, to (PR):

- a) reach the floor of fire origin;
- b) search the general area of fire origin;
- c) protect their means of egress.

C5.7 Buildings must be provided with means of giving clear information to enable firefighters to (PR):

- a) establish the general location of the fire;
- b) identify the fire safety systems available in the building;
- c) establish the presence of hazardous substances or process in the building.

Subclauses C5.3, C5.4, C5.5, C5.6 and C5.7 facilitate firefighter and rescue operations using methods that are conventional and easily anticipated by the fire service. It is not expected that performance-based design would be carried out in relation to the systems provided here. It would be expected that, in the unusual event of any solutions being proposed for firefighting and rescue operations that were considered "out of the ordinary", these would be discussed in detail with and agreed to by the fire service in advance.

C5.8 Means to provide access for and safety of firefighters in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems (PR).

Subclause C5.8 means that, where provided, fire safety systems including automatic detectors, sprinklers, hydrants, smoke/heat venting systems and use of fire rated construction elements shall meet acceptable standards for their design, construction, installation and maintenance to ensure that their level of reliability and effectiveness are appropriate for the particular application.

B.3.2.5 Clause C6 Structural Stability

C6.1 Structural systems in buildings must be constructed to maintain structural stability during fire so that there is (FNR):

- a) a low probability of injury or illness to occupants;
- b) a low probability of injury or illness to fire service personnel during rescue and firefighting operations;
- c) a low probability of direct or consequential damage to adjacent household units or other property.

C6.2 Structural systems in buildings that are necessary for structural stability in fire must be designed and constructed so that they remain stable during fire and after fire when required to protect other property taking into account (PR):

- a) the fire severity;
- b) any automatic fire sprinkler systems within the buildings;
- c) any other active fire safety systems that affect the fire severity and its impact on structural stability;
- d) the likelihood and consequence of failure of any fire safety systems that affect the fire severity and its impact on structural stability.

C6.3 Structural systems in buildings that are necessary to provide firefighters with safe access to floors for the purpose of conducting firefighting and rescue operations must be designed and constructed so that they remain stable during and after fire (PR).

C6.4 Collapse of building elements that have a lesser fire resistance must not cause the consequential collapse of elements that are required to have a higher fire resistance.

B.4 Bibliography

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