

Australian Standard[®]

Tunnel fire safety



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The following are represented on Committee FP-023:

- AUSTROADS
 - Australasian Fire and Emergency Service Authorities Council
 - Australian Automobile Association
 - Australian Tunnel Operators Group
 - CSIRO Manufacturing and Materials Technology
 - Engineers Australia
 - Fire Protection Association Australia
 - Main Roads Department, Queensland
 - Main Roads Western Australia
 - Society of Fire Safety
 - RailCorp
 - Risk Management Institution of Australasia
 - Roads and Traffic Authority of NSW
-

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Tunnel fire safety

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PREFACE

This Standard was prepared by Standards Australia Committee FP-023, Tunnel Fire Safety.

Whilst a number of existing overseas Standards and guidance documents were considered by the committee during the preparation of this first edition of the Standard, the document is not based upon any other Standard.

The committee decided that the most appropriate format for the Standard is to facilitate the current Australian practice of adopting a performance-based approach to fire safety in tunnels. Such an approach is reliant on fire safety engineering methodologies similar to those described in the *International Fire safety engineering Guidelines* which is extensively used in Australia for performance-based design for fire safety in buildings.

The Standard is intended to provide a generic framework for establishing the fire safety systems that are required in road, rail or bus tunnels to provide an acceptable level of safety in case of fire. This Standard is intended to guide professional fire safety engineers in the development of a fire safety strategy, the design and documentation of fire safety systems for tunnels.

Specifically, this Standard—

- (a) recommends appropriate performances of the fire safety system;
- (b) provides guidance on appropriate fire safety strategies;
- (c) provides information on what may constitute appropriate trial concept design for various tunnels;
- (d) does not restrict innovative approaches or new technology provided that the required performance can be demonstrated;
- (e) outlines what may be appropriate analysis methodology;
- (f) allows for both deterministic and probabilistic (risk-based) analysis and approach;
- (g) specifies what may constitute appropriate acceptance criteria;
- (h) provides general guidelines on system installation and maintenance, which is intended to facilitate making appropriate assumptions in the engineering analysis; and
- (i) refers to other Standards providing greater detail where appropriate.

It is not the purpose of this Standard to prescribe an acceptable level of fire safety for tunnels rather to provide a framework for establishing the required fire safety systems.

As it not possible to prescribe either the fire safety measures or the analysis required, the Standard has been written as an ‘informative’ document providing guidance to competent designers to undertake a performance-based design for fire safety. Further, the information presented permits a systematic consideration of a fire safety strategy with fire safety measures that can form the input into the fire safety engineering analysis to demonstrate to stakeholders that an acceptable level of safety can be achieved by the design.

This Standard incorporates a Commentary on some Clauses. The Commentary directly follows the relevant Clause, is designated by ‘C’ preceding the Clause number and is printed in italics in a panel.

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FOREWORD

The design and implementation of fire safety measures and a management system for a tunnel will be influenced by the varying needs and operational requirements pertinent to the tunnel's use. Factors such as traffic volume, nature of vehicles, length of tunnel, and traffic conditions, all influence the risk and hence the level of safety within tunnels. Thus, fire safety measures that may be adequate to provide an acceptable level of risk under one set of operating conditions, may not be adequate under a different set of circumstances. Therefore, it is not possible to provide a prescriptive list of fire safety measures suitable for tunnels that, at first glance, are similar in specific characteristics (e.g. length).

The acceptability of a specific tunnel design is a matter for all the stakeholders, which include authorities having a regulatory function, in addition to the tunnel's owner and operator.

Fire safety engineering is an iterative process consisting of the evaluation of an initial concept design and a series of design assumptions that are tested through an analysis process. If the analysis reveals that the acceptance criteria are not met, then the concept design is modified until an acceptable outcome is obtained. The design assumptions used in the analysis then needs to be implemented in both the design and the built works to arrive at a tunnel with an acceptable level of safety.

STANDARDS AUSTRALIA

Australian Standard
Tunnel fire safety

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard provides guidelines for fire safety in new road, rail and bus tunnels. It covers uni-directional and bi-directional tunnels of various lengths meeting the limitations outlined in Clause 1.3.

This Standard can be applied to tunnels involving vehicles with no drivers such as driverless trains, although special additional considerations may apply. For rail and bus tunnels, this Standard addresses the tunnel/station interface. This Standard addresses tunnels used to carry both passengers and freight, and the combustible materials and goods carried by those vehicles.

This Standard is not specifically intended for existing tunnels; however, the general principles may be applied to the upgrade of existing tunnels to improve fire safety. In the case of modification works to a tunnel, the modification should be treated as building a new tunnel for interpretation of this Standard. The existing constraints however, may limit the choice of fire safety measures that can be implemented. Such constraints may result in the fire safety measures not being able to fully satisfy the objective contained in this Standard.

1.2 OBJECTIVE

The objective of this Standard is to provide guidance on design, system selection, construction, operation and emergency management of road, rail and bus tunnels in order to satisfy fire safety objectives and other objectives identified by the stakeholders.

1.3 LIMITATIONS OF STANDARD

This Standard does not apply to the following types of tunnels:

- (a) Tunnels that do not meet the definition of a tunnel in Clause 1.6.
- (b) Funicular tunnels.
- (c) Service tunnels.
- (d) Pedestrian or bicycle tunnels.
- (e) Railway and bus stations.
- (f) Tunnels for vehicles with no persons onboard.

This Standard does not cover transportation of dangerous goods through tunnels.

NOTE: Transportation of dangerous goods usually involves a comprehensive risk assessment as to the optimum transportation route and other safety considerations. If dangerous goods or bulk fuels are to be transported through a tunnel, consideration should be given to any additional fire safety measures or precautions required to that are given in this Standard.

This Standard does not address fire safety during construction.

1.4 TUNNEL CLASSIFICATION

Tunnel classification is provided for the purpose of establishing the preliminary fire safety measures for tunnels with different design characteristics for the purposes of an initial concept design.

Tunnels are classified according to four criteria:

- (a) Tunnel length:
 - (i) *Long tunnel (L)* Where the length is greater than 120 m in the case of road and bus tunnels and 250 m in the case of rail tunnel.
 - (ii) *Short tunnel (S)* Where the length is less than the long tunnels.
- (b) Traffic condition—Road tunnel only:
 - (i) *High traffic (HT)* Where there is a high volume of traffic or high likelihood of congested traffic.
 - (ii) *Low traffic (LT)* Where there is a low volume of or low likelihood of congested traffic.
- (c) Direction of traffic:
 - (i) Uni-directional (U). (See Clause 1.6.)
 - (ii) Bi-directional (B). (See Clause 1.6.)
- (d) Intersection:
 - (i) No intersection within tunnel (N). (See Clause 1.6.)
 - (ii) One or more intersections within tunnel (O). (See Clause 1.6.)

1.5 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1530	Methods for fire tests on building materials, components and structures
1530.4	Part 4: Fire-resistance test of elements of construction
1603	Automatic fire detection and alarm systems
1603.5	Part 5: Manual call points
1603.7	Part 7: Optical beam smoke detectors
1603.8	Part 8: Multi-point aspirated smoke detectors
1668	The use of ventilation and airconditioning in buildings
1668.1	Part 1: Fire and smoke control in multi-compartment buildings
1670	Fire detection, warning, control and intercom systems—System design, installation and commissioning
1670.1	Part 1: Fire
1670.4	Part 4: Sound systems and intercom systems for emergency purposes
1851	Maintenance of fire protection systems and equipment
1905	Components for the protection of openings in fire-resistant walls
1905.1	Part 1: Fire-resistant doorsets
2118	Automatic fire sprinkler systems
2118.1	Part 1: General systems
2118.3	Part 3: Deluge
2293	Emergency escape lighting and exit signs for buildings
2293.1	Part 1: System design, installation and operation

AS	
2419	Fire hydrant installations
2419.1	Part 1: System design, installation and commissioning
2441	Installation of fire hose reels
2444	Portable fire extinguishers and fire blankets—Selection and location
2484	Fire—Glossary of terms
2484.1	Part 1: Fire tests
2484.2	Part 2: Fire protection and firefighting equipment
3600	Concrete structures
3745	Emergency control organization and procedures for buildings, structures and workplaces
4118	Fire sprinkler systems
4118.2.1	Part 2.1: Piping—General
4391	Smoke management systems—Hot smoke test
4587	Water mist fire protection systems—System design, installation and commissioning
7240	Fire detection and alarm systems
7240.10	Part 10: Point-type flame detectors
AS/NZS	
1170	Structural design actions
1170.1	Part 1: Permanent imposed and other actions
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)
AS/NZS ISO	
31000	Risk management—Principles and guidelines
BCA	Building Code of Australia
ISO	
834	Fire-resistance tests—Elements of building construction
834-1	Part 1: General requirements
9001	Quality management systems—Requirements
BCA	Building Code of Australia
NFPA	
11	Standard for Low-, Medium-, and High-Expansion Foam
15	Standard for Water Spray Fixed Systems for Fire Protection
16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
502	Standard for road tunnels, bridges, and other limited access highways
750	Standard on water mist fire protection systems
SFPE	The SFPE Handbook of Fire Protection Engineering
International fire safety engineering guidelines (IFEG)	
PIARC	Systems and Equipment for Fire and Smoke Control in Tunnels
UPTUN	WP-2 Fire development and mitigation measures
http://www.uptun.net/index.asp	

1.6 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 2484.1, AS 2484.2 and those below apply.

1.6.1 Bi-directional

Traffic flowing in both directions within the same aerodynamic space.

1.6.2 Bus tunnel

Tunnel designed for principal use by commuter buses driven by drivers with training in emergency response procedures, excluding coaches or other vehicles driven by drivers without training.

1.6.3 Congested traffic

Traffic conditions where there is a risk of a vehicle not being able to drive out at a speed greater than the rate of longitudinal spread of smoke.

NOTE: Congested traffic includes stopped traffic conditions where driving out ahead of the longitudinal smoke flow is not a practical option. For example, uncontrolled signalized intersection in close proximity to the tunnel. The risk of congested conditions coexisting with fire incidents should be considered through the FEB process.

1.6.4 Dangerous goods

Any material that complies with the definition of dangerous goods as published in the ADG Code and/or is nominated as such by the authority having jurisdiction.

1.6.5 Egress passage

Protected exit route to a non-incident tunnel, refuge, exit or other place of safety.

1.6.6 Elevated walkway

Walkway elevated above road or track level to facilitate egress from vehicles.

1.6.7 Emergency lighting

Lighting that provides illumination during emergencies.

1.6.8 Fire alarm system

An arrangement of components and apparatus for giving an audible, visible or other perceptible alarm of fire, which may also initiate other actions.

1.6.9 Fire brigade intervention

All fire agency activities from time of notification up to departure from the incident site and includes all fire brigade operations.

1.6.10 Fire brigade operations

All firefighter activities from time of arrival at an incident including set-up, search and rescue, fire attack extinguishment and other activities up to time of departure from the incident site.

1.6.11 Fire detection system

An arrangement of detectors and control and indicating equipment employed for automatically detecting fire and initiating other actions.

1.6.12 Fire safety system

Collection of all fire safety measures that contribute to fire safety within the tunnel.

1.6.13 Fire safety measures

Any measure including any fire protection system, form of construction and operational protocol that contributes to fire safety within the tunnel.

1.6.14 Fire-suppression system

A system designed to discharge a fire-suppression agent into or onto a protected area to suppress fire growth.

1.6.15 Freight tunnel

Tunnel primarily for the use of traffic with a high fire load and low population.

1.6.16 Intersection

Two or more merging or diverging tunnel bores.

1.6.17 Longitudinal ventilation

Ventilation mode where airflow is principally longitudinal; air is supplied via tunnel portals or other openings and exhausted at other portals, shafts or openings.

1.6.18 Metro passenger rail tunnel

Tunnel predominantly for the use of frequent passenger trains in an urban environment. Normally found in major cities and characterized by underground stations and frequent traffic that may be required to be held within the tunnel. This may include heavy rail or metro style systems.

1.6.19 Normal lighting

Lighting levels during normal tunnel operations.

1.6.20 Passenger tunnel

Tunnel primarily for the use of traffic with a low fire load and high population.

1.6.21 Rail tunnel

Tunnel for use by rail vehicles on a track way.

1.6.22 Regional passenger/freight rail tunnel

Tunnel for the use of a mix of passenger trains and freight trains in an outer urban or rural environment. Normally characterized by above-ground stations and relatively infrequent traffic not required to stop within the tunnel.

1.6.23 Remotely controlled passenger vehicle

A vehicle where the driver or operating personnel are not onboard the vehicle.

1.6.24 Road tunnel

A tunnel carrying a traffic mix of cars, trucks and vehicles driven by drivers without tunnel safety training.

1.6.25 RABT

A fast-growing fire designed to replicate a single truck fire (see Clause 1.7).

NOTE: A graphical representation of this fire curve is provided in Appendix B.

1.6.26 RWS

A fast-growing fire designed to replicate a fuel tank on fire in a confined space (see Clause 1.7).

NOTES:

- 1 A graphical representation of this fire curve is provided in Appendix B.
- 2 The RWS fire curve is for evaluating the temperatures at the concrete and protective covering interface. A temperature limit for concrete during a 2 h fire is 380°C. Reinforcement within concrete is limited to 250°C.

1.6.27 Semi-transverse ventilation

A ventilation mode where air is supplied (or exhausted) longitudinally but exhausted (or supplied) at points along the tunnel.

1.6.28 Separating elements

Elements of construction that form the boundaries of fire-isolated or fire-separated spaces.

1.6.29 Smoke exhaust

Mechanical system involving fans, ducts or other means to remove smoke and heat from a localized section of a tunnel.

1.6.30 Smoke venting

Openings or other means to provide natural (buoyancy driven) ventilation of smoke and heat in the event of a fire.

1.6.31 Transverse ventilation

A ventilation mode where air is supplied normally and exhausted effectively in the same cross-section of a tunnel.

1.6.32 Tunnel

A substantially enclosed roadway or track-way greater than 80 m in length.

NOTE: What constitutes a tunnel depends on the likelihood of development of untenable conditions. If the degree of cover is less than 75%, the accumulation of smoke is unlikely.

1.6.33 Uni-directional

Traffic flowing in single direction within the same aerodynamic space.

1.6.34 Walkway

Designated path for tunnel occupants to walk to egress passage or exit.

1.6.35 Wayfinding

Fire safety measures that facilitate occupants to negotiate the evacuation route. It includes lit and unlit signs, guidance strips, markings and beacons intended to aid occupants in identifying and following egress routes.

1.7 ABBREVIATIONS

ADG	Australian Dangerous Goods
ASET	Available safe egress time
BGA	Brake glass alarm
CCTV	Closed-circuit television
CFD	Computational fluid dynamics
DHTC	Dedicated hardwired telephone circuit
EMP	Emergency management plan
FAT	Factory acceptance testing
FBIM	Fire Brigade Intervention Model
FEB	Fire engineering brief
FER	Fire engineering report
GRN	Government radio network
HRR	Heat release rate
ICR	Incident control room
IRPs	Incident response plans
PA	Public announcement
QRA	Quantitative risk assessment
RABT	Richtlinien für die Ausstattung und den Betrieb von Strassentunneln (Germany)
RRB	Radio rebroadcast
RSET	Required safe egress time
RWS	Rijkswaterstaat (Netherlands)
SOP	Standard operating procedure
TCD	Trial concept design
TMCS	Traffic management control system
TOCR	Traffic operations control room
UPS	Uninterruptible power supply

SECTION 2 KEY INFORMATION AND DESIGN CONSIDERATION

2.1 SCOPE OF SECTION

This Section describes the project characteristics that need to be considered in the development of fire safety design.

NOTE: It should be noted that this is an ongoing process and will need review throughout the development of a project.

2.2 PHYSICAL CHARACTERISTICS

The main physical characteristics that influence tunnel fire safety include the following:

- (a) Tunnel dimensions (including length, width and height).
- (b) Ventilation system including ventilation openings and meteorological conditions.
- (c) Road or track gradient.
- (d) Entry and exit ramps.
- (e) Intersections.
- (f) Crossovers.
- (g) Drainage provisions.
- (h) Number of lanes or tracks.
- (i) Nature or type of the structure (e.g. submerged or located under critical structure).
- (j) Depths below surface.
- (k) Uni-directional or bi-directional traffic movement.
- (l) Number of bores and their relative proximity.
- (m) Road alignment and geometry, including sight lines, stopping sight distance, lane and shoulder widths.

2.3 DESIGN CONSIDERATIONS

2.3.1 Objective

The aim of any tunnel design is to provide an adequate level of fire safety for the tunnel occupants, firefighters, and maintenance and other emergency services personnel. Fire safety objectives include the following:

- (a) Safety of occupants (reduce fire risk to acceptable level).
- (b) Facilitation effective emergency services intervention.
- (c) Protection of adjoining property and third parties.

Other objectives may include the following:

- (i) Minimization of interruption to tunnel operations.
- (ii) Minimization of property damage.
- (iii) Minimization of fire incidents.
- (iv) Minimization of the adverse impact of fires on the environment.
- (v) Minimization of capital and life cycle costs.

2.3.2 Traffic characteristics

Traffic characteristics that should be considered include the following:

- (a) Traffic volume, speeds and headways.
- (b) Mix and type of vehicles including cargo.
- (c) Vehicle length and occupancy.
- (d) Traffic management or signalling systems.
- (e) Lane closure and lane changing arrangements or track switching.
- (f) Lane merges and weaves.
- (g) Likelihood of stopped traffic.
- (h) Uni-directional or bi-directional traffic flow.

2.3.3 Preventive measures

Measures should be provided to reduce the likelihood of an incident. Measures to be considered include the following:

- (a) Operational plan to minimize occupant risk.
- (b) Staff training (vehicle and tunnel).
- (c) Public education.
- (d) Maintenance.
- (e) Control on combustibles.
- (f) Control of potential ignition sources.
- (g) Good traffic flow and tunnel geometry design.
- (h) Control of vehicle speed.
- (i) Control of unsuitable vehicles.

2.3.4 Incident mitigation

Measures should be provided to mitigate the impact of an incident. Measures to be considered include the following:

- (a) Active and passive protection system including but not limited to—
 - (i) fire detection and alarm systems;
 - (ii) smoke management;
 - (iii) structural protection, fire separation and compartmentation;
 - (iv) egress systems;
 - (v) fire-suppression;
 - (vi) control of combustibles and spread of flame; and
 - (vii) first attack and communication facilities.
- (b) Emergency management—
 - (i) staff training;
 - (ii) emergency services training;
 - (iii) emergency drills and exercises; and
 - (iv) public education.

2.3.5 Asset protection

The level of asset protection is a matter for the asset owner and should include consideration of the following:

- (a) Life cycle costing with a balance between capital and recurrent expenditure.
- (b) Provisions for protection of the structure.
- (c) Protection of adjoining critical structures or infrastructure.
- (d) Ease of operation, inspection and maintenance.
- (e) Provision for protection of fire safety measures from mechanical or accidental damage.

2.3.6 Business interruption

The effects of business interruption due to an incident need to be considered in the context of the following:

- (a) Criticality of infrastructure.
- (b) Criticality of adjoining infrastructure.
- (c) Impact on community.
- (d) Ability and time required to recover normal operation.
- (e) Ability to function safely during degraded modes of operation.
- (f) Potential loss of revenue.

2.3.7 Structural damage

As a minimum, the level of fire protection to limit structural damage should meet life safety, asset protection and business interruption requirements. Factors to be considered include the following:

- (a) Potential for collapse or failure in critical areas.
- (b) Protection of emergency services.
- (c) Repair technique.
- (d) Progressive collapse.
- (e) Structural damage resulting in failure of safety systems.
- (f) Proposed fire-suppression system.
- (g) Failure of fire-separating element.

2.3.8 Emergency services intervention

The design for emergency services intervention needs to consider the following:

- (a) Level of emergency services intervention required.
- (b) Regulatory requirements.
- (c) Emergency services intervention policy.
- (d) Response time and capability.
- (e) Design to facilitate emergency services activities.
- (f) Intervention access (terrain).
- (g) Water supply.
- (h) Emergency services interface with safety measures and normal operational systems.

2.3.9 Incident management

Incident management should take into consideration the following:

- (a) Tunnel length.
- (b) Traffic density.
- (c) Level of monitoring and surveillance.
- (d) Presence of trained operator.
- (e) Presence and availability of safety systems (including electrical isolation).
- (f) Availability of incident response crew.
- (g) Availability of emergency services.
- (h) Communication systems.
- (i) Traffic network control and management.
- (j) Incident management protocol of responding emergency services.

2.3.10 Environment

Environmental considerations should include the following:

- (a) Environmental regulations.
- (b) Points of discharge of smoke.
- (c) Contaminated fire water.
- (d) Spill containment.
- (e) Noise pollution.
- (f) Local environmental conditions.
- (g) Tunnel environs.
- (h) Sustainability.

2.3.11 Tunnel configuration

The tunnel configuration can influence the fire dynamics and fire safety strategy. Examples of tunnel configuration considerations include the following:

- (a) Twin tunnel, which affords the opportunity to use the adjacent tunnel as a place of relative safety.
- (b) The physical dimensions and geometry of the tunnel, which can influence the fire dynamics and fire behaviour.
- (c) Egress routes to places of safety.

2.3.12 Constructability

Fire safety solutions will be influenced by the constructability of the tunnel. Constructability will be constrained by factors such as tunnel geometry, terrain, ground type, groundwater, construction method, mining method and costs.

2.3.13 Maintainability

Maintainability considerations include the following:

- (a) Maintenance policy and plan (see Section 11).
- (b) Constraints on maintenance access including availability criteria.
- (c) Scheduled maintenance frequency.

- (d) Design life and durability.
- (e) Relevant maintenance Standards for fire protection systems (e.g. AS 1851).

2.3.14 Reliability and redundancy

The reliability and redundancy of all tunnel systems that have an impact on safety should be considered as part of the design. This may be directly related to project availability requirements.

2.3.15 Method of operation

The method of operation of the tunnel will influence the fire safety measures required. Operational considerations include the following:

- (a) Presence of a tunnel operator.
- (b) Degree of automation.
- (c) Remote versus on-site monitoring, control and operation.
- (d) Operator interface.
- (e) Emergency services intervention.

2.3.16 Other considerations

Other aspects to be considered include the following:

- (a) Need for fire safety measures to cater for emergencies other than fire.
- (b) Need for fire safety measures to cater for other operational requirements.
- (c) Safety in design requirements.
- (d) Occupational health and safety.

SECTION 3 FIRE ENGINEERING PROCESS

3.1 SCOPE OF SECTION

This Section provides a framework to guide both the project parties and external groups in their input to a project. The parties noted are restricted to those relevant to tunnel fire safety.

This Section also prescribes the documentation that should be produced as part of a tunnel project, to record the design inputs, assumptions and decisions, along with the design results.

3.2 ROLES OF STAKEHOLDERS

3.2.1 General

Stakeholders should be involved in the fire safety engineering process. Stakeholder roles within a project should be clearly defined in the FEB. Roles may be defined by legislation, contract documentation or other project requirement. Stakeholders are described in Clauses 3.2.2 to 3.2.12.

3.2.2 Principal

For tunnel projects in Australia, the Principal is usually the Federal, State or local government, or an entity owned by one of the levels of government. If the Principal undertakes or directly contracts the design, project management and management of third party interfaces, then the Principal is also the proponent. The Principal, in contracting for a tunnel facility, will normally retain responsibility for scope and associated approvals.

The Principal is the nominated authority that ensures that the fire safety requirements of the project are administered.

The Principal will determine decisions based on advice from various parties including the following:

- (a) Fire safety engineer.
- (b) Third party independent peer reviewer.
- (c) Relevant stakeholders.

The Principal has responsibilities in relation to administering the fire safety requirements including the following:

- (i) Approval of the trial concept design and relevant fire and life safety elements.
- (ii) Defining the project objectives and performance requirements applicable to the trial concept design and relevant fire and life safety elements.
- (iii) Providing advice during the FEB process.
- (iv) Carrying out the appropriate regulatory functions.
- (v) Accepting third-party review of the trial concept design.
- (vi) Arbitration where there is a dispute between the stakeholders.

3.2.3 Proponent

Proponent is taken to mean the entity that has contracted with the Principal to build the tunnel. The proponent may also be the operator under a concession from the Principal, and may contract others to undertake specific tasks, such as design and regulatory approvals. In particular, the proponent may construct the project directly, or engage a construction contractor to carry out construction, and may pass interfacing responsibilities also to the contractor.

3.2.4 Contractor

The contractor is the entity that will engage staff and resources to build the project. It may be part of the proponent organization or separate to it.

3.2.5 Design entities

The Principal, the proponent or the contractor arranges for design work for the project to be done by one or more design entities who are responsible for translating FEB and other fire safety engineering reports into detailed design and documentation for construction.

3.2.6 Third-party peer reviewer

The 'third-party peer reviewer' provides an objective technical review of the design. The 'third-party peer review' should be conducted by a fire safety engineer who has a level of experience in the design of projects similar to the one being reviewed, at least comparable to that of the fire safety engineer responsible for the project.

3.2.7 Fire safety engineer

The role of the fire safety engineer is to develop the fire safety design and demonstrate the adequate performance of that design to the satisfaction of the Principal.

NOTE: A fire safety engineer is a person appropriately qualified to the satisfaction of the stakeholders to undertake fire safety engineering tasks.

3.2.8 Tunnel operator

The tunnel operator (for the purposes of tunnel fire safety) manages and is responsible for the tunnel fire safety systems, including their maintenance, and incident response.

3.2.9 Fire authority

The fire authority provides input to the fire engineering process in relation to its statutory role of the fire authority. This input may include—

- (a) protection of persons, property and the environment from fire and hazardous materials emergencies;
- (b) management of emergencies; and
- (c) provision of an advisory service and undertaking of other activities, to promote tunnel fire safety and operational requirements.

3.2.10 Other emergency services

The other emergency services generally support the fire authority activities and provide an advisory service with respect to their activities during a tunnel fire safety incident.

3.2.11 Disability advisor

The disability advisor provides advice on the needs of persons with disability and compliance with appropriate disability Standards and statutory requirements.

3.2.12 Transport safety agencies

The 'transport safety agencies' (usually specialist government departments) provide an advisory service with respect to their operations that are relevant to tunnel fire safety. This role also includes those sections of road, rail and bus operators and design agencies responsible for overseeing safety in a particular transport mode.

3.3 FIRE SAFETY DESIGN STAGES

3.3.1 General

The fire safety design advances in line with the general design process. Initial focus is on the input to the design such as stakeholder objectives and performance expectations. As the general design develops, the fire safety design advances through fire safety strategy at the concept level to more detailed specifications of the fire safety measures. The idealized stages described in this Clause may overlap and vary in practice and will tend to advance in line with the overall tunnel design. The final documentation should be specific to the fire systems that have been adopted and should demonstrate the adequacy of the systems.

3.3.2 Trial concept design (fire safety strategy)

The purpose of the trial concept design process is to reach a broad consensus on an appropriate fire safety system and fire safety strategy that meets with the fire safety objectives for the tunnel. This will require an understanding of the physical attributes and likely use of the tunnel and identification of the potential hazards that may arise when the tunnel is put into operation.

The trial concept design will identify preliminary fire safety measures that will be assessed from the perspective of achieving acceptable performance in terms of the agreed fire safety objectives in the context of identified hazards and fire scenarios.

To develop the trial concept design, a series of workshops with stakeholders may be required and the preliminary fire safety measures may be amended by consensus of the stakeholder group.

3.3.3 Schematic design (FEB)

During the schematic design stage, the fire safety strategy and fire safety measures for the tunnel will be developed further and will be documented in a FEB. The purpose of the FEB is to document the design parameters and acceptance criteria to gain agreement, in principle, of the stakeholders.

3.3.4 Design development (fire engineering assessment)

The aim of the design development stage is to assess and further develop the schematic fire engineering design and develop a fire safety strategy that meets the tunnel fire safety objectives by appropriately responding to the identified hazards arising from the use of the tunnel. The process of fire engineering assessment involves testing of the adequacy of the proposed design through a number of scenario analyses, or through a rigorous risk analysis process, as determined at the FEB stage. The fire safety system is considered to be adequate when the outcome of the analysis demonstrates achievement of the acceptance criteria.

3.3.5 Design/construction documentation

The fire safety engineer should prepare structured, comprehensive and concise documentation to enable the design requirements to be incorporated into the design/construction documentation and specification.

3.3.6 Installation and construction

The fire safety design will provide input for the installation and construction stages. The fire safety engineer should review the construction documentation and undertake site inspections to ensure the construction is in accordance with the FER.

If there are modifications made to the fire safety system which alter the fire engineering design as presented to the stakeholders, such changes are to be assessed by a fire safety engineer and reviewed by the stakeholders prior to implementation of the changes.

3.3.7 Commissioning and testing

Adequate commissioning and testing should be undertaken to ensure that the design requirements have been realized in the completed works. The fire safety engineer should witness commissioning and testing to ensure the system performance is in accordance with the FER.

3.3.8 Operation and maintenance

Operation and maintenance of the tunnel fire safety system need to be in accordance with trial concept design (fire safety strategy) as defined in Clause 3.3.2, and incorporated into the tunnel's incident management and response plans. The fire safety engineer should direct or be involved in the development of the incident management and response plans as well as contribute to the operation and maintenance plan.

3.4 FIRE SAFETY DOCUMENTATION

3.4.1 General

The documentation process involves the preparation of the FEB in consultation with the project stakeholders and seeking agreement, in principle, from all the stakeholders. This is followed by the preparation of a detailed fire engineering assessment report, which may have a number of sections.

Within the documentation process there should be flexibility in the format and presentation of the project fire safety documentation. The format and presentation may also be guided by the contractual and regulatory requirements around the project.

The design documentation is required to—

- (a) communicate the trial concept design to other parties and reviewers for their input;
- (b) communicate the fire safety requirements to the designers of other components, systems and procedures for the project;
- (c) act as an archival record for those seeking, at a future date, to understand the design reasoning and outcomes;
- (d) document the responses of third parties to the design, the designer's responses, and the resolution of the issues raised;
- (e) remain as an essential part of the designer's quality assurance; and
- (f) satisfy the documentation requirements for any regulatory or approval process.

3.4.2 Documentation

The following set of documentation is suggested as a basis for the fire safety design documentation. Where the fire safety engineer has not prepared the following documents, the fire safety engineer should review the document for consistency with the fire safety strategy and design assumptions:

- (a) *Fire engineering brief (FEB)* The FEB is an essential part of the fire engineering process, which defines the scope of work for the fire engineering analysis. Its purpose is to set down the basis, as agreed by the relevant stakeholders, on which the fire safety analysis will be undertaken.

Areas for consideration during the FEB stage include the following:

- (i) Fire safety objectives.
- (ii) Occupant characteristics.
- (iii) Trial concept design.
- (iv) Preliminary technical assessment.
- (v) Acceptance criteria.
- (vi) Assessment methods.

- (b) *Fire engineering report (FER)* The FER is the core document recording the fire safety design. It should record the relevant project parameters, features and safety provisions, design inputs and assumptions, and the concepts behind the design. The FER should clearly set out the hazards, the response to those hazards, and whether analysis is, or was, required to further understand the hazards or the design. The FER should document the analysis outcomes and may contain some key points of the analysis. The bulk of the analysis detail should be incorporated in one or more appendices.

The FER should demonstrate and conclude that the trial concept design meets the level of performance and acceptance criteria agreed in the FEB.

The FER should contain all of the relevant information defined in the fire engineering design process including details of inputs into computer analysis programs, detailed explanations of the fire safety system, assessment criteria and approaches and reference material. Reference material should be described with clear explanations of how the material is used to justify the fire safety system and the degree to which the reference material is validated and applicable.

Any other records of stakeholder input, including meeting and workshop minutes, questions raised and review comments, should be recorded in the final versions of the appropriate reports.

Third-party and any peer review comments and the response of the designer should also be documented in the FER. Other reports, as set out in Items (c) to (i) below, may be sections of the FER, or stand-alone documents summarized in the FER. The FER, at its various stages, should include an appropriate level of detail on the following topics:

- (i) Fire safety objectives (see Section 1).
- (ii) Key information on the tunnel project (see Section 2).
- (iii) The fire safety measures in the tunnel (see Section 4).
- (iv) Performance of fire safety measures (see Section 5).
- (v) Fire hazards in the tunnel (see Section 6).

- (vi) Design scenarios (see Section 6).
 - (vii) Inputs and assumptions for the design and analysis of fire safety and structural fire resistance (see Section 6).
 - (viii) Approach to assessing the level of fire safety and criteria relating to that approach (see Section 6).
 - (ix) Fire engineering assessment (see Section 6).
 - (x) Third-party comments and the designer's response.
- (c) *Tunnel ventilation report* Smoke control is central to fire safety and the ventilation concept and plant design should be done holistically, considering ventilation for pollution and smoke control simultaneously in synthesizing the concepts and details. Consequently, the tunnel ventilation report should describe the design of both ventilation purposes. Ventilation for smoke control should not be separated from ventilation for normal operations.
- (d) *Incident response* The fire safety design will be based on assumptions about the response of the tunnel operators and others to a fire incident. It is important to document the requirements expected of the incident response for the fire safety outcomes to be realized. This will inform the development of the project's incident response plan, normally prepared by the operator.
- (e) *Operations and maintenance* As for incident response, the basis of the fire safety design will place requirements on the project operations and maintenance, which should be developed and documented in consultation with the operator. The document should specify the competencies required of operators.
- (f) *Control system functional description* This document will record all the functionality of the ventilation and other fire safety systems that should be implemented by the control system hardware and software. The ventilation system should cover the modes of operation, the timings expected, the flows and velocities and the sensors and actuators involved in the control. It should be sufficiently detailed for the controls systems designers and programmers to use as a full basis for their work.
- (g) *Fire resistance report* This document will record the fire resistance requirements for each tunnel element. The assessment should take into consideration structural fire resistance and fire separation requirements. Considerations are provision of fire resistance for life safety, firefighter operations, operational continuity and the protection of adjoining property, and assets and infrastructure. The fire resistance levels should be justified by an appropriate level of assessment as agreed by relevant stakeholders.
- (h) *Drawings* The project documentation will necessarily include construction drawings of all equipment in the tunnel. These may be detailed by the fire safety engineer, or by others. To the extent that they are central to the engineering design, they would be included in the fire engineering package. The majority of the drawings, which detail the installation but do not add information to the engineering concepts or key sizing, would normally be packaged separately.
- (i) *Commissioning* The 'commissioning' document will summarize the commissioning tests required by the fire safety engineer to assess whether or not the system is performing as required.

SECTION 4 TRIAL CONCEPT DESIGN (TCD)

The trial concept design (TCD) encompasses a list of fire safety measures that are considered to be appropriate for initial assumptions as to the fire safety measures that may be required for a particular type of tunnel. TCD provides input into the analysis and detailed design. This section provides guidance as to fire safety measures that should be considered for the initial TCD of various types of tunnels. Fire safety measures should be selected such that the performance expectations outlined in Section 5 can be met.

TCD for various tunnel configurations is indicated in Table 4.1, Table 4.2 and Table 4.3 for road, rail and bus tunnels respectively. For each fire safety measure, an assumed performance should be documented.

Tables 4.1 to 4.3 use the following symbols to identify the need of a system:

- ✓ Typically required.
- S Sometimes required.
- N Not typically required.
- X Systems not recommended.

Table 4.4 provides guidance on the selection of appropriate fire resistance time-temperature curves relative to traffic type and tunnel structure.