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Large outdoor fires and the built environment — Global overview of different approaches to standardization

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Large outdoor fires have the potential to negatively impact the built environment.

Examples of such fires are:

— wildland-urban interface (WUI) fires (wildland fires that spread into communities; this type of fire has become a global problem);

  NOTE Once a WUI reaches a community, a large urban fire can develop.

— post-earthquake fires (large urban fires that potentially occur after an earthquake);

— tsunami-generated fires (fires potentially generated from tsunamis);

— volcano-generated fires (fires potentially generated from volcanic activity); and

— fires that occur in informal settlements.

This document provides an overview of approaches to standardization for lessening the destruction on the built environment caused by such fire exposure. Evacuation is not included as there are no known approaches to standardization as the present time.

Large outdoor fires and the built environment — Global overview of different approaches to standardization

1 Scope

This document provides a review of global testing methodologies related to the vulnerabilities of buildings from large outdoor fire exposures. It also provides information on land use management practices. Some of the test methods outlined in this document have been developed in the context of building fires and extrapolated to external fire exposures.

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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
bushfire
unplanned fire in a vegetated area, as opposed to an urban area

Note 1 to entry: Used primarily, but not exclusively, in Australia, New Zealand, and Africa.

Note 2 to entry: It is likely that the term was first used in South Africa and is possibly derived from the Dutch word 'bosch' meaning uncultivated land. In Australia the term was first used in the first half of the 19^{th} century. The term passed into legislation in the first half of the 20^{th} century, first in the Australian Capital Territory (Bushfire Act, 1936), Western Australia (A Bush Fires Act, 1937) and New South Wales (Bush Fires Act, 1949).

Note 3 to entry: Definition adapted from Reference [42].

3.1.2
direct flame contact
flame impinging on building systems and materials

Note 1 to entry: Direct flame contact is one of the three structure ignition pathways, together with firebrands and radiant heat.

Note 2 to entry: The flames can come either from the main wildfire flames, from burning elements and ornamental vegetation surrounding structures, or from adjacent structures.

Note 3 to entry: Definition adapted from Reference [42].

3.1.3
evacuation
dispersal or removal of people from dangerous areas and their arrival at a place of relative safety

Note 1 to entry: Definition taken from Reference [42].

3.1.4
post-earthquake fire
fire which occurs after an earthquake

3.1.5
firebrand
airborne object capable of acting as an ignition source and carried for some distance in an airstream

Note 1 to entry: Firebrands are also sometimes referred to as flying brands or brands.

Note 2 to entry: Firebrands are similar to embers but with a slight distinction: ember refers to any small, hot, carbonaceous particle and when embers have the capability of setting additional fires, they become firebrands.

Note 3 to entry: The aerodynamic properties of firebrands is an important characteristic requiring consideration.

Note 4 to entry: Firebrands or embers can be burning, flaming or smouldering.

Note 5 to entry: Definition adapted from Reference [42].

3.1.7
informal settlement
unplanned settlement or area where housing is not in compliance with current planning and building regulations (unauthorized housing)

[SOURCE: Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997]

3.1.8
large outdoor fire
urban fire, tsunami-generated fire, volcano-generated fire, WUI fire, wildland fire, or informal settlement fire, where the total burnout area is significant

3.1.9
spot fire
fire caused by flying firebrands at a distance from the original fire

3.1.10
tsunami-generated fire
fire caused by tsunami, typically by burning elements contained in the flood waters

3.1.11
urban fire
fire which occurs in an urbanized area

3.1.13
volcano-generated fire
fire caused by volcanic eruption

3.1.14
wildland
land that either has never suffered human intervention or has been allowed to return to its natural state, or that is managed for forestry or ecological purposes

[SOURCE: ISO/TS 19677:2019, 3.2]

3.1.15
wildland fire
fire occurring in peat, forests, scrublands, grasslands or rangelands, either of natural origin or caused by human intervention

Note 1 to entry: Used primarily, but not exclusively, in North America.

[SOURCE: ISO/TS 19677:2019, 3.3, modified — reference to "peat" added and Note 1 to entry added.]

3.1.16
wildland firefighting
suppressive action involving a fire in forests, scrublands, grasslands or rangelands

3.1.17
wildland-urban interface
WUI
area where structures and other human development adjoin or overlap with wildland

[SOURCE: ISO/TS 19677:2019, 3.4]

3.1.18
wildland-urban interface community
WUI community
community where humans and their development meet or intermix with wildland fuel

Note 1 to entry: Definition adapted from Reference [45].

3.1.19
wildland-urban interface fire
WUI fire
wildland fire that has spread into the wildland-urban interface (WUI)

Note 1 to entry: It is also possible for fires to start in the wildland-urban interface (WUI) and spread into the wildland.

3.1.20
wildland-urban interface firefighting
WUI firefighting
suppressive action involving a fire in the wildland-urban interface (WUI) where the action, tactics and equipment used can differ from urban firefighting

4 Ignition scenarios

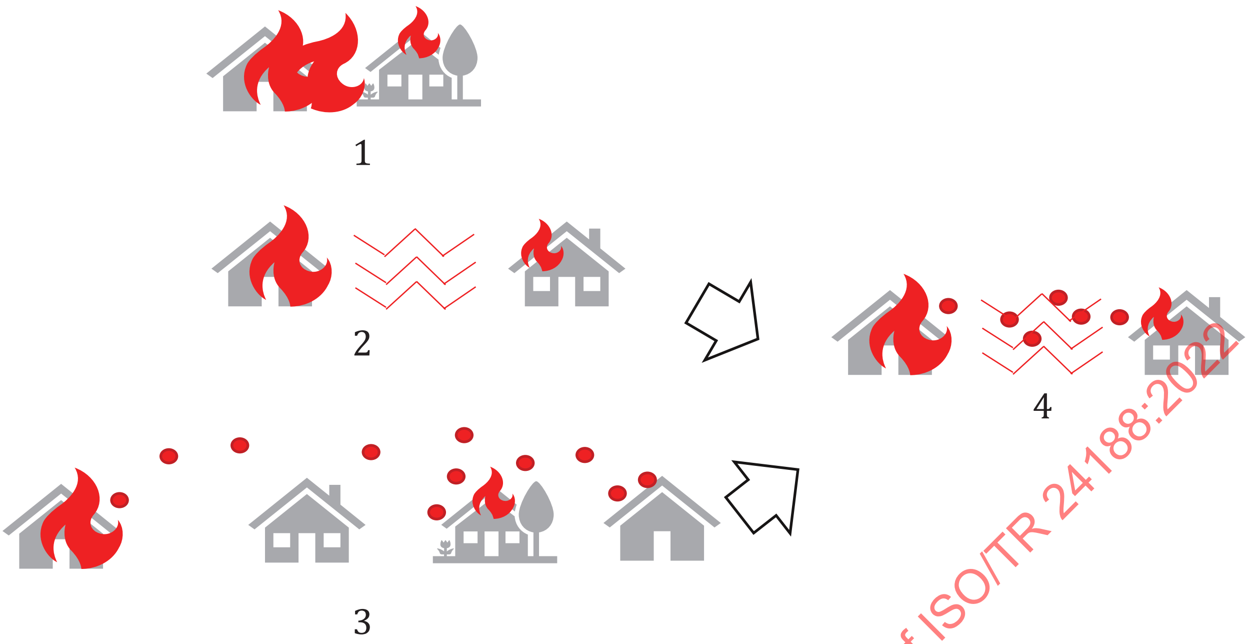
It is important to understand that large outdoor fires involve the interaction of topography, weather, vegetation and structures. Large outdoor fires differ from enclosure fires in several ways; most notably the fire spread processes are not limited to well-defined boundaries, as is the case of traditional building or enclosure fires. Wildland firefighting and WUI firefighting techniques, as well as fire mitigation, also differ in their nature, application and in terms of the distances involved in such situations. At the interface, the interaction of buildings, construction products used, and urbanization rules are also key parameters. Reference [32] gives a good overview of these phenomena. There are three ways in which ignition can occur:

— Direct flame contact — This is the aspect usually managed by fire tests from building regulations.

— Thermal radiation — The probability of ignition depends on the distance and time of exposure. This can occur at distances of tenths of meters.

— Firebrands — The probability of ignition depends on the accumulation. Spot fires can occur at long distances (several hundred meters).

A combination of any of these three points is also possible. Direct flame contact and thermal radiation act in combination as a flame exists and emits thermal radiation. Direct flame contact and firebrands can also act in combination while direct flame contact is likely dominant. Thermal radiation and firebrands can act in combination as shown in Figure 1.



Key

1 direct flame contact

2 thermal radiation

3 firebrands

4 thermal radiation and firebrands

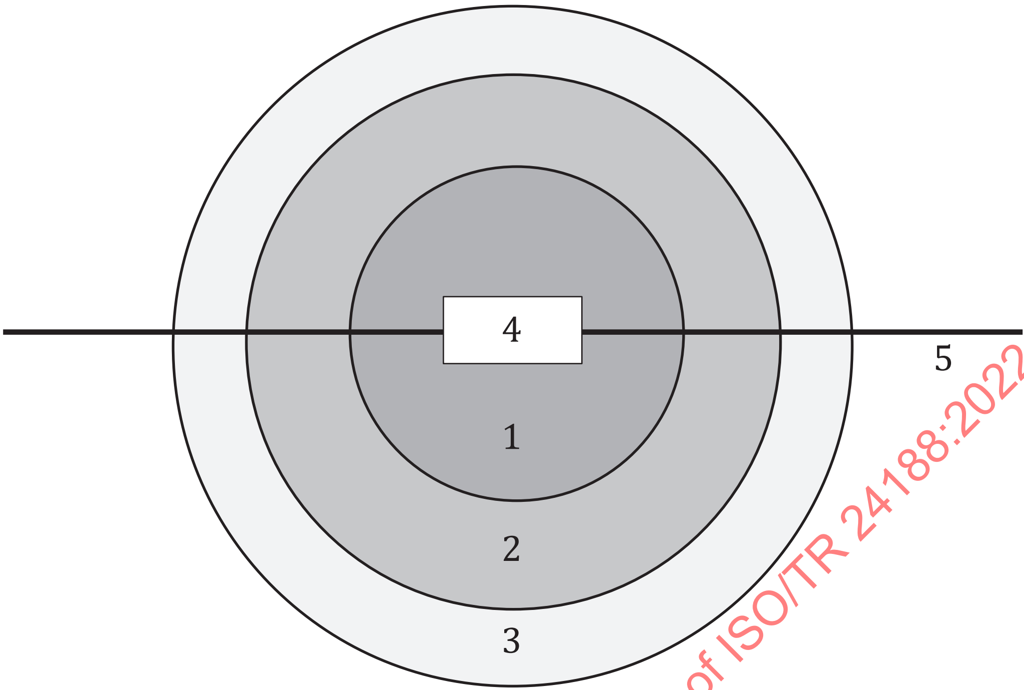
Figure 1 — Fire propagation modes in large outdoor fires (from Reference [32])

5 Regulation principle and strategies

5.1 Japan

The Building Standard Law (BSL) of Japan[25] aims to cover the threat of large urban fires. According to the BSL, there are two major fire tests conducted in Japan in the context of preventing urban fire spread: a roof test and a fire resistance test for exterior walls.

The purpose of the BSL is to safeguard the life, health and property of people by providing minimum standards concerning the site, construction, equipment and use of buildings, and thereby to contribute to the furtherance of the public welfare. To prevent fires from spreading from one building to the next and to minimize the occurrence of urban fires, buildings located in "fire protection zones (FPZs)", "quasi-fire protection zones (QFPZs)", and "cities under Article 22" are required to conform to the BSL. Figure 2 illustrates the basic philosophy of zoning. While no scientific research has yet been carried out to determine the efficacy of these regulations, due at least in part to the regulations, large urban fires are a relatively rare occurrence in Japan today, and are most likely to occur under extreme conditions (in themselves rare), such as those following a major earthquake or in extremely high winds.



Key

1 fire protection zone
2 quasi-fire protection zone
3 city under Article 22
4 station
5 railway

Figure 2 — Zoning concept according to BSL of Japan (from Reference [25])

5.2 California State Building Code (US)

California refers to California Building Code, Title 24, Part 1, Chapter 7A Materials and Construction Methods for Exterior Wildfire Exposure, as well as Chapter 49, Requirements for Wildland-Urban Interface Areas. The following California State Fire Marshal (SFM) Test Standards are described: 12-7A-1,[6] 12-7A-2,[20] 12-7A-3,[18] 12-7A-4,[14] 12-7A-5.[21]

5.3 NFPA 1144, Standard for Reducing Structure Ignition Hazards from Wildland Fire (US)

The National Fire Protection Association (NFPA) published the current edition of NFPA 1144[50] in 2018. This standard can serve as a model for adoption (in total or with amendment) by local building codes. The scope of the document ranges from assessing fire hazard in the structure ignition zone to building design, location and construction. Building components covered include: roof, exterior walls, openings (including windows and doors), chimneys, and accessory structures. Sample qualitative and quantitative hazard assessment methodologies are included in the Annex. In the 2022 revision process this document is to be combined with NFPA 1141[48] and NFPA 1143[49] to form a single document, NFPA 1140.

5.4 International Wildland Urban Interface Code (IWUIC)

The International Code Council (ICC) published the current edition of the IWUIC in 2018.[47] This model ranges in scope from water supply and vehicles access to building construction and fire protection requirements. Appendix sections provide additional information on topics including: vegetation management, fire hazard severity assessment forms and "self-defence mechanisms". Notable is the Ignition-Resistance Construction system described in Chapter 5. The system contains three class levels (Class 1, Class 2 and Class 3) and specifies construction requirements for each. Class 3 requires the nominally most ignition-resistant materials and construction. Several standards and test methods from other organizations including ASTM, NFPA and UL are referenced.

5.5 France

The French standards and regulations are mainly dedicated to design (or certification by standard tests) fire resistance or reaction to fire of construction products against compartment fire or traditional building fires. Nevertheless, standards or performance requirements concern the design of products against external fire. The Eurocode EN-1991-1-2[51] provides a dedicated external fire curve (temperature-time) pertinent for exposure of structural construction elements against external flame coming out from windows of other compartments, but this standard is not used for classification tests. The European Standard EN-1363-2[37] indicates that this curve can be considered for outside fire, but in practice it is also not employed for classification tests.

For wildland-urban interface (WUI) fires, no standards specify the fire exposure explicitly. Instead, one finds two different categories of approaching standard tests are reviewed in detail in the following subclauses:

— tests for some structural elements (roofs and facades essentially) which are ad hoc tests, allowing to test reaction and resistance to fire with ad hoc fire curves and ad hoc acceptance criteria.

— tests for other structural elements which are tests with standard generic fire curves and acceptance criteria.

5.6 Australia

The Australian National Construction Code (NCC) has performance provisions that address buildings that are located in a designated bushfire-prone area (WUI fire-prone area). The NCC has three volumes—the Building Code of Australia is Volume One and Volume Two and the Plumbing Code of Australia is Volume Three.[54] Bushfire areas of the NCC 2019 Volume Two is satisfied if the building is constructed in accordance with either 1) AS 3959[52] or 2) NASH Bushfire Standard — Non-combustible building cavity construction in bushfire areas.[44] AS 3959 contains normative reference to the two standards in the Australian Standard AS 1530.8.1[9] and AS 1530.8.2[8] test standards. The testing standards have been applied to roof, wall and other assembly types. Baker *et al.*[41] provide a comprehensive overview of the regulatory framework of Australia for interested readers.

6 Approach for roofing assemblies

6.1 Japan

Roof tests in Japan are based on ISO 12468-1, with a minor modification of the size of the cribs placed on the surface of roof specimens. Different cribs are used for the roofs located in different zones. For the roof specimens which will be constructed in FPZs and QFPZs, total size of crib is (80 × 80 × 60) mm, which is composed by lumbers, and each configuration is (19 × 19 × 80) mm. On the other hand, for the roof specimens in "Cities under Article 22 of BSL (Building Standard Law)"[25] or "Low-flame-spread roof area", lumber is used, where the size is (40 × 40 × 40) mm, which conforms to the specifications of "Brand B" in ISO 12468-1. This difference on firebrands stems from the assumption that buildings in FPZs and QFPZs are closely adjacent to each other and can therefore produce larger firebrands than fires in "Cities under Article 22 of BSL". Furthermore, the roofs of the buildings located in the FPZ and QFPZ can be less vulnerable to the attacking of flying firebrands in case of urban fire than those in "Cities under Article 22 of BSL". The same criteria are applied when interpreting the results of tests for all specimens, even when different crib configurations are used. There are three major elements in the criteria, namely, 1) fire propagation (not reaching to the edge of specimen), 2) integrity (no flame on the reverse side of the specimen), and 3) defect [no through-hole larger than (10 ×10) mm]. Furthermore, non-combustible roof tiles do not even need to be tested. Recent joint USA/Japan research has shown these methods do not simulate firebrand showers seen in large outdoor fires.[27]

6.2 North America

There are a few existing test methods that measure the ability of a roof assembly to resist the passage of fire into the attic and spread of fire on the roof surface. In Canada, CAN/ULC-S107[10] is used to measure the roof performance, which follows a similar procedure as ASTM E-108[17], UL 790[11] and NFPA 276[12]. During the test the assembly is exposed to flames from a calibrated burner. For combustible roof decks, a series of burning standard brands and an intermittent flame exposure are also required. The roof assemblies are classified based on their effectiveness against fire exposure, flammability/combustibility, and degree of fire protection provided to the roof deck, and propensity to produce flying brands. They provide three classes, Class A, Class B, and Class C. Class A is the most resistant and Class C the least resistant. Recent joint US/Japan research has shown these methods do not simulate firebrand showers seen in large outdoor fires.[27]

6.3 France

CEN/TS 1187[34] is a collection of 4 separate tests, and in France, test 3 is applied. Even if a roof is validated according to test 3, it is not considered valid in the 3 other tests. Details are provided in Annex A.

Test 3 has an ad hoc experimental setup, including firebrands positioned at defined positions on the roof before being flamed, low atmospheric wind conditions (around 3 m/s) possibly propagating the fire to the roof components, and a radiative heating from a radiant panel at about 12,5 kWm^{-2}. The firebrands are composed of 4 pieces of wood assembled together to build a crib of (55 × 55 × 32) mm, pre-conditioned in temperature and relative humidity. This setup has been initially designed not to represent wildfire firebrands, but rather to represent burning pieces of timber or construction wooden items, which have been projected from a neighbouring building fire. A 30 min fire exposure is performed. Classification criteria (A, B, ... roof) are given by the adjacent standard EN 13501-5 :2005+1 :2009.[35] Precise details on this test design, as well as comparison with the other tests, are found in Annex A.

6.4 Australia

AS 1530.8.2[8] is the Australian test standard for WUI exposure. AS 1530.8.2 is for severe fire exposure or direct flame impingement (BAL FZ). During AS 1530.8.2, a representative element of construction or combination of elements is exposed to the standard fire curve. The test duration is 90 min which includes a 30-min exposure to the standard fire and a 60-min monitoring period.

For lower exposure levels, another standard, AS 1530.8.1,[9] is used, which exposes the specimen to a radiant heat, burning firebrands and burning debris. AS 1530.8.1 provides standard test methods to determine the performance when a specimen is exposed to radiant heat, firebrands and burning debris. Exposure to firebrands is simulated by application of a small gas flame and exposure to burning debris is simulated by wood cribs. The radiant heat rapidly rises initially until it reaches a specified maximum radiant heat of either 12.5, 19, 29, or 40 kW/m^2 depending on the severity of exposure. The maximum radiation is maintained for two minutes followed by a gradual decay period. The total radiant heat exposure period is 10 minutes. Overall, the Australian approach is more representative of the WUI exposure with some shortcomings; the main one is the lack of wind during the tests. Radiation exposure is more representative of the approaching wildfire.

A successful testing outcome from either of these testing methods is deemed to be sufficient evidence of conformance to the standard up to and including the particular exposure level to which it was tested. In addition to this testing conformance, the roof exterior is required to be non-combustible, and the NASH standard also requires the roof internals to be non-combustible.

7 Approach for exterior walls and facades

7.1 Japan

Ordinary wall furnaces (3 m × 3 m) are used in Japan for the fire resistance tests following ISO 834-1 standard fire. Regarding the traditional classification system of fire resistance in Japan, there are four different classes: 1) fire-resistive construction, 2) quasi-fire-resistive construction, 3) fire preventive construction, and 4) quasi-fire preventive construction. Among these, especially 3) fire preventive construction, and 4) quasi-fire preventive construction are the performance required for an exterior wall to restrict the spread of a normal fire that starts in the area surrounding a building, for thirty minutes in case of 3), and for twenty minutes in case of 4). Regarding these two classes, only stability and insulation, (not integrity), are counted for evaluating the fire resistance of exterior walls.

For reference, regarding the other two classes, 1) fire-resistive construction, is the performance required for the building parts to prevent a normal fire from causing both the collapse of the building and the spread of fire even after the end of a normal fire, and 2) quasi-fire-resistive construction, is the performance required for the building parts to prevent a normal fire from causing both the collapse of the building and the spread of fire until the end of a normal fire.

Additionally, regarding building façade fire safety in Japan, there is JIS A 1310 "Test method for fire propagation over building façades"[26], which is a screening method for determining the fire propagation of products and constructions of a building façade when exposed to flames ejected from the building opening. The primary aim of JIS A 1310 is to assess the vertical fire propagation over facades, but it can be partially applied for evaluating the potential horizontal fire spreading from the building where façade is burning to its adjacent building, because it is prescribed by JIS A 1310 to install the heat flux meter at two meters horizontally separated from the façade specimen. Additionally, its measured heat flux data can be helpful for fire engineers to technically extrapolate whether the adjacent building could be ignited or not. According to the current Building Standard Law of Japan, JIS A 1310 is not mandatory but voluntary, and used for research and development purposes.

7.2 North America

7.2.1 Fire resistance for exterior walls based on traditional inside-building fire test methods

Standards CAN/ULC S101,[1] ASTM E119,[2] UL 263,[3] and NFPA 251[4] describe the standard method of determining the fire resistance of building components. During fire resistance tests, the assembly is exposed to heat from a furnace whose temperature follows a specific time-temperature curve. The assembly fails if the fire passes through the assembly, or the temperature of the unexposed side rises by a certain amount or if the assembly collapses. Since these tests were developed to represent the fire severity of a compartment fire, they impose a very high temperature (which follows a standard time-temperature curve reaching approximately ~1 100 °C at 2 h) which is not representative of an external transient fire source. In Canada, the National Building Code of Canada (NBCC) imposes a certain fire resistance rating for walls. When fire resistance ratings are required for an exterior wall assembly, the exposure to CAN/ULC-S101 is only required to be assessed from the interior of the building to the outside. The NBCC does not require fire resistance ratings to be determined from the exterior to the interior. Other measures are used to limit the fire hazard posed by materials used on the exterior of buildings.

7.2.2 Exterior walls outdoor fire exposures

Standards SFM 12-7A-1[6] and ASTM E2707[7] utilize a diffusion burner to expose the wall to a short 10-min exposure to a 150 kW fire. The test attempts to simulate a scenario where an indirect exposure of flame impingement happens as a result of ignition of plants, trash, a deck or other combustible materials beside the wall. Unless fire resistance of a longer period is also prescribed in addition to this test, the test does not apply to a scenario where the building is exposed to a large radiation source for a long duration of time, such as the burning of an adjacent building.

7.3 France

Façades are covered by LEPIR2 test (National decree of 10-09-1970).[36] This French specification is currently part of an ongoing work of EU harmonization. The current façade test is a large-scale test performed on façade mock-ups. Its field of application is to all façade systems (including testing of windows). Its setup includes a two-level façade, with fire starting in the lower compartment (600 kg of wood cribs), and openings at the two levels (no glass in the generic setup). A 30 min, fire exposure is performed. Then, requirements regarding fire spread through façades (external surface but also through cavity, facade floor-junction.) need to fulfil rules based on available combustible mass calculations and technical arrangements about installation (C+D rules).

Exterior walls: Even if the norm EN-1363-2[37] was initially designed for the characterization of external flame temperatures of compartment fire, it could be used to design fire curve of “natural” external fire, although link to the thread observed in real wildland fires is questionable. Internal fire curve (EN-1363-1[38]) is used by default to test structural elements in fire resistance (REI criteria). It is based on ISO 834-1, which reflects the fire in compartment context. Some local prescriptions ask for such curve to be applied to a building envelope close to wildland, even if the relation between this standard exposure and the real fire is questionable in terms of intensity and time.

7.4 Australia

AS 1530.8.2[8] is the Australian test standard for WUI exposure. AS 1530.8.2 is for severe fire exposure or direct flame impingement (BAL FZ). In AS 1530.8.2, a representative element of construction or combination of elements is exposed to the standard fire curve. The test duration is 90 min which includes a 30-min exposure to the standard fire and a 60-min monitoring period.

For lower exposure levels, another standard AS 1530.8.1[9] is used, which exposes the specimen to a radiant heat, firebrands and burning debris. AS 1530.8.1 provides standard test methods to determine the performance when a specimen is exposed to radiant heat, firebrands and burning debris. Exposure to firebrands is simulated by application of a small gas flame and exposure to burning debris is simulated by wood cribs. The radiant heat rapidly rises initially until it reaches a specified maximum radiant heat of either 12,5, 19, 29, or 40 kW/m^2 depending on the severity of exposure. The maximum radiation is maintained for two min followed by a gradual decay period. The total radiant heat exposure period is 10 minutes. Overall, the Australian approach is more representative of the WUI exposure with some shortcomings: the main one is the lack of wind during the tests. Radiation exposure is more representative of the approaching wildfire.

A successful testing outcome from either of these testing methods is deemed to be sufficient evidence of conformance to the standard up to and including the particular exposure level to which it was tested. In addition, the NASH standard also requires the whole wall assembly to be non-combustible.

8 Other building elements

8.1 Vents

The US refers to ASTM E2886.[13] While protecting roofs by ignition-resistant materials can protect the combustible materials in the attic, the entry of firebrands through vents or other openings can compromise the effectiveness of the fire protection system. ASTM E2886[13] attempts to measure the performance of vents to resist the entry of firebrands and direct flames. During the firebrand test, a flow of generated firebrands are pulled using a fan to pass through a vent. The firebrand generator consists of a rotating steel mesh tumbler. Burning Class C firebrands are placed inside the rotating tumbler and generated by the agitation of the brands and steel nuts that pass the perimeter steel mesh is transported by the flow of air through the vent. If the vent prevents the ignition of cotton pads which are located at the end, it passes the test. USA/Japan experiments form the scientific basis for this test method, and a detailed comparison was undertaken with ASTM to develop this test method.[28] Flame intrusion is evaluated separately using different test procedures.

8.2 Decks

The standards concerned in North America are SFM 12-7A-4;[14] ASTM E2632;[15] and ASTM E2726.[16]

Combustible decking material during a WUI fire event is a vulnerable section of a building. Since decks are attached to the building, ignition of decks could result in the spread of fire to the building itself. Firebrands from the wildfire could accumulate under or within the crevices of the deck and result in the ignition of the deck. There are several standard test methods for decks. The California building code has adopted SFM 12-7A-4 for this purpose. The test exposes a 60 cm × 60 cm (24 inch × 24 inch) sample of the deck to a either a flame (SFM 12-7A-4A) or a burning brand (SFM 12-7A-4B). Two scenarios are considered: in the first one it is assumed that the accumulation of firebrands has resulted in a fire under the deck, and the second scenario assumes the firebrands are accumulated over the deck. During the deck flame test the deck is exposed to a flame of 80 kW for 3 min, equivalent to 1 kg of paper. The sample fails if there is runaway combustion, structural collapse, or flaming dripping materials. The test procedure requires the sample to be observed for 40 min after the flame exposure.

The ASTM E2632 test method is almost identical to SFM 12-7A-4A. In SFM 12-7A-4B /ASTM 2726, a standard burning brand (standard brand of ASTM E108[17]) is placed over the deck while a fan blows an air flow of approximately 5,4 m/s (12 mph) over the specimen and the sample is observed for 40 min for signs of sustained flaming or falling brands. In all tests, the samples need to be exposed to conditions of accelerated aging or weathering to create a more realistic representation of the actual deck in the test. Recent firebrand shower research has shown these tests are not adequate for wind-driven firebrand exposure.[29-31]

8.3 Eaves

Eaves or similar projections are vulnerable to ignition, namely because heat partially accumulates under the eave and the material used for the construction of eaves cannot be as fire resistant at the roofing and exterior walls. Open eaves are a particularly weak point for entry of flames or firebrands. SFM 12-7A-3[18] or ASTM E2957[19] both expose a 609 mm projection to a flame of 300 kW for 10 min. The sample is then observed for another 30 min to monitor the existence of glowing or flaming on the unexposed side of the specimen.

8.4 Windows

8.4.1 North America

California refers to SFM 12-7A-2.[20] In order to assess the performance of windows exposed to direct flames, SFM 12-7A-2 uses a 150 kW, 100 mm by 1 000 mm diffusion burner under the target window. The specimen is exposed to the flame for 8 min. This test simulates a scenario where a flame is burning a combustible material around the building and under a window.

8.4.2 Australia

For radiation exposure of windows, AS 1530.8.2[8] or AS 1530.8.1[9] can be considered.

9 Additional provisions

9.1 Reaction-to-fire — California

Ignition-resistant material is defined in SFM 12-7A-5.[21]. Any material designated as ignition resistant is required to pass a 30 min ASTM E84 test.[46] ASTM E84 was not developed by the SFM of California but is a legacy standard test method, also known as the Steiner Tunnel test method.

9.2 Reaction-to-fire — France

Reaction-to-fire of construction products according to EN 13501-1[39] is requested for all products listed in the EU Construction Product Directive.[53] For the other elements, such as sun blinds, curtains, etc, M- classification,[40] formerly the French reaction-to-fire provisions, are still applicable; some requirements are prescribed locally in areas subject to possible wildland fire attack.

10 Summary of scenarios and tests

Table 1 summarizes which scenario of fire is modelled by each standard test reviewed in the previous clause, detailed according to three different exposures on buildings: radiative effect, firebrands and direct flame contact.

Table 1 — Summary of test methods

Tested structural element	Country	Method	Radiative effect scenario	Firebrands scenario	Wind effect scenario	Others
Roofs	Japan	ISO 12468-1	No	Cribs placed on roof surface, of different types according to a building protection zone criteria (FPZ, QFPZ, “Low-flame-spread”)	No	—
	USA / Canada	CAN/ULC-S107[10] ASTM E108[17] UL 790[11] NFPA 276[12]	Flames from a calibrated burner	Burning standard brands, Intermittent / cyclic flame exposure test	Yes. The spread of flame test is conducted at a 5,4 m/s (12 mph) wind speed.	
	France	CEN TS 1187[34] (test 3)	Exposure to a radiant panel of 10-12,5 kW/m^2 (includes slope angle effect of the roof) during 30 min	Standard cribs placed on roof surface	In some extent, using a blower: for fire propagation on roof only, not for hot gases	—
	Australia	AS 1530.8.1[9] AS 1530.8.2[8]	4+1 scenarios: - Direct flame impingement, based on interior fire exposure - 4 scenarios of distant flame impingement: radiant panel (or radiation produced from furnace) at exposures of 12,5, 19, 29, or 40 kW/m^2 for 10 min	Burning debris simulated by standard wood cribs placed beside the wall.	No	Specific to wildland fires exposure.
Exterior walls Facades	Japan	ISO 834 Fire resistance	Yes Based on interior fire exposure	No	No	Adapted for long-duration exposure scenarios

Table 1 *(continued)*

Tested structural element	Country	Method	Radiative effect scenario	Firebrands scenario	Wind effect scenario	Others
		JIS A 1310[26] Reaction to fire for façades	Main façade: 1,8 m × 4,1 m, wing façade (optional): 0,9 m × 4,1 m Opening in main façade: 0,9 m × 0,9 m Fire source: propane (approx. 900 kW), test duration: 20 min.	No	No	
	USA / Canada	USA – ASTM E119[2] or UL 263[3] Canada – CAN/ULC-S101[1]	Yes – USA – Fire resistance can be based on interior or exterior fire exposure. Yes – Canada – Fire resistance based on interior fire exposure only	No	No	Internal fire aggression. Adapted for long-duration exposure scenarios
	USA	SFM 12-7A-1[6] ASTM E2707[7]	Yes 10 min exposure to 150 kW fire, reflective of plants, trash, deck, etc. beside the wall	—	—	External fire aggression. Adapted for short-duration exposure scenarios
	France	ISO 834 EN 1363-2[37]	General ignition-resistant material, internal fire. Based on interior fire exposure	No	No	Adapted for long-duration exposure scenarios
			General ignition-resistant material, external fire. Based on exterior fire exposure (reaching 660 °C after 30 min)	No	No	Adapted for long-duration exposure scenarios
		Facades LEPIR2[36]	A two-level facade, with fire starting in the lower compartment (fire of 600 kg of wood cribs), and openings at the two levels (no glass in the generic setup). A 30 min fire exposure is performed	No	No	—
	Australia	AS 1530.8.1[9] AS 1530.8.2[8]	Similar to roofs			

Table 1 *(continued)*

Tested structural element	Country	Method	Radiative effect scenario	Firebrands scenario	Wind effect scenario	Others
Vents	USA	ASTM E2886[13]	No	Firebrand generator (fan)	No	Also contains flame intrusion test using different test procedures
Decks	USA	SFM 12-7A-4[14] ASTM E2632[15] ASTM E2726[16]	Flame of 80 kW for 3 min, for 2 scenarios of deck ignited by firebrands accumulation: under or over the deck	Standard burning brand placed over the deck, with a fan blowing an air flow of approximately 5,4 m/s (12 mph) over the specimen for 40 min	Yes in ASTM E2726 / SFM 12-7A-4 No in ASTM E2632	Adapted for short-duration exposure scenarios
Eaves Eaves and soffits	USA / Canada	SFM 12-7A-3[18] ASTM E2957[19] CAN/ULC-S114,[22] CAN/ULC-S135[23]	Flame of 300 kW for 10 min Regulated based on combustibility of materials	No No	No No	Adapted for short-duration exposure scenarios
Windows	USA	SFM 12-7A-2[20]	150 kW, 100 mm × 1 000 mm diffusion burner under the target window. The specimen is exposed to the flame for 8 min	No	No	—
	Australia	AS 1530.8.1[9] AS 1530.8.2[8]	Similar to exterior walls			
Other provisions – reaction-to-fire	USA	SFM 12-7A-5[21]	2 burners of 88 kW for 10 min	No	No	Ignition-resistant material Steiner Tunnel test method ASTM E84[46]
	France	EN 13501-1[39] M-Classification	Similar to requirements for enclosures	No	No	—

Annex A
(informative)

Precise description of tests for roof performance defined in the European Standard CEN/TS 1187

This annex describes how the test 3 employed in France is precisely defined and how it compares to the three other tests used in other EU countries. CEN/TS 1187 specifies four methods for determining the performance of roofs to external fire exposure. The four test methods assess the performance of roofs under the following conditions:

a) test 1 - with burning firebrands;

b) test 2 - with burning firebrands and wind;

c) test 3 - with burning firebrands, wind and additional radiant heat;

d) test 4 - with two stages incorporating burning brands, wind and additional radiant heat.

The tests assess the spread of fire across the external surface of the roof, the spread of fire within the roof (tests 1, 2 and 3), the penetration of fire (tests 1, 3 and 4) and the production of flaming droplets or debris falling from the underside of the roof or from the exposed surface (tests 1, 3 and 4). Tests 2 and 3 are not applicable to geometrically irregular roofs or to roof-mounted appliances (for example: ventilators and roof lights).

The four tests listed above do not imply any ranking order. They derive from existing national test methods in Europe. Each test stands on its own without the possibility of substituting or exchanging one for another. Depending on the test performed, an interpretation of the test data can be done through the classification standard so that a classification can be attributed to the tested product. A test according to:

— test 1 leads to the classes Broof(t1), Froof(t1),

— test 2 leads to the classes Broof(t2), Froof(t2),

— test 3 leads to the classes Broof(t3), Croof(t3), Droof(t3), Froof(t3),

— test 4 leads to the classes Broof(t4), Croof(t4), Droof(t4), Eroof(t4), Froof(t4),

where the test number is indicated by t1 (test 1), t2 (test 2), t3 (test 3) and t4 (test 4). The type of index which is used depends on the country where a declaration is wanted. As such, France requires a t3 class, the Netherlands and Germany a Broof(t1) and the UK a t4 class while the Scandinavian countries opt rather for a Broof(t2). Several Eastern European countries follow the German example and ask for a Broof(t1).

The test 1 equipment consists of:

— A basket, made from 3 mm diameter mild steel wire forming a mesh of approximately 50 mm × 50 mm. This is an open basket at the top and bottom and has four projecting feet 10 mm long, one at each corner. The outer dimensions of the basket is 300 mm × 300 mm × 200 mm deep. The mass of the basket is 650 ± 50 g.

— Wood wool, consisting of fibres approximately 2 mm wide × 0,2 mm to 0,3 mm thick and manufactured from softwood.

— Balance, used to weigh the wood wool and with a nominal capacity of at least 2 kg and an accuracy of ±1 g.

