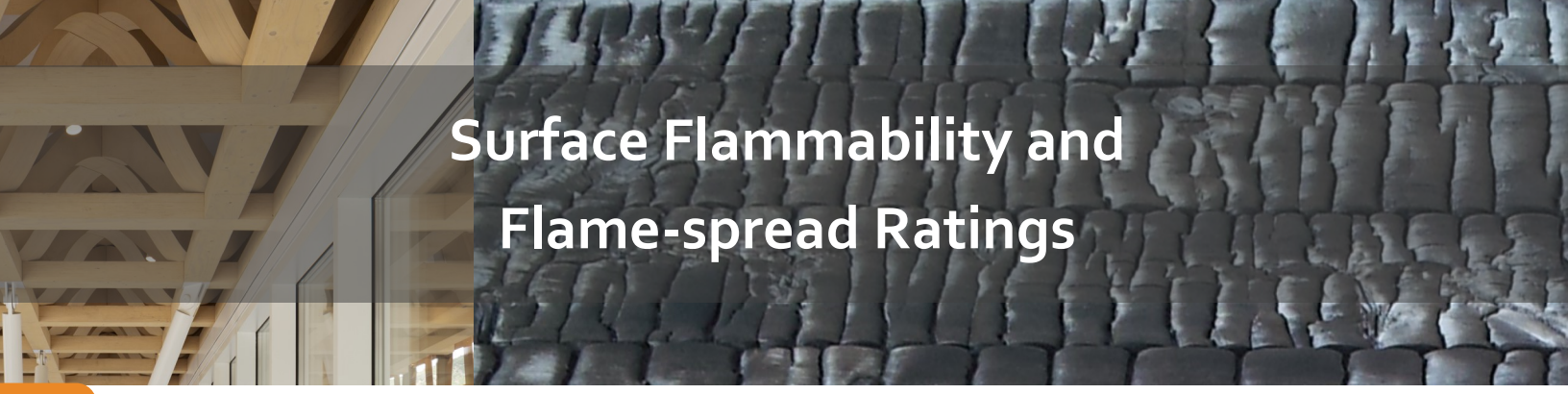
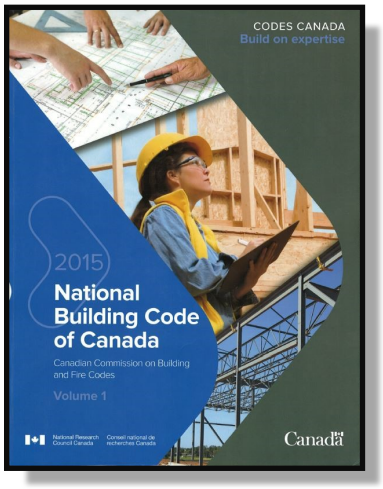


Surface Flammability and Flame-spread Ratings

FACT SHEET
FIRE

Background

The rate at which flame spreads on the exposed interior surfaces or a room or space can have an impact on the rate of fire growth within an area, especially if the materials of the exposed surfaces are highly flammable. Therefore, the *National Building Code of Canada* (NBC)[1] regulates the surface flammability of any material that forms part of the interior surface of walls, ceilings and, in some cases, floors, in buildings. Based on a standard fire-test method, the NBC uses a rating system to quantify surface flammability that allows comparison of one material to another, and the ratings within that system are called flame-spread ratings (FSR).



For some buildings, the smoke generated by materials or products lining some areas of the building when they burn is also regulated by the NBC. Since it may take some additional time for occupants to exit the building, this applies to all unsprinklered high buildings and all elevators or Group B occupancies in high buildings. The FSR and SDC is also regulated for some materials used in ducts and plenums. The smoke produced from a material or product is measured and quantified through another rating system, based on a standard fire-test method — the smoke developed classification (SDC). For most wood products used as interior finishes, both of these properties — the FSR and the SDC — are to be determined in accordance with CAN/ULC-S102, "Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies."[2] For flooring, CAN/ULC-S102.2 "Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Coverings, and Miscellaneous Materials and Assemblies"[3] is to be used when a SDC or FSR is required.

Objectives and Functional Statements Related to Surface Flammability in the NBC

The NBC is an objective-based code, meaning that the objectives of the code are fully defined. The objectives describe, in very broad terms, the overall goals that the NBC's requirements are intended to achieve.

A designer now has the option to follow the acceptable solution provided in Division B of the NBC or they may instead propose an alternative solution. The alternative solution must achieve at least the minimum level of performance provided by the acceptable solution in Division B in the areas defined by the applicable objectives and functional statements.

The functional statements provide more detail than the objectives and describe conditions in the building that help satisfy the objectives.

Each requirement under the prescriptive solutions provided in Division B has been assigned one or more objectives and functional statements. This allows the designer or regulatory official to identify what the objective of the requirement is, which then opens the door for alternative solutions to meet the specific objective.

With respect to surface flammability, the NBC has identified two main sub-objectives that the acceptable solutions are intended to achieve.

OS1: An objective of the NBC is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire.

CAN/ULC-S102 Steiner Tunnel Apparatus

- **OS1.2:** The risks of injury due to fire related to surface flammability are those caused by fire or explosion impacting areas beyond its point of origin.

OP1: An objective of the NBC is to limit the probability that, as a result of its design or construction, the building will be exposed to an unacceptable risk of damage due to fire.

- **OP1.2:** The risks of damage due to fire related to surface flammability are those caused by fire or explosion impacting areas beyond its point of origin.

For each sub-objective, there is one functional statement applied:

- **F02:** The applied functional statement, intended to provide additional guidance to the designer, states "limit the severity and effects of fire or explosions".

More information on the objectives and functional statements in the NBC can be found in the CWC Fire Fact Sheet entitled "Fire Safety and Canadian Building Codes – General Information."

Test Methods

The FSR and SDC of building materials are to be determined on the basis of not less than three (3) tests conducted in conformance with CAN/ULC-S102 or CAN/ULC-S102.2, as required by the type and use of the product.

The standard CAN/ULC-S102 provides a relative assessment of the surface burning characteristics of materials. The test is commonly referred to as the "Steiner tunnel" or just the "tunnel" because of the shape of the test apparatus: it consists of a rectangular duct 7.6 m long, 0.45 m wide and 0.3 m deep. The walls and floor of the tunnel are constructed of refractory brick, except for a row of glazed ports used for viewing. These windows extend the length of the chamber on one side. The tunnel has a noncombustible, full-length airtight lid, which can be removed to position the test specimen sample in the tunnel apparatus.

For most wood-based materials, the test specimen is installed on the ceiling of the tunnel, as required by CAN/ULC-S102. At one end of the tunnel, gas burners produce a flame with a steady heat release that impinges directly on the test specimen. A steady draft of air lightly fans the flames toward the other end of the tunnel. The test duration is 10 minutes, during which the distance traveled by the flame front is observed by a lab technician through the viewing ports and recorded with time. This data is used to calculate the FSR.

The rate and distance of flame spread measured on a specific product or material is evaluated against two products, which serve to calibrate the tunnel apparatus:

- Inorganic reinforced cement board, which is assigned a flame-spread rating of 0; and,
- Red oak, which is assigned an approximate flame-spread rating of 100.*

At the vent end of the tunnel apparatus, a photo-electric device measures the opacity (density) of the smoke. This provides an indication of the amount of smoke released from the burning material. Similar to the calibration of the flame-spread rating, the smoke developed classification is calibrated so that the inorganic reinforced cement board provides a classification of zero and red oak provides a classification of approximately 100.

* While the test standard at one time assigned the red oak calibration deck a flame-spread rating of 100, the standard now specifies that the flame shall reach the end of the red oak deck in 5.5 minutes. This may result in a flame spread slightly higher or lower than 100 based on the rate of flame spread, and the resulting area under the flame spread distance vs. time graph used to calculate flame-spread ratings.

All tested materials are compared to these two reference materials for flame spread and smoke developed values and the average results of the "at least three (3)" tests provide the FSR and the SDC.

The standard CAN/ULC-S102.2 utilizes the same tunnel apparatus as CAN/ULC-S102 with the exception that the burner is turned so that the flame extends down towards the sample, which is placed on the floor of the tunnel rather than the ceiling. For example, wood flooring would be tested to CAN/ULC-S102.2 and is installed on the floor of the tunnel.

Available Flame-spread Rating Information

In many cases, the FSRs and SDCs for materials or products have already been determined by testing, and are available as generic ratings in the NBC, proprietary listings, literature produced by the manufacturer or in other publications.

Generic Flame-spread Ratings in the NBC

Generic FSRs and SDCs for a number of common building materials such as lumber, plywood and gypsum board can be found in Table D-3.1.1.A in Appendix D of the NBC (summarized in Table 1). For several of the categories, because the generic values each cover a range of products (e.g. the category "Lumber" encompasses the 26+ Canadian softwood lumber species in the *Standard Grading Rules for Canadian Lumber*),[4] the FSR and SDC values represent the maximum in the range of test values, but many specific products/materials will have lower FSR and SDC values than their generic values – some significantly lower. (See Table 2.)

Proprietary Listings

Product listings are published by accredited listing/certification organizations and provide test results for specific products produced by a particular manufacturer. As it is the responsibility of the certification organization to ensure that the performance of the listed product continues to represent what was originally tested, they typically require quality control systems to be in place for the manufacture of the products. Examples of organizations in North America that currently offer product listing services for FSRs are listed below:

- Intertek
- QAI
- Underwriters Laboratories of Canada / Underwriters Laboratories

Table 1. Generic flame-spread ratings and smoke developed classification for various materials.

Materials	Applicable Material Standard	Minimum Thickness, mm	FSR/SDC	
			Surface Coating	
			Unfinished	Paint or Varnish not more than 1.3 mm Thick, Cellulosic Wallpaper not more than One Layer[1][2]
Brick, concrete, tile Steel, copper, aluminum Gypsum plaster	None None CSA A82.22-M	None 0.33 None	0/0	25/50
Gypsum wallboard	CAN/CSA-A82.27-M ASTM C 1396/C 1396M	9.5	25/50	25/50
Lumber	None	16	150/300	150/300
Douglas Fir plywood[3] Poplar plywood[3] Plywood with Spruce face veneer[3]	CSA O121 CSA O153-M CSA O151	11	150/100	150/300
Douglas Fir plywood[3]	CSA O121	6	150/100	150/100
Fiberboard low density	CAN/ULC-S706	11	X/100	150/100
Hardboard Type 1 Standard	CAN/CGSB-11.3-M	 9 6	 150/X 150/300	 [4] 150/300
Particleboard	ANSI A208.1	12.7	150/300	[4]
Waferboard, OSB	CSA O437.0	-	[4]	[4]
	CAN/CSA-O325	-	[4]	[4]

[1] Flame-spread ratings and smoke developed classifications for paints and varnish are not applicable to shellac or lacquer.
[2] Flame-spread ratings and smoke developed classifications for paints apply only to alkyd and latex paints.
[3] The flame-spread ratings and smoke developed classifications shown are for those plywoods without a cellulose resin overlay.
[4] Insufficient test information available.

Table 2. CAN/ULC-S102 Flame-Spread Ratings and Smoke Developed Classifications of various wood species.

Lumber, 19 mm thickness			Flame-spread Rating	Smoke Developed Classification	Source / Report No.
Commercial Name(s)		Botanical Name			
Cedar	Eastern White (Northern White)	*Thuja occidentalis*	50	135	T-15321[5]
	Pacific Coast Yellow (Yellow Cypress) (Alaskan)	*Chamaecyparis nootkatensis*	50	90	T-15569[5]
	Western Red	*Thuja plicata*	60	100	T-15041[3]
Fir	Amabilis (Pacific Silver)	*Abies amabilis*	69	58	FSDB[1]
	Balsam	*Abies balsamea*	50	75	T-15568[5]
	Douglas	*Pseudotsuga menziesii*	40	80	T-15322[5]
Hemlock	Eastern	*Tsuga canadensis*	40	110	T-15323[5]
	Western (Pacific Coast)	*Tsuga heterophylla*	75	25	15-002-475(A2)[4]
Larch	Tamarack (Eastern)	*Larix laricina*	35	60	T-15379[5]
Maple (flooring)		-	104	157	FSDB[1]
Oak	Red or White	-	100	100	FSDB[1]
Pine	Eastern White	*Pinus strobus*	85	100	CHM[2]
	Jack	*Pinus banksiana*	55	135	T-15571[5]
	Lodgepole	*Pinus contorta*	60	115	T-15039[3]
	Ponderosa (Yellow)	*Pinus ponderosa*	105-230	-	FSDB[1]
	Red	*Pinus resinosa*	180	70	15-002-475(B2)[4]
	Western White	*Pinus monticola*	75	-	FSDB[1]
Poplar/Aspen (Trembling Aspen, Quaking Aspen)		*Populus tremuloides*	180	55	15-002-475(C2)[4]
Spruce	Eastern Red	*Picea rubens*	65	175	T-15038[3]
	Sitka (Coast Sitka)	*Picea sitchensis*	74	74	FSDB[1]
	White (Western White)	*Picea glauca*	50	70	T-15040[3]

[1] CWC's publication *Fire Safety Design in Buildings* (1996).
[2] CHM Fire Consultants Ltd fire test report, "Revisiting Surface Burning Characteristics of Softwood Lumber" (2015) (average of 12 tests conducted at 4 fire test laboratories).
[3] Tested at Hardwood Plywood Veneer Association (HPVA) (2015).
[4] Tested at EXOVA (2015).
[5] Tested at HPVA – Hardwood Plywood Veneer Association (2017).

Manufacturers' Literature and Publications

Manufacturers often will include flame-spread rating values in the material specifications and/or marketing material for the specific products that they produce either instead of or as well as having a product listing with a listing/certification organization.

In addition to FSR and SDC values by species developed through earlier testing that the Canadian Wood Council has published in *Fire Safety Design in Buildings*[5] and *The Wood Reference Handbook*[6], CWC has more recently completed a multi-year fire research project to re-test a number of Canadian softwood lumber species. Table 2 includes FSRs and SDCs for different Canadian wood species based on both sets of data.

Testing

In some cases, when there is a desire to use a product/material in a building design that has not been tested and does not fall under the generic ratings in the

building code, the designer and/or manufacturer may decide to have the product tested to demonstrate performance. While fire testing of building materials tends to be rather expensive, CAN/ULC-S102 tends to be one of the least expensive standard fire tests. This means that for large projects, justification can often be made to test the product to gain approval for use in that project.

If interested in testing a product, any fire test laboratory that is accredited (e.g. by Standards Council Canada) to test to CAN/ULC-S102 can be contracted. The listing/certification organizations previously listed above were all accredited to perform CAN/ULC-S102 at the time of testing, and there are other independent labs that are accredited.

Code Requirements for Surface Flammability of Interior Finishes

The NBC regulates the surface flame-spread rating of any material that forms part of the interior surface of walls, ceilings, and sometimes floors, of buildings. A summary of the NBC flame spread requirements is provided in Table 3. In many cases the flame-spread rating is limited to a maximum of 150, allowing the use of lumber and many wood panel products as indicated in Tables 1 and 2. In cases where a FSR of 25 or less is required, in a building permitted to be of combustible construction, either wood with a fire-retardant coating or fire-retardant-treated wood can be used, while in buildings required to be of noncombustible construction, only fire-retardant-treated wood is permitted. More information on fire-retardant-treated wood products can be found in the CWC Fire Fact Sheet entitled "Fire-retardant-treated Wood."

Differences between CAN/ULC-S102 and ASTM-E84

While the NBC and each provincial building code recognizes FSRs based on tests conducted in accordance with CAN/ULC-S102, the United States building codes reference the ASTM equivalent standard, ASTM E84, "Standard Test Method for Surface Burning Characteristics of Building Materials".[7] A common question arises when a material tested in accordance with ASTM E84 is to be used in Canada: Is the flame-spread index (FSI) determined in accordance with ASTM E84 equivalent to the FSR determined in accordance with CAN/ULS-S102? In addition to the difference in nomenclature, in order to provide insight into this question it is helpful to look at the primary differences between the two test methods.

The equations in CAN/ULC-S102 used to calculate the FSR, based on the area under the flame travel distance vs. time curve, are different and result in a value that is approximately 10 percent greater than the equations in ASTM-E84 used to calculate the FSI provide, given the same flame travel distance vs. time history.

FSRs determined in accordance with CAN/ULC-S102 must be based on results of not less than three (3) identical test specimens, while ASTM E84 requires only one test to determine the FSI of a material or product. However, when a product has a listing with a listing/certification organization to ASTM E84 for a FSI, the certification organization typically requires three ASTM E84 tests to determine the flame-spread classification (e.g. A, B or C — see Table 4 for the specific range of FSI corresponding to each classification), as part of their quality control assurance. (It also should be noted that the Canadian codes do not use flame-spread classifications of A, B or C.)

Table 4. US flame-spread classification based on FSI.

Class	FSI Range
A	0-25
B	30-75
C	80-200

The tunnels used in the two test methods are approximately the same dimensions. However, in accordance with CAN/ULC-S102, the windows along the side of the furnace are flush with the outside surface, creating pockets along the length of the tunnel that create turbulence in the air flow. In ASTM E84, the windows along the side of the furnace are flush with the inside surface. In order to create turbulence, bricks are placed along the length of the bottom/floor of the furnace along both sides. It is not clear to what degree, if any, this difference in turbulence in the tunnel would affect the rate of flame spread.

Some fire test laboratories are able to run both tests using the same tunnel apparatus by changing the location of windows (flush with inside or outside) and the placement or removal of bricks inside the tunnel.

Table 3. Summary of surface flammability requirements for interior finishes in the NBC.

Description of Regulated Area	NBC Reference	Interior Finish Requirements[1] (FSR — flame-spread rating)
Buildings required to be of noncombustible construction	3.1.5.12.	150 FSR for walls, provided they are not more than 25 mm thick and FSR is homogeneous throughout material[2] 25 FSR for ceilings, provided they are not more than 25 mm thick, and FSR is homogeneous throughout material[2] or material is fire-retardant-treated wood; 10% of ceiling area within a fire compartment may have up to a 150 FSR
Group A, Division 1 occupancies including doors, skylights, glazing and light diffusers and lenses	3.1.13.2.	75 FSR without sprinklers[3] 150 FSR with sprinklers
Group B occupancies	3.1.13.2.	75 FSR without sprinklers[4] 150 FSR with sprinklers
Exits	3.1.13.2.	25 FSR[4][5][6]
Lobbies used for exiting (as described in Sentence 3.4.4.2.(2))	3.1.13.2.	25 FSR[4][5][6]
Covered vehicular passageways, except for roof assemblies of heavy timber construction	3.1.13.2.	25 FSR[4]
Vertical service spaces	3.1.13.2.	25 FSR[4]
Interior finishes not specified elsewhere in table	3.1.13.2.	150 FSR for walls and ceilings
Public corridors, corridors used by the public in an assembly occupancy, and corridors serving classrooms, as well as occupancies in such corridors	3.1.13.6.	75 FSR for walls or 150 FSR on bottom half and 25 FSR on top half, both without sprinklers[4] 150 FSR for walls with sprinklers 25 FSR for ceilings without sprinklers[4] 150 FSR for ceilings with sprinklers
Doors in all occupancies other than Group A, Division 1 and dwelling units	3.1.13.2.	200 FSR
Doors within dwelling unit	3.1.13.2.	FSR not regulated
Bathrooms in residential suites	3.1.13.3.	200 FSR for wall and ceiling finishes
Additional requirements specific to high buildings[7]		
Exit stairways, vestibules to exit stairs and lobbies described in Sentence 3.4.4.2.(2)	3.1.13.7.	FSR 25 on walls, ceilings and floors[8][9]
Corridors not within suites	3.1.13.7.	300 FSR for floors[8][9]
Elevator cars	3.1.13.7.	75 FSR for walls and ceilings 300 FSR for floors
Elevator vestibules	3.1.13.7.	25 FSR for walls and ceilings 300 FSR for floors
Service spaces and service rooms	3.1.13.7.	25 FSR for walls, ceilings and floors
Other locations and elements	3.1.13.7.	No limit on floors

[1] Exposed foam plastics are not permitted on walls or ceilings in combustible construction (Sentence 3.1.4.2.(1)) or noncombustible construction (3.1.5.12.(2) and 3.1.5.12.(3)).

[2] The material must have a flame-spread rating not more than 25 on any exposed surface, or on any surface that would be exposed by cutting through the material in any direction.

[3] Up to 10% of the total wall area and 10% of the total ceiling area of a wall or ceiling finish is permitted to have a FSR not more than 150. Combustible doors, skylights, glazing and light diffusers and lenses shall be considered in the calculation of wall and ceiling areas. (Sentences 3.1.13.2.(4) and (5)).

[4] Up to 10% of the total wall area and 10% of the total ceiling area of a wall or ceiling finish is permitted to have a FSR not more than 150. Combustible doors, skylights, glazing and light diffusers and lenses shall not be considered in the calculation of wall and ceiling areas (Sentences 3.1.13.2.(4) and (5)).

[5] In buildings required to be of noncombustible construction, the FSR must be homogeneous throughout the material excluding doors, heavy timber construction in a sprinklered building and fire-retardant-treated wood (Sentence 3.1.13.8.(1)). Also, the wall and ceiling finishes of an exterior exit passageway that provides the only means of egress from the rooms or suites it serves, including the soffit beneath and the guard on the passageway, must have a flame-spread rating not more than 25, except that a flame-spread rating not more than 150 is permitted for up to 10% of the total wall area and for up to 10% of the total ceiling area (Sentence 3.1.13.10.(1)).

[6] Up to 25% of the total wall area of lobbies described in Sentence 3.4.4.2.(2) is permitted to have a flame-spread rating not more than 150. In the case of Group A, Division 1 occupancies, combustible doors shall not be considered in the calculation of wall areas (Sentences 3.1.13.2.(4) and (5).

[7] Except for a building of Group B major occupancy and elevator cars, the FSR of interior wall, floor and ceiling finishes need not conform to these values, provided the building is sprinklered.

[8] Trim and mill work can be up to 10% of the area of the wall or ceiling on which they occur provided they have less than a 150 FSR and less than a 300 SDC (Sentence 3.1.13.7.(3)).

[9] Doors can be up to 10% of the area of the wall in which they occur provided they have less than a 200 FSR and less than a 300 SDC (Sentence 3.1.13.7.(4)).

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However, the tunnel must be calibrated separately for each standard, which typically results in slight changes to the burner output in order to calibrate to the two different standards.

For more information on ASTM E84, and ASTM E84 test results on wood products, the American Wood Council (AWC) publishes a document titled "Design for Code Acceptance (DCA) 1 - Flame Spread Performance of Wood Products Used for Interior Finish".[8] In addition to recent testing of Canadian softwood lumber species to CAN/ULC-S102 as listed in Table 2, the same species have also been tested to ASTM E84 and the resultant FSIs (and smoke development indices) can be found in DCA 1.

Further differences exist when testing the surface flammability of fire-retardant treated wood. While in Canada CAN/ULC-S102 is used and the test is conducted for the standard duration of 10 minutes, the US codes reference ASTM E84 but require the test to be conducted for an extended duration of 30 minutes. Further details on testing fire-retardant treated wood can be found in the CWC Fire Fact Sheet entitled "Fire-retardant-treated Wood."

FOR MORE INFORMATION

1 *National Building Code of Canada*, 2015 edition, Codes Canada, National Research Council of Canada (2015).

2 CAN/ULC-S102 "Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies," ULC Standards (2010).

3 CAN/ULC-S102.2 Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Coverings, and Miscellaneous Materials and Assemblies," ULC Standards (2010).

4 *Standard Grading Rules For Canadian Lumber*, National Lumber Grades Authority (2014).

5 *Fire Safety Design in Buildings*, Canadian Wood Council (1996).

6 *Wood Reference Handbook*, Canadian Wood Council (2000).

7 ASTM E84 "Standard Test Method for Surface Burning Characteristics of Building Materials," ASTM International (2019).

8 "Design for Code Acceptance (DCA) 1 - Flame Spread Performance of Wood Products Used for Interior Finish," American Wood Council (2018).