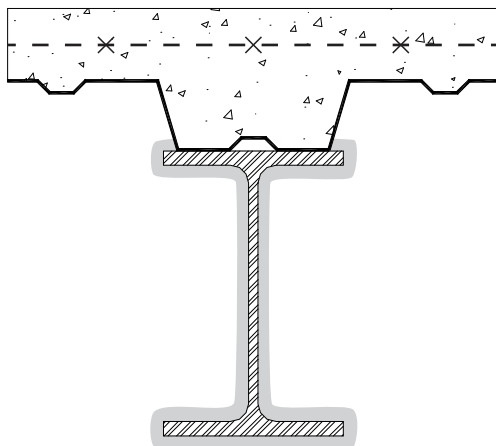


CISC Steel Design Series

Module 1 ***ULC and cUL Spray-Applied*** ***Fire-Rated Designs***



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MODULE 1

ULC AND cUL SPRAY-APPLIED FIRE-RATED DESIGNS

1. Introduction

Where fire-resistance ratings apply, steel-framed building structures in modern-day construction are usually protected by means of spray-applied or membrane protection. Spray-applied fire-resistive materials (SFRM) have traditionally been referred to as cementitious and fibrous but are now categorized as wet-mix and dry-mix products, respectively. This bulletin aims to provide a summary of SFRM fire-rated designs that are valid for use in commercial, institutional, light industrial and residential buildings in Canada, and are free from “load restriction”. They include selected designs listed in the *Underwriter Laboratories of Canada (ULC) Directory* and those listed in the *Underwriter Laboratories Inc. (UL) Directory* as cUL Designs. Many designs that feature intumescent coatings are also available. This subject will soon be covered in another issue of the *CISC Steel Design Series*. In the future, it is anticipated that these ULC and cUL listings will be consolidated into one directory.

2. Selection Criteria

Some ULC and UL listed designs are subjected to “load restrictions”. While the concept of “load restrictions” – related to limit states design versus working stress design – is controversial and may confuse some users, the subject is beyond the scope of this bulletin. **This bulletin focuses on ULC and cUL listed designs that are free from “load restriction”.** The vast majority of these designs were listed recently following a comprehensive series of testing, including those conducted by AISI, AISC and UL as part of their collaborative research studies and series of tests sponsored by SFRM manufacturers.

Other criteria have been established in selecting those listed designs considered suitable for inclusion in this bulletin. The designs chosen for inclusion are those considered to be generally cost-effective, yet having the widest application. Other designs not listed here may be in fact more economical in some of their components but embody inherent restrictions that limit their usefulness in general.

In any category of listed design (e.g. 2-hour floor assemblies), there are often several directly comparable designs. This is not to say that each design is identical. There may be considerable detail differences that should be taken into consideration and which may well favour one design over another in a particular situation. In general, several designs featuring a different manufacturer’s product are applicable for a given rating and configuration, thus permitting alternative equivalent designs to be specified and allowing the marketplace to decide on the most economical.

3. Variations from Selected Designs

Research conducted in North America for over half a century has culminated in design procedures that enable the designer to vary specific details in a listed design. Design considerations and rules for certain common variations are provided in ULC and UL directories. While they agree in principle, they are not identical in all aspects. ULC covers the subject under *Consideration of Variations from Tested Designs* in the ULC Directory, whereas UL provides information supplemental to individual tested designs under *Design Information Section*.

4. Floor Assemblies

In modern-day building construction, steel-framed floors protected with SFRM typically consist of a concrete cover slab on profiled sheet steel deck supported on I-shape steel beams, open-web steel joists (OWSJ), or both. While these beams and joists are sprayed with SFRM, the underside of the steel deck is either sprayed or bare. Numerous floor assemblies are listed as ULC and cUL Designs. A summary of relatively recent listings that comply with the above-mentioned criteria is presented in Tables A to B2. Table A covers floor assemblies that feature sprayed deck designs, while Tables B1 and B2 feature 1-hour and 2-hour unsprayed deck designs. Generally, concrete density is not a design parameter for a sprayed deck design. For a given rating, unsprayed deck designs employ either a thicker concrete cover slab, lower density concrete, or both. In any case, a minimum concrete strength applies.

4.1 Variations in “Minimum” Beam Size

4.1.1 ULC Designs

Virtually all listed ULC Designs specify a *minimum beam size*. The term “minimum” is defined as a minimum M/D ratio, where M = mass per metre length of the steel member (kg/m), and D = heated perimeter, visualized as the inside surface of the protective covering in square metres per metre length of the steel member (m^2/m). Therefore, the SFRM thickness listed for a rating is the minimum thickness to be applied to the *minimum beam size* for that rating. The SFRM thicknesses for other beam sizes may be adjusted according to their M/D ratios. ULC's *Online Directories* (accessible at the time of preparation of this bulletin), under *General Information for Fire-Resistance Ratings*, provide a formula for the *Adjustment of Thickness of Sprayed-Applied Fire-Resistive Material for Beams of Alternate Size*. This equation is based on the relationship of the M/D ratio of the actual beam, compared to the M/D ratio of the tested beam:

$$T_2 = T_1 \times \frac{(M/D)_1 + 38.2}{(M/D)_2 + 38.2}$$

where:

T = Thickness (mm) of spray-applied material

M = Mass of steel beam (kg/m)

D = Heated perimeter of steel section (m), taken to be $2d + 3b$

d = depth of section (m)

b = flange width (m)

Subscript 1 refers to the given (minimum) beam size and protection thickness specified in the design or a configuration in the design, while subscript 2 refers to the desired beam size and required protection thickness.

This equation is applicable only to those designs that have been assigned beam ratings and it can be used to adjust the thickness of sprayed material up or down, provided $(M/D)_2 \geq 23$, and $T_2 \geq 10$ mm.

The following example illustrates the use of this equation.

4.1.1.1 Example

ULC Design No. F906

This Design includes beam ratings, and hence the formula is applicable.

Listed thickness of sprayed material = $T_1 = 13$ mm

Listed *minimum beam size*: W200x42

D of *minimum beam size* = $2d + 3b = 2 \times 0.205 + 3 \times 0.166 = 0.908$ m

$(M/D)_1$ of *minimum beam size* = $(42 \text{ kg/m}) / 0.908 \text{ m} = 46.3 \text{ (kg/m)/m}$

Desired beam size: W150x14

D of desired beam = $2d + 3b = 2 \times 0.150 + 3 \times 0.100 = 0.600$ m

$(M/D)_2$ of desired beam size = $(14 \text{ kg/m}) / 0.600 \text{ m} = 23.3 \text{ (kg/m)/m} > 23 \text{ (kg/m)/m}$

The required protection thickness is given by:

$$T_2 = T_1 \times \frac{(M/D)_1 + 38.2}{(M/D)_2 + 38.2} = 13 \times \frac{46.3 + 38.2}{23.3 + 38.2} = 17.9 \text{ mm} > 10 \text{ mm}$$

In situations where the equation cannot be used (e.g. where the Listed Design does not include beam ratings), beams with larger M/D ratios than the “minimum” may be freely substituted without adjustment of sprayed thickness.

4.1.2 cUL Designs

A formula for thickness adjustment is also available from UL Directories:

$$T_1 = \frac{[(W_2/D_2) + 0.6] T_2}{(W_1/D_1) + 0.6}$$

where:

T = Thickness of spray-applied material, inches

W = Weight of steel beam, lb/ft

D = Heated perimeter of steel section (excluding the top of the top flange which is covered by the deck-slab), inches

Subscript 1 refers to the desired beam size and required protection thickness, while subscript 2 refers to the given (minimum) beam size and protection thickness specified in the individual designs (contrary to the convention in the ULC formula above), and:

$W/D \geq 0.37 \text{ (lb/ft)/in.}$,

$T_1 \geq \frac{3}{8} \text{ in.}$, and

Unrestrained and restrained beam ratings $\geq 1\text{h}$.

4.2 Extension of Tested Designs

Variations in actual construction (compared with tested designs) may be made in accordance with certain criteria established by ULC. These criteria are specified in ULC's Online Directories under *Consideration of Variations from Tested Design*. UL's Directories cover the subject under *Design Information Section* and its sub-sections for beams, joists, concrete, steel floor and form units, etc.

5. Roof Assemblies

The vast majority of steel-framed roofs (for non-combustible construction) do not require a *fire-resistance* rating. However, when a *fire-resistance* rating applies, listed designs that are free from "load restriction" are available. They include: cUL P753 for roof assembly ratings, and cUL S750, S751 and S812 for beam-only ratings.

6. Columns

Steel columns in taller and larger buildings are required to meet fire-resistance ratings. Typically, these columns are protected by means of gypsum wallboard enclosure or with SFRM. Intumescent coatings are also used. This bulletin focuses on SFRM protection. Unlike floor assemblies, individual columns do not serve as fire separations. The fire resistance of a steel column subjected to a given load magnitude can be determined according to steel temperatures and the pre-established relationship between its load capacity and steel temperature. The vast majority of fire-rated designs for steel columns have been established in accordance with the said temperature criteria. The above-mentioned "load restrictions" do not apply to these listed designs for steel columns.

Numerous steel column designs are listed in ULC and cUL Directories. Many feature a fixed protection thickness for a minimum column size, and this protection thickness can be conservatively applied to columns having larger M/D (or W/D) ratios. Other listings permit the protection thickness to be adjusted in accordance with formulas, tables or both. The latter are most common due to their versatility and cost effectiveness. A selection of these popular designs is provided in the tables below:

- Table C1 covers wide-flange columns.
- Table C2 features ULC designs for hollow structural columns, and
- Table C3 includes cUL designs for hollow structural columns, where the formulas are given as functions of the cross-section area to heated perimeter ratio, A/P , instead of W/D .

Since all sides of a column are exposed to heat, all four sides of the column should be included in calculating its heated perimeter (D or P). It should be noted that each listed design provides a unique formula(s) for the determination of protection thickness and a "minimum" column size(s) that are only applicable for that design.

7. Tables

This bulletin provides summary tables to facilitate the selection of rated floor assemblies, roof assemblies and columns. The abbreviated name of the SFRM manufacturer for each listed design is identified as follows:

- A/D Fire: A/D Fire Protection Systems Inc.
- GCP: GCP Applied Technologies Inc.
- Isolatek: Isolatek International
- Southwest: Southwest Fireproofing Products Co.

SPRAYED-DECK FLOOR ASSEMBLIES

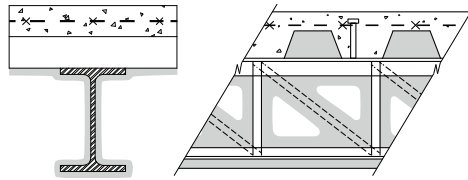


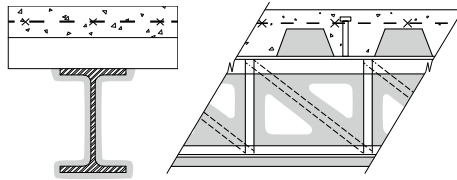
Table A 1-Hour to 2-Hour Ratings¹

Steel Floor Members ²	Concrete	Steel Deck ³	cUL/ULC Design Number	SFRM		Examples of Non-Load-Restricted Beam/Joist Designs and Other Remarks
	Cover Slab Thickness	Depth mm		Manufacturer	Product	
Joists	≥ 65 mm	38/76	ULC F817	A/D Fire	Dry & wet	ULC F906; see notes 4 & 5
Beams, joists	≥ 64 mm	38/51/76	cUL D798	GCP	Wet-mix	cUL N852, ULC N815, N816
Beams, joists	≥ 64 mm	38/51/76	cUL D799	Isolatek	Wet-mix	cUL N743, N792
Beams	≥ 64 mm	38/51/76	cUL E701	Isolatek	Dry-mix	See note 4
Beams	≥ 64 mm	38/51/76	cUL E702	Isolatek	Dry-mix	

Notes:

- ¹ Tabulated designs include provisions for restrained and unrestrained assembly ratings.
- ² May select non-load-restricted beams, joists or both from cUL D700, N700, N800 Series or ULC F900, N700 series (see examples in rightmost column) in accordance with the *Transfer of Components* criteria. Consult the Laboratories and SFRM manufacturers.
- ³ See individual design for applicable steel deck products.
- ⁴ Includes cellular decks and raceway components; consult manufacturers.
- ⁵ For unrestrained assembly rating, restrictions apply.

UNSPRAYED-DECK FLOOR ASSEMBLIES



**Table B1
1-Hour Rating¹**

Steel Floor Members ²	Conc. Cover Slab		Steel Deck Depth ³	cUL/ULC Design Number	SFRM		Examples of Non-Load-Restricted Beam/Joist Designs and Other Remarks
	Density	Thickness mm			Manu- facturer	Product	
Beams	Normal	≥ 83	38 / 51 / 76	ULC F906	A/D Fire	Dry & wet	Unrestrained deck clear span ≤ 2.9 m
Beams, joists		≥ 89	38 / 51 / 76	cUL D985	GCP	Wet-mix	cUL N852, ULC N815, N816
Beams, joists		≥ 89	38 / 51 / 476	cUL D988	Isolatek	Wet-mix Dry-mix	cUL N743, N792 cUL N860
Beams	Low or semi-low	≥ 64	38 / 51 / 76	ULC F906	A/D Fire	Dry & wet	Unrestrained deck clear span ≤ 2.9 m
Beams, joists		≥ 67 ⁴	38 / 51 / 76	cUL D985	GCP	Wet-mix	cUL N852, ULC N815, N816
Beams, joists		≥ 67 ⁴	38 / 51 / 476	cUL D988	Isolatek	Wet-mix Dry-mix	cUL N743, N792 cUL N860

Notes:

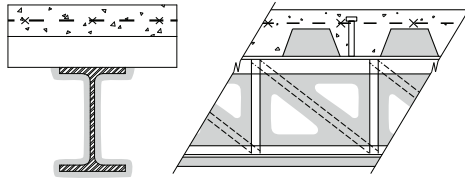
¹ For unrestrained assembly rating, deck span restrictions may apply.

² May select non-load-restricted beams, joists or both from cUL D900, N700, N800 Series or ULC F900, N700 series (see examples in rightmost column) in accordance with the *Transfer of Components* criteria. Consult SFRM manufacturer.

³ See individual design for applicable steel deck products.

⁴ Minimum cover slab thickness for low-density concrete is 64 mm.

UNSPRAYED-DECK FLOOR ASSEMBLIES



**Table B2
2-Hour¹
Restrained Rating**

Steel Floor Members ²	Conc. Cover Slab		Steel Deck Depth ³	cUL/ULC Design Number	SFRM		Examples of Non-Load-Restricted Beam/Joist Designs and Other Remarks
	Density	Thickness mm			Manu- facturer	Product	
Beams	Normal	≥ 114	38/51/76	ULC F906	A/D Fire	Dry & wet	
Beams		≥ 114	38/51/76	cUL D982			See note 4. Also valid for 2h unrestrained assembly rating.
Beams, joists		≥ 114	38/51/76	cUL D985	GCP	Wet-mix	cUL N852, ULC N815, N816
beams, joists		≥ 114	38/51/76	cUL D988	Isolatek	Wet-mix Dry-mix	cUL N743, N792 cUL N860
Beams	Semi-low	≥ 85	38/51/76	ULC F906	A/D Fire	Dry & wet	
Beams, joists		≥ 89	38/51/76	cUL D985	GCP	Wet-mix	cUL N852, ULC N815, N816
Beams, joists		≥ 89	38/51/76	cUL D988	Isolatek	Wet-mix Dry-mix	cUL N743, N792 cUL N860
Beams	Low	≥ 85	38/51/76	ULC F906	A/D Fire	Dry & wet	
Beams		≥ 83	38/51/76	cUL D982			See note 4. Also valid for 2h unrestrained assembly rating.
Beams, joists		≥ 83	38/51/76	cUL D985	GCP	Wet-mix	cUL N852, ULC N815, N816
Beams, joists		≥ 83	38/51/76	cUL D988	Isolatek	Wet-mix Dry-mix	cUL N743, N792 cUL N860

Notes:

¹ For unrestrained assembly rating, deck span restrictions may apply.

² May select non-load-restricted beams, joists or both from cUL D900, N700, N800 Series or ULC F900, N700 series (see examples in rightmost column) in accordance with the *Transfer of Components* criteria. Consult SFRM manufacturer.

³ See individual design for applicable steel deck products.

⁴ May select non-load-restricted beams from cUL D900, N700, N800 Series or ULC F900, N700 series in accordance with the *Transfer of Components* criteria. Consult SFRM manufacturer.

WIDE-FLANGE COLUMNS

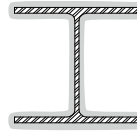


Table C1

Fire Rating	Minimum Column Size			ULC/cUL Design Number	SFRM		Minimum SFRM Thickness, t and Valid Range of t for Formula Use
	Example (Metric)	M/D kg/m	W/D lb/in		Manufacturer	Product	
1 h to 4 h	W150x22	24.4		ULC Z805	A/D Fire	Dry & wet	$t \geq 13$ mm; valid for $t \leq 127$ mm
1 h to 4 h	W150x14		0.33	cUL Y724	GCP	Wet-mix	$t \geq \frac{1}{4}$ in; valid for $t \leq \frac{3}{8}$ in.
1 h to 4 h	W150x14		0.33	cUL Y725	Southwest	Wet-mix	$t \geq \frac{1}{4}$ in; valid for $t \leq \frac{3}{8}$ in.
1 h to 4 h	W150x14		0.33	cUL X764*	Isolatek	Wet-mix	$t \geq 0.35$ in; valid for $t \leq 2\frac{1}{2}$ in. For $t > 2\frac{1}{2}$ in., use Table.
1 h to 4 h	W150x14		0.33	cUL X772	GCP, Southwest	Wet-mix	$t \geq \frac{1}{4}$ in; valid for $t \leq \frac{3}{8}$ in.
1 h to 4 h	W150x14		0.33	cUL X790	Isolatek	Wet-mix	$t \geq \frac{1}{4}$ in; valid for $t \leq 4\frac{1}{2}$ in.
				cUL X795	GCP	Wet-mix	
1 h to 3 h	W200x15		0.30	cUL X829	Isolatek	Dry-mix	$t \geq \frac{3}{8}$ in; if t calculated $> 3\frac{3}{4}$ in., use Table.
4 h			0.55				

* Investigated for exterior use

HOLLOW STRUCTURAL STEEL COLUMNS

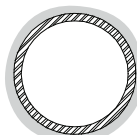


Table C2 ULC Designs

Fire Rating	Column Size and Limits			ULC Design Number	SFRM		SFRM Thickness Determination
	Min. Size (Metric) ³		M/D Range		Manu- facturer	Product	
	Sq. or Rect.	Round	kg/m				
1h to 4h	102x4.8	N/A	36.2 – 187.5	Z806	A/D Fire	Dry & wet	Formula & table
1h to 4h	N/A	114x6.4	36.2 – 87.5	Z807	A/D Fire	Dry & wet	Formula & table

HOLLOW STRUCTURAL STEEL COLUMNS

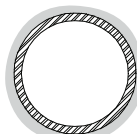


Table C3 cUL Designs

Fire Rating	Column Size and Limits			cUL Design Number	SFRM		SFRM Thickness Determination
	Min. Size (Metric) ³		A/P Range		Manu- facturer	Product	
	Sq. or Rect.	Round	in.				
1h to 4h	76x4.8	76x4.8	0.18 – 0.44 ¹	X768 ²	Isolatek	Wet-mix	Formula & table
¾h to 4h	76x4.8	76x4.8	0.18 – 2.0	X771	GCP, Southwest	Wet-mix	Formula
1h to 4h	76x4.8	76x4.8	0.18 – 0.49 ¹	X790	Isolatek	Wet-mix	Formula & table
1h to 2h	76x4.8	76x4.8	0.18 – 2.0	X827	Isolatek	Dry-mix	Formula & table
3h & 4h	102x4.8	102x6.0					
¾h to 3h 4h	76x4.8	76x4.8	0.18 – 2.0	Y710	GCP	Wet-mix	Formula & table
	76x6.4	76x6.4	0.23 – 2.0				

Notes:

¹ Upper limit for formula use only

² Investigated for exterior use

³ Min. size shown typically reflects the minimum size included in the testing program but is not necessarily a readily available section today. Consult the steel industry or the current CISC Handbook.