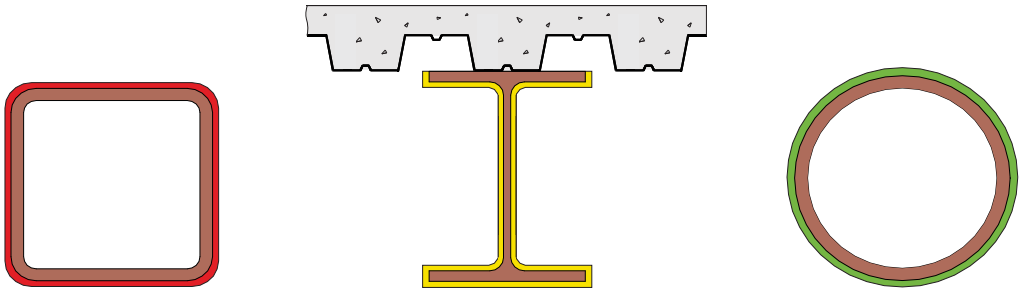
CISC Steel Design Series

Part 6
ULC and cUL Thin-Film Intumescent Coatings Fire-Rated Designs



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PART 6

ULC AND cUL THIN-FILM INTUMESCENT COATINGS FIRE-RATED DESIGNS

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1. Introduction

CISC Steel Design Series Part 6 (SDS-6) provides a summary of fire-rated designs using thin-film intumescent coatings, another fire protection material used to protect steel in a fire and an alternative to spray-applied fire-resistive materials (SFRM) summarized in *CISC Steel Design Series* Part 1 (SDS-1). Intumescent coatings are traditionally more expensive then SFRM but provide many benefits, including lighter weight per surface area protected, durability, aesthetic acceptance for exposed steel, and good adhesion. Architects have increasingly utilized structural steel's potential for architectural expression, leading to the relatively newly defined term in steel design codes and handbooks, namely, *Architecturally Exposed Structural Steel* (AESS). In order to meet building code requirements for the fire safety of the primary steel structure, thin-film intumescent coatings can be used as one of the options to protect AESS and structural steel members. Fire-rated designs using thin-film intumescent coatings are valid for use in commercial, institutional, light industrial and residential buildings in Canada, and the designs tabulated in SDS-6 are free from the "load restriction" issue, i.e., Limit States Design (LSD) vs. Working Stress Design (WSD) as noted in SDS-1. The designs selected for SDS-6 are listed in the *Underwriter Laboratories of Canada* (*ULC*) *Directory* and those listed in the *Underwriter Laboratories Inc.* (*UL*) *Directory* as cUL Designs. In the future, it is anticipated that these ULC and cUL listings will be consolidated into one directory.

Intumescent coatings are paint-like materials applied to structural steel with typical thickness of 1 to 3 mm. When a fire occurs, an intumescent coating changes dramatically from a relatively thin paint-like coating to what may be described as a meringue-like insulating ash that may be 50 to 100 mm or more in thickness. It is the intumescent ash that insulates and protects the steel from fire. It is known as a passive fire protection method, i.e., no mechanical, electrical or human action is necessary to activate its fire protection. Instead, depending on the formulation, a temperature of 100 to 300 °C activates the intumescent chemical reactions.

Intumescence is the property of swelling as a reaction to the application of heat. Intumescent coating products are complex formulations that tend to be proprietary, with their thermal properties rarely reported in the literature. Intumescent coating technology can be traced back to 1938 and, since that time, fatal fires in the USA space program and on Navy aircraft carriers brought an impetus for significant development of intumescent coating technology during the 1970s. During this period, Underwriters Laboratories Inc. listed 2-hour ratings for beams and 1½-hours for columns. Developments in intumescent coating technology since that time have increased ratings to 3-hours, and the number of published test designs for thin-film intumescents has also increased.

2. Selection Criteria

Tables provided in this Steel Design Series provide an inclusive list of fire-rated floor/roof and column designs protected by thin-film intumescent coatings and are without any type of "load restrictions". With assemblies tested after the advent of LSD in material design standards in

Canada, these designs are not affected by the restriction associated with the concept of the "load restrictions" related to LSD versus WSD.

Other designs not listed in the tables, namely ULC F910 (0.89 load restriction) and ULC F916 (0.74 load restriction) are due to a purposefully lower load applied during the fire test and not due to the WSD-LSD issue. In any category of listed design (e.g. 2-hour floor assemblies), there are 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 thin-film intumescent coatings typically consist of a concrete cover slab on profiled sheet steel deck supported on I-shape steel beams. When using thin-film intumescent coatings, only the beam is coated, with the underside of the steel deck left bare. Floor assemblies are listed as ULC and cUL Designs, and Tables A1 and A2 summarize some 1-hour and 2-hour unsprayed deck designs, respectively. 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 for ULC and cUL 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 of 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 of length of the steel member (m^2/m). Therefore, the thin-film intumescent coating thickness listed for a given rating is the minimum thickness to be applied to the *minimum beam size* for that rating.

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 with thin-film

intumescent coatings are not provided, hence structural steel fire protection requires SFRM or membrane protection.

6. Columns

Steel columns are required to meet fire-resistance ratings and are typically protected by means of a gypsum wallboard enclosure or SFRM. Intumescent coatings are also used, and Tables B1 to B4 provide a wider range of ULC and cUL fire-rated designs for wide-flange and hollow structural columns than floor assemblies. 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 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", i.e., WSD vs. LSD do not apply to these listed designs for steel columns.

Many of the fire-rated designs feature a fixed protection thickness for a minimum column size, and this protection thickness can be conservatively applied to columns having larger *M/D* ratios. Other listings permit the protection thickness to be adjusted in accordance with formulas, tables or both, as noted in Tables B1 to B4. Adjustments based on tables are the most common due to their versatility and cost effectiveness.

Since all sides of a column are exposed to heat, all four sides should be included in calculating its heated perimeter (*D*). 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 and columns. The abbreviated name of the thin-film intumescent coatings manufacturer for each listed design is identified as follows:

A/D Fire:	A/D Fire Protection Systems Inc.
Albi:	Albi Protective Coatings
Carboline:	Carboline Co.
International:	International Paint Ltd.
Isolatek:	Isolatek International
PPG:	PPG Protective & Marine Coatings
Sherwin:	Sherwin Williams Co.

UNSPRAYED-DECK FLOOR ASSEMBLIES

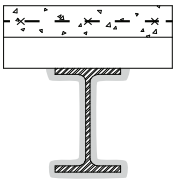


Table A1
1-Hour Rating
Restrained Rating

Steel Floor Members	Concrete Cover Slab		Steel Deck Depth	cUL / ULC Design Number	Manufacturer
	Density	Thickness			
	mm	mm	mm		
Beams	Normal	≥ 83	38 / 51 / 76	ULC F906	A/D Fire
				ULC F920	Isolatek
	Low or semi-low	≥ 64	38 / 51 / 76	ULC F906	A/D Fire
				ULC F920	Isolatek

UNSPRAYED-DECK FLOOR ASSEMBLIES

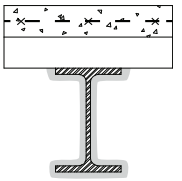


Table A2
2-Hour Rating
Restrained Rating

Steel Floor Members	Concrete Cover Slab		Steel Deck Depth	cUL / ULC Design Number	Manufacturer
	Density	Thickness			
	mm	mm	mm		
Beams	Normal	≥ 114	38 / 51 / 76	ULC F906	A/D Fire
				ULC F912	
			76	cUL D941	
			38 / 51 / 76	cUL D994	Sherwin
			76	cUL N641	A/D Fire
	Low or semi-low	≥ 85	38 / 51 / 76	ULC F906	A/D Fire
		≥ 83	38 / 51 / 76	cUL D994	Sherwin

WIDE-FLANGE COLUMNS

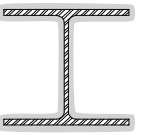


Table B1
ULC Designs

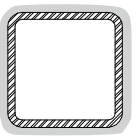
Fire Rating	Minimum Column Size		ULC Design Number	Thin-Film Intumescent Coating		
	Example (Metric)	M / D (kg/m)/m		Manufacturer	Minimum Dry Film Thickness	Thickness Determination
3 h	W310x253	130	Z608	A/D Fire	3.30 mm	---
2 h to 3 h	W250x101	66	Z609		2.67 mm	Table
¾ h to 2 h	Formula	24.4	Z610		0.4 mm	Formula
1½ h to 2 h	W200x46	38	Z612		5.4 mm	Table
2 h	W250x115	74	Z617		3.5 mm	---
1 h to 2 h	W250x73	49	Z624		1.35 mm	Table
¾ h to 1 h	W200x36	34	Z626		2.71 mm	Table
3 h	W250x115	74	Z627		6.83 mm	---
1 h to 4 h	W250x73	49	Z631	Carboline	3.05 mm	Table
1 h to 2½ h	W250x73	49	Z632		3.13 mm	Table
3 h	W360x509	209	Z633		7.37 mm	---
1 h to 3 h	W200x36	34	Z634		1.62 mm	Table
	W200x36	34	Z637		1.62 mm	Table

WIDE-FLANGE COLUMNS

Table B2
cUL Designs

Fire Rating	Minimum Column Size		cUL Design Number	Thin-Film Intumescent Coating		
	Example (Metric)	W / D (lb/ft)/in		Manufacturer	Minimum Dry Film Thickness	Thickness Determination
2 h	W250x73	0.84	X601	Albi	0.5 in	---
1 h	W250x73	0.84	X606		0.25 in	---
1 h to 3 h	W250x73	0.84	X623	PPG	0.19 in	Table & Formula
1 h to 4 h	W200x15	0.33	X649	Isolatek	0.145 in	Table & Formula
1 h to 3 h	W150x24	0.58	X664	International	0.132 in	Table
1 h to 3 h	W150x18	0.44	Y615	Isolatek	0.093 in	Table & Formula
1 h to 2½ h	W150x18	0.45	Y623	Sherwin	0.129 in	Table
¾ h to 3½ h	W150x22	0.43	Y635		0.067 in	Table
1 h to 2 h	W150x24	0.58	Y638	Carboline	0.092 in	Table
1 h to 4 h	W100x19	0.55	Y642		0.107 in	Table
4 h	W360x347	2.53	Y645	Sherwin	9.68 mm	---

HOLLOW STRUCTURAL COLUMNS



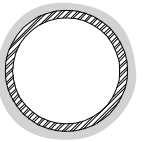
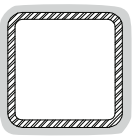


Table B3
ULC Designs

Fire Rating	Column Size and Limits			ULC Design Number	Thin-Film Intumescent Coating	
	Min. Size (Metric)		M/D Range		Manufacturer	Thickness Determination
	Sq. or Rect.	Round	(kg/m)/m			
¾ h to 2 h	127x76x6.4	102x4.8	35.7 – 93.0	Z611	A/D Fire	Table
2 h	254x254x9.5	N/A	70	Z616		
	N/A	114x17*	113.9	Z617		
1 h to 1½ h	102x102x6.4	102x6.4	44.0 – 115.0	Z625	A/D Fire	Table
1½ h to 2 h	254x254x7.9	N/A	59	Z628		
¾ h to 3 h	203x203x13	N/A	90	Z629		
¾ h to 1 h	127x76x6.4	219x6.4	44.0 – 48.0	Z630		
1 h to 3 h	102x102x6.4	N/A	47.0 – 120.0	Z635	Carboline	Table
	102x102x6.4	N/A	47.0 – 120.0	Z638		

* Steel pipe, DN 100 XXS weight class

HOLLOW STRUCTURAL COLUMNS



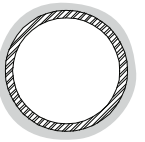


Table B4 cUL Designs

Fire Rating	Column Size and Limits			cUL Design Number	Thin-Film Intumescent Coating	
	Min. Size (Metric)		A/P Range		Manufacturer	Thickness Determination
	Sq. or Rect.	Round	in.			
1 h to 2 h	N/A	114x6.0*	0.20	X615	Albi	Table
1 h to 3 h	89x89x4.8	114x8.0*	0.18 – 0.79	X650	Isolatek	Table
3 h	305x305x25	324x25*	0.92	X651	PPG	Table
1 h to 3 h	N/A	219x6.4	0.24 – 1.26	X662	Carboline	Table
1 h to 3 h	89x89x4.8	102x4.8	0.18 – 1.67	X674	International	Table
1 h to 3 h	89x89x4.8	114x8.0*	0.18 – 0.47	Y614	Isolatek	Table
1 h to 3 h	127x76x6.4	76x6.4	0.23 – 0.47	Y616		Table
1 h to 4 h	203x203x16	N/A	0.58 – 2.44	Y622		Table
1 h to 2 h	51x51x6.4	76x5.5*	0.19 – 0.56	Y624	Sherwin	Table
1 h to 1½ h	178x102x6.4	168x6.4	0.23 – 0.56	Y636		Table
1 h to 2 h	178x178x9.5	N/A	0.35 – 0.60	Y639	Carboline	Table
1 h to 2 h	N/A	51x11*	0.36 – 0.75	Y640		Table
1 h to 4 h	51x51x4.8	N/A	0.17 – 1.67	Y643		Table
1 h to 2 h	N/A	102x4.8	0.18 – 1.60	Y644		Table
2 h	203x203x6.4	219x13	0.23 – 0.61	Y647	Sherwin	Table

* Steel pipe