Australian Institute of Architects | Refuel CPD Provider

Intumescent Coatings for Steel

Dulux Protective Coatings

1 Formal CPD Point

Fire Protection of Steel - Introduction

Steel building design is popular because it is practical, relatively lightweight and versatile

It is a NCC requirement that the steel used in structures remain erect and able to bear load for a certain amount of time

This is achieved through a combination of active and passive fire protection

Fire Protection of Steel - Introduction

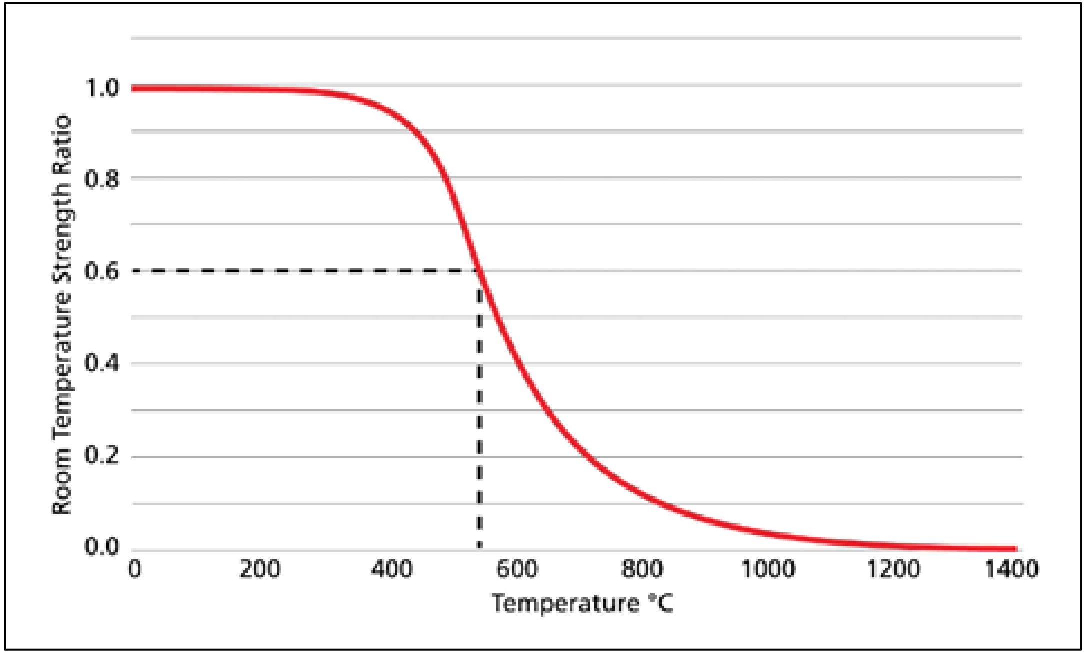


Image: https://www.building.co.uk/cpd/cpd-3-2018-steel-and-fire-protection/5091899.article

In a building fire temperatures rise rapidly and reach high temperatures

At around 550°C steel loses load-bearing capacity and will buckle and collapse and consequently the building itself may collapse

Failure to ensure the adequate fire protection of steel may lead to the collapse of a building in the event of a fire

Fire Protection of Steel - Introduction

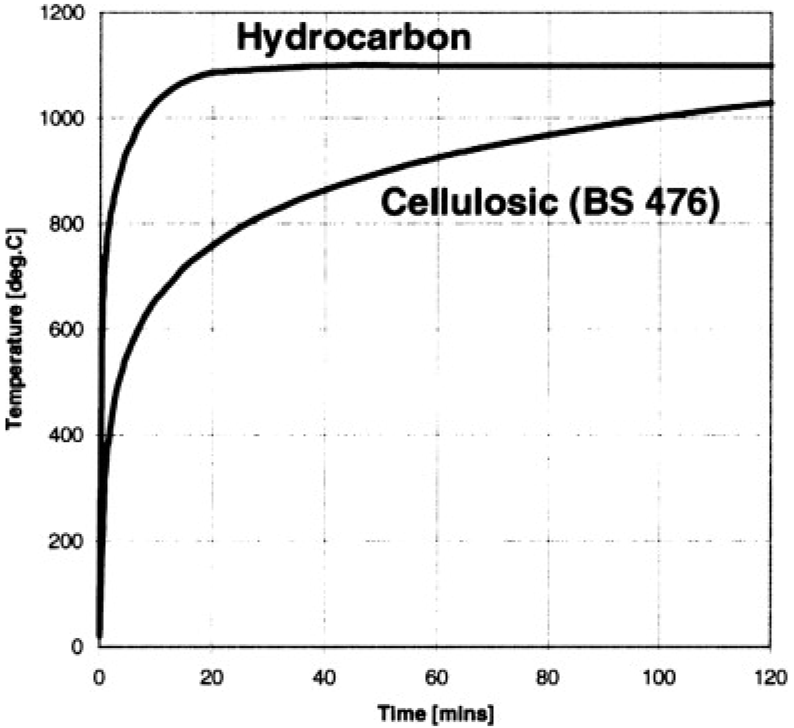


Image: https://www.sciencedirect.com/topics/engineering/fire-resistance-test

Fire temperatures themselves, and how they develop over time depends on the source of the fire

Cellulosic is a fire from a cellulose-based source such as wood, furniture and paper. Hydrocarbon is a fire from a combustible liquid or gas such as oil. Other types of fire sources exist.

This presentation will cover protection against cellulosic fire which is more typical in the commercial building space

Active vs Passive Fire Protection

Active fire protection takes action in order to put out a fire.

Passive fire protection will help prevent a fire from spreading or resist the initial ignition.

The systems can be used throughout the building to alert people inside the building of a fire and safely containing the fire so that people may evacuate and/or try to suppress the fire.

Active Fire Protection
e.g. Roof Sprinkler System
Image source: Wikipedia

Passive Fire Protection of Steel - Vermiculite

- Cementitious and gypsum sprays (**vermiculite**) can be used for passive protection
- Sprayed onto erected steel
- Internal steel only
- Low cost, economical option
- Monolithic coating
- Applied directly to steel
- Needs to be protected from water ingress
- Requires site access with space and free from other trades
- Prone to overspray and requires site cleaning after installation.
- Can be damaged easily

Image & Reference: Vermiculite
https://www.youtube.com/watch?v=NldixkzIAuo

Passive Fire Protection of Steel - Board Claddings

- **Board claddings**, generally made of gypsum can be used for protection
- Installed around steel or timber structures to provide a barrier
- Low cost
- Even finish
- Requires installation of fitting and clips around the steel
- Labour intensive to install, longer time on-site
- Boards can get heavy at greater thicknesses
- Multiple layers of board may be required
- Requires additional space around the protected member

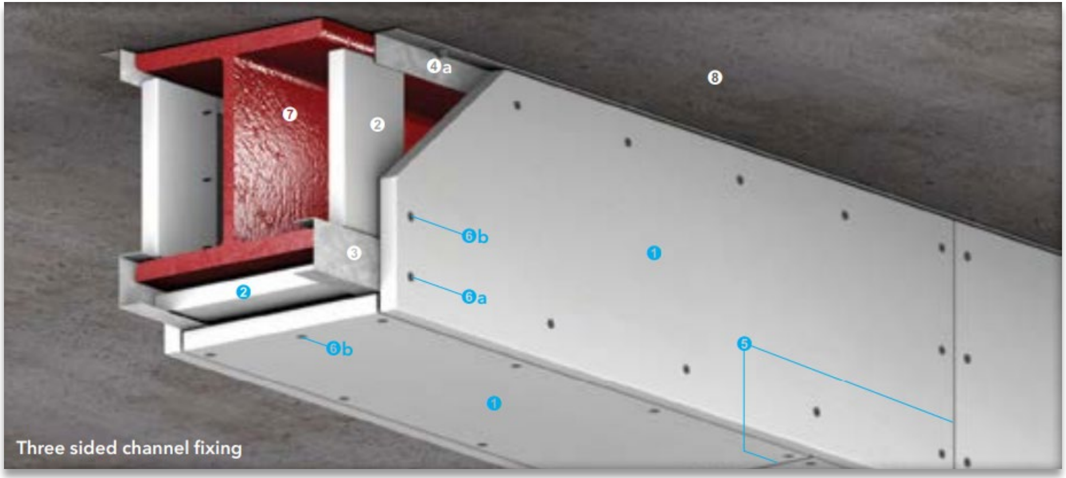


Image & Reference: Promat Boards
https://www.architectureanddesign.com.au

Passive Fire Protection of Steel - Intumescent Coatings

- **Intumescent coatings** can be used for passive protection
- The newest of the three popular fire protection technologies
- A specialty coating that reacts in a fire event
- Various base technologies offering options for different project requirements
- Applied to primed or prepared steel
- Applied on-site or off-site
- Can be used interior- or exterior-exposed scenarios
- Thin film or high build options

Image & Reference: Intumescent Coating
https://www.duluxprotectivecoatings.com.au

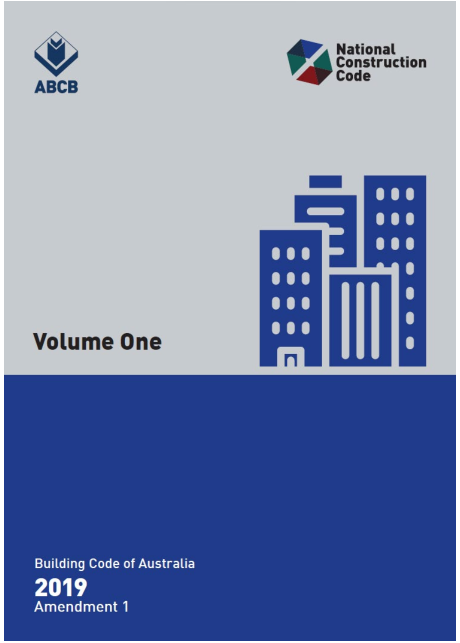
Building Code - FRL Design Requirements

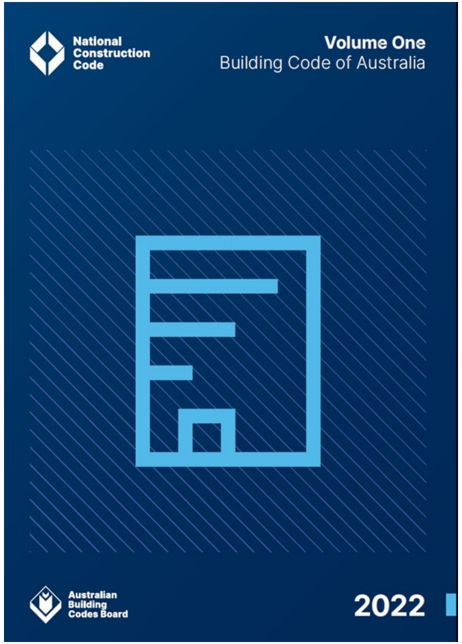
- The requirement is dictated by a measure called **Fire Resistance Level (FRL)**

- The FRL is the time in minutes typically 30, 60, 90 ,120 min

- **The three criteria are**
  1. Structural adequacy
  2. Integrity
  3. Insulation

- The FRL is expressed as 1/2/3





What Constitutes the FRL?

Structural Adequacy — The element must remain in place for the duration of the fire resistance period

Integrity — The element will not develop holes, gaps or fissures which allow the spread of fire, smoke or hot gasses for the duration of the fire resistance period

Insulation — The temperature increase of the unexposed side of the system remains below the set limits for the duration of the fire resistance period

With structural steel, only the Structural Adequacy criterion is required, hence the FRL achieved after the coating system is completed will be 30/-/-, 60/-/-, 90/-/-, or 120/-/-

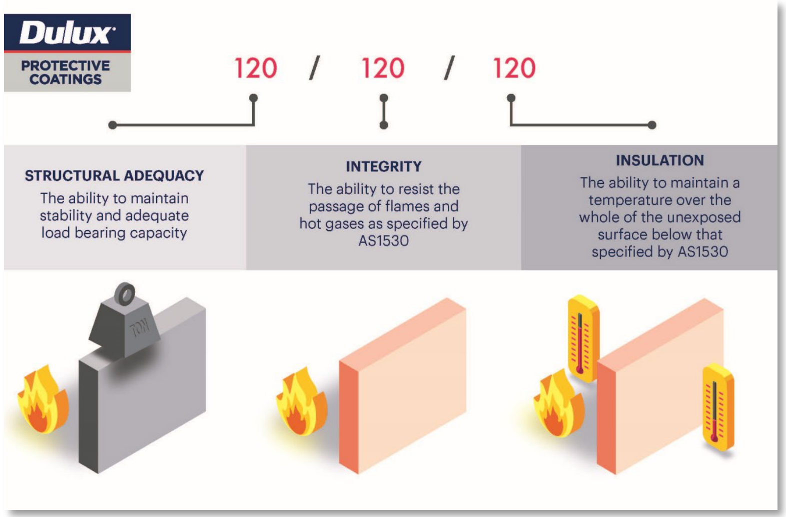


Image Source: Dulux Protective Coatings

Determine the Required Protection

Image & Reference: www.duluxprotectivecoatings.com.au/media/1744/dulux_pc_promat_brochure_v2.pdf

The required protection of a steel member depends on a few variables

- The required fire rating;
  30, 60, 90, 120 minutes
- Steel size
- Exposed sides of the steel;
  1, 2, 3 or 4 sides

Determine the Required Protection - FRL

- Determine required FRL by identifying
  - Building class (top)
  - Type of element (e.g. internal beam)

Table 3 Type A construction: FRL of building elements

Building element	Class of building — FRL: (in minutes) *Structural adequacy/Integrity/Insulation*			
	2, 3 or 4 part	5, 7a or 9	6	7b or 8
EXTERNAL WALL (including any column and other building element incorporated within it) or other external building element, where the distance from any *fire-source feature* to which it is exposed is—				
For *loadbearing* parts—				
less than 1.5 m	90/ 90/ 90	120/120/120	180/180/180	240/240/240
1.5 to less than 3 m	90/ 60/ 60	120/ 90/ 90	180/180/120	240/240/180
3 m or more	90/ 60/ 30	120/ 60/ 30	180/120/ 90	240/180/ 90
For non-*loadbearing* parts—				
less than 1.5 m	–/ 90/ 90	–/120/120	–/180/180	–/240/240
1.5 to less than 3 m	–/ 60/ 60	–/ 90/ 90	–/180/120	–/240/180
3 m or more	–/–/–	–/–/–	–/–/–	–/–/–
EXTERNAL COLUMN not incorporated in an *external wall*—				
For *loadbearing* columns—	90/–/–	120/–/–	180/–/–	240/–/–
For non-*loadbearing* columns—	–/–/–	–/–/–	–/–/–	–/–/–
COMMON WALLS and FIRE WALLS—	90/ 90/ 90	120/120/120	180/180/180	240/240/240
INTERNAL WALLS—				
Fire-resisting lift and stair *shafts*—				
Loadbearing	90/ 90/ 90	120/120/120	180/120/120	240/120/120
Non-*loadbearing*	–/ 90/ 90	–/120/120	–/120/120	–/120/120
Bounding *public corridors*, public lobbies and the like—				
Loadbearing	90/ 90/ 90	120/–/–	180/–/–	240/–/–
Non-*loadbearing*	–/ 60/ 60	–/–/–	–/–/–	–/–/–
Between or bounding *sole-occupancy units*—				
Loadbearing	90/ 90/ 90	120/–/–	180/–/–	240/–/–
Non-*loadbearing*	–/ 60/ 60	–/–/–	–/–/–	–/–/–
Ventilating, pipe, garbage, and like *shafts* not used for the discharge of hot products of combustion—				
Loadbearing	90/ 90/ 90	120/ 90/ 90	180/120/120	240/120/120
Non-*loadbearing*	–/ 90/ 90	–/ 90/ 90	–/120/120	–/120/120
OTHER LOADBEARING INTERNAL WALLS, INTERNAL BEAMS, TRUSSES and COLUMNS—	90/–/–	120/–/–	180/–/–	240/–/–
FLOORS	90/ 90/ 90	120/120/120	180/180/180	240/240/240

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Determine the Required Protection - Steel

- Different steel sections and sizes have **different levels of strength**
- Dependent on the specifications of the steel, the amount of required protection differs
- The outer perimeter will be the surface area exposed to heat – this is called the heated perimeter (Hp)
- Cross sectional area is the amount of steel / volume / mass (A)
- The ratio of Hp/A is an indicator of how fast the steel will increase in temperature
- The heated perimeter may be limited through design by reducing the amount of exposed sides
- i.e. a section of steel butted against concrete on the entirety of one side may only require protection on the three exposed sides

Table 14 Universal Beams – Properties for Assessing Section Capacity

Designation	Yield Stress		Form Factor	About x-axis		About y-axis		Yield Stress		Form Factor	About x-axis		About y-axis		Designation
	Flange	Web		Compactness		Compactness		Flange	Web		Compactness		Compactness		
	f_y	f_y	k_f		Z_{ex}		Z_{ey}	f_y	f_y	k_f		Z_{ex}		Z_{ey}	
	MPa	MPa			10^3mm^3		10^3mm^3	MPa	MPa			10^3mm^3		10^3mm^3	
			300PLUS® *								AS/NZS 3679.1-350				
610 UB 125	280	300	0.950	C	3680	C	515	340	340	0.916	C	3680	C	515	610 UB 125
113	280	300	0.926	C	3290	C	451	340	340	0.891	C	3290	C	451	113
101	300	320	0.888	C	2900	C	386	340	360	0.867	C	2900	C	386	101
530 UB 92.4	300	320	0.928	C	2370	C	342	340	360	0.907	C	2370	C	342	530 UB 92.4
82.0	300	320	0.902	C	2070	C	289	340	360	0880	C	2070	C	289	82.0

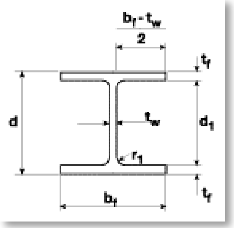


Image & Reference: https://www.libertygfg.com/media/165356/seventh-edition-hot-rolled-and-structural-steel-productsseventh-edition-hot-rolled-and-structural-steel-products.pdf

Passive Fire Protection - Intumescent Coatings

- In a fire, a chemical reaction causes the intumescent coatings to **expand**
- This forms and insulating layer called the ‘char’ which slows the rate that the temperature of the steel rises
- The reaction occurs at approximately 200°C
- The steel maintains integrity for the given length of time (to meet the required FRL timeframe)
- Each intumescent coating is tested rigorously to determine how much coating is required to protect a certain specification of steel for a certain amount of time
- This testing results in a ‘loading table’ that dictates the amount of intumescent required in the form of a **dry film thickness (DFT)**

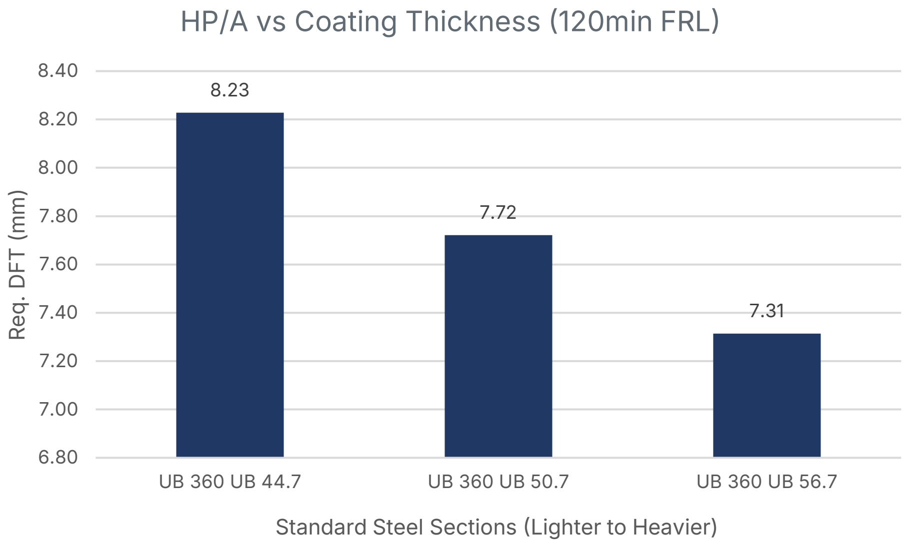
Image & Reference:
https://www.constructionspecifier.com/specifying-intumescent-coating-film-thicknesses/

Passive Fire Protection - Intumescent Coatings

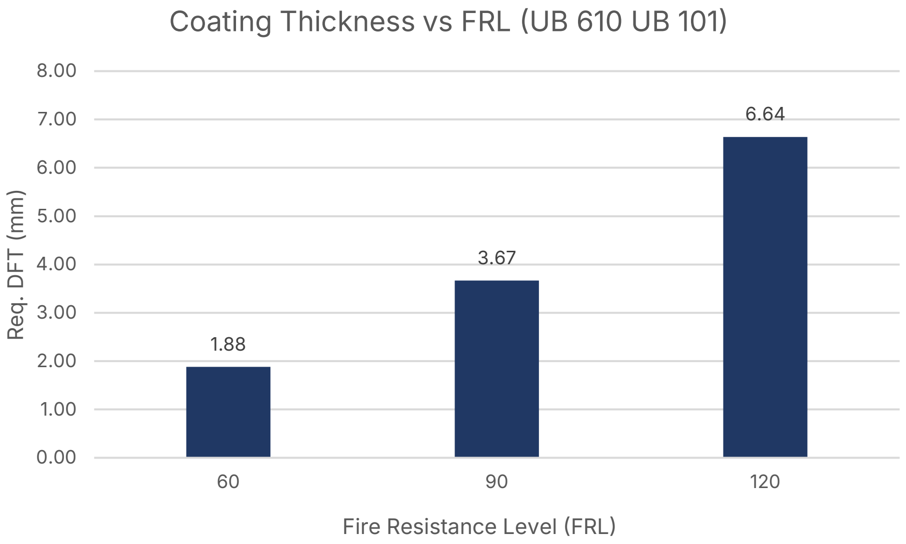
- Dry film thickness (DFT) is **the thickness of a coating as measured above the substrate**
- An intumescent will expand many times the applied DFT
- This can consist of a single layer or multiple layers
- DFT measures the total (not the individual layers)
- DFT is measured on cured protective coatings at ambient temperature
- Example: water based intumescent applied at 1mm coating could expand to approximately 50mm
- Expansion space must be allowed for

Image & Reference:
https://www.constructionspecifier.com/specifying-intumescent-coating-film-thicknesses/

Intumescent Coatings and Required Protection

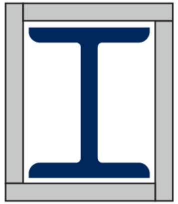


- The measure of HP/A dictates the coating thickness (DFT) to achieve a standard of protection
- The above illustrates the coating thickness required across three beams with different mass at the same FRL

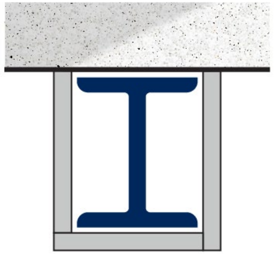


- The FRL also dictates the required coating thickness (DFT)
- The above illustrates the required coating thickness to protect the same steel specification across different FRL

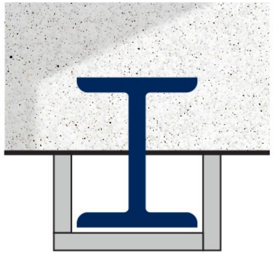
Intumescent Coatings and Required Protection



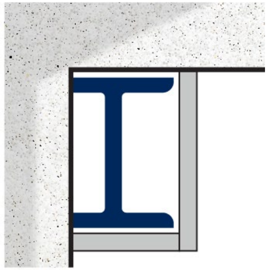
4 sides exposed



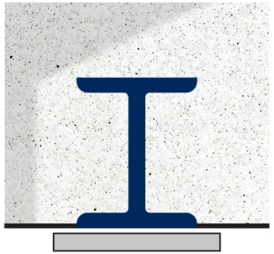
3 sides exposed



3 sides exposed



2 sides exposed

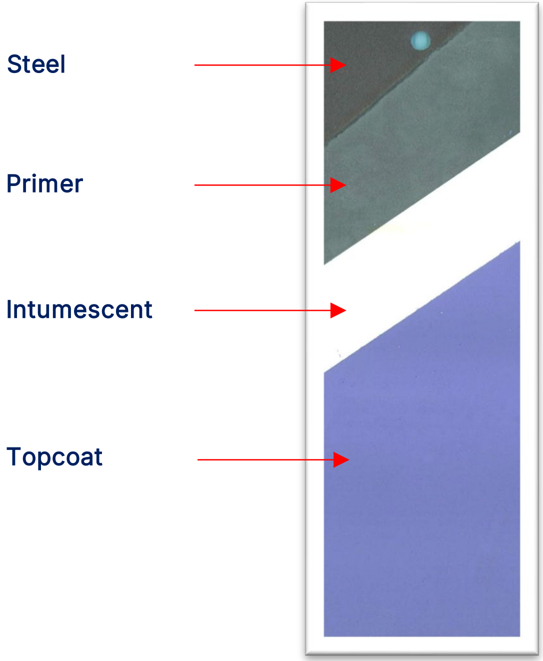


1 side exposed

	Dry Film Thickness (mm)			
	4-sided Steel @ 550°C Limiting Temp.		3-sided Steel @ 620°C Limiting Temp.	
Steel Size	60 Minute FRL	120 Minute FRL	60 Minute FRL	120 Minute FRL
610 UB 101	2.103	7.361	1.531	4.961
610 UB 125	1.778	6.495	1.277	3.999

Intumescent Coating System

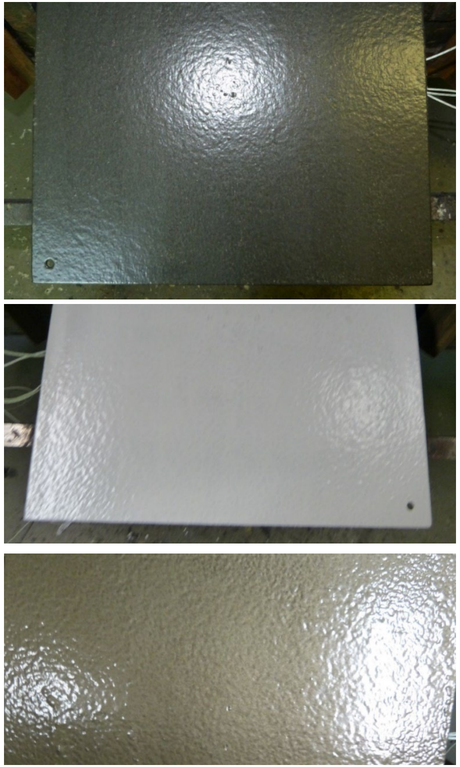
- An intumescent coating forms part of a **coating system**
- Various factors would dictate which other coatings are used with an intumescent
  - Durability / life expectancy
  - Exterior / interior exposure
  - Aesthetic considerations
- The graphic displayed is a typical three-coat system, but many systems can be used depending on the requirements
- New technology with durable intumescent coatings, can eliminate the need for primers and top-coats



Intumescent Coating System Testing

- A system of products must be tested in several ways
- The component coats must **adhere** to each other
- Any overcoat **must not inhibit** the intumescent from expanding
- Panels are compared with a control panel without an overcoat to ensure performance is not inhibited

Before



After

Intumescent Coating System Testing

- Testing the approved systems including primers and topcoats is needed to compile meaningful specifications
- Prohesion testing simulates accelerated severe exposure for 2000 hours
- This testing confirms the **suitability** of the intumescent type and the full system for **different corrosion environments**

How Intumescent Coatings are applied

Image & Reference: www.duluxprotectivecoatings.com.au/media/1744/dulux_pc_promat_brochure_v2.pdf

Intumescent coatings are generally applied in one of two ways:

- **Airless Spray**
  - The most cost-effective application, smooth finish, consistency of coating thickness
- **Brush / roller / trowel**
  - This application is used for small repairs only

Locations where intumescent coatings are applied

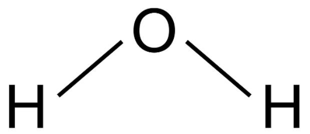
Image & Reference: www.duluxprotectivecoatings.com.au/media/1744/dulux_pc_promat_brochure_v2.pdf

The location of intumescent coating application can generally be defined in two ways:

- **In-situ / On-site**
    - Applied onto erected steel on a construction site
- **Off-site / Yard-applied**
    - Applied onto steel at steel fabrication and/or paint yard
    - The coated steel is then transported to site and erected

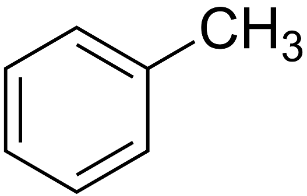
Water-based Intumescent Coatings

- Typically, lower VOC due to water base
- Airless spray application, or repairs via brush and roller
- Good on-site application due to:
  - Spray equipment being suited to on-site application
  - Low VOC
  - Low odour
  - Water used for thinning and equipment cleaning
- Curing is dependent on ambient conditions such as temperature, humidity and air flow
  - To form a film the water base needs to evaporate out
  - Ambient and surface temperature below 10°C are not recommended
- Not suitable for external applications even if overcoated
  - Designed for internal dry conditions



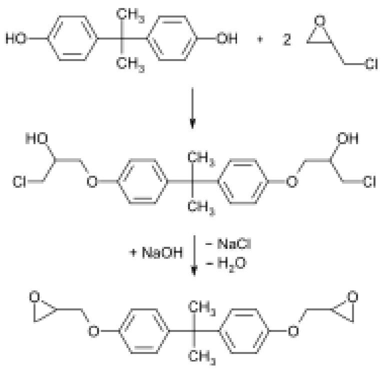
Solvent-based Intumescent Coatings

- Typically, higher VOC due to solvent base
- Airless spray application, or repairs via brush and roller
- Good on-site application due to:
  - Spray equipment being suited to on-site application
  - Quick drying
- Curing is dependent on ambient conditions such as temperature, humidity and air flow
  - To form a film the solvent base needs to evaporate out
  - Ambient and surface temperature below 5°C are not recommended
- Not suitable for exposed external applications even if overcoated
  - Designed for internal dry conditions or non-exposed exterior conditions



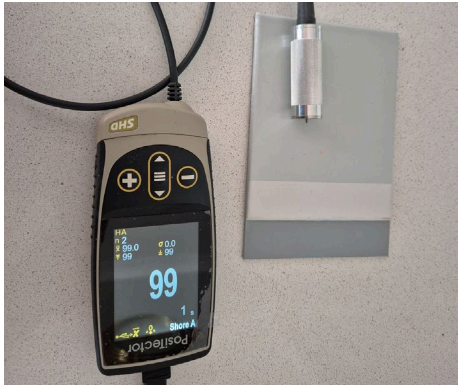
Chemically-Cured Intumescent Coatings

- Different chemical technologies are available e.g. epoxy, methyl methcrylate, STP
- VOC levels can vary – very low or high
- Can be used in a wide variety of project types and locations
- Suited to off-site application:
  - Requires heavy duty single leg airless or plural pump application equipment
  - Once set up and spraying, very cost effective
  - Highly durable, will not be damaged in transit to site
  - Fast drying – high throughput
- Removes the issues of on-site application
  - Access, power, working at heights, VOC emission, difficult structures
- High film build, fewer coats to meet FRL requirements,



Variations in Performance

- Products that share a technology pathway or share ability to deliver 120/-/- are not going to perform the same.
- E.g. an epoxy-based product from one supplier may be different than an epoxy-based product from another supplier.
- When thinking about product selections, you may want to factor in the following considerations.
- Abrasion resistance
- Hardness
- Moisture resistance
- Surface tackiness
- Surface porosity
- Coating film build
- Visual appearance/finish



Example Technology	Shore A Hardness	Shore D Hardness
Water-based	94	44
Epoxy-based	100	58
Methyl Methacrylate	99	56
Hybrid	81	27

Intumescent Coating System - Finishes

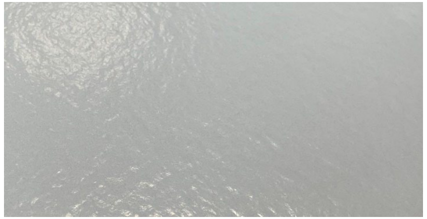
- The aesthetics of the finished intumescent can vary depending on the application method and ease of access.
- The standard of finish required by the client should be included in the coating specification and agreed upon before commencing application.
- To ensure everyone agrees on the visual standard, the use of samples or test patches provided by the applicator is recommended.
- Typically, the type of finishes that can be required are:

a) Basic finish – The coating system itself achieves the required performance for fire and corrosion protection. No requirements for aesthetics;

b) Decorative finish – As for a basic finish, however a satisfactory level of aesthetics is required when viewed from 5m. It will be smooth and even with minor 'orange peel'/ brush marks. No visible runs or sags; or

c) Architectural finish – The coating is to have a very high level of aesthetics (even, smooth, gloss level) when viewed from 2m. This finish level should apply to visible steel only

An example of what might be considered a Basic finish (viewed from 2m)



An example of what might be considered a Decorative finish (viewed from 2m)