Intumescent Coatings for advanced Passive Fire Protection

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Content

- Fire protection by intumescent coatings
- Specification principles
- Development and testing of intumescent products
- Global approvals
- Reliability and durability of intumescent coatings
- Approval of paint systems for fire protection

Introduction to fire & fire protection


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HEMPACORE PASSIVE FIRE PROTECTION

Types of fires

There are 3 main types of fire

Cellulosic fires

- Occur when burning wood, textiles and paper etc.
- Civil construction

Hydrocarbon fires

- Occur when burning oil or gas
- O&G or petrochemical industry

Jet fires

- Occur when burning compressed oil and gas
- O&G or petrochemical industry

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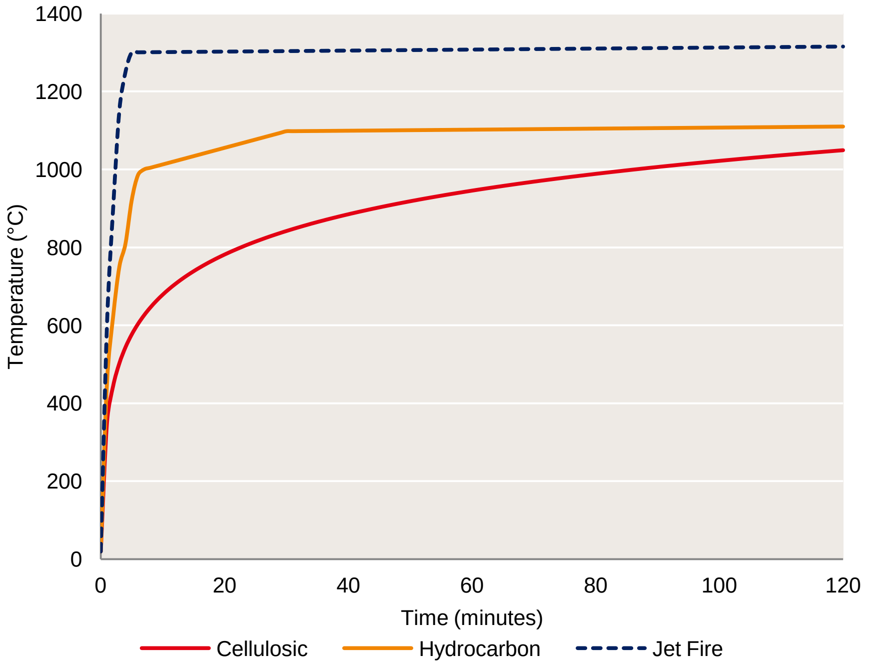
Types of fires

Temperature development of different fire types

- Cellulosic fires
  - ISO 834
  - T = 20 + 345 * log (8 * t + 1)
- Hydrocarbon fires
  - UL1709/BS476
  - $T = 20 + 1080 * (1 – 0.325 * e^{-0,167 * t} – 0.675 * e^{- 2,5 * t})$
- Jet fires
  - ISO 22899
  - Estimated temperature curve



Jet Fire Resistance (ISO22899-1)

- 1500x1500mm 10mm thick steel box with 250mm deep, 20mm thick flange (~500kg)
- Jet impinges on flange 375mm from base
  - 0,3kg/s^{-1} ±0,05 kg propane
  - 260m/s^{-1} velocity at impact area
- First thermocouple to 400°C = FAILURE!
  - Requires Epoxy intumescents


Active and passive fire protection

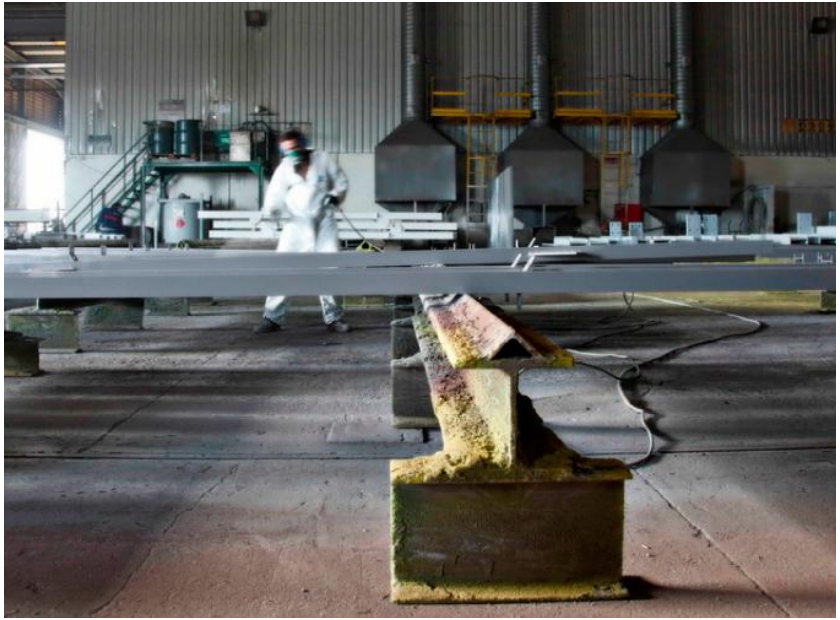
Fire protection of steel can be done with two methods:

Active fire protection

- Methods that require a certain amount of motion and response in order to react to put out the fire
- E.g. sprinkler systems, fire extinguisher systems

Passive fire protection

- Methods that contain, minimize the impact, or slow the spread of the fire
- Contrary to active fire protection, the passive type does not need a response before reacting to the fire
- E.g. intumescent coatings, boards, fire walls, foams



Cellulosic and Hydrocarbon intumescent

Cellulosic Intumescent	Hydrocarbon & Jet Fire Intumescent
Also called **Thin film intumescent**	Also called **Thick film intumescent**
Normally Acrylic based	Normally Epoxy based
Water or solvent based	Solvent free
1 component	2 component
Application by Airless Spray	Application by Plural Component Spray followed by trowelling
White	Grey/Blue/Beige
~0.2–5 mm dry film thickness	~2-40 mm dry film thickness
~40-60x expansion	~4-10x expansion

Normal airless and Plural Component spray equipment

Intumescent coatings for cellulosic fires

Basic concept of intumescent

- Intumescent is a substance which swells as a result of heat exposure, thus increasing in volume, and decreasing in density.
- Expansion is normally around 40-60 times the applied DFT
- Char of low thermal conductivity that reduces heat transfer to substrate
- Thermal insulation of substrate

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Reactions during intumescence

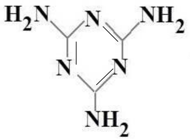
- Softening of binder **(Acrylic resin)**
- **Acid catalyst** (Ammonium polyphosphate)

$$(NH_4PO_3)_n \xrightarrow[-n\,NH_3]{>300^\circ C} (HPO_3)_n \xrightarrow[-\frac{n}{2}\,H_2O]{>550^\circ C} \frac{n}{4}\,P_4O_{10}$$

- **Carbon source** (Pentaerithritol)

$$(HPO_3)_n + C_x(H_2O)_m \longrightarrow \left[\text{"C"}\right]_x + (HPO_3)_n \;\; m\,H_2O$$

- **Blowing agent** (Melamine)



$$\xrightarrow{\Delta} NH_3 \xrightarrow{O_2} N_2 + H_2O$$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Specification of fire protective coatings

Specification principles

Specifications of thickness of intumescent vary depending on the substrate and steel profile

- Factors influencing the specification
  - Type of section (open/ closed/cellular profile)
  - Massivity of the steel (Hp/A)
  - Exposure (i.e. 3 sided, 4 sided exposure)
  - Fire Rating FR (30/ 60/ 90/ 120 min)
  - Critical temperature (CT)

Hp/A concept

High Hp/A value

- Low mass of steel
- Fast heating
- Higher dry film thickness of intumescent

Low Hp/A value

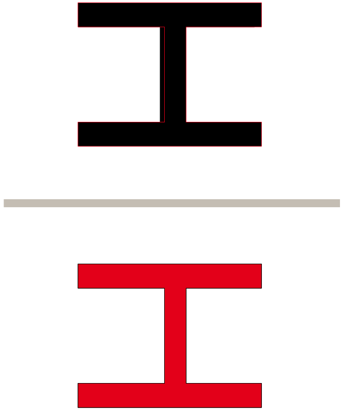
- High mass of steel
- Slow heating
- Lower dry film thickness of intumescent

Hp/A concept

Hp/A factor

- Synonyms: A/V ; Massivity ; Section Factor
- Hp/A is a calculated numerical value [m-1]
- Hp = Heated Perimeter of the steel [m]
- A = Cross-sectional Area of the steel [m2]

Hp/A =

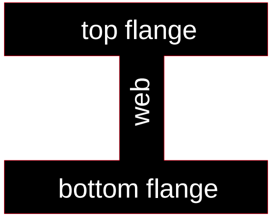


Heated perimeter

cross-sectional area

Hp/A calculation

4 side-exposure

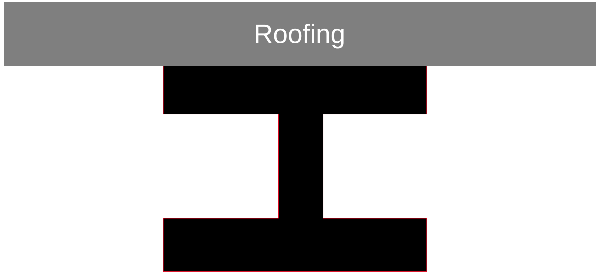


Hp = 1,140 m
A = 53,80 cm^2

Hp = 1,140 m = 1,140 m
A = 53,80 cm^2 = 0,00538 m^2

Hp/A = 212 m^{-1}

3 side-exposure



Hp = 0,940 m
A = 53,80 cm^2

Hp = 0,940 m = 0,940 m
A = 53,80 cm^2 = 0,00538 m^2

Hp/A = 175 m^{-1}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Loading tables – 4 sided Columns

Table 11 Required thickness of HEMPACORE ONE 43600 or HEMPACORE ONE FD 43601 (mm) for a fire resistance period of 120 minutes

Section factor (m^{-1})	Design temperature (°C)								
	350	400	450	500	550	600	650	700	750
70	-	-	3.146	2.248	1.740	1.175	1.094	0.994	0.811
75	-	-	3.243	2.360	1.852	1.277	1.174	1.072	0.883
80	-	-	3.340	2.471	1.965	1.379	1.253	1.149	0.955
85	-	-	3.436	2.583	2.078	1.481	1.333	1.227	1.028
90	-	-	3.533	2.694	2.190	1.583	1.413	1.304	1.100
95	-	-	3.630	2.806	2.303	1.685	1.493	1.382	1.172
100	-	-	3.727	2.917	2.416	1.787	1.572	1.459	1.244
105	-	-	3.823	3.029	2.525	1.889	1.652	1.537	1.316
110	-	-	3.955	3.140	2.632	1.992	1.732	1.614	1.389
115	-	-	4.100	3.251	2.740	2.094	1.812	1.692	1.461
120	-	-	4.245	3.363	2.847	2.196	1.891	1.769	1.533
125	-	-	4.390	3.474	2.955	2.298	1.971	1.847	1.605
130	-	-	4.535	3.586	3.062	2.400	2.051	1.924	1.678
135	-	-	4.680	3.697	[illegible]	[illegible]	[illegible]	.002	1.750
140	-	-	4.825	3.809	[illegible]	[illegible]	[illegible]	.079	1.822
145	-	-	4.971	3.940	[illegible]	[illegible]	[illegible]	.157	1.894
150	-	-	5.116	4.082	3.492	2.873	2.370	2.234	1.966
155	-	-	5.261	4.224	3.599	2.994	2.449	2.312	2.039

R90 (550ºC): 1.360 mm

Hempel's R&D Fire Protection

Focussed investment to support Hempel's growth plans

- Increasing legislation in fire protection
- Intumescent coatings are essential part of the protection system
- In the past, Hempel has had licensing agreements with other manufacturers
- The development of our own products is part of the growth strategy in Industrial protection
- State-of-the art facilities
- Highly qualified experts

HEMPEL IR&D Centre in Polinya, Barcelona

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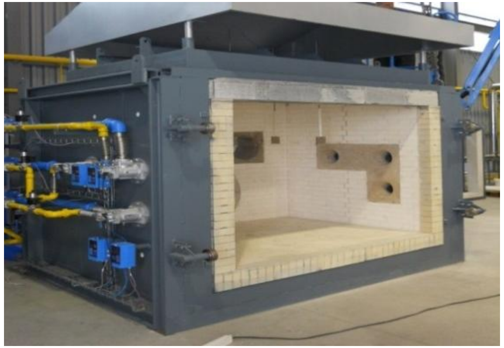
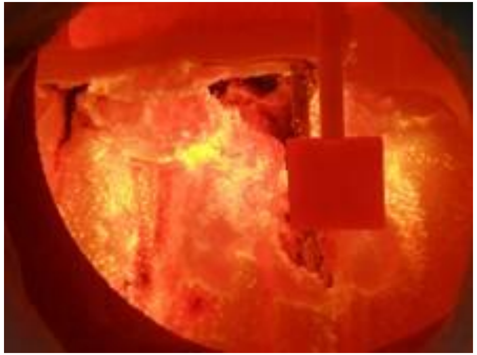
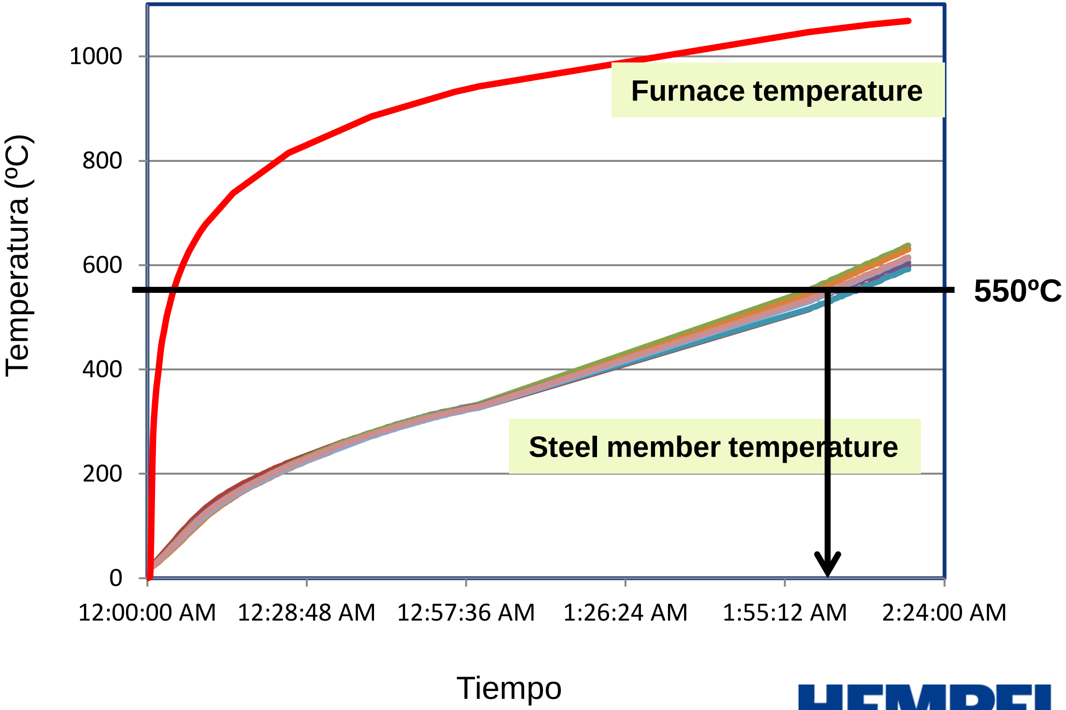
New R&D Laboratory for Fire Protection




Standardized testing for fire resistance



Internal testing

External testing

Screening tests in small-scale furnaces

- Plates 30x20 cm
- Formulation adjustment

Indicative tests in medium scale furnaces

- Sections 1 meter
- DFT range
- Massivity range

Official fire tests at third party institute

- According to international standards

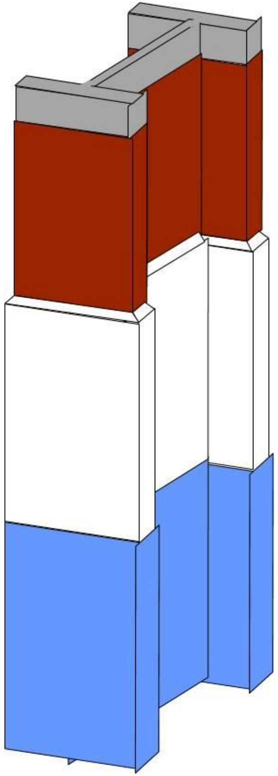
Global approvals for cellulosic products

▪ BS 476-21	Middle East, UK, APAC
▪ EN 13381-8	Europe
▪ UL 263	America, Middle East
▪ GB 14907	China
▪ GOST 53295	Rusia
▪ AS1530.4	Australia

- Other
  - Singapore BS8202
  - Korea – KS1227

Specification of Intumescent coating systems

Fire protection coating system



Primer
- Adhesion to substrate in cold state
- Anticorrosion protection
- Stickability of intumescent char formed during fire exposure

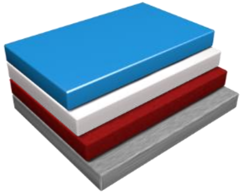
Intumescent
- Provides thermal insulation in fire exposure
- Contribution to anticorrosion by barrier effect

Top-coat
- Aesthetic function
- Sealer function to prevent early degradation and inactivation of intumescent layer
- Weathering resistance to end-use conditions

Typical intumescent coating systems

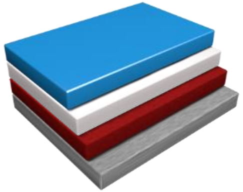
Medium/High corrosion category - Exterior areas up to C4 (ISO12944)

Epoxy primer with Zinc phosphate	1 x 100µm	HEMPADUR 15570
Intumescent Coating	1 x acc spec.	HEMPACORE ONE 43600
Polyuretane topcoat	1 x 100µm	HEMPATHANE 55610



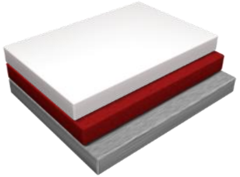
Low/Medium corrosion category – Interior/exterior areas up to C3 (ISO12944)

Epoxy primer with Zinc phosphate	1 x 80µm	HEMPADUR 15570
Intumescent Coating	1 x acc spec.	HEMPACORE ONE 43600
Acrylic Topcoat	1 x 50µm	HEMPATEX ENAMEL 56360



Very low corrosion category - Interior areas up to C2 – indoor (ISO12944)

Epoxy primer with Zinc phosphate	1 x 80µm	HEMPADUR 15570
Intumescent Coating	1 x acc spec.	HEMPACORE ONE 43600



Extension of Assessment report to systems

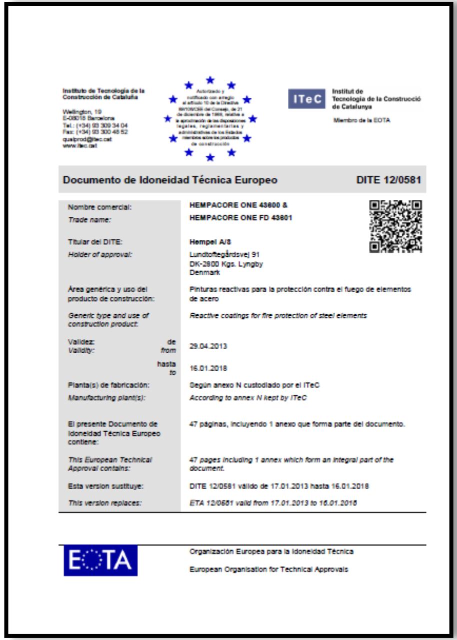
- Classification of Resistance to Fire by Third party evaluation – FR 30, 60, 90, 120 minutes
  - EN, BS, UL standards
  - Fire testing of 1 paint system: primer/intumescent with or without topcoat

  - BS8202
  - ETAG18-2 – European Technical Approval Guideline – EOTA (since year 2008)
  - Work in progress to new standard prEN16623

ETA – European Technical Assessment and CE marking

- According to ETAG018 Part 2 – Technical Guideline
- Issued by Notified Body – member of EOTA

- Fitness for end-use:
  - Resistance to fire (EN13381-8) – Loading tables
  - Reaction to fire (EN13501-1) – Smoke generation and flame spread
  - Primer compatibility - Substrates
  - Durability of systems in weathering exposure conditions
  - Slow heating exposure
  - Identification (fingerprint) of primers and topcoats



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Miembro de la EOTA

Documento de Idoneidad Técnica Europeo **DITE 12/0581**

Nombre comercial: *Trade name:*	**HEMPACORE ONE 43600 & HEMPACORE ONE FD 43601**
Titular del DITE: *Holder of approval:*	**Hempel A/S** Lundtoftegårdsvej 91 DK-2800 Kgs. Lyngby Denmark
Área genérica y uso del producto de construcción:	Pinturas reactivas para la protección contra el fuego de elementos de acero
Generic type and use of construction product:	*Reactive coatings for fire protection of steel elements*
Validez: de *Validity: from*	29.04.2013
hasta *to*	16.01.2018
Planta(s) de fabricación:	Según anexo N custodiado por el ITeC
Manufacturing plant(s):	*According to annex N kept by ITeC*
El presente Documento de Idoneidad Técnica Europeo contiene:	47 páginas, incluyendo 1 anexo que forma parte del documento.
This European Technical Approval contains:	*47 pages including 1 annex which form an integral part of the document.*
Esta version sustituye:	DITE 12/0581 válido de 17.01.2013 hasta 16.01.2018
This version replaces:	*ETA 12/0581 valid from 17.01.2013 to 16.01.2018*

EOTA

Organización Europea para la Idoneidad Técnica

European Organisation for Technical Approvals

CE

CERTIFICADO DE CONFORMIDAD CE

1220-CPD-1320

Hempacore One 43600

Pinturas reactivas para la protección contra el fuego de elementos de acero

Fabricado por
HEMPEL A/S

En la factoria de
PINTURAS HEMPEL SAU

DITE 12/0581

Barcelona, 15 de febrero de 2013

ITeC Institut de Tecnologia de la Construcció de Catalunya

Anton M. Checa Torres
Director General del ITeC

Para conocer la vigencia de este certificado consulte la página web de ITeC: www.itec.es / www.itec.cat

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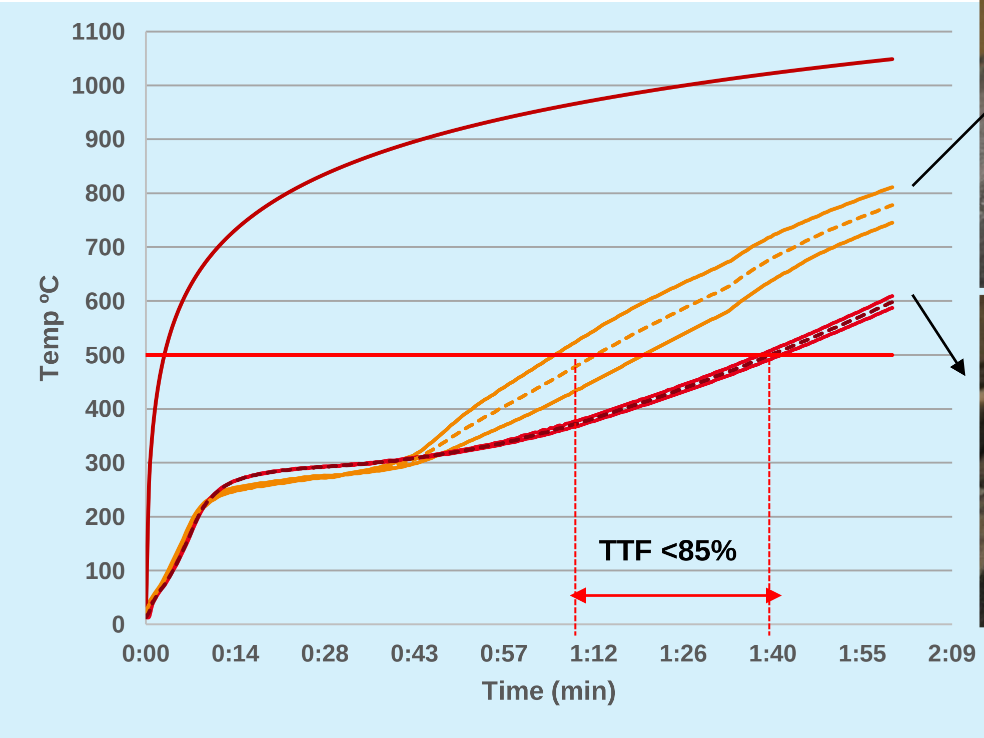
Guidelines for compatibility testing of primers only in Europe - ETAG18-2

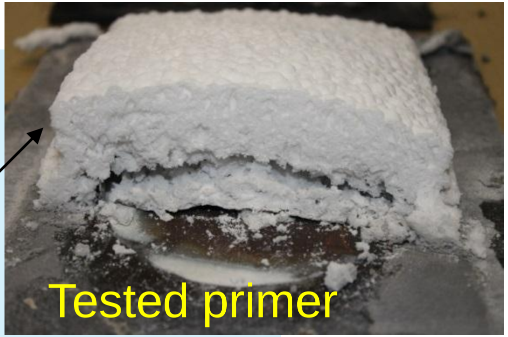
- Only 1 primer from each primer family is subjected to testing (separate for each intumescent product)

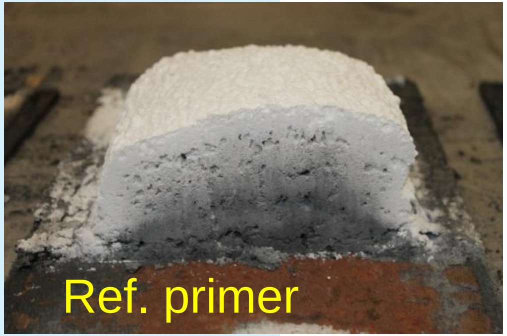
Generic Primer Type	Maximum Approved Tested Thick-ness + (%)
Acrylic	50
Short/medium oil alkyd	50
Two component epoxy	50
Zinc rich epoxy (containing about 80% by mass of metallic zinc powder)	50
zinc silicate	50

- Substrates other than carbon steel must be tested with relevant primer
- Aim is to prove similar protection time than ref. primer used in initial type testing
- Fire tests at external lab on 2 panels per primer – 1000 microns DFT intumescent
- Multi-coat primer systems of more than one primer or more than one coat of the same primer shall be tested as one primer system
- A primer on top of a temporary blast primer (pre-construction) is not considered a multi-coat system

Compatibility testing of primers – ETAG18-2







Additional internal testing of primers

Good stickability steel-primer and primer-intumescent

Bad stickability: lack of adhesion steel-primer causing char detachment

Exposure conditions – topcoat approval

- Intumescent coatings are sensitive to humidity
- Topcoat act as sealer to prevent moisture penetration and ensure long-life
- Testing in different end-use conditions is necessary

- ETAG describes the following environmental conditions:

Exposure	
Type X	Exterior
Type Y	Semi exposed
Type Z1	Interior high humidity
Type Z2	Interior

Increased reliability & durability

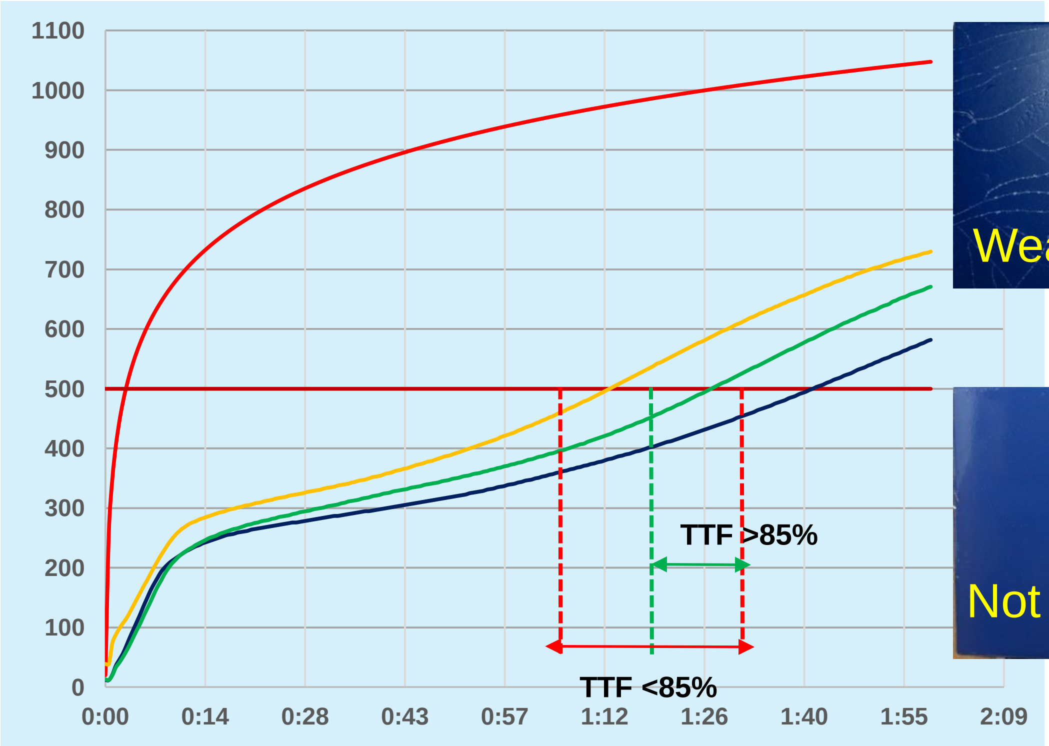
Exposure tests according to ETAG-018 Type X-conditions (outdoor conditions)

- Phase 1: **<u>Spray QUV (</u>**112 cycles in 28 days) of:
  - 5 hours of dry UV exposure at 50ºC (± 3ºC) with relative air humidity of 10% (± 5%)
  - 1 hour of water spray at 20ºC (± 3ºC)

- Phase 2: **<u>Climatic chamber </u>**(2 cycles as described in the below table where the coating is exposed to extreme temperature and humidity changes)

Day	6 hours	6 hours	6 hours	6 hours
1. + 2.	20ºC ± 3ºC 95% ± 5% rh	70ºC ± 3ºC 20% ± 5% rh	20ºC ± 3ºC 95% ± 5% rh	70ºC ± 3ºC 20% ± 5% rh
3. + 4.	20ºC ± 3ºC 95% ± 5% rh	30ºC ± 3ºC 40% ± 5% rh	40ºC ± 3ºC 95% ± 5% rh	30ºC ± 3ºC 40% ± 5% rh
5. + 6 +7.	-20ºC ± ºC	40ºC ± 3ºC 95% ± 5% rh	-20ºC ± 3ºC	40ºC ± 3ºC 95% ± 5% rh

Compatibility testing of topcoats – ETAG18-2

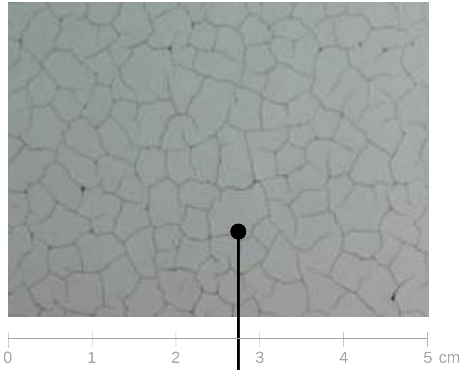


HEMPACORE PASSIVE FIRE PROTECTION

Increased reliability & durability

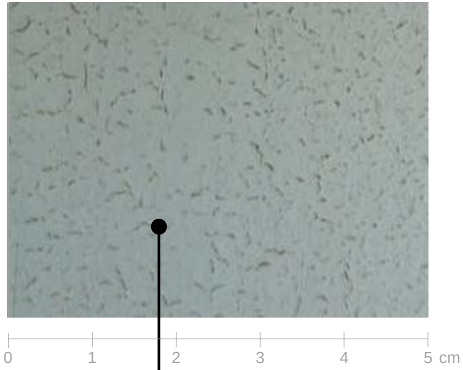
- Results show superior durability under exterior conditions

Product A



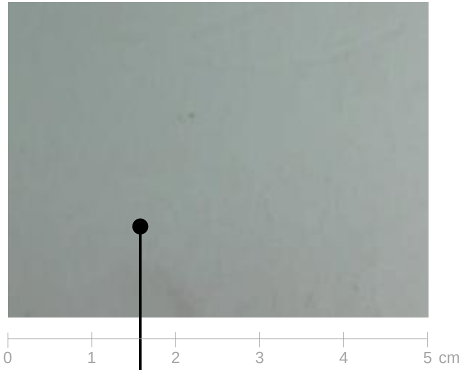
Cracking

Product B



Micro Cracking

HEMPACORE ONE 43600



No film defects

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Securing high quality

Quality control

- Factory Production Control - production only in approved and certified factories
- Quality control of raw materials and finished product
- Control of changes
- Process controls
- Initial audit
- Continuous surveillance
- Voluntary adoption of “**Guidance to a quality control fire test regime for intumescent coatings**” prepared by the Intumescent Coatings Technical Committee (ICTC) of CEPE

Quality assurance

Testing required for

- Changes in production equipment/processes
- Change of formulation
- Change in raw material supply

Probability of effect on fire protection performance	Fire test level	Test to be performed
Certain	5	Loaded beam at maximum DFT according to EN 13381-8 at accredited laboratory
High	4	1 m specimens according to EN 13381-8 at accredited laboratory
Moderate	3	1 m specimens according to EN 13381-8 internally
Low	2	Insulating efficiency test according to Laboratory Instruction RD-142
Very low	1	Char expansion test according to Laboratory Instruction RD-141

Wrap-up

- PFP of structural steel is a matter of safety
- Reliability and Durability of fire resistance coatings are essential – Only one chance to perform during lifetime of the building
- Third party certifications – Quality assurance
- Additional stringent internal test protocols

Thank you…