Measuring fire behaviour of composites

May 16, 2023

finnester coatings

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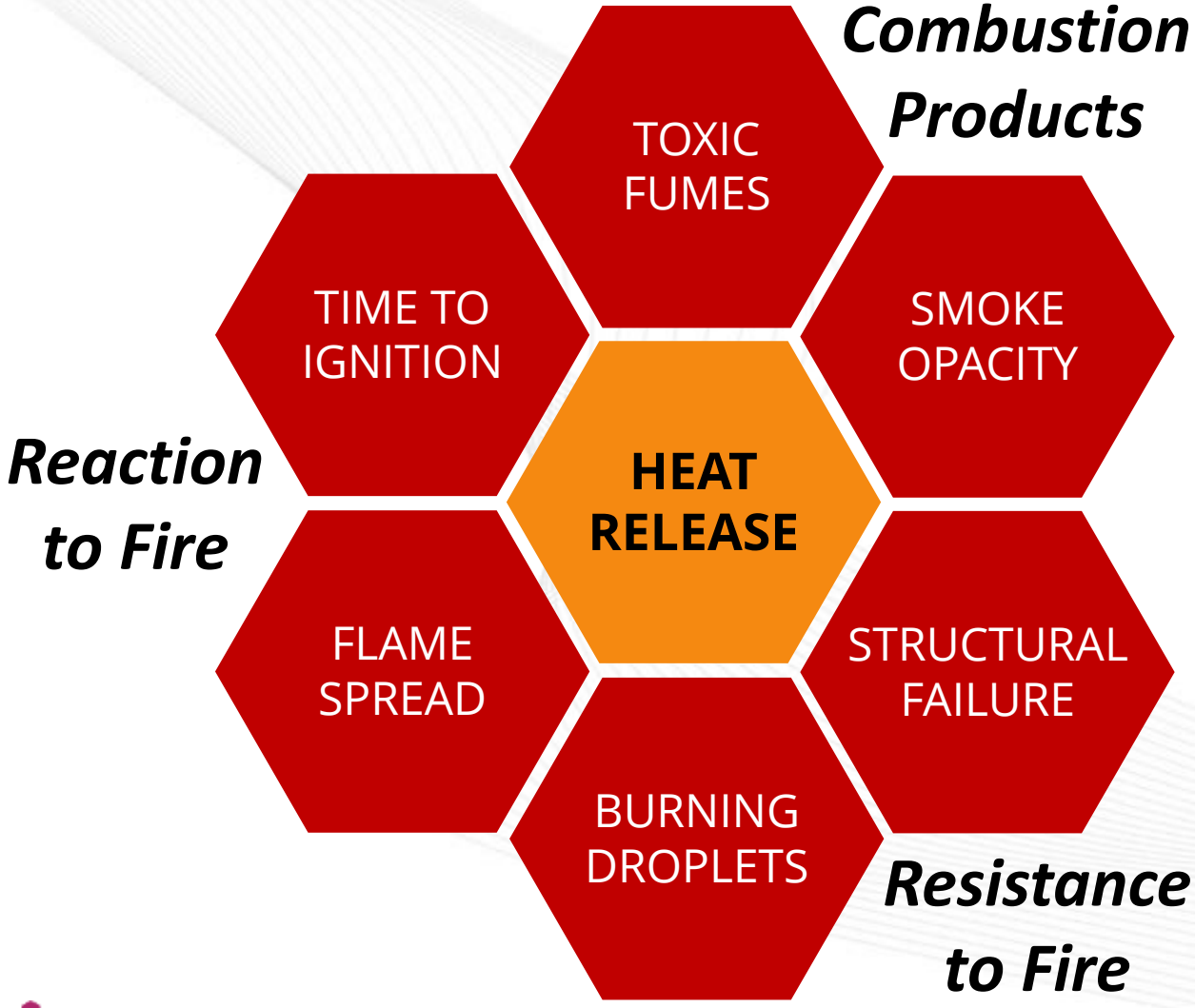
UNDERSTANDING FIRE



Combustion Products

Reaction to Fire

Resistance to Fire

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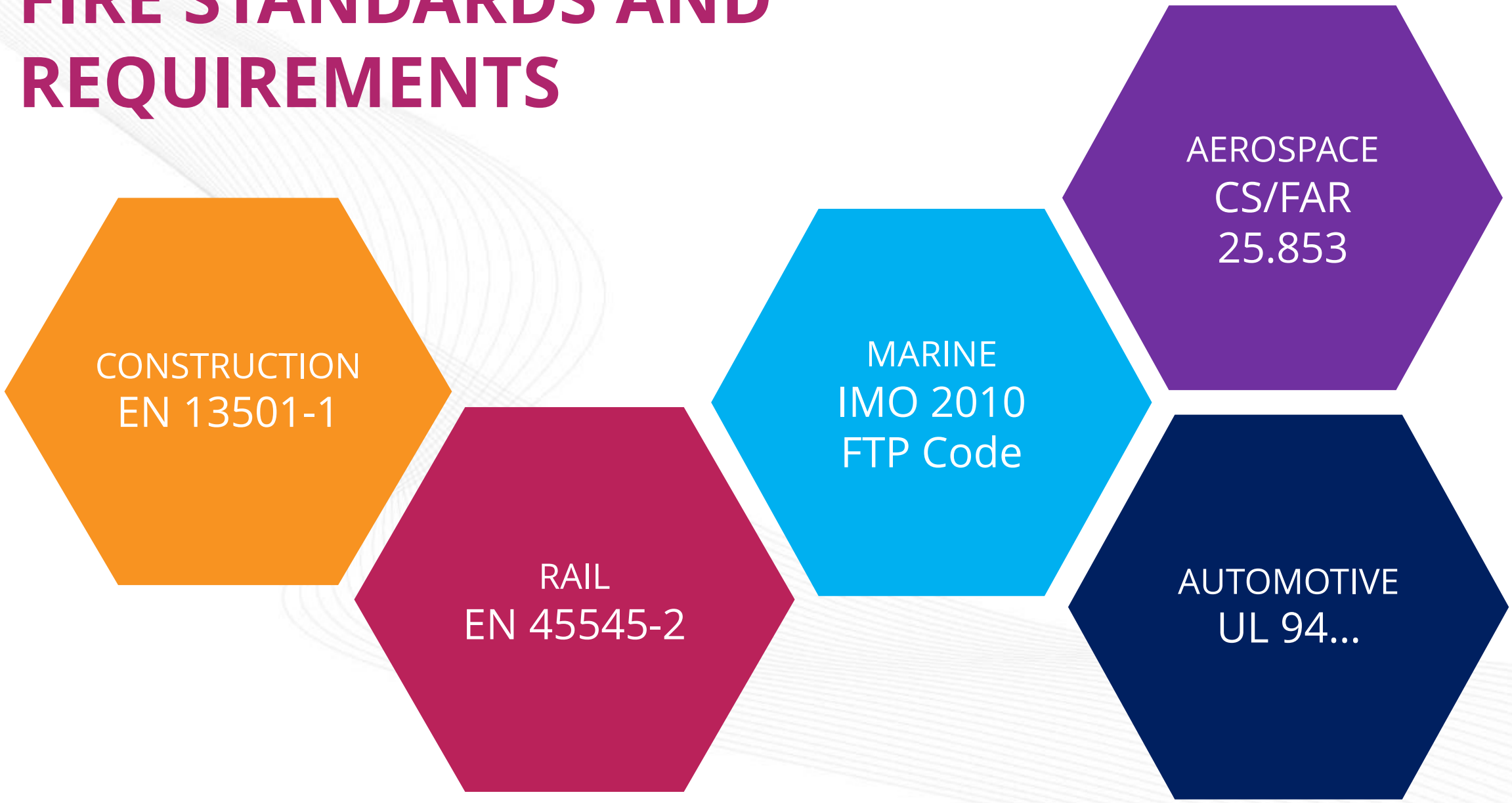
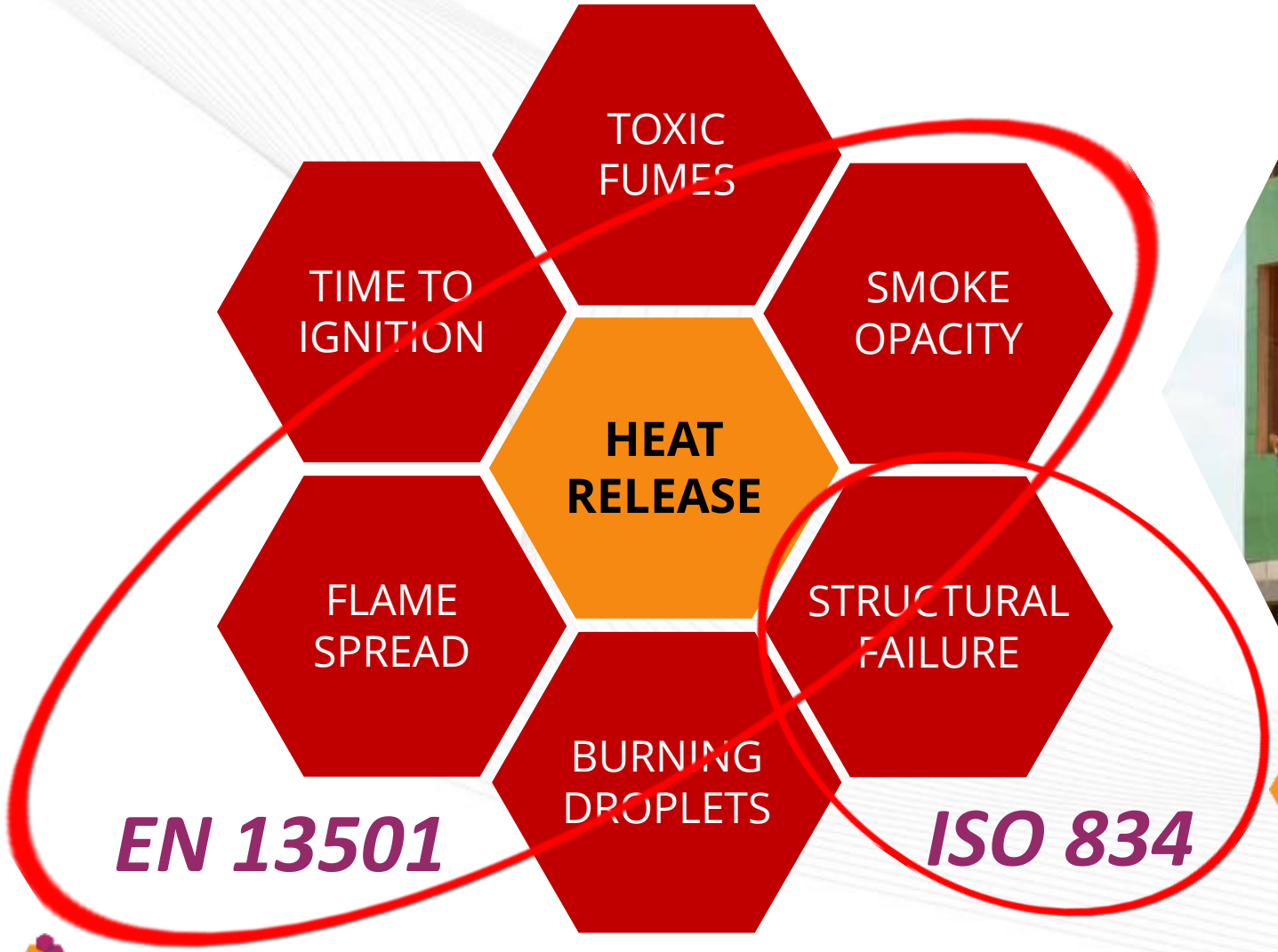
FIRE STANDARDS AND REQUIREMENTS



CONSTRUCTION EN 13501-1



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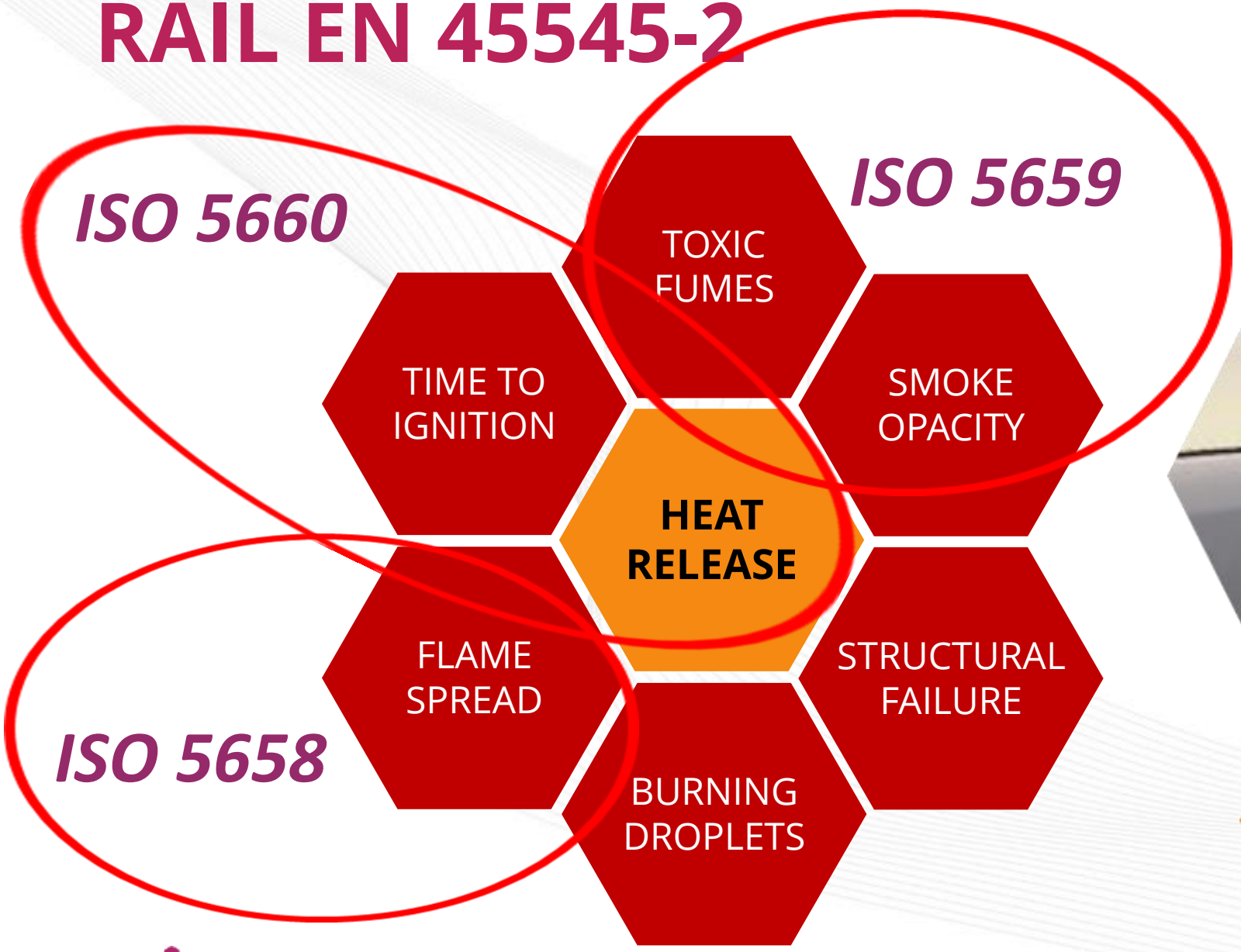
RAIL EN 45545-2



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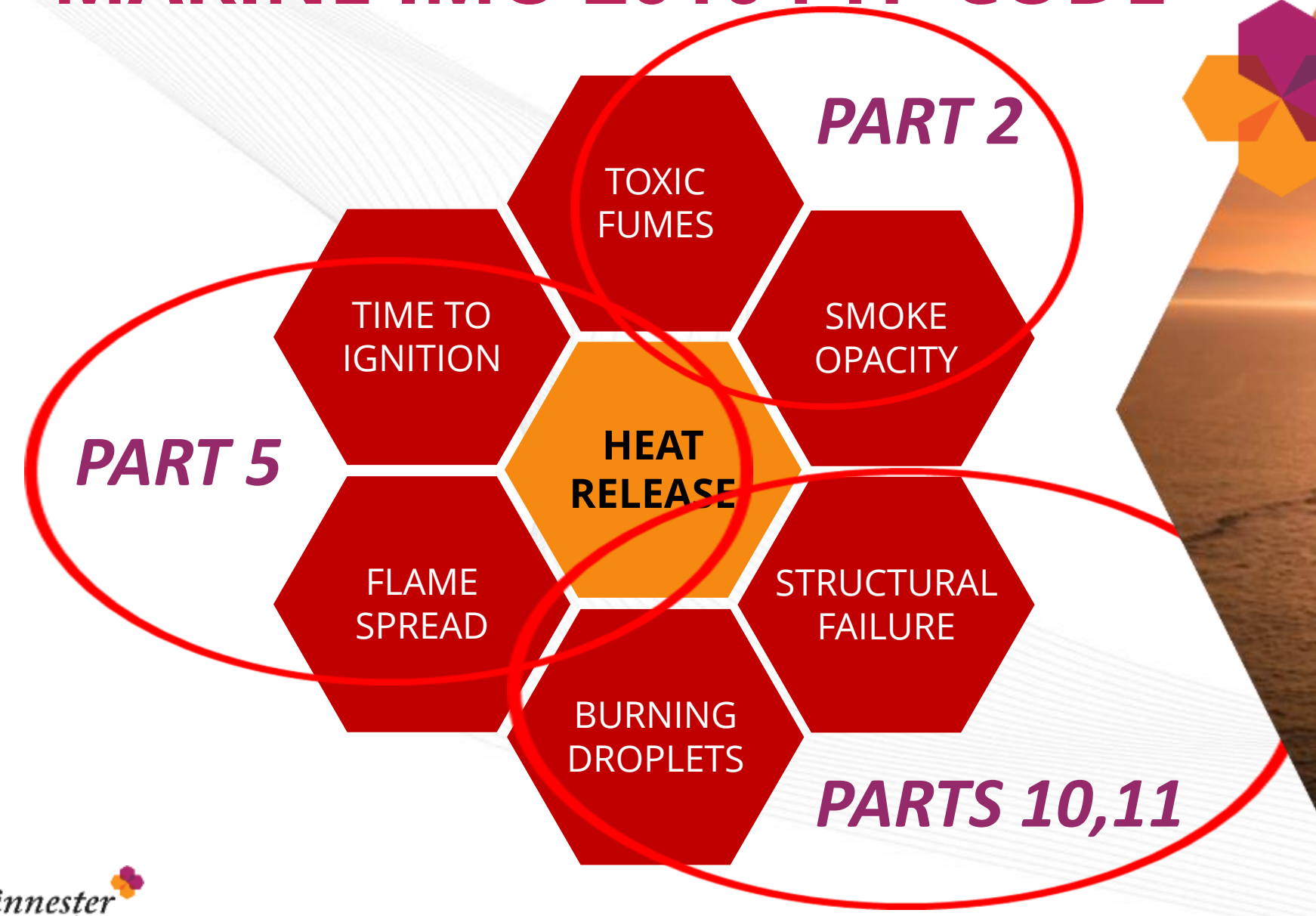
MARINE IMO 2010 FTP CODE



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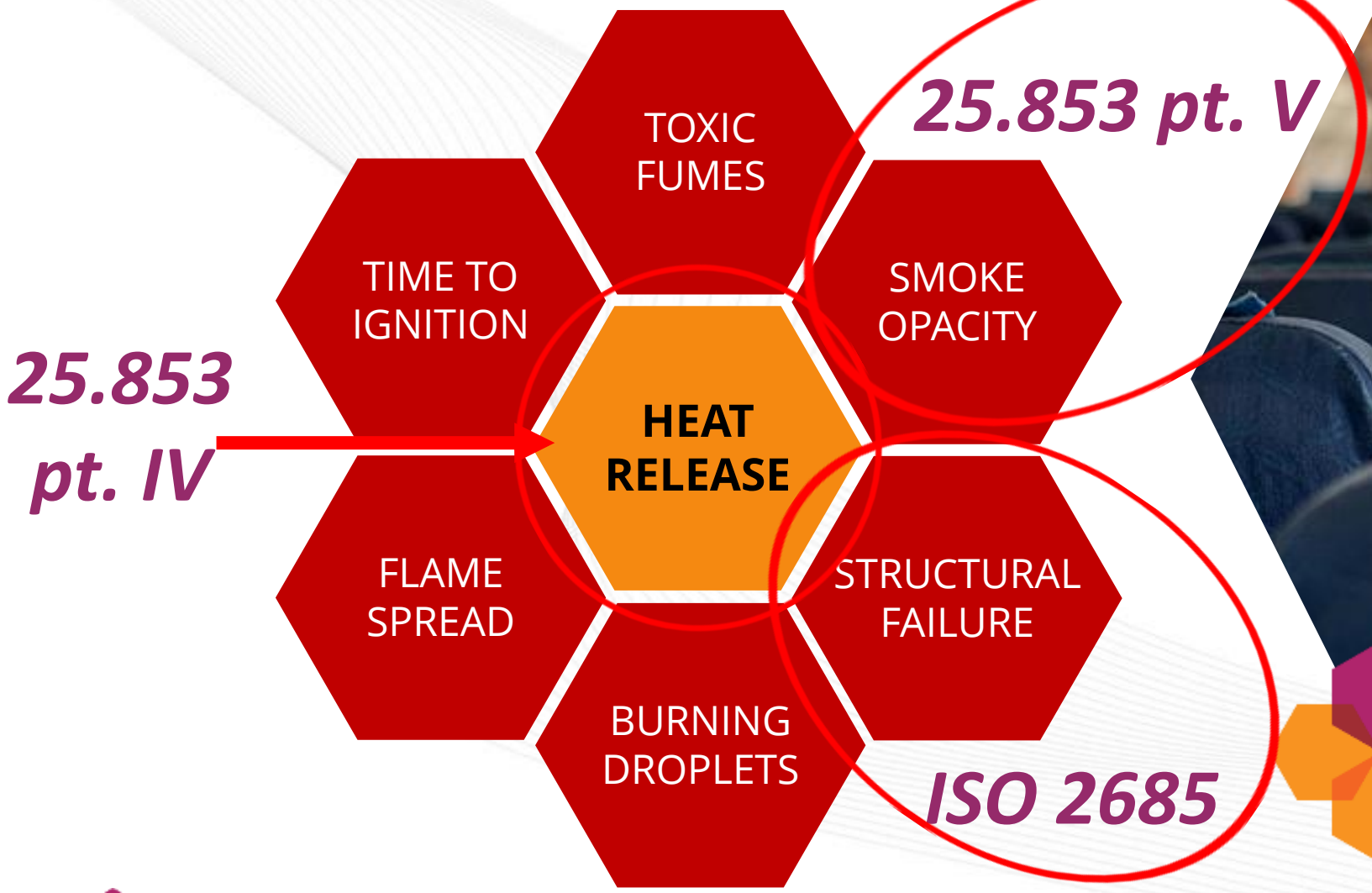
AEROSPACE CS/FAR 25.853



25.853 pt. V

25.853 pt. IV

ISO 2685

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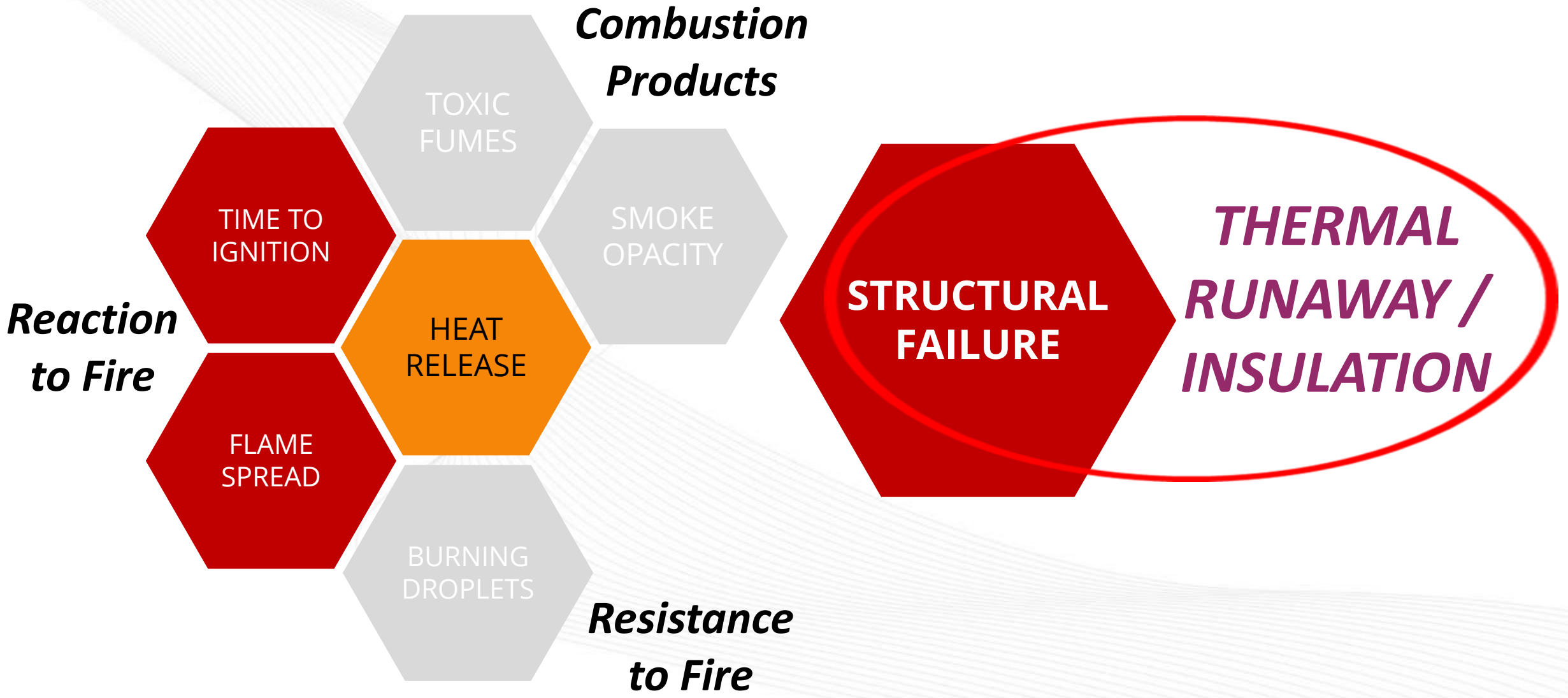
ELECTRICAL VECHICLES



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DIRECT FLAME TESTS

- Thermal Insulation
  - *Heat transfer to the composite substrate*
- Thermal runaway (UL 2596)
  - *Burn through time*
- Other
  - *Flammability of Plastics (UL 94)*
  - *SBI (EN 13823)*

THERMAL INSULATION

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THERMAL INSULATION

- Gas-fired Bunsen Burner ‘Blue flame’
  - 1000-1100°C (max gas flow)
  - 2-5 cm from test piece
- Temperature measurements
  - IR gun
    - Exposed & unexposed surfaces
  - Thermocouples inside composite
    - Different depths from surface

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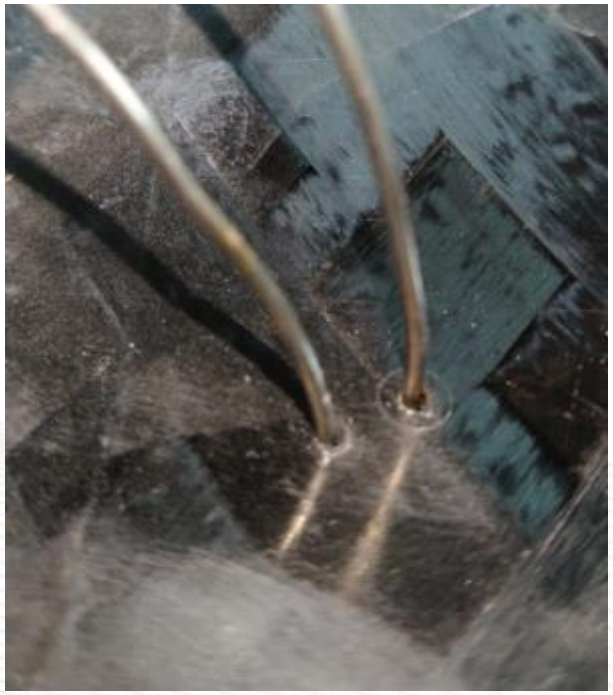
DATA & VISUAL OUTPUT

- Temperature recorded every minute
- 30-60 minutes
- Graphs summarise the results:
  - exposed / outer surface temperature
  - unexposed / inner surface
  - inside composite core
- Panels after burning
    - discolouration
    - fibre exposure
    - structural damage



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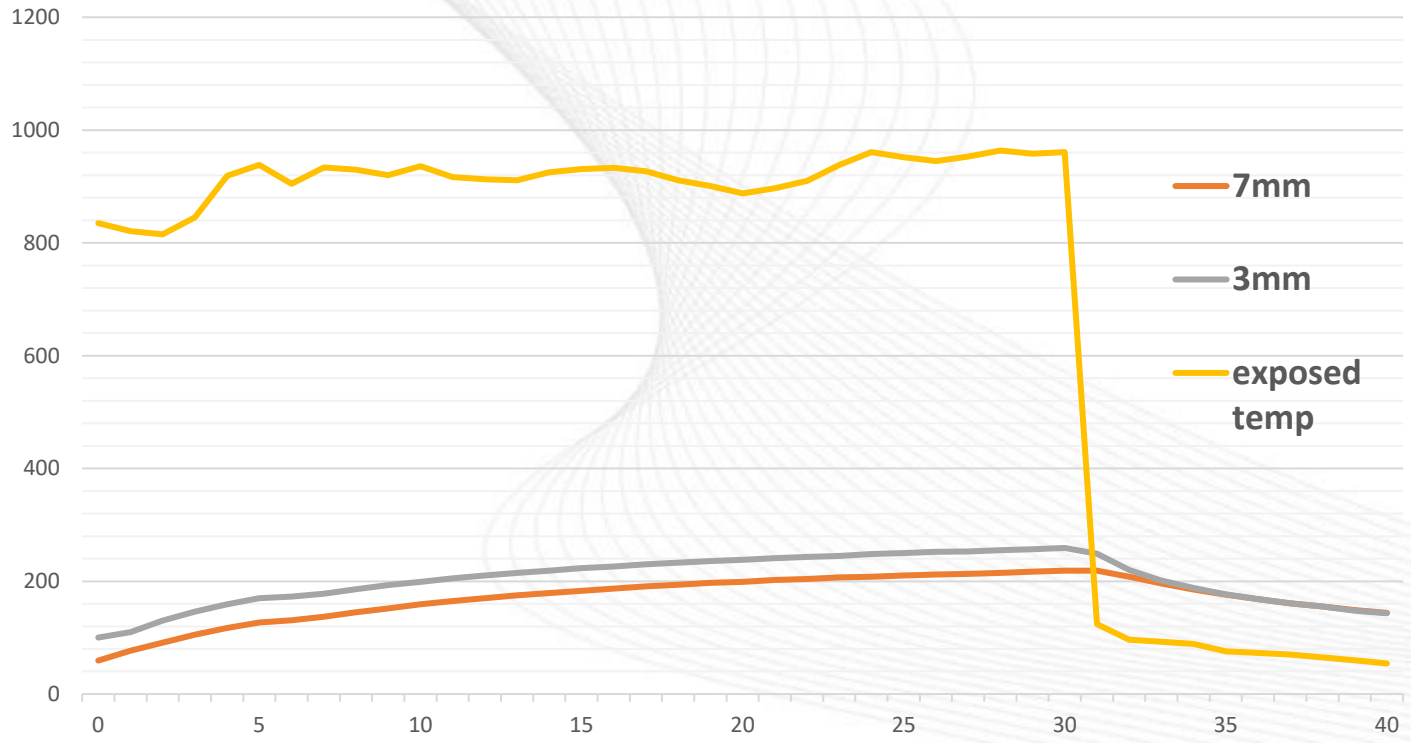
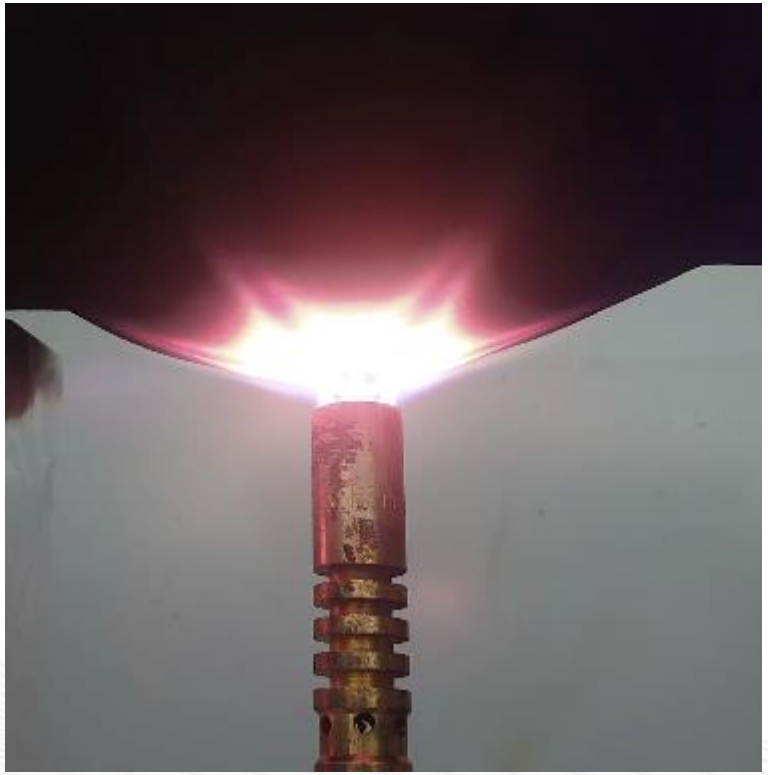
THERMAL INSULATION

THERMAL INSULATION





VISUAL OUTPUT

THERMAL RUNAWAY

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THERMAL RUNAWAY

Burn-through destructive testing using an acetylene torch

1200°C, 30 mins

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UL 94

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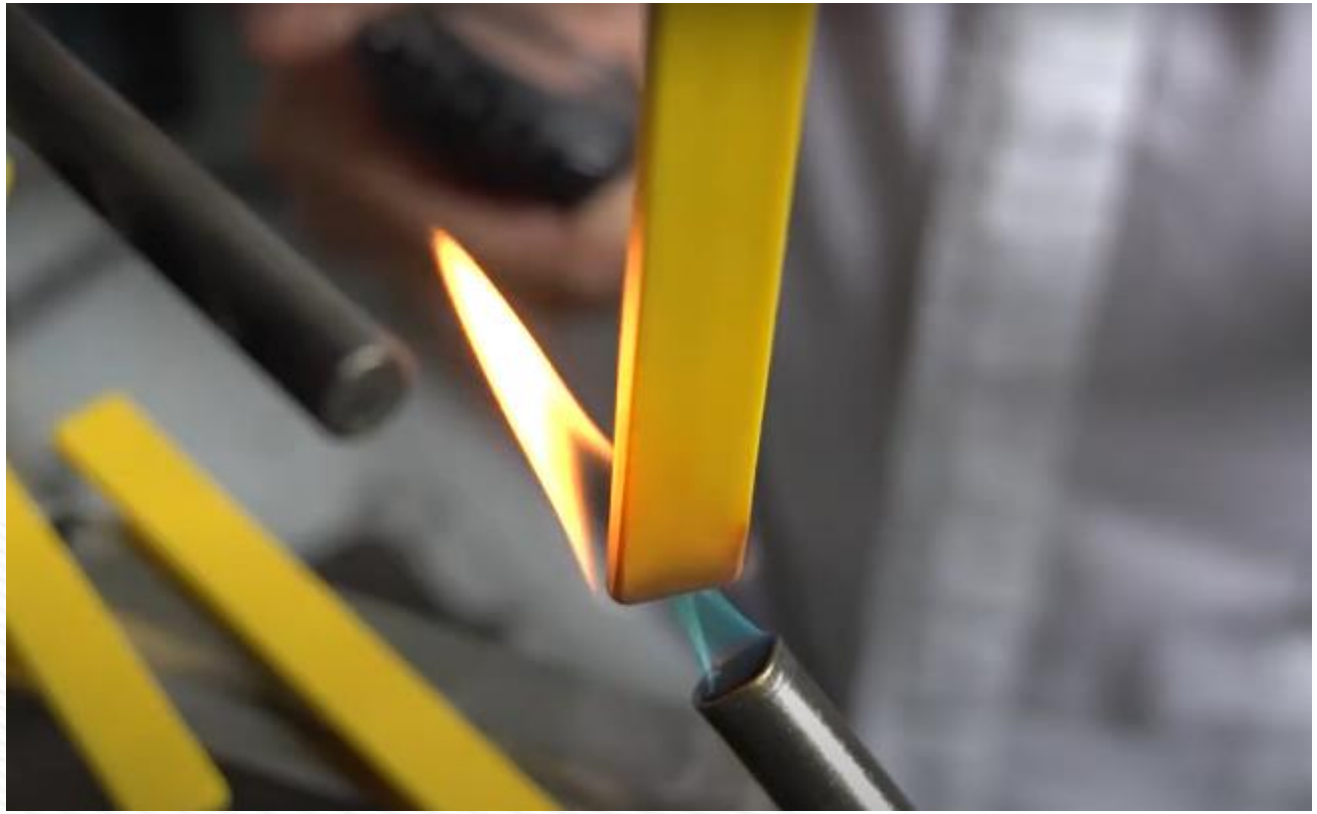
UL 94 FIRE TEST

Typical requirement for

- automotive parts
- PCB’s

Homogeneous materials



EN 13501-1

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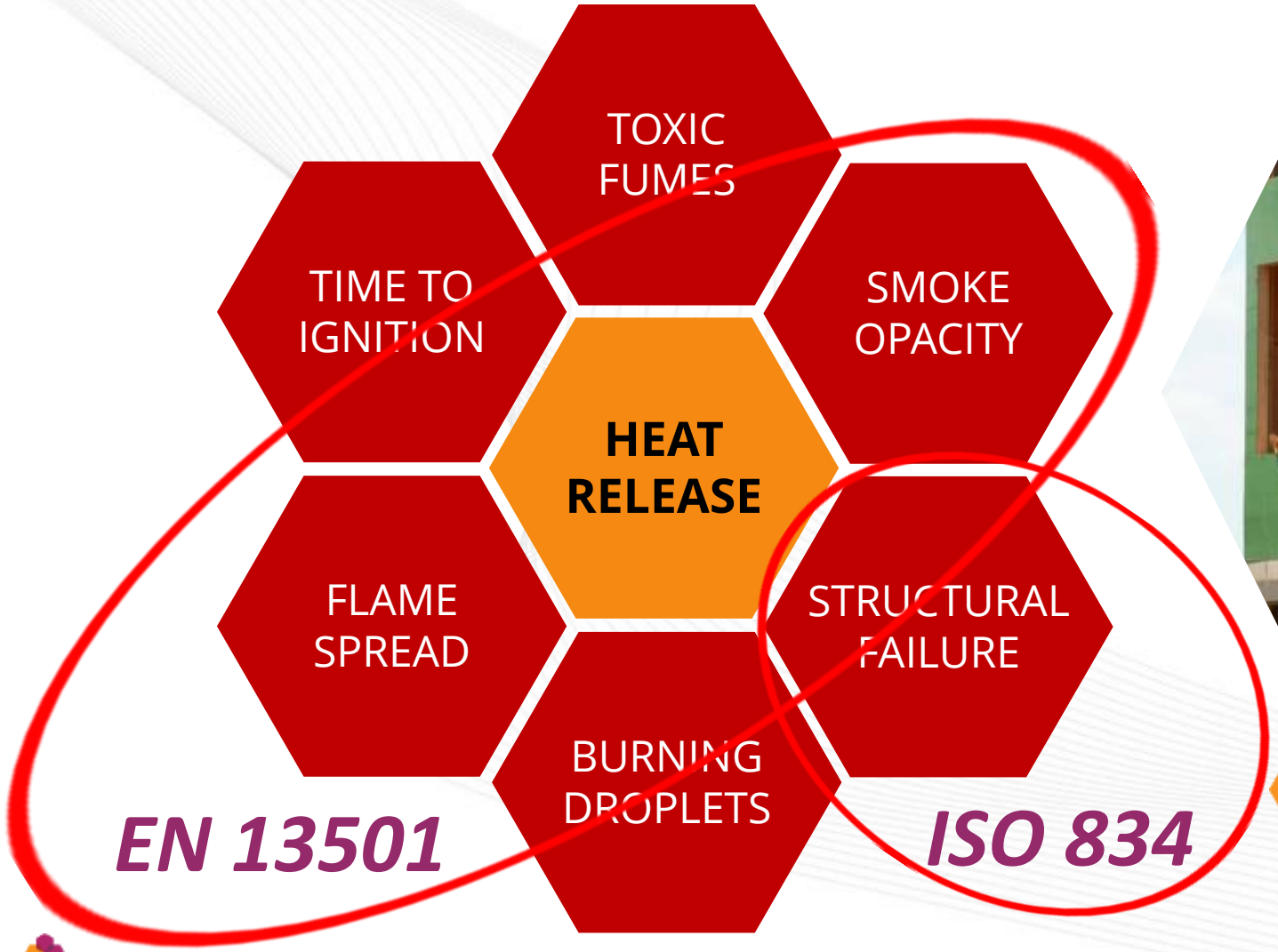
CONSTRUCTION EN 13501-1



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EN 13501-1 INTRODUCTION

- EU Classification for '**Reaction to Fire**' Elements
- Replaces / may be combined with National Standards
  - BS 476, DIN 4102 etc.
  - Simple, easy to understand
  - Includes Single-Burning-Item (SBI) test
- Separate requirements for e.g.
  - flooring, external roofs, cabling, piping

EN 13501-1 CLASSIFICATION

- 1st part = Alphabetical Classification
  - A1, A2 = Non-combustible materials
  - B = very limited contribution to fire
  - C = limited contribution to fire
  - D, E = medium contribution to fire
- **Target = B class**
  - Standard composites will not pass the non-combustibility tests for A classes

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EN 13501-1:2019 – THE TESTS (1st Part)

- Key test standards
  - EN 13823 (SBI)
  - EN 11925 (Ignitability)
  - EN ISO 1716 (A only)

EN13501	EN 11925	EN 13823 (SBI-test)			EN 1716
Class	Fs	FIGRA	LFS	THR600s	PCS
A2		< 120 W/s	< edge	≤ 7,5 MJ	≤ 3,0 MJ/kg
B	≤ 150mm 60 s	≤ 120 W/s	< edge	≤ 7,5 MJ	
C	≤ 150mm 60 s	≤ 250 W/s	< edge	≤ 15 MJ	
D	≤ 150mm 60 s	≤ 750 W/s			
E	≤ 150mm 20 s				

- Key parameters
  - FIGRA = **Fire Growth Rate** Index
  - THR_{600s} = **Total Heat Release**
  - F_s = **Ignition**

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EN 13501-1:2019 – FULL CLASSIFICATION

2nd Part = Classifying smoke emissions (s) and flaming droplets (d)

- Smoke classification
  - s1 = best classification, lowest amount
  - s2 = average amount of smoke
  - s3 = worst classification
- Flaming Droplets classification
  - d0 = best classification, no droplets
  - d1 = no droplets staying more than 10 secs
  - d2 = worst classification, persistent droplets

Overall target classification for composites = **B-s1-d0**

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EN 13823 SBI (over Polyester GF)

	RED	EN 13501 B Classification Requirements
FIGRA (0,4MJ)	**< 50** (B class)	≤ 120 W/s
LFS	< edge (B Class)	< edge (B Class)
THR 600s	**< 1,5** (B class)	≤ 7,5 MJ
SMOGRA	< 6,0 (s1)	
TSP 600s	< 35 (s1)	
Flaming droplets	None (d0)	

Also passes the EN 11925 Ignitability Test

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RADIANT HEAT TEST

- Cone calorimeter (ISO 5660-2)

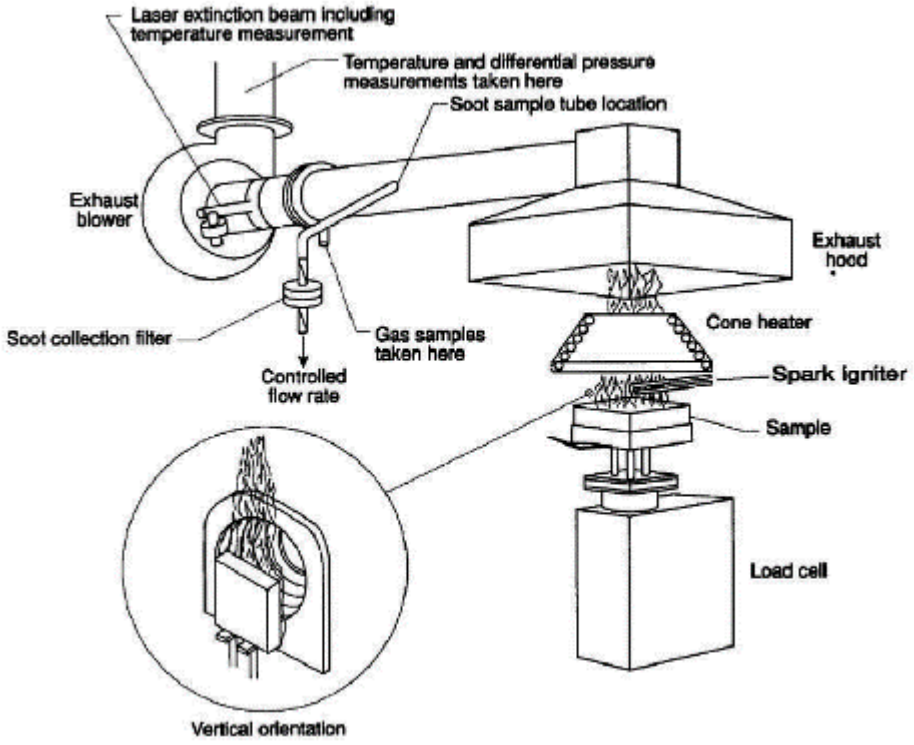
Workhorse for more demanding fire standards

  - *heat release*
  - *smoke production*
  - *mass loss rate*

- Flame spread (ISO 5658-2)

- Smoke analysis (ISO 5659)

RADIANT HEAT TEST



100 x 100 mm flat panel samples

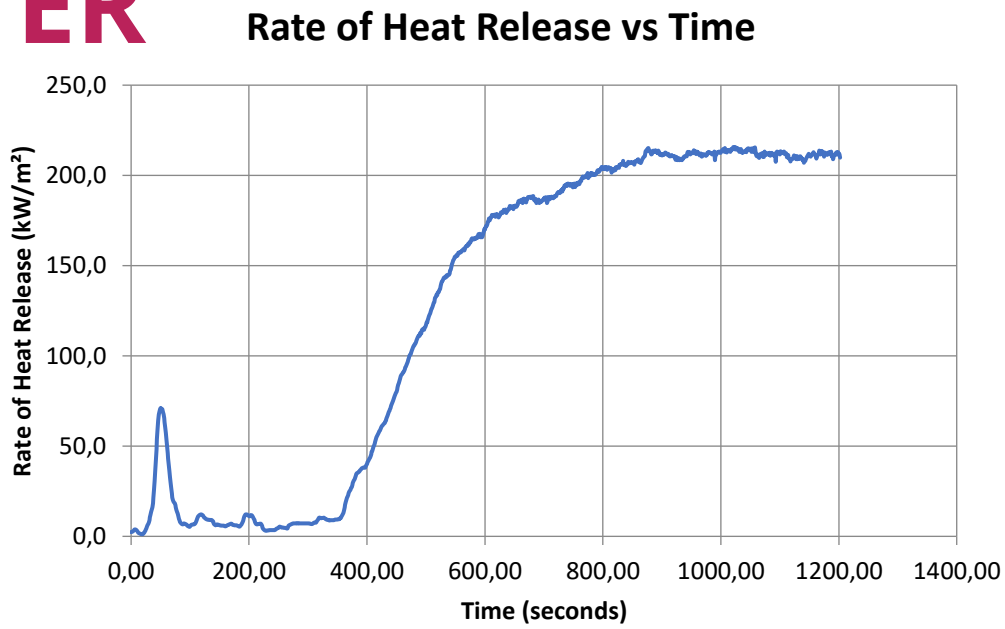
After 20 min burn with 50 kW/m^2

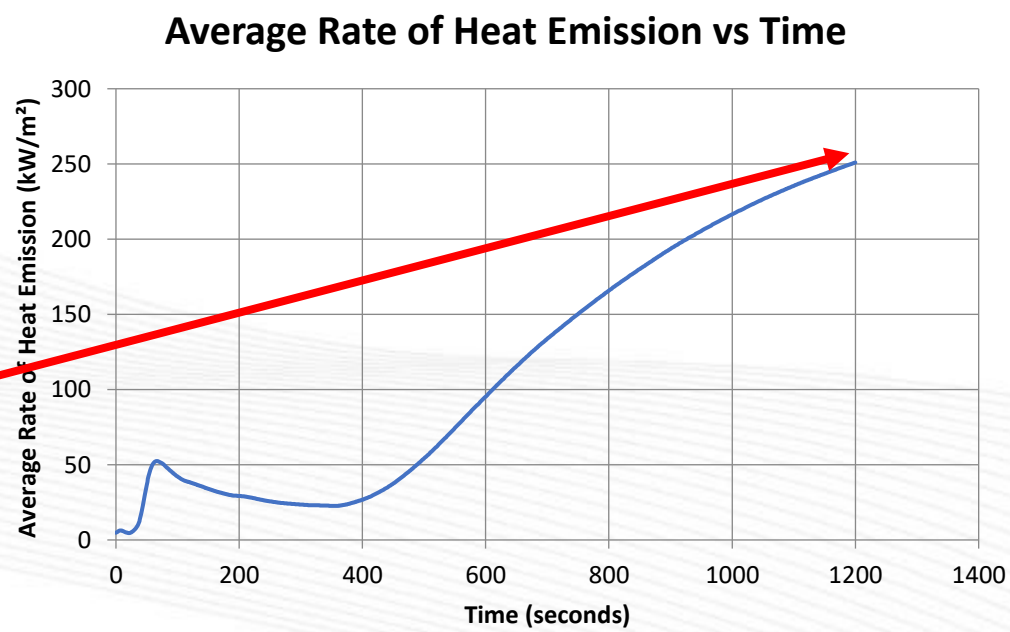
ISO 5660 CONE CALORIMETER

- Radiant heat with spark ignitor
- Output
  - Smoke production
  - Mass loss rate
  - Heat Release Rate / time
    - ARHE [kW/m^2]

ISO 5660 CONE CALORIMETER

MARHE [kW/m^2]





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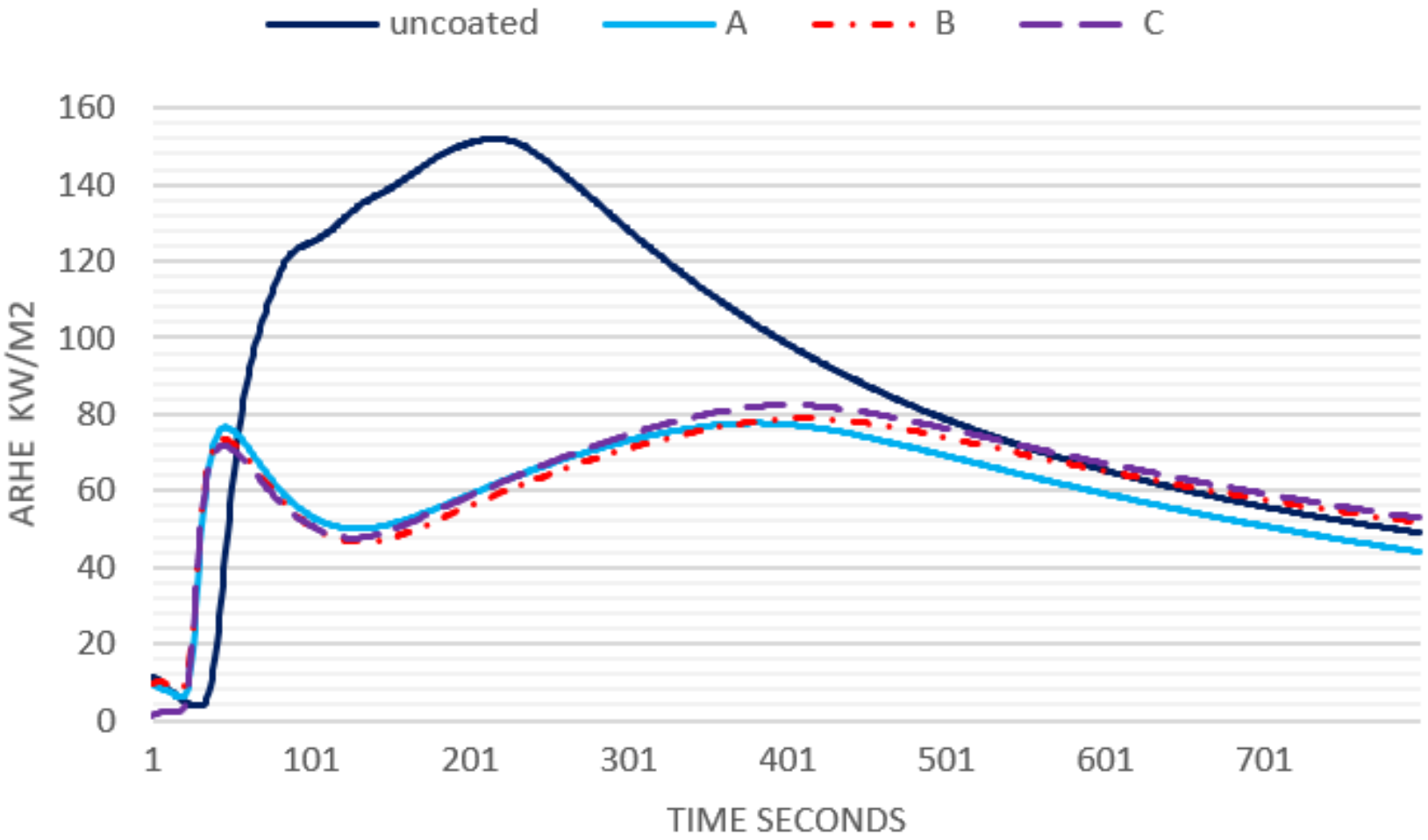
HEAT RELEASE

Polyamide + glass-fibre, coated with RED 2-coat System, 3 repeat samples A, B & C

Coating	MARHE* kW/m²	
Uncoated	152	
Sample A	77,7	HL2
Sample B	78,9	
Sample C	82,4	

** Maximum Average Rate of Heat Emission*



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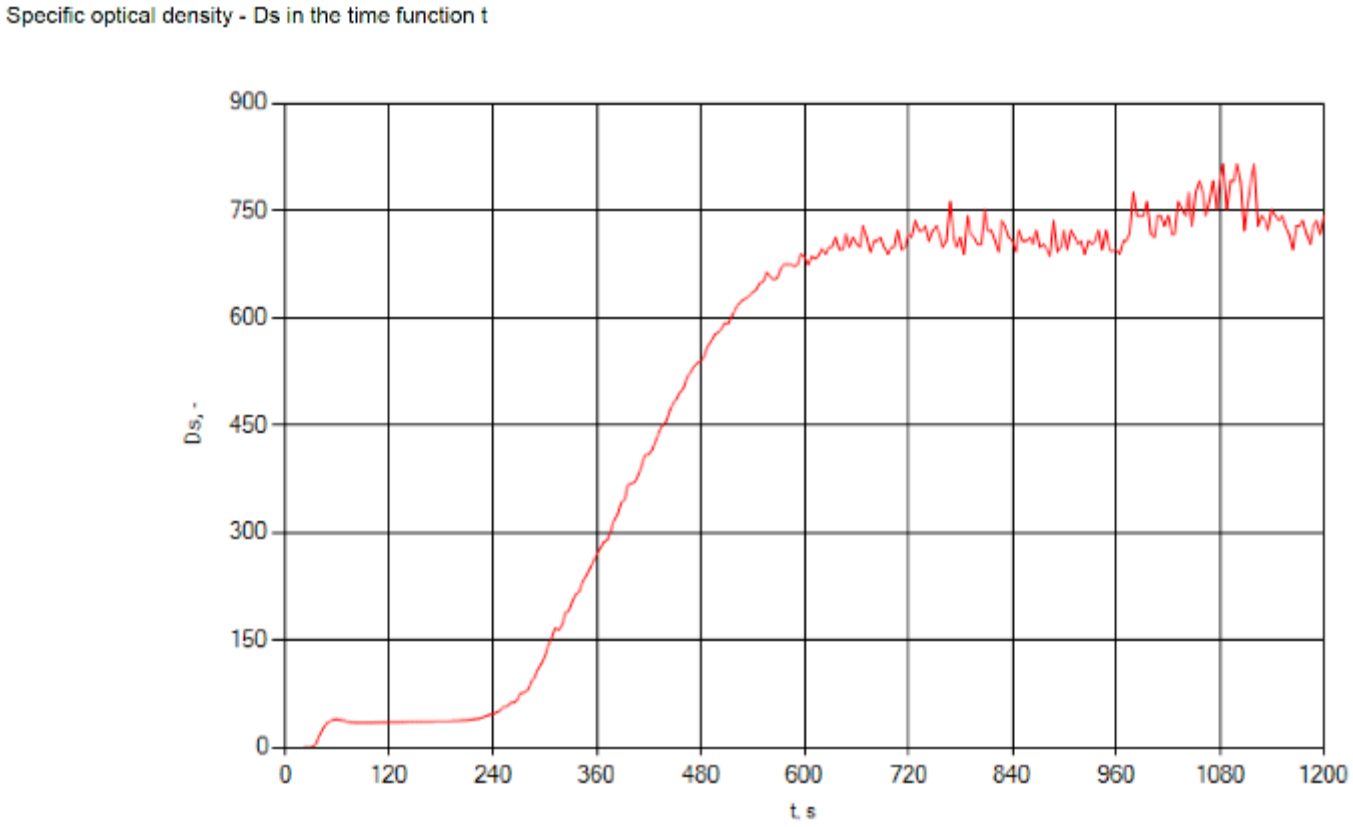
FLAME SPREAD

- Radiant heat with pilot flame
  - IMO Part 5 for marine (also heat release measured)
  - ISO 5658-2 for railway EN45545-2
- CFE = Critical heat Flux at Extinguishment

SMOKE OPACITY



SMOKE TOXICITY

Carbon dioxide CO_2

Carbon monoxide CO

Nitrogen dioxide NO_2

Nitrogen monoxide NO

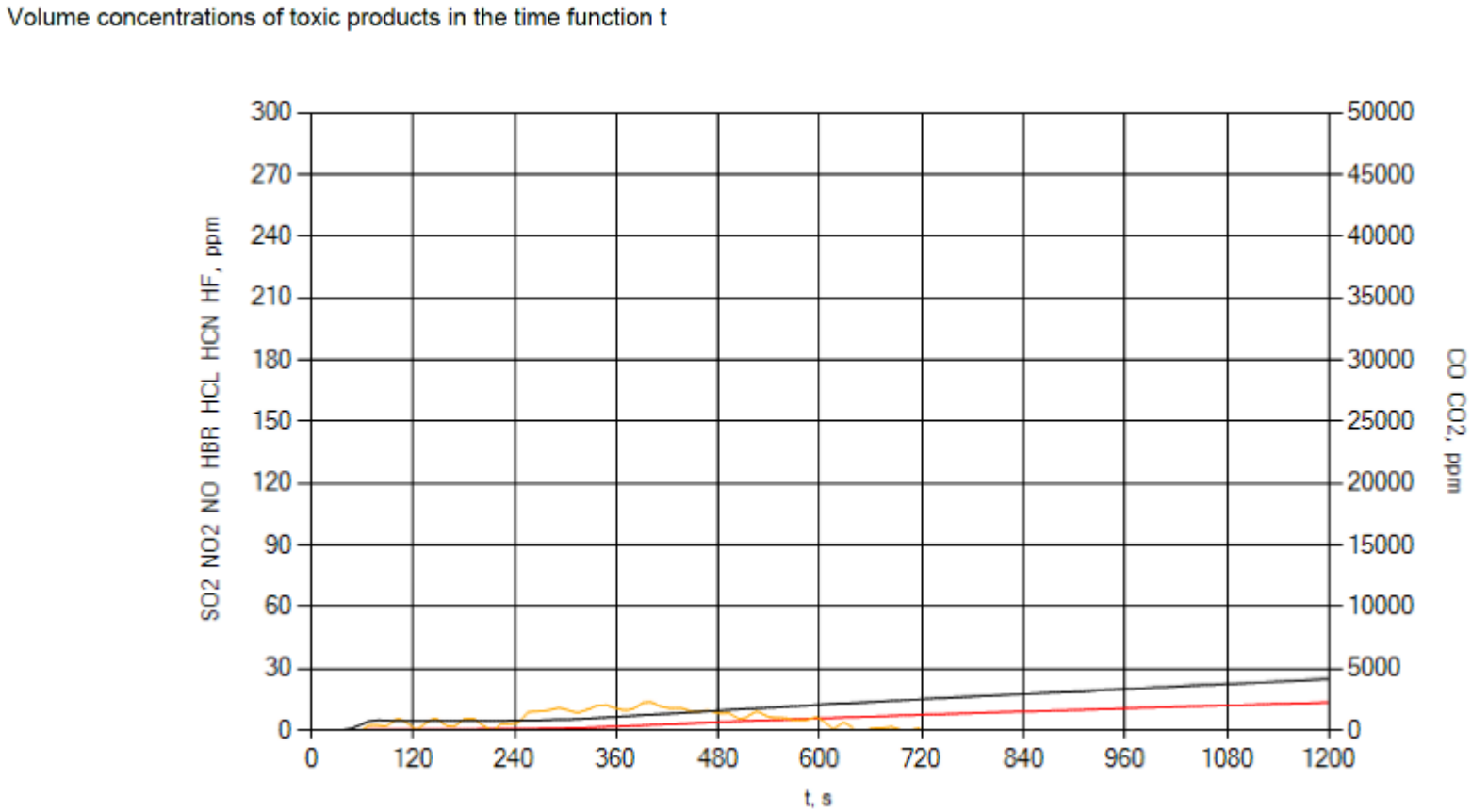
Sulphur dioxide SO_2

Hydrocyanic acid HCN

Hydrogen chloride HCI

Hydrogen bromide HBr

Hydrogen fluoride HF



SUMMARY

- Composites burn
- To solve fire protection for composites
  - What are fire requirements and standards
  - How does the composite substrate itself burn
  - What are manufacturing processes involved
  - What are other than fire related requirements

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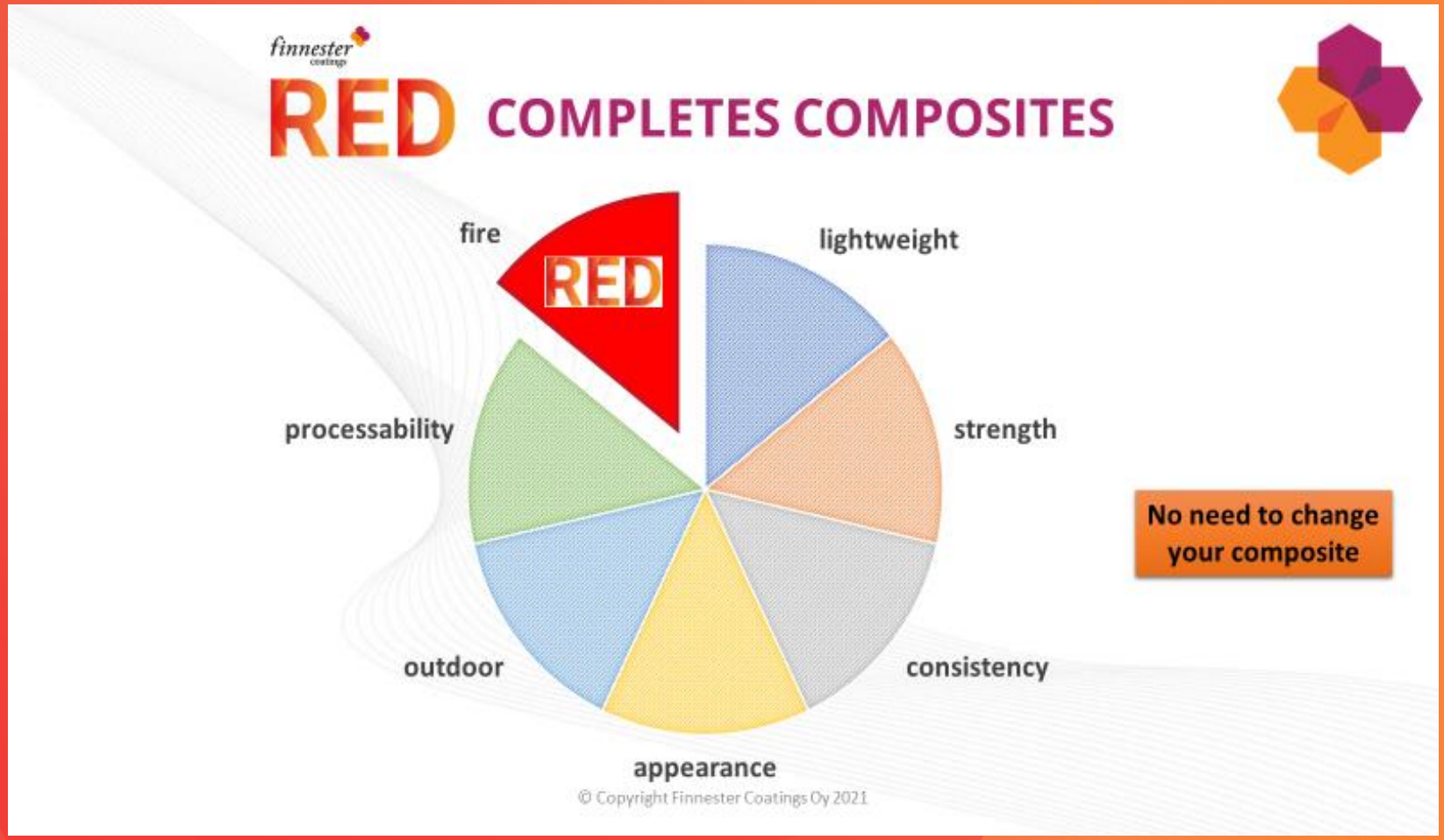

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