



Formulated Systems

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# Enhanced Polyisocyanurate Foams for Metal Faced Panels

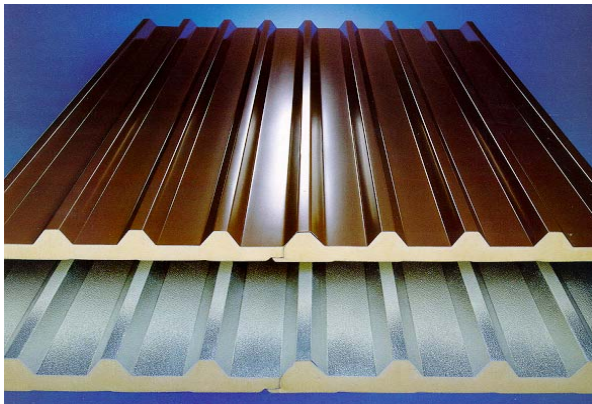
*Everton Campioto, Rodnei Abe*

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# Agenda



- Summary
- RF-DBL Production Process
- The Fire Behaviour
- Fire Tests
- Structure-Property Relationships
- VORATHERM™ PIR Performance





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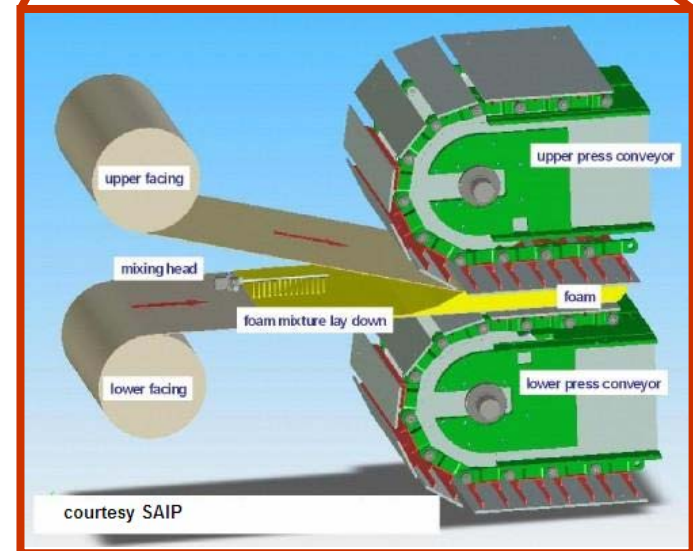
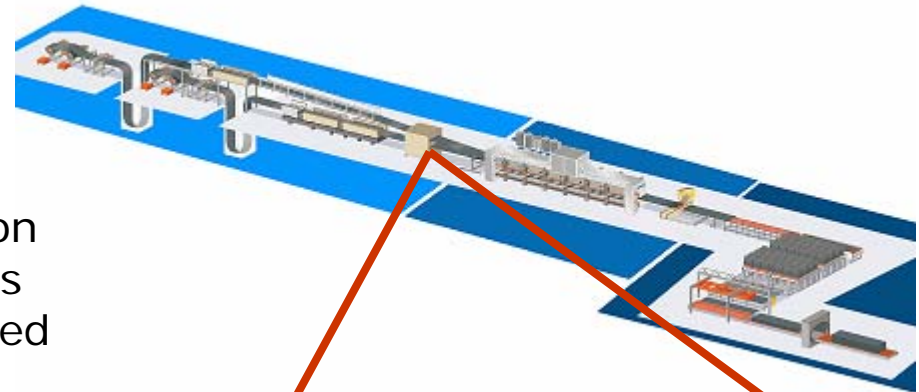
# Executive Summary

- This study is about fire performance of **Polyisocyanurate** (PIR) foams for RF-DBL insulated metal panels
- Small scale test results on PIR foams are analyzed in comparison with full scale panel classification tests
- The use of isothermal **TGA Lyon method** is explored targeting resistance-to-fire performance correlation
- Dow **VORATHERM™** PIR fire reaction and fire resistance rating are presented, as well as process-ability and thermal insulation properties

# Production Processes

## RF-DBL

- Rigid Faced Double Belt Lamination (RF-DBL) is a **continuous** process for producing steel faced foam filled building panels
- Insulated panels are used for walls, interior partitions, insulated roofs
- The construction product may need to be in compliance with stringent **combustibility** standards, which is why Polyisocyanurate (PIR) modified polyurethane foams are increasingly preferred to their polyurethane (PUR) based counterparts





# Fire Behavior

## Reaction and Resistance to Fire

- Fire reaction and fire resistance are the two base concepts for passive **prevention** systems to protect people and goods from the effects of a fire in a building
- Fire **reaction** is about products behavior in the early stages of a fire, from ignition to flashover
- Fire **resistance** is about keeping structural stability, integrity and thermal protection in a fully developed fire

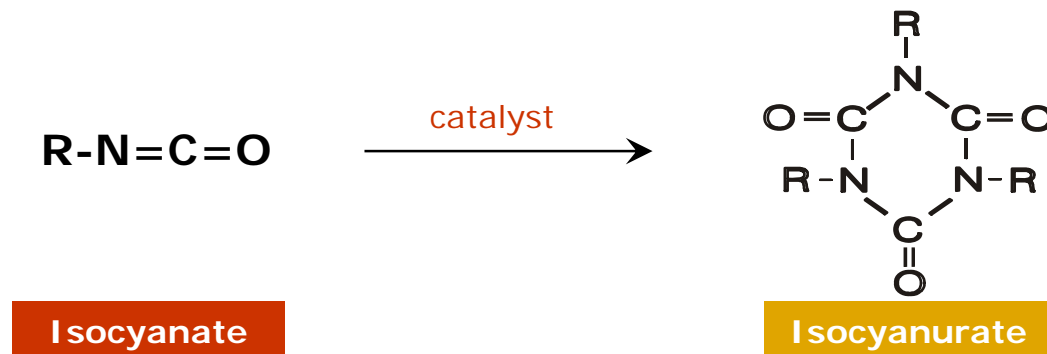
Fire parameters related to classification and testing

<b>Developing fire</b>	Reaction to fire	Ignability Heat release Flame spread
<b>Fully developed fire</b>	Resistance to fire	Loadbearing Insulation and Integrity capacity

*source ISOPA*

# Why Polyisocyanurate?

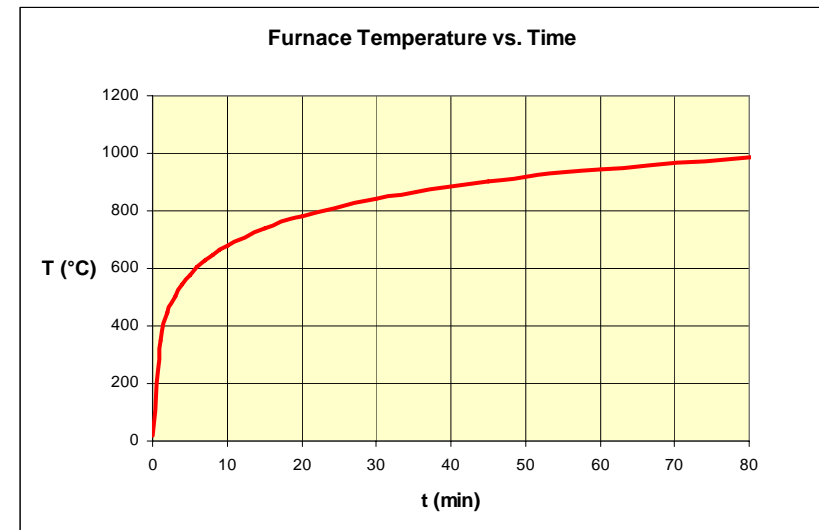
- It is documented in the literature and known in the industry that the chemical modification of the PUR backbone through the introduction of isocyanurate structures is a viable method for improving **thermal stability**
- Among the others, Kordomenos reports for **PIR** and **PUR** model compounds decomposition starts at 380 and 260°C respectively





# Fire Resistance – EN 1363

- Steel faced sandwich panels are placed on a **furnace** opening, and thermocouples are located on the non-exposed facing
- Typically three panels need to be jointed together to cover a 3x3 meter surface
- Failure criteria:
  - **Insulation**
  - **Integrity**
- Orientation tests for product development can be executed on smaller panels (50x50 cm)



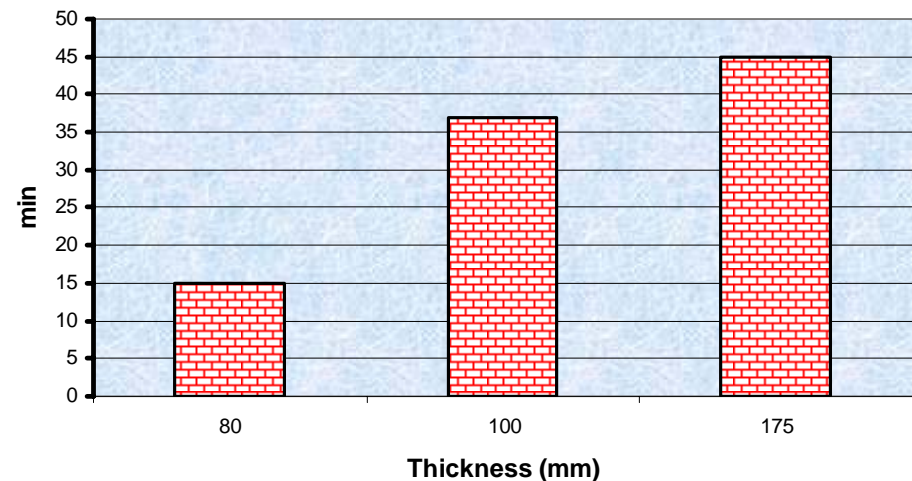
**EN 1363 fire resistance test -  
Furnace temperature vs. time**

# Effect of the Thickness

- Considering how insulation and integrity are measured during the fire resistance test, it is intuitive that the performance of the panel will be proportional to the panel thickness



**Insulation Endurance vs. Panel Thickness**







# Structure-Property Relationship

## Reaction-to-Fire

- Researchers have since long tried to **correlate** polymer chemical and physical structure with combustion behavior
- Regarding fire reaction,
  - the **cone calorimeter** (heat release measurement) has been found very useful to support the development towards Euroclass classifications.
  - The NBS **smoke chamber** is a key tool for screening formulations aiming to match the smoke density level needed for class I according to ASTM E 84.

Cone calorimeter and Smoke Chamber characterization of some VORATHERM™ PIR foams			
Property	Low Index	Medium Index	High Index
Isocyanate Index	2.0	2.8	3.4
<i>Cone Calorimeter</i>			
Heat release, total (MJ/m <sup>2</sup> )	26.2	15.3	13.8
Heat release, rate peak (kWw/m <sup>2</sup> )	118.2	87.3	77.2
Total smoke produced in the first 200 s (m <sup>2</sup> )	3.1	1.9	2.2
<i>NBS Smoke Chamber</i>			
Avg D <sub>s</sub> max	135.6	32.7	42.65
Avg wt loss (%)	39.6	21.6	22.9

- Heat release data correlate well with isocyanate index
- In the case of smoke opacity, it seems that isocyanate index is not the only factor

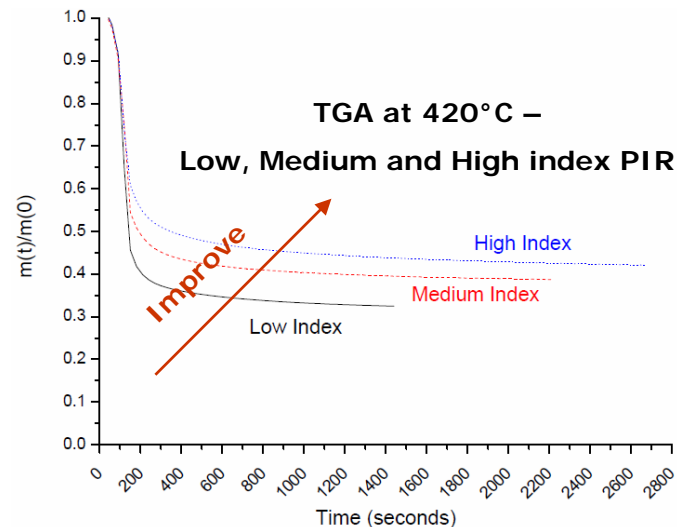
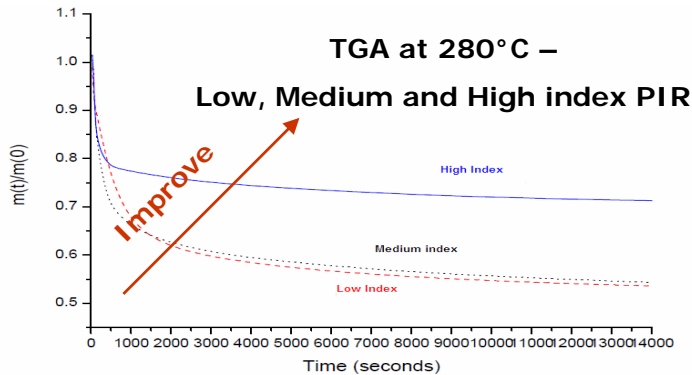


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# TGA-Lyon Method

## TGA Experiments



- Isothermal Thermo Gravimetric Analysis (TGA) curves for low and medium index systems seems to be quite similar at 280°C, while at 420°C, the differences among the two is amplified
- High isocyanate index foams show much slower decay than low and medium at both temperatures.



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# Fire Classification

## VORATHERM™ PIR - Fire Classification

Reaction-to-fire and Resistance-to-fire classification achieved with VORATHERM™ PIR foams					
Index	Euroclass Bs2d0	ASTM E-84 Class I	FM 4880	LPS 1181	EI
2.0	Pass				<b>15 @ 60 mm</b>
2.7-2.9	Pass	Pass	Pass		15 @ 60 mm
3.4-3.8	Pass			Pass	30 @ 100 mm
					60 @ 200 mm

- The **low index** VORATHERM™ PIR, demonstrated to deliver EI 15 resistance-to-fire, not easily achievable with PUR
- Moreover low index VORATHERM™ PIR systems can be processed at the typical conveyor **temperature** used for PUR panels manufacturing, offering a valuable attribute for the panel manufacturers



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# Other Properties

- All the data generated and summarized in previous slides reinforce the beneficial effects of isocyanate **trimer content** towards the increasing of the thermal stability and fire behavior of PIR-PUR foams
- This study is also about the ability of VORATHERM™ PIR foams to match the fire performance with **mechanical**, thermal insulation properties and processability, through proper formulation

Examples of properties achievable with VORATHERM™ PIR systems			
Property	Low Index	Medium Index	High Index
Index	2.0	2.9	3.4
Core Density (kg/m <sup>3</sup> )	34.1	41.3	37.7
Compressive strength $\perp$ thickness (kPa)	165	158	128
Lambda @ 10°C (W/m·K)	0.0213	0.0218	0.0199



# Conclusions

- The attempt of correlating intrinsic properties of PIR foam materials with extrinsic behavior of sandwich panels led to the confirmation of utility of using cone calorimeter and NBS smoke chamber as developmental tool for reaction-to-fire classifications
- The isothermal **TGA Lyon method** seems to be a useful tool to indicate the direction for improving resistance-to-fire performance
- A variety of **VORATHERM™ PIR** tailored formulations have been developed to match severe fire coding in compliance with regulations and insurance standards
- On the top of fire performance, Dow VORATHERM™ family of products exhibit **balanced** process-ability and good mechanical and thermal insulation properties
- Within the family of VORATHERM™ PIR, the low index range is of particular interest, being developed with the scope of offering a PUR like processing, coupled with the possibility to achieve EI 15 fire resistance rating, even with minimizing the use of halogenated additives aiming to halogen free compositions



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**THANK YOU**

**QUESTIONS ?**