The value-in-use of steel ladles and the role of thermal efficiency from a modelling perspective

Paul van Beurden
Tata Steel Europe R&D

Steel meets Refractory

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Tata Steel IJmuiden has developed an in-house value-in-use model for its steel ladles. This model efficiently calculates and predicts all the costs and benefits of changes in refractory designs and refractory materials. The model helps to explain in a comprehensive way the financial effects of modifications. This has resulted in an increased ladle life and capacity as well as enhanced safety with decreased overall refractory costs and energy consumption. In this webinar I will focus on the thermal efficiency aspects of the value-in-use model from a modelling perspective.

Storyline

- **Steel ladles** - what, how and when: ***design*** and ***use***
- The **value-in-use** concept for ***steel ladles***: -- it's all about ***refractory costs***, right?
- The **thermal efficiency** of ***steel ladles***: -- just putting in more ***insulation***, right?

The steel ladles at Tata Steel IJmuiden

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Some information about our ladles

Dimensions
5 meters high,
4 meters wide

Capacity
340 tons

Production
55-60 heats/day
7 Mt/year

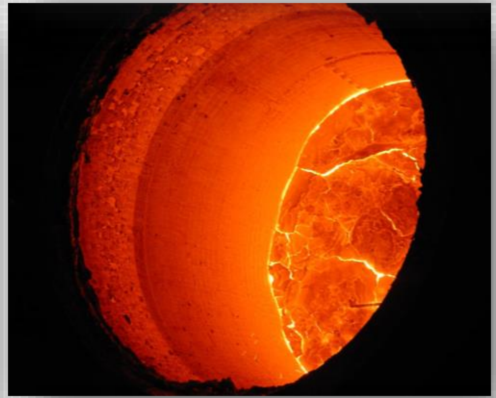
Temperatures

Liquid steel
1650 – 1550 °C

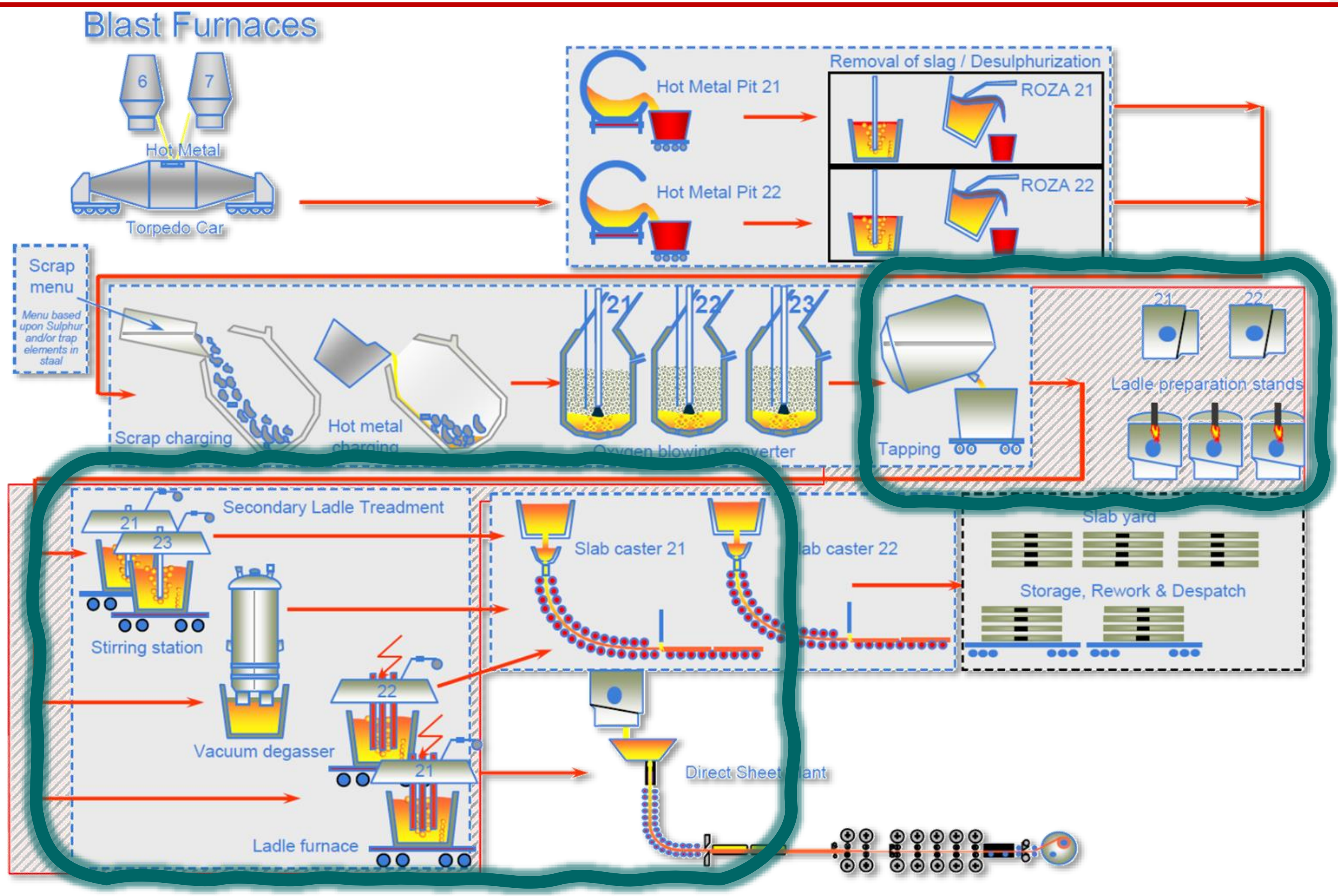
Shell
250 – 300 °C







Process flow BOS plant IJmuiden



Sensitivity: general

The value-in-use of steel ladles

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Value-in-use…
is it a new concept?

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STATE OF THE ART IN STEEL PLANT REFRACTORIES

Throughout the 70's, the refractory industry provided the steelmaker with a variety of ever improving and sophisticated products. As these new and frequently more expensive products came to the forefront, the industry began to do a better job of looking at the overall value of a refractory as a part of the total cost system. The use of this system concept allowed trials of many of the new products brought into the marketplace during that period. That system is centered around a straightforward equation that will remain the method of evaluation. The equation can be written in the following manner:

$$\boxed{S = Pr + Ci + Qs + CCo}$$

where

- S = Refractory System Success
- Pr = Refractory Price
- Ci = Cost of Installation
- Qs = Impact on Steel Quality
- CCo = Contribution to Continuous Operation

Michel Rigaud, 1987

Cost/savings affecting the value-in-use of a steel ladle

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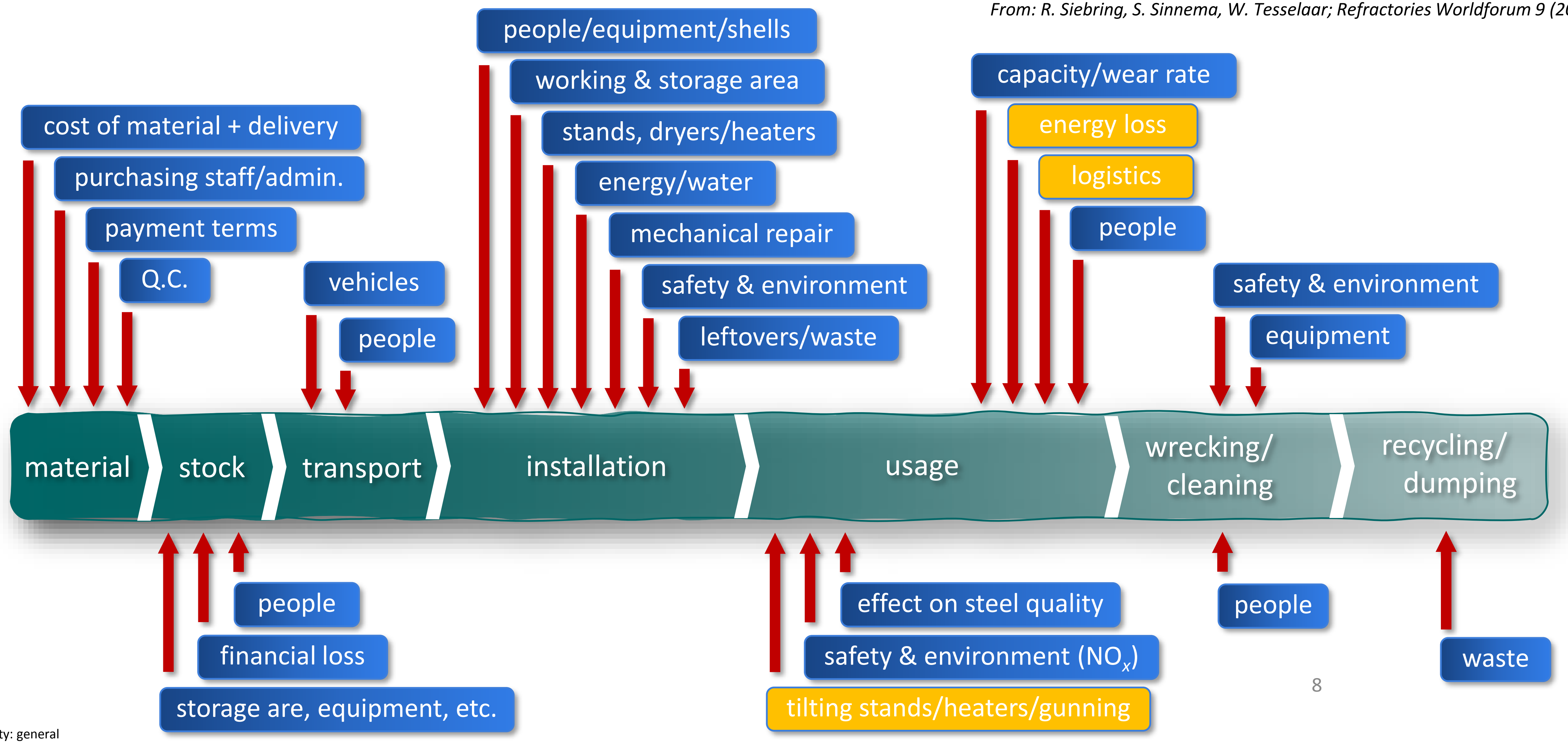
From: R. Siebring, S. Sinnema, W. Tesselaar; Refractories Worldforum 9 (2017).



Economic model of the steel ladle

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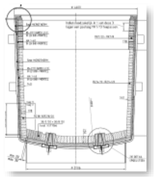
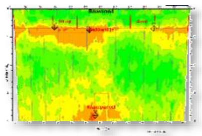
Economic model

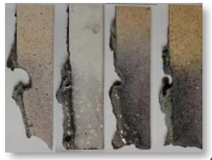
Ladle design



Refract. wear → ladle life

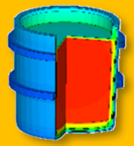


Material properties



Install. costs
Repair freq.

Effect steel temperature



Refractory costs

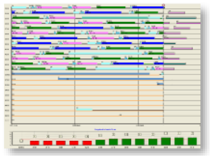
€

Savings for extra t & T

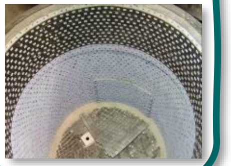
€

Ladle safety

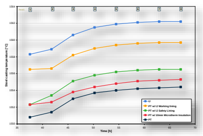
Ladle availability



Total refractory costs



Steel temperature



Ladle volume

From: R. Siebring, S. Sinnema, W. Tesselaar; Refractories Worldforum 9 (2017).

Cost/savings affecting the value-in-use of a steel ladle

Process benefits

- Reliability (predictability, safety)
- Steel quality
- Capacity benefits
- Steel energy loss

40 %

Related costs

- Purchasing, QC, R&D and storage
- Drying/heating
- Breakouts/incident repairs
- Mechanical repairs
- Health, environment and safety actions

30 %

Direct costs

- Refractory materials
- Transport supplier to steel works
- Installation of refractories

30 %

From: R. Siebring, S. Sinnema, W. Tesselaar; Refractories Worldforum 9 (2017).

Thermal efficiency of steel ladles

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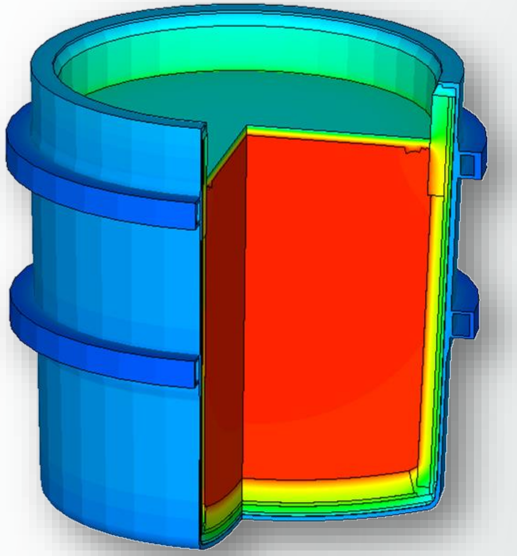
Thermal efficiency of the steel ladle

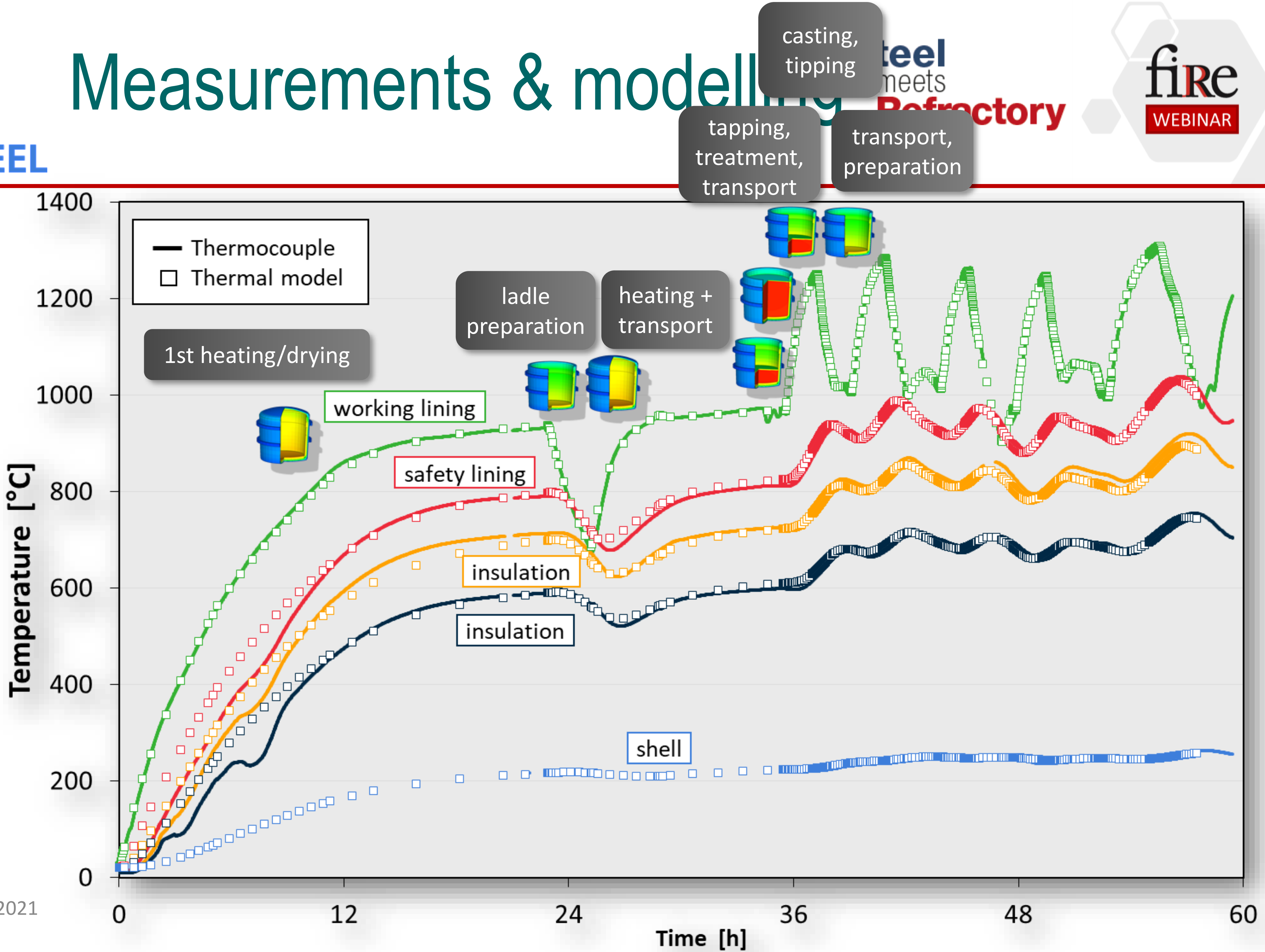


Thermal efficiency: ***Energy efficiency*** and ***Process efficiency***

- Comparing designs/materials
- Influence of process (empty, full, lidding): process management
- Understanding: what happens why and when…

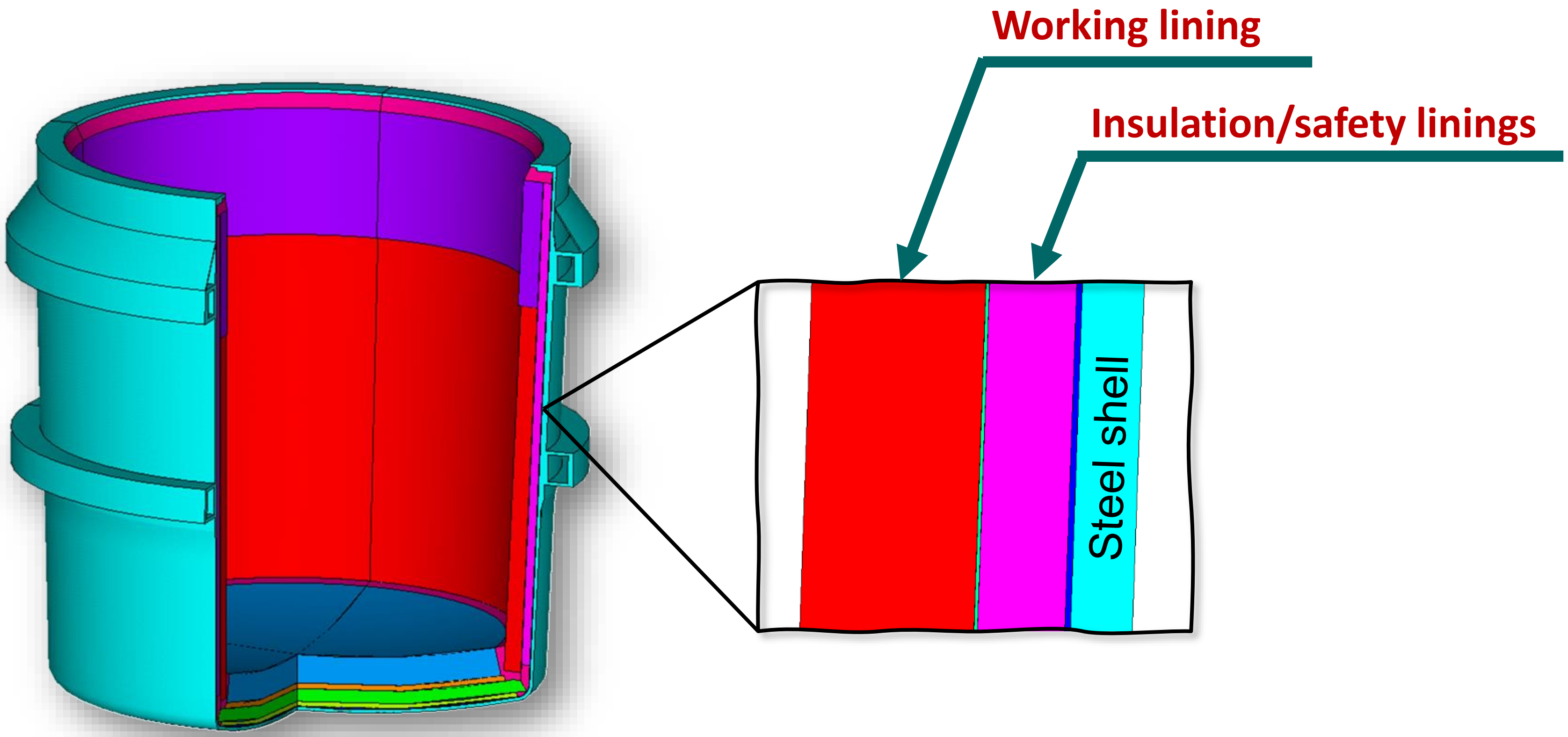
☝ *More to it than putting in more insulation; be open to the idea that things can be much more complicated than you would expect at first sight*

Measurements & modelling



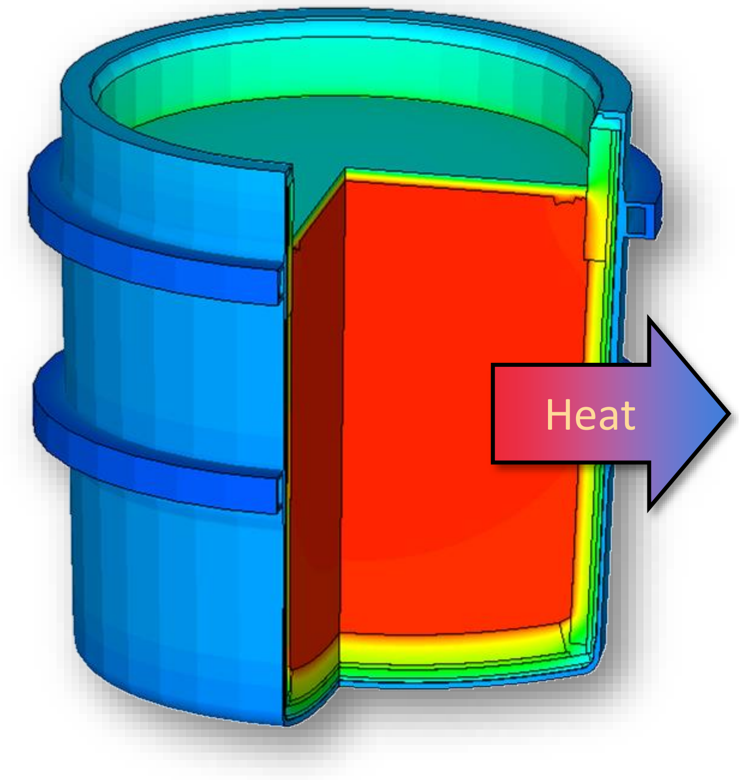
The IJmuiden vs. Port Talbot steel ladle

The IJmuiden vs. Port Talbot steel ladle



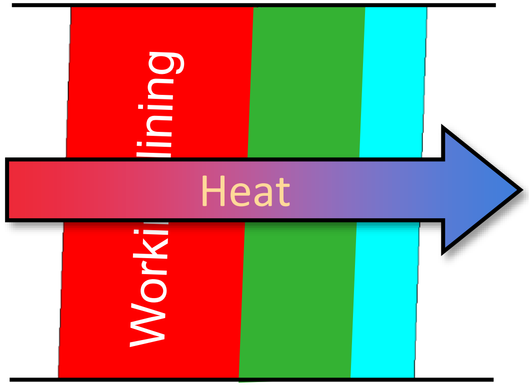
- *Reduce* **steel temperature losses** between converter and casting
- *Port Talbot losses are* **~10 °C higher** than IJmuiden under similar conditions
- The '*value*' of **1 °C** steel temperature is **~350 k€/year** for IJmuiden

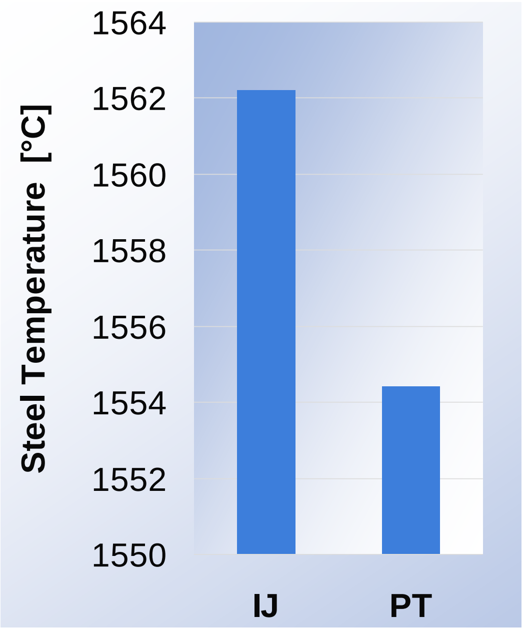
The IJmuiden vs. Port Talbot steel ladle



R_{PT} = 25
R_{IJ} = 44

R_{PT} = 75
R_{IJ} = 108

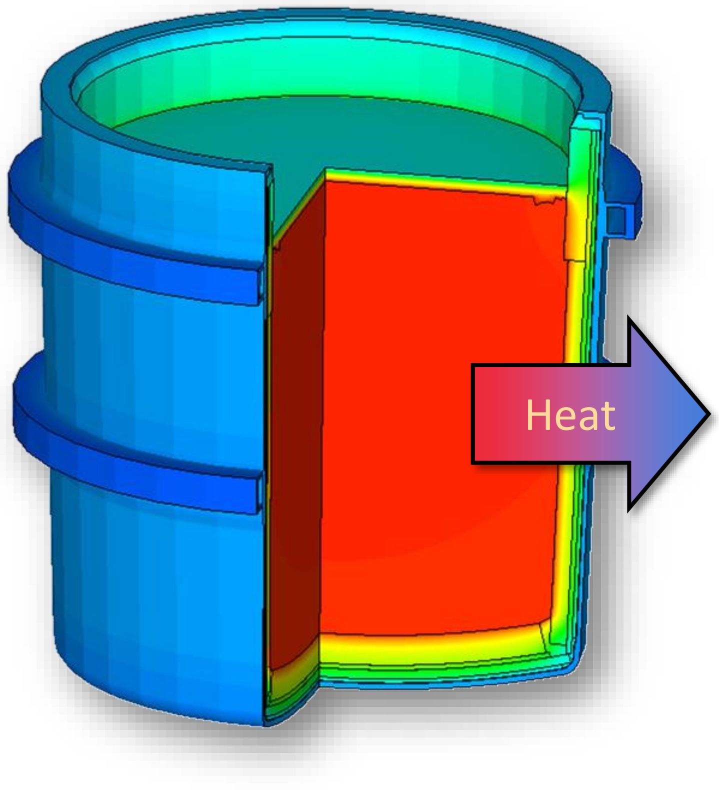




Thermal resistance $R(\boldsymbol{\lambda})$ in [mK·m^2/W]

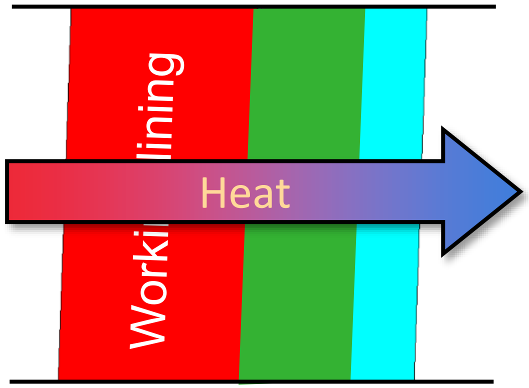
Sensitivity: general

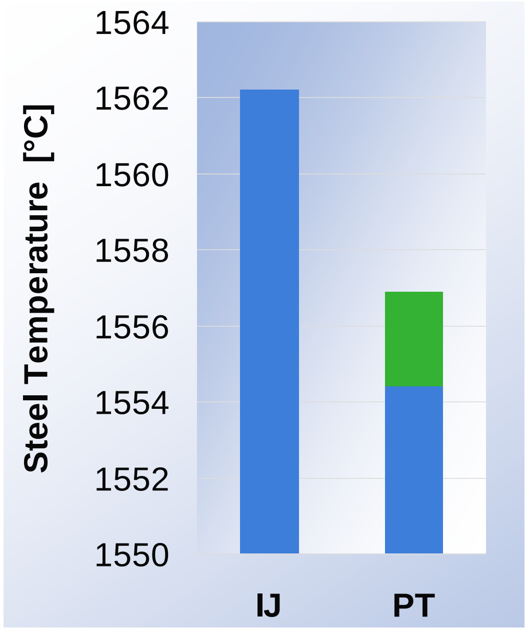
The IJmuiden vs. Port Talbot steel ladle



R_{PT} = 25
R_{IJ} = 44

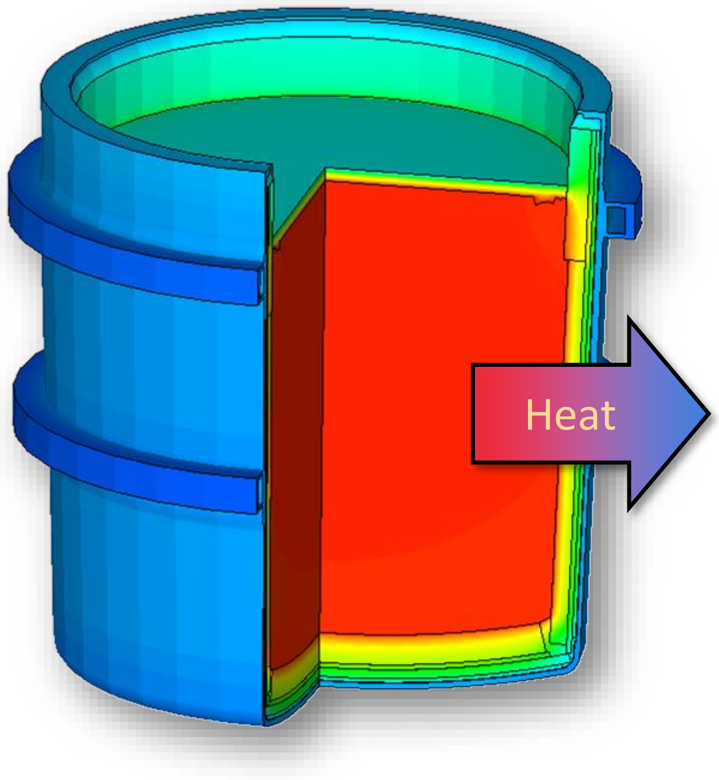
R_{PT} = 108
R_{IJ} = 108





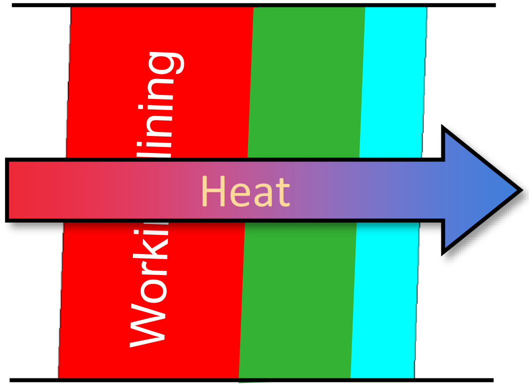
Thermal resistance $R(\boldsymbol{\lambda})$ in [$mK \cdot m^2/W$]

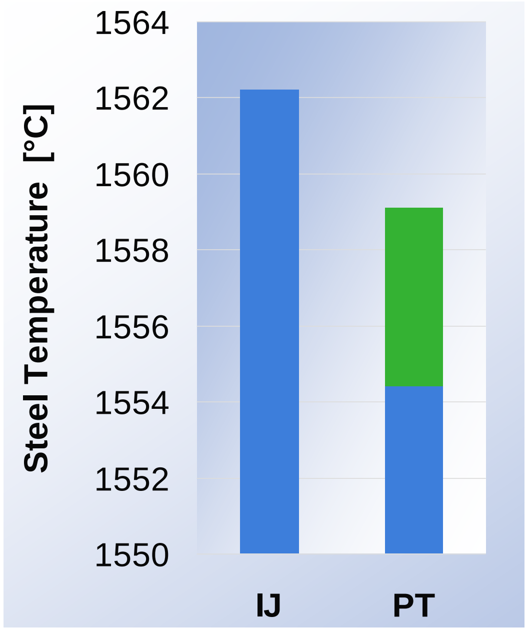
The IJmuiden vs. Port Talbot steel ladle



R_{PT} = 25
R_{IJ} = 44

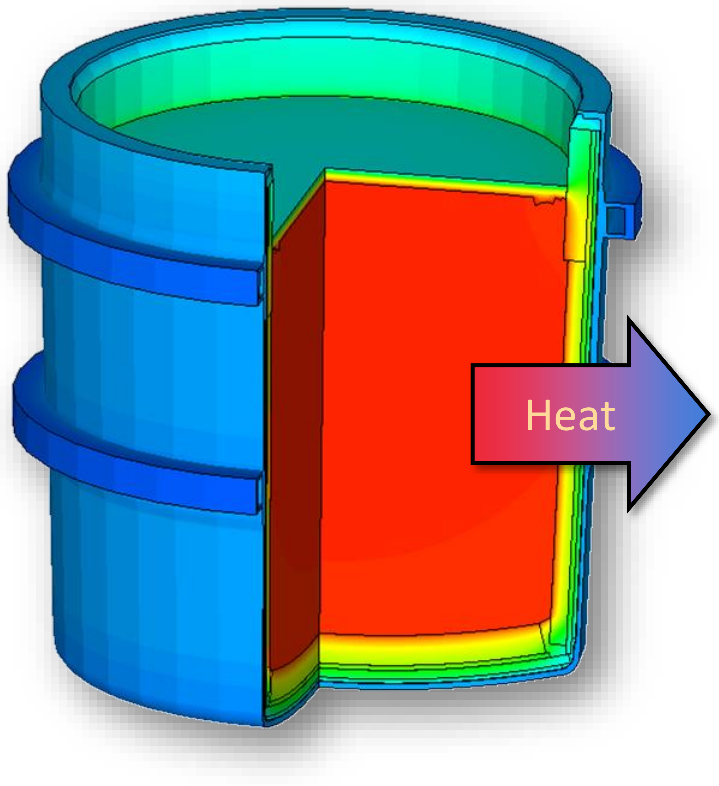
R_{PT} = **200**
R_{IJ} = 108





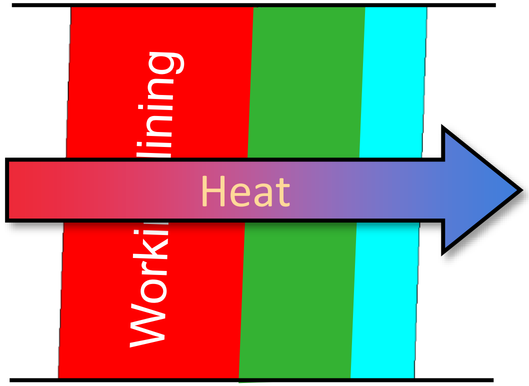
Thermal resistance $R(\boldsymbol{\lambda})$ in [mK·m^2/W]

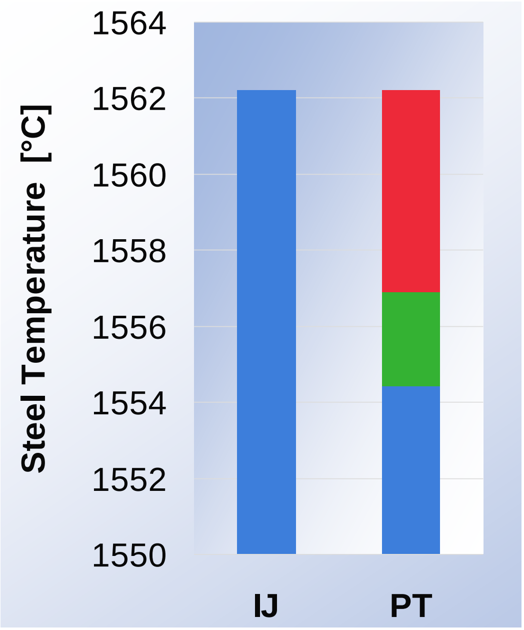
The IJmuiden vs. Port Talbot steel ladle



$R_{PT} = 44$
$R_{IJ} = 44$

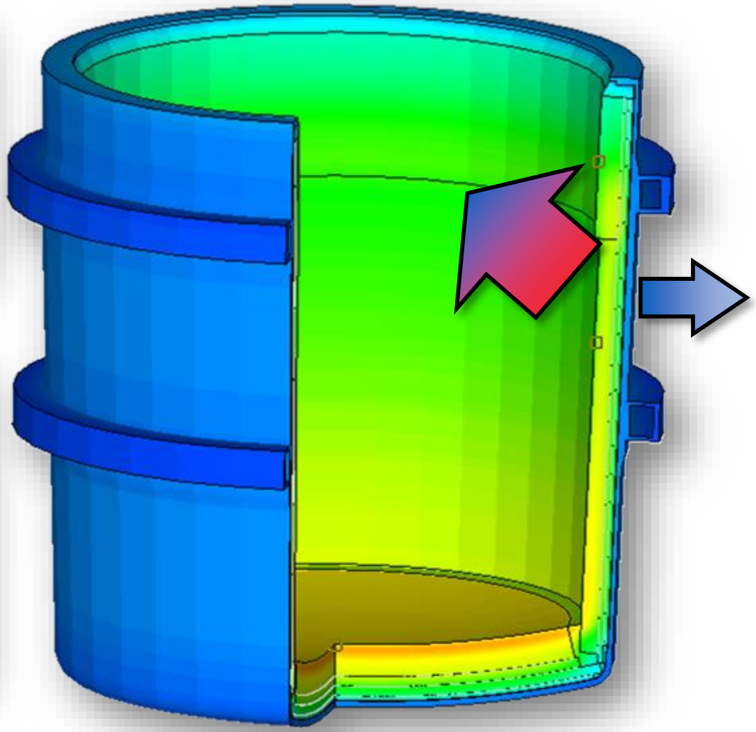
$R_{PT} = 108$
$R_{IJ} = 108$

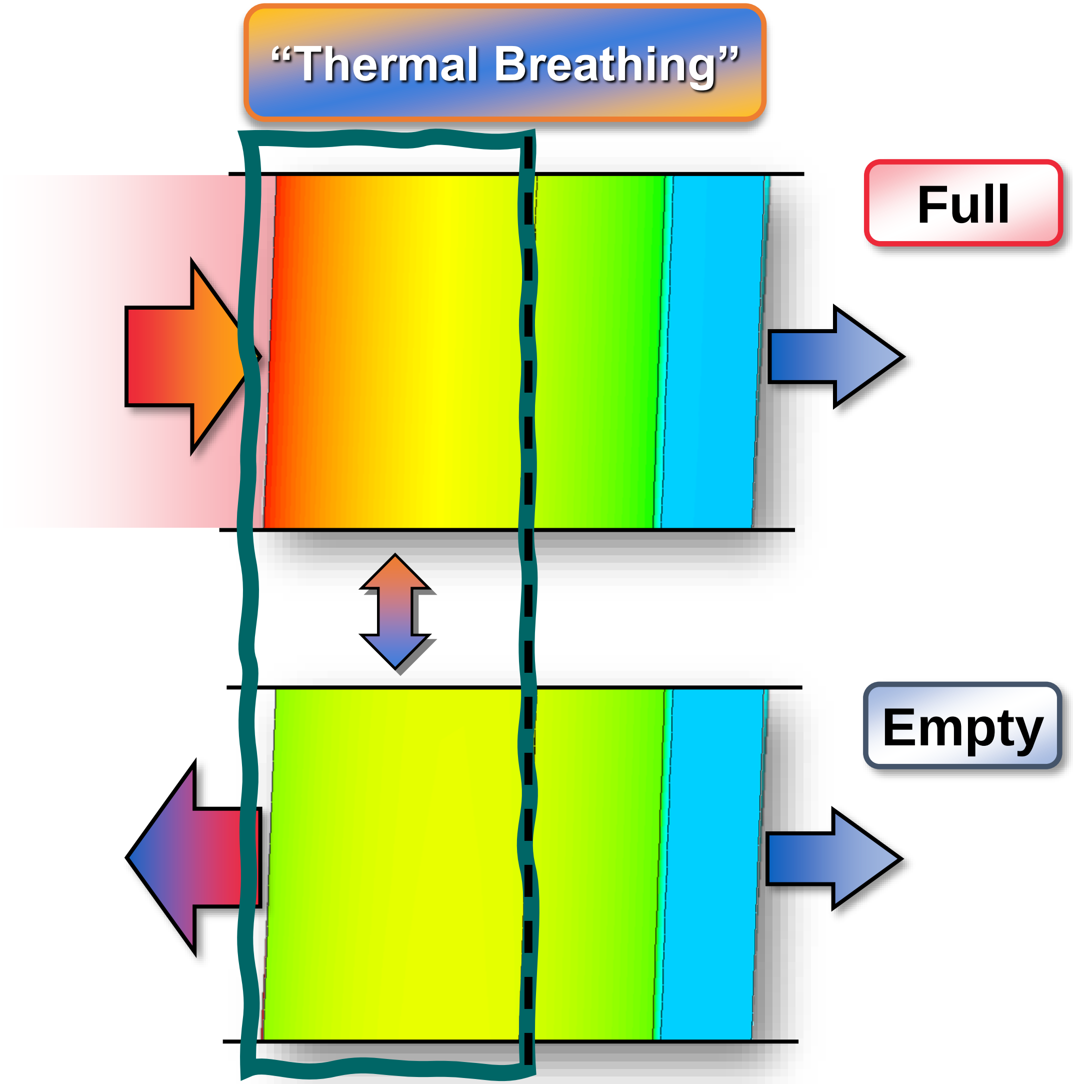




Thermal resistance $R(\boldsymbol{\lambda})$ in [mK·m^2/W]

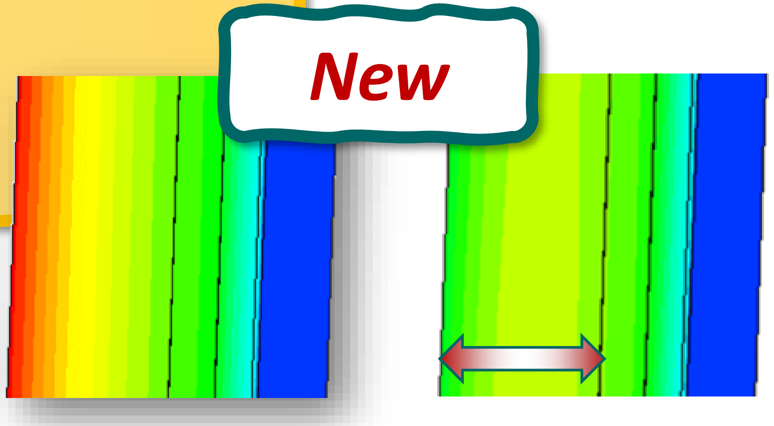
The IJmuiden vs. Port Talbot steel ladle



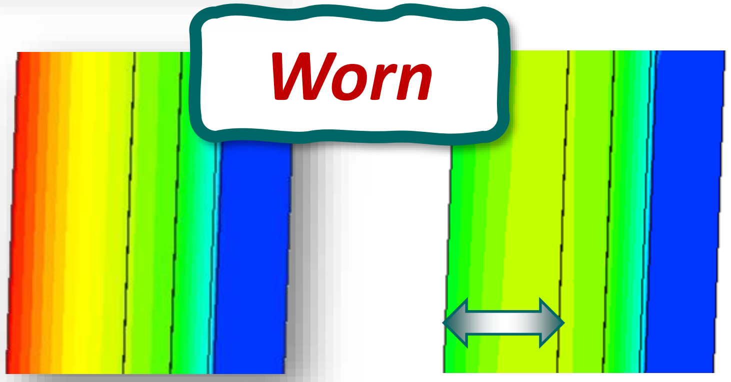


Thinner (worn) working lining, better thermal efficiency

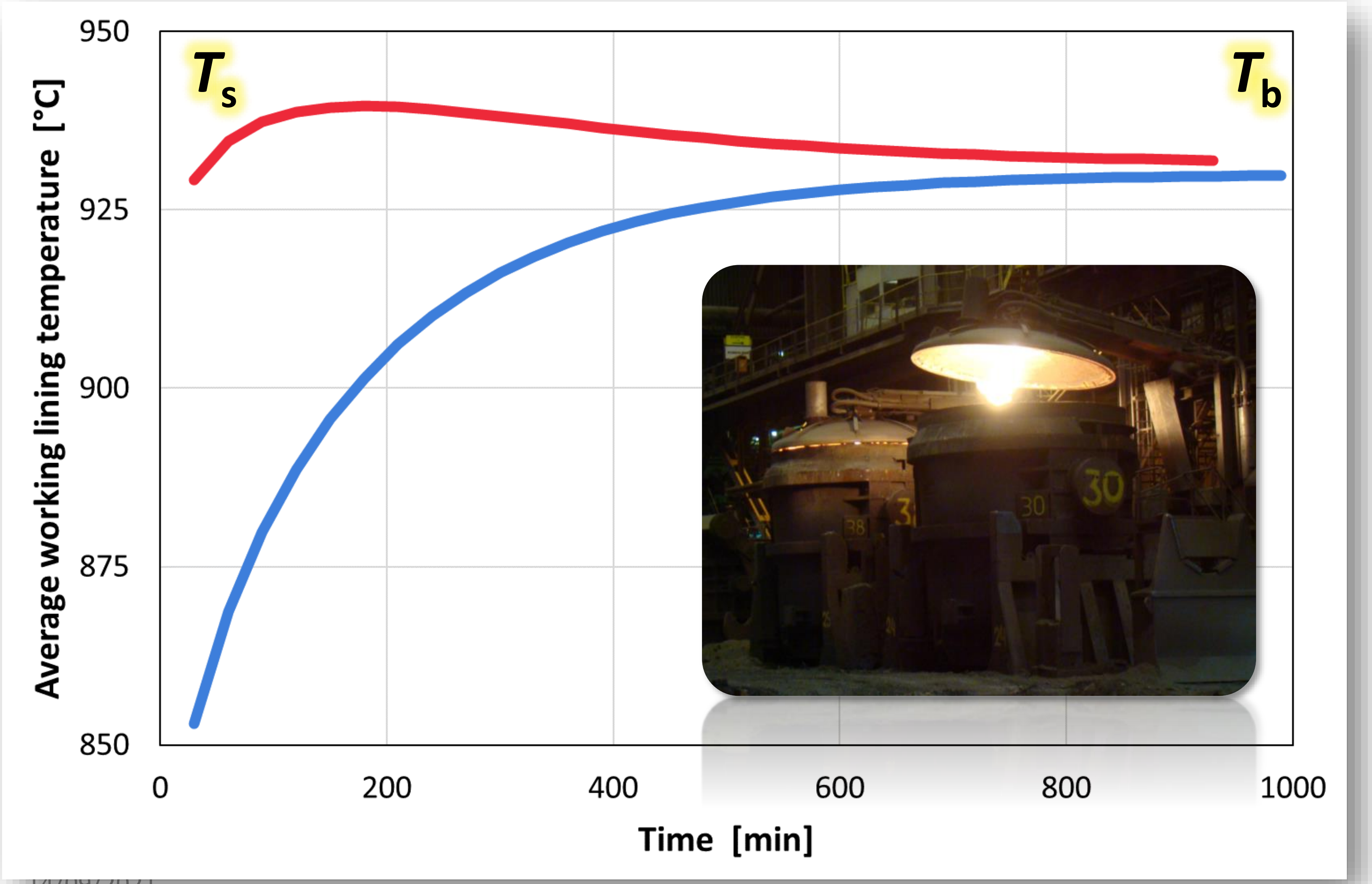
*"What did you just say? A **thinner** working lining means a **better** thermal efficiency??*
What the …!?"

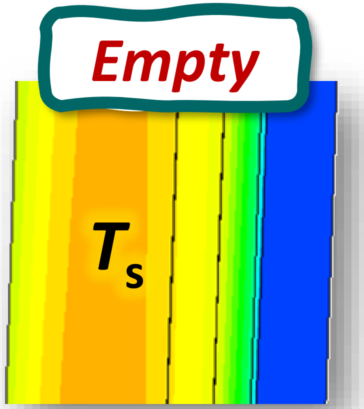


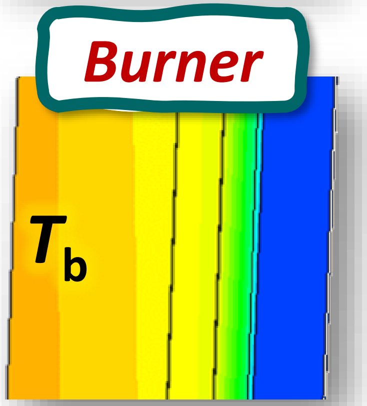
- **Two reasons:**
  1. ***Larger* ladle volume** (more liquid steel)
  2. ***Less* thermal mass** to be heated



Use a burner to prevent cool down?







Epilogue

Concluding…

- The ***economics of refractories*** is **more than just the refractory costs** or even the refractory costs per tonne of steel
- ***Energy efficiency*** is **not just about putting in more insulation**!
- The ***thermal behavior*** of something as (seemingly) 'simple' as a ***steel ladle*** appears to be **surprisingly complex**: sometimes straightforward and sometimes an intriguing eye-opener or even counter-intuitive
  - ➡ A steel ladle is *not* simple!
- ***Thermal modelling*** is a **vital tool** to a complete and comprehensive **value-in-use model** for the steel ladle (or any other steelmaking installation)