



Institute Of Refractories Engineers

IRE Training Day

Explosive Spalling

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1



Institute Of Refractories Engineers

- **What is Explosive Spalling**
- **How to reduce the risk of Explosive Spalling**
- **Control of Dry Out procedure**

2



What is Explosive Spalling

When a refractory castable is installed, the castable is mixed with water to achieve a fluid consistency. This allows the mix to flow into the required shape.

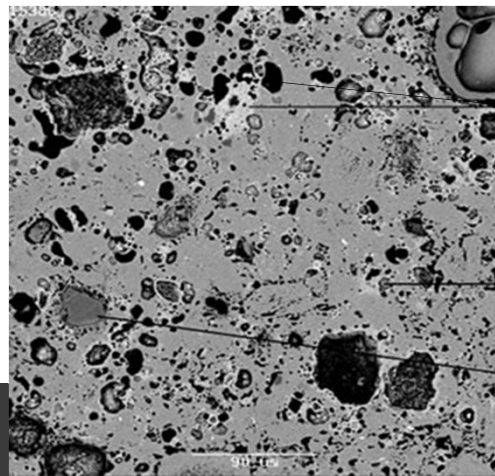
Before the castable can go into service the water must be removed.

Explosive spalling can occur during the drying procedure, when water inside a castable is allowed to turn into steam within the pores. In turn, as the steam pressure increases with temperature, it can eventually overcome the strength of the castable.

3



Explosive Spalling - Porosity



- Closed Porosity
Can be in the region of 10 to 20%

4



Explosive Spalling - Strength

In the green state, the compressive strength of a typical refractory castable is in the range of 10 to 40 N.mm⁻²

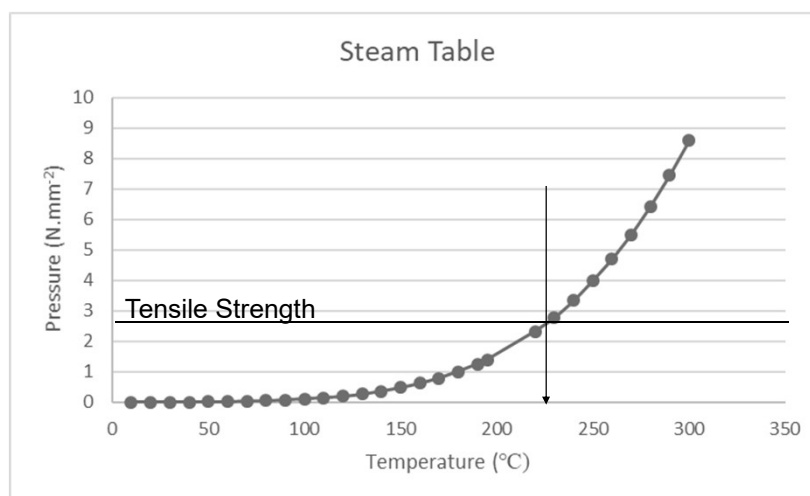
However

The tensile strength of these castables is in the range of 1.2 to 2.7 N.mm⁻²

5



Steam Pressure



6



Explosive Spalling



7



Explosive Spalling

- Can we reduce the risk of explosive spalling?
- Yes
- Introduce Permeability to the structure

8



Explosive Spalling - Permeability

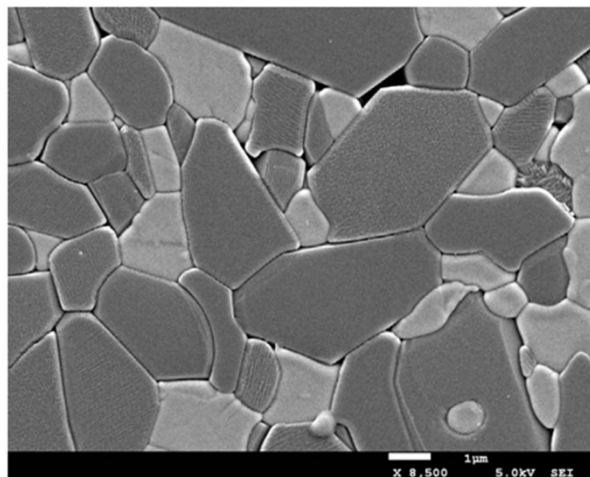
- **Permeability is the measure of a materials ability to allow fluids to pass through them**



9



Explosive Spalling - Permeability



10



Controlled Permeability

The permeability of a cast shape can be increased by using an addition of

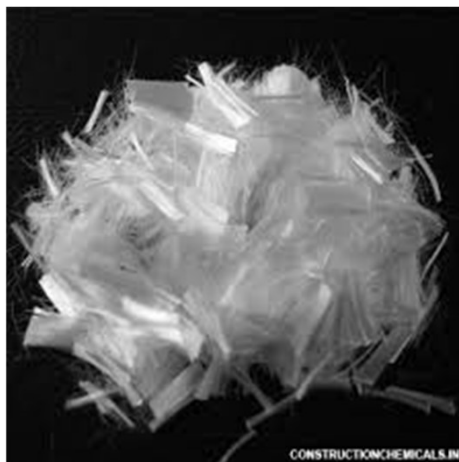
- **Plastic Fibers (+0.05%)**
when heated to 100°C the fibers melt leaving a network of tubes which connect with the pores

11



Polypropylene Fibres

Fibres are available 15 to 50µm diameter



12



Controlled Permeability

- **The permeability of a cast shape can be increased by using an addition of**
- **-64µm Aluminium Powder (+0.3%)**
the aluminium powder reacts with the water and forms Hydrogen gas. The gas pushes through the castable during the setting process leaving a network of passages

13



Explosive Spalling - Permeability

Any problem with using Hydrogen to create Permeability?



There would be about 30kg of Aluminium used in a 10t casting

This would equal approximately 37,000 litres of Hydrogen Gas

14



Refractory Castable – Cement Bonding

- Refractory castable usually contains “Calcium Aluminate Cement” to impart a set and green strength to the final shape.
- The strength develops as a result of the cement reacting with the water to form several crystalline and gel hydrates which lock the structure together.
- The castable also contains an amount of free water

15



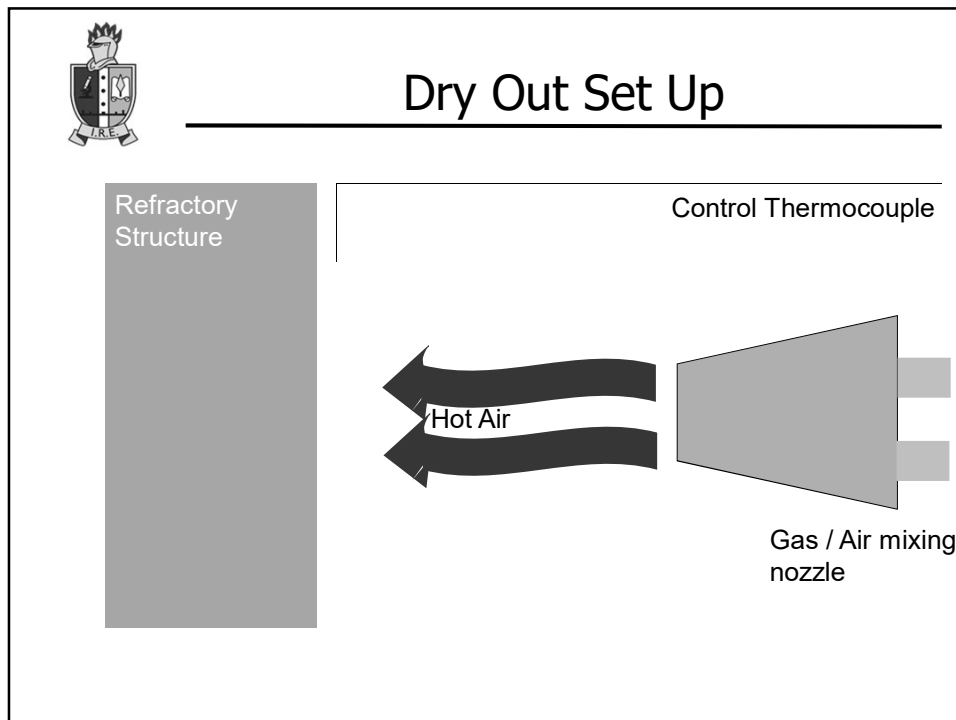
Water Removal

- The free water will eventually be driven off by holding the castable at a temperature of 110°C
- The products of hydration have higher dehydration temperatures

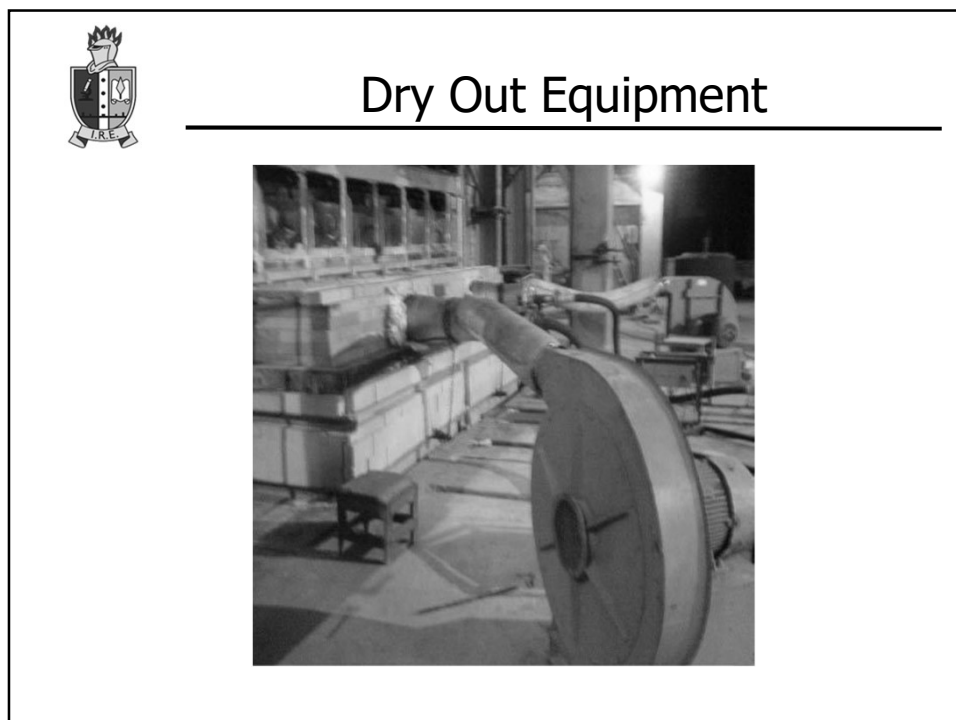
Hydrate	CAH ₁₀	C ₂ AH ₈	AH ₃	C ₃ AH ₆
Formation Temperature °C	<20	20 – 30	>40	>30
Dehydration Temperature °C	100 – 130	170 – 195	210 – 300	300 – 360

→ C₃AH_{1.5} dehydrates at > 500°C

16



17



18



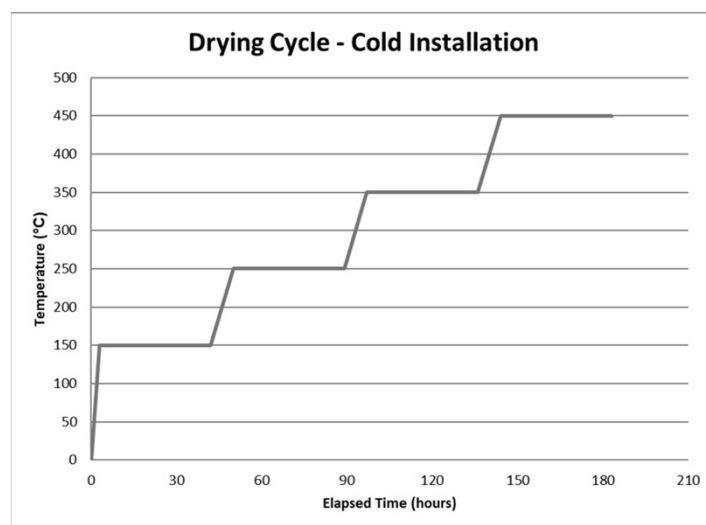
Typical Dry Out Procedure

Function	Time (hr)	Elapsed Time (hr)	Temperature (°C)	Heating Rate (°C/hr)
Start		0	0	
Heat	3	3	150	50
Hold	39	42	150	
Heat	8	50	250	12.5
Hold	39	89	250	
Heat	8	97	350	12.5
Hold	39	136	350	
Heat	8	144	450	12.5
Hold	39	183	450	

19



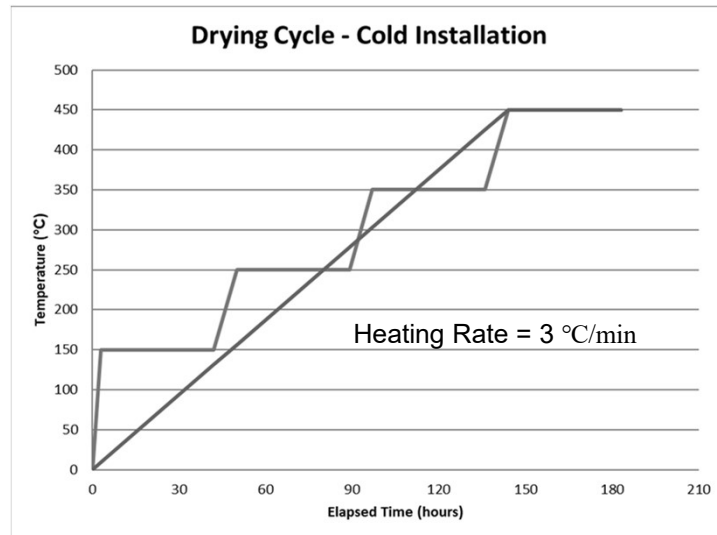
Dry Out Curve



20



Modern Dry Out Curve



21



Explosive Spalling - Conclusions

- **Refractory castables are a quick solution for the installation of complicated shapes**
- **Closed porosity is inherent in castables**
- **Permeability can be increased by the addition of Plastic Fibers and/or Aluminium Powder**
- **Controlled dry-out is the key to successful Drying**

22



Explosive Spalling

Thank you for your attention