Institute of Refractories Engineers

Design

The Good and The Bad

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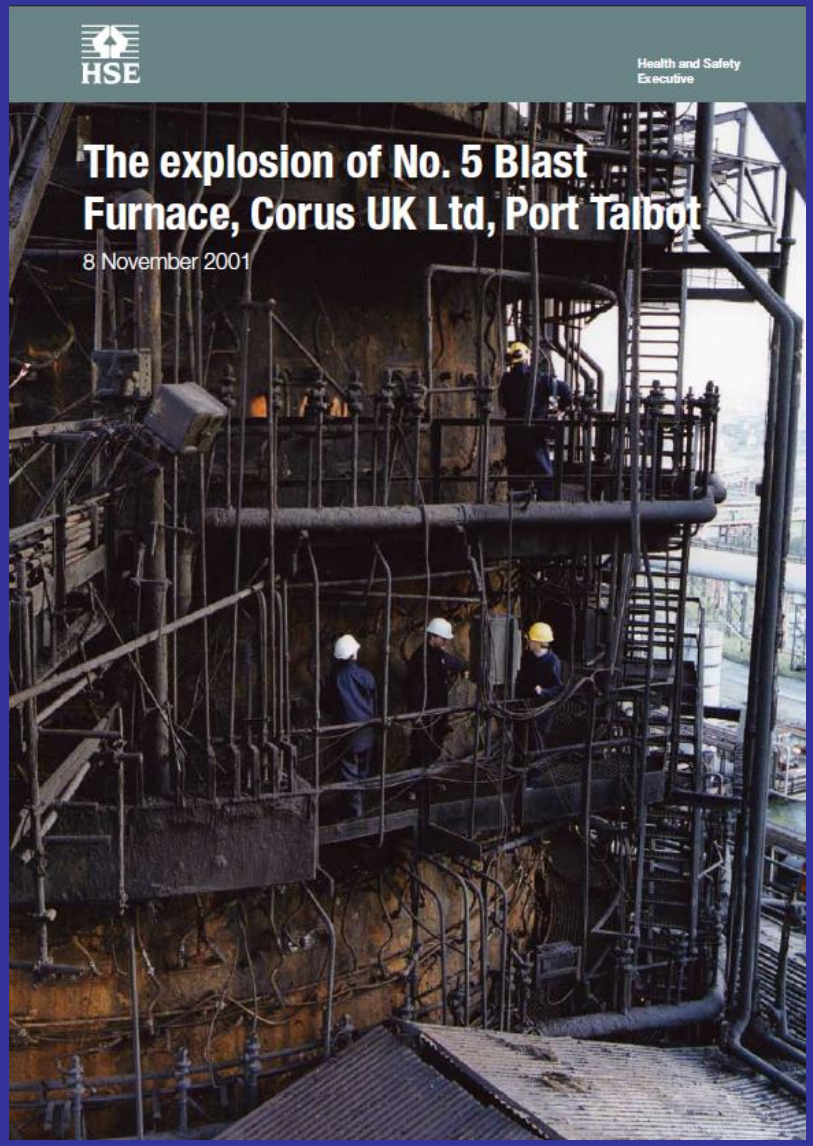
Consequences of Failure

Refractory Failure can lead to

- Loss of Containment of
  - Hot Gas, Liquid and Solid
  - Loss of Pressure Containment
  - Escape of Toxic Materials

- Loss of Production
- Damage to Capital Plant
- Environmental Damage
- Injury and Death



Material Selection

Thermal

- Temperature Gradient
- Temperature cycles

Mechanical

- Abrasion
- Vibration
- Stress

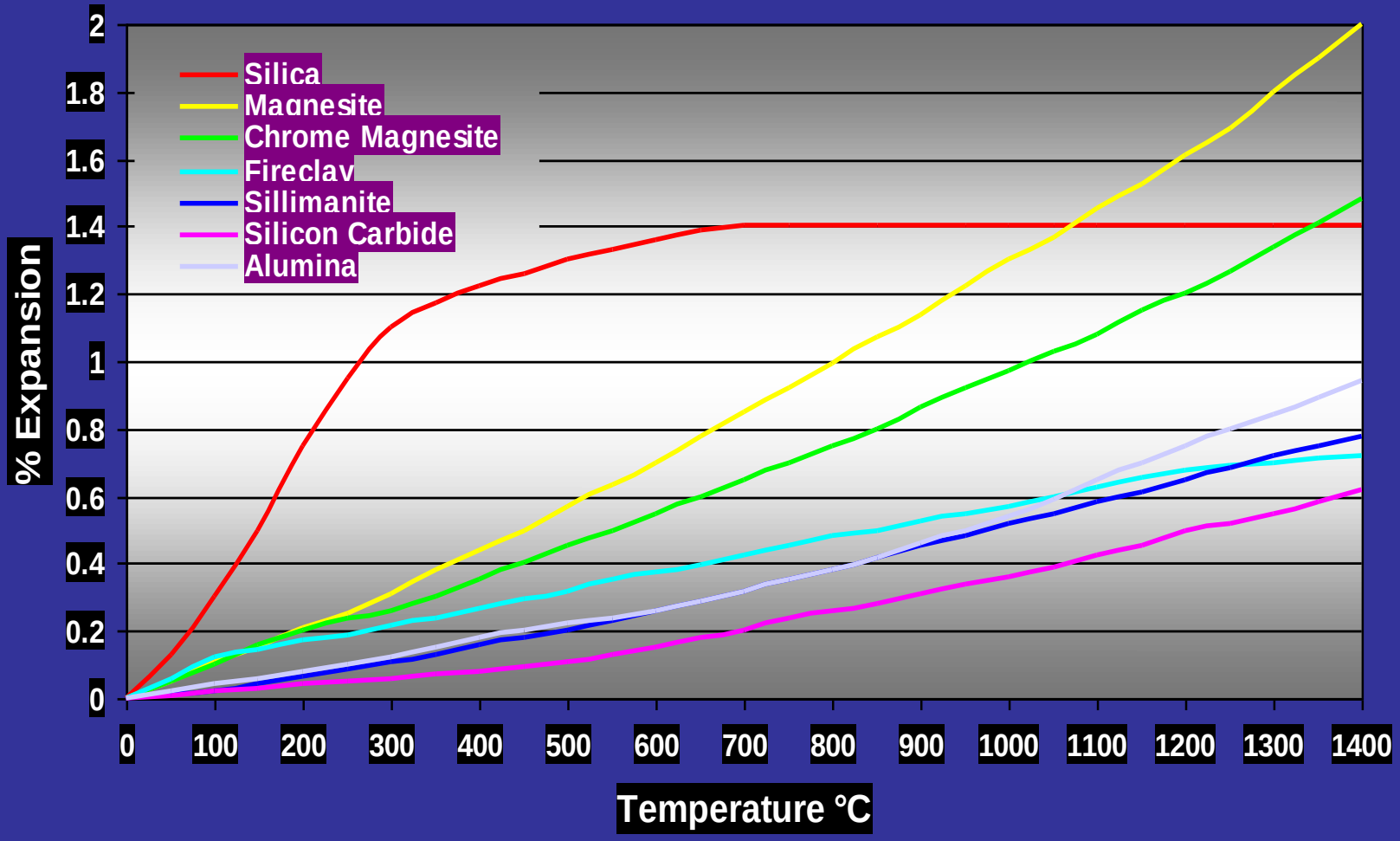
Chemical

Corrosion from hydrogen	Reducing Atmosphere	Gases

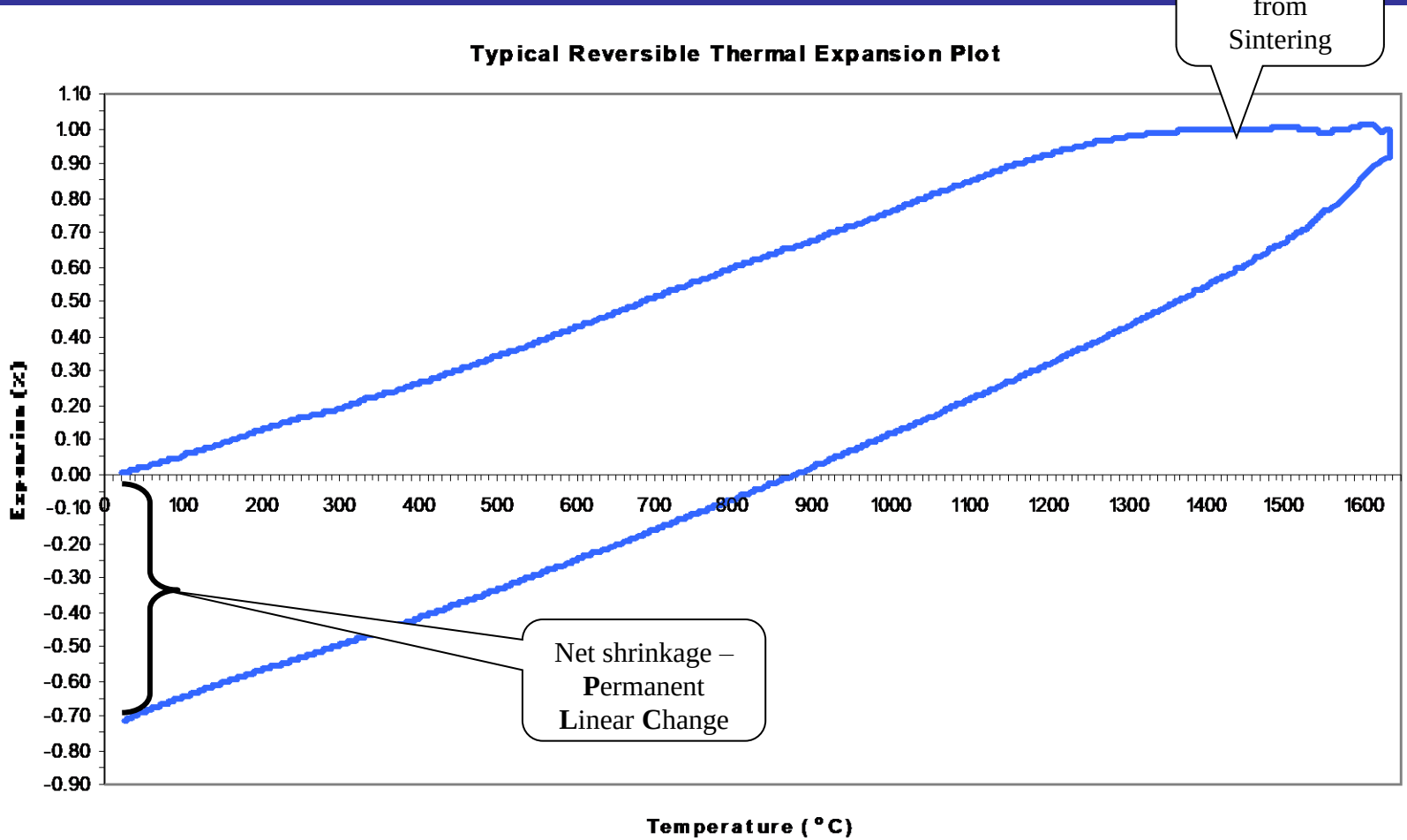
Thermal Expansion

- A Material Property – independent of shape
- $cte = \frac{\Delta L}{L} . \frac{1}{\Delta T}$
- ΔL is change in length (expansion)
- ΔT is temp change
- $\Delta L = cte . L . \Delta T$

Thermal Expansion



Thermal Expansion and Permanent Linear Change



Thermal Expansion

Consider a duct 10m long, 2m dia lined with 230mm thick fireclay brick at a temperature of 1000°C. Elastic Modulus is ~ 20 Gpa.

- Thermal expansion is 55mm.
- Restraining force for zero movement – 28,000tonnes

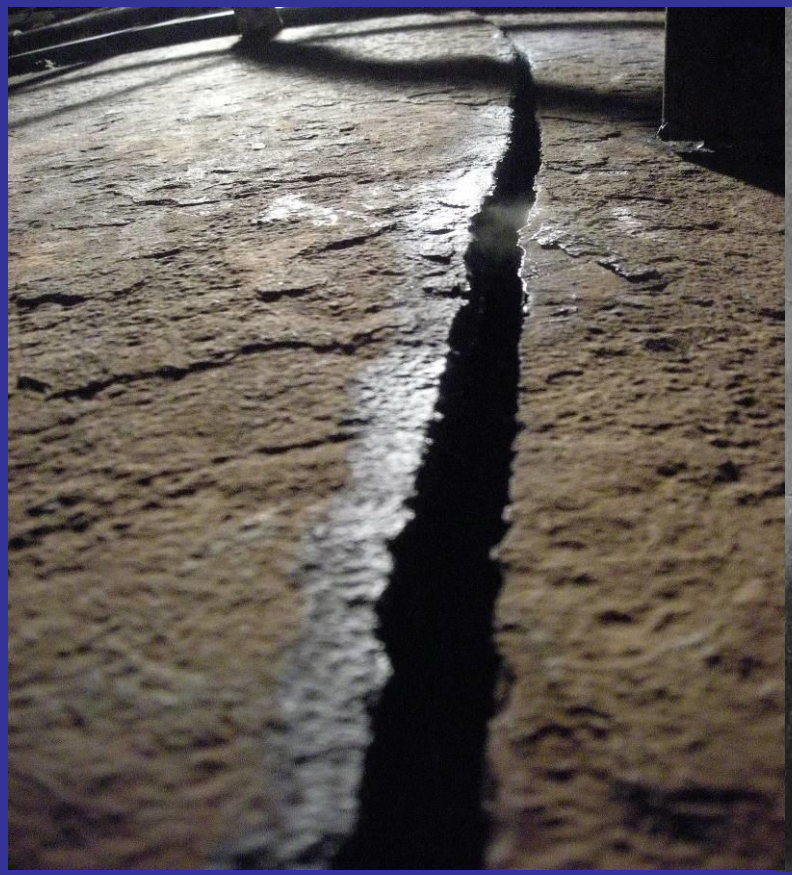
Thermal Expansion

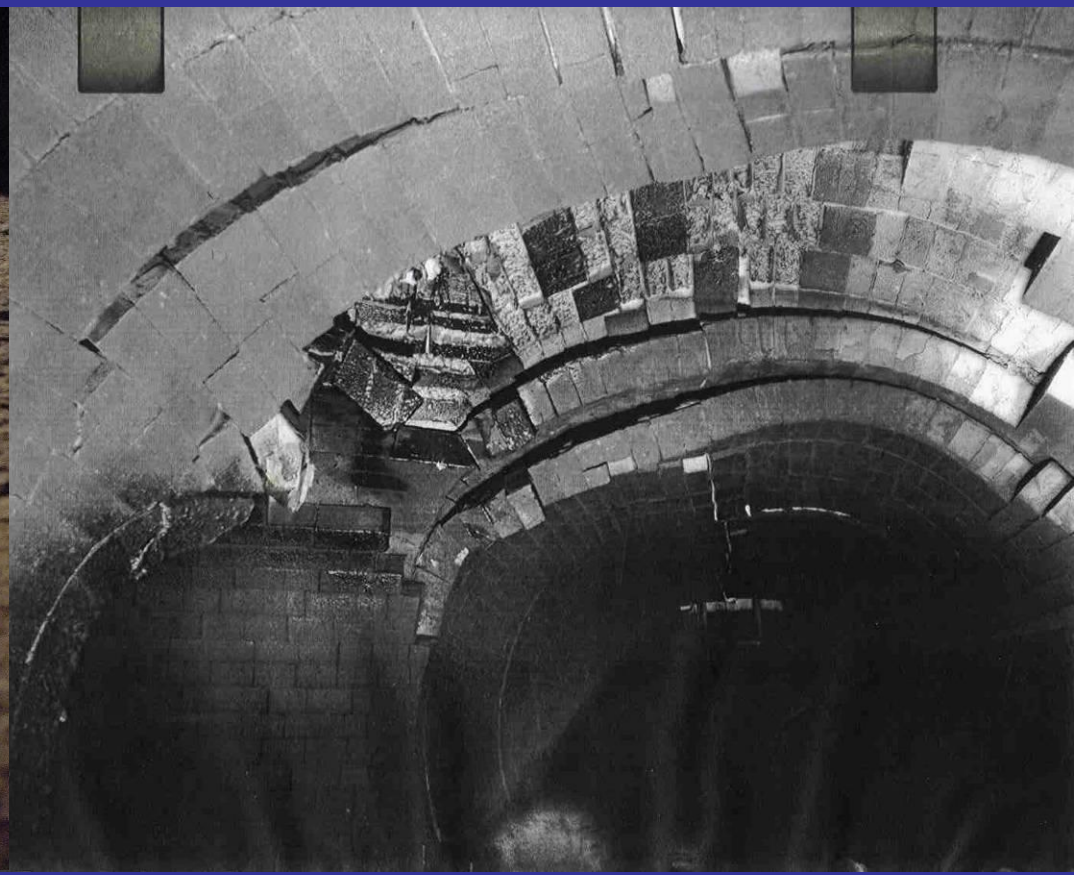
If the unstoppable force meets the immovable object, something gets broken.

- Splitting of shell
- Weld failure
- Flange bolts stretch
- Shell Yields
- Insulation crushed
- Lining spalls

It is essential to make a suitable allowance for thermal expansion in any design. Several methods are commonly used.

Thermal Expansion





Expansion Allowance

Regular Gaps

- Leave gaps of pre-determined size
- These close up on heating
- Few, large gaps – typically 50mm

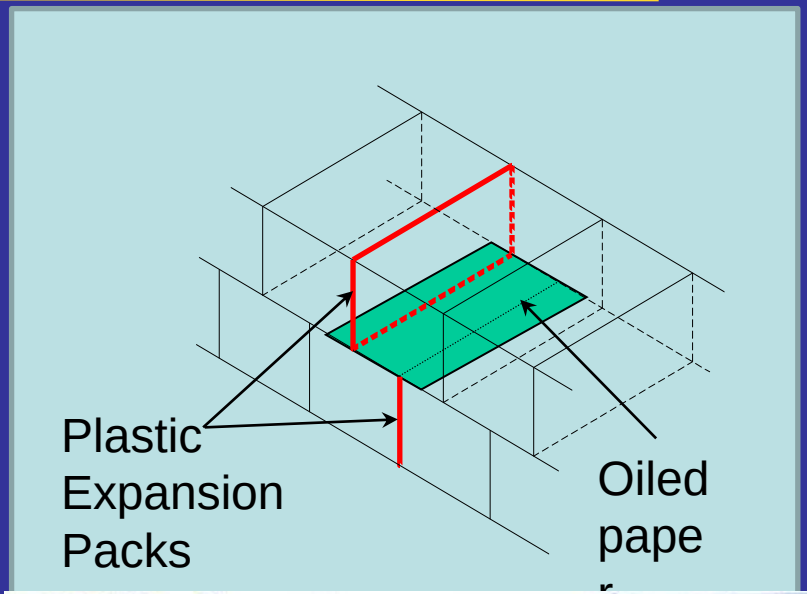
- What can go wrong?
- What happens at branches?

Expansion Allowance

Burn-Out packs

- Smaller gaps, placed more frequently
- Less risk of slipping

- What can go wrong?



Expansion Allowance

Compressible Layer

- Layer can be behind hot face or fill gaps
  - Can eliminate gaps in hot face
- Range of compressible materials
- Compression is PLASTIC

- What can go wrong?

Anchor Expansion

- Expansion of anchors can cause anchor to cracking
  - cte 310 = $18 \times 10^{-6}/°C$
  - cte 1600 castable ≈ $6 \times 10^{-6}/°C$
  - Anchor temp is higher than refractory temp

Design with Shaped Refractories

The last significant development in refractory design was made by the Romans

Arch Design

- An arch can span an opening and only has COMPRESSIVE FORCES
- In an arch there is a horizontal component of the force in the thrust line
- If the horizontal component is not constrained, the arch will collapse

- Circular lining is like an arch but 360°
- Where does the horizontal thrust go?

- Alternate view – the wedge shape keeps the bricks in.
- How to get the last brick in?
- Every Brick is a ‘Keystone’

- What load is placed on the vessel shell

Arch Construction

If the lining is not properly held in place, it will move and this causes problems

- Collapse
- Fluid Penetration

Local damage spreads

Bonding Bricks

- Bricks in cylindrical structures can be bonded to improve stability
- Two ways to bond the bricks

Ring-for-ring

Bonded

Branches and Openings

- Since every brick is a ‘keystone’, openings in the side of a cylinder remove the keystone.
- The larger the opening the bigger the problem
- Turbulence and abrasion can be worse in this area

Branches and Openings

- Brick Past Opening and Drill out
  - Simple design.
  - Hole size limited
  - Water to drill?
  - Where do joints lie?

Branches and Openings

- Special Brick/block
  - Simple design.
  - Can be built around instruments
  - Size limitations
  - Mould cost

Branches and Openings

- Monolithics
  - Simple
  - Why not use monolithic for whole lining? Is it OK in this area
  - Anchors and shuttering needed

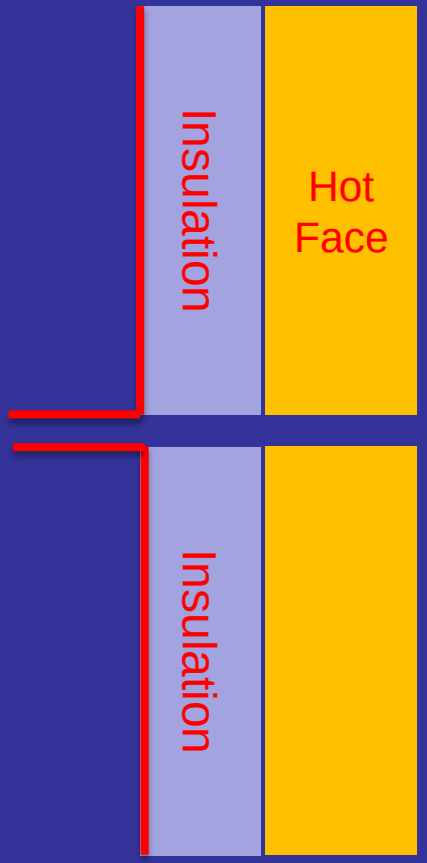
Branches and Openings

- Can use different solutions in combination
- Cut in at bottom
- Monolithic at top
  - Why?

Branches and Insulation

Poor Design

- Insulation is exposed to process fluids
- Weld on shell exposed to radiant heat
- Gas tracking through porous insulation?
  - Risk of hot spot



Monolithic Linings and Anchors

- Metal Anchoring
  - Rod Anchors
  - Mesh
  - Cells & Steel Dividers
- Ceramic Anchors

Branches and Insulation

Solution

- Carry insulation and/or dense lining into branch
- Shell is fully insulated
- Can prevent gas tracking

- Larger branch and flange

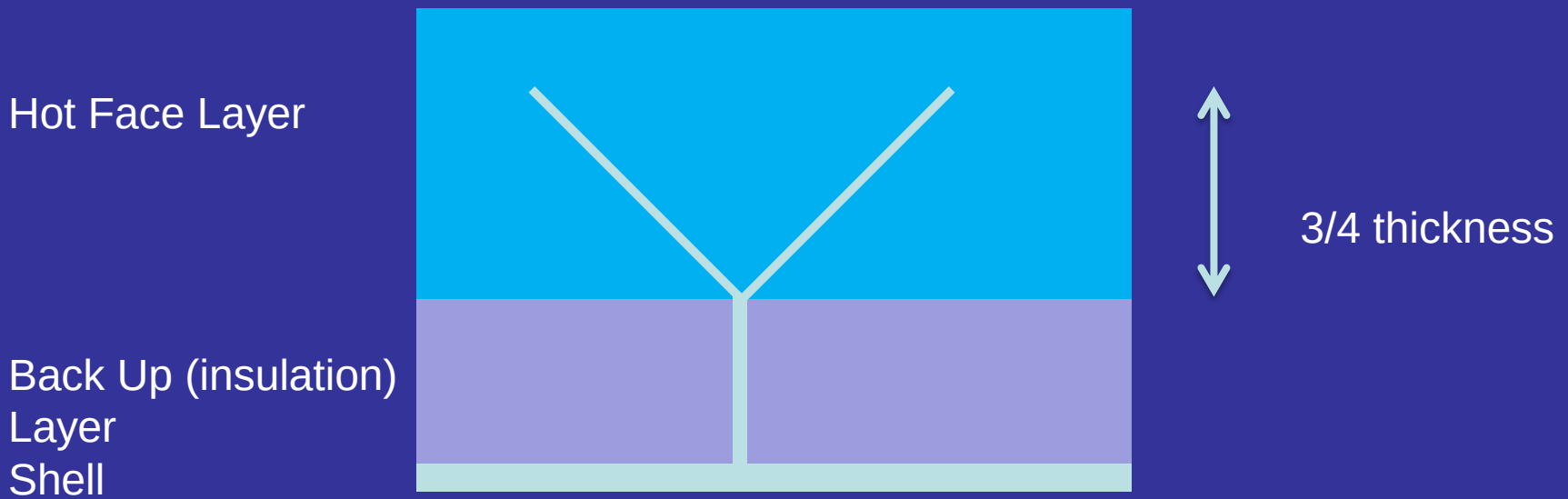
Monolithic Linings and Anchors

Anchor Pitching

Need to AVOID a regular array with possibility for long straight cracks

Monolithic Linings and Anchors

- Hex mesh, Speed Cells, K Bars – through to hot face
- Ceramic Anchors- through to hot face
- Metallic Anchors – approx 2/3 of hot face thickness



Thank You For Your Attention