



Blast Furnace Cooling Stave Design

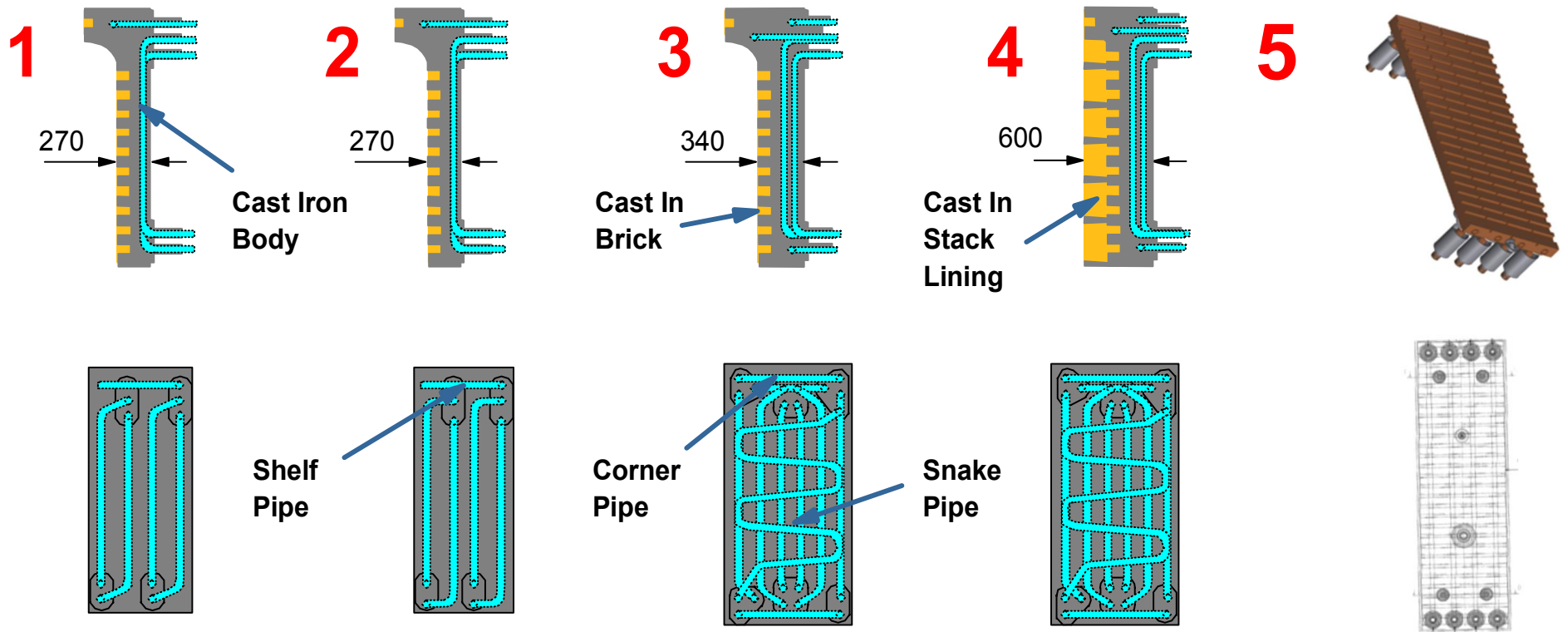
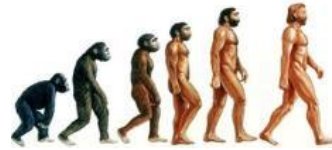
ECIC 12th – 14th September 2016

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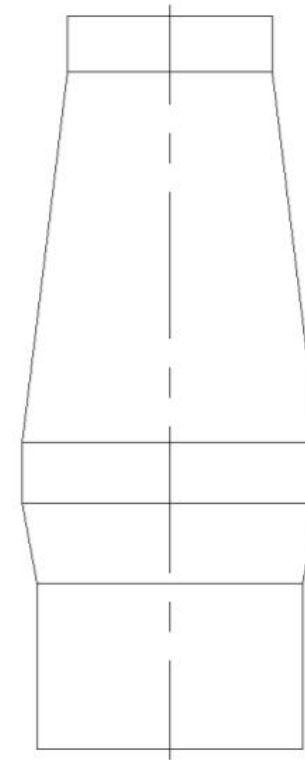


Introduction – Stave Evolution



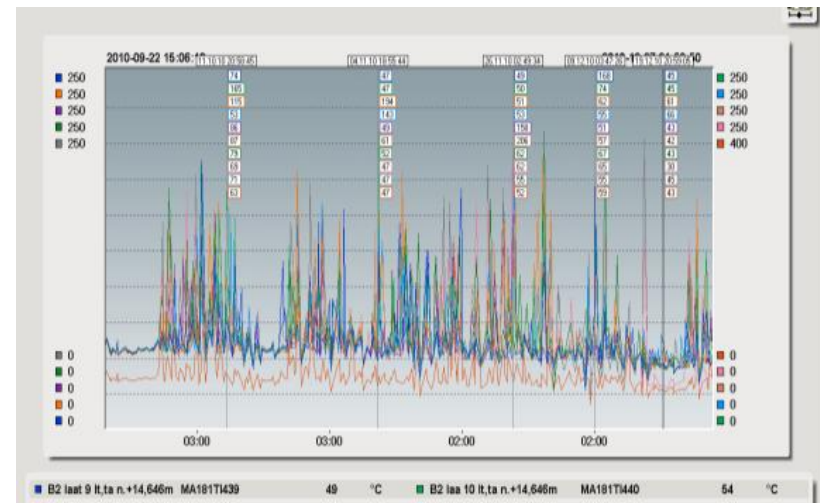
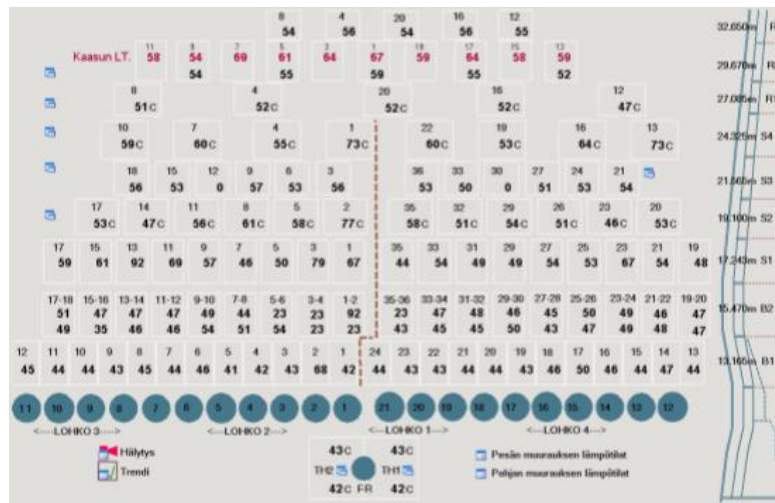
An Ideal World – Designing a new blast furnace

- Bosh and Hearth = corrosive liquids
- Upper Stack = Solids – Cast Iron for Erosion
- Lower Stack = Cohesive Zone – Copper for accretion layer
- Physical and Chemical properties of Burden
- Low Chlorine, Zinc and Alkalis
- High automation level
- Optimise burden distribution and gas permeability
- Sufficient drainage in the hearth
- **Optimised cooling system**
- **Correct furnace profile**



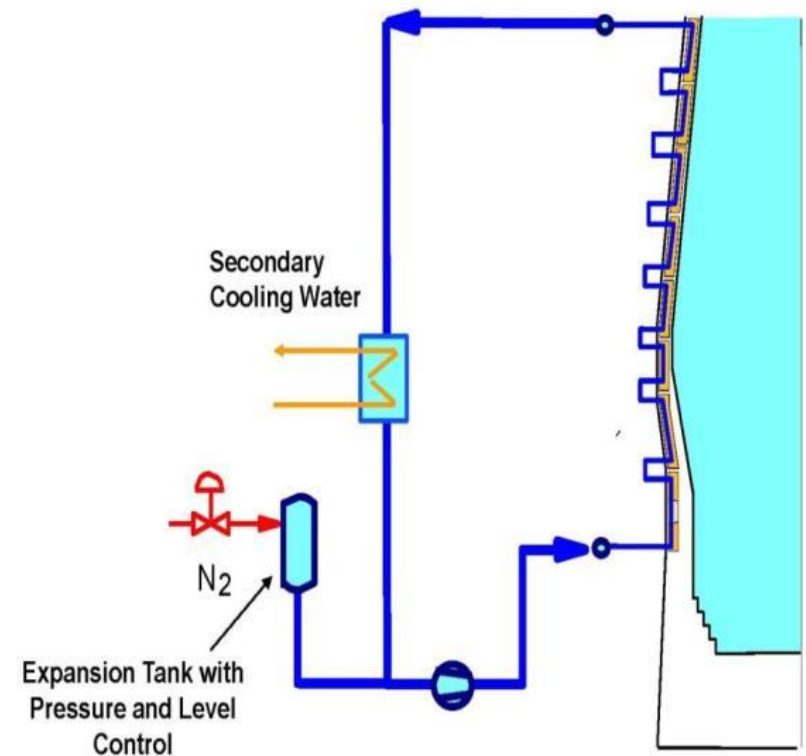
Heat Flux Monitoring

- In all designs, heat flux monitoring and leak detection are of paramount importance.
- Heat flux monitoring in its most simple sense relates to flow and temperature measurement on a zonal basis. Again, the balance between cost of infinite instrumentation, and ability to use the data, needs to be considered.
- Vertical and horizontal (circumferential) zones are the norm for Primetals but with no hard or fast rule to be applied to any particular project, rather a clear desire to agree with the Customer what is required.

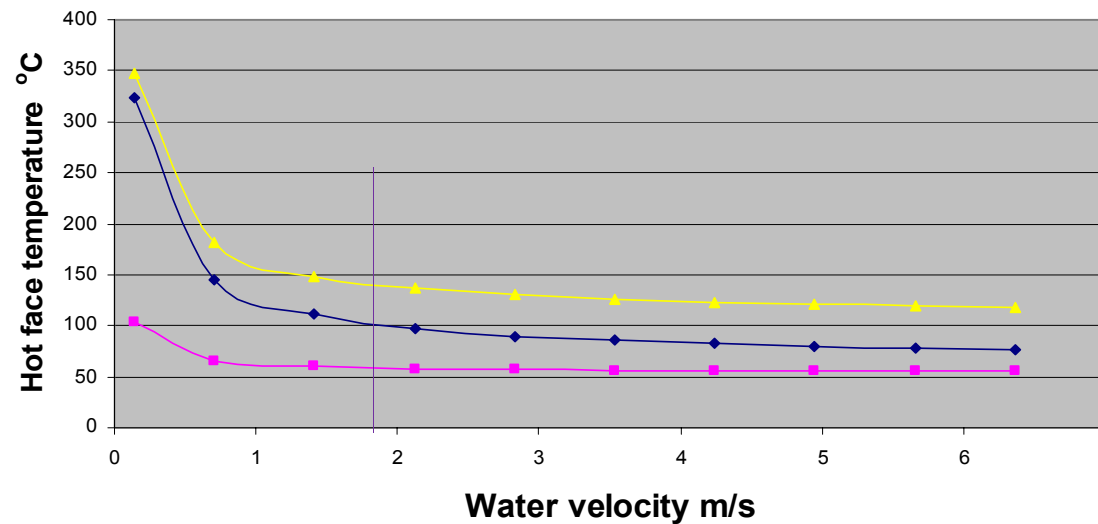
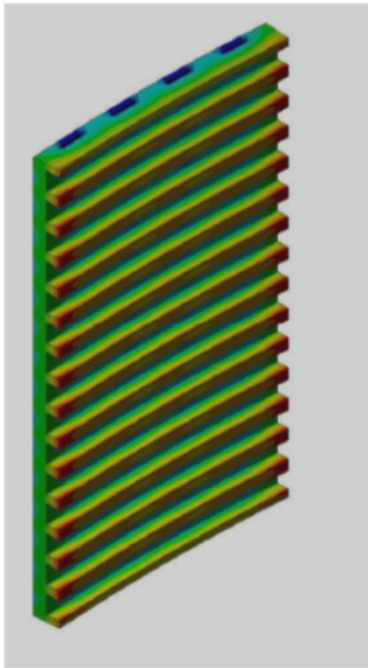


So ... where are we with copper staves?

- The use of copper staves in the high heat load areas of the Blast Furnace increased rapidly from the turn of the century as confidence in their durability grew.
- As more installations came into service, however, initial problems were reported at some plants with stave cooling circuit failures, generally due to effects of thermal expansion (i.e. resulting in water leaks).
- More recently failures have been reported due to premature wear of the staves themselves (erosion).
- This has raised questions over the long term design concept although many plants do still continue to operate without such problems.



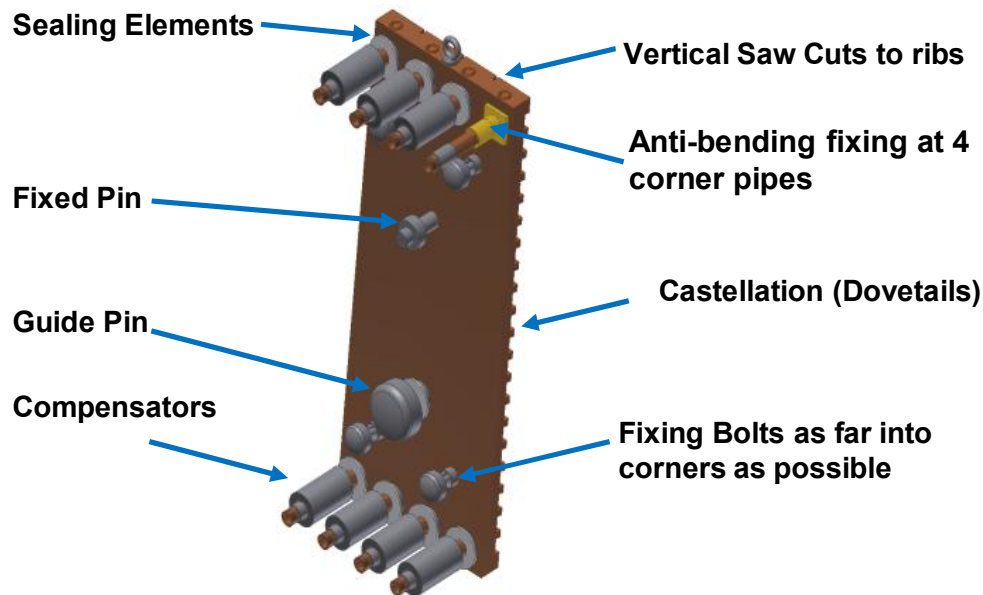
Stave System Detailed Design – the Starting Point



- From the simple starting point the water volume required to cool the stave element based on a water velocity of 1.8 m/s in a channel of a certain size, the actual cooling system can be developed.

Primetals Copper Stave – Key Design Features

Primetals standard stave design has been developed over many years and has numerous key design features that have enabled proven long service life and optimum performance. Standard design parameters plus the use of 3D CAD and Finite Element Analysis (FEA) software allow us to analyse solutions in particular for rebuild / campaign extension projects.



- Ribbed hot face with “vertical slots” in the rib to alleviate the stresses and reduce bending effects
- Water-cooled ledges to encourage the creation of a protective ‘skull’
- ‘Anti-bending’ solution for stave fixing
- If required, refractory inserts for greater wear protection (beneficial cooling effects)

Some Examples

- JSW 3 and 4



- SSI Redcar 2012



- SSAB BF 3 2015 Reline



- Ternium BF 2 2012 Repair



JSW BF No.3 and BF No.4

Standard solution

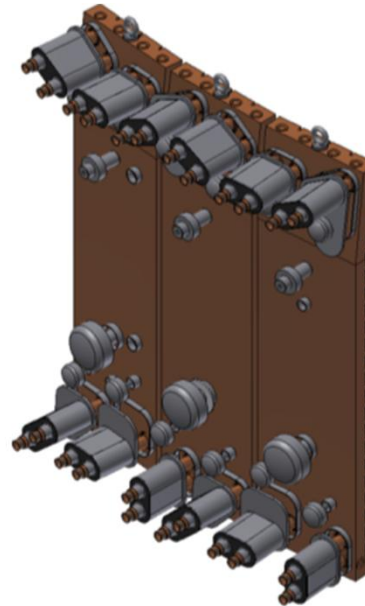
- Two large blast furnaces that began their operation in 2009 and 2011 respectively.
- Cooling systems consists of:
 - Cast iron staves in the hearth, Upper Stack and Throat
 - Five rows of copper staves are installed in the high heat flux zones of the Bosh, Belly and Lower stack
- A new blast furnace shell means the use of the standard Primetals Copper Stave



SSI Redcar Blast Furnace Reline

Maximising use of existing shell cut-outs

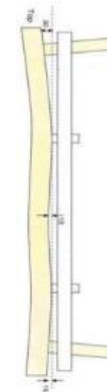
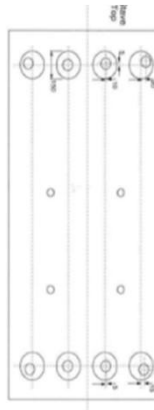
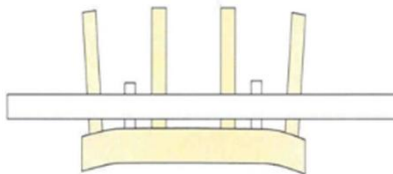
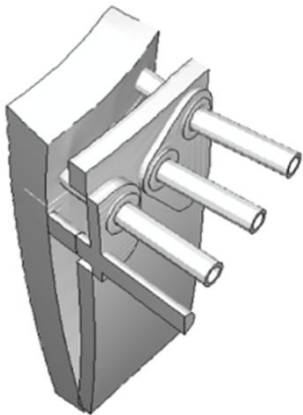
- Replacement copper staves were required for four rows within the furnace.
- Primetals proposed replacing existing arrangement of 48 staves per row with 72 staves per row
- Existing holes in the shell were designed for old cast iron staves: new Staves re-used most holes in the shell – reducing programme
- How much welding can you avoid.....?



Copper Stave Bending Problems

Stave bending is a result of the following:

- Rapid changes of temperature due to either protective layer being lost or furnace conditions causing stave temperatures to cycle and deflect at the points where it is least restrained
 - Deflection of the stave at the corners allows material to get behind the stave
 - Allows material to get into the compensator
 - Resulting in fatigue failure of the weld connection of the water pipe to stave body
 - Stave design of course is a significant contributor

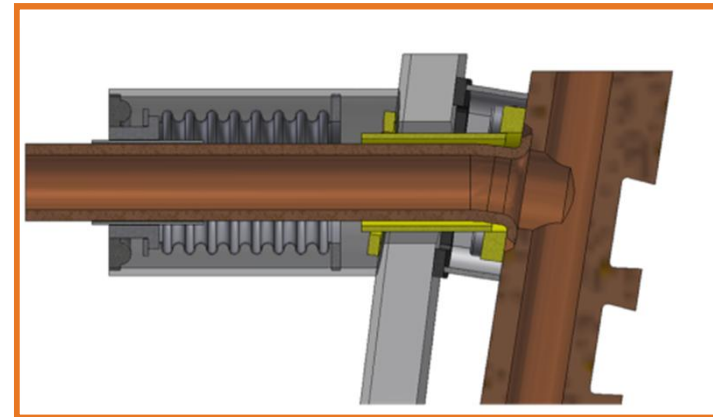


SSAB Lulea Blast Furnace No.3 Reline 2015

- Full replacement of both cast iron and copper staves.
- In the previous campaign the “banana” effect has been apparent – bolts in the wrong location



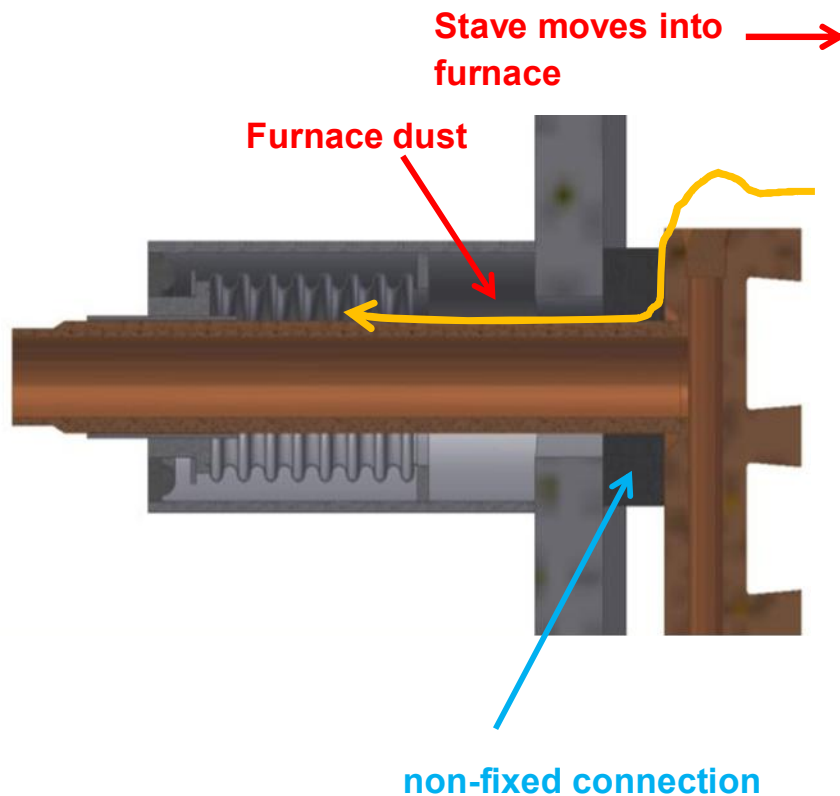
- Primetals stave to utilise existing holes in the shell
- How to stop the banana effect – installation of the Primetals pipe fixing
- The pipe fixing design prevents the stave from bending in at the corners and allows the stave to thermally expand and move during its operation.



- 1 Sealing washer welded only to pipe. Allowed to move on shell but not bow in
- 2 Bolted to Stave

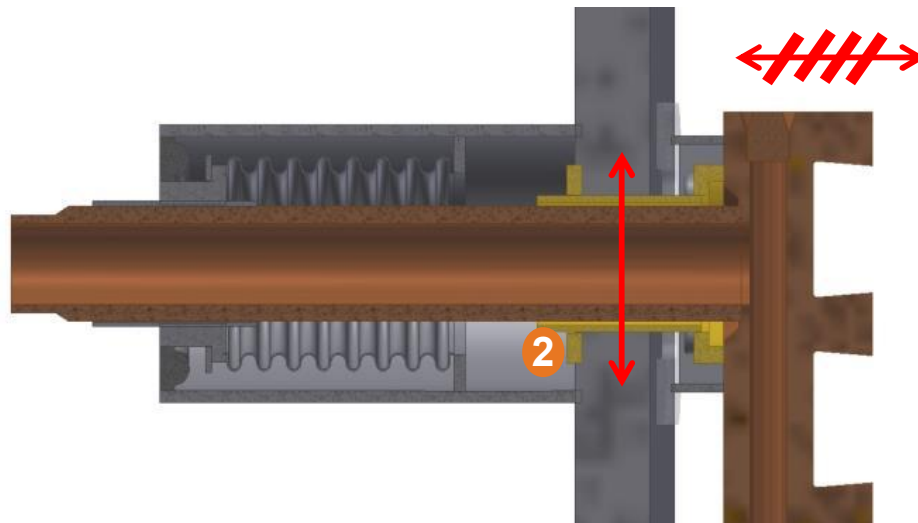
Primetals Pipe Fixing Design
Patented

Bending / Leakage Problems – Root Causes

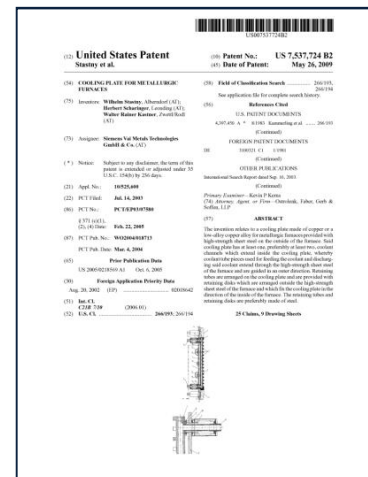


- Differential temperature between hot and cold face of copper stave causes bending, and stave moves into furnace
- Compression against the shell is lost
- Furnace dust enters between gasket and furnace shell and into compensators
- Compensator fills with dust and “locks” stave movements
- Weld of pipe to stave body fails in fatigue
- Water leaks into furnace.
- Water channel isolated – stave gets hotter
- Eventually furnace shell gets hot and cracks occur

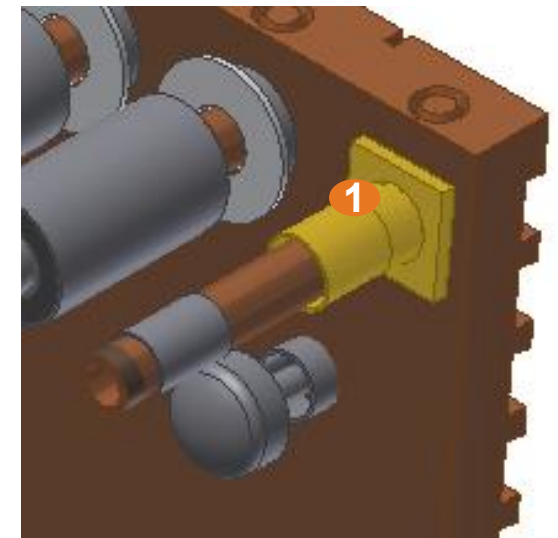
Avoiding Bending Problems



- 1 Flanged-Pipe bolted to Stave
- 2 Sealing washer welded only to pipe. Allowed to move on shell but not bow in



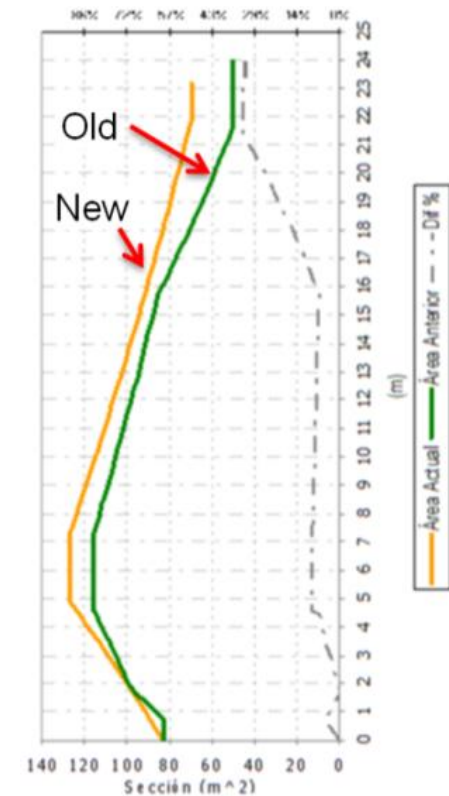
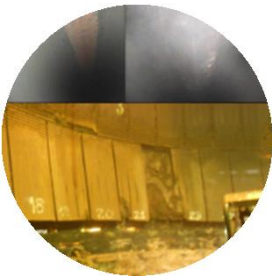
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Copper Stave Wear

Stave wear is generally a function of some of the following:

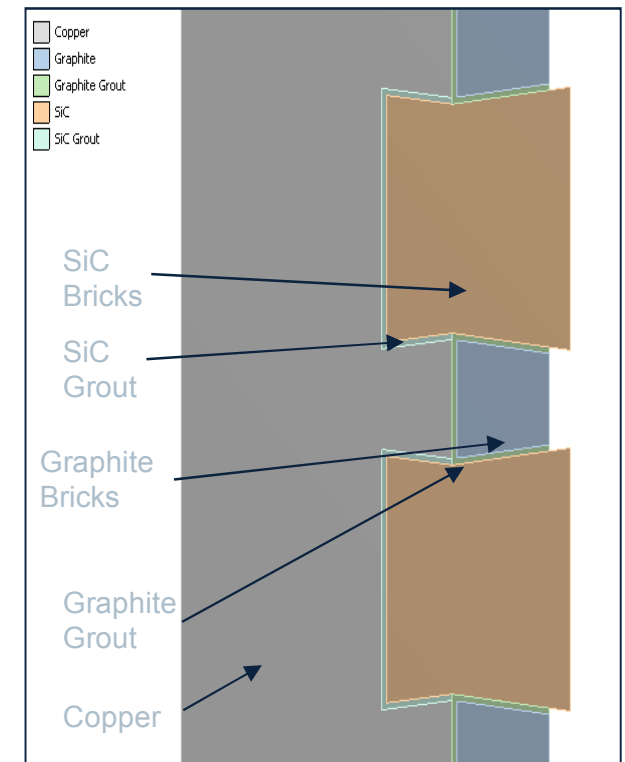
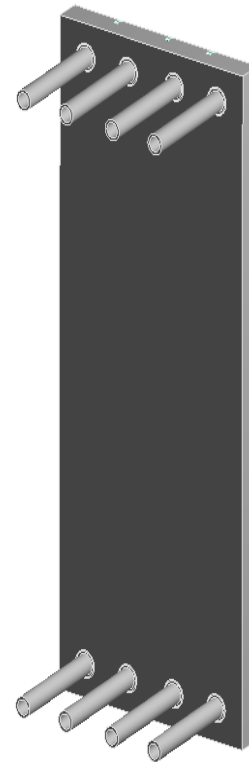
- Bending staves (avoid with the pipe fixing design)
- Not developing a protective layer on the stave hot face
- Furnace process and position of cohesive zone
- High rates of injection / productivity
- Furnace charging
- Furnace burden
- Furnace lines/ profile



Ternium Blast Furnace No. 2 Reline 2012

Optimised stave design for maximum life

- Repair required early in the campaign due to extreme wear of copper staves
- Existing holes in the shell re-used with only the addition of a guide pin hole added
- Severe nature of wear that occurred in the previous campaign decided that extra protection of the hot face would be required.
- Silicon carbide and graphite inserts used for the best possible protection



Ternium Blast Furnace No. 2 Repair 2012

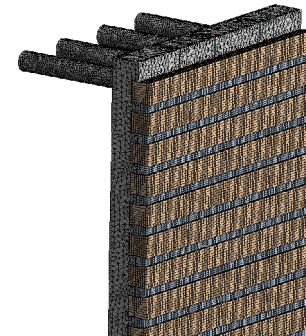


Ternium Blast Furnace No. 2 Reline 2012

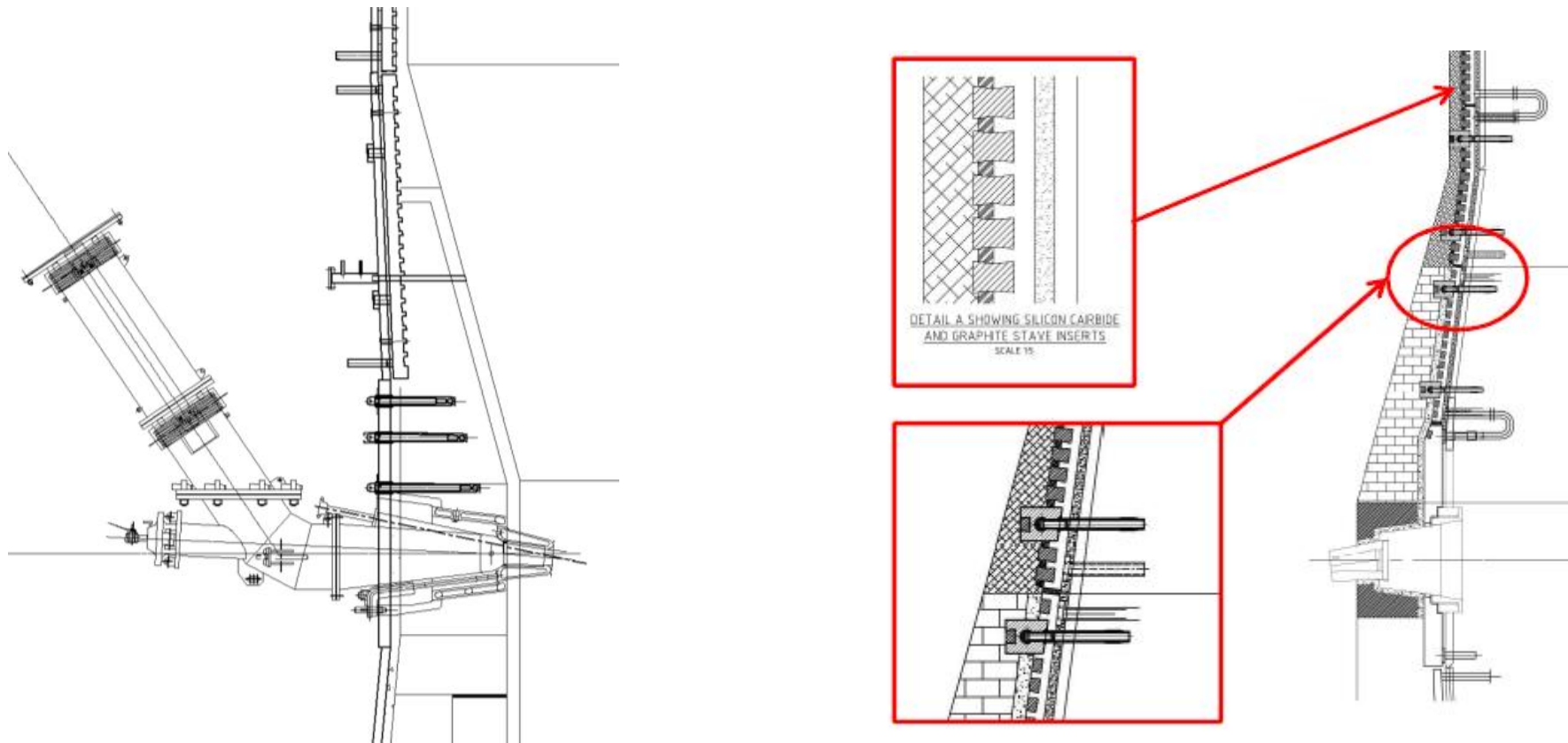


Pause for Thought

- We are (generally) in a rebuild / campaign extension situation
- We must consider suitable changes for the maximum benefit
- Can we optimise the furnace profile, or make the best of what we have?
- How can we minimise the overall cost of equipment plus installation
- How can we minimise the furnace shutdown
- Staves can be designed to minimise the amount of re-work and reduce installation time during short shut downs
- The challenge of designing staves to be integrated into an existing shell is something that Primetals excels at.



The Future ... ?



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