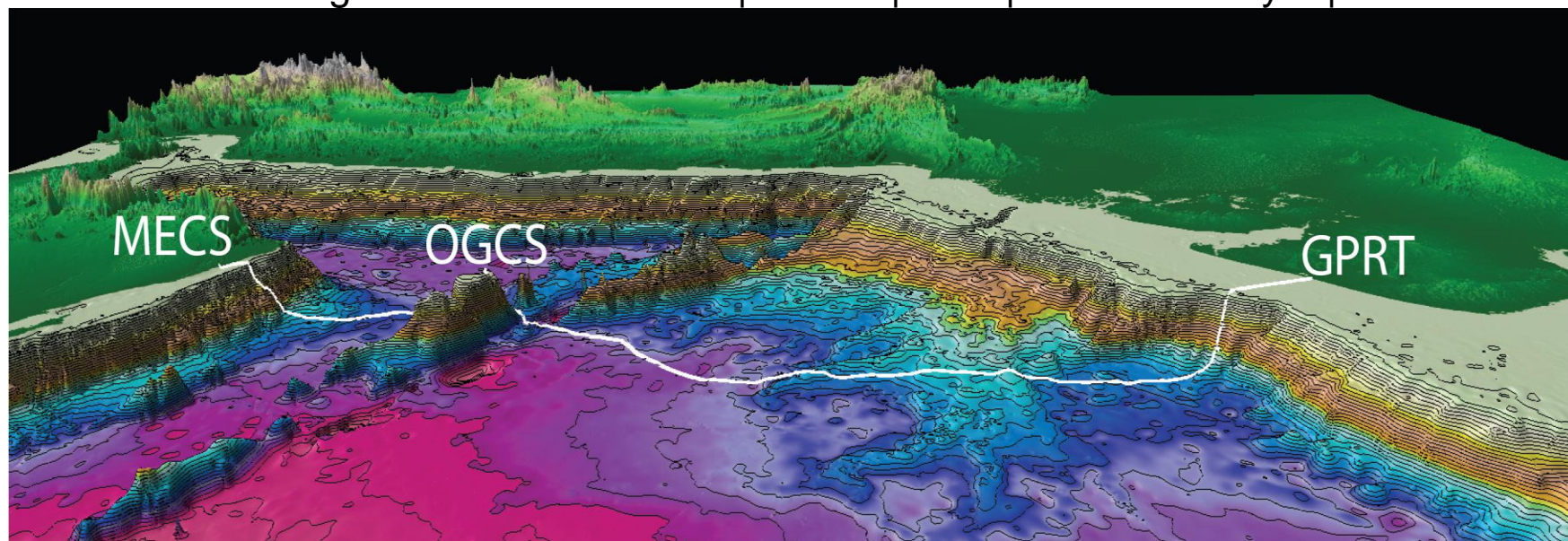


# ISOPE-2013 Anchorage Conference

## The 23rd International Ocean and Polar Engineering Conference

Anchorage Convention Centre | Alaska | USA | June 30 - July 5 | 2013



## The Production and Testing of MEIDP Line-Pipe for 3500m Application

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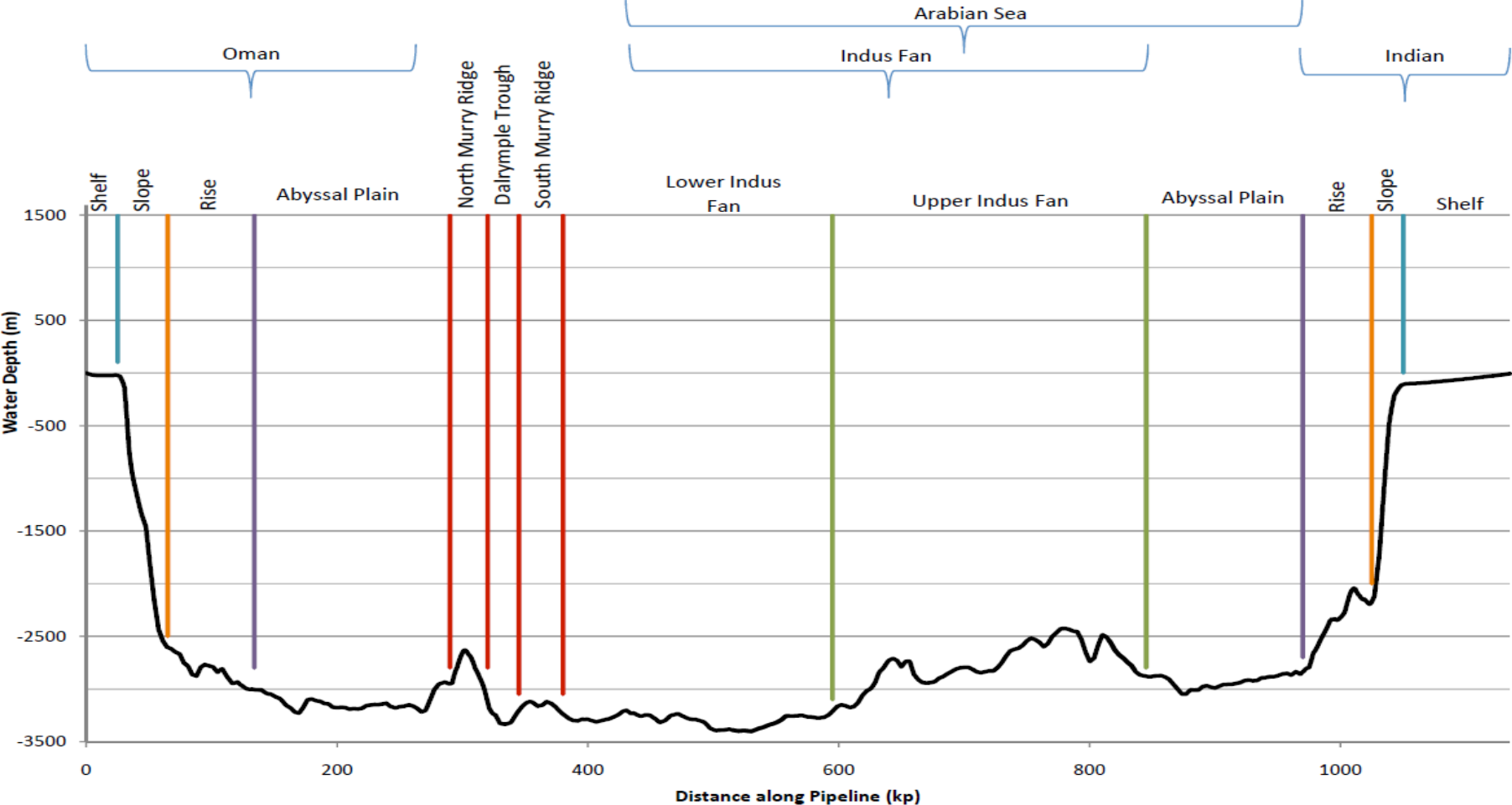
*Operations Director, Peritus International Ltd.*

*Woking, Surrey, UK*

- Project Background
- Wall Thickness design
- Pipe Manufacture
- Pipe testing
- FEA Modelling
- Ring Collapse Testing
- Conclusions

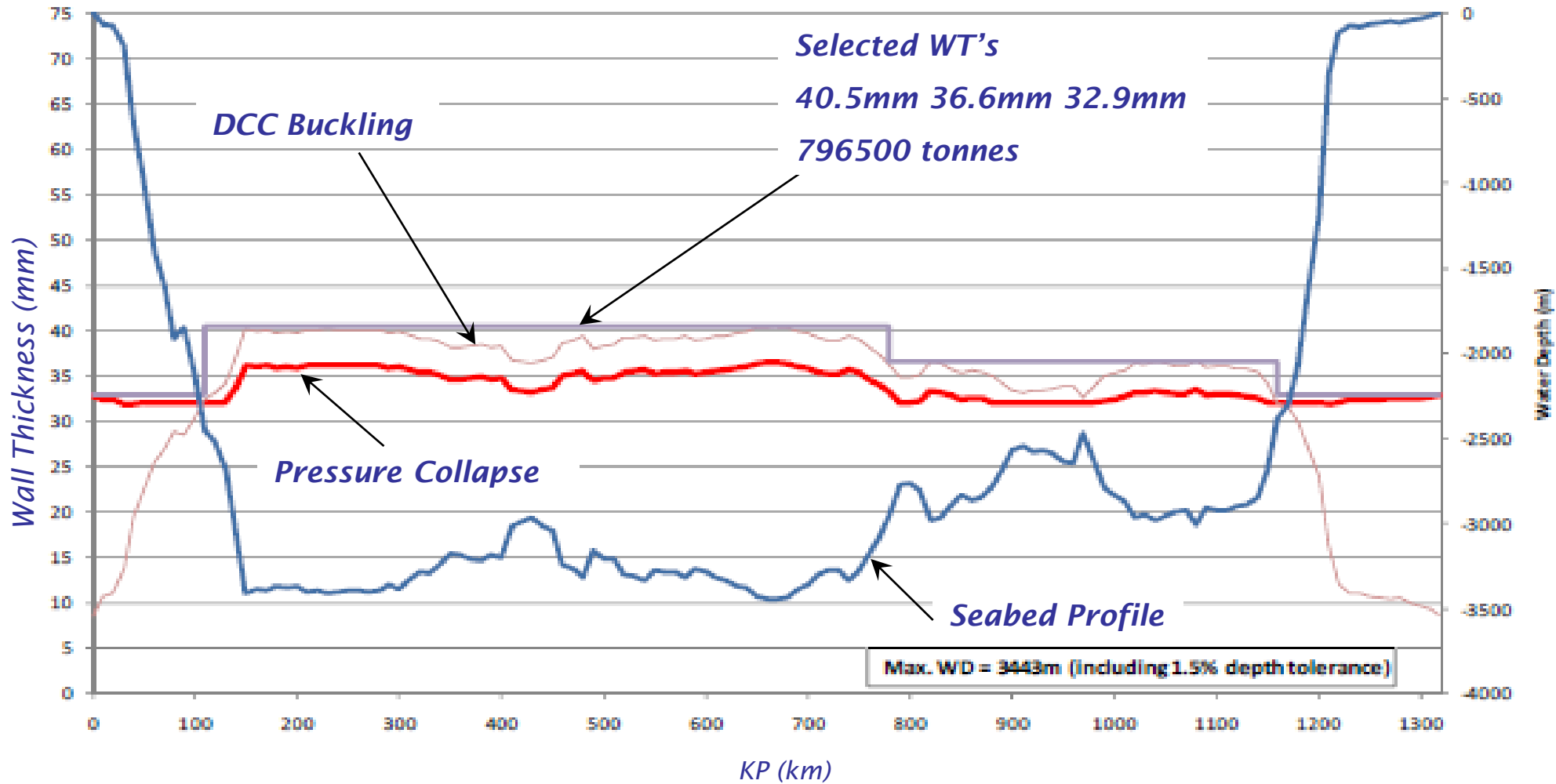
- ❑ South Asia Gas Enterprise Pvt Ltd (SAGE), has for a number of years been working to develop the Middle East to India Deepwater Pipeline (MEIDP), a transnational, natural gas pipeline system to bring much needed gas from the Middle East region to India, by the safest and cheapest means
- ❑ The MEIDP will be located in water depths up to 3500m and consequently be subjected to very high external pressures which make the pipe collapse strength a major consideration for the project
- ❑ Nearly all testing of deepwater linepipe has to date been on pipe made by the UOE forming process. Typically Indian Pipe mills however use the JCOE process
- ❑ In 2012 two Indian Pipe mills entered into a qualification program to prove that pipe suitable for use on MEIDP could be manufactured by JCOE method

# MEIDP Route Profile



# Pipe Wall Thickness Requirements

## OS-F101 SAWL485 UDF



The following summarises the generally accepted differences between JCOE and UOE manufacture:

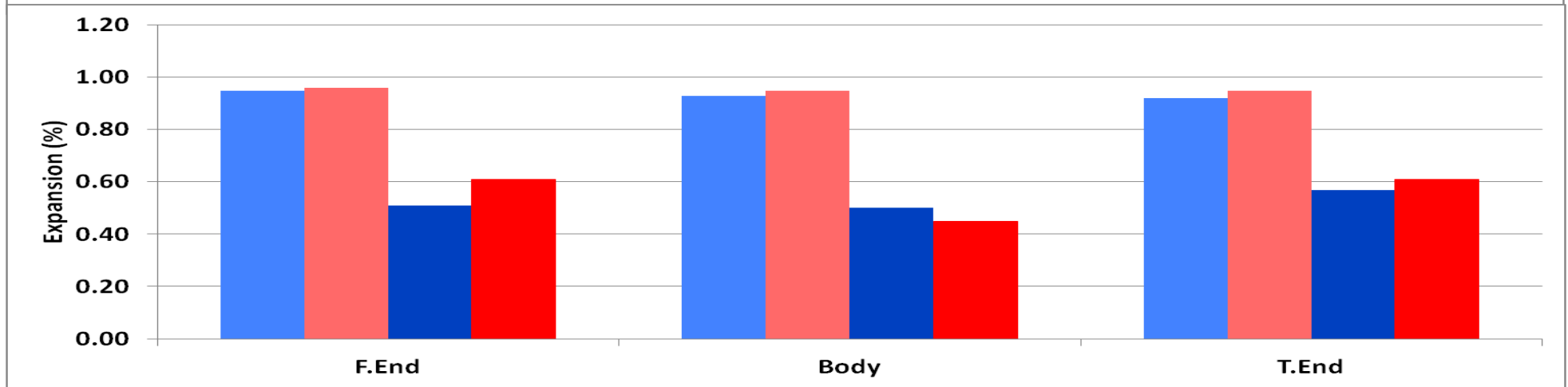
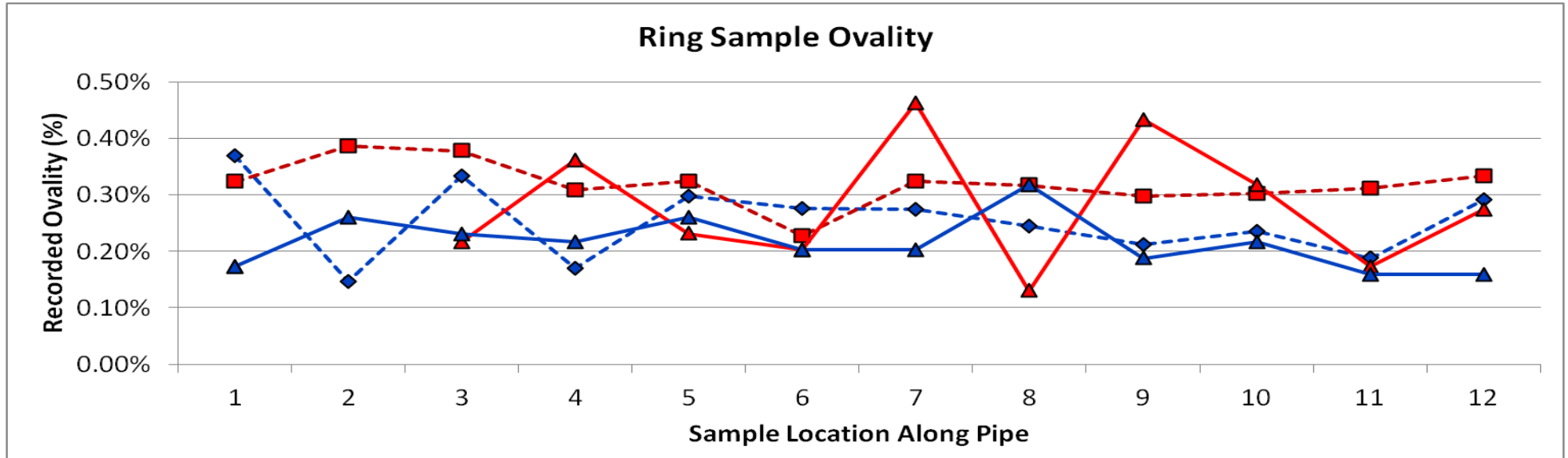
- ❑ Forces and hence press sizes are smaller, therefore less power is required for JCOE than UOE
- ❑ Circumferential strength characteristics more uniform in JCOE than UOE
- ❑ Circumferential residual stresses are likely to be lower in JCOE than UOE
- ❑ The forming process requires many more “Punches” for JCOE than UOE, so the JCOE pipe process is significantly slower



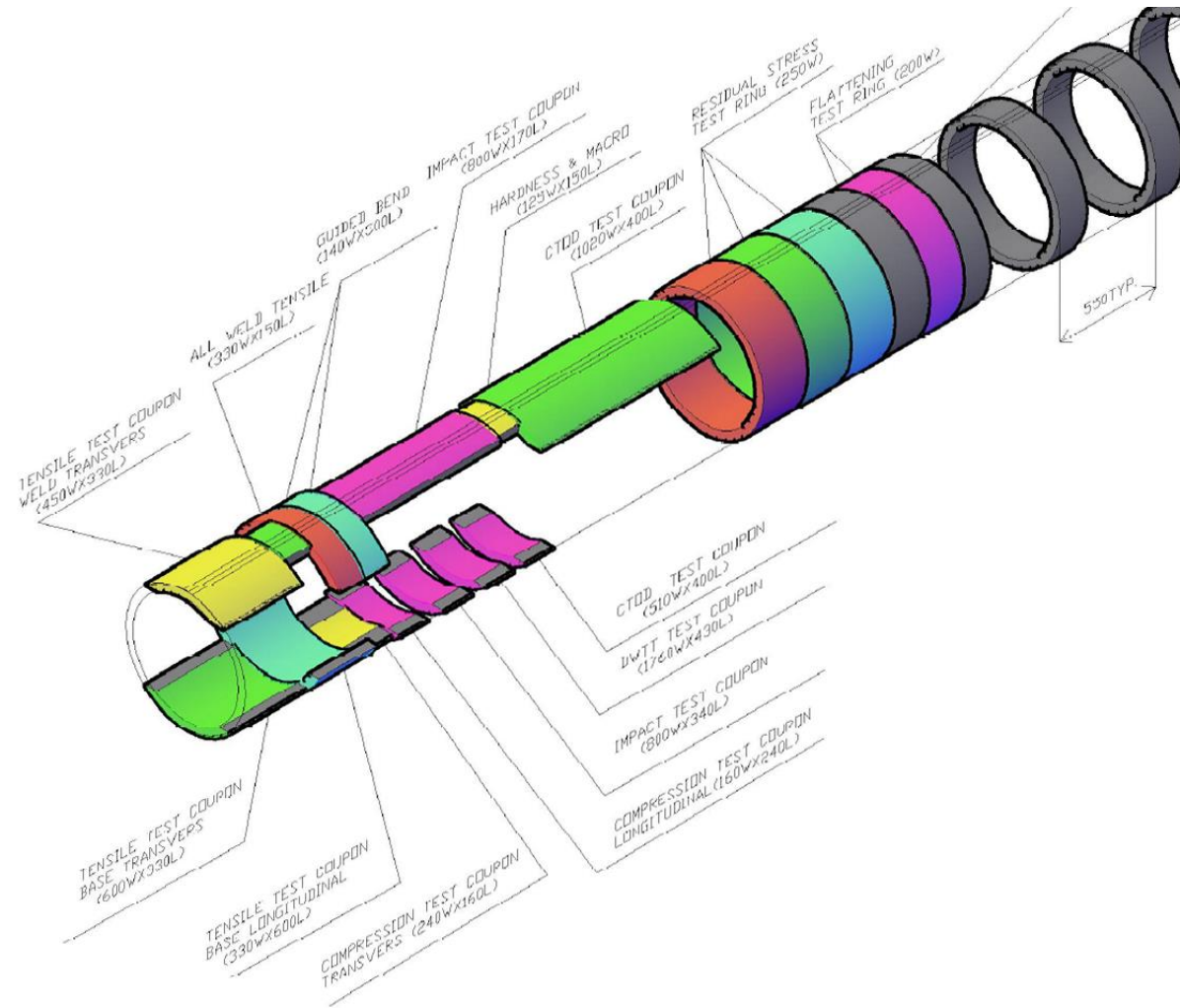
a) "J-ing" Stage

b) "C-ing" Stage  
**JCOE Process**

c) "O-ing" Stage







## □ Tensile & Compression Testing

- Longitudinal
- Transverse
  - Plate
  - “J”-ing
  - “O”-ing
  - Expansion
  - After heat soaking

## □ Guided Bend

## □ Impact DWTT

## □ Hardness & Macro

## □ Residual Stress

## □ CTOD

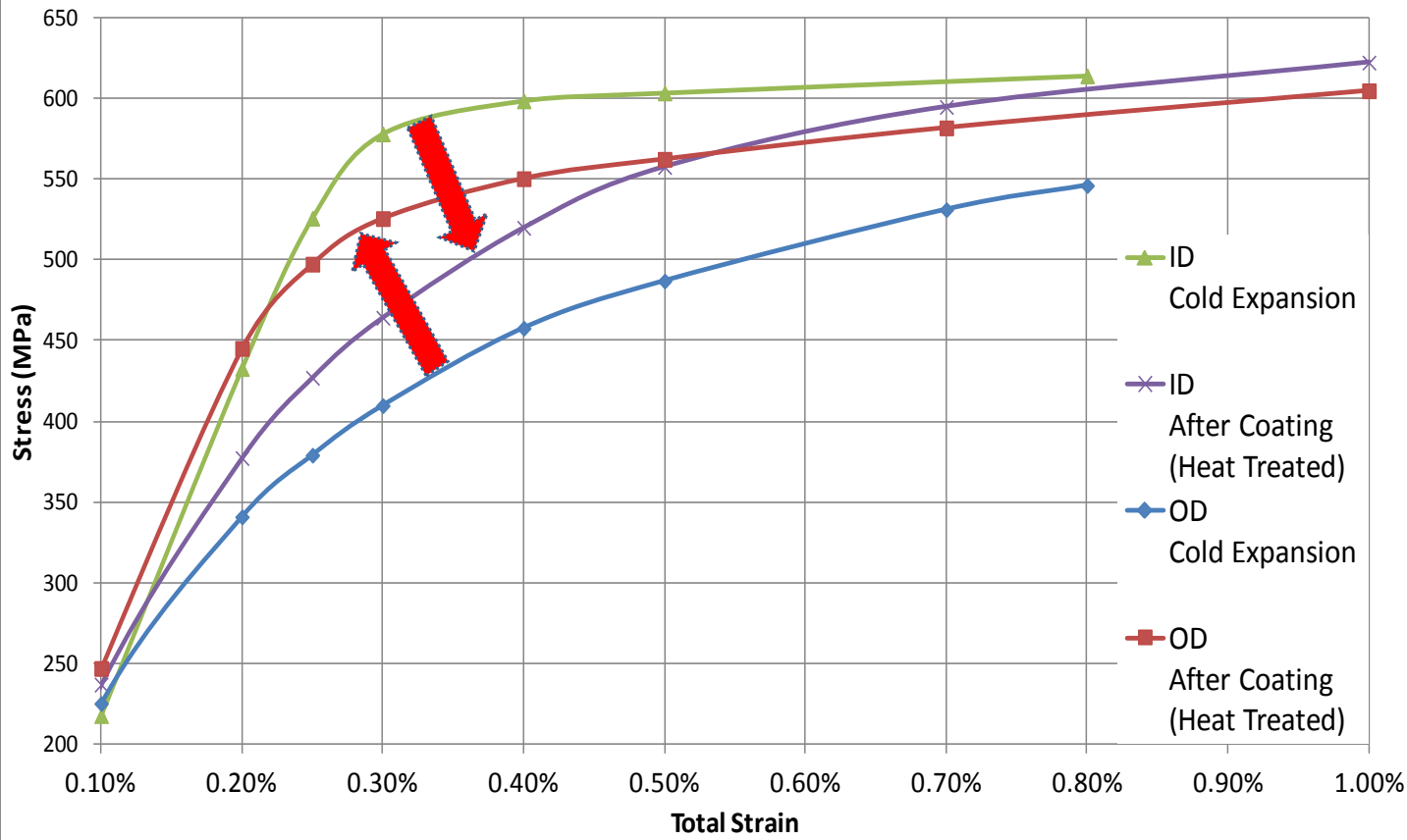
## □ Flattening

## □ Weldability

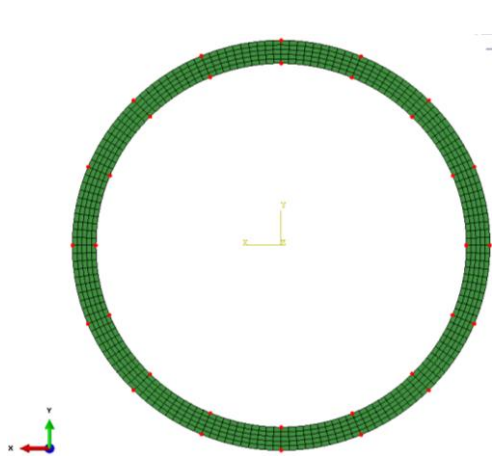
## □ Ring Collapse Testing

- Expansion
- After heat soaking

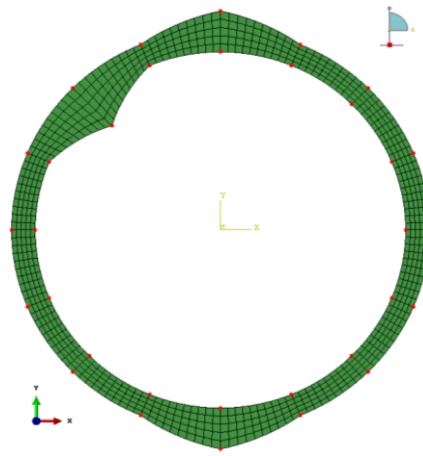
Typical Transverse Compressive Properties  
Inside & Outside Diameter before and After Heat treatment



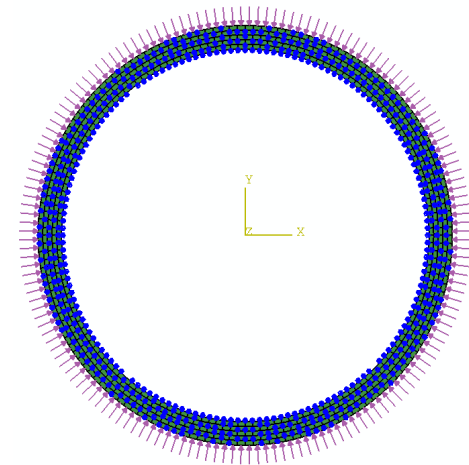
- ❑ General reduction in yield strength of the inside diameter
- ❑ General Increase in yield strength of the outside diameter



*32 Nodes used to define ring corresponding to the ring sample measurements*

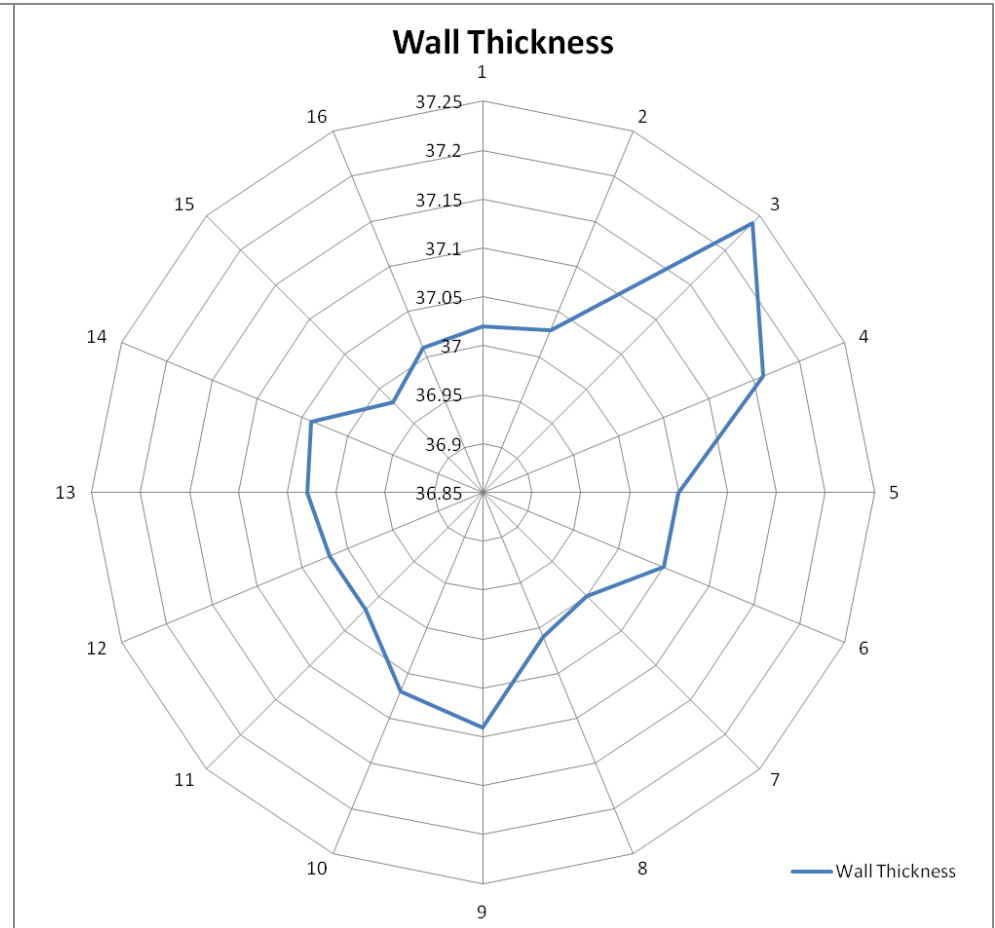
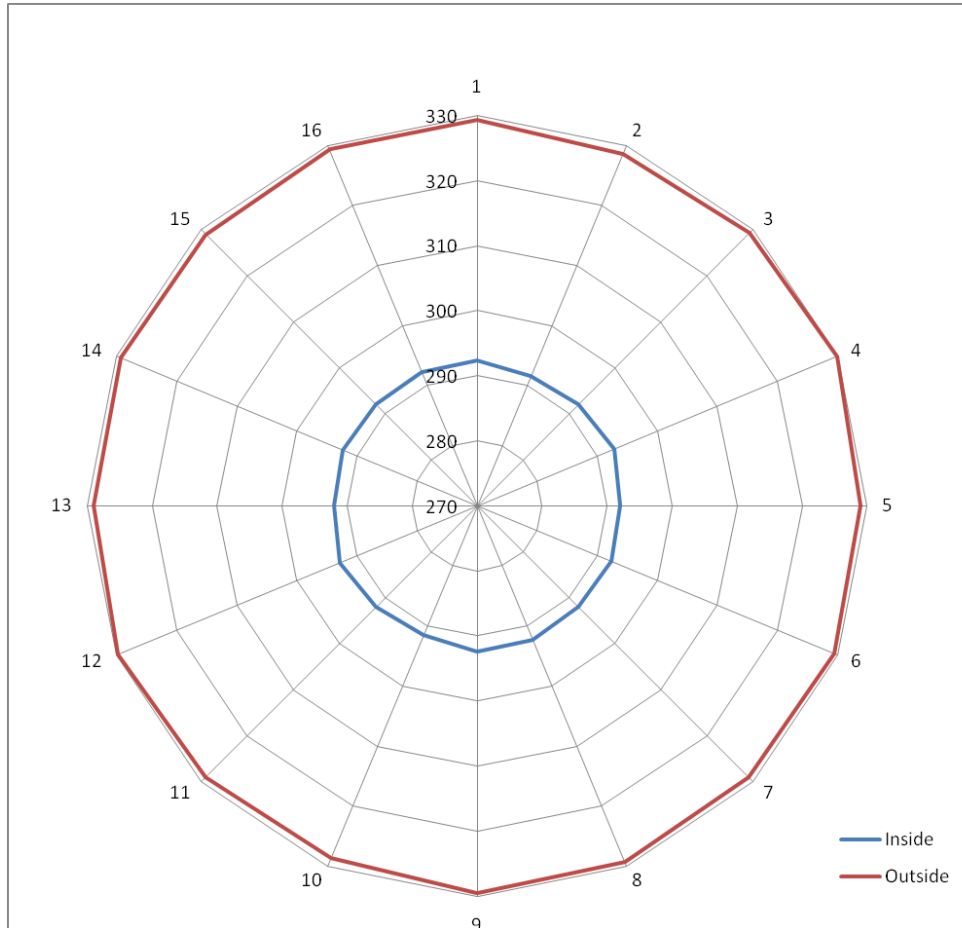


*Diameter and Wall thickness variations accounted for at each node*



*Single large deformation static step with 1 bar pressure increments*

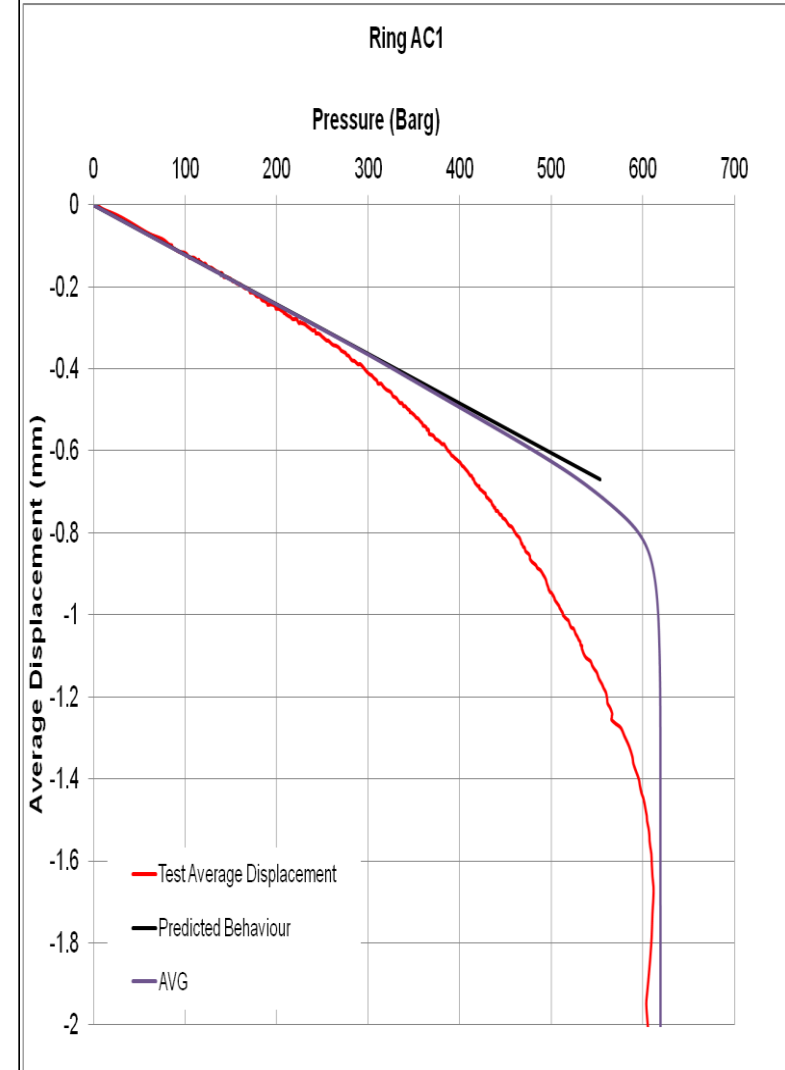
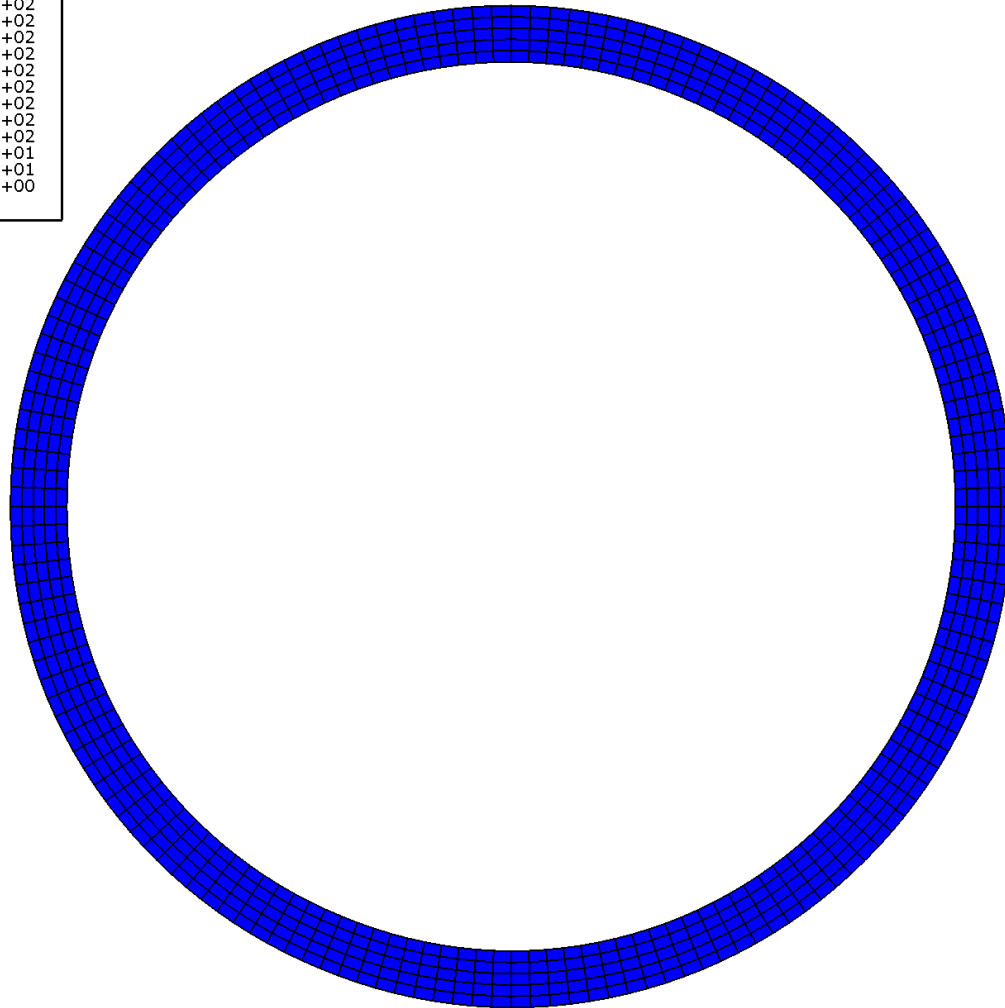
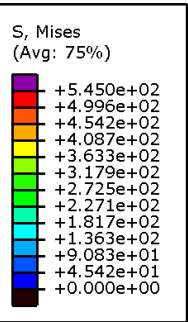
# Dimensional Data from ring AC-1



❑ Recording only diameters results in either the ID or OD having a rotationally symmetrical shape

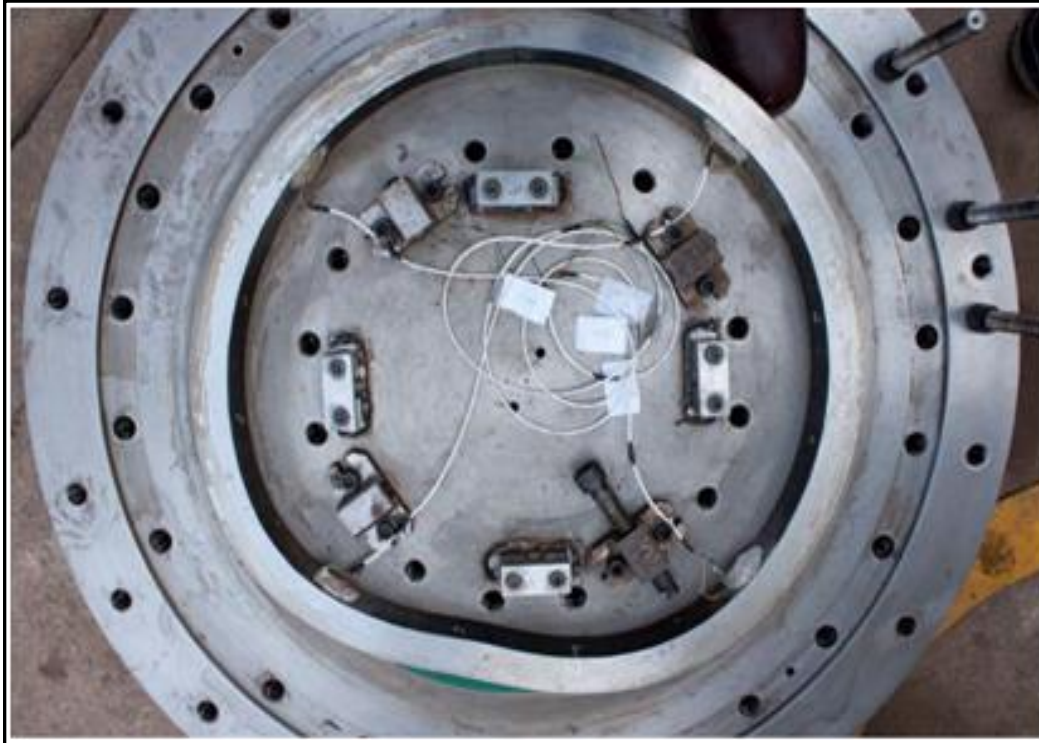
# Stress development in ring during pressure loading

Step: Apply Pr Frame: 1  
Total Time: 0.010000

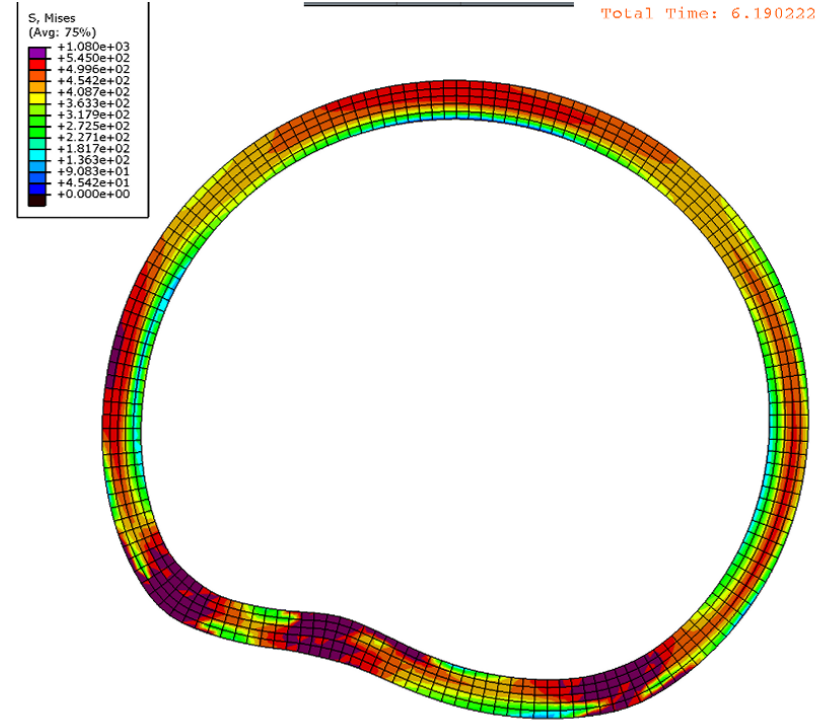


The production and testing of linepipe for the MEIDP 3500m application

# Example of Real Collapse V's FE Prediction

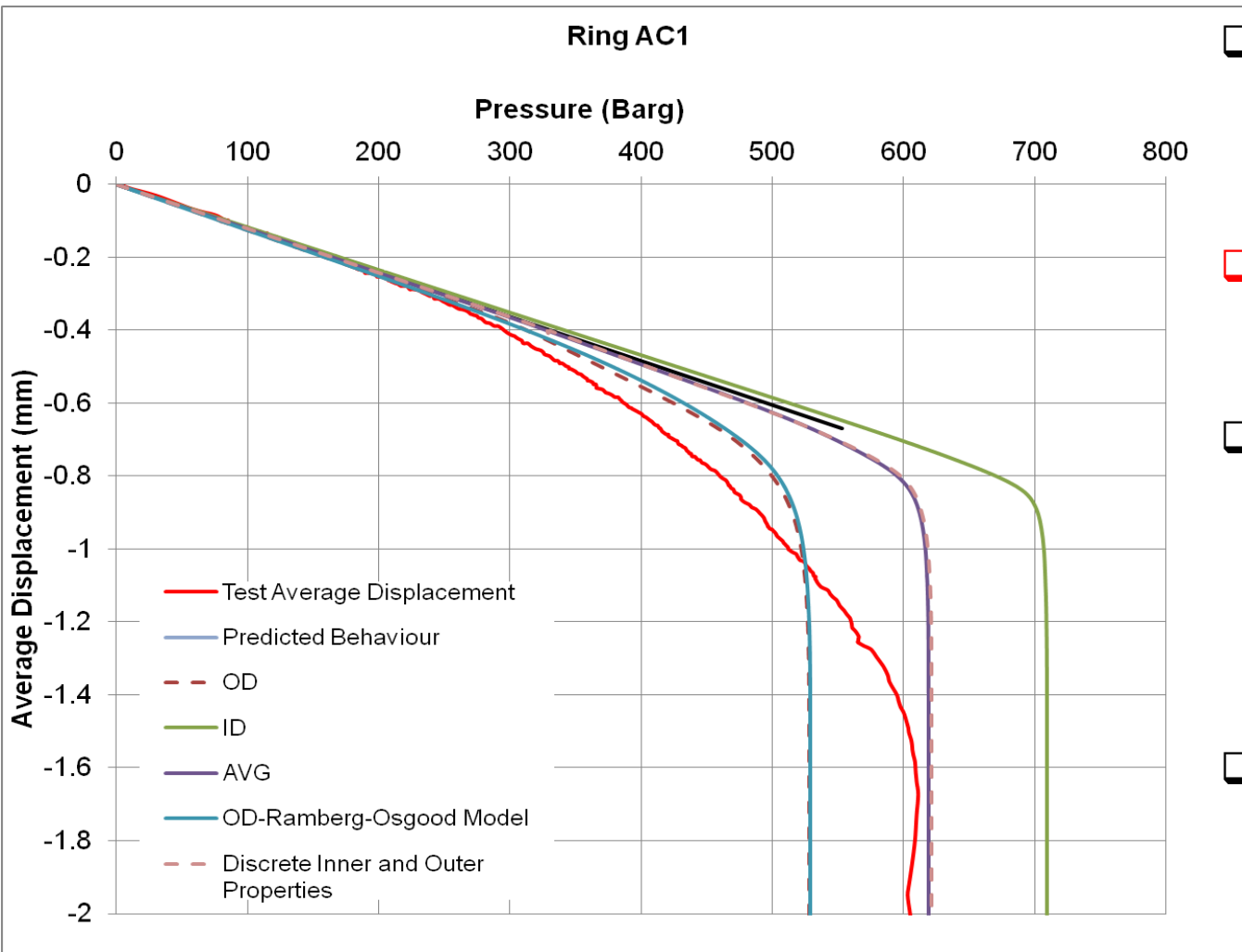


*Actual Collapsed shape*

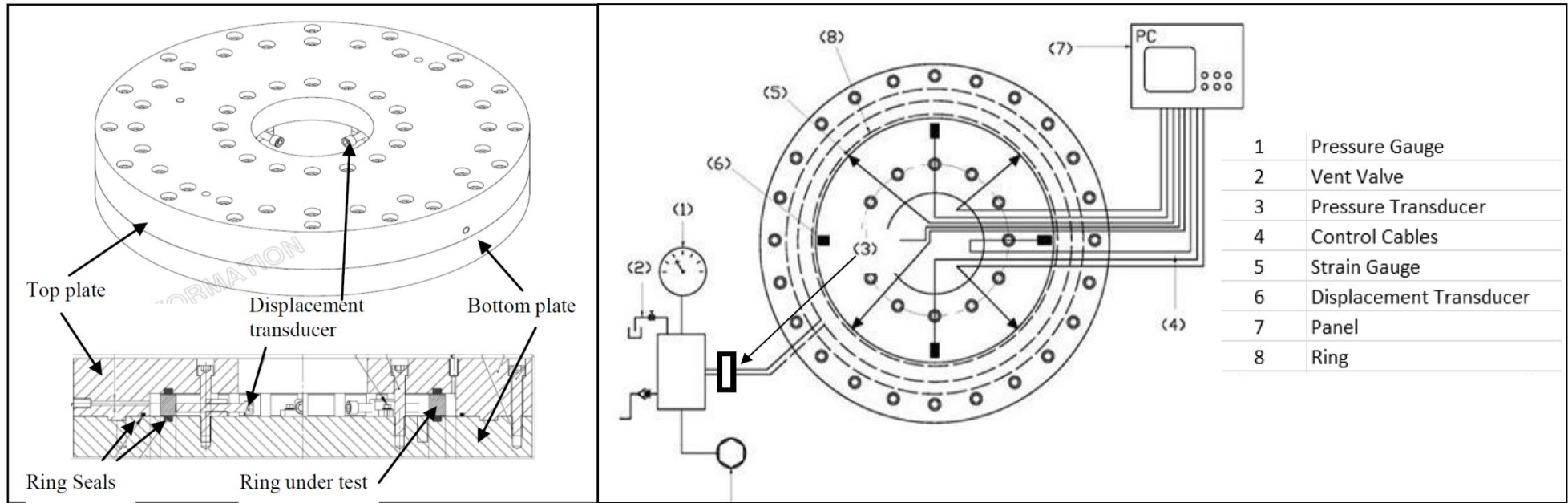


*FE Predicted Collapse Shape*

# Average displacement development in ring during pressure loading



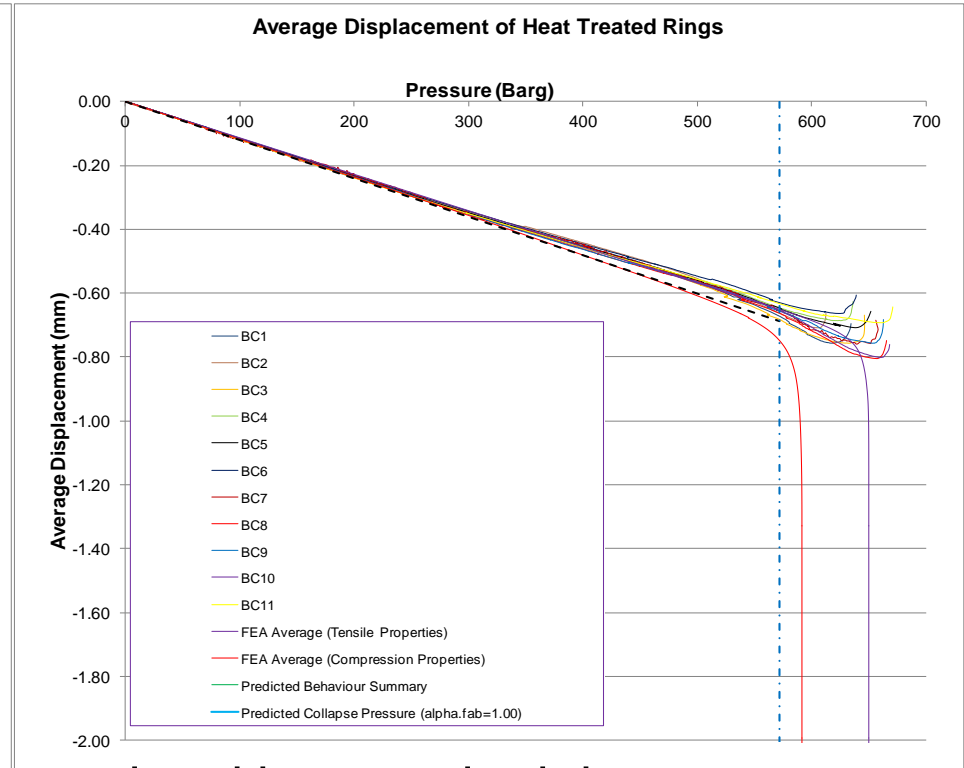
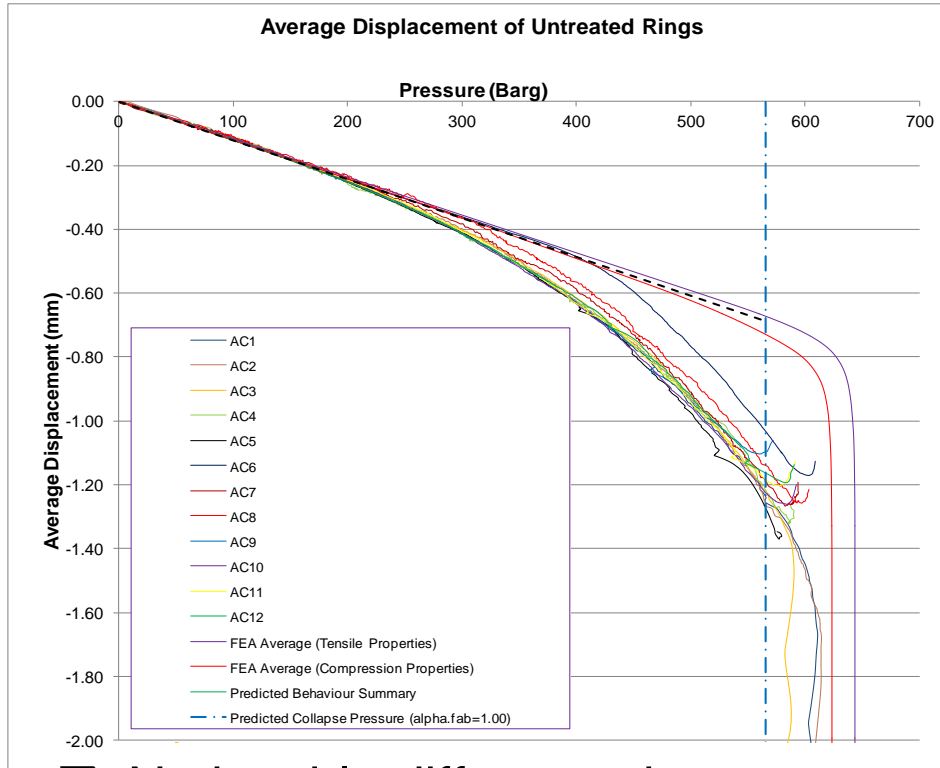
- Actual pipe failure occurs close to the **average** of inner and outer transverse compressive **properties**
- Outer** pipe properties most closely reflect the **movement away from the predicted line**
- Modelling actual inner and outer transverse compressive properties at respective locations yielded **similar results** to the **average value** applied over the **whole section**
- From FE modelling the **RO** stress-strain curve yields **similar results to the actual** stress strain curves



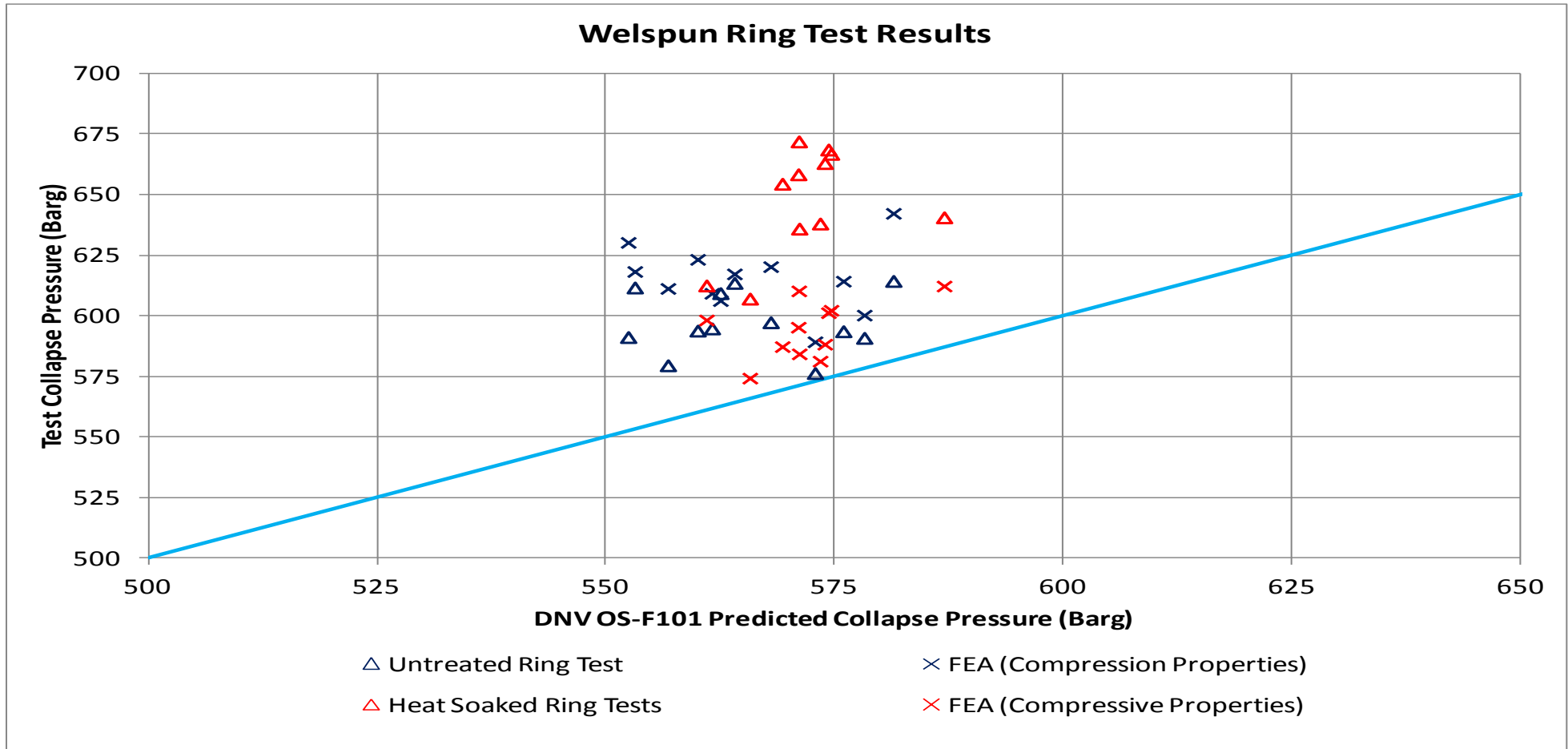
- ❑ 50mm long ring cold cut from a pipe joint
- ❑ Ring is instrumented for strain and displacement
- ❑ Sandwiched between a top and bottom plate with seal rings
- ❑ Roberts P, Walker A, Method and apparatus for pipe testing. United States Patent No. 20100212405:2010



# Average Displacement curves for Welspun

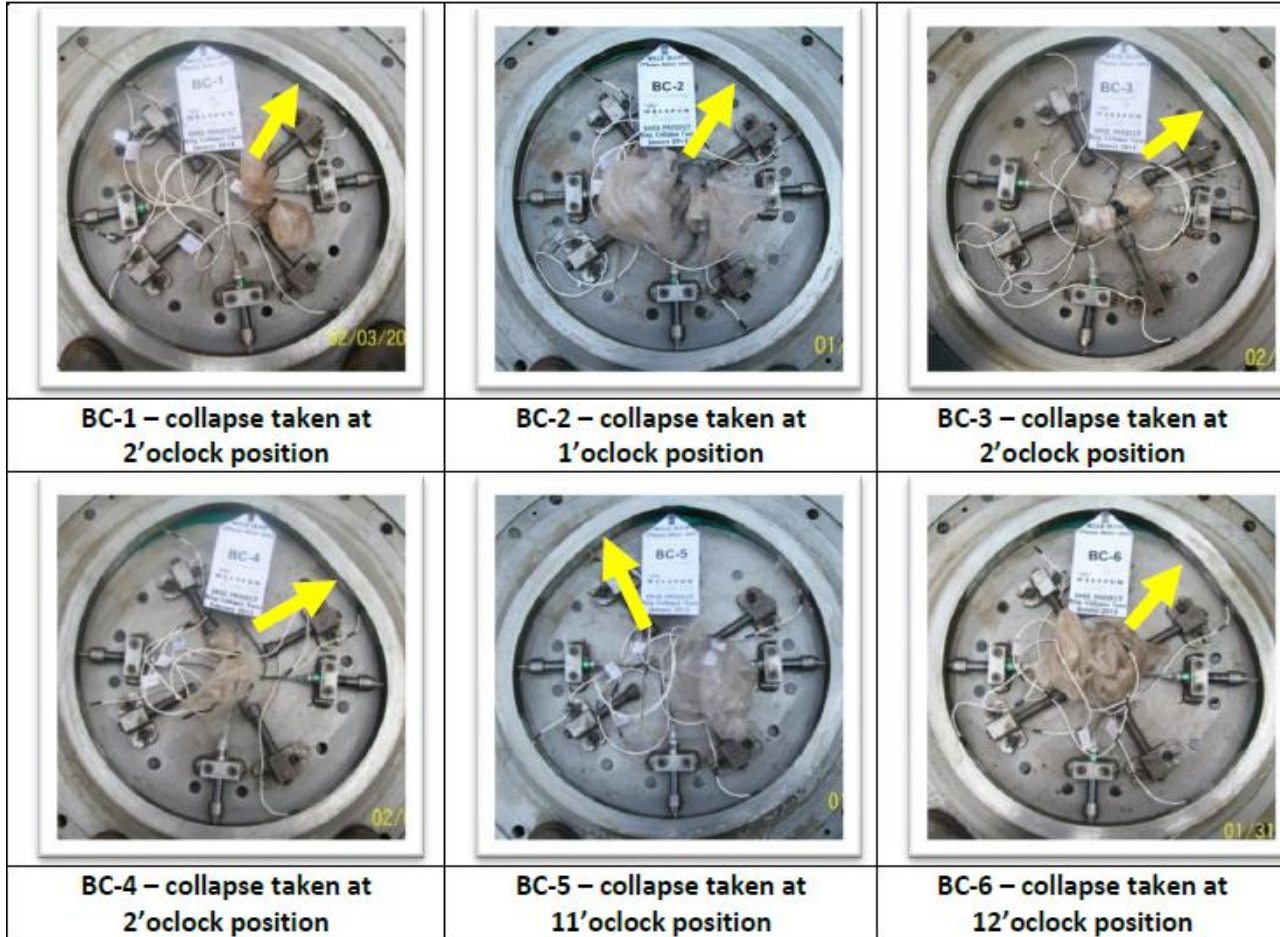


- ❑ Noticeable difference between untreated and heat soaked rings
- ❑ Heat Soaked rings followed predicted path almost to failure
- ❑ All rings failed at pressure higher than predicted by DnV
- ❑ Untreated rings failed at pressures lower than predicted by FEA

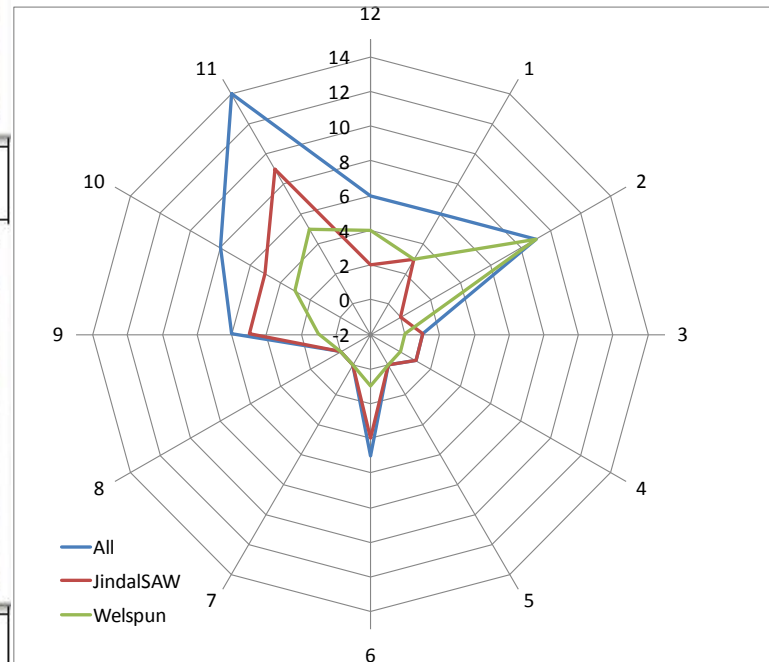


☐ All results (FEA and Actual) are higher than predicted by OS-F101 Equations

# Observed Failure Locations



*The vast majority (77%) of the rings tested showed collapse occurring between 10 - 2 O'clock*



- ❑ Two Indian pipe mills have shown that **MEIDP linepipe can be successfully manufactured** by the JCOE forming process.
- ❑ It has been possible to successfully deploy heat soaking equipment at the end of the production line at the mills and this **heat soaking can be included in the production process**.
- ❑ **Ring testing equipment has been successfully deployed at the pipe mills** and it is possible to successfully conduct ring collapse testing as part of the production testing process.
- ❑ The **pipe through wall temperatures vary significantly** as the pipe passes through the induction heating and quenching process.
- ❑ Whilst the use of installed thermocouples in the pipe joint is a good mechanism for determining the heat history of pipe joints during prequalification testing it will not be possible to use this method during the pipe production. **Alternative methods to confirm the heating history of each pipe joint need to be investigated**.
- ❑ The **dimension of the rings need to be taken as radii rather than diameters** a method of defining the ovality based on radius measurements as part of the production process needs to be developed.

- ❑ For the JCOE Process **marked differences** were observed between internal and external wall samples during transverse compression testing with and without heat soaking
- ❑ Further testing to **establish heat treatment parameters** and their effect on internal and external wall locations is clearly required.
- ❑ Ring collapse tests performed at Welspun showed a **noticeable increase in the collapse pressure** of samples that passed through a heat soaking process (Expansion 0.9%).
- ❑ Ring collapse tests performed at JindalSAW however, show only slight improvement in collapse pressure (Expansion 0.5%).
- ❑ Ring collapse test and FEA modeling of pipe rings shows **consistently higher collapse pressures than predicted by DNV OS-F101** based on actual Young's modulus and yield strength ( $R_{TCt05}$ ) pipe properties.
- ❑ This indicates that if minimum **transverse compressive yield strength criterion is specified** in linepipe specifications and used in calculation of predicted collapse then a fabrication factor  $\alpha_{fab} = 1.0$  can be used in DNV formulation of collapse pressure.

The authors would like to thank South Asia Gas Enterprise PVT Ltd, Welspun PVT Ltd and JindalSAW Ltd. for giving permission to publish this work and the team in Peritus, for their continued hard work on the project.