

PHMSA

Pipeline Safety Research and Development Forum
October 31 to November 1, 2023

STRAIN TOLERANCE OF LINEPIPE

SEISMIC RESISTANCE OF NPS 24 X 17.6 X65 HFW PIPE

- Strain-based design
 - Strain capacity
 - Post buckling behavior
- Pipe qualification to Japan Gas Association requirements
- Numerical crack initiation model validation
- Advanced instrumentation



15 MN (3,500 kip) load frame

Specimen capacity:

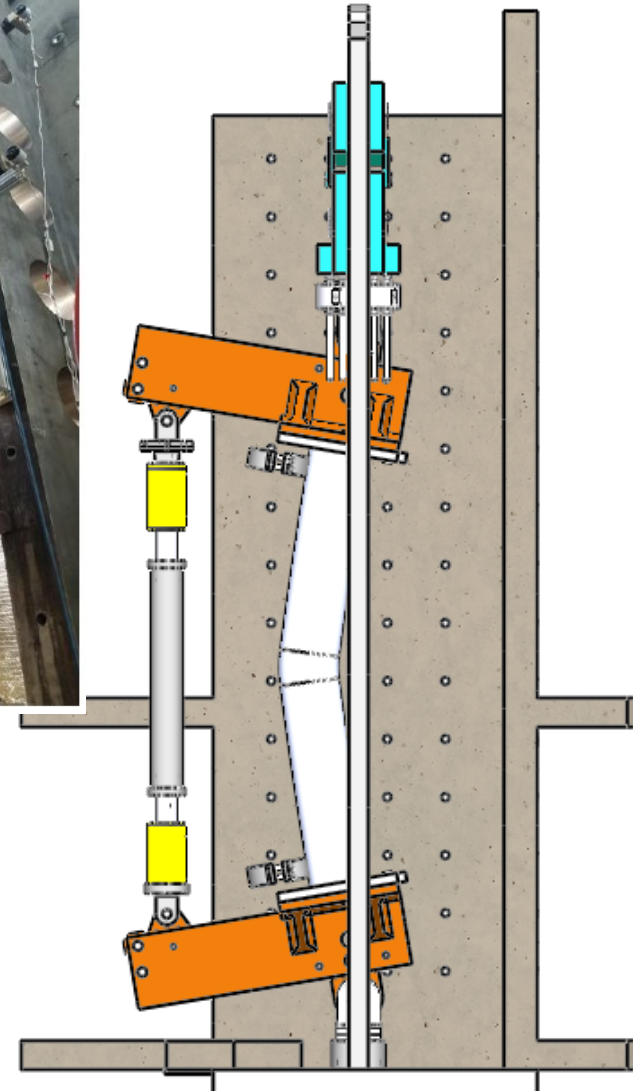
15 m (49 ft) length

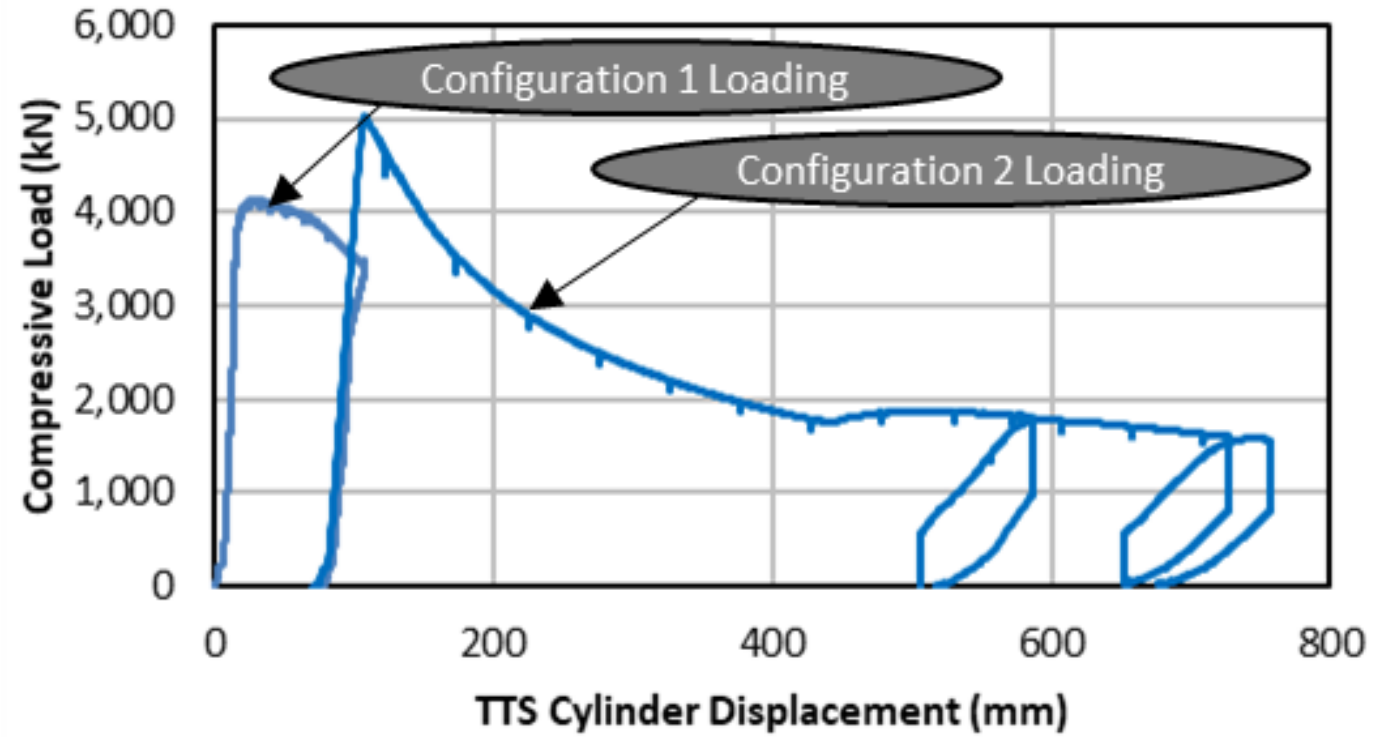
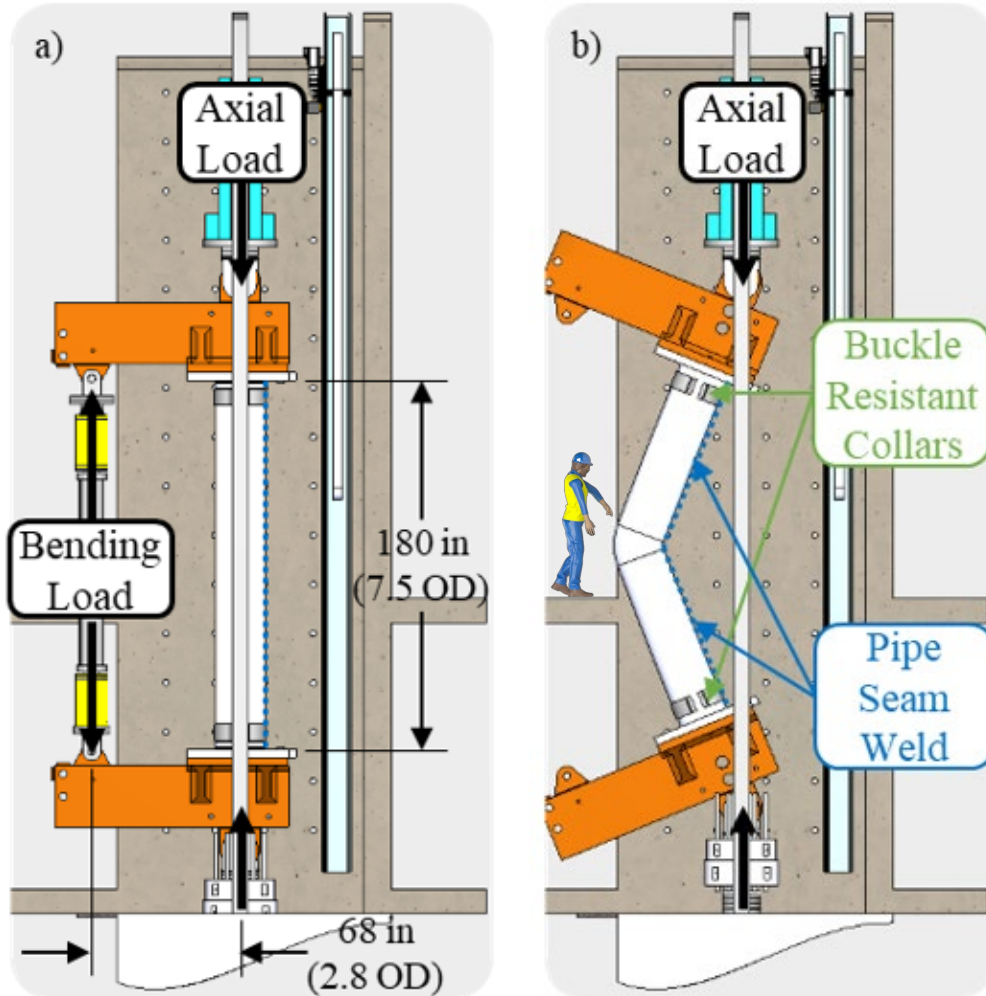
1.5 m (59 in) diameter

27 MNm (20,000 ft-kip) moment
arms and bending actuator



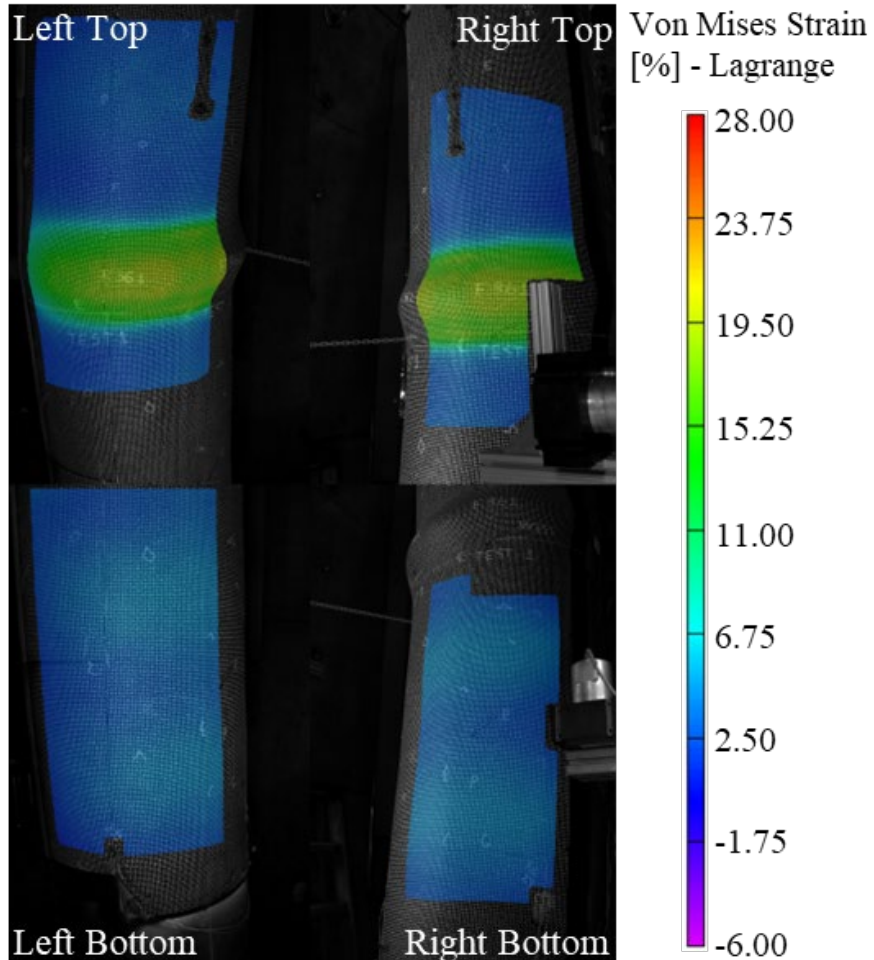
Apparatus



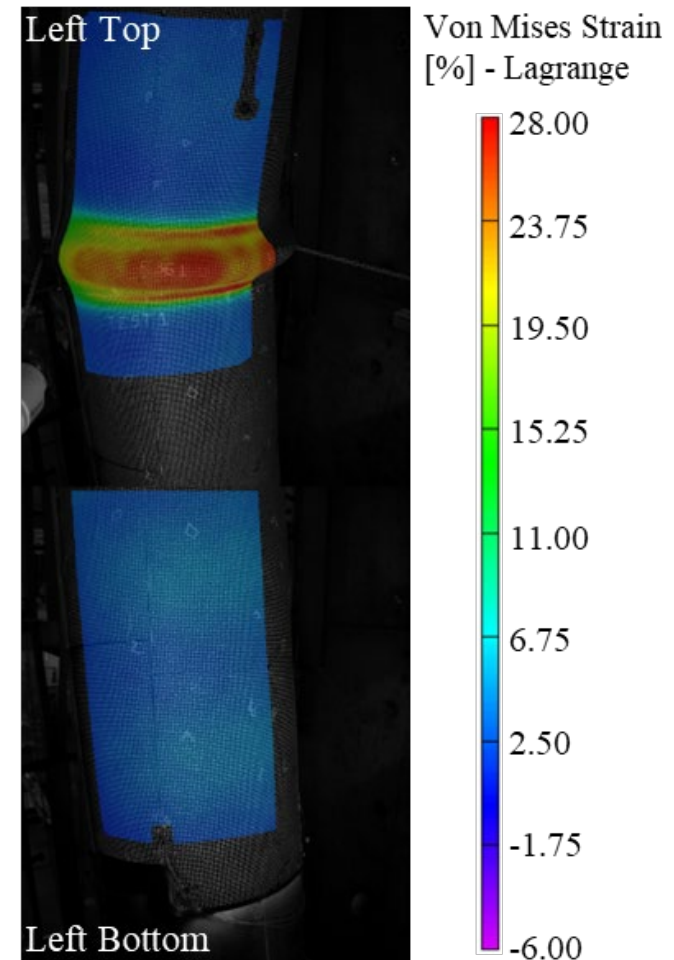


Strains Measurements During Testing

17.8° Bend Angle



22.6° Bend Angle



Achieved a 51.2° bend angle

**Observed severe buckling
with self-contact**

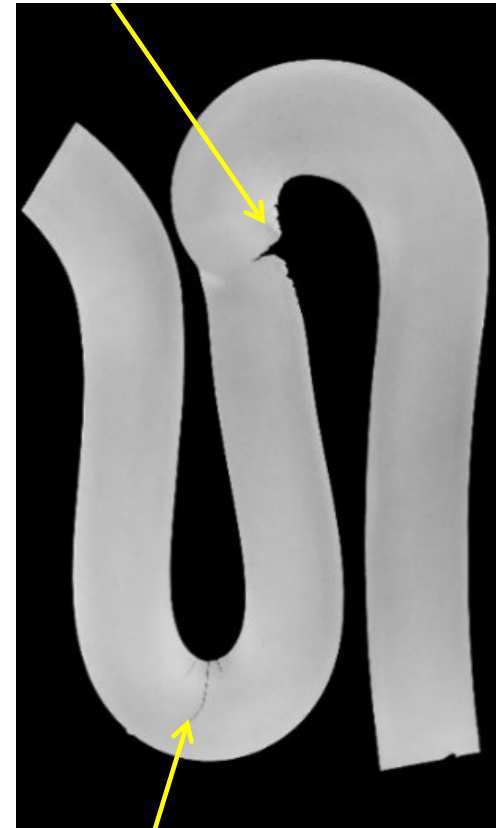
**Found no leakage or loss of
containment**



Post Test Examination

- Crack on inner surface of buckle crest
 - 69% of wall
- Tearing through outer surface of buckle valley
 - 36% of wall
 - Possible local strain reversal
- Approaching critical state but no leakage

Tear from OD



Crack from ID

Images from Timms, C., Tsuru, E., Kobayashi, S. and Klaczek, W.
"Experimental Results from Full-Scale Bend Testing of NPS24 X65
Pipe." Proceedings of ISOPE. Ottawa, Canada, June 19-23, 2023.

Axial Pre-strain Followed by Burst



Specimen Identification	2D Axial Pre-strain	Burst Pressure	Maximum Hoop Strain at Burst
	(% ϵ)	(MPa)	Top/Bottom (% ϵ)
1	0	31.2	6.4
2	-1.11	31.9	7.7
3	-17.2	28.2	31.4 (19.3 at burst location)

- NPS24 X65 pipe bend test
 - 51.2° bend angle
 - Buckle developed past the point of self contact
 - No leakage or loss of containment
 - Cracking/tearing likely due to local strain reversal
- Other C-FER Testing Experience
 - Pressure capacity does not seem to be significantly undermined by high axial strains
 - Pipe body materials have sufficient ductility to accommodate significant axial strains

- Interaction of large strains with girth welds
 - Central to developed protocols
- Interaction of large strains with seam welds
 - Seam weld strength undermatch may be problematic
- Strain capacity under cyclic loading may fall short of results for monotonic loading
 - Cyclic loading arising from seismic events
- Hydrogen pipelines may have reduced strain capacity
 - Hydrogen exposure undermines fracture toughness