Sureflex JIP - Industry Guidance and Good Practice for Unbonded Flexible Pipe Systems

Subsea Expo ‘24

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21st February 2024

The Sureflex JIP

1990 — HSE Monitoring / Integrity JIP

2000 — UKOOA Flexible Pipe Integrity JIP

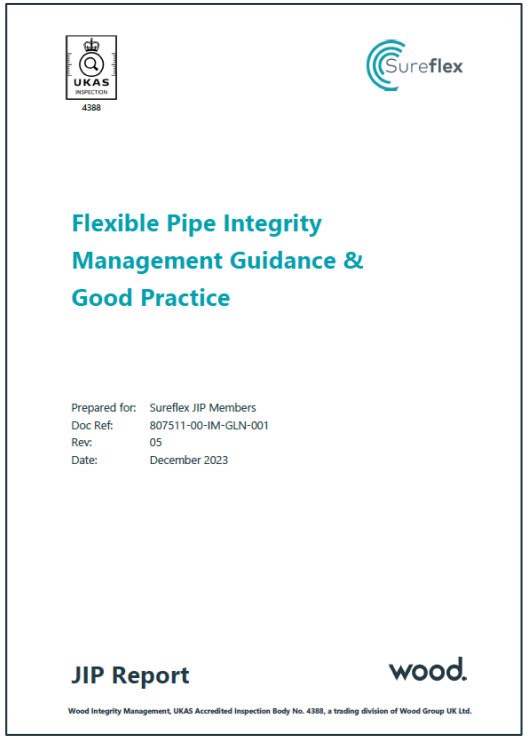
2010 — Sureflex JIP (2009/10), Oil & Gas UK

Sureflex JIP (2015-17), Oil & Gas UK

2020 — **Sureflex JIP (2020-23)**
Sureflex Network (2024-26)

SureFlex JIP:

- Integrity Management of Unbonded Flexible Pipes
- SureFlex JIP, lead by Wood, formed in 2010
- Previous update published 2017.
- 5th Generation JIP issued in December 2023
- https://www.woodplc.com/sureflex-report-dec2023-flexiblepipeintegrity
- Contributions from: Global Operators, Manufacturers, Certification Bodies, and Third-Party Vendors.
- Sureflex Network Scope in progress.



Scope of the JIP:

- Capture Population and Damage / Failure statistics.
- Share Integrity Management guidance and good practice.
- Share Operator Case Studies and identify emerging threats.
- Review Inspection and Monitoring and Repair Technologies.
- Work collectively to improve the operational integrity and prevent incidents.

THE most comprehensive and widest reaching database relating to Unbonded Flexible Pipe Integrity Management.

Sureflex - The Members

Sureflex

anp Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

Baker Hughes

bp

Canadian Natural

Chevron

equinor

ExxonMobil

Harbour Energy

HSE

INPEX

NOPSEMA Australia's offshore energy regulator

NOV

BR PETROBRAS

PETROLEUM SAFETY AUTHORITY NORWAY

PETRONAS

PetroRio

Santos

TechnipFMC

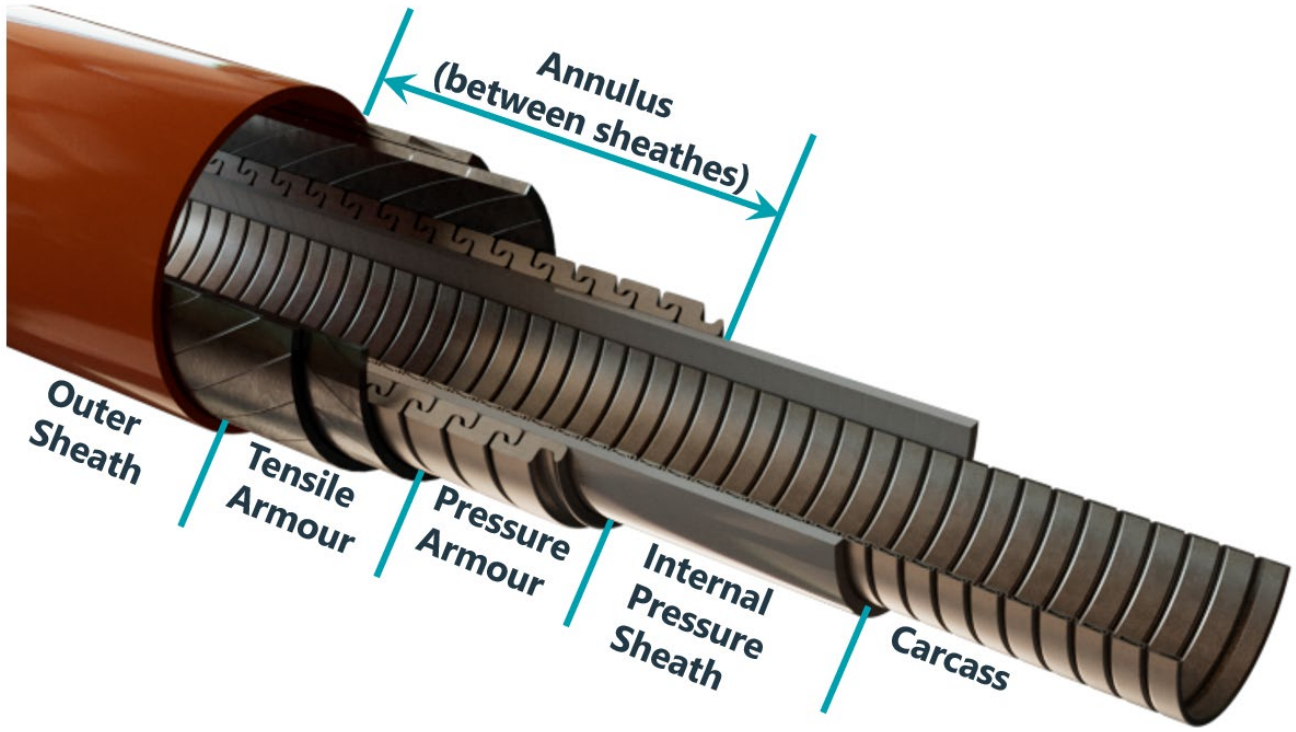
Woodside

Flexible Pipe Construction

Key points:

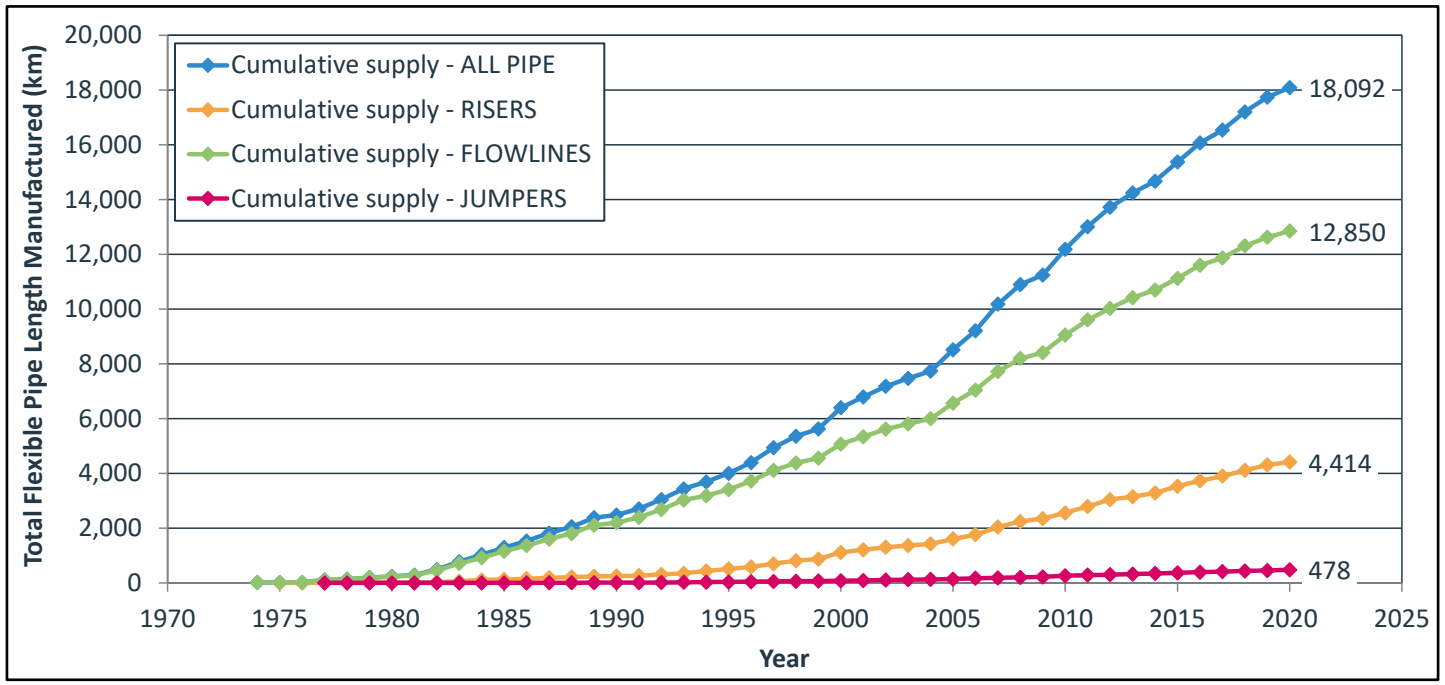
1. The pressure retaining layer is the pressure sheath, NOT the carcass.
2. Tensile armour is one continuous strip for the length of the pipe. Note: There are welds in the strips.
3. A flexible pipe will always have:
   - Pressure sheath
   - Tensile armour
   - Outer sheath

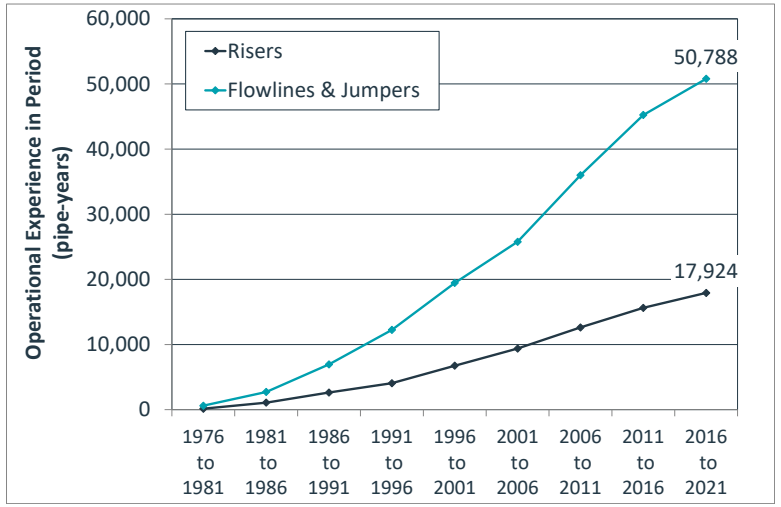
- All other layers are specific to design/project requirements.

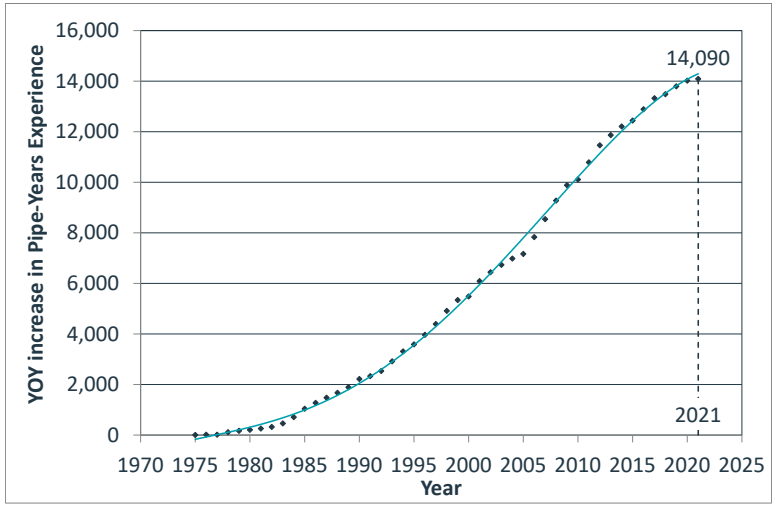


Flexible Pipe Population

The Sureflex membership includes the three main manufactures allowing the JIP to compile the most comprehensive dataset relating to the global population supply of unbonded flexible pipes.



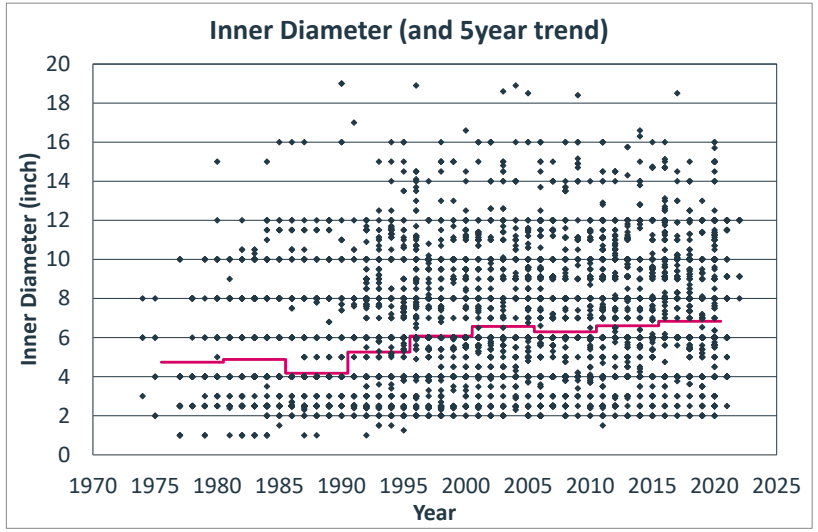


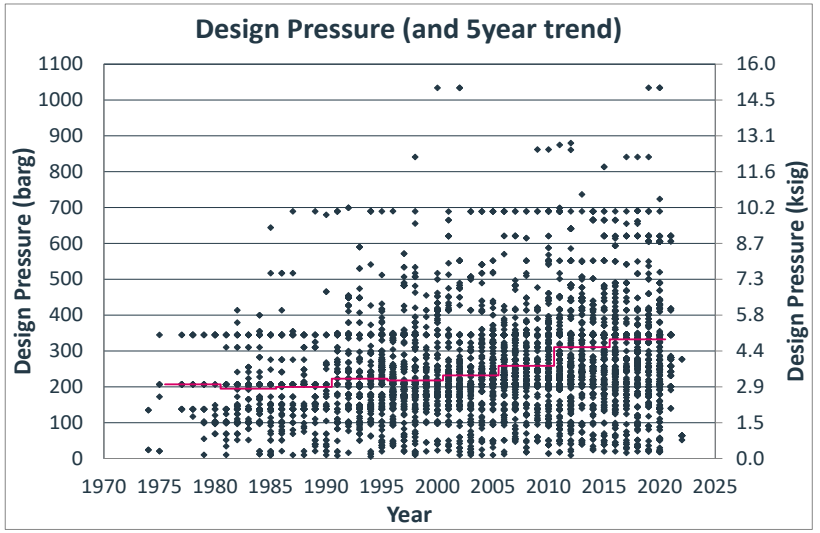


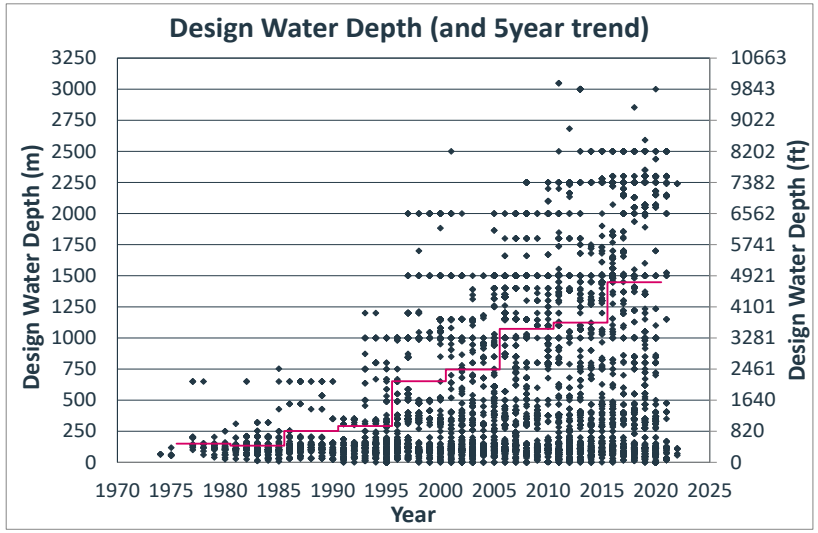
Supplied Pipe Experience

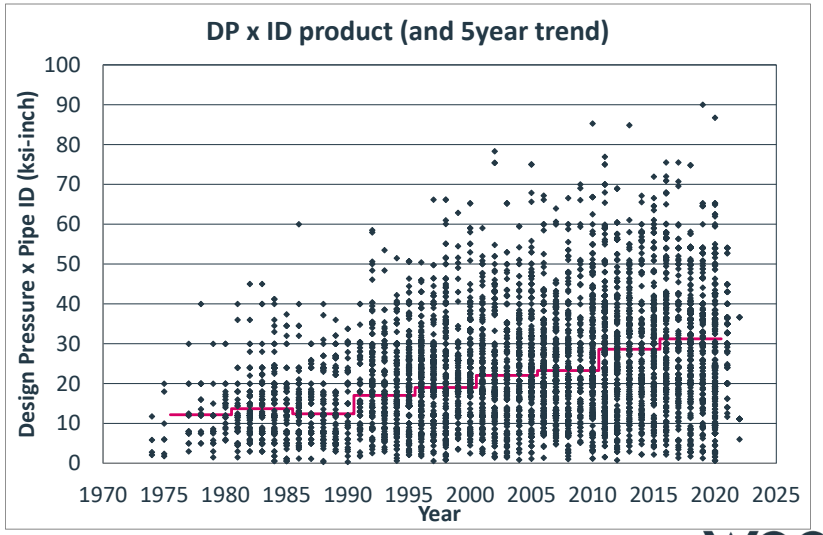
Supplied Pipe experience showing 5-year increasing trends for pipe design parameters as the operational envelope expands.

(Clockwise from top left: Inner Diameter; Design Pressure; Design Water Depth; DP x ID Product.)

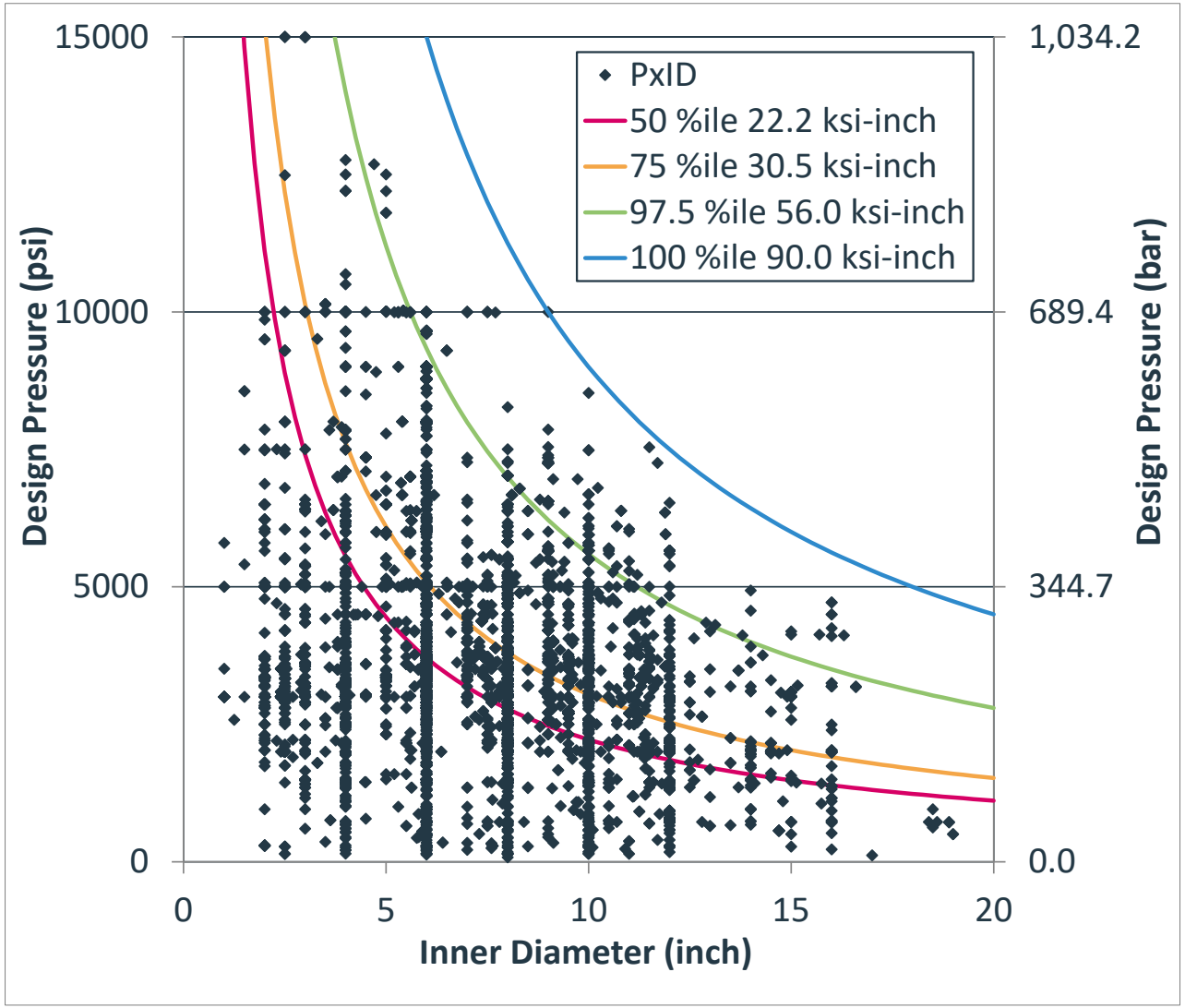


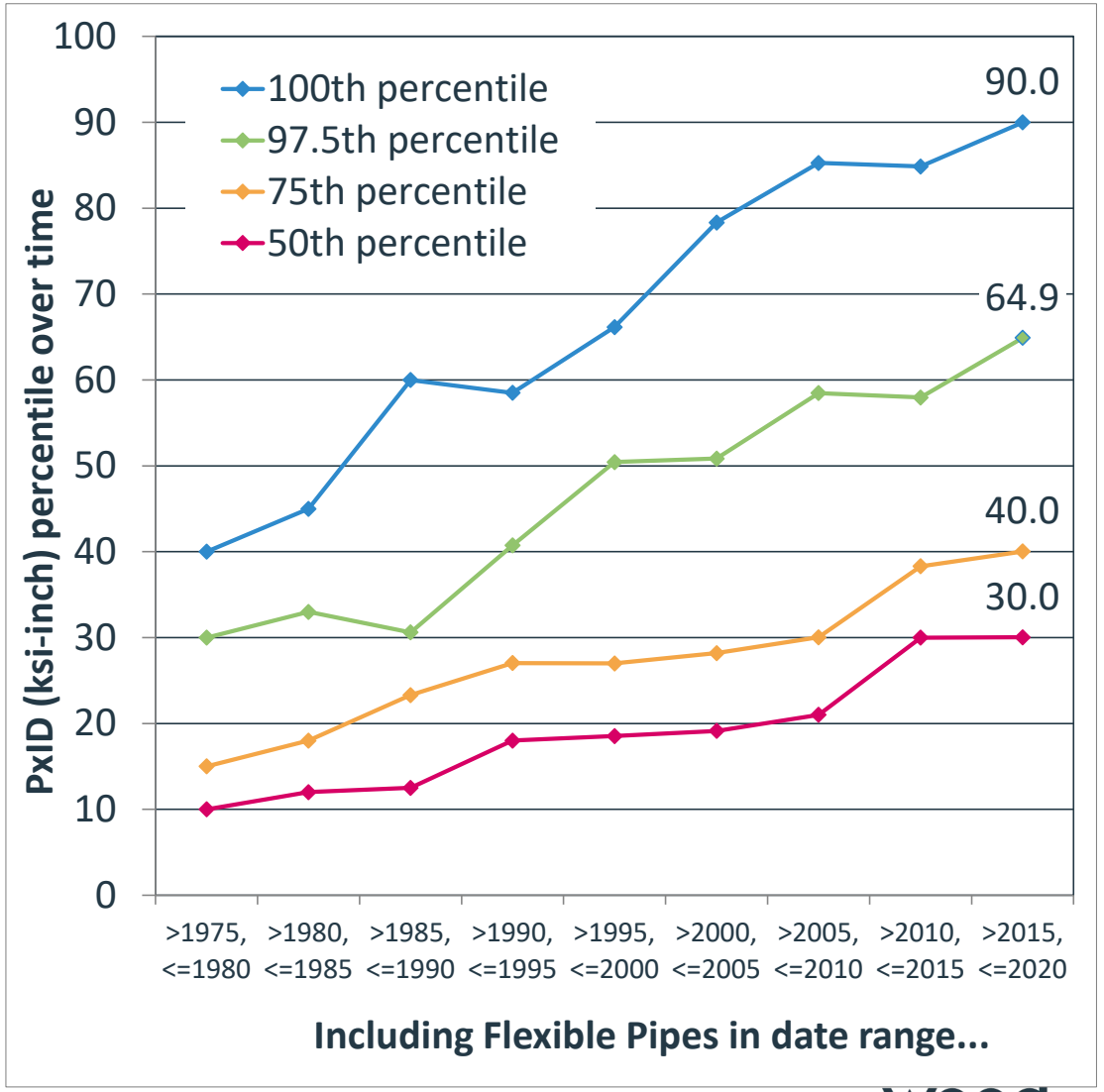




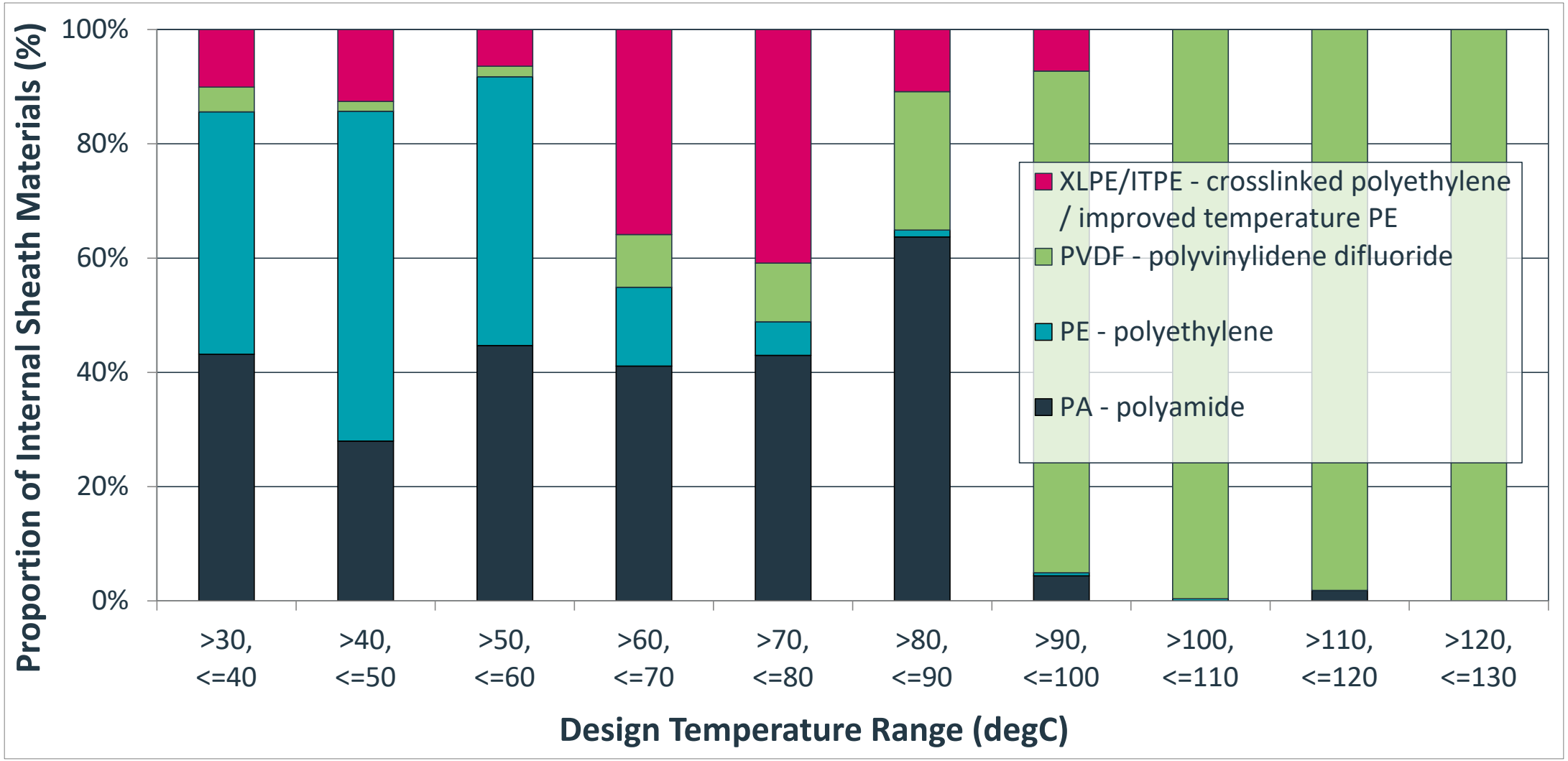


Design Pressure vs Inner Diameter





Pressure Sheath Polymers



Damage and Failure

Damage and Failure reporting from around the globe.

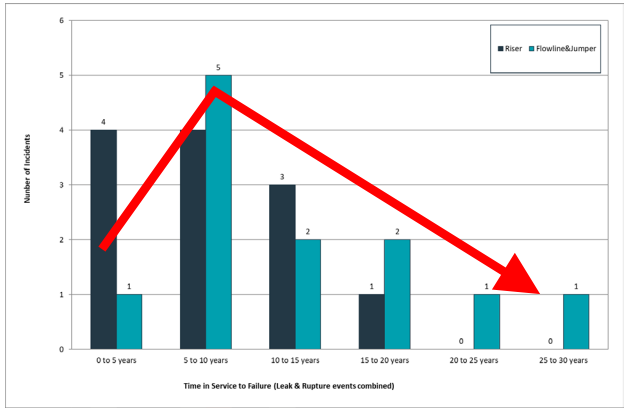
Used to identify trends, influence design improvements/mitigations and drive development of inspection and monitoring technologies.

Supports risk assessment development through estimation of damage/ failure rates.

Damaged ≠ Failure and ≠ Unfit for continued operation

- All events are reviewed and carefully categorised by:
  - **Status** e.g. Minor Defect, Shutdown, Damaged, Leak, Rupture
  - **Damage Mechanism** – extensive list of mechanisms to provide industry with clarity and trending

Selected event groupings are shared in the report. Members can interrogate the database directly through a Power BI Interface and create their own analyses.



Impact
How severe would the outcomes be if the risk occurred?

Probability ***What is the probability the risk will happen?***

	Insignificant 1	Minor 2	Significant 3	Major 4	Severe 5
5 Almost Certain	Medium 5	High 10	Very high 15	Extreme 20	Extreme 25
4 Likely	Medium 4	Medium 8	High 12	Very high 16	Extreme 20
3 Moderate	Low 3	Medium 6	Medium 9	High 12	Very high 15
2 Unlikely	Very low 2	Low 4	Medium 6	Medium 8	High 10
1 Rare	Very low 1	Very low 2	Low 3	Medium 4	Medium 5

Damage / Failure Cause	Number of cases, by status					Total	%
	Minor defect / damage	Shut-down (integrity concern)	Damaged (failure initiator)	Failed - leak	Failed - rupture		
Line Recovered Proactively - No significant damage / defect identified		44				44	5.0%
Carcass Failure - Fatigue				1		1	0.1%
Carcass Failure - Multilayer PVDF Collapse		9	24	6		39	4.5%
Carcass Failure - Tearing / Pullout	1	5	6	5		17	1.9%
Internal Damage - Pigging			2			2	0.2%
Internal Pressure Sheath - Ageing		27	1	21		49	5.6%
Internal Pressure Sheath - End Fitting Pull-out	2	19	3	19		43	4.9%
Internal Pressure Sheath - Fatigue / Fracture / Microleaks	2	1	3	9		15	1.7%
Internal Pressure Sheath - Smooth Bore Liner Collapse	3			6	3	12	1.4%
Tensile Armour Wire Breakage - in / close to end fitting				3	1	4	0.5%
Tensile Armour Wire Breakage - in main pipe section		1	12	1	8	22	2.5%
Tensile Armours - Birdcaging			6	13	1	20	2.3%
Corrosion of Armours - Major / Catastrophic			5	13	15	33	3.8%
Corrosion of Armours - Moderate	5	4	7			16	1.8%
Annulus Flooding - Cause Unknown	22	5	90			117	13.4%
Annulus Flooding - Defective Annulus Vent System	14		4			18	2.1%
Annulus Flooding - Outer Sheath Damage - Ageing / Fracture	1		4			5	0.6%
Annulus Flooding - Outer Sheath Damage - Mechanical / Impact / Wear	45	18	99			162	18.5%
Annulus Flooding - Permeated Liquids	2					2	0.2%
Outer Sheath Damage - Annulus NOT flooded - Ageing / Fracture	4					4	0.5%
Outer Sheath Damage - Annulus NOT flooded - Mechanical / Impact / Wear	21		6			27	3.1%
End Fitting Leak / Failure			1	25	3	29	3.3%
Ancillary Equipment - Bend Stiffener - Connection / Interface	7	2	28			37	4.2%
Ancillary Equipment - Bend Stiffener - 2 part failure			11			11	1.3%
Ancillary Equipment - Bend Stiffener - other	4		2	2		8	0.9%
Ancillary Equipment - Buoyancy Modules	1	1				2	0.2%
Ancillary Equipment - Hang-off Failure			1			1	0.1%
Ancillary Equipment - Hold-down Failure (tethers / clamps / connections)	2		6	1		9	1.0%
Ancillary Equipment - Mid Water Arch	2	2	5	1		10	1.1%
Ancillary Equipment - Vent System Anomalies / Blockage	21	3	18			42	4.8%
Ancillary Equipment - Other				2		2	0.2%
Global Pipe Defect - Dropped Object / 3rd Party Interaction / Dragging	7	2	3	1		13	1.5%
Global Pipe Defect - Excess Tension					1	1	0.1%
Global Pipe Defect - Excess Torsion			2	1	1	4	0.5%
Global Pipe Defect - Flow Induced Pulsation (FLIP) causing wider system effect		5				5	0.6%
Global Pipe Defect - Ovalisation			4			4	0.5%
Global Pipe Defect - Overbend / Pressure Armour Unlock			5	12	1	18	2.1%
Global Pipe Defect - Rough Bore Collapse			2	1		3	0.3%
Global Pipe Defect - Upheaval Buckling	3		1	3		7	0.8%
Global Pipe Defect - Pipe Blockage (wax/hydrates/other)	3	1	9			13	1.5%
Global Pipe Defect - Excess Marine Growth			1			1	0.1%
Failure Mechanism Disputed	1			1		2	0.2%
Total	**173**	**149**	**371**	**147**	**34**	**874**	**100.0%**
%	**19.8%**	**17.0%**	**42.4%**	**16.8%**	**3.9%**	**100.0%**	

Loss of Containment Cases

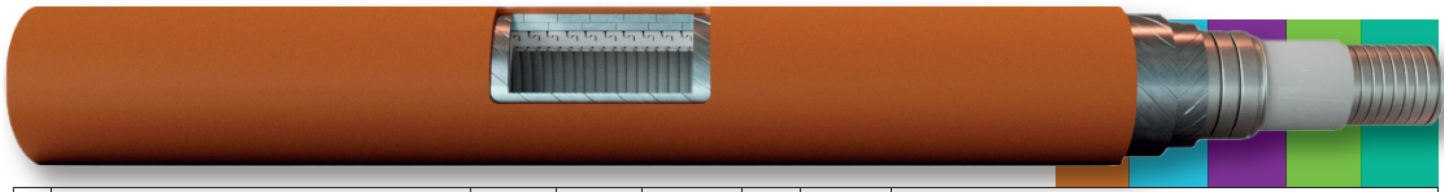
Damage / Failure Cause	Failed - leak				Failed - rupture			
	Total cases	With dates	Cases since Jul-11	Cases since Jul-16	Total cases	With dates	Cases since Jul-11	Cases since Jul-16
Carcass Failure - Fatigue	1	1						
Carcass Failure - Multilayer PVDF Collapse	6	6	1	1				
Carcass Failure - Tearing / Pullout	5	5	1					
Internal Pressure Sheath - Ageing	21	19	2					
Internal Pressure Sheath - End Fitting Pull-out	19	19	1					
Internal Pressure Sheath - Fatigue / Fracture / Microleaks	9	8	2					
Internal Pressure Sheath - Smooth Bore Liner Collapse	6	4			3	3		
Tensile Armour Wire Breakage - in / close to end fitting	3				1	1	1	1
Tensile Armour Wire Breakage - in main pipe section	1	1	1		8	8	8	4
Tensile Armours - Birdcaging	13	11	1		1	1		
Corrosion of Armours - Major / Catastrophic	13	9	4		15	15	11	8
End Fitting Leak / Failure	25	24	10	6	3	3		
Ancillary Equipment - Bend Stiffener - other	2	2						
Ancillary Equipment - Hold-down Failure (tethers / clamps / connections)	1							
Ancillary Equipment - Mid Water Arch	1	1						
Ancillary Equipment - Other	2	2						
Global pipe defect - Dropped Object / 3rd Party Interaction / Dragging	1	1	1	1				
Global pipe Defect - Excess Tension					1	1		
Global pipe Defect - Excess Torsion	1	1			1	1	1	1
Global pipe defect - Overbend / Pressure Armour Unlock	12	9	1	1	1	1	1	1
Global pipe defect - Rough Bore Collapse	1	1	1	1				
Global pipe Defect - Upheaval Buckling	3	3	2	1				
Failure Mechanism Disputed	1	1	1					
Total	**147**	**128**	**29**	**11**	**34**	**34**	**22**	**15**
%	**-**	**87.1%**	**22.7%**	**8.6%**	**-**	**100.0%**	**64.7%**	**44.1%**

Key Emergent Threats

Key emergent failure modes that have been shared with the industry during the most recent revision of the JIP:

- Stress corrosion cracking of armours due to CO_2 (rapid failure mode)
- Corrosion failures due to atmospheric backflow (air-breathing vents)
- Additional fatigue / corrosion-fatigue failures with new contributory factors

Inspection Monitoring Maintenance and Repair



App B Ref	Inspection / Monitoring / Technology	Monitoring	Inspection / Testing	Maintenance / Repair	Take Up (1-5)	JIP Member Feedback (1-5)	Technology Readiness Level (1-7)						
							Global Riser	Ancillary Equipment	Outer Sheath	Tensile Armour	Pressure Armour	Pressure Sheath	Carcass
B.1	Visual Inspection ROV		X		5	4	7	7	7				
B.2	Visual Inspection Diver		X		2	4	7	7	7				
B.3	Visual Inspection Micro-ROV		X		2	4	7	7	7				
B.4	Visual Inspection Roped Access		X		2	4	7	7	7				
B.5	Visual Inspection ROAV		X		1	4	7	7	7				
B.6	I-Tube Inspection		X		2	4		7	7				
B.7	Laser Measurement		X		2	5		7	7				
B.8	Marine Growth Removal			X	3	4		6	6				
B.9	Environment Monitoring	X			4	4	7			7			
B.10	Offset and Motion Monitoring	X			5/4	4	7						
B.11	Embedded Curvature Monitoring	X			1	N/A	5			5	5		
B.12	Sonar Monitoring (Bend Stiffeners/Risers)	X			1	4	6	6					
B.13	Integrated Fibre Optic Strain Monitoring	X			2	2	6			6			
B.14	Retrofit Bending Control			X	1	N/A	6/5	6/5					
B.15	Temperature Monitoring Inline	X			5	4			7			7	
B.16	Temperature Monitoring Remote	X			2	4		6/5	6/5			6/5	
B.17	Integrated Fibre Optic Temperature Monitoring	X			2	4			7			7	
B.18	Pressure Monitoring Inline	X			5	4				7	7	7	7
B.19	Pressure Testing (Hydro Testing)		X		5/3	3				7	7	7	
B.20	Topsides Annulus Vent Systems Inspection	X	X	X	3	5		7					
B.21	Topsides Annulus Testing		X		5	4			7			7	
B.22	Topsides Annulus Monitoring	X			3	4			7			7	
B.23	Subsea Annulus Testing / Monitoring	X	X		1	N/A			6				
B.24	Vent Port Unblocking			X	1	N/A			6				
B.25	Ultrasonic Testing	X	X		4	4			7	7			
B.26	Electrical Oter Sheath Breach Detection	X	X		1	N/A			5				
B.27	Fibreoptic Armour Wire Inspection (End Fitting)		X		1	N/A				5			
B.28	Clamped Outer Sheath Repair			X	3	4			7				
B.29	Polymer Coupon Monitoring	X			4	4			7			7	
B.30	Bore Fluid Sampling	X			4	5				7	7	7	7
B.31	X-Ray Computer Tomography		X		1	N/A			7	7	7	7	7
B.32	Eddy Current Inspection		X		2	3				7	5		
B.33	Direct Strain Measurement	X	X		2	3				6			
B.34	Magnetic Stress Measurement	X	X		3	2				6/5	4		
B.35	Microwave Inspection		X		1	N/A				5			
B.36	Radiography		X		2	4/2				7/5	7/5	3	7/5
B.37	Acoustic Emission Monitoring - Tensile Armour	X			1	4				7			
B.38	Acoustic Emission Monitoring - Carcass	X			1	2							6
B.39	Internal Inspection		X		2	4							7/6
B.40	Flexible ILI		X		2	3							7
B.41	Flexible Dissection		X		4/3	5	7	7		7	7	7	7

Inspection Maintenance Monitoring and Repair Example Tables

Standardised format for all technologies reviewed.

Generic and not vendor specific.

Captures real world experiences.

Table B.10 Technology Review – Topsides Inspection – Annulus Vent Systems

Inspection / Monitoring / Technology Name	Topsides Inspection – Annulus Vent Systems
Technology Readiness Level (TRL) (Range 1 to 7)	7
Take-Up (Range 1 to 5)	3
Industry (JIP) Feedback (Range 1 to 5)	5

Summary

The main intent of this inspection is to ensure that an unrestricted vent path exists to allow venting of permeated gasses through the topsides end fitting for all risers. De-aerated WI lines are unlikely to require ongoing venting, although access to the annulus for annulus monitoring may be of significant benefit (Refer to Table B.12).

Benefits	**Limitations**
• Confirms free venting of the riser annulus. • Confirms potential flow rate limitations of the installed system (insufficient rate of through flow can lead to annulus pressure build up).	• Requires safe and independent access to the vent system.

Procedure

Inspection should ensure that a clear and free vent path exists, as follows:

- if an annulus pressure gauge is present, the pressure should be recorded
- any in-line valves should be verified as being open, and registered in a locked open / closed register
- if NRV's / PRV's are present, their functionality should be verified, or they should be replaced
- record any corrosion products, externally or retrieved via drain points, or other damage for remediation

Industry Practice

Normal good practice is to perform this maintenance activity annually. It is often performed in conjunction with an annulus testing campaign, when the end fitting vent ports can also be verified as being free and clear.

Guidance Note

Verifying that a clear annulus vent path exists is critical to annulus integrity as it mitigates the risk of annulus over pressure and failure of the outer sheath. There have been several historic reports where multiple risers have been partially or fully flooded as a result of fluids flowing into the risers from a comingled or common vent system.

Good practice utilises NRVs between the individual risers and the vent header to mitigate against this risk. There is recent failure experience (three events) attributed to cyclic backflow of moisture / atmospheric air, leading to catastrophic corrosion failures within the end fitting which would have been prevented had NRVs been installed.

The Future

JIP Report published for free access and use by the industry.

https://www.woodplc.com/sureflex-report-dec2023-flexiblepipeintegrity

Sureflex Network 2024-2026

- Almost 100% of existing JIP members already signed up to the Network scope.
- New non-member operators of the JIP have agreed to join.
- Rapid sharing of emerging threats and lessons learned.
- Sharing feedback on emerging inspection technologies.

Working together to improve unbonded flexible pipe integrity.

Further Information and Contact

If you have any specific questions about the integrity management of unbonded flexible pipes or would be interested in joining the ongoing Sureflex Network please reach out to the team using the below contact details:

Sureflex@woodplc.com

Any Questions?


wood.