Zap-Lok – A Mechanical Interference Connection to Overcome Today's Offshore Installation Challenges

Presented by: *Dr. Ben Chapman, Director – Line Pipe Products & Services*

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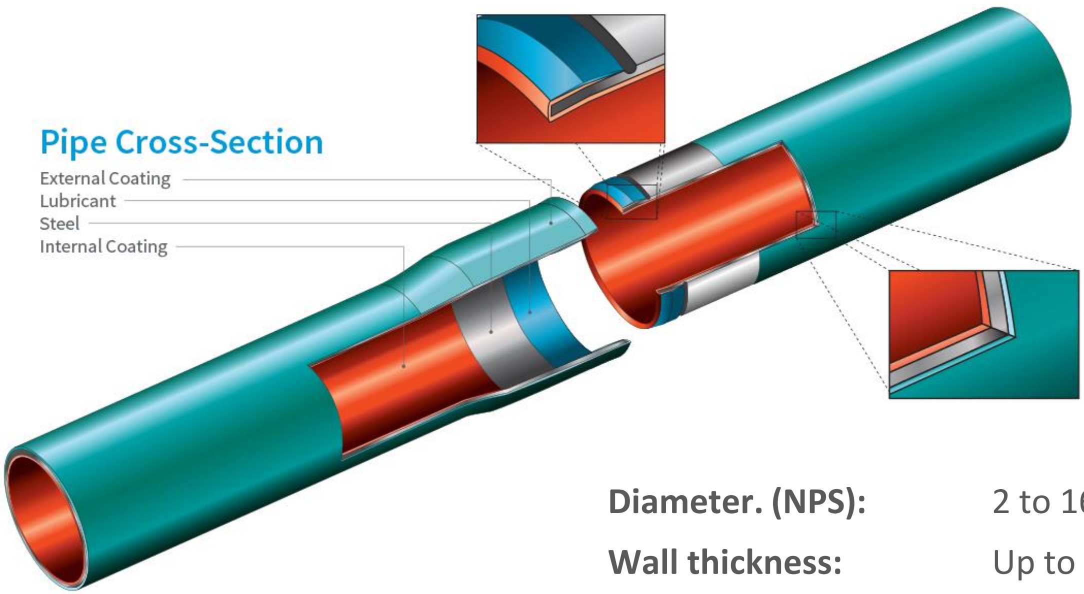
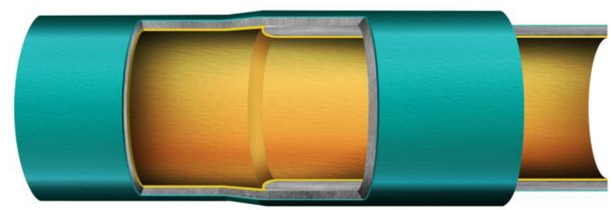
1. Enabling Concept

1.1 Zap-Lok Mechanical Interference Connection and Internal Plastic Coating (IPC)





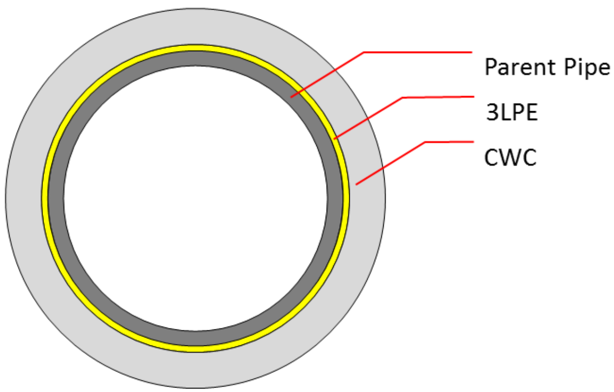
Diameter. (NPS):	2 to 16-inch (50-400mm)
Wall thickness:	Up to 1.000” (25.4mm)
Material:	Grade B to X70; SMLS, HFI or ERW
Service:	Sweet and sour crude, gas, condensate, water, steam
Pressure:	As per line pipe material specification
Corrosion Barrier:	Epoxy / Phenolic – up to 2% H_2S, CO_2, Acids, SRBs

1. Enabling Concept

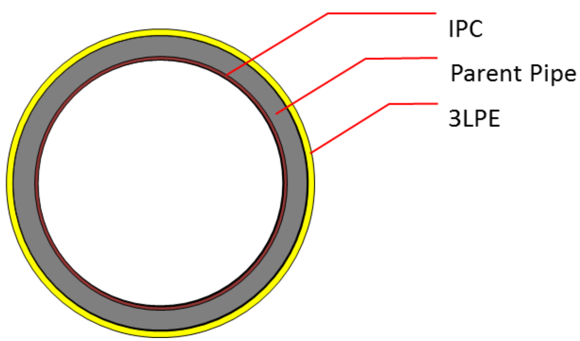
1.2 Zap-Lok / Internal Plastic Coating (IPC) Design

Design Schematic

Traditional Design



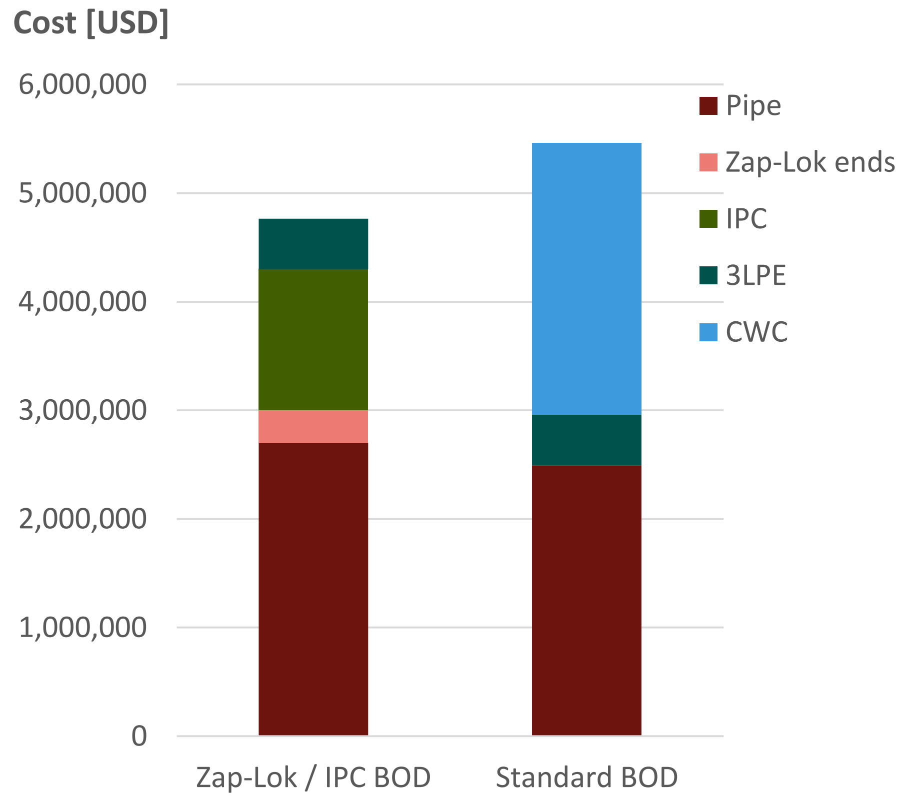
Zap-Lok IPC Design



Raw Material Cost Comparison (DDU)

25km x 10 ¾" OD, API 5L Gr. X52 HFI PSL2, SG 1.25

Zap-Lok / IPC: 17.5mm wt, 3LPE, TK70
Traditional: 12.7mm wt + 3mm CA, 3LPE +40mm CWC



1. Enabling Concept

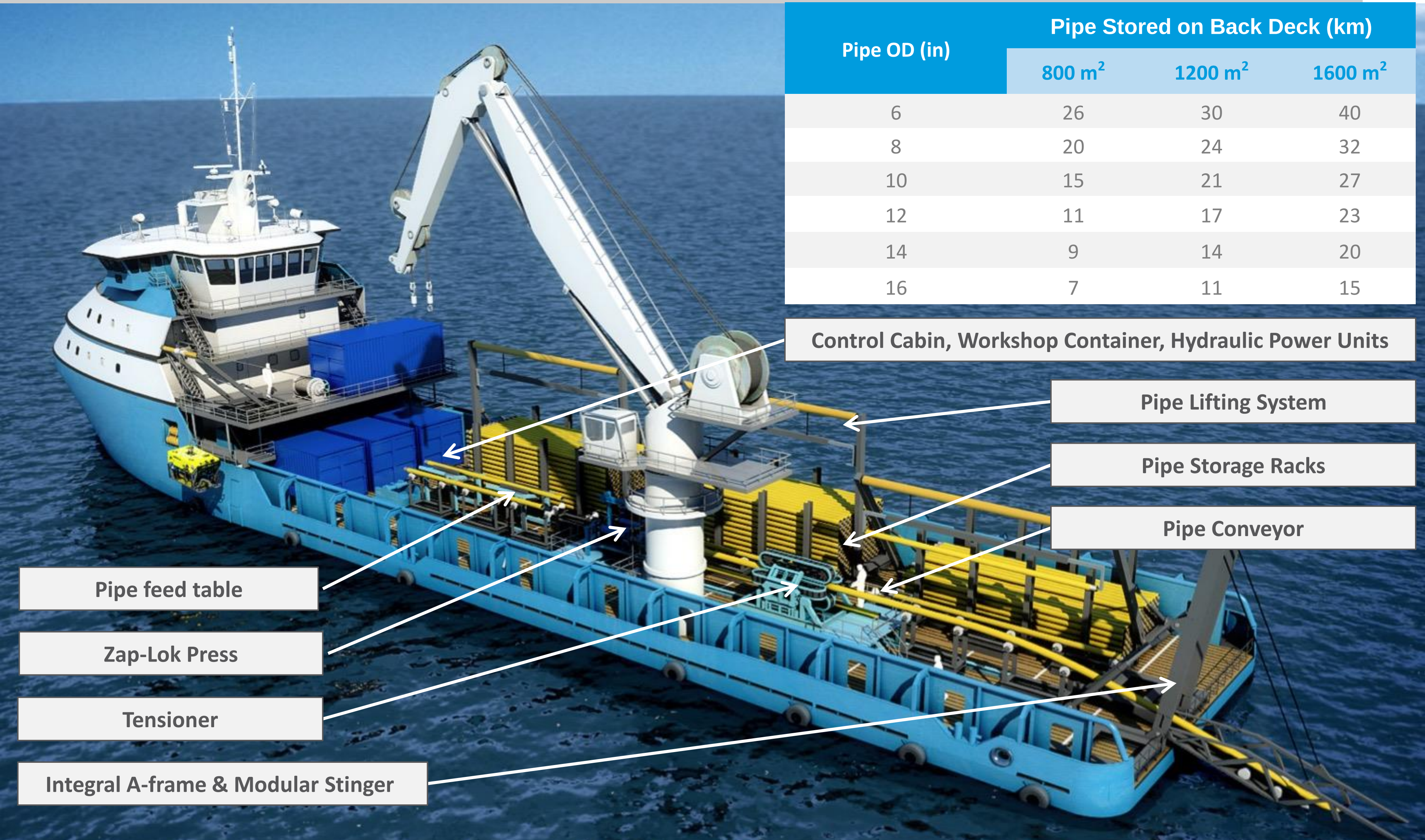
1.3 Utilization of Vessels of Opportunity

Zap-Lok connectors enable the end user to consider smaller vessels of opportunity as the amount of offshore work is reduced, i.e. only one connection station no field jointing stations are required. Considering a standard S-Lay construction method, the mobilization / demobilization costs and day rates are dramatically reduced.

1. Enabling Concept

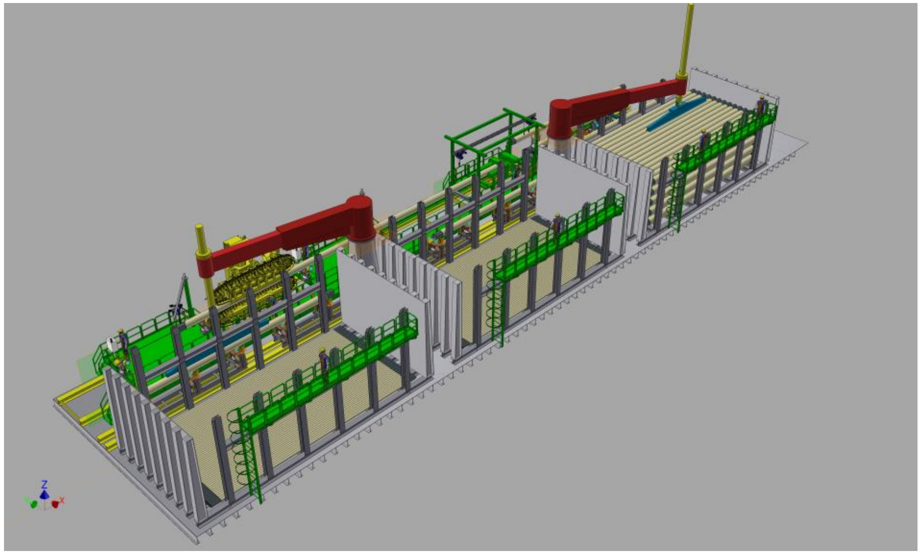
1.4 Modular Pipelay System (MPS)

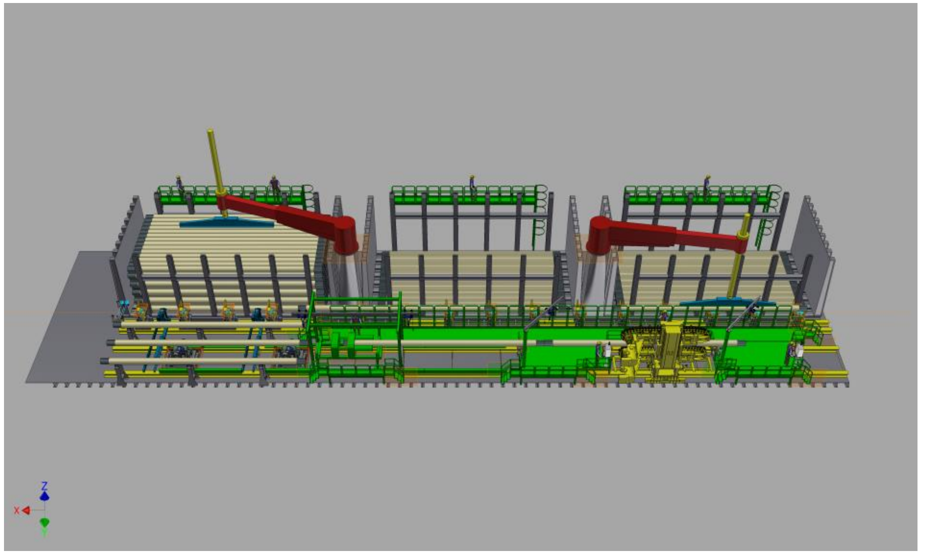
Pipe OD (in)	Pipe Stored on Back Deck (km)		
	$800\ m^2$	$1200\ m^2$	$1600\ m^2$
6	26	30	40
8	20	24	32
10	15	21	27
12	11	17	23
14	9	14	20
16	7	11	15



1. Enabling Concept

1.4 Modular Pipelay System (MPS)





The Remacut Modular Pipelay System (MPS)

- **Fully automated**
- **Fully North Sea compliant**
- **$4-6m per system including stinger (not shown here)**

1. Enabling Concept

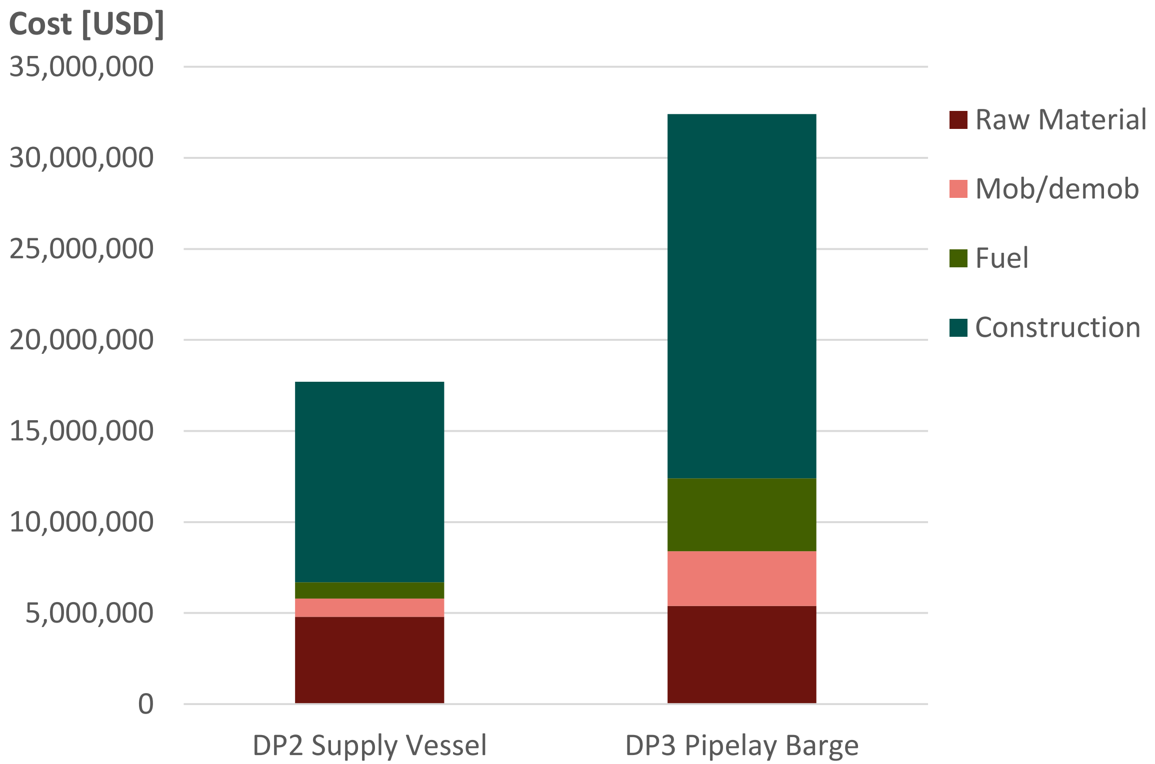
1.4 Modular Pipelay System (MPS)

1. Enabling Concept

1.5 Tie-back Cost Summary – DP2 S-Lay

25km x 10 ¾” OD, API 5L Gr. X52 HFI PSL2, SG 1.25

Zap-Lok IPC BOD: DP2 supply vessel (modified S-Lay) using Zap-Lok connector and MPS
Traditional BOD: DP3 pipelay barge (S-Lay) using girth welding



Additional OPEX Benefits

Increased flow rates

No corrosion

No MIB

No waxing

No scaling

No inhibitors

No erosion

Reduced pigging

LOP costs dramatically reduced

CAPEX and OPEX reduced

2. Zap-Lok Mechanical Interference Connection

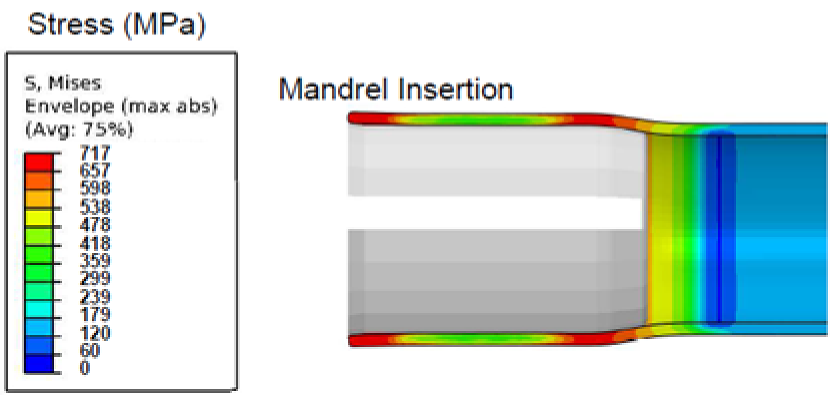
2.1 Operating Envelope

Test	Average Result	Compliance
Axial Tension	70% UTS	ASME B31.4 / B31.8, ISO 21329 (app. Level 4)
Axial Compression	> 95% UTS	ASME B31.4 / B31.8, ISO 21329 (app. Level 4)
Internal Pressure	> 95% UTS	ASME B31.4 / B31.8, ISO 21329 (app. Level 4)
Bending	> 95% UTS	ASME B31.4 / B31.8, ISO 21329 (app. Level 4)
Fatigue – in air	DnV D Class weld curve	BS 7608 F2 / DNV C1, ISO 21329 (app. Level 4)
Fatigue –in water	DnV C2 Class weld curve	BS 7608 F2 / DNV C1, ISO 21329 (app. Level 4)
Stress Corrosion Cracking	No reduction in strength	NACE MR0175 / NACE TM0177 – Method A
Crevice Corrosion	No reduction in strength	1 month exposure at 130°F and 500psi in brine with 1,000ppm acetic acid, 30% CO_2, 70%N_2
Electrical Resistivity	±1μΩ / connection	N.B. 10A, 25mV FSD

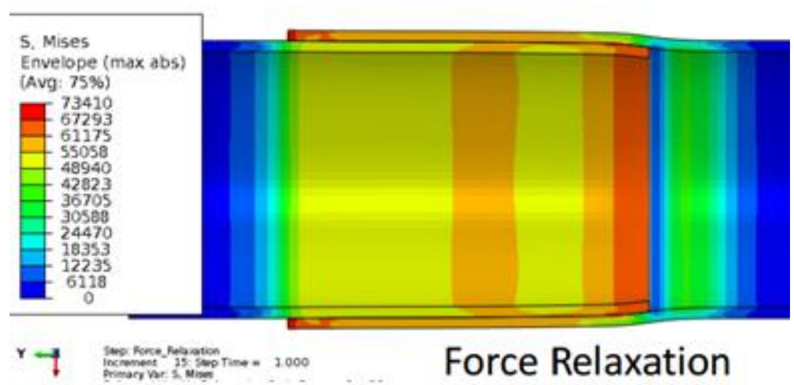
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

Make-Up Loads - Static



Stresses during mandrel insertion



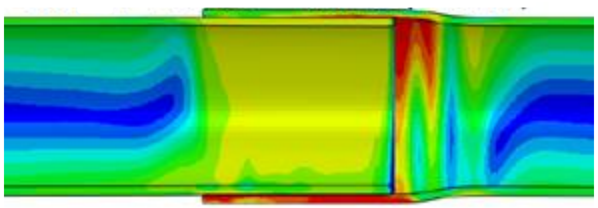
Stresses following pin insertion.

12-inch, 0.500” wt, Grade X65

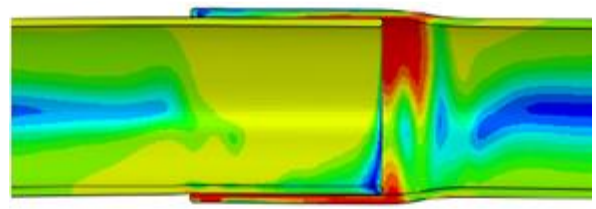
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

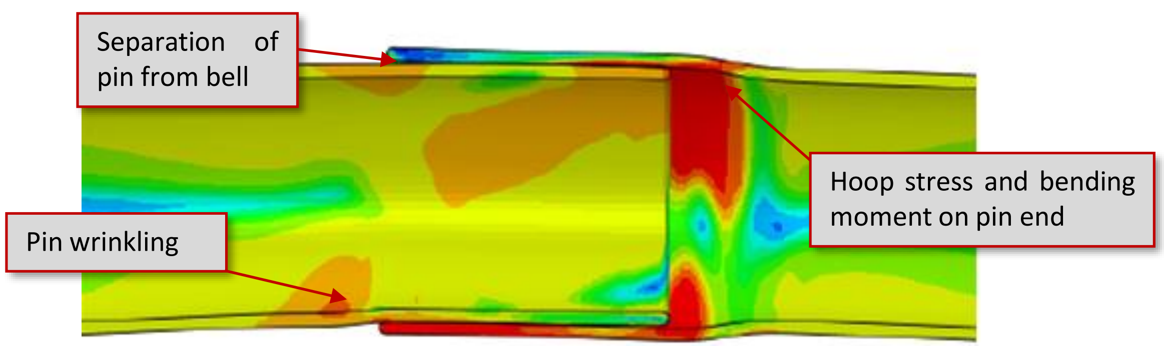
Installation Loads - Dynamic



Bending to 140m radius



Bending to 67m radius



Bending to 30m radius.

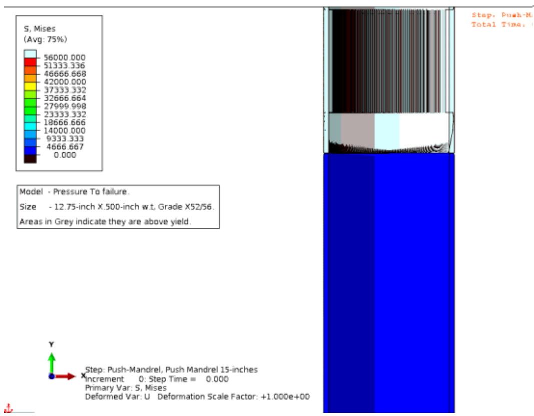
12-inch, 0.500” wt, Grade X65

2. Zap-Lok Mechanical Interference Connection

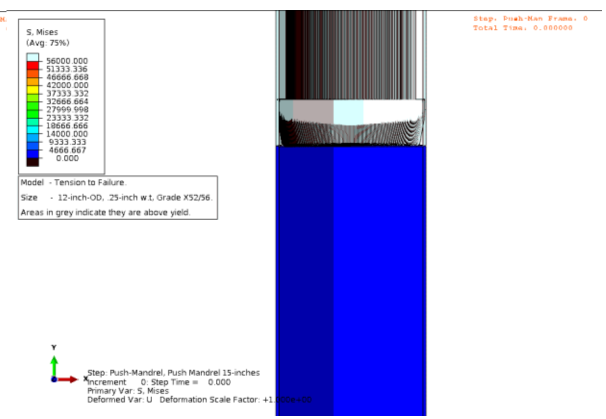
2.1 Operating Envelope

Service Loads - Static

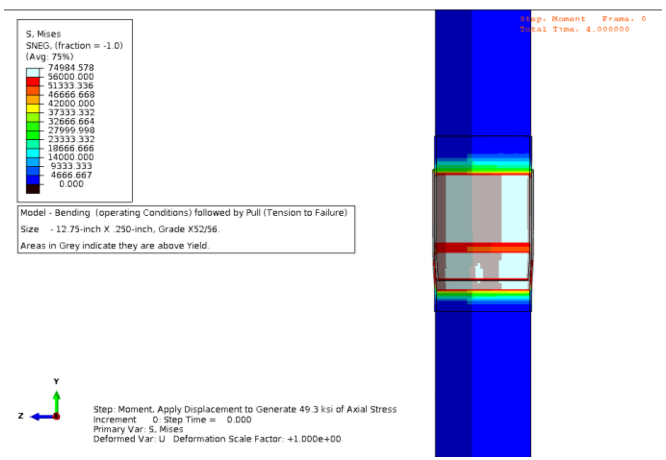
Pressure to Failure



Tension to Failure



Bending and Tension

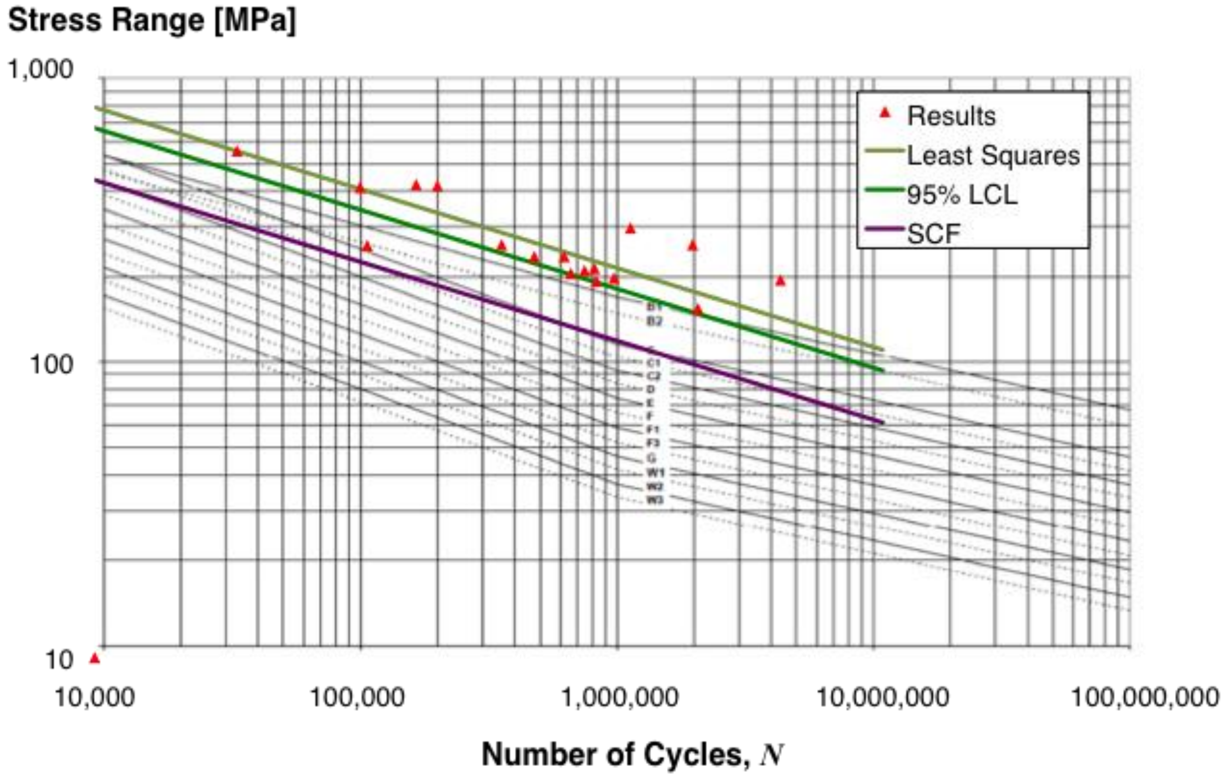


12-inch, 0.500” wt, Grade X65

2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

Service Loads - Dynamic



DNV-RP-C203 and Zap-Lok S-N Curves in Seawater with CP vs. Weld Curves

1. Zap-Lok Mechanical Interference Connection

2.2 End Preparation

- Mobile plant reduces handling costs – 3 x 40ft ISO containers
- Safe production of ends with Zap-Lok experts and local labour
- High production rate of 2,000-3,000m/12hr shift
- QC checks conducted at plant ensuring consistency of shipped product.
- Repeatability of production method permits CAR insurance on connection.

2. Zap-Lok Mechanical Interference Connection

2.2 End Preparation

2. Zap-Lok Mechanical Interference Connection

2.3 End Preparation Quality Control

- Tuboscope inspectors complete 100% visual and dimensional inspections using calibrated equipment during end preparation.
- 100% MPI and 10% UT are generally conducted for offshore products.
- 3 x control burst tests are completed on joints taken from each mill heat.

Photo 5: Pin end – Groove quality check

Photo 6: Pin end – turndown check

Photo 7: Pin end – Groove depth check

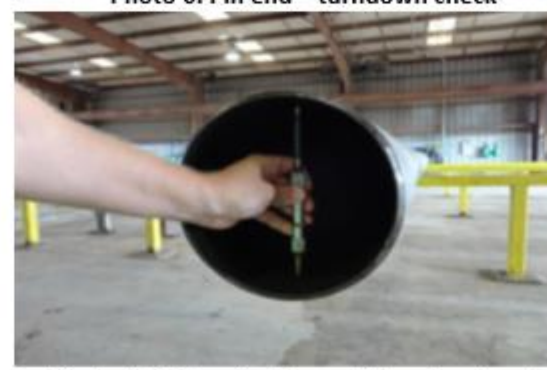


Photo 8: Bell end – Internal Diameter check

2. Zap-Lok Mechanical Interference Connection

2.4 Installation Equipment

8000-16 press

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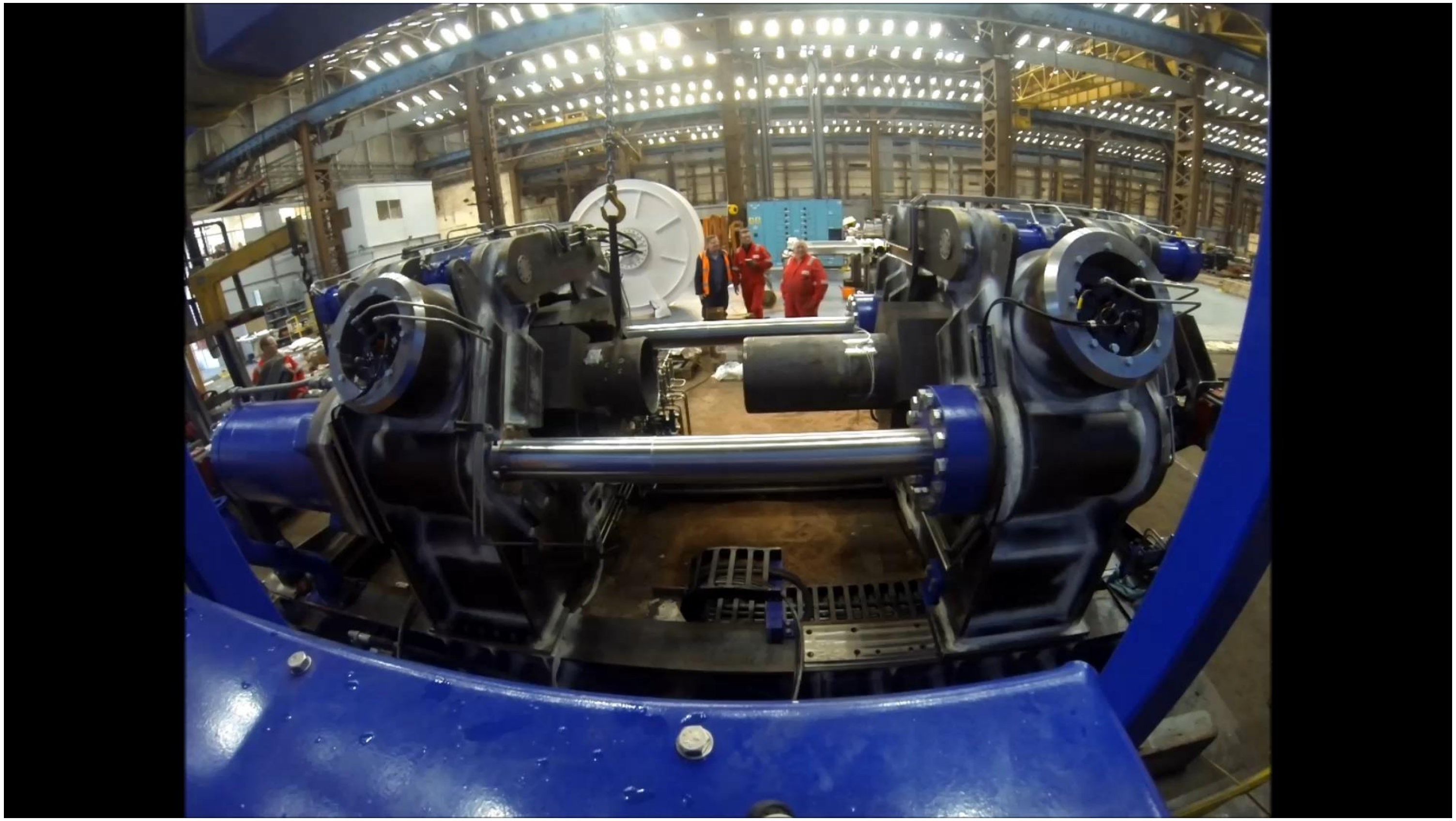
2. Zap-Lok Mechanical Interference Connection

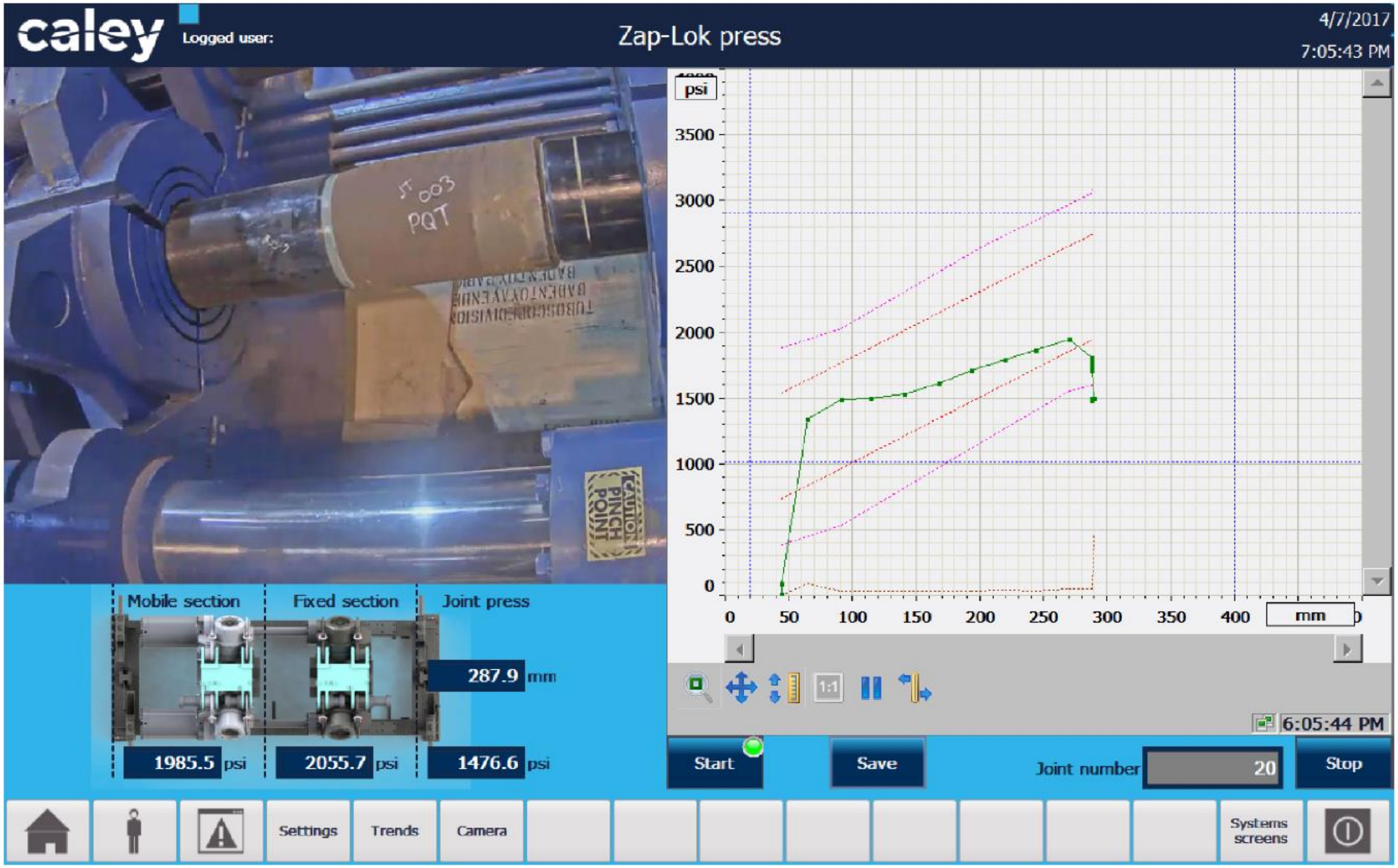
2.5 Jointing



16-inch, 0.843” wt, Grade X65

2. Zap-Lok Mechanical Interference Connection

2.6 Installation Quality Control



2. Zap-Lok Mechanical Interference Connection

2.7 Certificates of Conformity

BUREAU
VERITAS

CERTIFICATE OF CONFORMITY
TECHNICAL CENTRE PARIS
N°E&P/11801-C-2011-01 REV. 00

This is to confirm that the Zap-Lok® line-pipe joining process applied on a 12.75" diameter rigid pipeline, to be used on the following PERENCO onshore pipeline in Peru, has been scrutinised with respect to conformity versus **ASME B31.4 2009 standard**, in particular with regard to the clause §404.8.4 "Sleeve, Coupled, and other Patented Joints" and the results of the verification have been found successful for:

Rigid pipeline	Onshore oil transfer line for the Block 67 in Peru, 49.5 km long. Trenched and buried.	
Line Pipe	Outer diameter	12.75 in (323.85 mm)
	Wall thickness	0.375 in (9.525 mm)
	X52, API 5L spec. PSL2 level with supplementary requirements as described in PPHQ-ZLK-PER-PRO-RPT-P003 Rev.0	
	Design pressure	93 bars (+10% to account for surge)
	Hydrostatic test pressure	116.25 bars
	Min / Max temperature	18°C / 103°C
	Corrosion allowance (internal)	0.125 in (3.175 mm)
Transported fluid	Diluted Crude Oil. Sweet service, i.e. 0ppm of H_2S	
Zap-Lok® connection	Bell end	mandrel length 15 in, general arrangement and expanding ring detailed drawings in BV report R1330
	Pin end	cut back length LPE corrosion coating 15 in, bead and backing rollers drawings for groove shape and pin end slope, see BV report R1330
	Epoxy	slow cure epoxy, Zapoxy Pipe compound kit ref. 138, white base and blue activator (mixing ratio one to one by volume)

In the process,

- The qualification test program has been evaluated, as per BV attestation E&P/11801-A-2011-01 Rev.00,
- The test campaign included 102 destructive samples representative of the above geometry which have been subjected to burst test (6 samples), tensile test (6 samples), bending-burst test (90 samples),
- The effect of the epoxy curing time and bending moment cyclic loadings (number and intensity) on the Zap-Lok® connection strength has been assessed,
- The design methodology has been scrutinised, compared against 260 destructive samples allowing to evaluate influence of geometrical tolerances and of scatter in material properties,
- QA/QC methods during fabrication have been evaluated (see report presented in PPHQ-ZLK-PER-PRO-RPT-P003 Rev.0). During construction 3 destructive tests per line-pipe batch are to be carried out.

In conclusion, taking into account the results of the above testings and sensitivity studies, the safety margins between the Zap-Lok® connection burst / pull-out limit states and the above Peruvian application are found adequate. The details of the verification activities are summarised in the technical report n° **R1330 / E&P11801-R-2011-001** which includes the list of documents and procedures provided.

Condition of use:

- Installation bending moments to remain within envelopes of report PPHQ-ZLK-PER-PRO-RPT-P002 Rev.0
- Spool sections, vertical sections (riser), river crossing, … are not to include Zap-Lok® connections.
- Zap-Lok® connections should only see static loadings during service.

Validation of the pipeline mechanical design or other aspects not related to the above Zap-Lok® connections (on-bottom stability, expansion, cathodic protection, installation analysis and procedure) is not covered by the present certificate.

In case of changes in the forming / machining tools, conditions of use, procedures, manufacture or quality control procedures, the present Certificate would de facto lose its validity.

To whom it may concern,
Issued in Paris on July, 22nd 2011

For and on behalf of Bureau VERITAS

F. MIGEON / L. GRIYECH
Project Lead Engineers

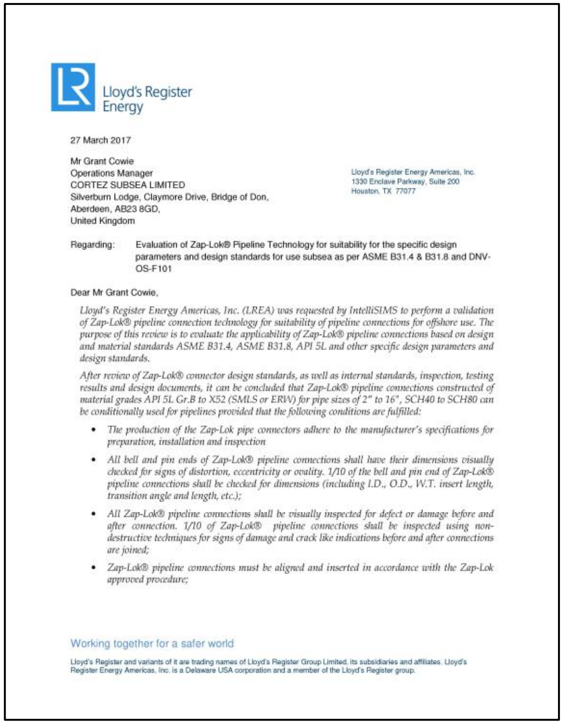
L. VERNEY
Pipelines & Structures Offshore Unit Manager

BUREAU VERITAS INDUSTRY TECHNICAL CENTER PARIS 1828

This certificate is delivered within the scope of the BUREAU VERITAS General Conditions of Service.

- BV witnessed certificate of conformity demonstrating onshore compliance with ASME B31.4

- Lloyd's Register Energy conformity certification for offshore compliance as per DNV-OS-F101



Lloyd's Register Energy

27 March 2017

Mr Grant Cowie
Operations Manager
CORTEZ SUBSEA LIMITED
Silverburn Lodge, Claymore Drive, Bridge of Don,
Aberdeen, AB23 8GD,
United Kingdom

Lloyd's Register Energy Americas, Inc.
1330 Enclave Parkway, Suite 200
Houston, TX 77077

Regarding: Evaluation of Zap-Lok® Pipeline Technology for suitability for the specific design parameters and design standards for use subsea as per ASME B31.4 & B31.8 and DNV-OS-F101

Dear Mr Grant Cowie,

Lloyd's Register Energy Americas, Inc. (LREA) was requested by IntelliSIMS to perform a validation of Zap-Lok® pipeline connection technology for suitability of pipeline connections for offshore use. The purpose of this review is to evaluate the applicability of Zap-Lok® pipeline connections based on design and material standards ASME B31.4, ASME B31.8, API 5L and other specific design parameters and design standards.

After review of Zap-Lok® connector design standards, as well as internal standards, inspection, testing results and design documents, it can be concluded that Zap-Lok® pipeline connections constructed of material grades API 5L Gr.B to X52 (SMLS or ERW) for pipe sizes of 2" to 16", SCH40 to SCH80 can be conditionally used for pipelines provided that the following conditions are fulfilled:

- *The production of the Zap-Lok pipe connectors adhere to the manufacturer's specifications for preparation, installation and inspection*
- *All bell and pin ends of Zap-Lok® pipeline connections shall have their dimensions visually checked for signs of distortion, eccentricity or ovality. 1/10 of the bell and pin end of Zap-Lok® pipeline connections shall be checked for dimensions (including I.D., O.D., W.T. insert length, transition angle and length, etc.);*
- *All Zap-Lok® pipeline connections shall be visually inspected for defect or damage before and after connection. 1/10 of Zap-Lok® pipeline connections shall be inspected using non-destructive techniques for signs of damage and crack like indications before and after connections are joined;*
- *Zap-Lok® pipeline connections must be aligned and inserted in accordance with the Zap-Lok approved procedure;*

Working together for a safer world

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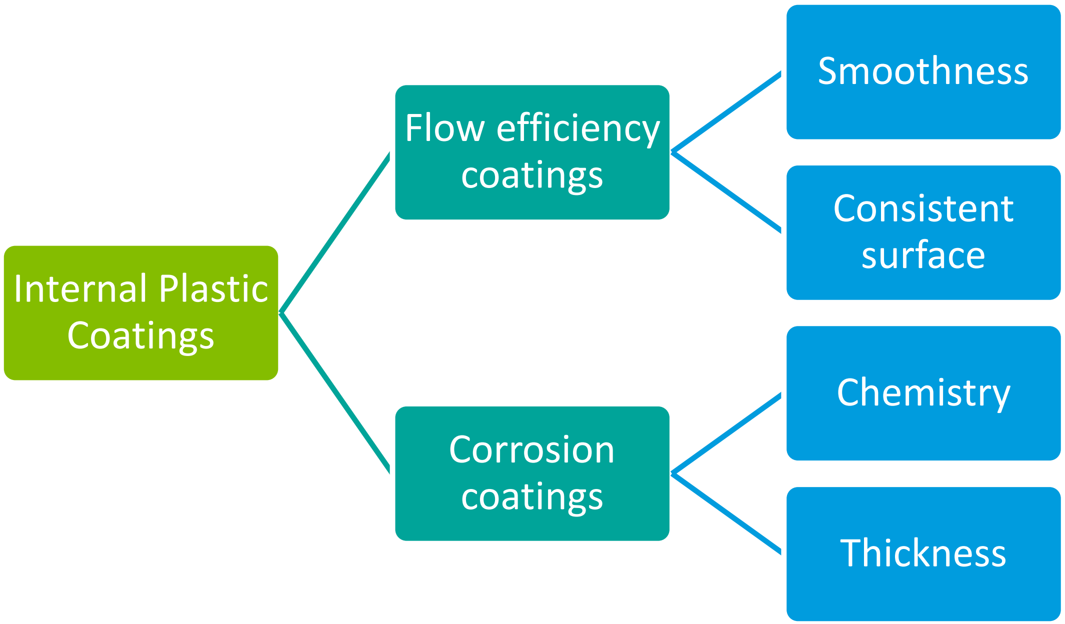
3. Internal Plastic Coating (IPC)

3.1 Flow efficiency & Corrosion Coatings



- Limited design life
- Thickness: 40-125µm
- Air-cured
- Sometimes holiday checked
- 4-5 yr life in harsh conditions

- 20-50 year design life
- Thickness: 150-500µm
- Heat-cured
- Rigourously holiday checked

Starting Point:

But not vice versa

3. Internal Plastic Coating (IPC)

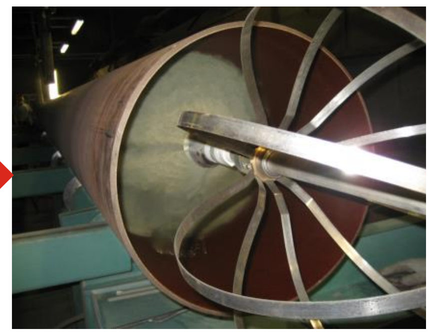
3.2 Manufacture


Pre-cleaning


Thermal cleaning


Internal shot blasting


Primer and pre-heat


IPC application


Thermal cure

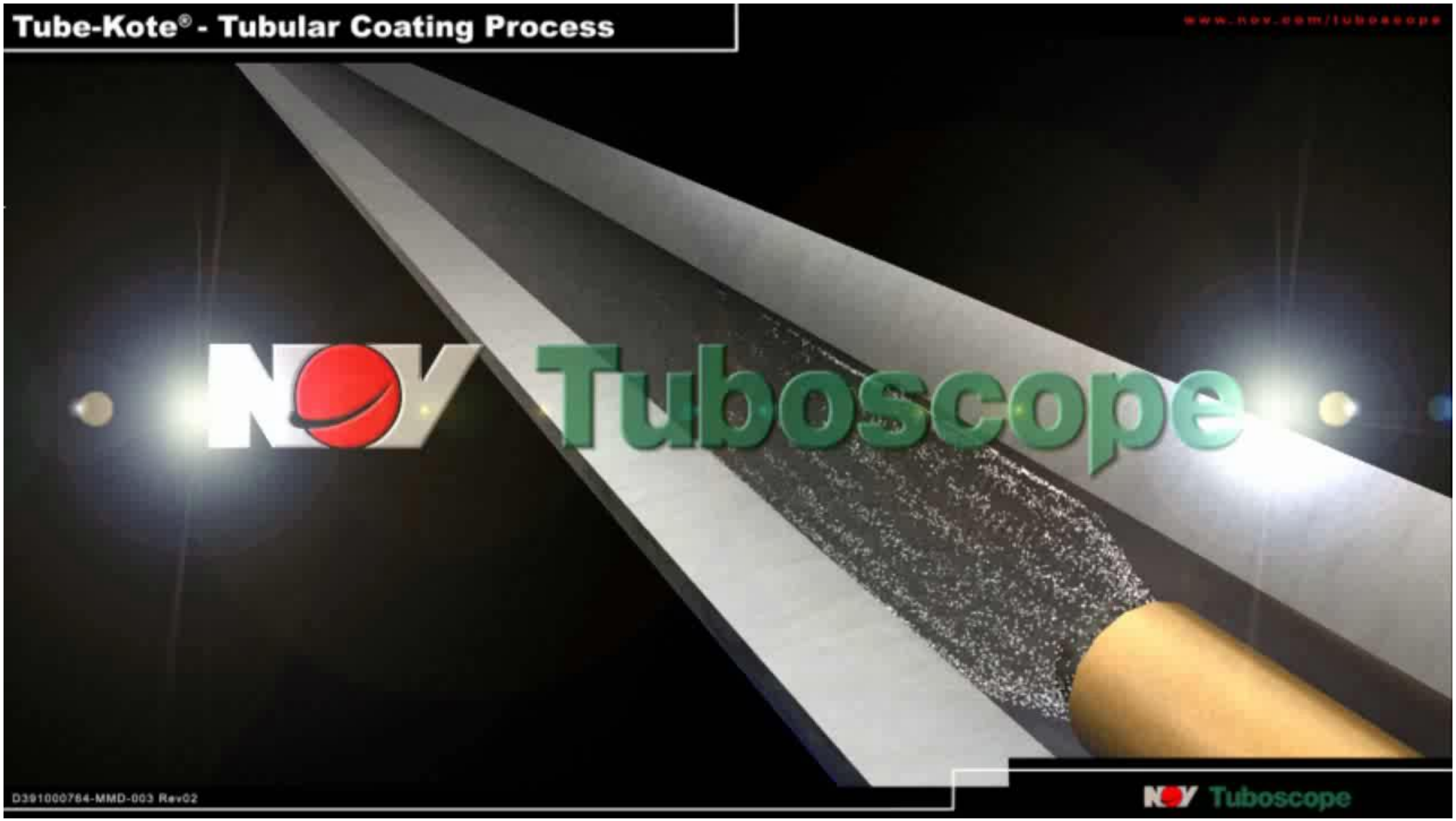

Quality control


External Varnish


Bundling and shipment

3. Internal Plastic Coating (IPC)

3.2 Manufacture



3. Internal Plastic Coating (IPC)

3.3 Reductions in CAPEX and OPEX

Pressure Rating: $$MAOP = f \times SMYS \times \frac{2(t_{press}+t_{corr}+t_{stab})}{OD}$$

For onshore applications, by applying IPC the corrosion allowance, t_{corr}, can be removed entirely such that we only need to consider wall thickness for pressure containment, t_{press}, thus saving raw material costs.

For offshore applications, again no corrosion allowance is required. The interesting trick here is to maintain a large wall thickness, i.e. increase t_{stab}, to give the required on-bottom stability as we know this will not be corroded or eroded. This enables the design engineer to negate the requirement for CWC therefore reducing CAPEX.

Flow Efficiency: $$\frac{dV}{dt} = -0.965\left(\frac{gD^5h_L}{L}\right)^{0.5}\log\left[\frac{\varepsilon}{3.7D} + \left(\frac{3.17v^2L}{gD^3h_L}\right)^{0.5}\right]$$ ***Valid for turbulent flow where Re > 2,300***

We can see that the above equation that the volume flow rate of a fluid is proportional to the surface roughness ε. Specifically $\dot{V} \propto \log \epsilon$.

Generally speaking for 6-12" pipe we can see that the differential in steel surface roughness (45µm) to that of IPC (1.5µm) leads to flow improvements of around 20% for crude to 30% for gas transmission. These ameliorations increase production rates and lead to reduction in raw material costs – reducing CAPEX.

It should be mentioned here that IPC also eliminates the requirement for corrosion inhibition – reducing OPEX.

3. Internal Plastic Coating (IPC)

3.4 Line Pipe Coating Performance

Coating	TK-44LP	TK-70	TK-70XT	TK-15	TK-15XT
Temperature	107°C (225°F)	107°C (225°F)	107°C (225°F)	149°C (300° F)	149°C (300°F)
Flexibility (Ring Crush)	>19 mm (0.750 inch)	>25.0 mm (1.0 inch)	>12.0 mm (0.5 inch)	>2.28 mm (0.09 inch)	>3.71 mm (0.146 inch)
Abrasion resistance	0.0018 mm/1000 cycles	0.0018 mm/1000 cycles	0.00106 mm/1000 cycles	0.0102 mm/1000 cycles	0.0071 mm/1000 cycles

Coating	Temperature	Pressure	Liquid Phase	Gas Phase	Duration
TK-44LP	121°C (250°F)	5,000 psi	Water / Hydrocarbon	50% CO_2/50% CH_4	16 hours
TK-70	135°C (275°F)	5,000 psi	H20 / Hydrocarbon	50% CO_2/50% CH_4	16 hours
TK-70XT	135°C (275°F)	5,000 psi	Water / Hydrocarbon	50% CO_2/50% CH_4	16 hours
TK-15	149°C (300°F)	9,000 psi	Water / Hydrocarbon	100% CO_2	120 hours
TK-15XT	149°C (300°F)	9,000 psi	Water / Hydrocarbon	100% CO_2	120 hours

Conclusion

Technical

- Zap-Lok connectors, having gained full industry acceptance, qualification and significant track record enable end-users to dramatically reduce installation costs of in field gathering systems.
- IPC is a fully qualified and proven system that gives lifetime corrosion integrity to in-field flowlines enabling the modified design techniques to be used to provide a more cost effective pipeline basis of design.
- The combined Zap-Lok technology is best suited to shallow water installations (up to 200m), encompassing relatively sour service where it is an ideal option for most applications.

Commercial

- Zap-Lok combined with Internal Coatings cab provide can significant savings on raw material costs, for offshore line pipe.
- These cost savings are amplified to give Capex installation cost savings that can be achieved using vessels of opportunity and modular pipelay (handling) systems for installation..
- Opex costs are dramatically reduced through improvements in hydraulic efficiency, elimination of inhibitors, and reduction in corrosion, erosion and therefore maintenance.

Questions?

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