

# Introduction to Flexible Pipe

The Life Cycle of Flexible Risers and Flowlines

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**Intecsea**  
Worley Group

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# Agenda

- Rigid vs. Flexible Pipe
- Different Types of Flexible Pipe
- Flexible Riser Configurations and in Australian Conditions
- Flexible Riser Design

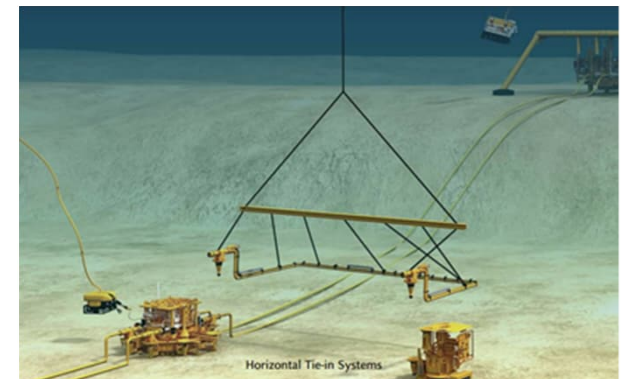
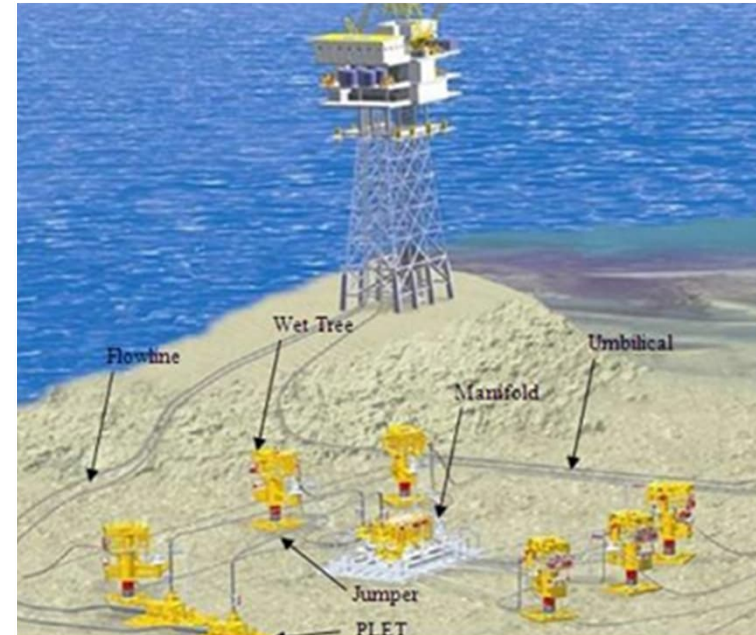
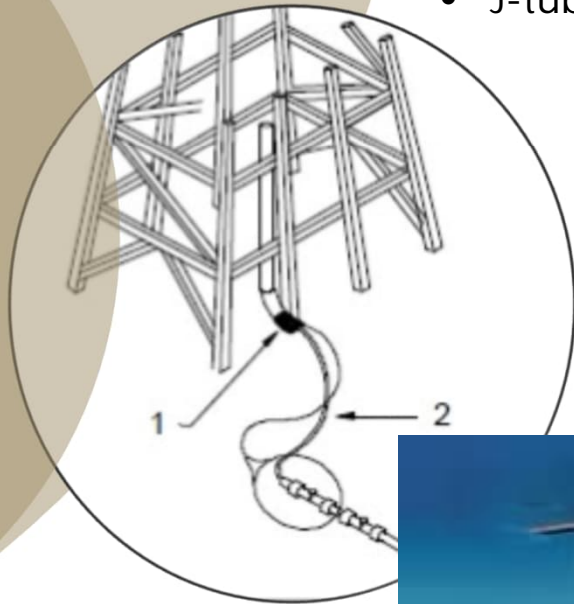


# Rigid vs. Flexible Pipe



# Static Applications for Flexible Pipe

- Pipelines or Flowlines
- Flexible Jumpers instead of rigid spools
- J-tube Pull-ins





## Cost Comparison – Rigid vs. Flexible Pipe

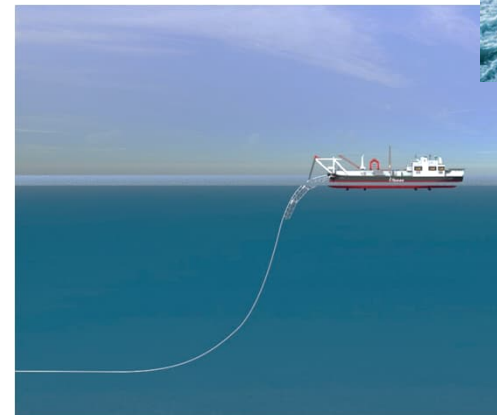
- The cost of the flexible pipe can range from USD2,000 to USD4,000 per metre of 10" ID + ancillaries
- Rigid CRA pipe is more cost efficient at:
  - ~ USD850/m for 12" OD Stainless Steel (316) lined
  - ~ USD1250/m for 12" OD Inconel (625) lined
- Rigid Carbon steel pipe is even more cost efficient at:
  - ~ USD250/m for 12" OD CS pipe

The cost of the Thermoplastic Composite Pipe (TCP) can be around USD2,000 per metre of 7.5" ID (ref. Strohm).



# Size Comparison and Installation Methods

- Flexible pipe always referred to by ID.
- Flexible pipe for oil & gas generally limited to 16" ID - up to 22" ID for low pressure applications.
- TCP can be manufactured up to 7.5" ID
- Both installed using a standard construction vessel with a lay spread.
- Reeled rigid pipe can be installed up to 18" OD - depending upon wall thickness using reel-lay vessels.
- Rigid pipe can be up to 48" OD for subsea oil & gas. Relies on J or S-Lay vessels.



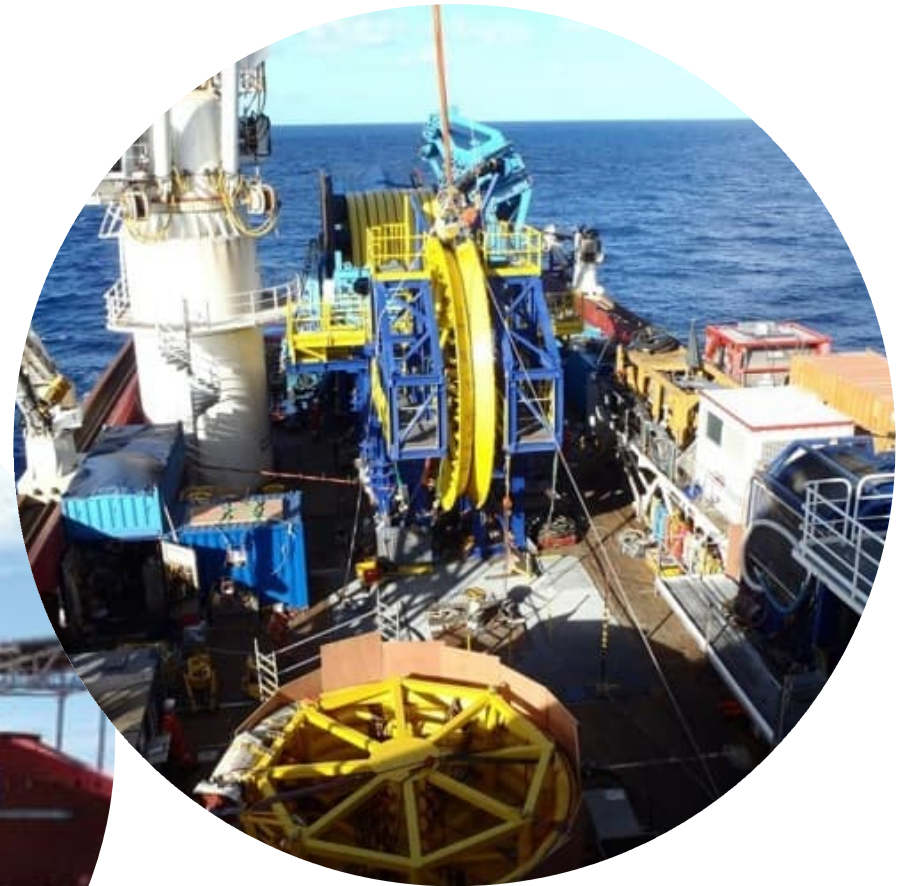
# Flexible Pipe Installation

- Directly off the reel – (*Limited applications*).
- Horizontally with tensioners.
- Vertically with tensioners also known as VLS.



# Flexible Pipe Installation

Even a relatively small vessel of opportunity...





# Flexible Pipe Transportation

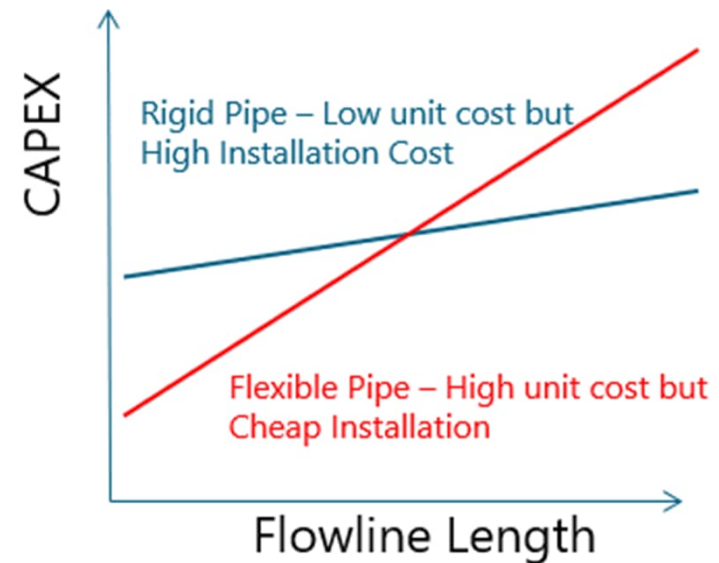
- Carousel: long lengths, vessel availability limited, can carry up to ~2500Te.
- Reels: diameter ~ 9 - 12m, weight ~250 - 350Te.
- Crates/Baskets/Pallets: short lengths only.

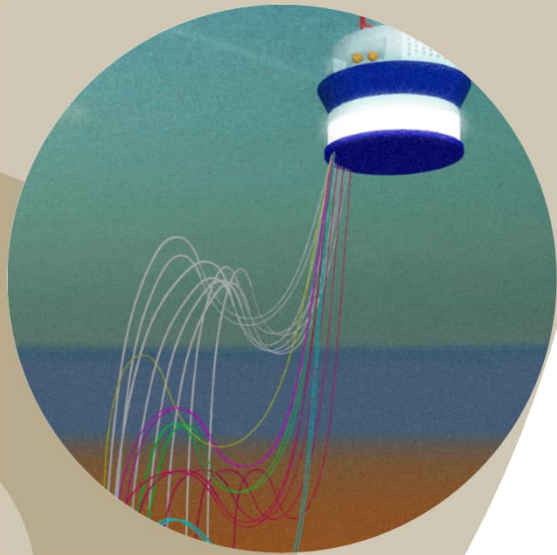


# Why Use Flexible Pipe for Static Applications?

- A flexible pipe installation spread can easily be placed on a construction vessel
- Specialised lay/reeling-barges/vessels not required.
- Flexibility makes tie-ins much quicker.

The *installed cost* is the driver for selection of flexible pipe for static applications.





## Dynamic Service: We Need the Flexibility

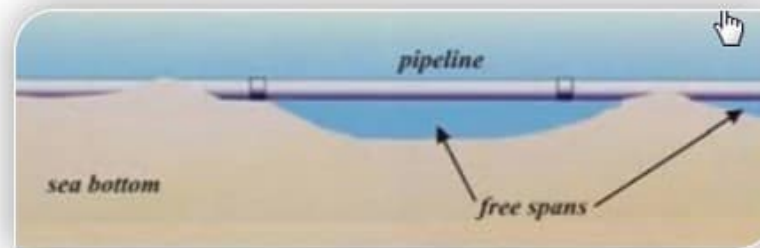
Dynamic riser systems are required for floating facilities:

- Decouple surface facility motions from fixed facilities on the seabed.
- Accommodate large amplitude motions and offsets.
- In less than 500m water depth, fatigue is generally prohibitive for SCRs or Steel Lazy Wave Risers.
- For deeper applications flexibles may still be the preferred option due to vessel motions or installation method for the rest of the pipes in the field.

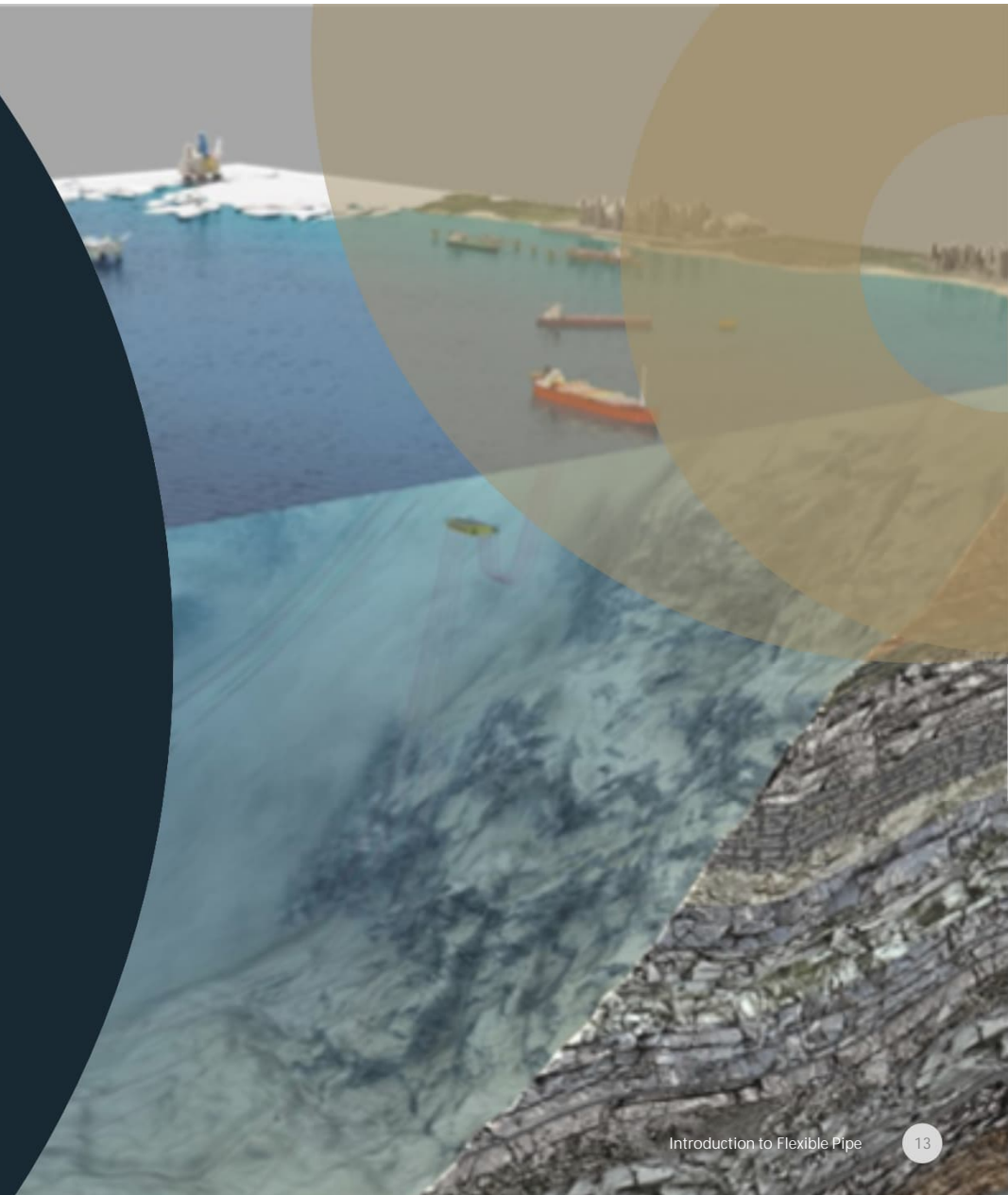


## Other Benefits of Flexibles

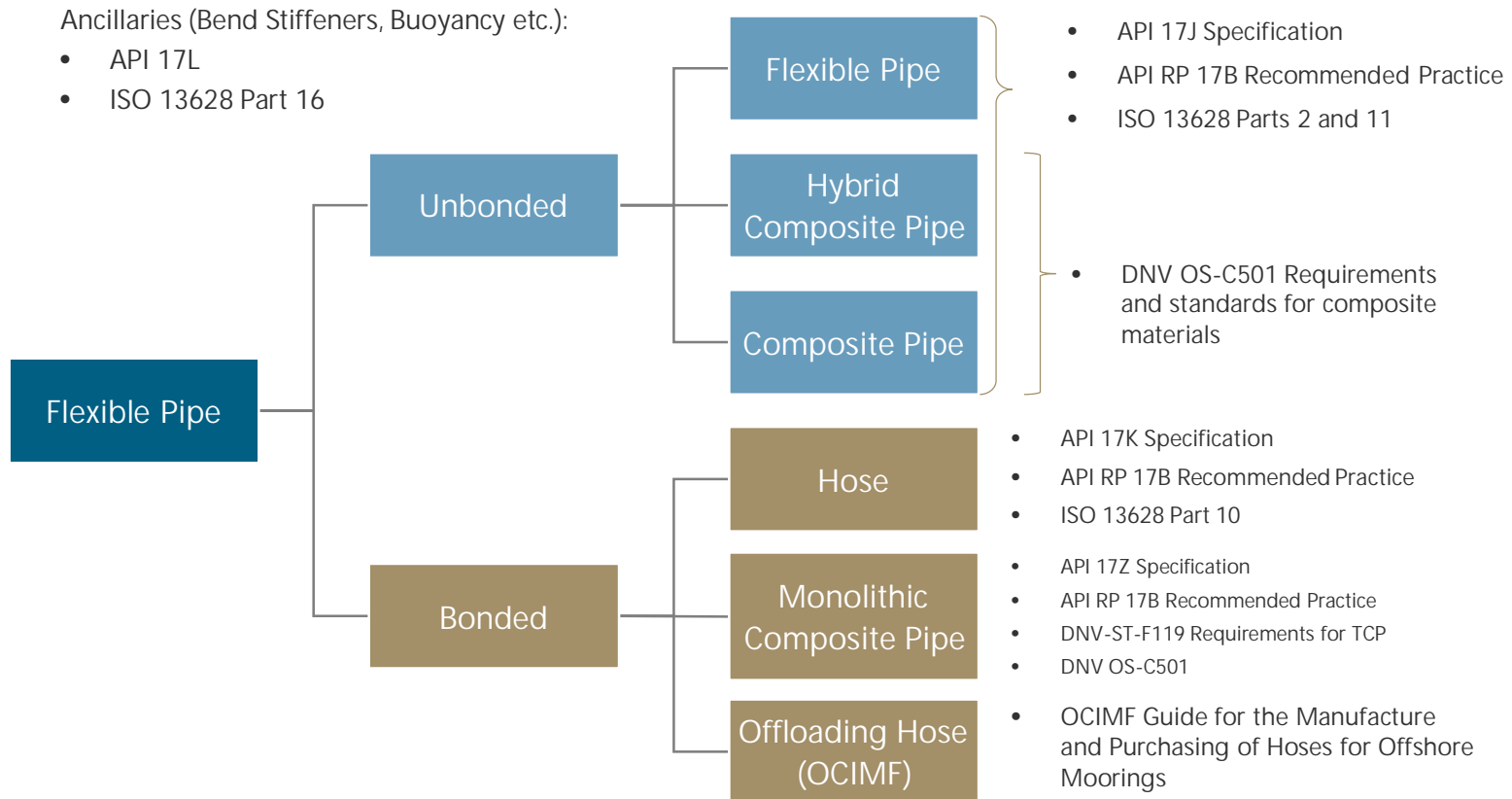
- Can accommodate large changes in seabed profile that would otherwise require remediation.
- Potential for recovery and re-use for other applications.
- Well insulated, which may offer flow assurance benefits.



# Different Types of Flexible Pipe



# Types of Flexible Pipe



# Flexible Pipe

There are three traditional suppliers of Unbonded Flexible Pipe:

- TechnipFMC
  - Manufacture in France, Brazil and Malaysia
- NOV
  - Manufacture in Denmark and Brazil
- BakerHughes Wellstream
  - Manufacture in UK and Brazil



# Flexible Pipe

There are now new suppliers of Unbonded Flexible Pipe:

- HAT Flex
  - Manufacture in China
- Neptune Offshore Engineering (NOED)
  - Manufacture in China





# Flexible Pipe



Carcass: Resists hydrostatic collapse of structure and prevents ovalisation during reeling. Protects sheath against e.g. sand or pigs. Typically 316L Stainless Steel, cold formed strip.



Pressure Sheath: Makes pipe leakproof. Extruded polymer, e.g.: Polyamide, Polyvinylidene Fluoride (PVDF), cross linked polyethylene.

Pressure Vault: Resists pressure (hoop stress). Carbon steel.

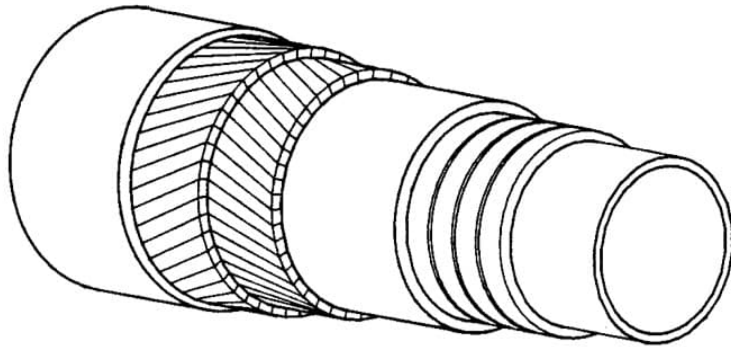


Armour Layers: Resist axial tension and contributes some hoop stress, function of angle. Carbon steel. Contrahelically wound cold formed wire.

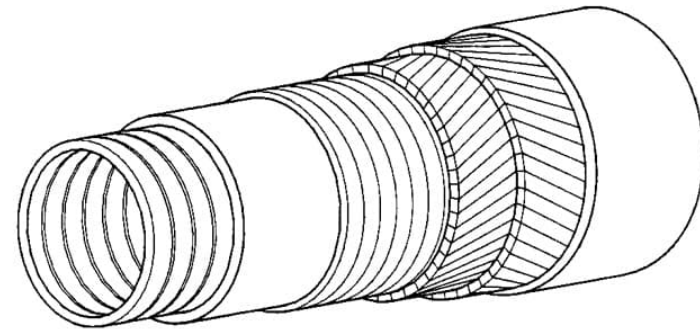
External Sheath: Provides mechanical protection to underlying steel layers and provides first line of defence against water ingress. Extruded polymer, e.g.: HDPE or Polyamide.

# Flexible Pipeline Generic Members

## SMOOTH BORE



## ROUGH BORE



- A rough bore pipe contains an inner steel carcass and is used whenever gas may be present in the transported fluid.
- Smooth bore pipe is suitable for applications where gas will not diffuse through the internal thermoplastic layer such as water or chemicals.
- Gas Applications of Smooth Bore require venting of the inner annulus.

# Flexible Risers – FLIP in Gas Export



- Demonstrated issue on at least 7 projects, including instances of topsides piping failures.
- Potential issue for standard rough bore pipe designs when gas has <1% liquid content (expected for Scarborough).
- Onset is difficult to predict and prevent. Mitigations on topsides and subsea piping can reduce risk but not eliminate entirely.

# Flexible Risers – Anti-FLIP designs



Figure 6-7 NOV K-Profile Carcass

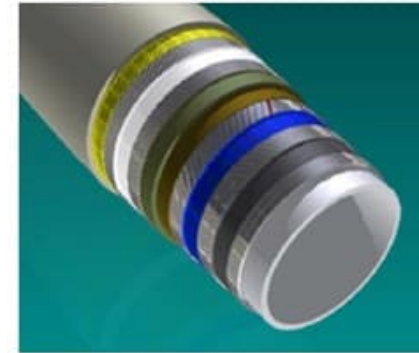
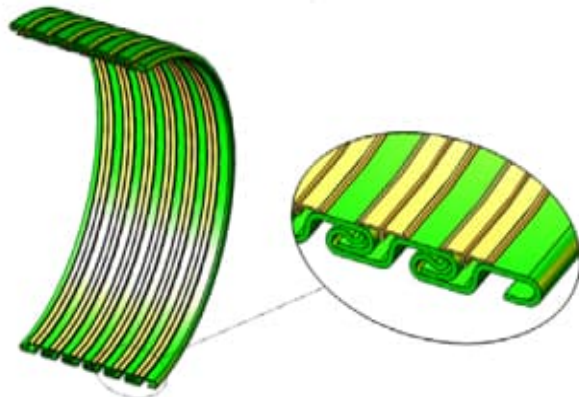


Figure 6-6 Smooth Bore Flexible Pipe Cross-section

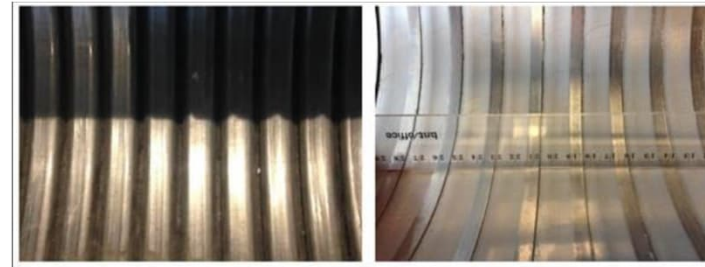
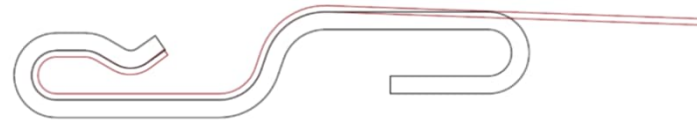
Project/Facility Name	Year	ID [inch]	DP [Bar]	Water Depth [m]
Prototype	2015	11.5	426	1350
Prototype	2015	8.0	426	3500
Prototype	2015	7.5	426	3100
Equinor Johan Castberg	2021			370

Project/Facility Name	Installation Year	Size [inch]	DP [Bar]	Water Depth [m]
Statoil Åsgard B	2006	14	240	310
GDF Suez Gjøa Field	2011	12		360
Statoil Norne	2014	9.6		380
BP Schiehallion	2015			400
INPEX Ichthys	2016	10		280
ENI Jankriek	2017	12		400

## Flexible Risers – Anti-FLIP designs



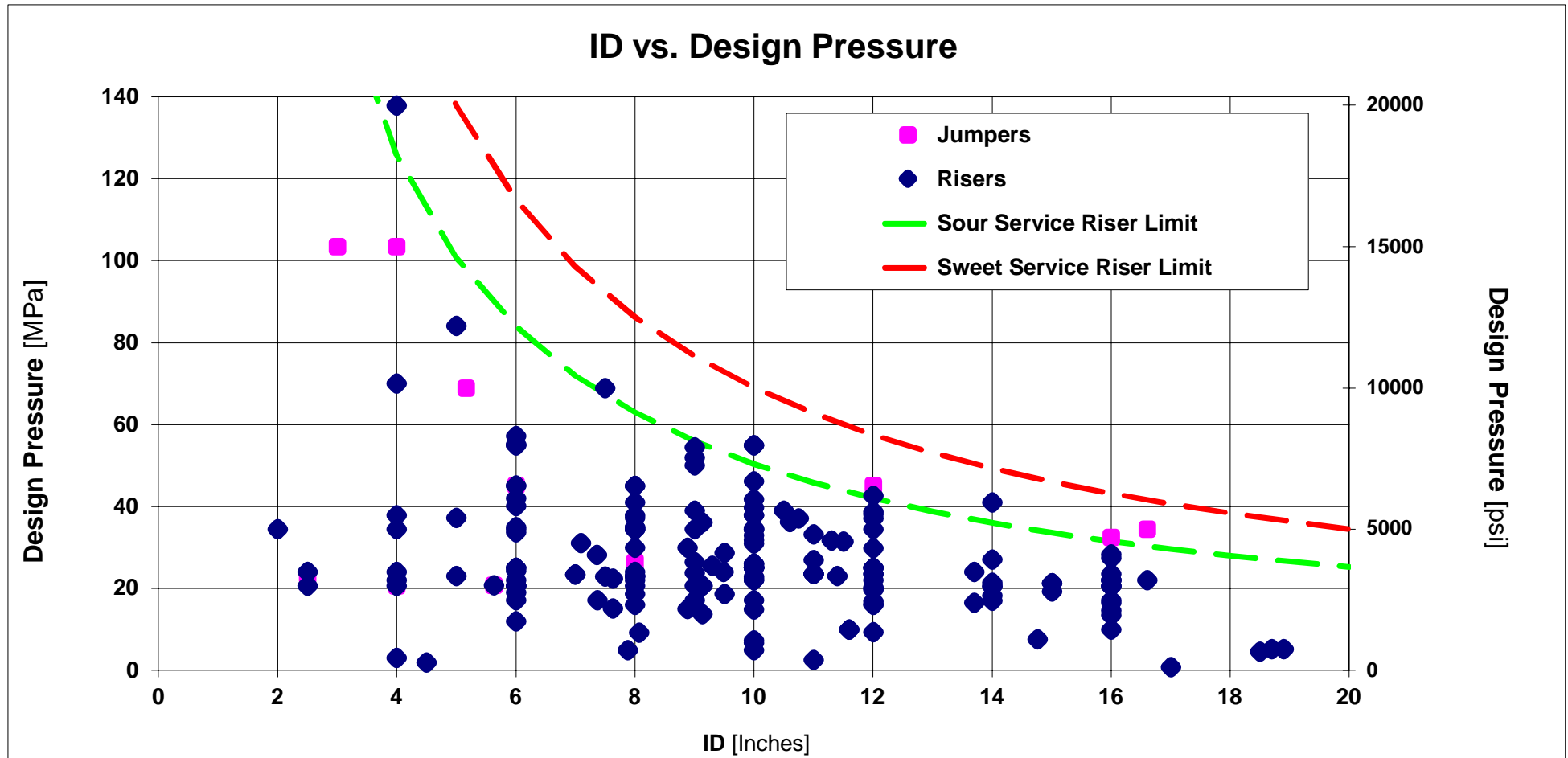
Courtesy of BHGE



Courtesy of NOV

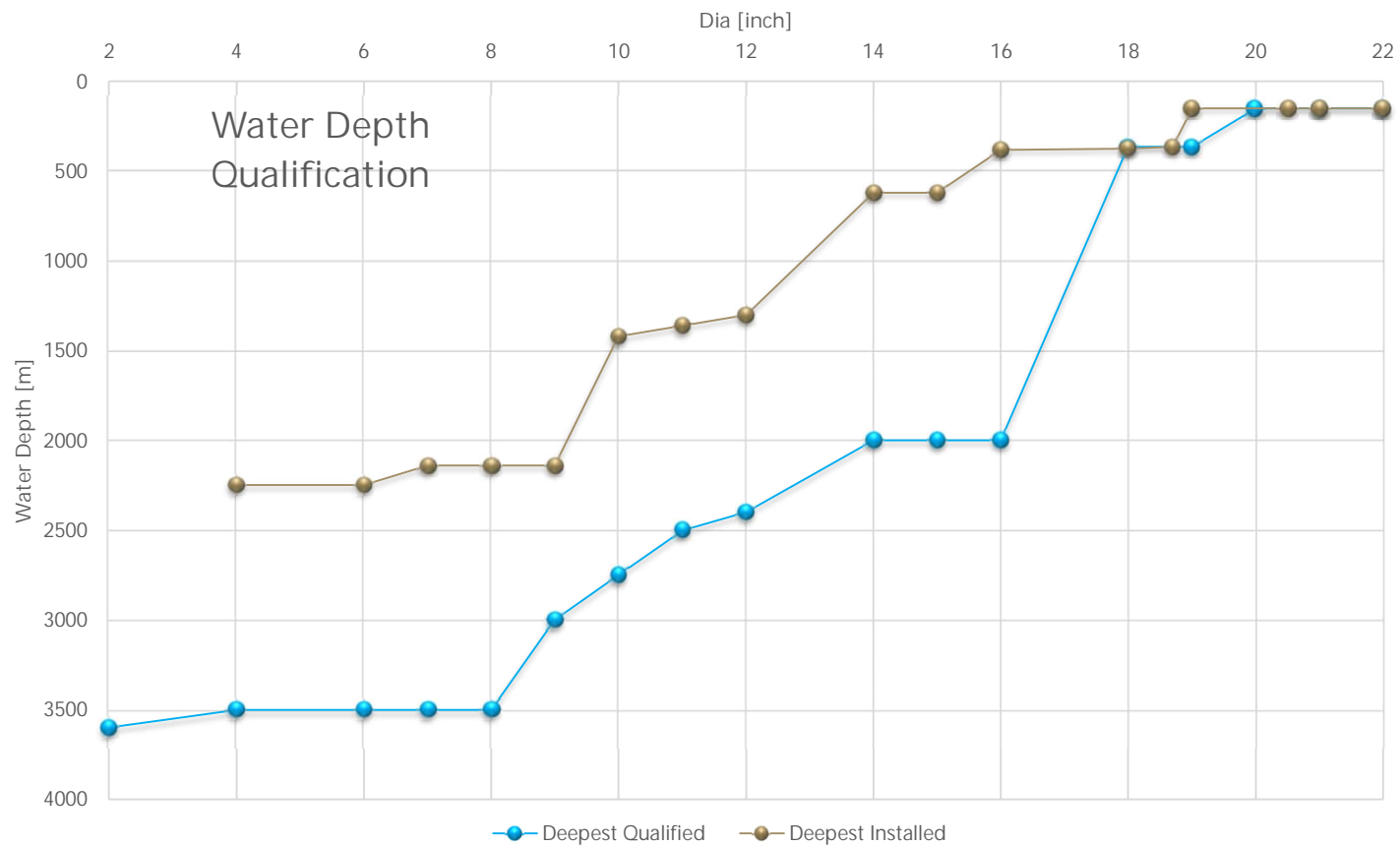
- All three manufacturers are now offering or qualifying a variation on an insert.
- This means that the flexible structure is essentially the same, so provides greater confidence.
- Unlike the plastic smooth bore, it can be pigged and is not at risk of collapse due to gas build up.

# Flexible Risers – Design Pressure

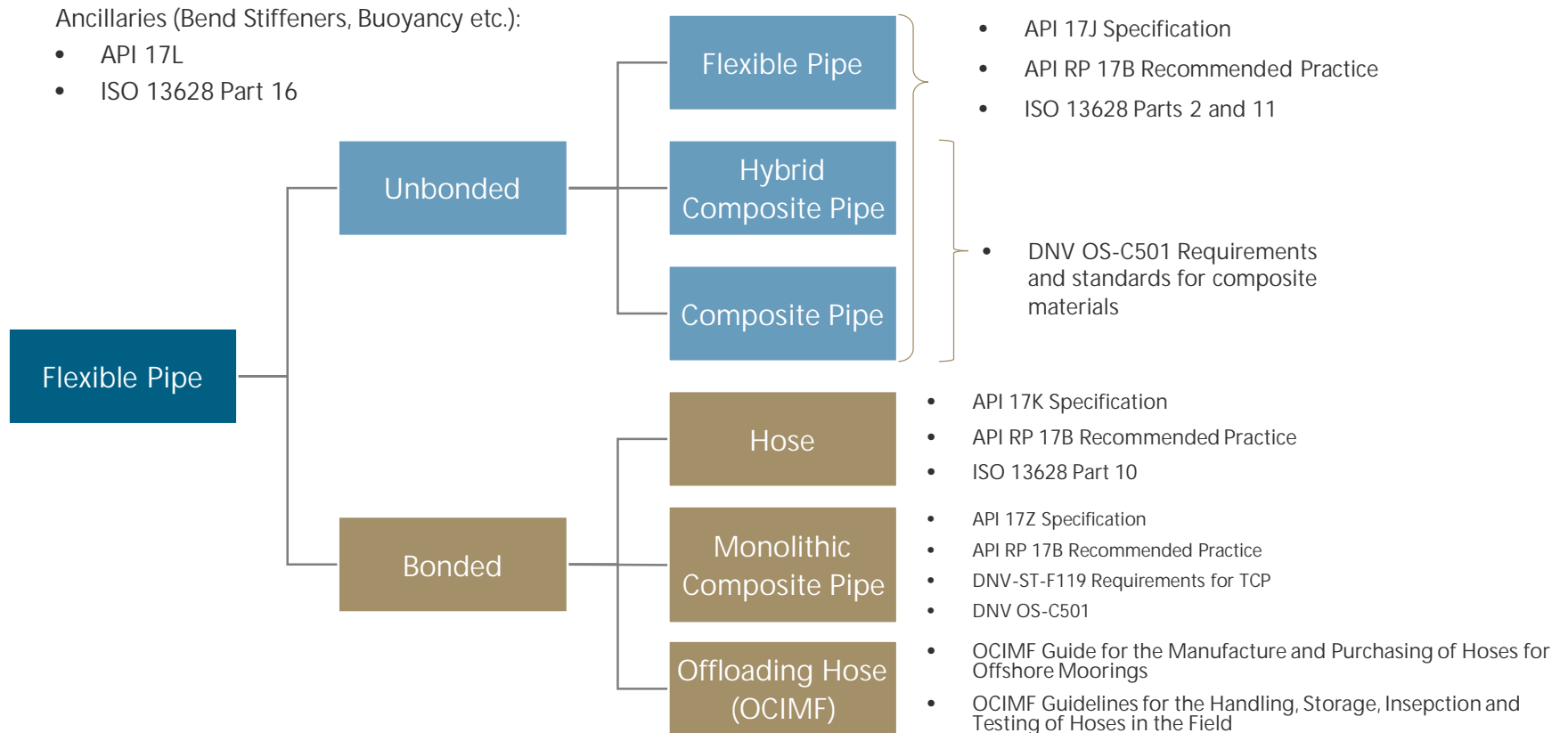




# Flexible Risers – Water Depth



# Types of Flexible Pipe



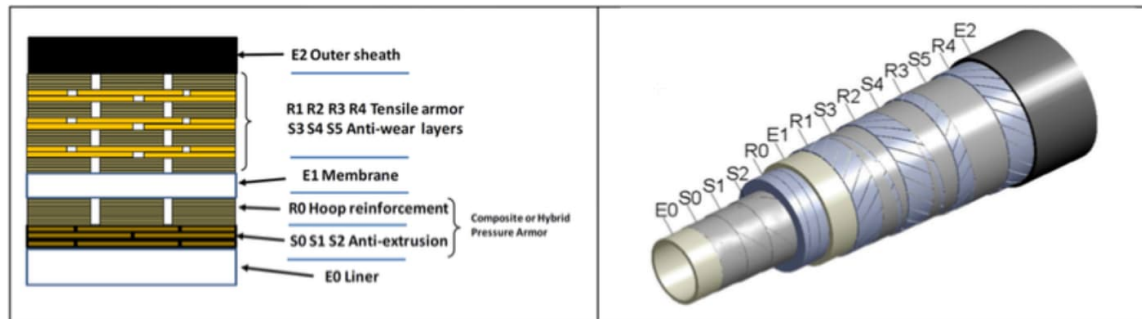


# Composite Pipe

- Developed by DeepFlex – no longer in business
- Similar to Un-bonded Flexible Pipe.
- All parts of made from composites or plastic instead of steel.

## POSITIVES

- No corrosion.
- Improved flow.
- Great fatigue resistance.
- Lightweight – low H/O weight.
- Lightweight – low installation weight.



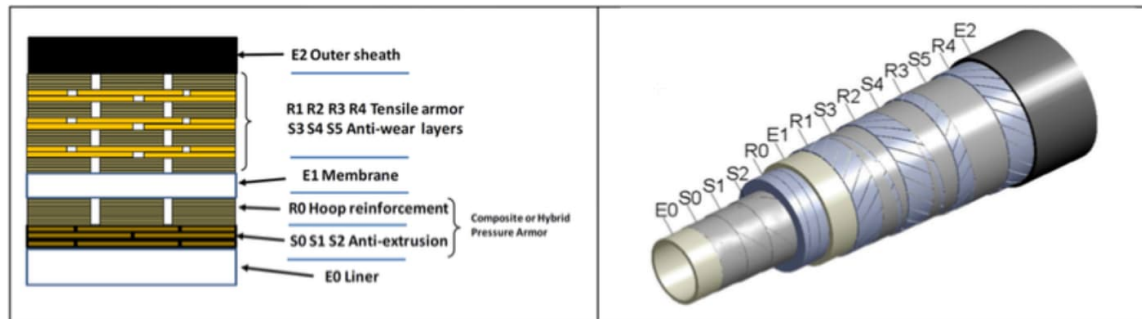
Deepflex Flexible Fibre Reinforced pipe for downline (Kalman, Yu & Durr, 2014)

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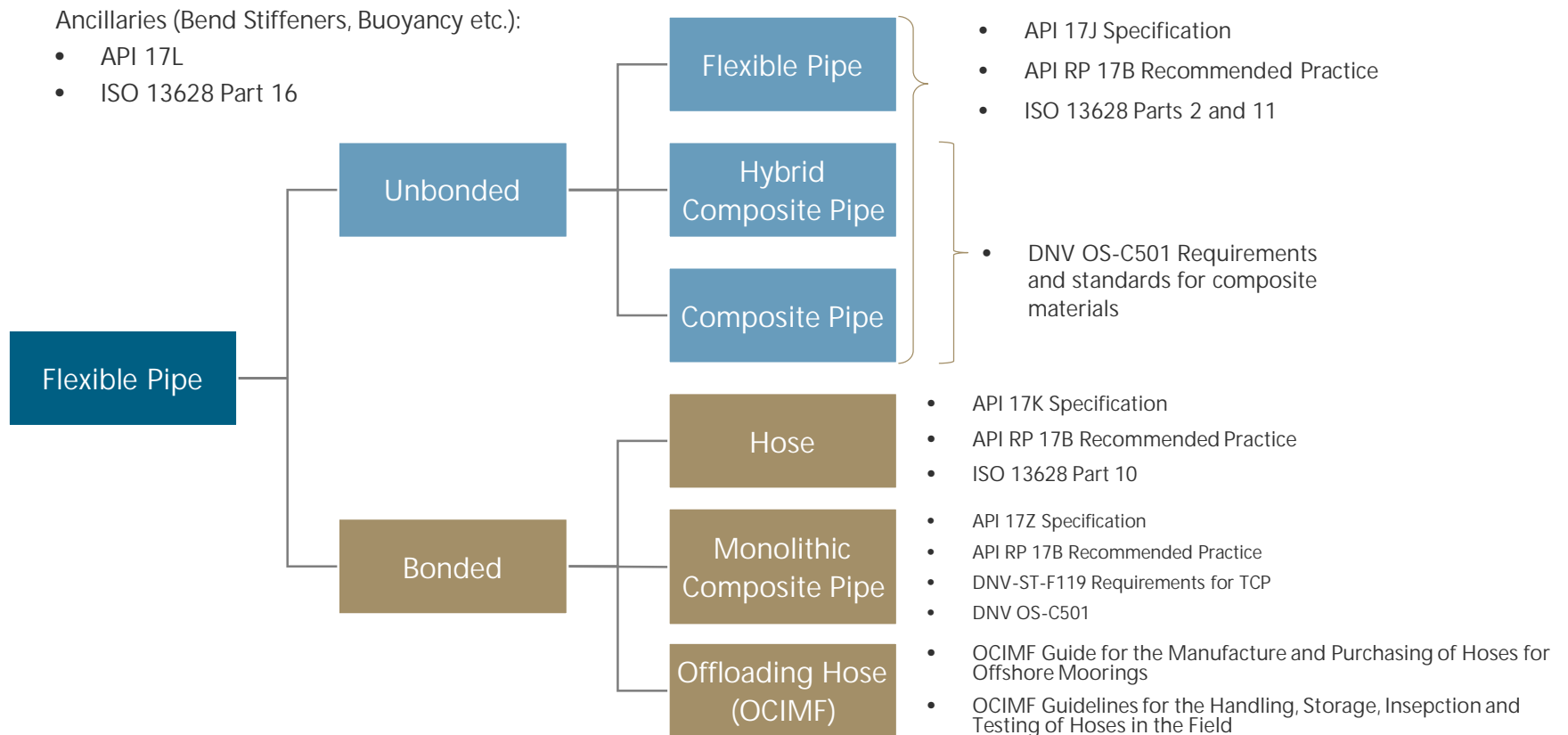
## NEGATIVES

- Very expensive materials.
- Too light – unstable.
- Difficult to inspect.
- Limited experience & track record in oil & gas.



Deepflex Flexible Fibre Reinforced pipe for downline (Kalman, Yu & Durr, 2014)

# Types of Flexible Pipe



# Hybrid Composite Pipe

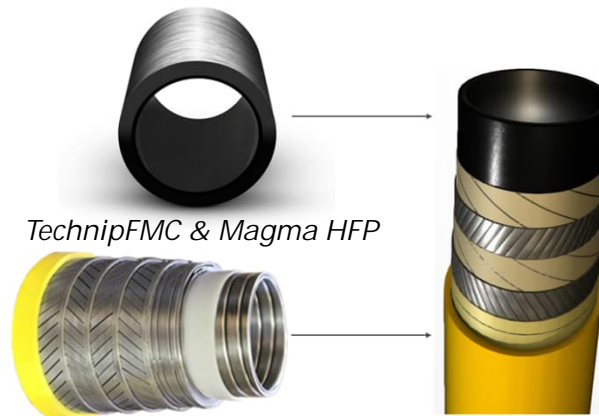
- Pressure containing layers made from a Monolithic Tube produced by TechnipFMC with MAGMA.
- Tensile Armour Wires made from stainless steel.

Or

- Conventional pressure containing layers
- Tensile Armour Wires made from Composites made by TechnipFMC and BakerHughes



*Baker Hughes Aptara Composite Pipe*



## POSITIVES

- Less novel components.
- Great potential for CO<sub>2</sub> transportation.
- No FLIP.
- 30 - 50% reduction in hang-off weight, but still stable.
- Low installation / hang-off weight.

# Hybrid Composite Pipe

- Pressure containing layers made from a Monolithic Tube.
- Tensile Armour Wires made from stainless steel.
- Produced by TechnipFMC with MAGMA.

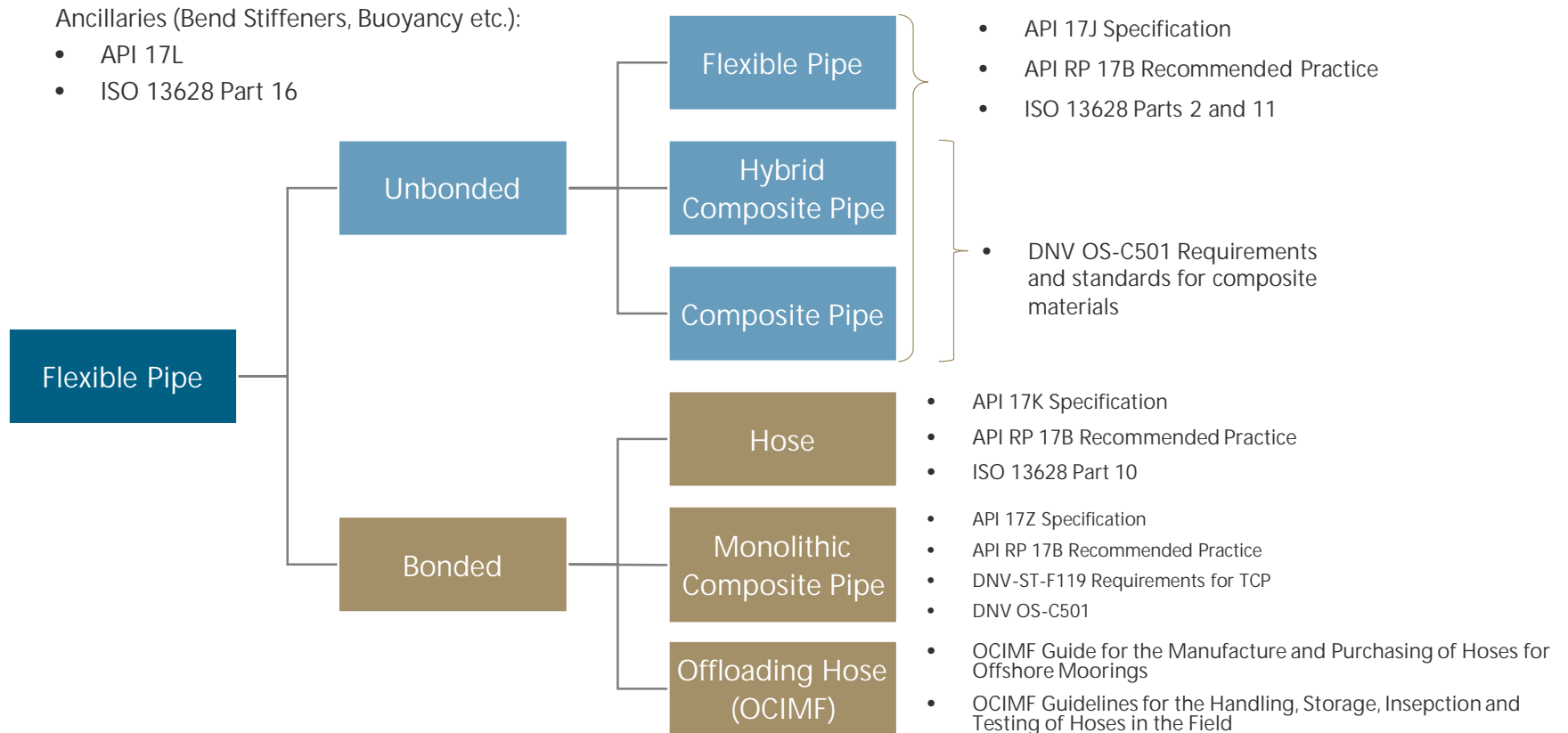


*TechnipFMC & Magma HFP*

## NEGATIVES

- Expensive materials.
- Difficult to inspect composite components e.g pressure tube or armour wires.
- Limited experience & track record in oil & gas.
- Very stiff and large MBRs, problematic for packing and shallow water.

# Types of Flexible Pipe

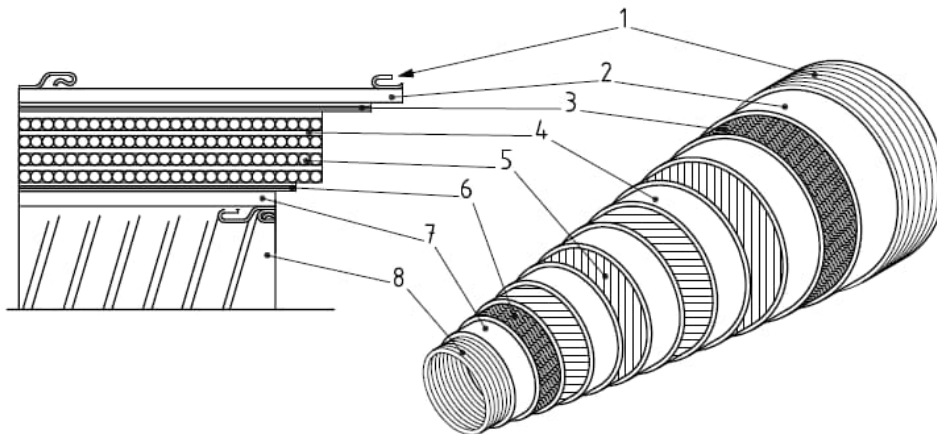


# High Pressure Hose

- Steel and rubber layers vulcanically bonded.
- Contain pressure above 15 bar.
- Smaller bore applications than Flexible Pipe.
- Produced by many manufacturers incl. Pirelli, Bridgestone, Manuli and Pirtek.

## POSITIVES

- Cheaper than Unbonded Pipe.
- Standard design.



### Key

- 1 outer wrap
- 2 cover
- 3 breaker layer
- 4 cushion layer

- 5 reinforcement layer
- 6 breaker layer
- 7 liner
- 8 carcass

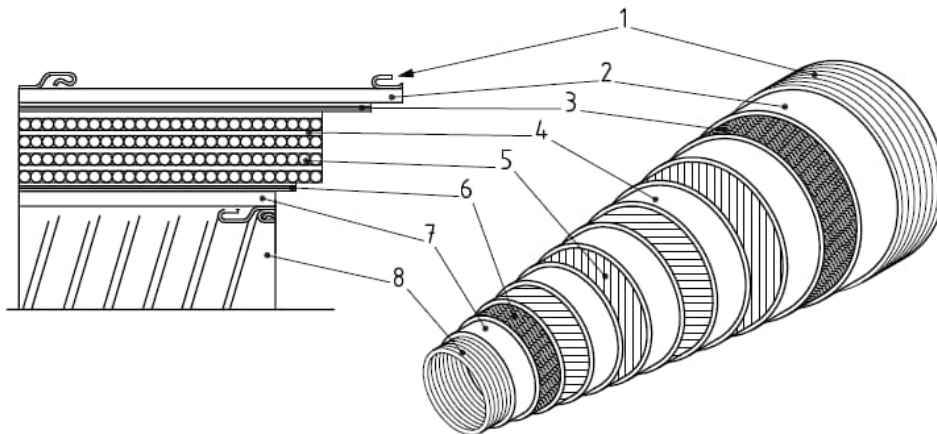
Figure 1 — Typical bonded flexible pipe

# High Pressure Hose

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- Contain pressure above 15 bar.
- Smaller bore applications than Flexible Pipe.
- Produced by many manufacturers incl. Pirelli, Bridgestone, Manuli and Pirtek.

## NEGATIVES

- Limited sizes and pressures.
- Limited collapse pressure.
- Limited Lengths <400m (4").
- Shorter service life 2 – 5 yrs.



### Key

- 1 outer wrap
- 2 cover
- 3 breaker layer
- 4 cushion layer

- 5 reinforcement layer
- 6 breaker layer
- 7 liner
- 8 carcass

Figure 1 — Typical bonded flexible pipe

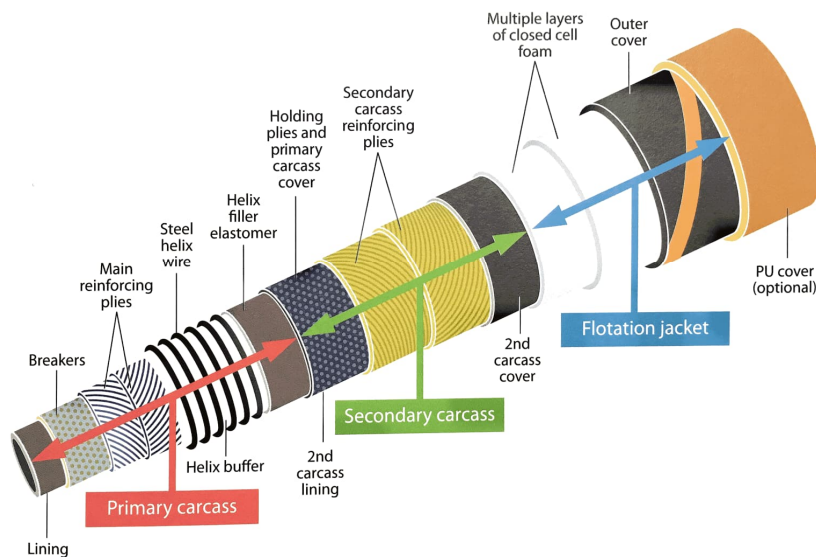


# Offloading Hose (OCIMF)

- Steel and rubber layers vulcanically bonded.
- Contain pressure below 21 bar.
- Produced by manufacturers incl. Pirelli, Bridgestone, Yokohama.
- Built up from multiple standard length of pipe.

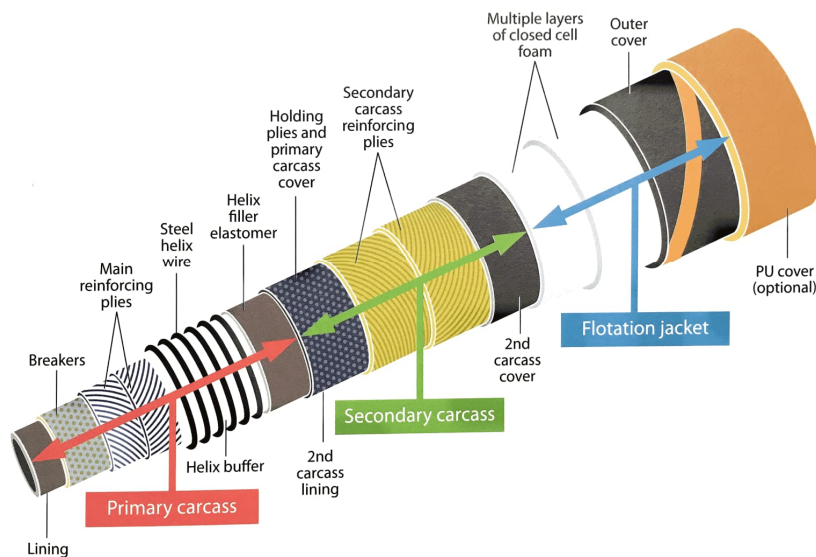
## POSITIVES

- Cheaper than Unbonded Pipe.
- Standard design.
- Extensive track record.



# Offloading Hose (OCIMF)

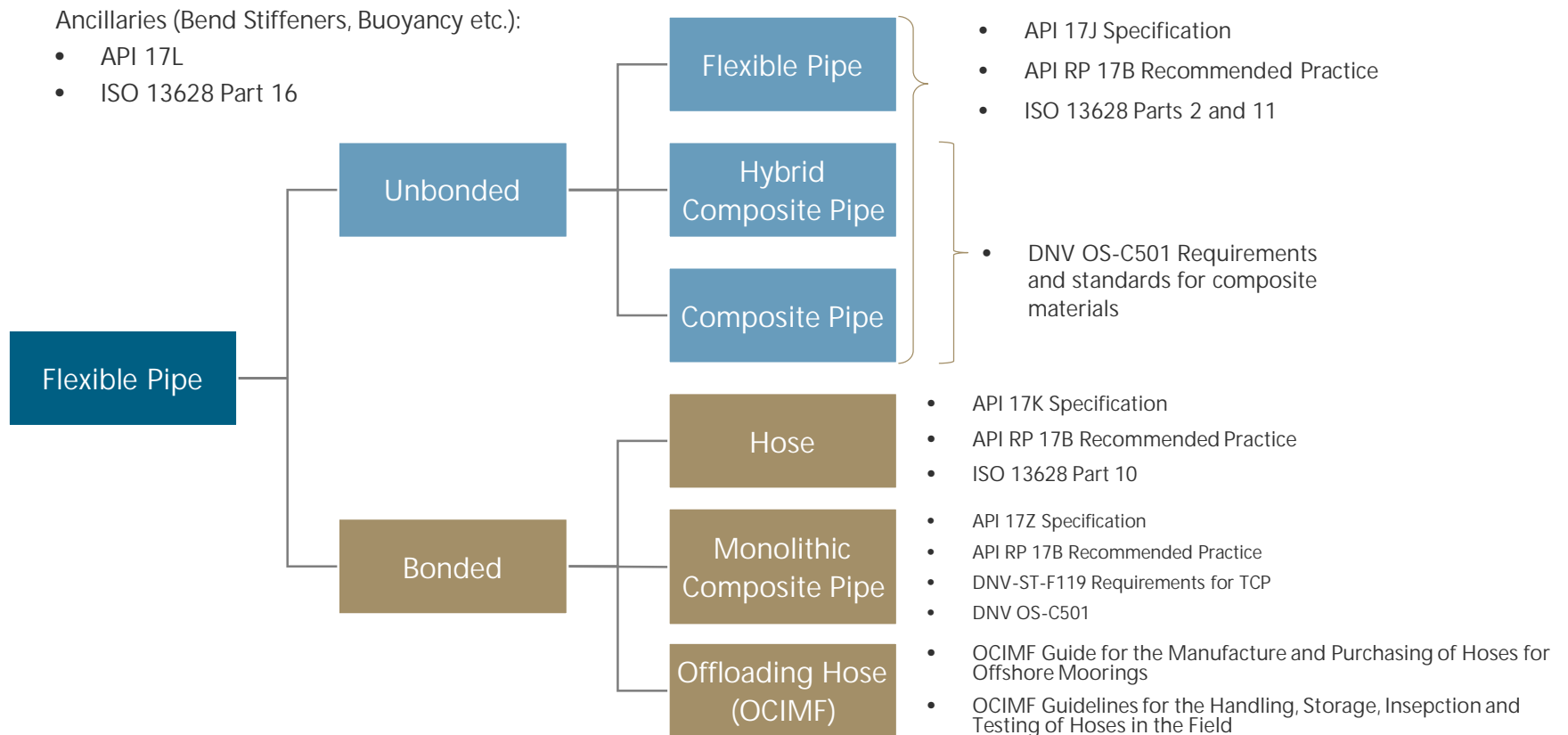
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## NEGATIVES

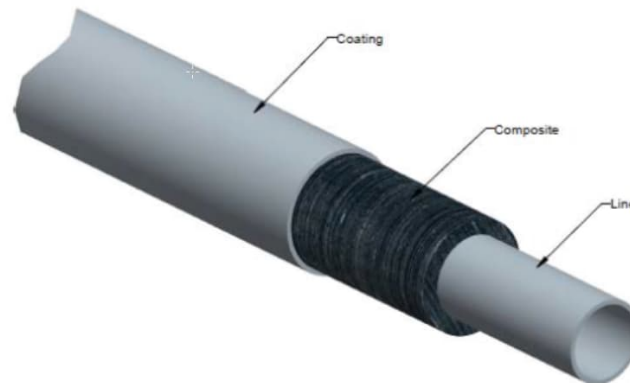
- Limited to 21 bar.
- Bulky – large OD / ID ratio.
- Require regular testing every 6 mo – 3yrs depending upon pipe section function
- Often require frequent replacement e.g. 2 – 5yrs.

# Types of Flexible Pipe



# Monolithic Composite Pipe

- Supplied by Strohm (Airborne), Magma (Now TechnipFMC) or Longpipes.
- 2 or 3 layers cooked together.
- Thermoplastic liner.
- Composite of fibers.
- Coating (Strohm).

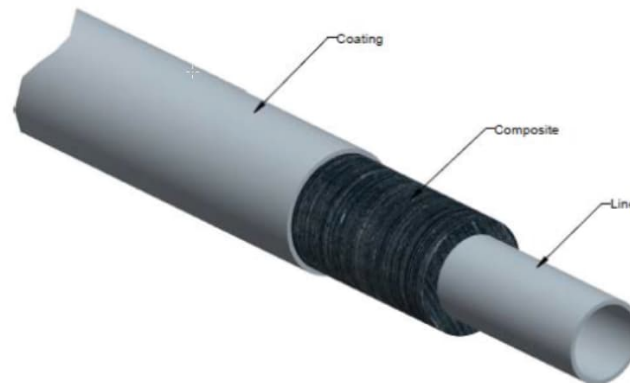


## POSITIVES.

- No corrosion.
- Suitable for CO<sub>2</sub> and H<sub>2</sub>S.
- Suitable for H<sub>2</sub>.
- Improved flow & No FLIP.
- Superior mechanical properties.
- Lightweight – Low H/O weight.
- Fast manufacture.
- In-field termination or re-termination.

# Monolithic Composite Pipe

- Supplied by Strohm (Airborne), Magma (Now TechnipFMC) or Longpipes.
- 2 or 3 layers cooked together.
- Thermoplastic liner.
- Composite of fibres.
- Coating (Strohm).



## NEGATIVES.

- Expensive materials.
- Unstable due to light weight.
- Limited experience and track record in oil & gas.
- Currently limited to 93°C or 121°C for PVDF.
- Currently limited to 7.5" ID

# Monolithic Composite Pipe

## Temperature Limitations

- Fully qualified to 60 Degrees C, option to 65 Degrees C (150 F)
- Medium pressure (5,000 psi)
- Low permeation
- High chemical resistance
- Weight coating option
- Flowlines and jumpers

- Up to 80 Degrees C (180 F)
- High pressure (10,000 psi)
- Low permeation
- Flowlines and jumpers

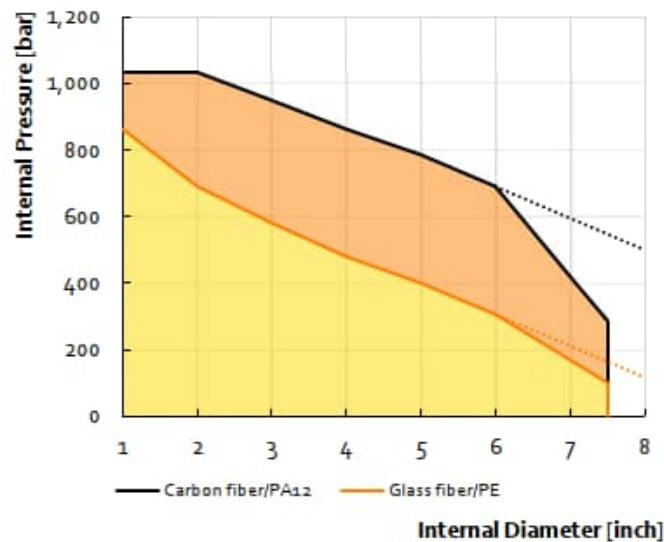
- Highest temperature up to 121 Degrees C (250 F)
- High pressure (10,000 psi)
- Highest chemical resistance
- DNV qualification complete 1H 2021
- Weight coating option



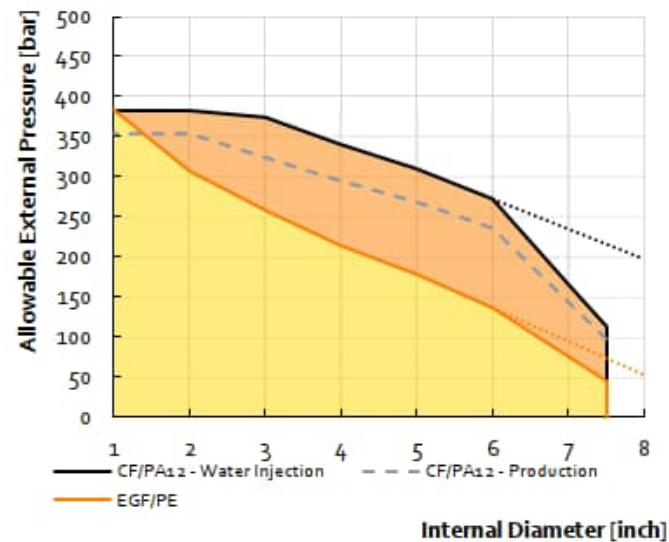
# Monolithic Composite Pipe

Size Qualification vs. Internal / External Pressure

## TCP Flowline and Jumper Spools: Envelope EGF/PE and CF/PA12



- Notes:
- Manufacturing limitations based on current equipment. Dotted lines indicate capability without manufacturing limitations.
  - EGF/PE Flowlines qualified for use up to 60°C.
  - Qualification ongoing for CF/PA12 up to 80°C and CF/PVDF up to 120°C (envelope not shown for PVDF).



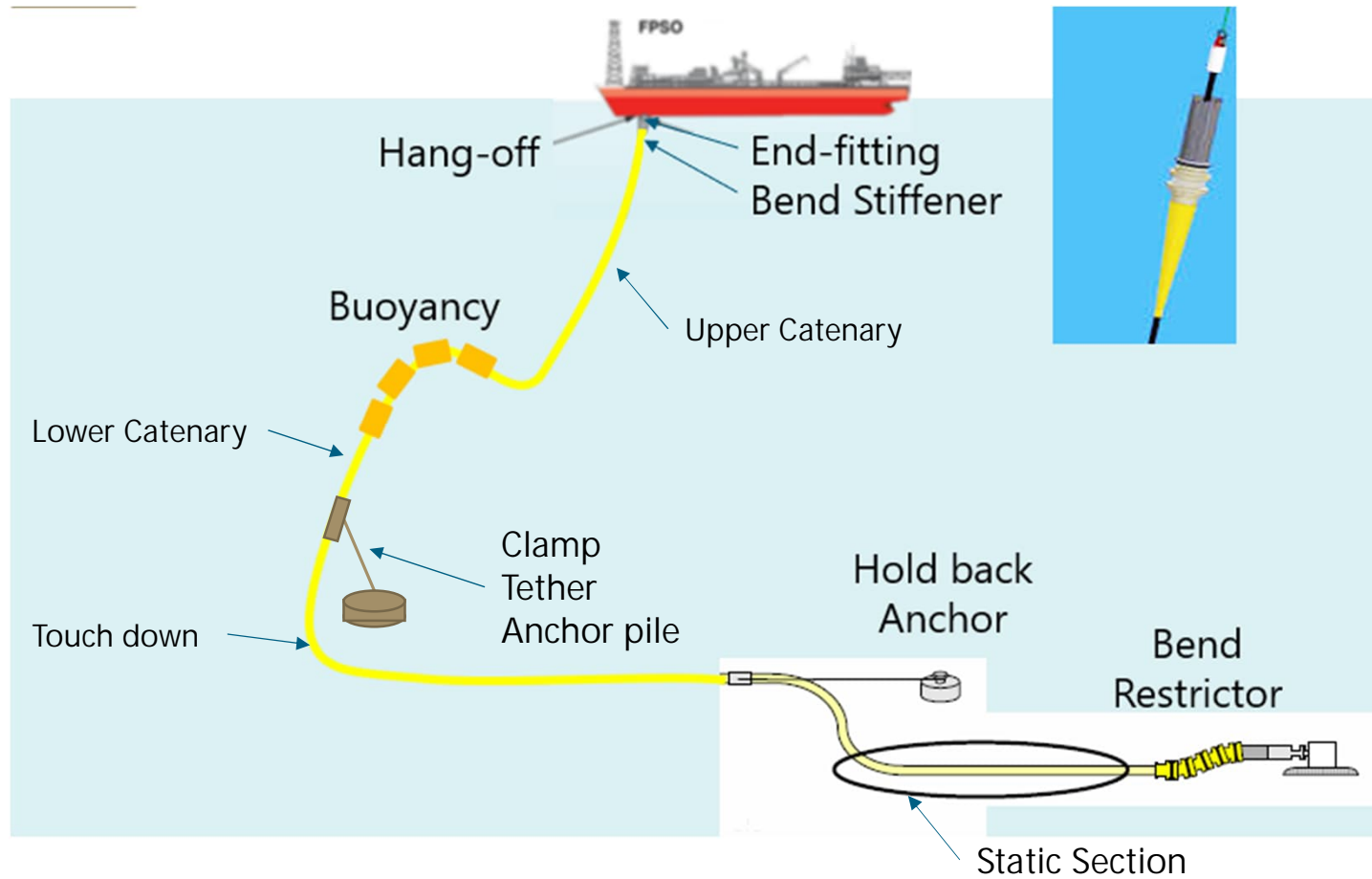
- Notes:
- Assumed pipe wall temperature for collapse calculations: 40°C
  - Allowable external pressure includes safety factors as per DNV safety class high

Strohm ))

# Flexible Riser Configurations and in Australian Conditions



# Typical Flexible Riser Components



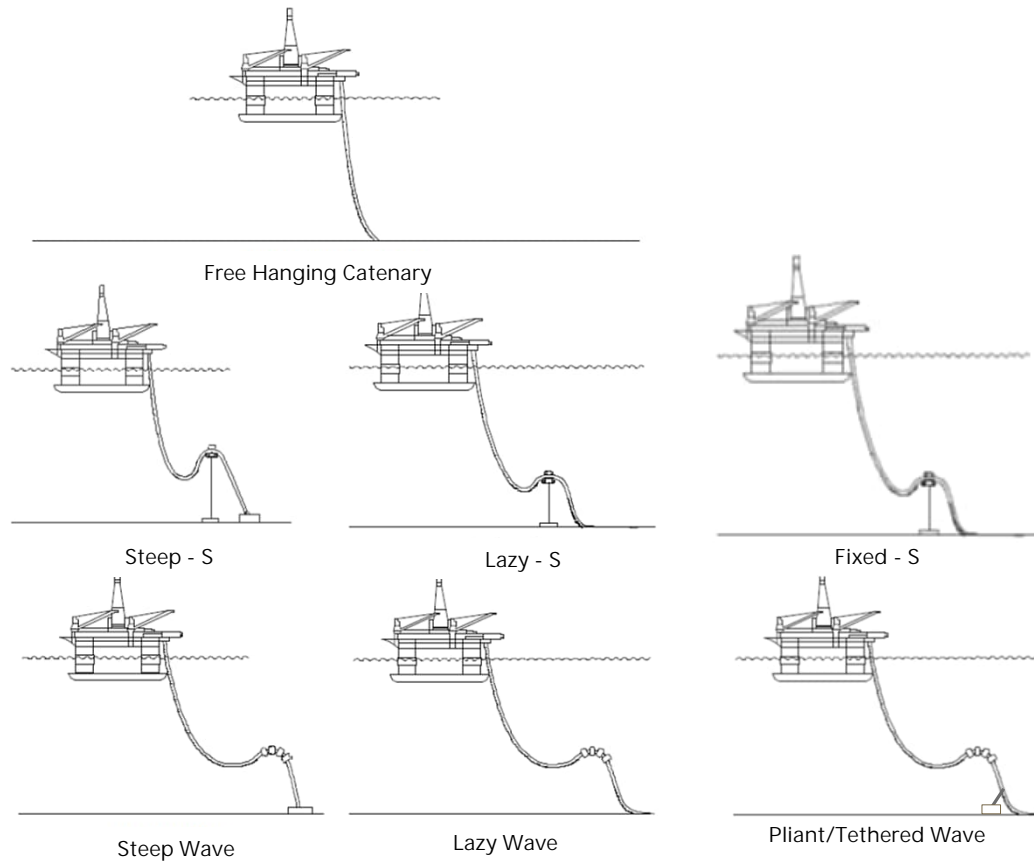
Typical End-fitting



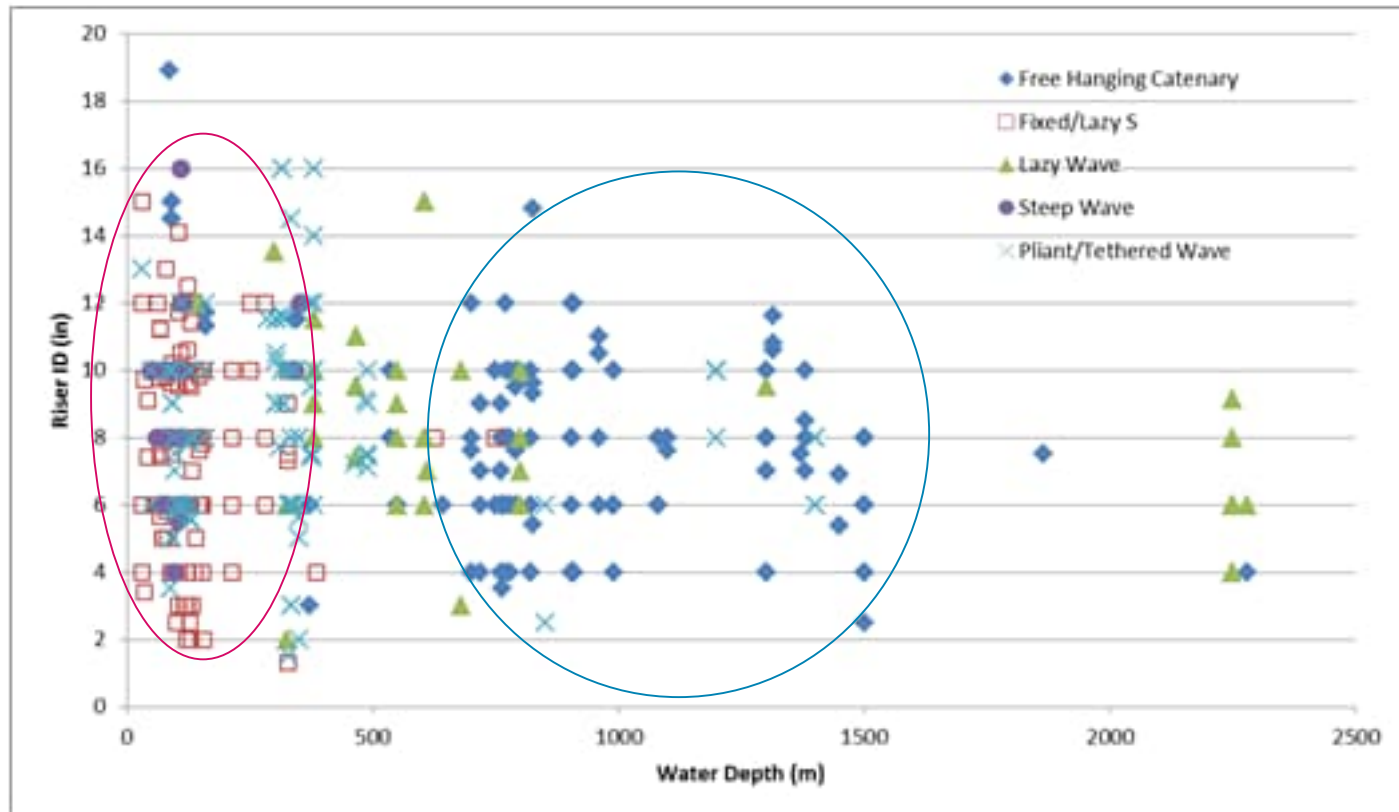
# Flexible Riser Concepts

Standard Riser Configuration Options:

- Free Hanging Catenary
- Steep S
- Steep Wave
- Lazy Wave
- Lazy S
- Fixed S



# Flexible Risers – Configuration



*Configuration Type – Installed Systems (All Regions)*

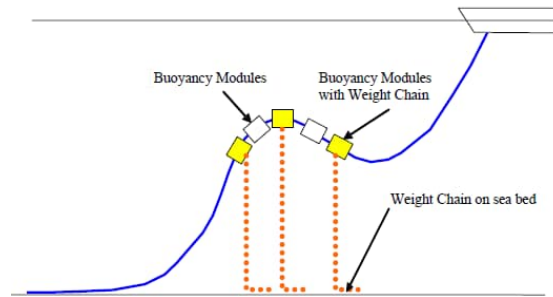
# Risers in Australian Waters

Vessel	Field	WD	NOR	Configuration
FPSO Front Puffin	Puffin	70	3	Steep-Wave (6", 3")
FPSO Okha	CWLH	76	6	Steep-Wave (6", 8", 10")
FPSO Montara Venture	Montara	83	6	Lazy or Pliant Wave (12", 6")
FPSO Four Rainbow	Woollybutt	100	12	Lazy-S
FPSO Challis	Challis	106		Rigid SALRAM
FPSO Griffin Venture	Griffin	131	9	Lazy-S
FPSO Crystal Ocean	BMG	155	3	Lazy-Wave
FPSO MODEC Venture	Mutineer Exeter	156	8	Lazy-S (2 Buoys)
FLNG Prelude	Prelude	248	5	
FPSO Pyrenees Venture	Pyrenees	250	15	Lazy-S (4 x 10", 4 x 8", 10", 6", 3 x 4", 2 x EHU)
FPSO Buffalo Venture	Buffalo	255		Pliant Wave
FPSO Ngujima-Yin	Vincent	340	8	Lazy-Wave with Hold Back Clamp (6", 10" + 14", 10", 8")
Semi-submersible	Ichthys	340	27	Fixed-S (10", 12", 8")
Ichthys FPSO	Ichthys	340	15	Lazy Wave (Umbilical)
FPSO Glas Dowl	Kitan	344	7	Pliant Wave (3 x 6" PR, 3 x 2" GL, 1 x EHU)
FPSO Ningaloo Vision	Van Gogh	380	5	Steep-Wave (10" x 4) Lazy Wave EHU
FPSO Northern Endeavour	Laminaria	380	6	Pliant-Wave (6", 10")
FPSO Ngangurra	Enfield	550	6	Lazy-Wave with Hold Back Clamp (6", 8", 9", 10")
FPSO Stybarrow	Stybarrow	825	9	Lazy-Wave with Hold Back Clamp

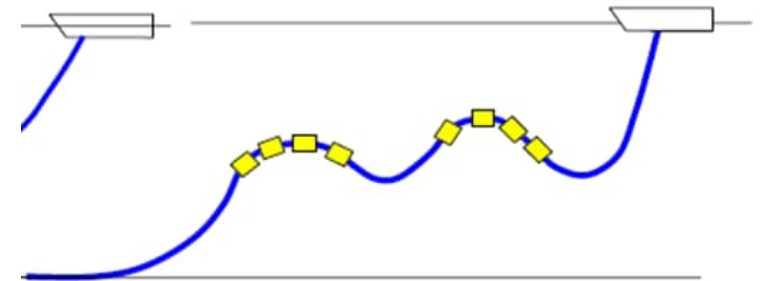
# Shallow Water Riser Concept

Shallow water options:

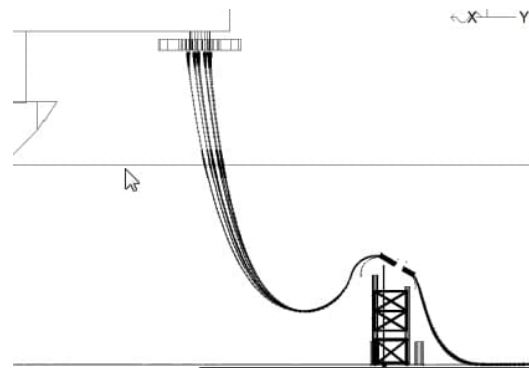
- Weight Added Wave
- Double Pliant Wave
- NOV's Fixed-S
- Chinese Lantern



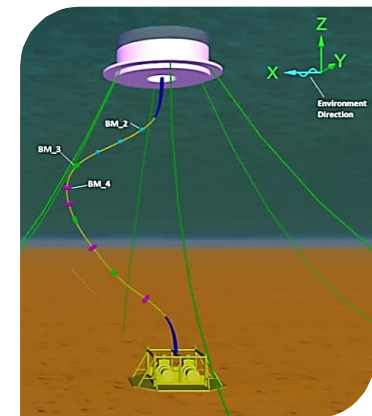
*Baker Hughes Weight Added Wave*



*Technip's Double Pliant Wave*



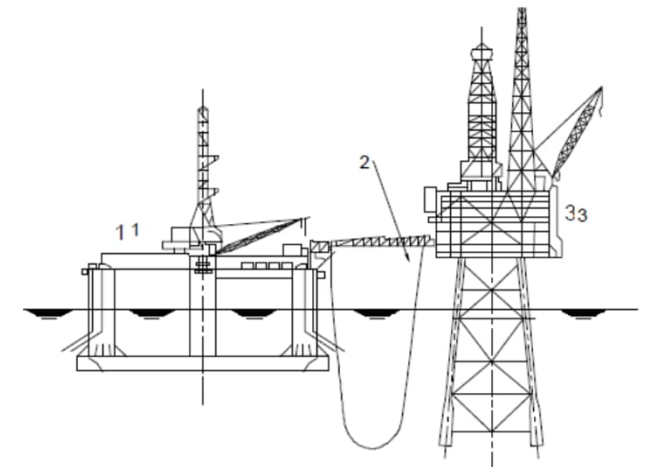
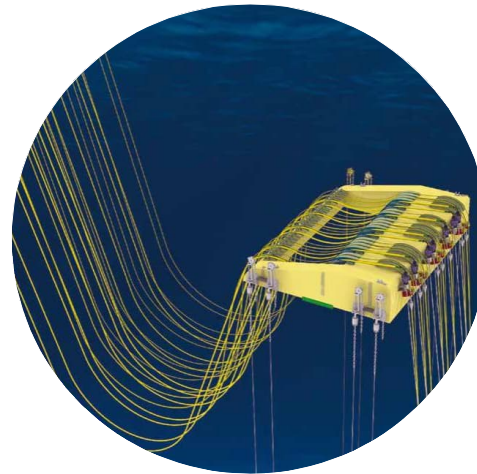
*NOV's Fixed-S*



# Other Dynamic Applications

Import/Export Facilities:

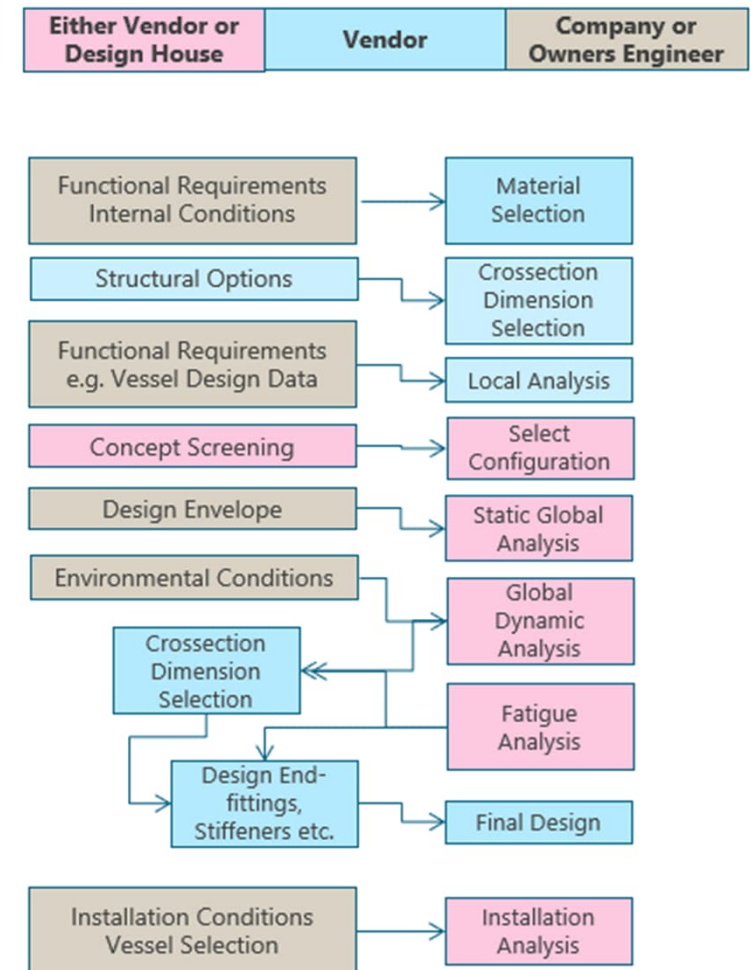
- CALM Buoys and other Terminal Buoys
- Offloading Buoys
- Fluid Transfer Lines
- Dynamic Jumpers at Topside Piping



# Flexible Riser Design

# Riser Design Activities

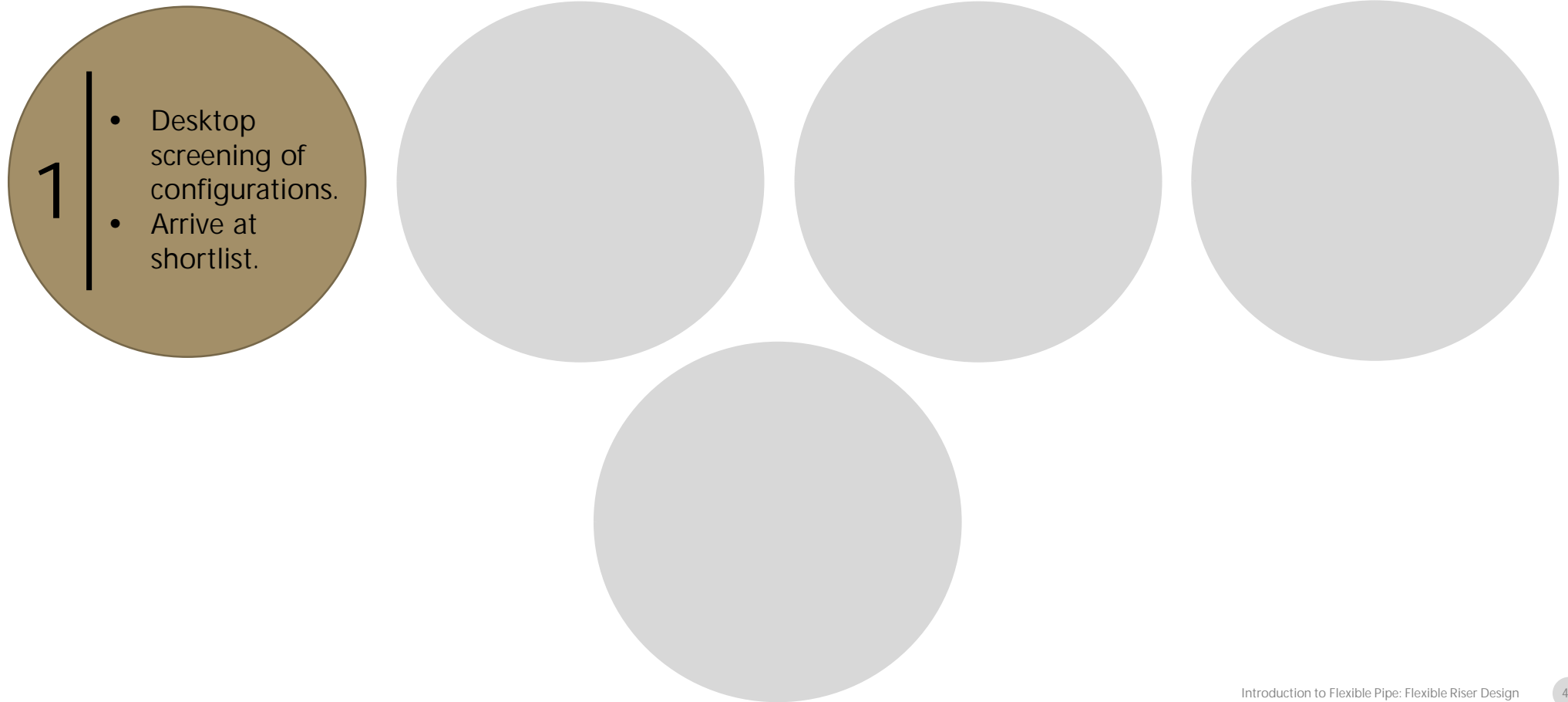
1. The chemical make-up of the contents will come from the BOD, which comes from down-hole essays/survey
  2. Diameter, contents conditions (pressure, temperature) and drive the material selection and are based on flow assurance studies.
  3. The feasibility, concepts and specifications are developed.
  4. Pipe local cross-section analysis, detailed configurations design performed by Flexible Vendors.
- Other design tasks include:
    - Design of ancillary components (e.g. buoyancy, bend stiffeners, bend restrictors).
    - Design of End Terminations and Connections.
    - Installation Analysis







# Typical Configuration Design Sequence

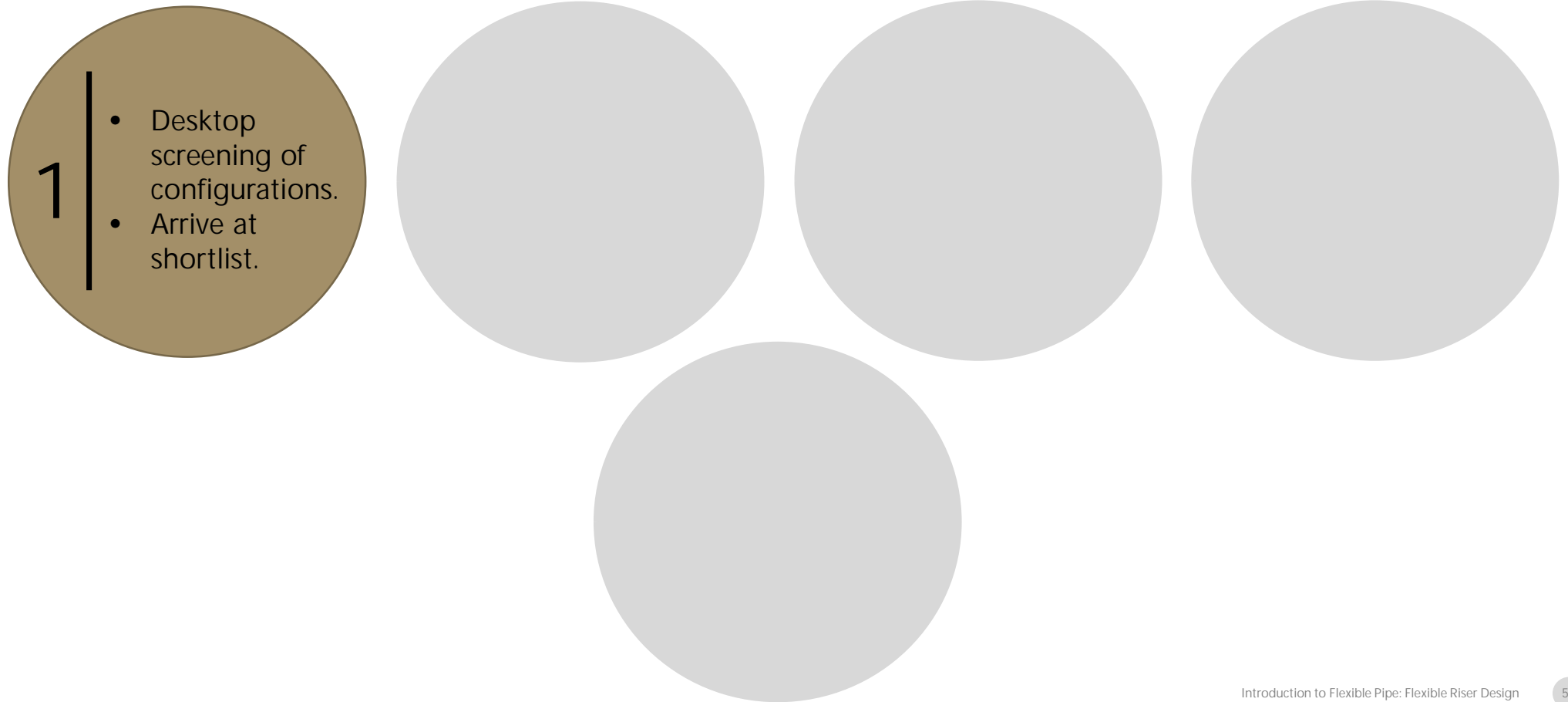


# Concept Screening

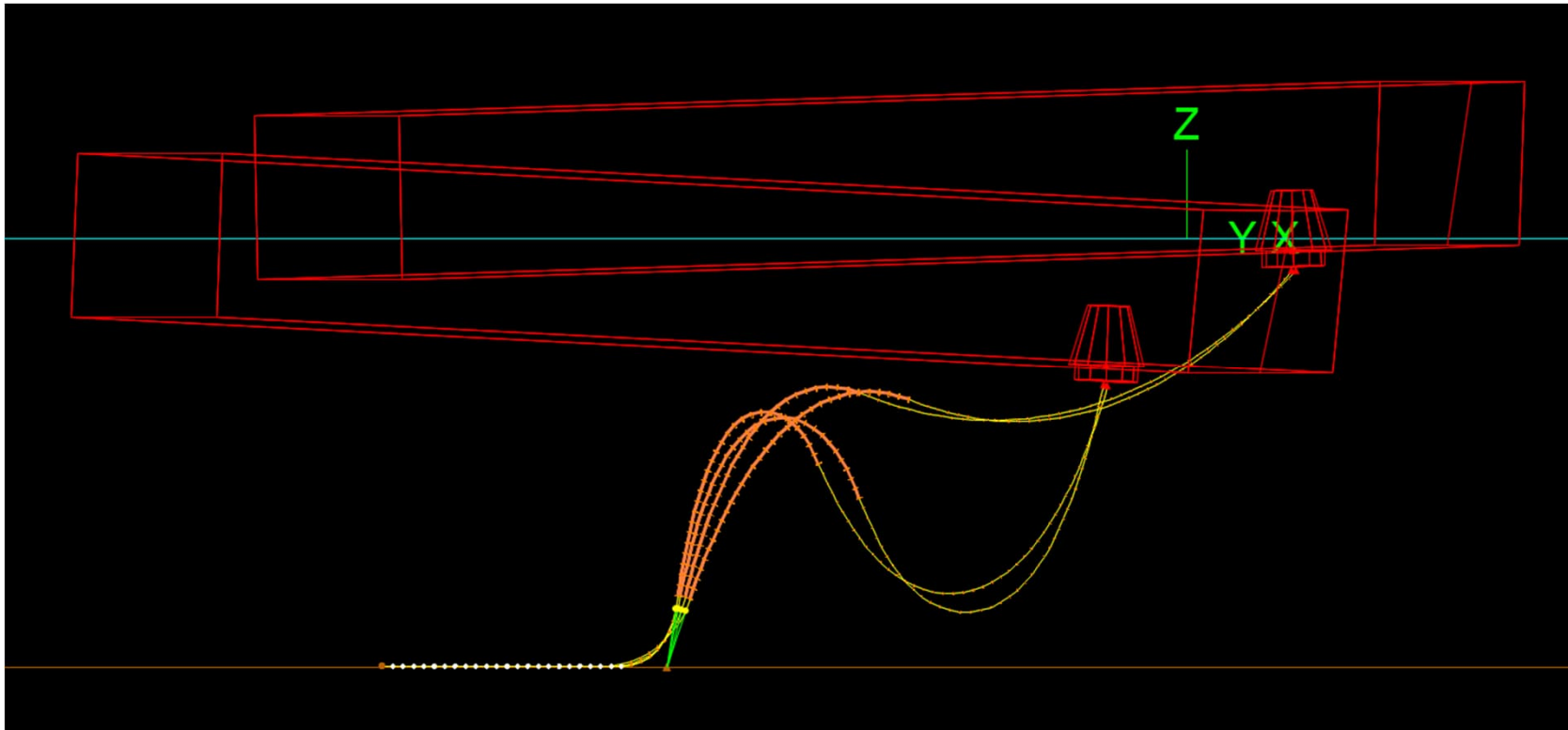
Weight	Configurations	Free Hanging Catenary	Lazy – S	Steep – S	Lazy Wave	Steep Wave	Fixed – S	Chinese Lantern
	<b>Assessment Criteria:</b>							
	<b>Working Ranges:</b>							
3	Feasibility	-1	0	0	1	2	-2	-3
3	Distance to Touchdown	2	0	1	-2	-1	1	
1	Clashing	2	1	1	-1	-2	2	
3	Offset Range	-2	1	1	2	2	-1	
1	Spacing Requirements at H/O	1	1	1	-2	-2	2	
1	Seabed Spread	0	-1	-1	-2	-2	2	
0.5	Riser Weight	0	0	0	-2	-1	2	
0.5	Riser Bend Stiffness	-1	-1	-1	0	-1	0	
1	Geometric Tolerances	1	-2	-2	2	1	-1	
	<b>Sub Total</b>	2	-1	0	-4	-4	5	-3
	<b>Sub Total inc. Weight</b>	0.5	1.5	4.5	-1	3	0	-9
	<b>Global Considerations:</b>							
3	Safety (Installation, Inspection)	0	-1	-1	-1	-1	-1	
3	Dropped Object Vulnerability	1	-1	-1	0	0	0	
3	Reliability (Leak Paths, Corrosion etc.)	1	-1	0	-1	-1	1	
1	Cost	2	-2	-1	-2	-1	-1	
2	Installability	2	-1	-1	0	0	-2	
2	Schedule (Lead Time & Installation Time)	1	-1	-1	0	0	-2	
3	Proven Technology	-1	1	-1	2	2	1	
2	Flow Assurance & Operability	1	0	0	0	0	0	
1	Expandability	0	-1	-1	0	0	-1	
2	Ease of Riser Replacement	1	-1	-1	0	0	1	
1	Foundations (Size and Complexity)	1	-2	-2	0	-1	-2	
2	Simplicity	2	-2	-2	-1	-1	-2	
1	Commonality (Interchangeable Parts)	1	0	0	-1	-1	1	
0.5	Ease of Inspection	1	-2	-2	0	-1	-2	
0.5	Ease of Repair	0	-2	-2	-1	-1	0	
	<b>Sub Total</b>	13	-16	-16	-5	-6	-9	0
	<b>Sub Total inc. Weight</b>	21.5	-23	-25	-5.5	-6	-11	0
	<b>Total inc. Weight</b>	22	-21.5	-20.5	-6.5	-3	-11	-9



# Typical Configuration Design Sequence

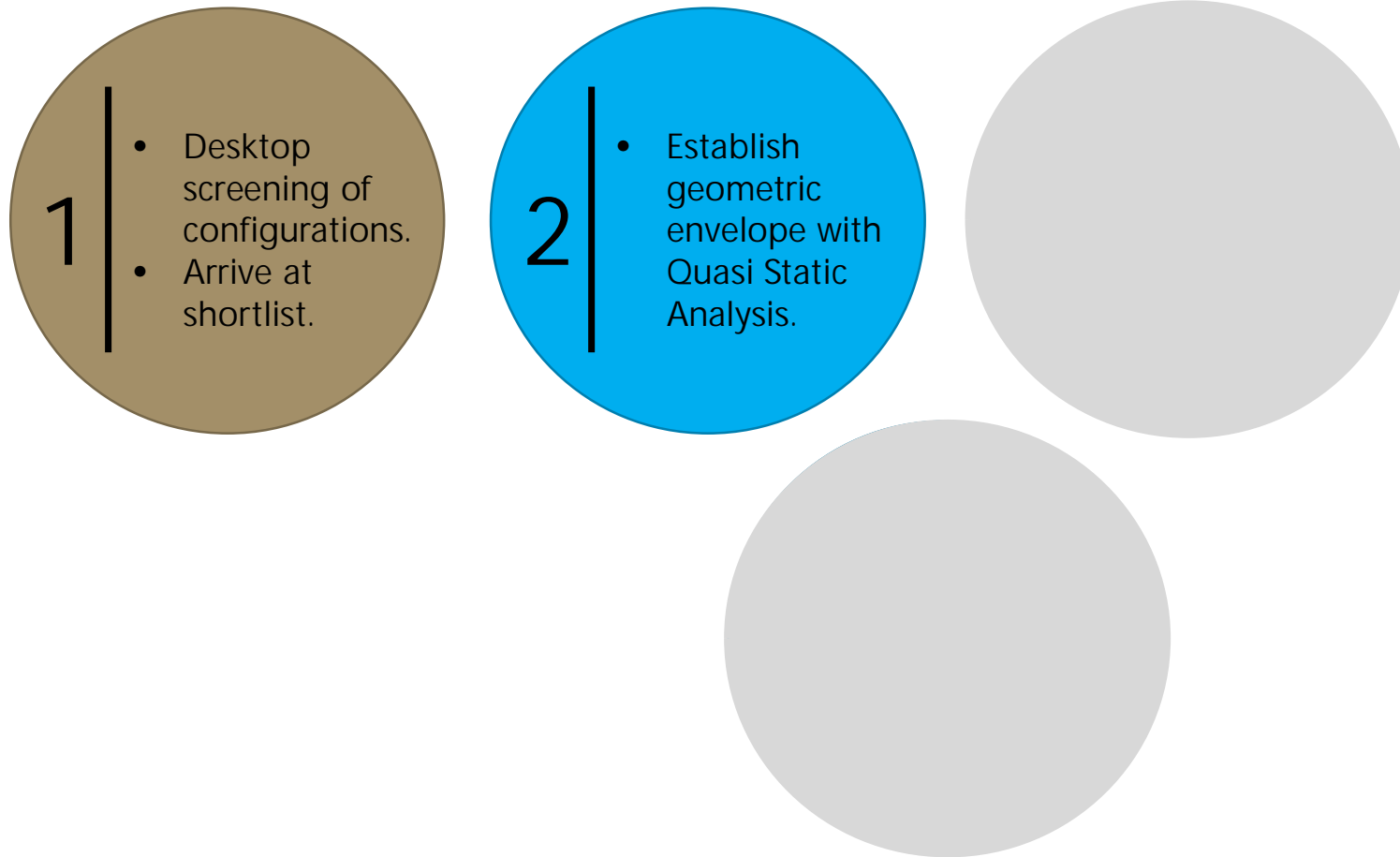


# Quasi-static Design Envelope

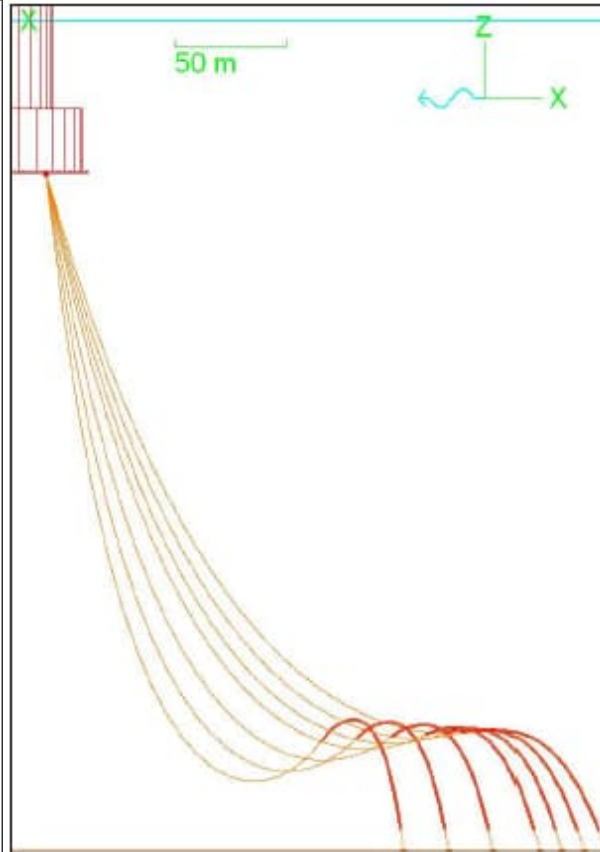
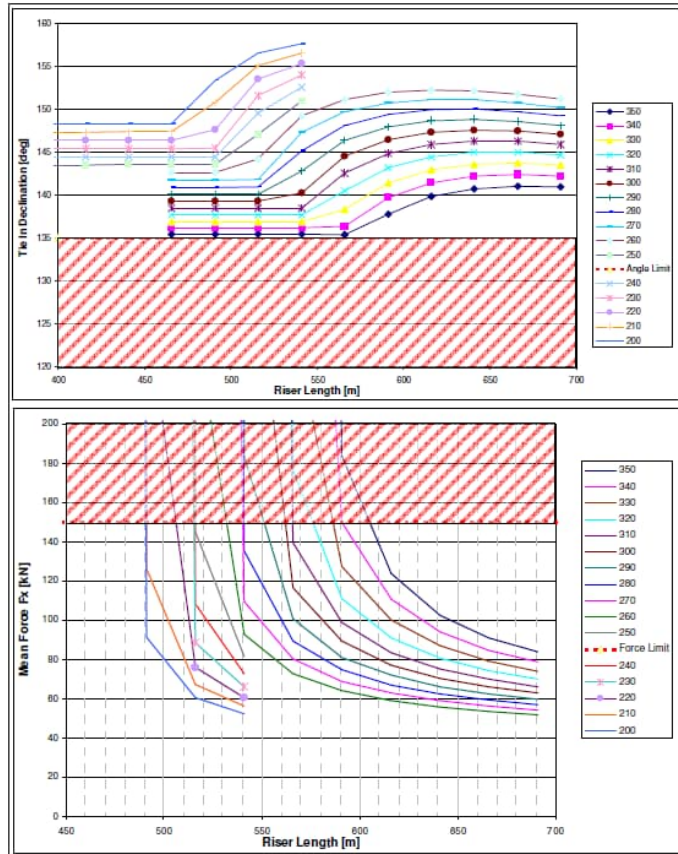




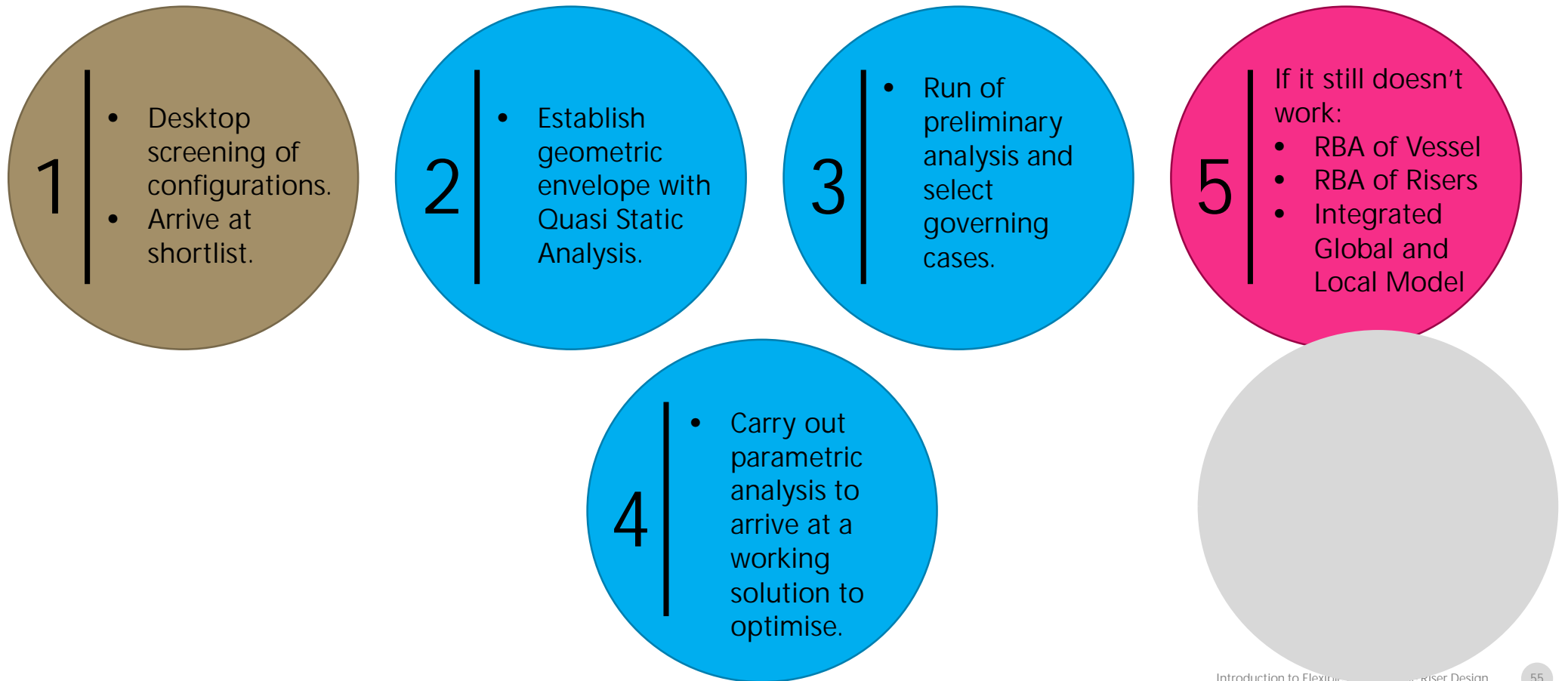
# Typical Configuration Design Sequence



# Parametric Analysis

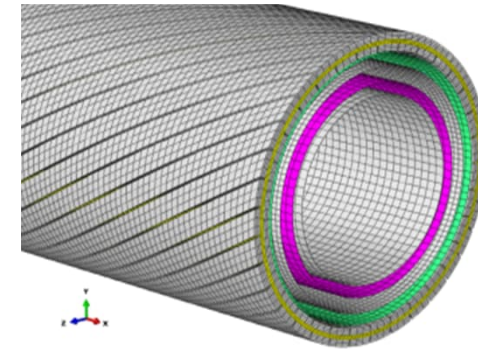
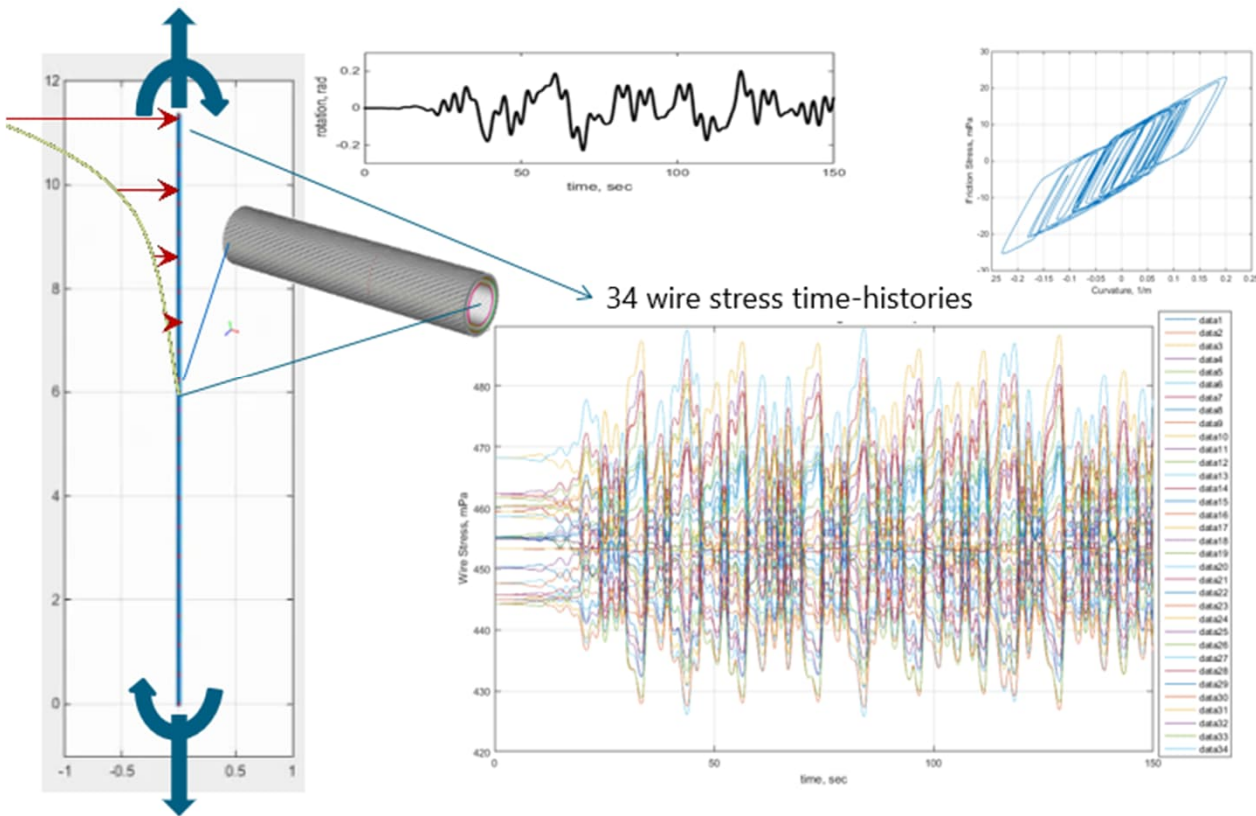


# Typical Configuration Design Sequence

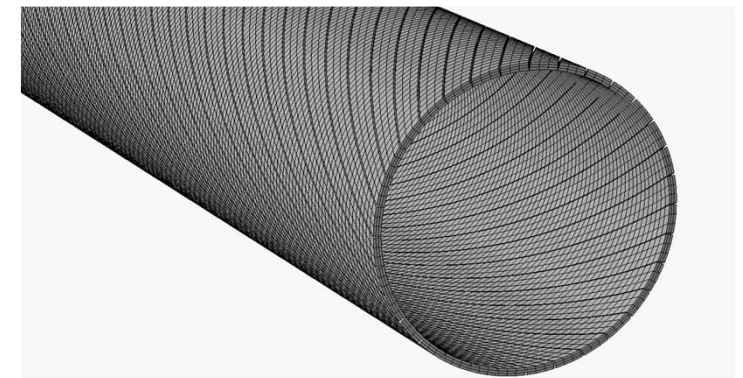


# Global Local Model

20 pitch (12m) riser simulation with 80 million DoF using FLEXAS™



*Intecsea's high fidelity FEM with 3D armour wires*



*Armour wire kinematics in axial extension*





# Intecsea

Worley Group



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- When required by law and/or government authorities.

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- In relation to any information where we reasonably believe it will be necessary to defend or prosecute or make a claim against you, us or a third party, we may retain that data for as long as that claim could be pursued.

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