Deepwater Flowline & Steel Catenary Riser Design Concepts

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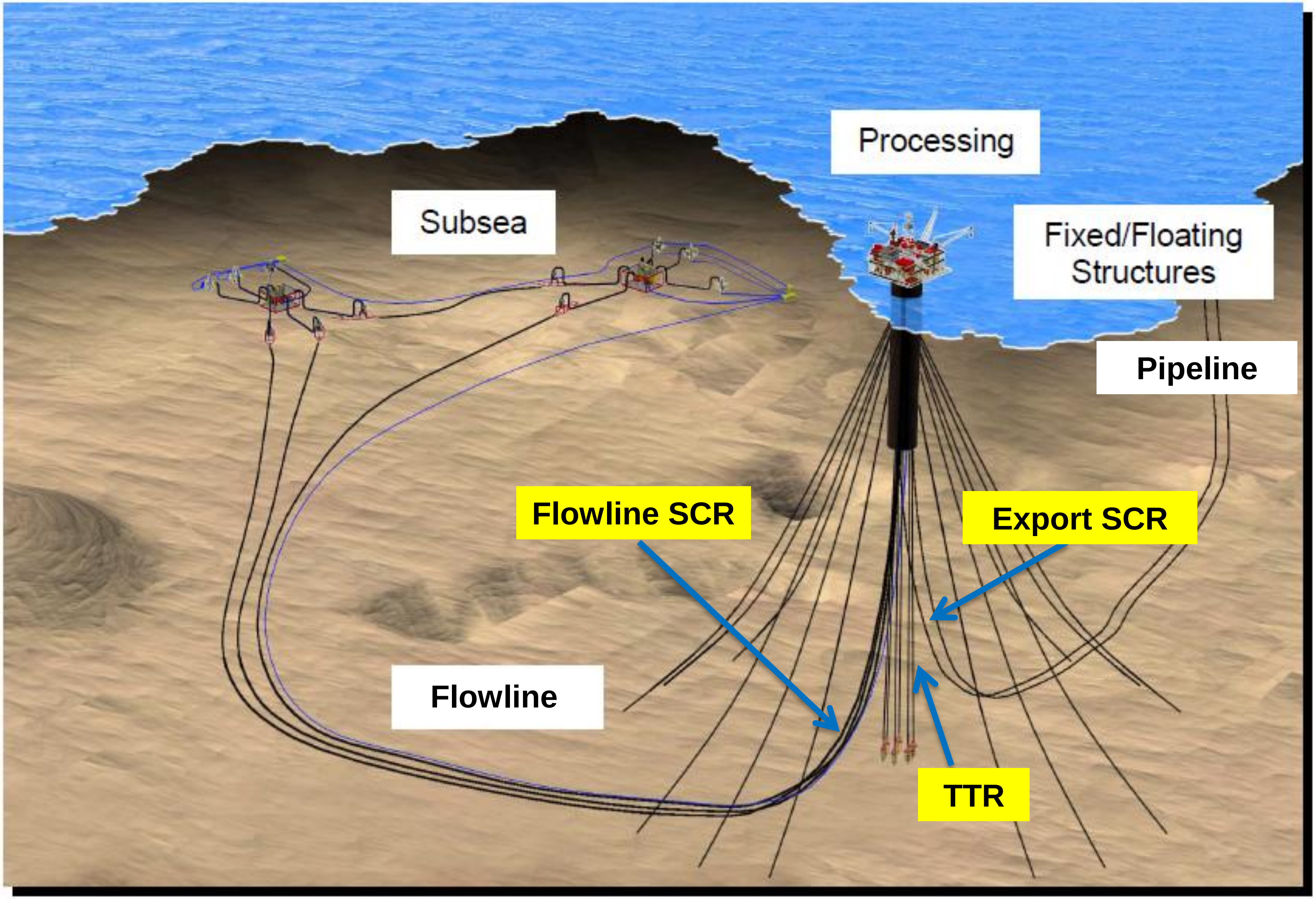


Flowlines & SCRs

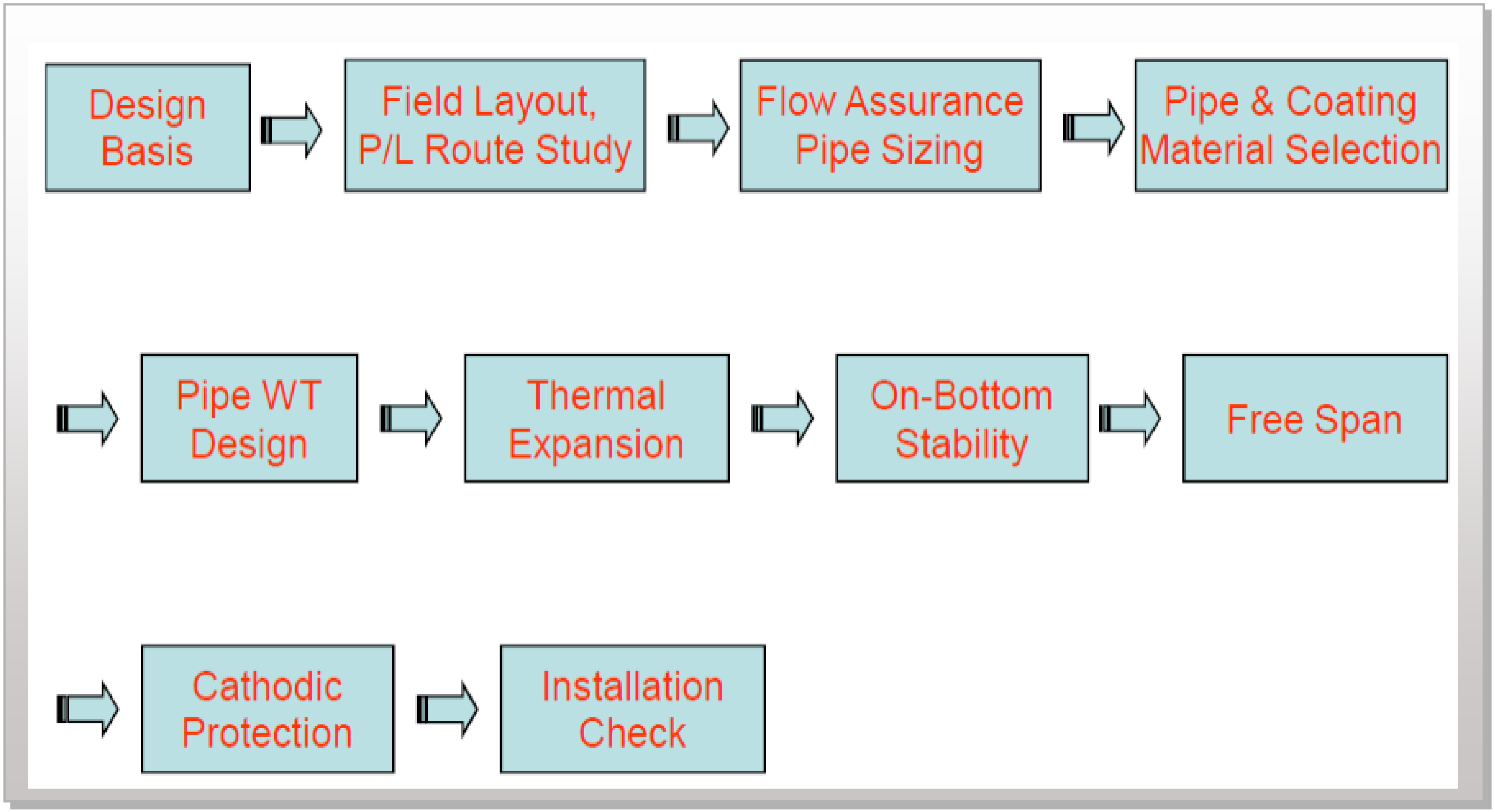
What are flowline and SCR ?

1. Deepwater ?
   - 200 m (Geological condition – Continental Shelf)
   - 300 m (Economic limit of fixed platform & BSEE, USA)
   - 500 m (Market analysis by Douglas-Westwood)

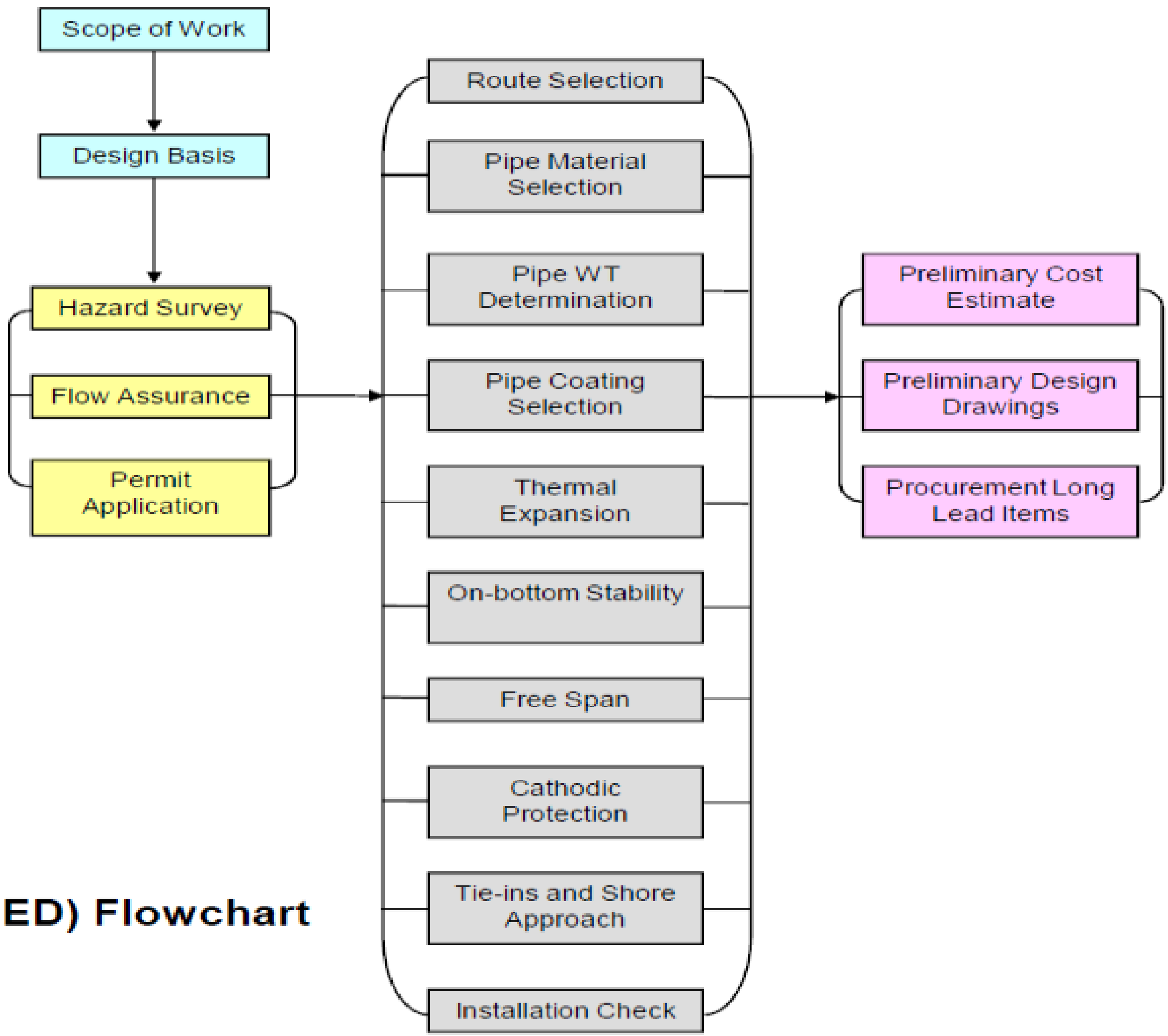
2. Flowline ?
   - Flowline is from wellhead to platform, (unprocessed hydrocarbon
   - Pipeline is export from platform (processed hydrocarbon)

3. Steel Catenary Riser (SCR) ?
   - Curved vertical portion of flowline/pipeline made by steel pipes
   - Best technical and commercial riser for deep and ultra-deepwater

Flowline Design Procedure



Flowline Design (FEED)



Preliminary Design (FEED) Flowchart

Design Basis for Flowline

➢ Design Codes

- API, ASME,
- DNV, BS

➢ Design Data

- Field & Environmental Data
- Pipeline Data
- Geotechnical & Soil Data

➢ Design Methodology

- Route
- D & WT
- On-Bottom
- Expansion
- Span
- CPS
- Installation

Considerations on Pipeline Design

- Pipe Size
- Design Pressure (@ wellhead or platform deck)
- Design Temperature
- Pressure and Temperature Profile
- Max/Min Water Depth
- Corrosion Allowance
- Required OHTC Value
- Design Code (ASME, API, or DNV)
- Installation Method (S, J, Reel, or Tow)
- Metocean Data
- Soil Data
- Design Life
- Fluid Property (sweet or sour)

Flowline Analysis – Wall Thickness

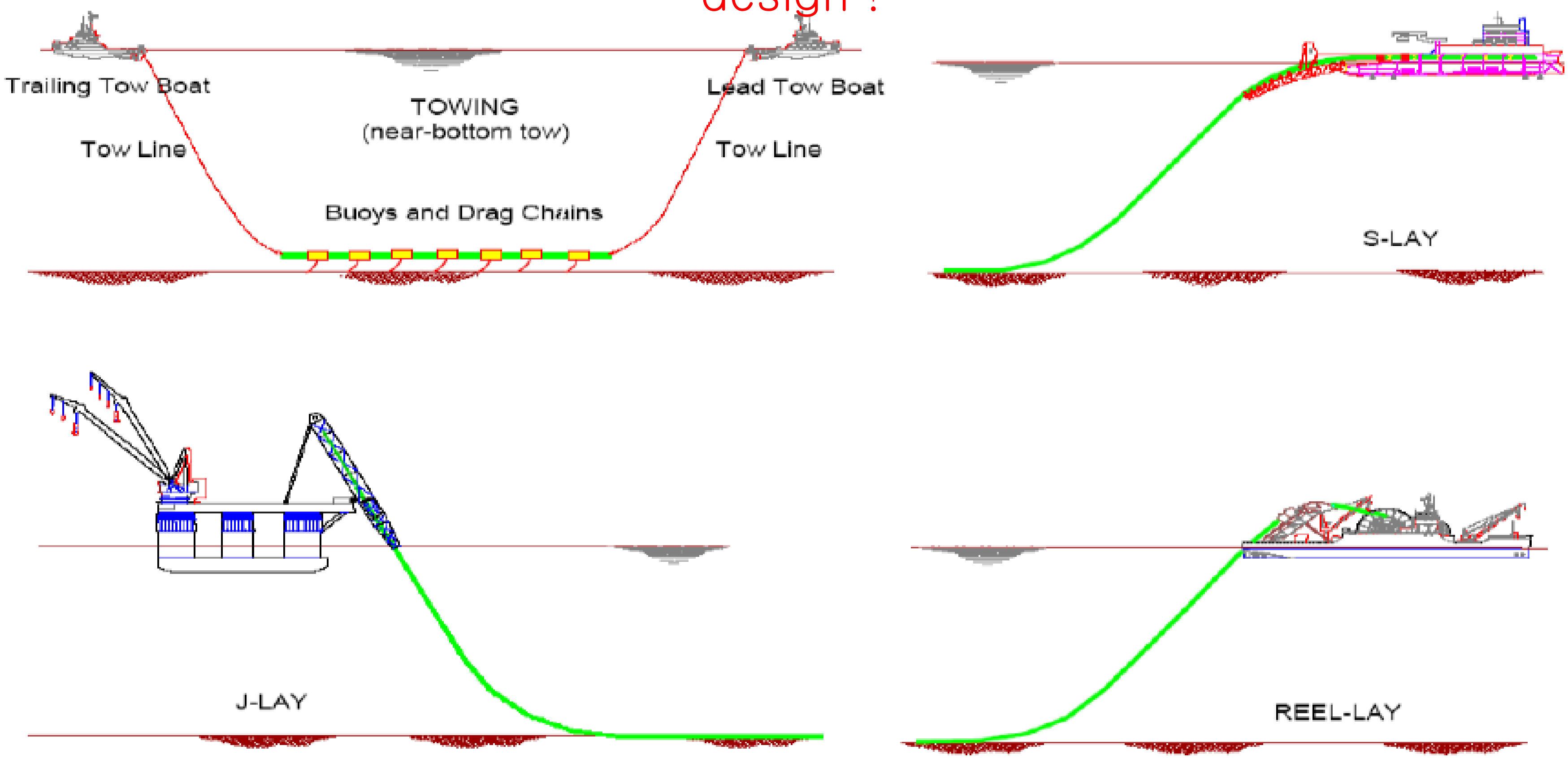
- Burst
- Collapse
- Combined Bending & External Pressure
- Buckle Propagation

Design Codes for Pipeline/SCR

	Upper Level Code		Practical Code	Common Code
Oil	F/L	DOI 30 CFR part 250	ASME B31.4	API-RP-2RD API-RP-1111
	P/L	DOT 49 CFR part 192		
Gas	F/L	DOI 30 CFR part 250	ASME B31.8	
	P/L	DOT 49 CFR part 195		
Oil & Gas	DNV OS-F101 Submarine Pipeline, DNV OS-F201 Dynamic Risers			

Pipeline Installation Methods

Installation analysis is a critical part of deepwater F/L & SCR design !



Design Basis for SCR

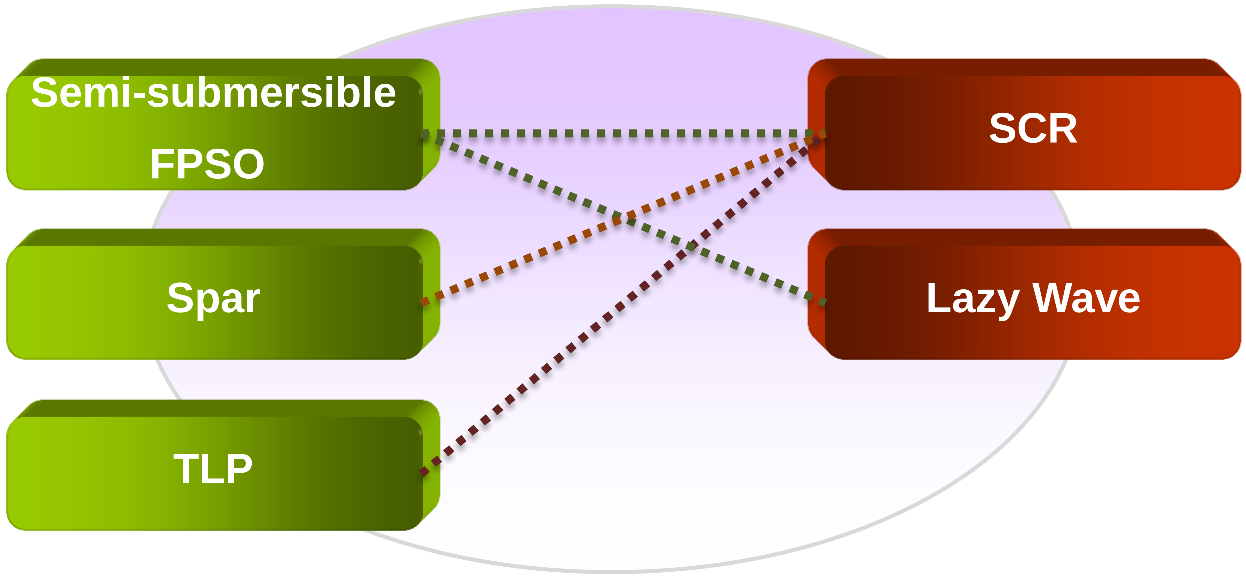
- **Design Codes**
  - API, ASME,
  - DNV, BS
- **Design Data**
  - Field & Environmental Data
  - Flowline, SCR and Floater Data
  - Geotechnical and Soil Data
- **Design Methodology**
  - Same as Flowlines
  - Dynamic Behavior & Fatigue Analysis
  - No model test can be done for SCRs

Why SCRs are best for deepwater ?

1. Low cost
2. Conceptual simplicity
3. Significant structural capacity
4. Ease of fabrication and offshore installation

Floaters & SCR

➢ Wet tree tied back to floaters



➢ Most contributing factor:

- Fatigue knockdown due to sour service

Design Criteria of SCR – Strength

- Strength by API-RP-2RD

$$\sigma_e < 0.8 * \sigma_y \quad \text{for extreme}$$

$$\sigma_e < 1.0 * \sigma_y \quad \text{for survival}$$

- Design Life (DL) = 20 yrs

- Factor of Safety (FOS) = { 10 for motion fatigue; 20 for VIV fatigue

Design Criteria of SCR – Fatigue

$$D_{combined} = FOS_{sour\ service} * (D_{Motion} + 2 * D_{VIV} + D_{VIM})$$

where

$D_{combined}$ = Combinded Fatigue Damage

$FOS_{sour\ service}$ = Knock down factor (depends on string / diameter)

D_{Motion} = Unfactored fatigue damage due to vessel first and second order motion

D_{VIV} = Unfactored fatigue damage due to riser VIV

D_{VIM} = Unfactored fatigue damage due to hull VIM

- Overall Fatigue Life = DL * FOS (10) * Installation (1.053)

  $1 / D_{combined} > 211$ years = Feasible solution

- Robustness solution = 3 * OFL = 633 yrs

SCR Design – Analysis

- Riser analysis by Flexcom-3D/Orcaflex/Riserflex
- VIV fatigue analysis by SHEAR7

- Wall thickness
- Strength analysis
- Wave fatigue
- VIV analysis
- Hull VIM analysis

SCR Design – Analysis

- Dynamic strength analysis
  - Co-linear wave and current load
  - Static vessel offsets + one failed mooring line
  - Vessel motion by RAO
  - Von Mises stress by effective tension, bending, and hoop

SCR Design – Analysis

➢ Time domain vessel motion fatigue

- 1st and 2nd order motion
- Long-term sea-states in up to 8 directions
- Time-trace effective tension and bending moment
- Fatigue damage rates from each sea-state and direction are factored by probability of occurrence.
- Total riser fatigue damages by Miner's rule

SCR Design – Analysis

- VIV fatigue analysis by SHEAR7

  - Current in plane of the riser and normal to the riser
  - Strake efficiency by reduction in the VIV amplitude
  - Lift coefficients vary to ensure target amplitude
  - VIV fatigue damage for each long-term current is factored by probability of occurrence.
  - Total fatigue damage is obtained by summing the factored fatigue damage rates.

SCR Design – Analysis

- Hull VIM
  - Hull VIM occur for reduced velocity

$$V_r = \frac{V * T_n}{D}$$

where

V_r = Reduced velocity

V=Current velocity

T_n = Surge / Sway natural period

D = Hull diameter / column dimension

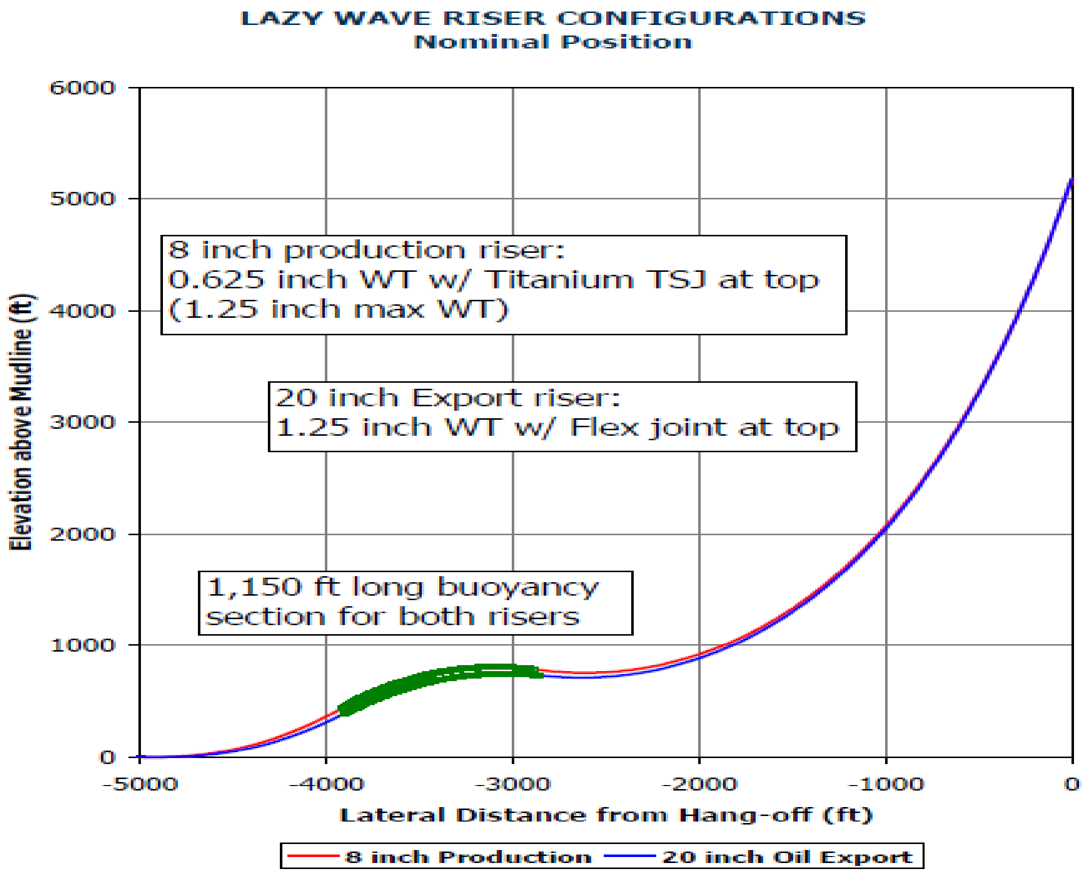
  - Motion amplitude is calculated for current bin w/ VIM
  - VIM response is simulated in the time domain

SCR Design – Interface

- Floater hull structures
- Floater mooring system
- Top hang-off system
- Subsea layout
- Flowline/pipeline
- Metocean data
- Installation

Other Solution – Steel Lazy Wave

- Steel lazy wave riser is a feasible solution with SS & FPSO
- Shell BC-10 field offshore Brazil (2013)



8 inch Production and 20 inch Export Lazy Risers

Other Solution – Steel Lazy Wave

- Steel lazy wave riser can not be used for production from SS & FPSO, unless:

  - criteria is relaxed or
  - sour service knockdown is determined to be less than assumed

Steel Lazy Wave Risers

- Caesar Tonga installed first steel lazy wave riser for Spar (2012)
  - Green Canyon block 683 (GOM)
  - Water depth: 1,500 m

- World 1st steel lazy wave riser for turret-moored FPSO (2009)
  - Shell Espirito Santos FPSO on Offshore Brazil
  - Water depth: 1,780 m

- World deepest steel lazy wave riser for turret-moored FPSO (2015?)
  - Shell Stone FPSO (GOM)
  - Water depth: 2,900 m

Conclusions

- Design of flowline is controlled by Design Rules.
- Design of SCR is controlled by analysis.
- Design of flowline & SCR is controlled by Installation.
- Steel Lazy Wave risers are possible in water depth greater than 1500 m.

The End

Thank you