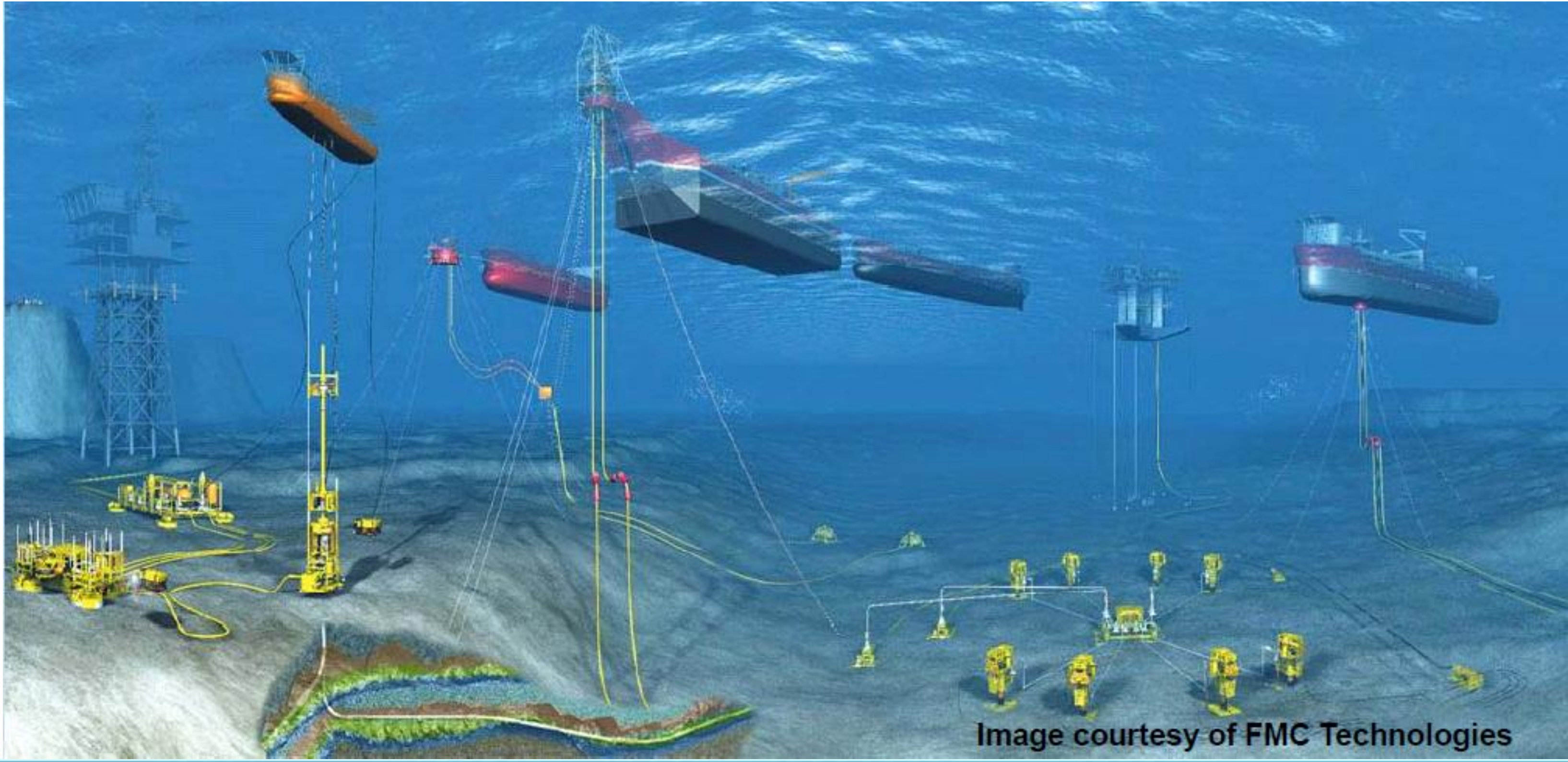
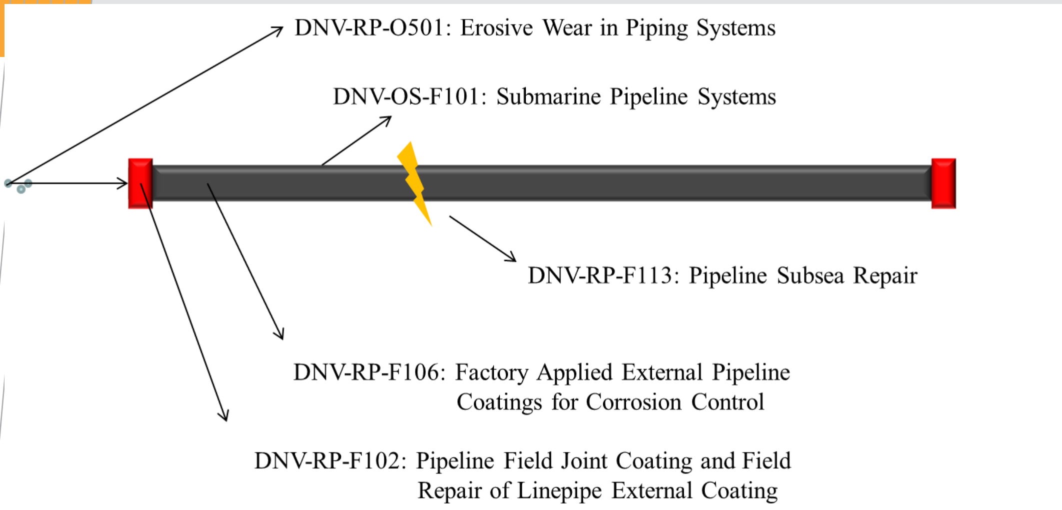


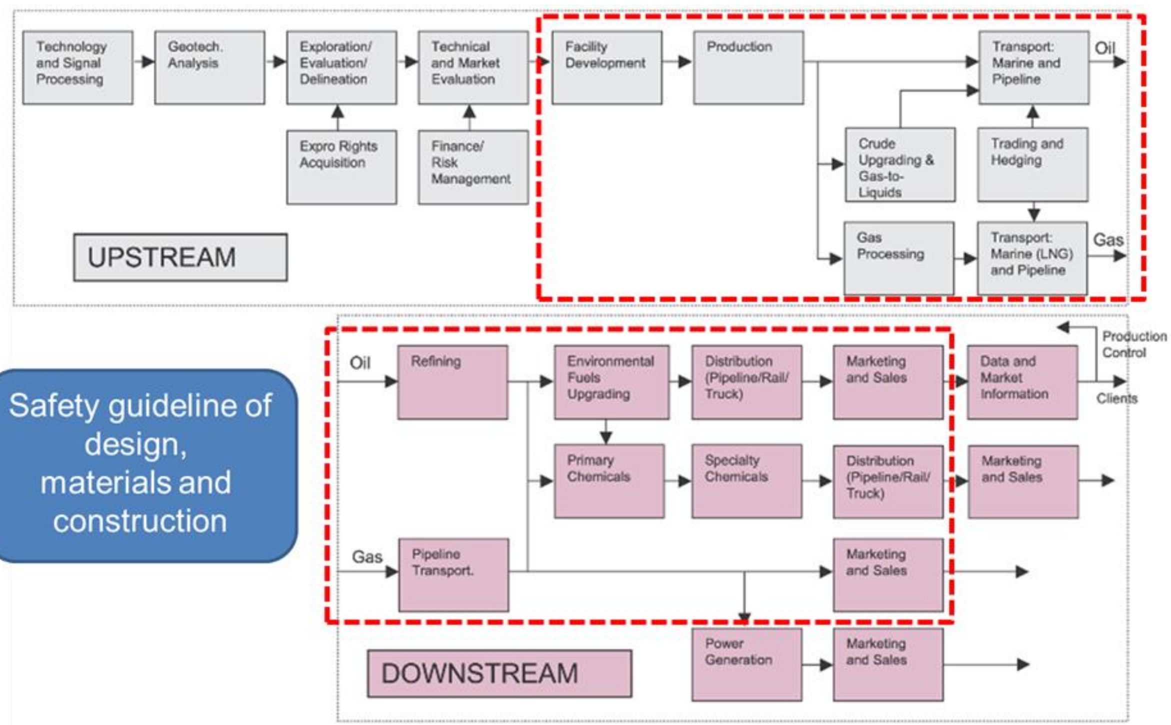
Flow Assurance

서유택

Code and Standard

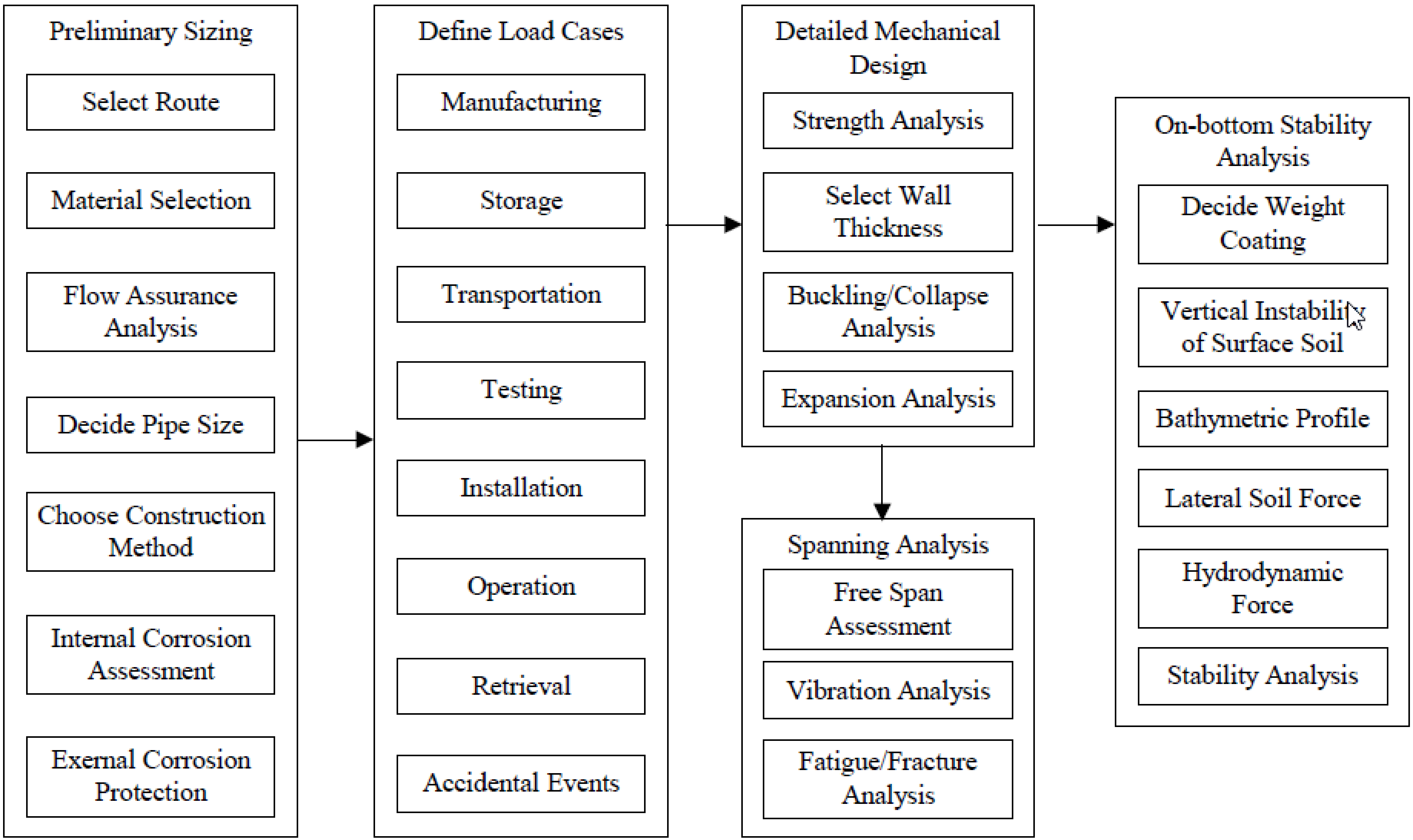
Pipeline	DNV-OSS-301 Certification and Verification of Pipelines
	DNV-OS-F101 Submarine Pipeline Systems
	DNV-RP-D101 Structural Analysis of Piping Systems
	DNV-RP-F101 Corroded Pipelines
	DNV-RP-F102 Pipeline Field Joint Coating and Field Repair of Line pipe Coating
	DNV-RP-F103 Cathodic Protection of Submarine Pipelines by Galvanic Anodes
	DNV-RP-F105 Free Spanning Pipelines
	DNV-RP-F106 Factory Applied External Pipeline Coatings for Corrosion Control
	DNV-RP-F107 Risk Assessment of Pipeline Protection
	DNV-RP-F108 Fracture Control for Pipeline Installation Methods Introducing Cyclic Plastic Strain
	DNV-RP-F109 On-Bottom Stability Design of Submarine Pipelines
	DNV-RP-F110 Global Buckling of Submarine Pipelines Structural Design due to HP/HT
	DNV-RP-F111 Interference Between Trawl Gear and Pipelines
	DNV-RP-F113 Pipeline Subsea Repair
	DNV-RP-F116 Integrity Management of Submarine Pipeline Systems
	DNV-RP-F118 Pipe Girth Weld System Qualification and Project Specific Procedure Validation
	DNV-RP-O501 Erosive Wear in Piping Systems
Riser	DNV-OSS-302 Offshore Riser Systems
	DNV-OS-F201 Dynamic Risers
	DNV-RP-F201 Design of Titanium Risers
	DNV-RP-F202 Composite Risers
	DNV-RP-F203 Riser Interference
	DNV-RP-F204 Riser Fatigue
	DNV-RP-F206 Riser Integrity Management
Oil and Gas Processing Systems	DNV-DSS-314 Verification of Hydrocarbon Refining and Petrochemical Facilities
	DNV-OSS-307 Verification of Process Facilities
	DNV-OS-E201 Oil and Gas Processing Systems
	DNV-RP-F301 Subsea Separator Structural Design





Safety guideline of design, materials and construction

Pipeline Design Flowchart

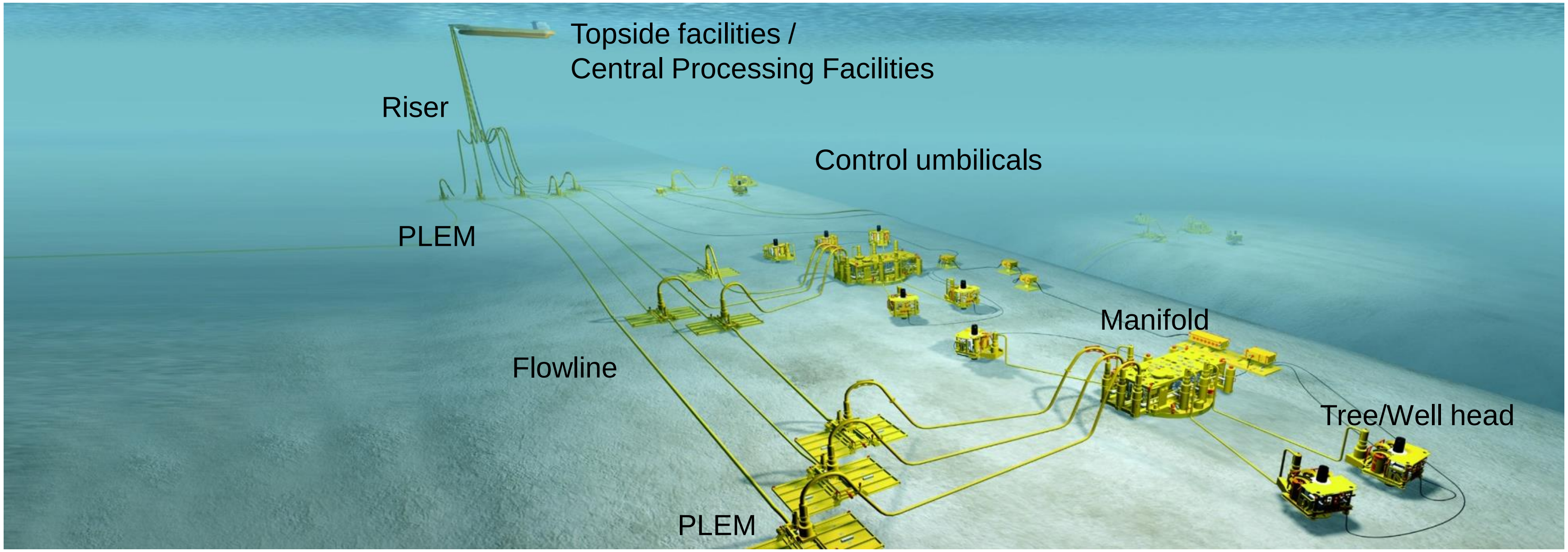


Flow Assurance: Definition

- Ensuring successful and economical flow of hydrocarbon stream from reservoir to the point of processing → Guarantee the flow
- Encompassing many discrete and specialized subjects, bridging across the engineering disciplines
- Involves from pre-FEED to detailed design, and beyond the operation
- Two main topics

  : Network modelling and transient multiphase flow simulation

  : Handling solid deposition including hydrate, wax, asphaltene, etc



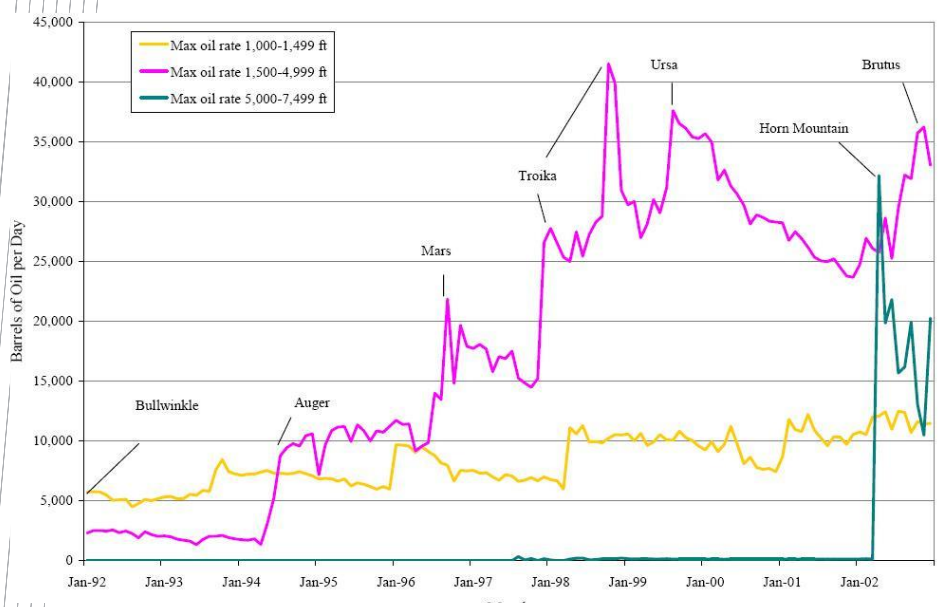
Flow Assurance in Project life cycle

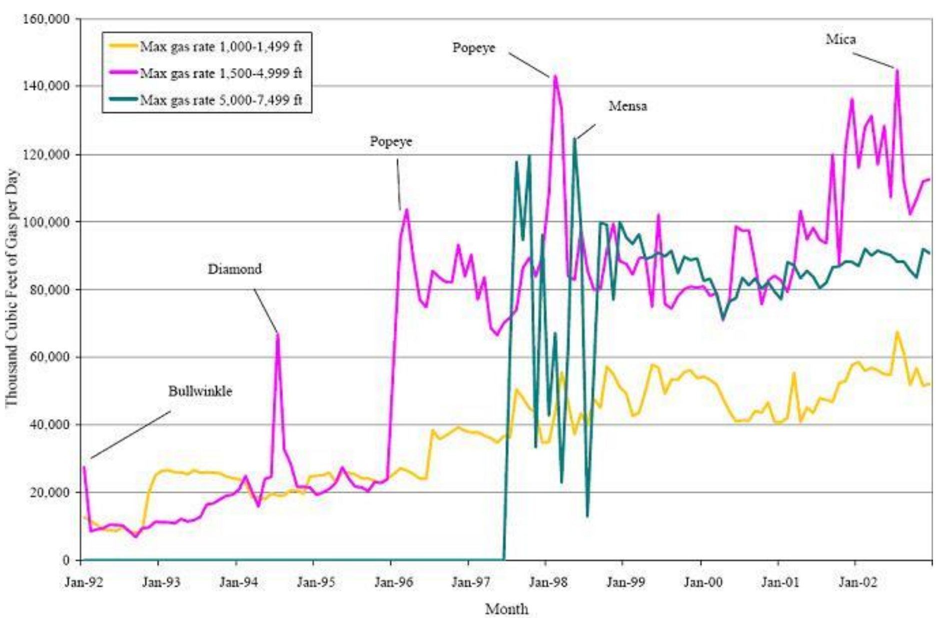
Project Life Cycle

Appraisal	Themo-hydraulic Modelling	System Design	System Operation
Sampling	Pressure Profiles	Design Concept	Operating Philosophy
Fluid Analysis	Temperature Profiles	Pipeline Sizes and Pressure Protection	Start-up and shut-down
Fluid Modelling	Flow Regimes	Insulation and Thermal Management	Pigging and Planned Intervention
	Hydrates, Wax, Asphaltenes and Scale	Chemical Requirements	Un-planned intervention
		Processing Requirements	

Flow Assurance in offshore developments

- FA becomes “important” more than every before
  - Deep waters
  - Longer tiebacks
  - Challenging reservoir characteristics
- FA is making sure a system is correctly sized and specified to achieve deliverability, integrity, and controllability



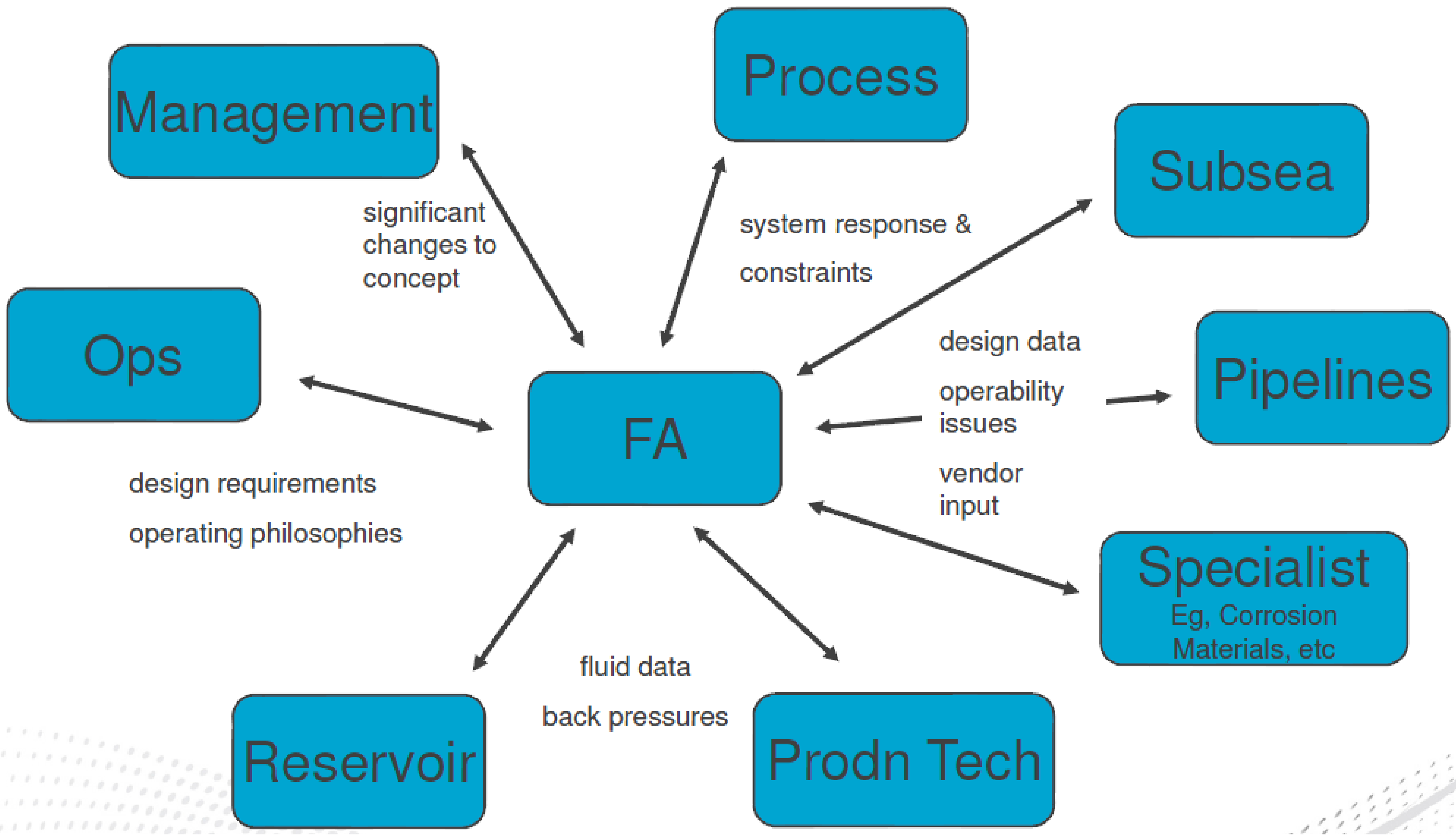


Role of Flow Assurance

- Deliverability – achieving production rate (boosting/lifting/sizing)
- Integrity – never fail (corrosion/erosion)
- Controllability – stable and flexible operation
- Uninterrupted production – prevent hydrates/wax/asphaltene
- Bridge between subsurface (reservoir) and surface (production or downstream)

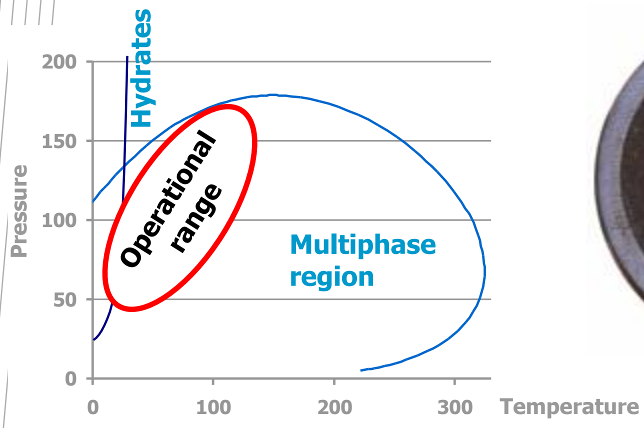
  : FA balances the inputs from reservoir with the demands and constraints from downstream

Flow Assurance and Interactions

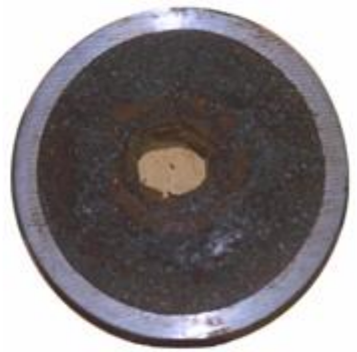


FA: Fluid Related Issues

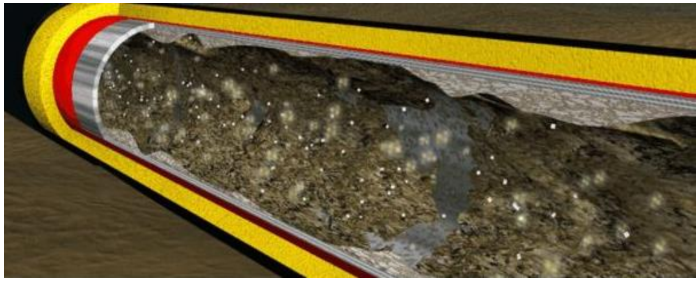
Multiphase composition



Wax / Asphaltenes



Emulsion / Foam



Sand / Erosion

Gas Hydrates

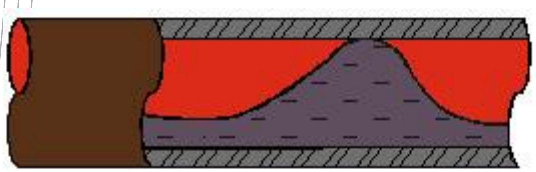
Corrosion

Scale (salts)

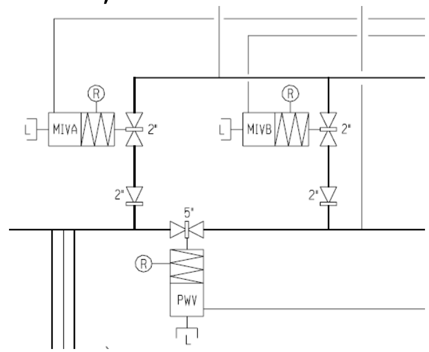
- **May have none, may have several, may have all !!**
- **FA risks from industry: Hydrate >> Wax >> Asphaltene**

FA: Design Related Issues

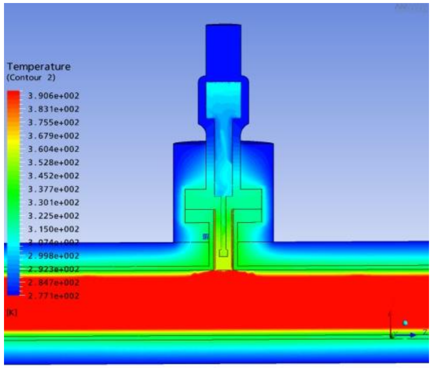
Pipeline sizing
pressure loss vs slugging



Design of Chemical Injection Systems (transfer line sizing)
to minimize risk of hydrates, scale, corrosion etc.



Thermal Insulation Design
to keep fluids warm and minimize risk of hydrates and wax

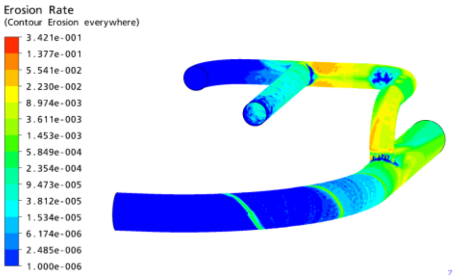


Choke design
to minimize pressure loss and erosion

C-factors, Flare capacity, Surge volume, Cooldown times, Liquid management, Pigging Depressurization, Gas lift system, etc

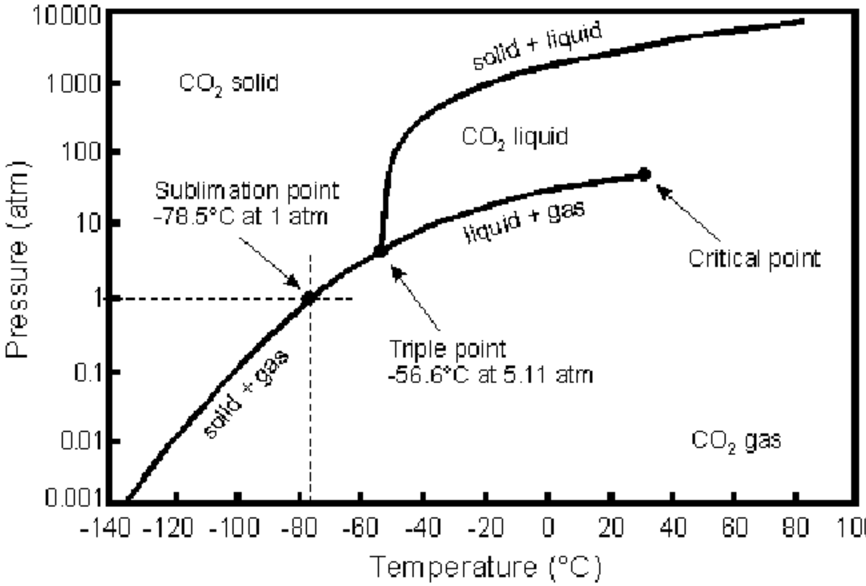
Flow assurance is
to take precautions to
Ensure Deliverability and Operability

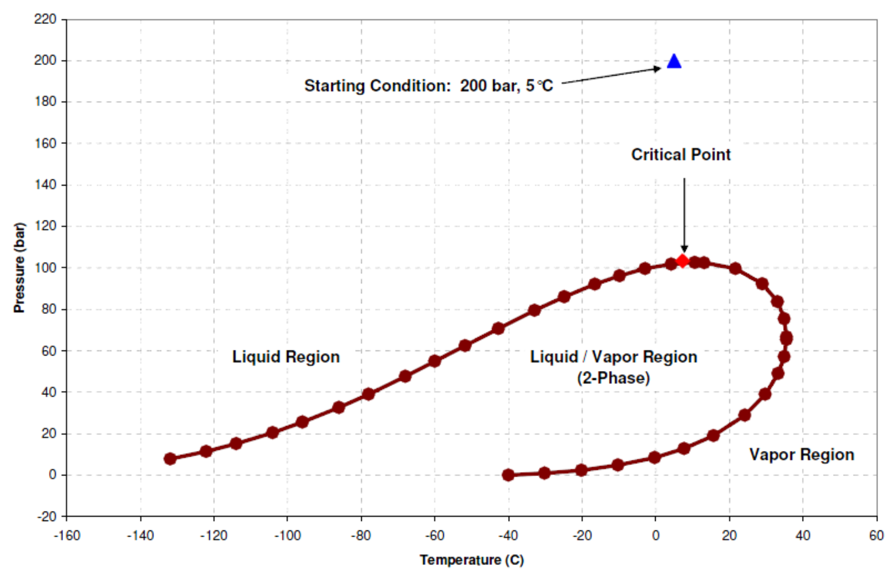
Erosion analysis
Erosion wear in complex geometries



Fluid characterization

- Understanding fluid phase behavior provides a roadmap for all subsequent analysis
- Fluid characterization is predicting accurate fluid properties, which is necessary for the specification of all materials and equipment in system
- If fluid characterization and properties prediction is done poorly, the system may not operate as predicted, or may be under- or over- sized.





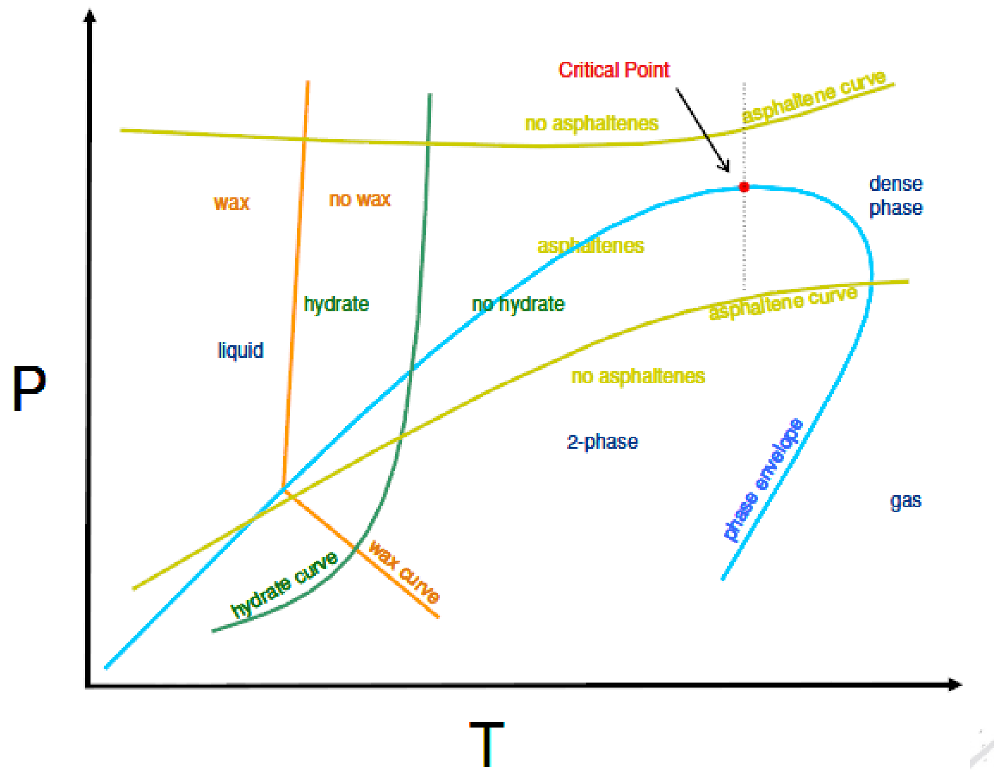
Phase behavior and Operating regions

- A PT operating envelope can be developed from the fluid behavior characteristics
- This envelope provides a good visual indication of operating limits

  : Hydrate will form at P & T to the left of the curve

  : Wax will form at P & T to the left of the curve

  etc



Fluid hydraulics

- Primarily concerned with “pressure drop” in the system
  - Influence size of equipment
  - Recovery from the reservoir
- Key aspect in understanding single phase and multiphase flow
  - Single phase flow is well understood
  - Multiphase flow is becoming better-defined, especially “slug flow”
- Essentially need to balance:
  - Flowrate
  - Required arrival pressure (separation train, gas processing units, etc)
  - Available inlet pressure (reservoir, subsea production system, etc)
  - Flowline inner diameter
  - Surge volume analysis for slug catcher design

Flow regime for horizontal and vertical flow

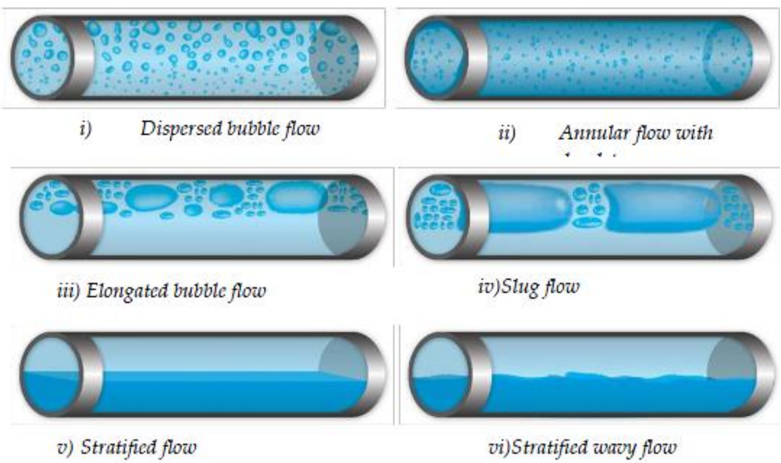
- Flow regime is a key factor in many aspects of FA analysis

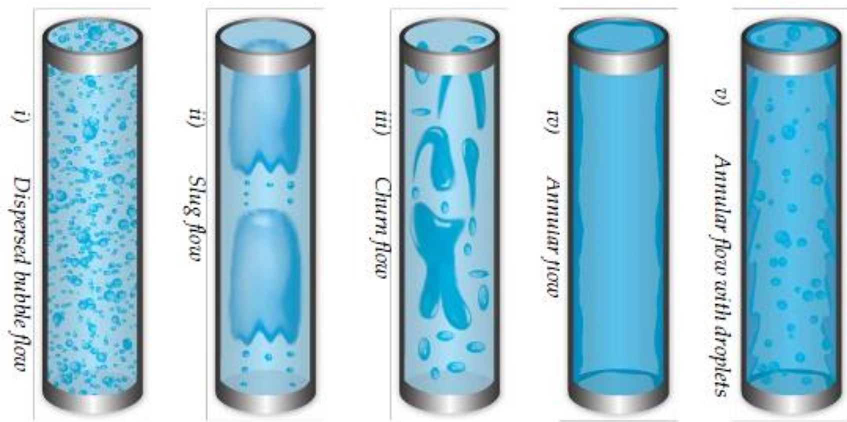
  : Pressure drop, operability, dynamic behavior

  : Heat transfer

  : Chemical distribution

  : Hydrate/wax forming potential

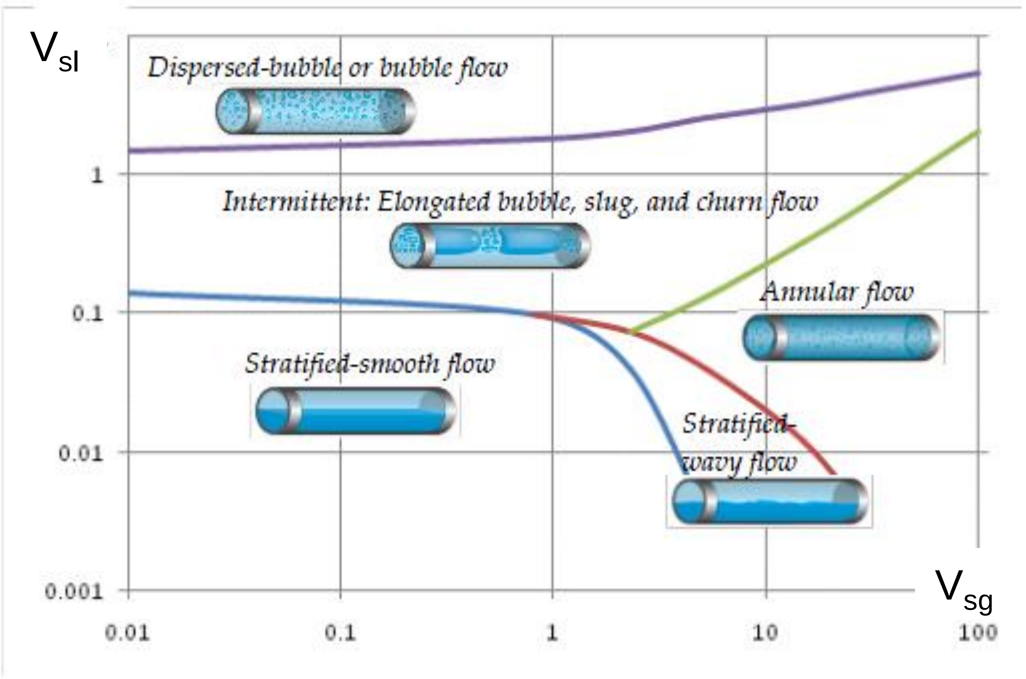




Flow regime map

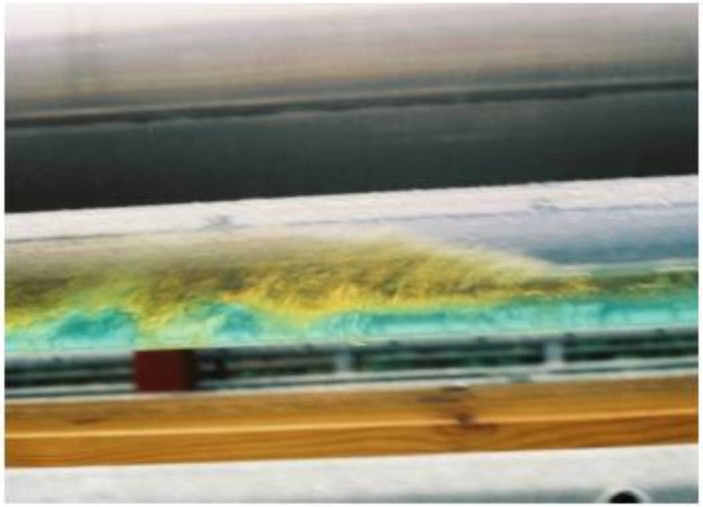
- Depict the transitions between the flow patterns.
- The superficial gas velocity (V_{sg}) is on the X-axis and the superficial liquid velocity (V_{sl}) is on the Y-axis.
- The flow pattern is also dependent on:

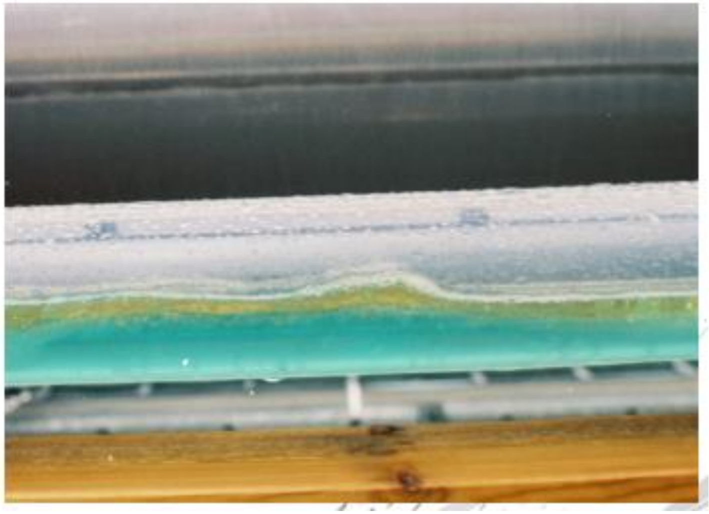
- the angle of inclination,
- pipe diameter,
- fluid composition,
- pressure and temperature.



Liquid holdup

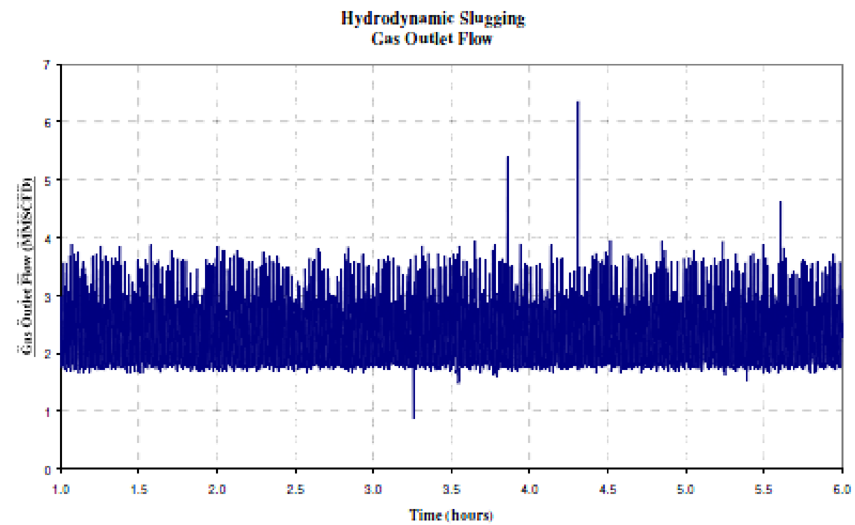
- Liquid holdup is the amount of liquid contained in a multi phase pipeline at particular flow conditions.
- The liquid phase is normally carried though the line by drag forces exerted by the gas phase.
- The holdup at a particular time will be produced as a liquid slug when the line is pigged. These aspects affect slug catcher sizing and peak onshore liquid processing requirements

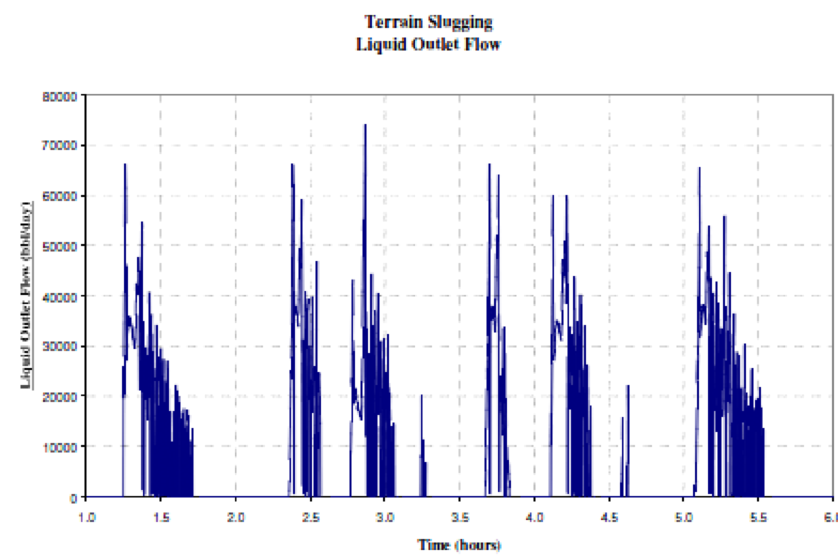




Slugging

- Slugging
  - : Periods of low flow followed by periods of high flow (liquid bomb)
  - : Occurs in multiphase flowlines at low gas velocities
  - : Causes
    - - Low fluid velocity
    - - Seabed bathymetry
    - - Riser type
- Hydrodynamic
  - : High frequency
  - : Minimal facilities impact
- Terrain
  - : High liquid/gas flowrates
  - : Topsides concern
  - : Riser fatigue concern





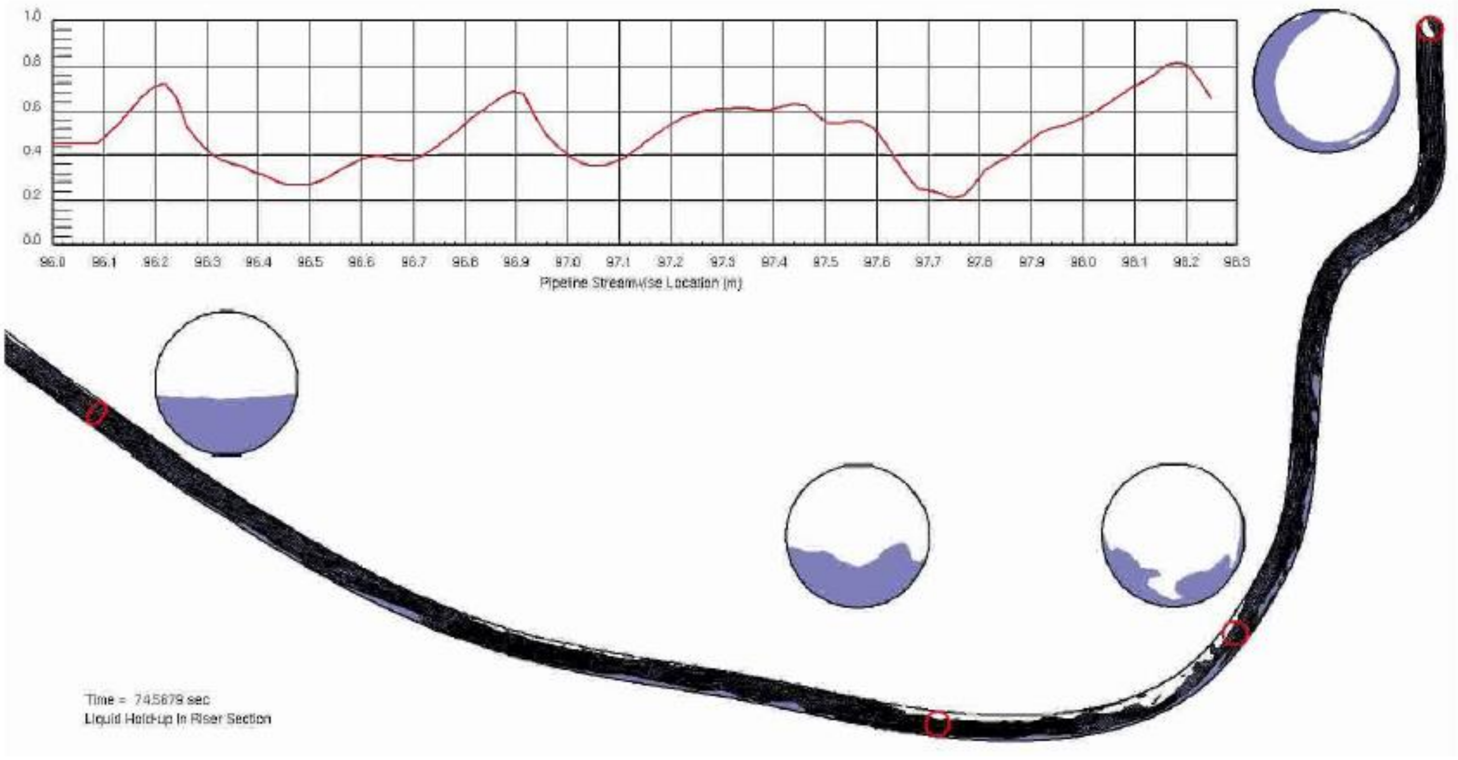
Slug flow simulations

- Lazy-S is a slug generator
- Prevention

  : Incrase gas flowrate

  : control separator pressure

  : Gas lift



Multiphase flow applications

- Hydraulics

  : Line sizing

  : Liquid holdup

  : Slugging / surge volume

  : Erosion velocity – Maximum from C-factor, Minimum from CI

  : Bigger is not better

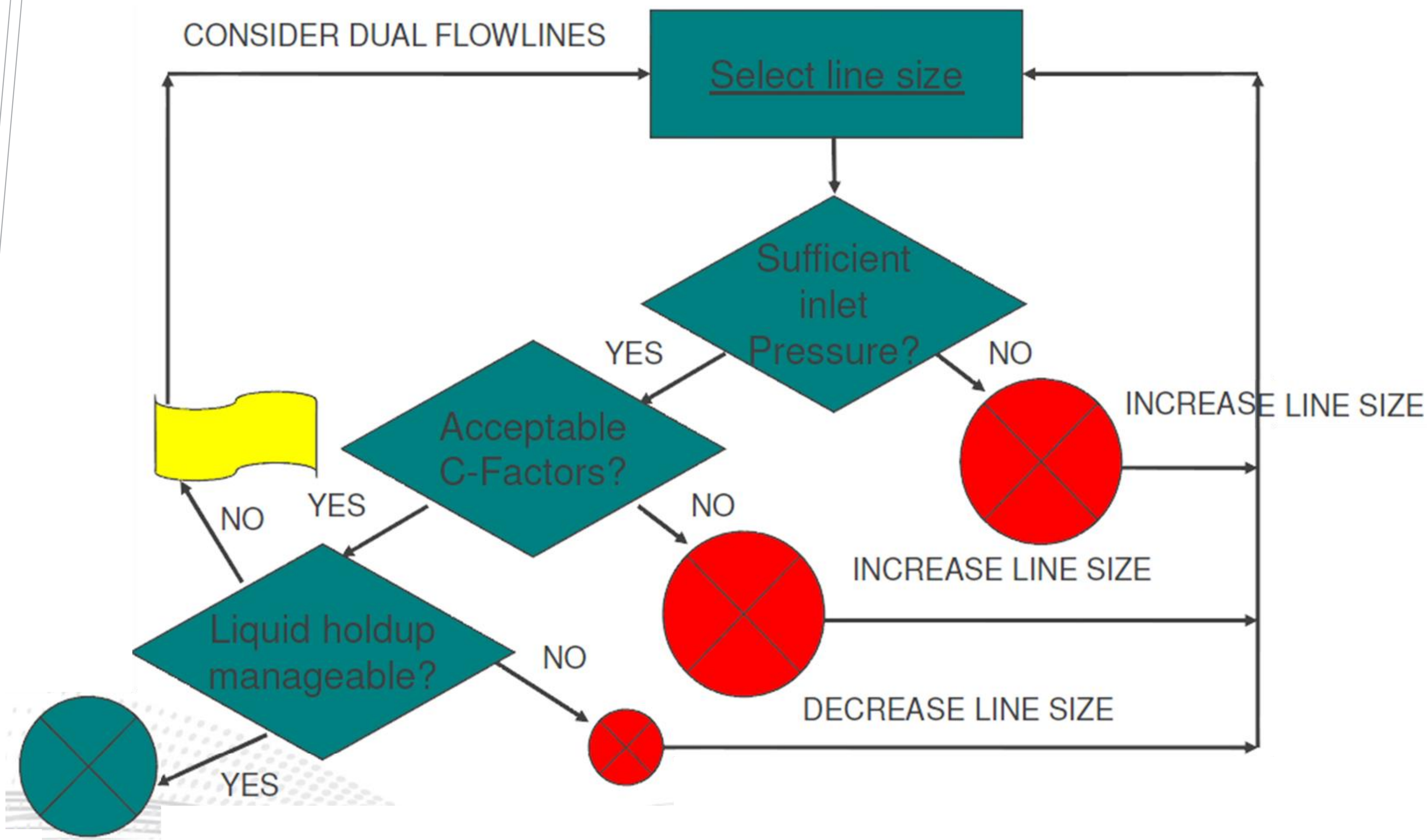
    + Higher throughput

    + Lower erosion velocities

    - Increased slugging tendency

    - Increased liquid holdup in pipeline

Line sizing checklist



Multiphase flow applications

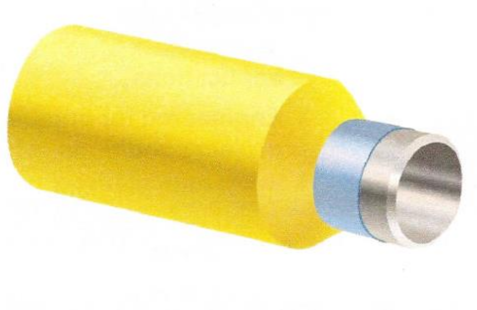
- Thermal design

  : Sometimes try to keep fluids hot

  - avoid hydrate formation
  - avoid wax deposition
  - how to? passive heating, active heating

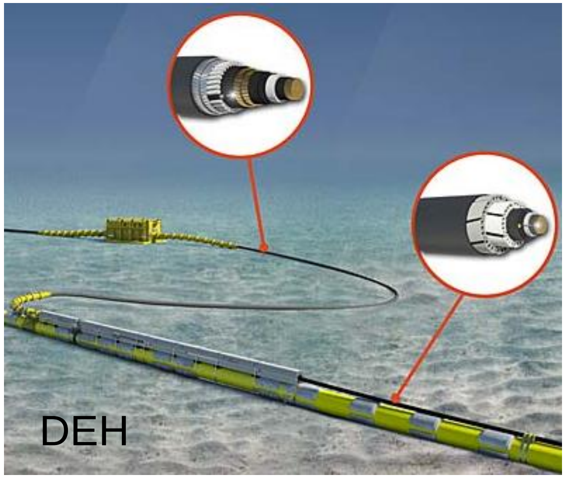
  : Or sometimes try to cool fluids down

  - reduce corrosion
  - manage maximum material temperature limits
  - how to? Subsea heat exchangers, ensure exposed piping



Single layer

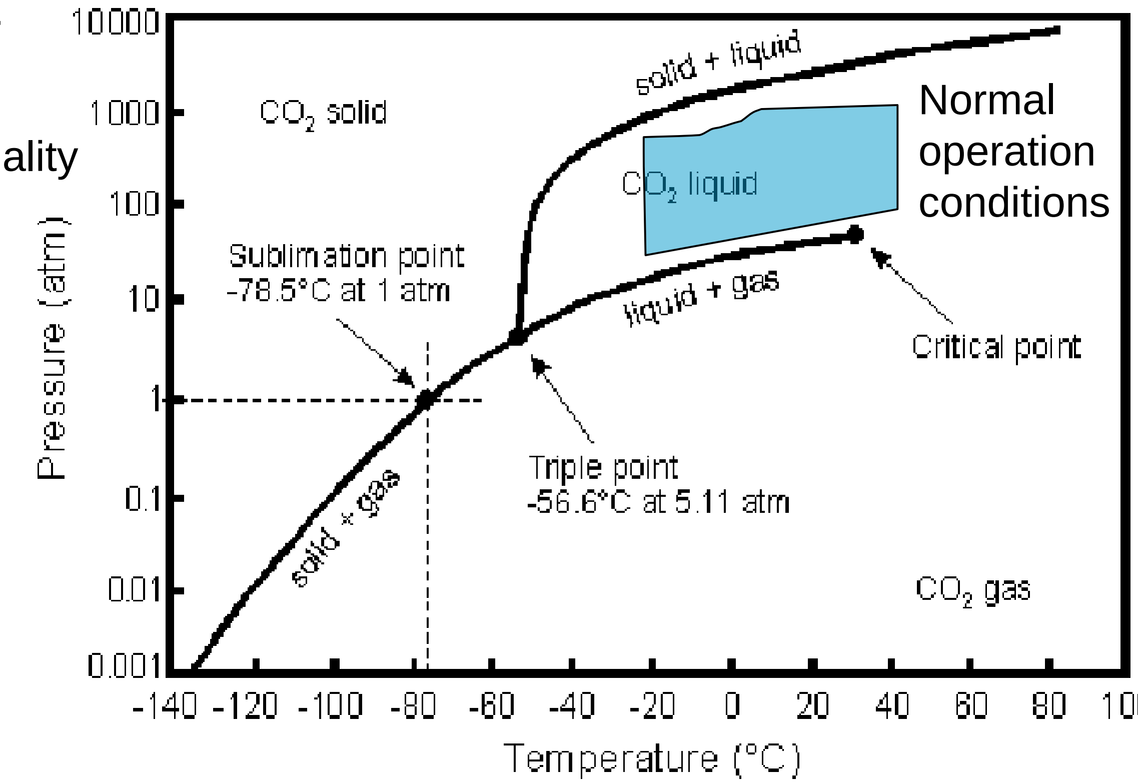
Multi layer



DEH

Role of Flow Assurance in CCS project

- Line sizing – initial inputs for the cost estimation
- Normal operational conditions
- Transient operational conditions
  : Depressurization
  : Initial pressurization
- Any other suggestions for
  : Hydrate management
  : Pigging operations, air quality



FA design for CCS project

- Initial line sizing

  : Trunkline system

  : Platform/subsea manifold

  : Infield system

  : Well tubing requirements
- Normal operation condition

  : Winter/Summer operation
- Transient operation

  : Shutdown and restart – JT cooling

  : Depressurization

  : CO_2 removal pigging

  : Initial pressurization

  : Pressure surge analysis

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Thank you