전 세계 Oil 생산량 및 매장량

- 전 세계 Oil 생산량: 86.7백만 B/D (Offshore 29백만 B/D, 33% 2014) → 49% ('30)
  - 연간 성장률: 1.64%로 향후 성장은 Offshore가 주도할 것으로 보임

전 세계적으로 원유의 Quality 감소: API 감소, TAN의 증가

- 육상 경질유 부족: EOR, 심해, 북극
- 대다수를 차지하고 있는 Medium 및 heavy Oil 개발
With oil prices expected to remain lower for longer, the core challenge remains:

- **how can the FPSO industry**
- increase efficiencies and
- lower costs to drive profitability

in the current low oil price environment?
<table>
<thead>
<tr>
<th>Region</th>
<th>FPSO</th>
<th>FPU</th>
<th>TLP</th>
<th>SPAR</th>
<th>CT</th>
<th>Total</th>
<th>% of Grand Total</th>
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<tbody>
<tr>
<td><strong>Sanctioned/Under Construction</strong></td>
<td>10</td>
<td>3</td>
<td>4</td>
<td>1</td>
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<td><strong>Operating</strong></td>
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<td>42</td>
<td>23</td>
<td>20</td>
<td>5</td>
<td>255</td>
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<tr>
<td><strong>Decommissioned</strong></td>
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<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>6</td>
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<tr>
<td><strong>Total</strong></td>
<td>177</td>
<td>45</td>
<td>30</td>
<td>22</td>
<td>5</td>
<td>279</td>
<td>100</td>
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</table>

**Note:** The table above provides a summary of the number of FPSO, FPU, TLP, SPAR, and CT vessels in various regions, categorized by status (Sanctioned/Under Construction, Operating, Decommissioned) and the percentage of the grand total.
Number of Production Floaters in Service or Available at the Beginning of Each Year

FPS Systems Awarded from 1997-2015
(Excludes MOPUs, FPSOs, and FSO/LNG; Production Barges included in FPSO count)

Legend:
- FPSO
- Semi FPSO
- TLP
- Spar
- Barge
- FSRU
- FLNG

Data: EMA (www.energymarinassociates.com)

Note: FSRU count excludes regas carriers not in terminal service. Source: IMA World Energy Reports - 2016 Forecast issue
해양플랜트 산업의 위기와 대책

위기의 원인:
• 기본 설계 능력 및 고급 엔지니어 인력 부족
  - 플랜트 기본설계 능력 부족, 리스크 관리 능력 부족, EPC 실행 능력 부족
  - 발주처의 복잡하고 까다로운 스펙/규정을 완전히 이해하고 있는 엔지니어의 부족
• 엔지니어링 능력 부족
  - 약 3개월간에 걸쳐 FEED 검증 수행 불가. 해외 ENG사의 의존하지만, FEED 설계 검증에 대한 모든 결과는 국내 EPC 기업이 책임집. 특히, 발주처의 다양한 설계 항목 분석 요청에 대한 대응능력 부족
  - 엔지니어링 역량의 장기적이고 체계적인 투자 활동 미흡 (현대중공업, 2016)
해양플랜트 산업의 위기와 대책

대책:
• 엔지니어링을 Project Management와 연계하기위한 System Engineering 기술 개발 필요
• FEED에서 상세설계까지 이르는 전체 Engineering 과정에서 해양플랜트의 성능 및 안전성에 심각한 영향을 미칠 수 있는 주요 설계 항목에 대한 해석 및 검토 능력 확보
  - 해양플랜트 상부 공정 주요 기자재의 자체 설계 능력 확보 및 국산화

→ Volume 경쟁에서 Value 경쟁으로

(조선협회, 2015)
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<td>DNV-OSS-301</td>
<td>Certification and Verification of Pipelines</td>
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<tr>
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<td>Global Buckling of Submarine Pipelines Structural Design due to HP/HT</td>
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<td>Interference Between Trawl Gear and Pipelines</td>
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<td>Pipe Girth Weld System Qualification and Project Specific Procedure Validation</td>
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<td>Subsea Separator Structural Design</td>
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DNV-RP-O501: Erosive Wear in Piping Systems

DNV-OS-F101: Submarine Pipeline Systems

DNV-RP-F113: Pipeline Subsea Repair

DNV-RP-F106: Factory Applied External Pipeline Coatings for Corrosion Control

DNV-RP-F102: Pipeline Field Joint Coating and Field Repair of Linepipe External Coating

Safety guideline of design, materials and construction
Pipeline Design Flowchart

Preliminary Sizing
- Select Route
- Material Selection
- Flow Assurance Analysis
- Decide Pipe Size
- Choose Construction Method
- Internal Corrosion Assessment
- External Corrosion Protection

Define Load Cases
- Manufacturing
- Storage
- Transportation
- Testing
- Installation

Detailed Mechanical Design
- Strength Analysis
- Select Wall Thickness
- Buckling/Collapse Analysis
- Expansion Analysis
- Spanning Analysis
- Free Span Assessment
- Vibration Analysis
- Fatigue/Fracture Analysis

On-bottom Stability Analysis
- Decide Weight Coating
- Vertical Instability of Surface Soil
- Bathymetric Profile
- Lateral Soil Force
- Hydrodynamic Force
- Stability Analysis

Accidental Events
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
- Sampling
- Fluid Analysis
- Fluid Modelling

Thermo-hydraulic Modelling
- Pressure Profiles
- Temperature Profiles
- Flow Regimes
- Hydrates, Wax, Asphaltene and Scale

System Design
- Design Concept
- Pipeline Sizes and Pressure Protection
- Insulation and Thermal Management
- Chemical Requirements
- Processing Requirements

System Operation
- Operating Philosophy
- Start-up and shut-down
- Pigging and Planned Intervention
- Un-planned intervention
Flow Assurance in offshore developments

- FA becomes “important” more than ever 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

- Management
  - significant changes to concept
- Process
  - system response & constraints
- Subsea
  - design data
  - operability issues
  - vendor input
- Pipelines
  - design data
- Specialist
  - Eg, Corrosion Materials, etc
- Ops
  - design requirements
  - operating philosophies
- Reservoir
  - fluid data
  - back pressures
- Prodn Tech
- 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

**Choke design**
- To minimize pressure loss and erosion

**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

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

**Erosion analysis**
- Erosion wear in complex geometries

**Flow assurance**
- Is to take precautions to ensure deliverability and operability
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.

![Phase behavior and Operating regions diagram]
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
  : Increase 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

CONSIDER DUAL FLOWLINES

Select line size

Sufficient inlet Pressure?

Acceptable C-Factors?

Liquid holdup manageable?

INCREASE LINE SIZE

DECREASE LINE SIZE

INCREASE LINE SIZE
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
  - CO2 removal pigging
  - Initial pressurization
  - Pressure surge analysis
Contact: Yutaek Seo

Email: Yutaek.Seo@snu.ac.kr

Thank you