Slugging in a Subsea Compact Separation System

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ExxonMobil Subsea Compact Separation System

- ExxonMobil Upstream Research Company (URC) designed and is testing a compact separation system for application in 3000m water depth and internal pressures up to 690 bar
- EM qualification philosophy is to qualify for a wide range instead of specific field conditions to reduce timeline of application
- Robust, flexible to inlet fluids, and scalable
  - API Gravity: 19°-38°
  - Oil Rate: 60 kBPD/train
  - Gas Rate: 1250 – 4000 Sm3/day
  - Water Cut: 0-90%
  - Slug Size: 5m3
- Currently being qualified at ProlabNL
  - (3) Crudes with API 19°, 28° & 38°
  - Scaled to 10-15 kBPD
  - Methane Gas at 45 bars
  - Gas Rate: 33-497 Am3/hr
  - Water cuts 10-70%
  - Slug Tests: 0.2 to 0.6m³
Simplified Schematic of ExxonMobil Subsea Compact Separation System being tested at ProLabNL.
Slugging in a Compact Separation System

- Compact Inline Separation devices do not perform well during slugging conditions
  - Very small residence time and buffer volume
  - Normally optimized for one phase
  - Sensitive to change in fluid density (GVF) and flow rates...inlet momentum changes and potential collapse of the swirl
  - Homogenous flow is desired

- This results in lower separation performance with undesirable liquid entrainment and gas carryunder

- Slugging effects can propagate through other downstream equipment

- Slugging effects can be minimized with sophisticated slug dampening control systems in combination with a flow conditioning device

Ref: Hannisdal, et. al. 2012 OTC 23223
Slugging in a Compact Separation System

➤ Subsea Compact Three Phase Separation System Studied the effects of hydrodynamic slugs

➤ Studied different size slugs and frequency to determine:
  ➤ Effectiveness of ExxonMobil’s Subsea Slug Catcher in buffering slugs
    ➤ Through CFDs, air/water tests, model fluid, high pressure tests
      studied a number of proprietary designs. Final design more effective for liquid dominated services
    ➤ Minimize liquid carryover to the ASCOM Monoline on the gas outlet
    ➤ Reduce dramatic liquid rate fluctuations downstream
    ➤ Measure the liquid outlet GVF to downstream equipment
    ➤ Liquid level control & hold-up

➤ ASCOM Monoline
  ➤ Liquid Carryover
  ➤ Measure gas carryunder from boot
  ➤ Liquid level control
Slugging in a Compact Separation System

- Studied different size slugs and frequency to determine:
  - ExxonMobil’s Pipe Separator
    - The effect on oil-water separation
    - Change on interface height and control.
    - Effect on emulsion stability due to increased GVF and rate changes
    - Measure oil outlet GVF
    - Measure OIW & WIO
    - Liquid level control & hold-up
  
- Dynamic simulation based on a potential field case
  - Optimized control systems
  - IP around novel control system

- Never the intention to validate dynamic model based on flow loop data
  - Due to pressure balance around a close loop system
  - No oil/water pumps on discharge
  - Preferred control system could not be implemented
Slugging in a Compact Separation System

 Slug Generator
- Allowed for controlled slug size feeding the system of various sizes: 0.1 to 0.6m³
- Number and frequency could be controlled
- Split flow possible with steady state flow and liquid slug volume

 ExxonMobil’s Subsea Slug Catcher
- Main function to separate the gas and liquid phases
- Temporary storage of liquids to buffer downstream equipment and maintain steady state conditions
- It did not consider the increase in flow rate tolerance of the downstream equipment as this was a test loop
- Limitations of a closed flow loop
Slugging in a Compact Separation System

Results – Slug Catcher Medium Crude

API 28° 50°C 20%WC – 0.4m³ Slug Auto Control

- Slug catcher caught the slug effectively.
- However, control valve released the slug too quickly
- Manual control of water outlet valve did not help

API 28° 50°C 20%WC – 0.4m³ Slug Manual Control

Ref: run 221M50SLm

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Results – Monoline Medium Crude

- Liquid carryover rate to the Monoline during slug trials were <2-3%LVF
- Decreased gas flow rate into Monoline due to liquid slug
- GVF in liquid leaving slug catcher remained fairly constant ~1%

Results – Slug Catcher Medium Crude

- GVF increases due to carry from additional turbulence

Courtesy of Ascom Advanced Separation Company

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Results – Pipe Separator Medium Crude

API 28° 50°C 20%WC – 0.4m³ Slug Manual Control

- Interface level increased as the slug was released
- Interface level remains fairly constant with some effect on oil-water separation quality. WIO suddenly increased
- Note there’s a process delay and a smoothing function with the TRACERCO Profiler™

Ref: run 221M50SLa

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Results – Slug Catcher Heavy Crude

API 19 70°C 20%WC – 0.4m³ Slug Manual Control

- With this crude slate modified parameters on oil outlet control valve
- Slug Catcher now holding and buffering flow better
- Interface level in pipe separator remains constant
- Temporary change in oil-water separation

Results – Pipe Separator Heavy Crude

Ref: run 221H70 DMSL

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Results – Slug Catcher Light Crude; Multiple slugs

API 38 50°C 70%WC – 0.6m³ Triple Slugs

- Very large slugs of 0.6m³
- Lighter crudes lower overall separation efficiency due to higher GOR
- Separation efficiency about 98%
- Liquid carried over to monoline

Ref: run 710aL50SL

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Results – Monoline; Multiple Slugs

- Monoline effectively captures the liquid carryover with an efficiency of 99.97% for this run
- Due to sudden increase in liquid, boot did not have sufficient time to degas. This gas carryunder had insignificant effect on the pipe separator due to overall small liquid volume.
Slugging in a Compact Separation System

Results – Pipe Separator Light Crude; Multiple slugs

API 38° 50°C 70%WC – 0.6m³ Triple Slugs

Density Tracerco vs Time

Time (hh:mm)

Density (kg/m³)

Slug Released

Note: Interface level higher at 70% WC than at 20%

• Very little effect downstream into the pipe separator on interface control
• WIO temporary increased

Ref: run 710aL50SL

All data generated by or on behalf of ExxonMobil
Slugging in a Compact Separation System

Concluding Remarks

- Slugging effects in a compact separation system can be dampened and controlled with a properly designed flow conditioning system.
- Attention to control system is a MUST!!
- Pressure drop around each piece of equipment needs to be considered to balance flows during upset conditions.
- Recycling streams to diminish slugging effects or increase turndown capabilities not necessary.
- Clean 3-phase separation that meets target performance was achieved.
- Compact separation system much more complex than traditional gravity separation vessel.
- Validation of dynamic simulation not possible in a closed test flow loop.
- High pressure testing provided valuable dynamic and separation performance data to be incorporated into the dynamic simulation.
- Fast acting control valves are not required.
- Compact separation systems are less forgiving to reservoir model prediction errors.
Thank You! Questions?

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BACK-UP SLIDES
ProlabNL Simplified Flow Loop Schematic

ExxonMobil URC Subsea Compact Separation System Test Unit