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Welcome!

The program will begin soon.

You will not hear audio until we begin.

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Pseudo Dry Gas – Technology Road Map

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27 October 2022

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ENHANCED SUBSEA GAS TIEBACKS

Net Zero Technology Centre
Technology Driving Transition

Intecsea
Worley Group

Worley
energy | chemicals | resources

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Introduction

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- This presentation is an overview of the technology development of a long distance / decarbonisation gas tieback technology – 'Pseudo Dry Gas'.

- Covered by JPT April 2022 and June 2018

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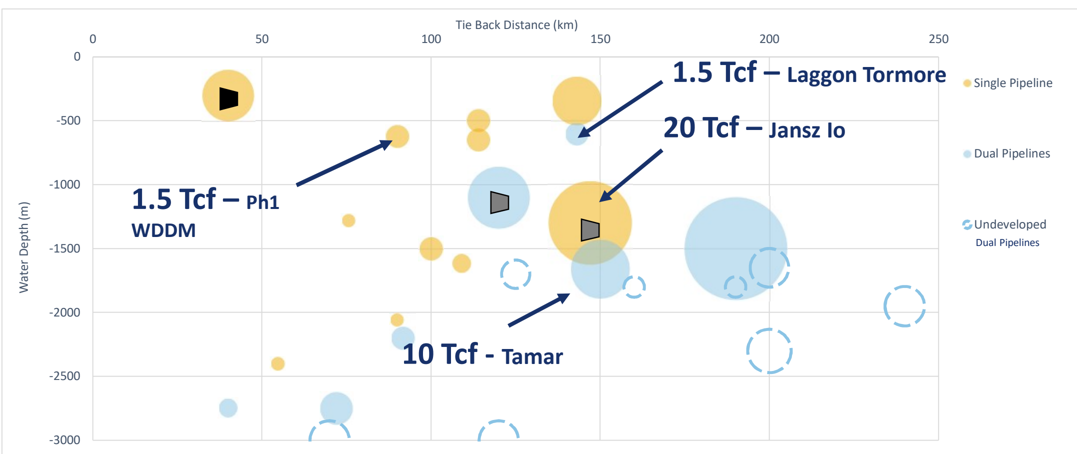
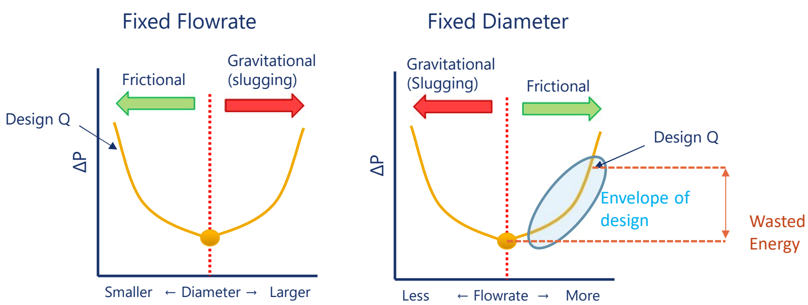
Industry Status Overview



Gas Line Sizing Criteria



Need operational envelope – hence need to turn down (typically 25% - 30%)

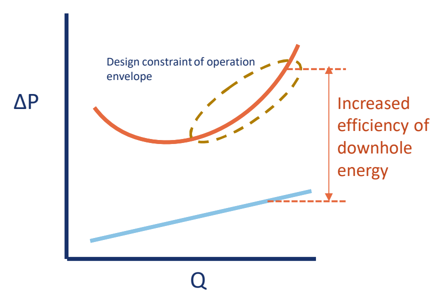
Long deep water gas tiebacks often need dual pipelines to enable the operability that is required without 'excessive' energy wasted

- Common belief that insufficient pressure (energy) at the wells is hindering viability of 'stranded gas' fields....however...
- ...typically, the underlying problem is the liquid generated by the gas during transportation which forces the design to be highly energy inefficient / wasteful of existing downhole energy.

Pseudo Dry Gas (PDG) Overview

Subsea Tieback Challenge
- Trend for gas condensate developments is longer distance in deeper water while using existing infrastructure
- Increasing backpressure due to gravitational and frictional losses
- Reduced recovery OR increased development costs

Pseudo Dry Gas Design Concept
- Single / Multiple piggable separators
- Removes liquids from wells and due to condensation during transportation
- Changes shape of tieback **'resistance curve'** for *quadratic* to *linear* function
- Changing shape of 'resistance curve' due to removal of multiphase flow constraints



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Generic Pseudo Dry Gas Configuration

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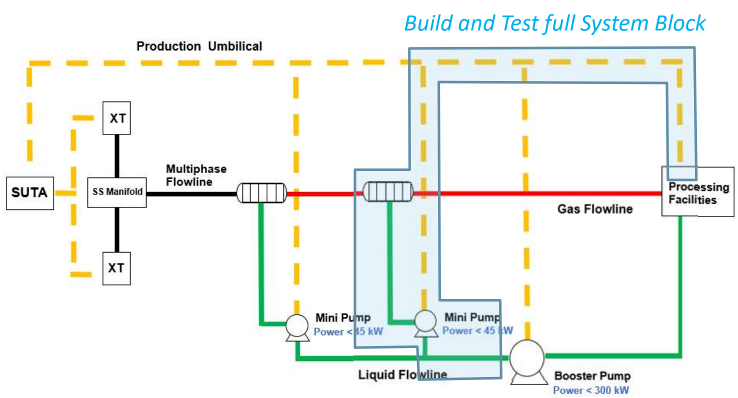

Single/Multiple PDG units can be installed, the number and location is based on life-of-field flow assurance analysis.

Liquids are removed via small diameter pipe and small single phase centrifugal pumps (kW).

Solids management is designed by hydrocyclone heads in separator units, pumps capable of handling solids.

Bulk MEG for hydrate control injected at drill centre. Low dose MEG at each PDG unit via umbilical.

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Concept Patented

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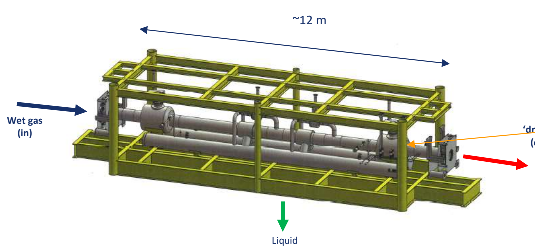
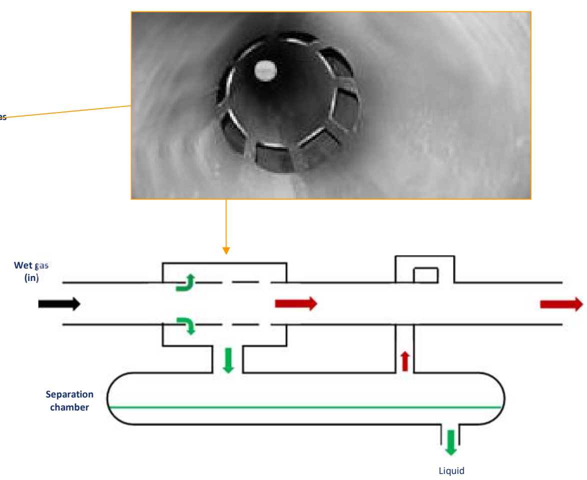
Pseudo Dry Gas Liquid Removal Unit





- Compact - installed at manifold or as a pipeline in-line structure
- Passive - no moving parts in the gas stream
- Piggable

Design Patented

Benefits

PDG has the potential to:

- Remove the need for a manned offshore facility **(tiebacks to >350km)**
- Mitigate the requirement for future compression
- Reduce the carbon intensity per unit hydrocarbon produced **(Upwards of 90%)**
- Mitigate Production Risks –
  - Greater degree of liquid uncertainty can be accommodated
  - Lower back out pressure – greater phasing of wells without loss of reserves
  - Greater tolerance to corrosion risks
- Mitigate condensate wax issues without stopping production
- Reduce backpressure on the reservoir and improve recovery **(>150 bar – Global effect)**
- Reduce MEG requirement due to lower operating pressure **(10-70%)**
- Significantly reduce the development CAPEX
- **Remove** the need for **Slug catchers** and high drainage rates **- often topside constraint**

The Road to Date

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Initiation – 2017
Pseudo Dry Gas incepted as an idea.
Fist funding for engineering definition and CFD studies.

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2018 – Engineering Definition
TRL 5-7: all related hardware & power system.
TRL2 : Liquid Removal.
NZTC joint study on known stranded gas fields, where several operators and tier 1 contractors joined .

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2019/2020 – Prototype (Flow Loop)
First prototype tests completed.
Liquid removal changed to TRL4

4

2021 – Q2 2023 – High Pressure Pilot
Install fully functional pre-production unit with supporting systems **Full system to TRL 5 – DNV Certificate**
Supported by Scottish Enterprise / Innovation Norway / Australian Research Council Grants due to upstream decarbonization potential – joint paper with OGA/NZTC – OTC-30941-MS

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Basis of Development

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- After review of market place and technology in development – all current subsea products had a **'red flag'** identified for deep water gas fields
  - Had to find low cost alternative
- Basis of PDG Unit design comes from onshore 'drip' systems – used for over 20 years onshore
- Sized 4" to 48" Industry
- Over 100 installed globally
- Used on high pressure pipelines to collect condensate / water drop out
- Designed to ASME B31.3 or ASME B31.8

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Development Cycle - TRL2 to TRL4 (API)

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Macro Flow Assurance Models

- Parametric studies to determine performance criteria

CFD Studies – input data from Macro models

- High pressure – Gas and Oil
- Strathclyde University and In house
- Generated design for prototype testing

Experimental Prototype

- 6" Scaled model of design build
- Tested to same conditions as macro FA studies on large flow loop - Cranfield Univerity
- Low pressure – Water and Air
- *With control system and pump*

CFD Studies

- Modelled experiment in CFD to create validated model
- Changed data points to high pressure – 'Scale up'

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Test Unit Modular Design

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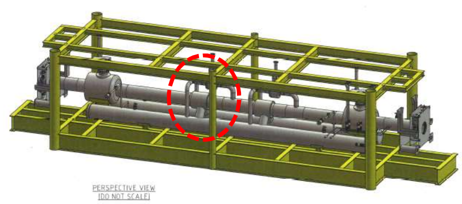
‘Base Case’ Design Configuration



Manifold structure version

The basic design has been broken down into a ‘meccano’ type package to allow physical testing of multiple parameters and internal designs. To prove the separation efficiency over a range of gas typical flow conditions.

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PDG Test Configurations

Matrix 1 Tests will analyse PDG performance for:
- Installation tolerance – pitch and roll
- Drop out vessel liquid level
- Drop out vessel size
- Gas return line size and length
- PDG internals – size, shape and can size
- Inlet spool configuration
- Sand deposition behaviour

Once completed had hold moment before testing two in series (Matrix 2)
- Transient effects – **Important for Operations**
- Collection of more data points

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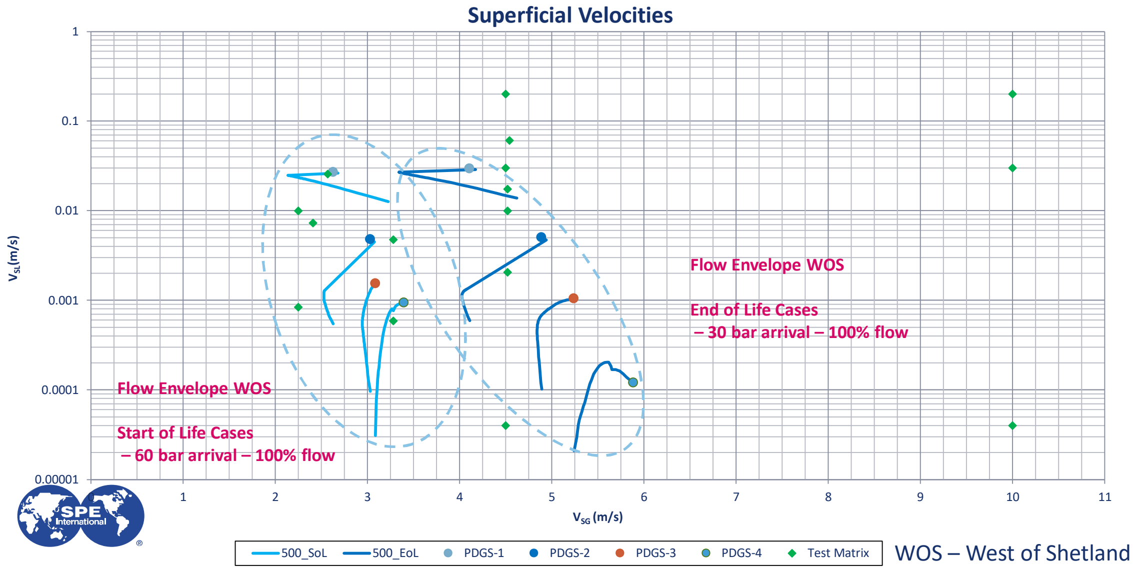
Test Points Vs WOS study



WOS – West of Shetland

Process Lab Overview

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Crane for testing slopes

PDG Test Unit

6” Pipe (45*d upstream)
Translucent

Sand Hopper and
injection

4” Pipe return flow

2” hose water return via
pump

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Process Lab Overview

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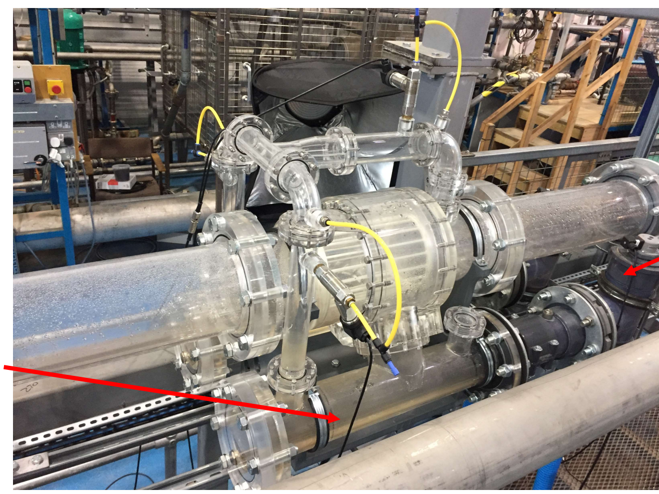

Representative liquid level control system with pump designed / installed

Liquid level controlled at set levels

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Process Lab Overview

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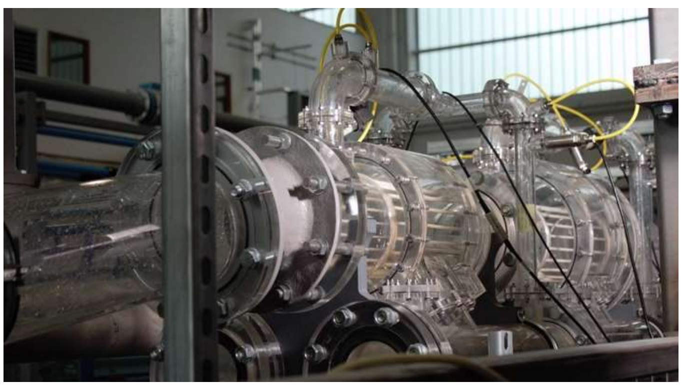

Full structure (2 units) tested in Matrix 2

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Flow Assurance Scaling Study

A flow assurance analysis was conducted in regards to the scalability of the prototype testing. The following criteria were reviewed and documented:

Scaling principles should consider at least these four dimensionless parameters:

1. Inclination angle ✓
2. Density Ratio ✗
3. Froude Number ✓
4. Liquid-to-gas superficial velocity ratio ✓

Based on this a further CFD was conducted, firstly to create a validated CFD model against actual results, then simulate at a higher pressure to align the density ratio.

Farokhpoor, R., Liu, L., Langsholt, M., Hald, K., Amundsen, J., Lawrence, C., 2019.
Dimensional analysis and scaling in two-phase gas-liquid stratified pipe flow-Methodology evaluation

Flow Assurance Scaling CFD Study

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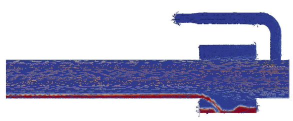
Additional studies were conducted to create validated CFD models of the experiment (within 1% accuracy) for *extreme operational PDG cases*. The input conditions were then updated to align pressure ratios – via Pipesim simulation of the flowloop.

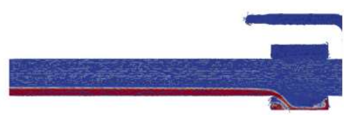
Case X



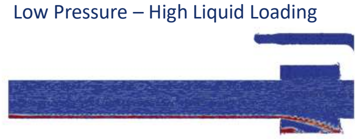
Low Pressure – High Gas Velocity

High Pressure – High Gas Velocity

Case Y



Low Pressure – High Liquid Loading



High Pressure – High Liquid Loading

Results from CFD were above performance required

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Development Programme (ESGT) to TRL5+

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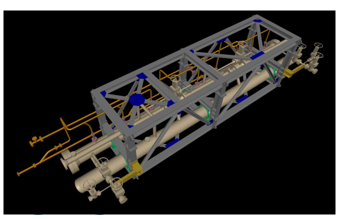
- *Funding from UK /Norwegian /Australian Decarbonisation Grants plus Worley with JIP Partners*
- **Scope** - Build 6” High pressure prototype (180 bar/2610psi) (10*2*3m) with subsea pump (mag drive), sand internals and ‘rented’ subsea control system – test at NEL (Glasgow) 130bar/1890psi nitrogen an hydrocarbon fluids flow loop.
  - Performance of unit on flow loop linked to non dimensional pipe flow parameters
  - University Western Australia (Perth) involved in third party FA verification and development of OLGA app
  - Supporting JIP via ‘Net Zero Technology Centre’ – BHP/Woodside, Petronas & CHC
  - **TRL 5 ‘system’ (API) & TRL 8 (EU/NASA) – Q1 2023**

Scaled for 24” testing to 1.5 Bcf/d



PDMS model of PDG Unit – currently being fabricated

Full scale subsea jumper with WGFM being tested at NEL

Magdrive Subsea Pump (Fsubsea)

Package Overview

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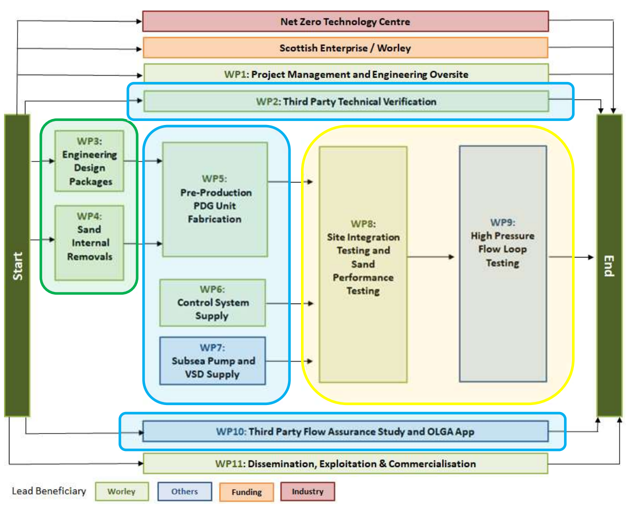

All contracts / POs placed.
WP3 / WP4 completed
WP5 / WP6 / WP7 /WP10 in execution
WP2 - Completed detail technology review with 3 operators over a week
WP8 / WP9 contracts placed and being planned

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Progress Overview

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Subsea pump casing being machined

Hydro cyclone solid removal system delivered

Bearing and Shaft

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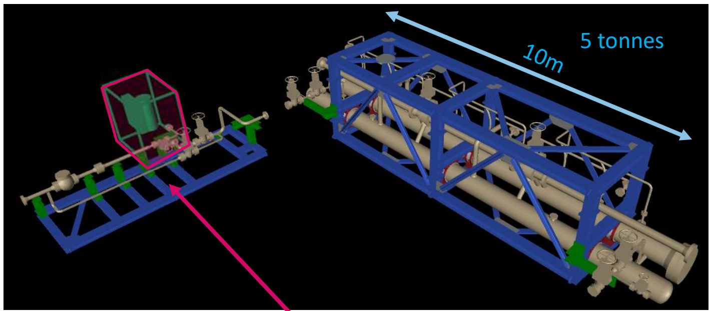
Progress Overview



Detail design of PDG Unit and pipe skid fully completed

Subsea Magnetic Drive Pump in pump curve validation test. (Norway)

Subsea Control Module (SCM) and SCM Test Stand after Factory Acceptance Testing. (England)

Flow Loop Set Up - Base Line

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Undertaking a range of test point as base line measurements to compare against at 0 and 2 degree inclination

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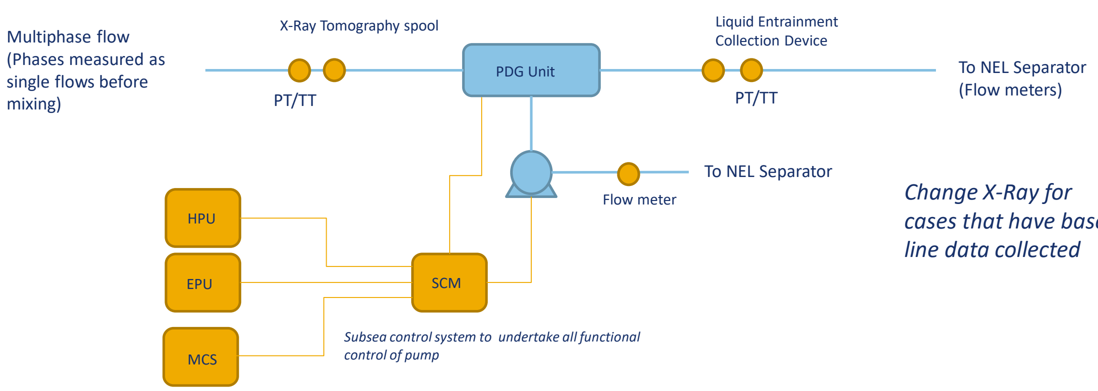
Flow Loop Set Up - PDG



Change X-Ray for cases that have base line data collected

Undertaking a range of test point with PDG unit at 0 and 2 degree inclination

Flow Loop Equipment – X Ray

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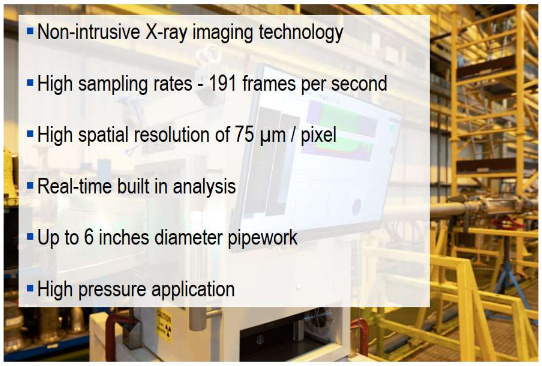
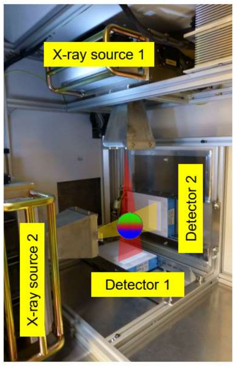
X-ray 2D 3 phase system





Completed extensive calibration work – can measure liquid hold down to 0.8%.

Can detect 'Tanzania' effect.

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Flow Loop Test Matrix

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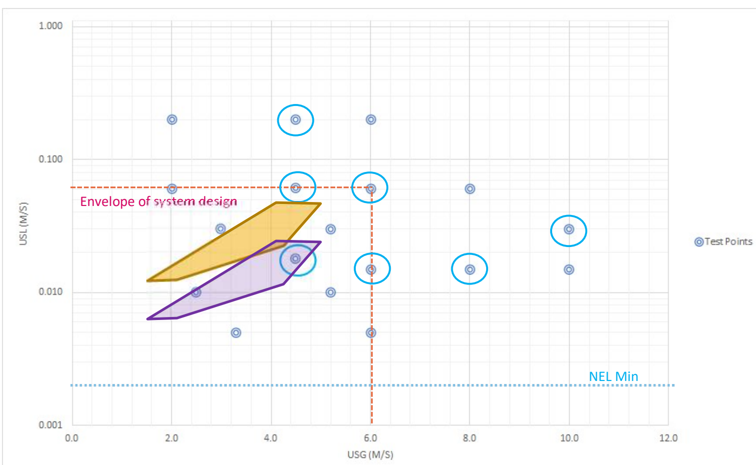
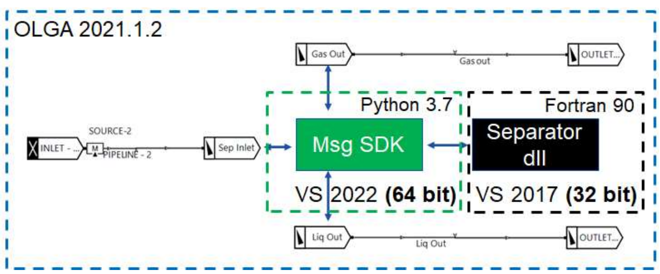


Expected operational envelopes from 'macro' FA work of a single unit. Defined by 100%, 50%, 25% flow, high and low arrival pressures. 'High' and 'low' liquid cases.

- Hydrocarbon liquid selected for very low surface tension and densities aligned to case studies.
- Blue Circle baseline test points
  - 100% water
  - 100% hydrocarbon
  - Mixed to inversion point
  - 65, 90 and 130 bar
  - Inclination 0 and 2 degrees
- All other test points with PDG Unit
  - 100% water
  - 100% hydrocarbon
  - Mixed to inversion point
  - 65, 90 and 130 bar
  - Inclination 0 and 2 degrees

Results Implementation

- Currently able to model full systems in OLGA with 'Work Arounds'.
- Results from high pressure Integrated testing will be implemented into an OLGA extension in order dynamic simulations can be undertaken to industry standards.
- Working with University of Western Australia in development of Extension.



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Summary / Questions

- PDG technology will be at TRL5 (API) / TRL8 (NASA/EU) by Q1 2023.
- Dynamic modelling is important to understanding systems.
- Concept reduces scope 1 and 2 CO_2 emissions by 60% to >70% (Reference OTC-30941-MS) through energy efficient flow against 'energy add' solutions.

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