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Roadmap for First Deployment – Pseudo Dry Gas

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Abstract

The development of the Pseudo Dry Gas (PDG) Concept has now been approved and funded for high pressure full system testing (TRL5 - API) within the first phase, with a second phase where the same equipment is to be deployed on its first hydrocarbon system (TRL6 - API). The project has been provided significant grant funding from British, Norwegian and Australian Governments due to the step change in reducing CO2 emissions from upstream gas gathering systems in relation to 'energy add' concepts, with reductions upwards of 70%-90% Ref 1 - OTC-30941-MS. Furthermore, this broad governmental support is further reinforced by a consortium of three Operators working within the Net Zero Technology Centre framework towards first deployment.

The extended abstract will give a high level overview of the development done to date and on the first stage of the roadmap covering the first 18 months to high pressure hydrocarbon testing

Keywords

Flow Assurance; Gas Tiebacks ; Emission Reductions

Introduction

Pseudo Dry Gas (PDG) technology is based on the concept of changing the resistance curve in subsea gas tiebacks. The quadratic behavior seen with standard multiphase flow subsea tiebacks is changed to a linear behavior with the additional benefit of lowering back pressure with PDG, see figure 1. The changing of the resistance curve enables significantly more efficient use of existing downhole energy. This efficient flow is created by the means of removing the liquid at multiple points along a pipeline and inducing dry gas hydraulic behavior.

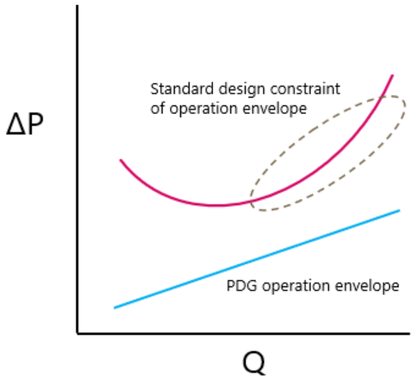


Figure 1 – Subsea Gas Tieback Resistance Curves

The extended abstract will focus on a summary of the development done to date and the first stage of funded work covering the first 18 months of high pressure hydrocarbon testing. The paper will also cover a review of the scientific basis of the testing envelopes, linked to field studies and CFD work, through the evaluation of the design and the low pressure prototype testing and how these and other factors relate to the higher pressure concept design.

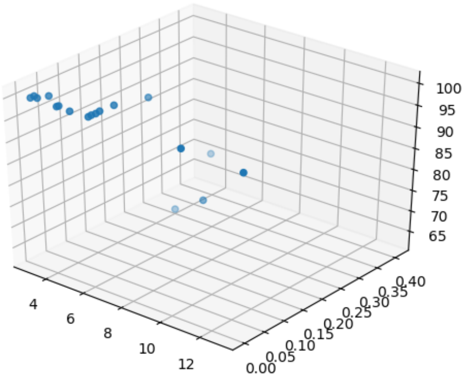
The goal of this extended abstract is to demonstrate the scientific basis to increase industry understanding of this decarbonization technology and demonstrate the roadmap of the pre-production qualification work.

Methodology

Prior to the start of the first experimental phase, a period of study and prototype development to design the prototype was undertaken with Strathclyde University over a twelve month period. The input data for the CFD models was linked to the macro flow assurance models from previous technical-economic field development studies (Ref 2 -Energies-12-02116). Several iterations of design were needed before a configuration was identified that produced a performance envelope greater than the previously identified minimum performance.

During the first experimental phase, a 7 bar PDG Liquid Removal prototype unit was built in acrylic material, see figure 2. The unit was designed as a construction set with parts that were interchangeable and enabled for different configurations to be created. That allowed testing over a range of cases and ultimately the identification of the optimal configuration. The unit was tested over two test matrices over a six month period at Cranfield University, with the efficiency results being directly linked to superficial gas and liquid velocities (flow maps), hence creating a performance surface of the separation efficiency, (x axis – Gas superficial velocity, y axis
- bulk liquid separation efficiency– and z axis Liquid superficial velocity), see figure 3.

Figure 2 – Flow Loop with Prototype Installed



y axis – Bulk liquid separation efficiency
x axis – Gas superficial velocity
z axis – Separation performance surface

Figure 3 – Separation Performance Surface

Post flowloop testing at pressure up to 7 bar, a scaling study was undertaken, based on the Institute of Energy Technologies (IFE) (Ref 3 - 2019-167 BHR). The IFE paper lists the following dimensionless parameters to consider when scaling experiments to operational oil and gas environments:

1) Inclination Angle θ: It is an important parameter with respect to geometrical similitude.
2) Density Ratio
3) Froude Number: It is the most important parameter to preserve dynamic similarity in hydraulic modelling of multiphase flow influenced by gravity. In the IFE paper it is used to determine target value Gas Superficial Velocity.
4) Liquid-to-gas Superficial Velocity Ratio: is used to obtain kinematic similarity. It is used in combination with the Froude Number to obtain the target value liquid superficial velocity (U_{SL}).

For all parameters apart from density ratio, good alignment was seen from the flowloop testing. In regard to the density ratio there was a difference of 25 to 150 times between the density ratios in the original FA data and the lab tests, this was due to the fact that the experiments were performed at near atmospheric pressure. To close this gap between the flowloop and operational data a CFD study was undertaken. This focused on repeating the lab tests in the CFD model using the same operating conditions (i.e. near atmospheric pressure and temperature) and benchmarking the performance of the PDG liquid removal unit in terms of efficiency. This was followed by increasing the pressure in the CFD study to obtain the right density ratios and comparing the efficiency of the liquid removal unit to the efficiencies obtained in the lab tests. (Ref 4 – SPE-200917)

The results from this CFD showed that the separation efficiency did degrade at higher gas and liquid velocities but was still above the minimum threshold required that had been established within the macro flow assurance studies of field developments.

The current stage of the project which is being executed is the construction of a 180bar high pressure pilot pre-production system. The main header is 6” with 18” drop out drums with the total manifold weighing in at 5 tonnes. Dimensions of 10m*2.5m*2.7m.

This will be tested at up to 130 bar on a flowloop with nitrogen, hydrocarbon fluids, water including tests at the inversion point of water and the hydrocarbon fluid. The test points will encompass the expected operating envelope of a PDG system, with a sufficient margin for any late life brown field applications or upset conditions, see Figure 4. A number of other parameters will be varied during the testing and the results will be directly linked to non-dimensional flow maps.

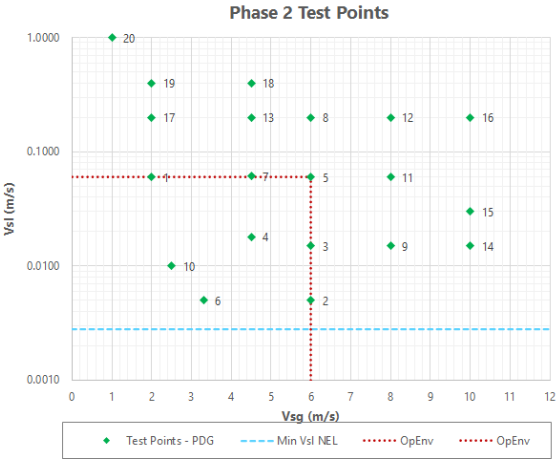


Figure 4 – Test Points for High Pressure Flow Loop Testing.

Furthermore, to ensure a TRL5 (API) rating the testing will use a Subsea Magnetic Drive Pump from Norway and Subsea Control System.

The University of Western Australia will compare the results of these pilot-scale investigations against the current gas-dominant hydrate formation extension deployed in OLGA. Through this comparison, the academic team will continue refining the extension to more accurately capture the experimental separation performance obtained in the pilot-scale tests, alongside the downstream hydrate formation probability and hydrate severity resultant in gas and liquid transport flowlines. The result will deliver an updated extension tool for OLGA that represents both the PDG system and subsequent risk of hydrate blockage formation.

As the extension currently describes some dosage-dependent effects of MEG on hydrate blockage risk, the combined extension tool will further enable operators to determine the potential degree of MEG reduction that which can be obtained from the implementation of PDG units in subsea tieback systems.

Upon successful completion of this round of testing the same equipment will be used on a subsea pilot field deployment on a shallow water gas field towards the end of life to take the final steps to the highest TRL rating (TRL 7).

Results and Discussion

The technology is currently at TRL4 (API) and has to date via the first low pressure flow loop testing and subsequent CFD work shown to perform better than required when mapped against the macro flow assurance field development cases.

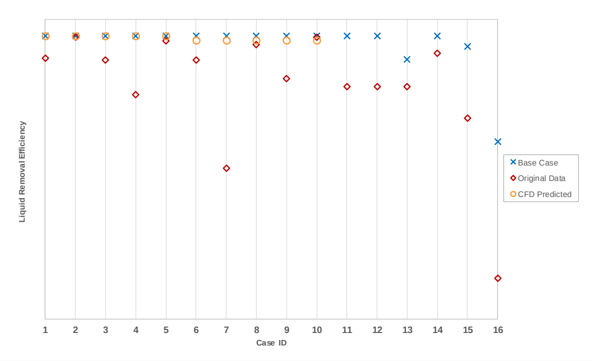


Figure 5 – Results for Flow loop Testing in Relation to Calibrated CFD at High Pressure and Minimum Efficiency Requirements.

This can be demonstrated with Figure 5, each ‘Case ID’ corresponds to a superficial liquid and gas velocity broadly aligned to the expected operating envelope of a PDG system, which is plotted against ‘Liquid removal efficiency’. The ‘Original data’ (red diamond) points shows the lowest separation performance required from the testing to be considered successful. This ‘Original data’ performance data set has been used in all full field flow assurance studies to date, enabling the change of the resistance curve to a liner function, see Figure 1. The ‘CFD Predicted’ (orange circle) data set shows the predicted performance of the prototype at higher pressure (Ref 2 - Engeries-12-02116). With the ‘Base case’ (Blue cross) showing the actual results from the low-pressure testing at Cranfield University. Both the ‘Base case’ and ‘CFD predicted’ showing higher performance than ‘Original data’.

The current scope of development work at high pressure including subsea pump and supporting control system, will take the technology to a level that it is ready for a pilot application.

Conclusions

Over the last four years a significant amount of work has been undertaken to develop the PDG system design and the passive piggable subsea separation unit. Upon completion of this current stage of developmental work, the TRL will be at 5 (API).

This technology has the ability to enable significant decarbonisation of upstream operational emissions by eliminating / mitigating the need for compression offshore/subsea and onshore without impacting the overall recovery (Ref 1 - OTC-30941-MS) by changing the shape of the flow resistance curve of gas tiebacks to better use the natural reservoir energy.

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