DEVELOPMENT OF INNOVATIVE MEMBRANE FOR OFFSHORE HIGH CO_2 SEPARATION

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Background

The depletion of large and sweet gas fields around the world has prompted researchers to seek for optimised Carbon Dioxide (CO_2) separation technology for the development of high CO_2 gas field reservoir. Currently, about 40% or 2600 Trillion Cubic Feet (Tcf) of the world's natural gas reserves are in the form of sour gas where H_2S and CO_2 compositions exceed 10% volumetric of the raw produced acid gas. In Southeast Asia, non-developed and potential gas reserves are estimated at 182 Tcf, Malaysia alone holds an estimated 37 Tcf of natural gas [1]. Most of these gas fields were not economically viable in the past due to the presence of large quantities of CO_2. These high CO_2 gas fields always associated with potentially high corrosion risk to the topside facilities and pipelines. The development of offshore high CO_2 gas fields requires prudent selection of CO_2 separation technology in order to optimise both capital and operating expenses for gas processing facilities.

Bulk CO_2 removal offshore using membrane technology has been utilised for more than 15 years. As new large fields require increasingly high gas volumes (more than 1 Bscfd production) and has very high CO_2 content (above 50%), older conventional membrane technology is no longer economical for such large field developments. In the past five years, the size of hollow fibre membranes has increased to 30" in diameter by 72" in length from the 16" in diameter by 72" in length. This has resulted in a 375% increase in gas throughput per membrane, which also translates to approximately 50% reduction in the equipment footprint on the platform.

In addition to increasing the membrane size, PETRONAS and Cameron have gone one step further with the latest development using two different zones of fibres with different characteristics on a single membrane module [2]. This can further reduce equipment footprint and weight since a single "multi-layer multi-fibre" (refer to as PN1 membrane) module can now efficiently replace what previously required two separate steps of membrane. The PN1 membrane is a new development in polymeric membrane which makes the membrane compact in size while enhancing its efficiency.

Aims

The aim of this research is to optimise the current membrane technology to address the challenges in developing large offshore gas fields with high CO_2 content, to be a commercially viable field development project.

Methods

Current membranes are fabricated with the same type of fibre materials. These membranes are limited to a single set range of performance characteristics even though the properties and gas volumes change throughout the membrane as permeation occurs (Figure 1).

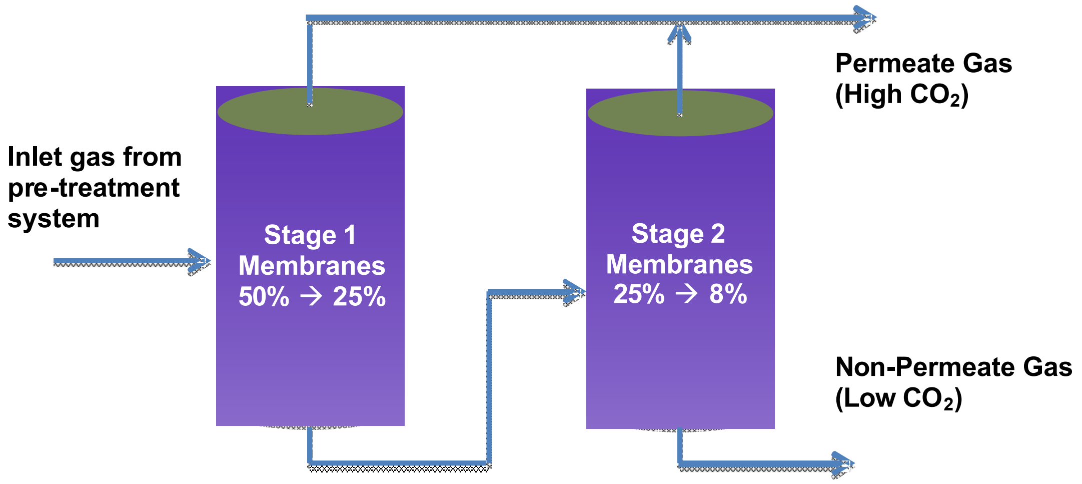

Figure 1. Current membrane configuration

The new innovative invention (PN1) improves the performance of the membrane module by increasing the overall capacity, thereby reducing or eliminating the need for multiple processing or separation steps (Figure 2).

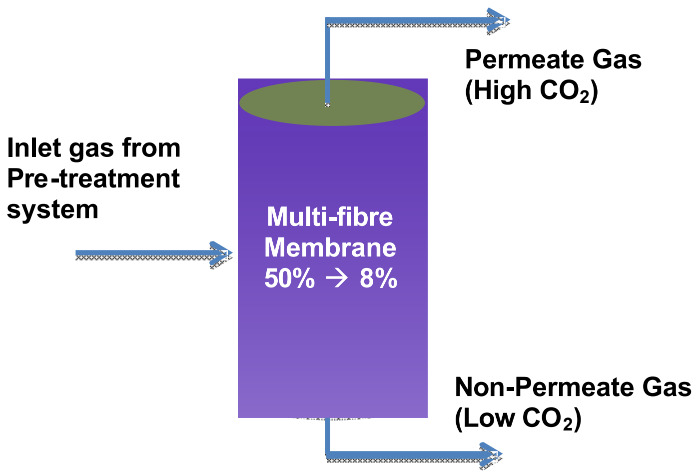

Figure 2. New invention application

The PN1 membrane incorporates two or more different types of membrane fibres into a single membrane module. This will maximise the overall capacity and separation performance of the membrane element as the gas passes through it.

A higher separation (lower capacity) fibre is located in Zone 1 to reduce hydrocarbon loss and a higher capacity (lower separation) fibre is located in Zone 2 to improve capacity where CO_2 is lower (Figure 3).

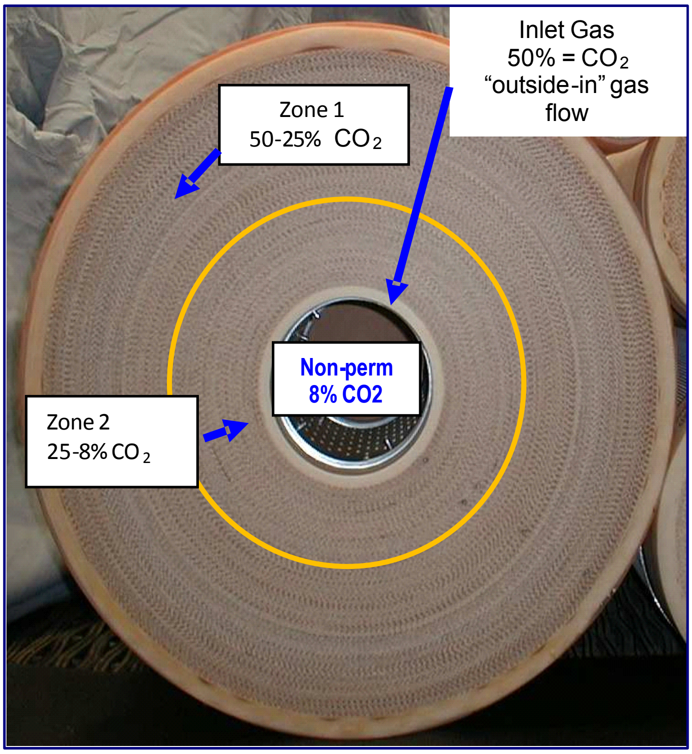

Figure 3. PN1 membrane system configuration (percentage of CO_2 shown are indicative).

Results

The PN1 membrane which consists of two layers of polymeric hollow fibres was compared with two 16 inch single-layer membranes (using two steps in series). For example, the two-step membrane system was previously recommended to remove 50% inlet to 8% CO_2 in the sales gas. With the multi-fibre PN1 membrane, this is achieved in a single membrane module configuration. First, the outer layer removes CO_2 from 50 to 25%. The second layer will then remove down to 8% of CO_2. The outer layer has higher separation performance, while the inner layer has higher relative capacity. In actual filed operations, the multi-layer membrane has demonstrated 8% to 10% higher capacity and has shown similar separation performance compared to a single fibre membrane. This single multi-fibre membrane can provide a further equipment footprint reduction of 7% to 10% and offers equivalent separation performance.

Testing condition for PN1 membranes is shown in Table 1 below. The tests were carried out at two separate sites. Site 1 compared PN1 with commercially available 30” membranes whilst site 2 compared PN1 with commercially available 16” membrane.

Table 1. Testing conditions

Parameters	Testing conditions	
	Site 1	**Site 2**
Inlet flow	20 - 36 MMscfd	14 – 22 MMscfd
Inlet pressure	34 - 36 bar(g)	39 – 45 bar(g)
Inlet temperature	19 - 28^{o}C	19 - 41^{o}C
Inlet membrane CO_2 Content	55 – 75% mol	35 – 40 mol
Non permeate membrane CO_2 Content	17 - 25%	9 – 19 mol

Results from the field testing are shown in Figures 4 and 5.

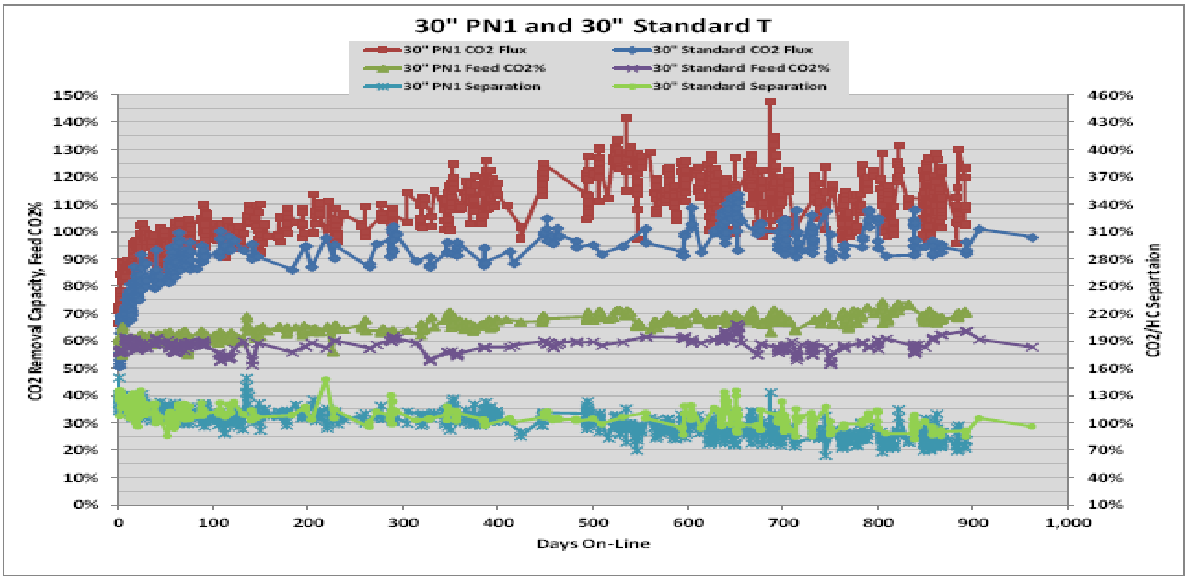

Figure 4. Results of 30” PN1 membrane as compared to 30” commercially available membrane

The 30” PN1 showed an average of 10% increase in CO_2 removal capacity with respect to commercially available 30” membranes. For CO_2 and hydrocarbon (HC) separation, both membranes maintained similar performance.

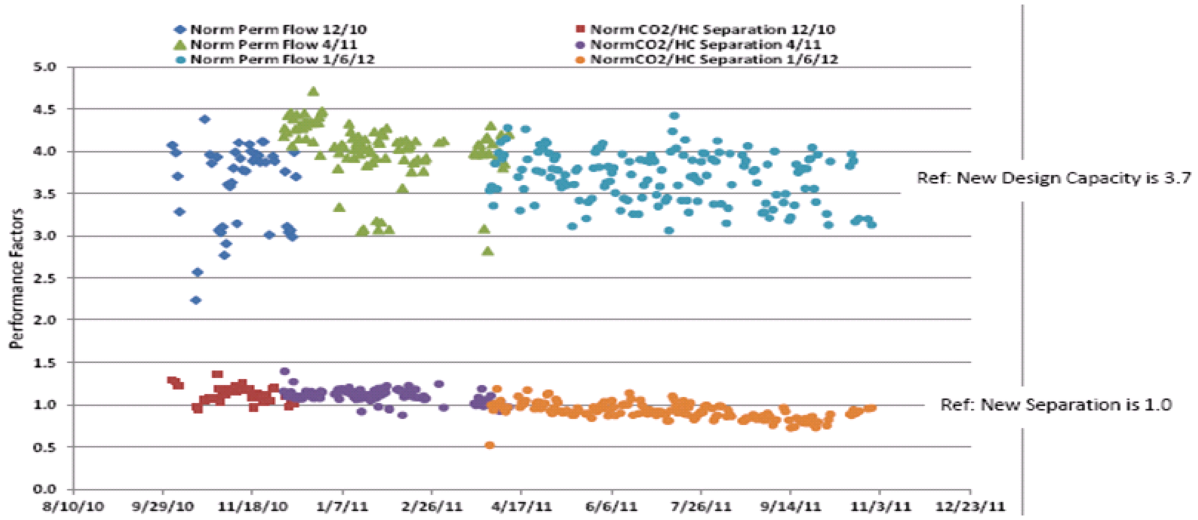

Figure 5. Results of 30” PN1 membrane as compared to 16” commercially available membranes

In terms of CO_2 removal capacity, the field data validates that PN1 30” has 3.7 times the capacity of commercially available 16” membranes. For CO_2/HC separation performance, PN1 showed almost similar performance (Figure 5).

Results from case study [3] conducted to evaluate the footprint and weight reduction of PN1 as compared to 16” commercially available membranes is shown in Figure 6.

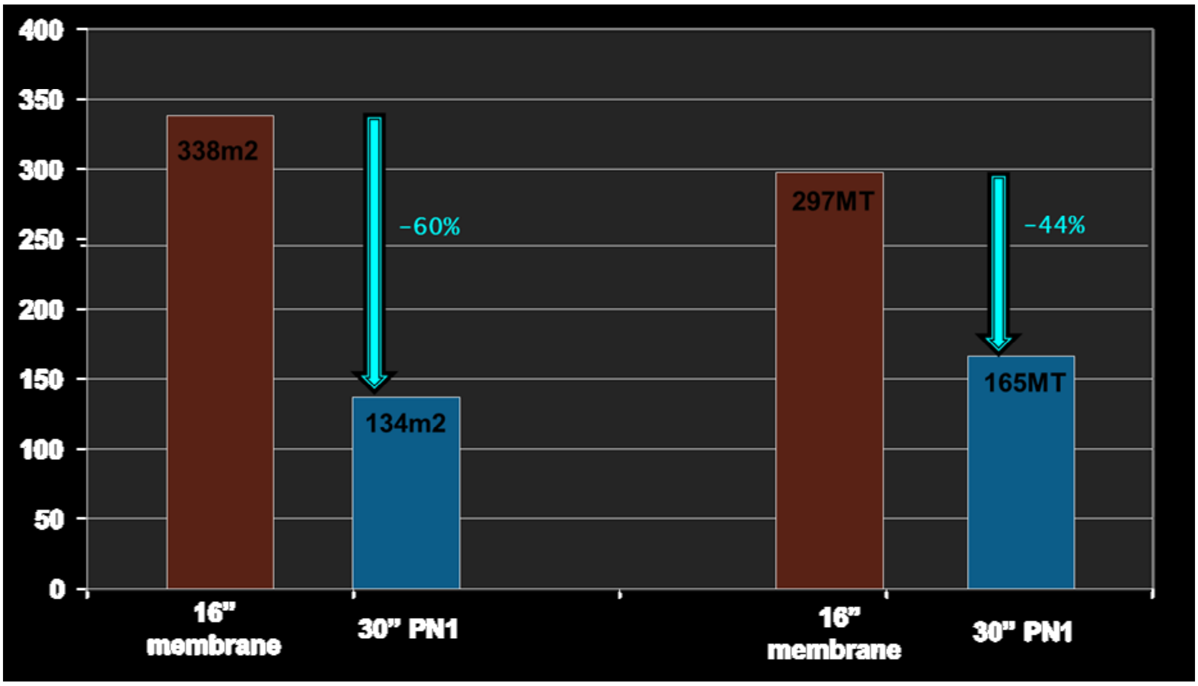

Figure 6. Results of 30” PN1 case study on footprint and weight reduction as compared to 16” commercially available membranes.

Based on the case study, the footprint and weight reduction was recorded at 60% and 44%, respectively. The calculations were based on the same feed-gas flow-rate, feed-gas and sales gas compositions. The additional advantage of the PN1 membrane is the elimination of interconnecting piping resulting in significant cost savings on offshore platforms. There is also no requirement to balance feed gas rates between multiple steps of membranes, or to change the relative loading between first step and second step membranes. This will ensure better monitoring of membrane performance with fewer steps of membranes to measure.

Conclusion

Development of PN1 membrane is found to be more efficient in removing high CO_2 content natural gas from large gas fields as compared to single-layer commercially available membranes. PN1 has 10% more CO2 removal capacity (flux) compared to 30” commercially available membranes. PN1 has 3.7 times CO2 removal capacity (flux) compared to 16” commercially available membranes, resulting in lower footprint and weight.

References

[1] Abas, A.Z.; Ramli, S.H.; Siang, S.W.; Johar, R.M. *MCI Symposium* **2011**, 6-7.
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