MEETING TECHNICAL CHALLENGES IN DEVELOPING HIGH CO₂ GAS FIELD OFFSHORE

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I. INTRODUCTION

Development of high Carbon Dioxide (CO₂) gas fields offshore will indisputably give significant new challenges for all E&P companies worldwide. PETRONAS has indeed realized these challenges as Malaysia is proven to be one of the countries with high CO₂ gas fields in the world. High CO₂ content gas reservoirs make most of the gas field development uneconomical and it has remained undeveloped. As a developing country, Malaysia's resources have to be developed timely to sustain supply to meet the increasing gas demand. In addition, the development of these high CO₂ gas fields requires prudent management of CO₂ capture, transportation and storage & utilization to enable commercialization of these gas fields.

II. OBJECTIVE

This paper will share the knowledge, experiences and challenges accumulated by PETRONAS's exploration and production arm, PETRONAS Carigali Sdn. Bhd. (PCSB) from its numerous high CO₂ gas field's projects undertaken since mid 90's. The application of CO₂ removal plant on offshore platform is few with limited feedback and established operations on the optimum choice of treatment or methodology within the industry. The main constraints for application on an offshore platform are space and weight limitations. Installing a complex system with numerous equipment and extensive utilities to support its operation is against the trend in the offshore industry to pursue compact facilities, reduce manning levels for safety and logistic reasons and operating costs.

III. TECHNOLOGY SCREENING

Technology hunt effort for bulk CO₂ removal offshore application started in PETRONAS for more than 10 years ago. By removal CO₂ offshore will not only reduce the corrosion problems but also reduce the size of the export gas pipeline and decrease the compression power.

The selection of the optimum technology for CO₂ removal is specific for each application. The factors governed are among others are reservoir conditions, feed gas rate and composition, operating pressure and temperature conditions, cost of product gas and fuel, availability and cost of utilities and environmental regulations.

PETRONAS which has extensive experiences in developing high CO₂ offshore gas fields projects had made extensive evaluation on several process for gas separation namely chemical absorption (amine), physical absorption, cryogenic distillation (Ryan Holmes process), membrane system and other current technologies.(1) The studies which undertaken with design consultant, technology provider and in house experts had lead to a conclusion that membrane is the most promising,
effective and economical way to date for offshore CO₂ removal due its compact size, moderate utility consumption, easy operation and reliability.

![Technology Screening](image)

*Figure 1: Technology screening for CO₂ removal*

In undertaking the selection process, the following selection criteria were used. There are Capex, Opex, Operating Flexibility, Reliability, Expandability, Environment Friendly, Weight, Foot print, CO₂ Removal Efficiency, CO₂ purity. Figure 1 clearly shown that the membrane is the optimized technology for CO₂ removal offshore.

**Membrane Technology**

Membrane is a thin semi permeable barrier that selectively separates some fluids from others. Membrane processes are driven by differences in driving force such as the pressure or concentration of the components across the membrane.

Membrane is ideal for bulk removal of CO₂ to meet product gas specification with high CO₂ percentage levels. For proper membrane operation and to ensure long service life, proper pretreatment of the feed gas is essential. Pretreatment essentially removes water and heavy hydrocarbon components in the gas that could damage the membrane. Pretreatment can be in the form of dehydration and chilling to knock off heavy ends or by adsorption of the heavy ends using molecular sieves. Problems encountered in membrane facilities resulting in short membrane life and inability to achieve design capacity is mainly caused by inadequate pretreatment. Membranes are also sensitive to rapid thermal and pressure variations in the feed gas conditions. Uncontrolled thermal and pressure swings will shorten membrane life.

Membrane performance deteriorates over time. Flow through the membrane has to be set based on the performance and condition of the membrane. Gas chromatograph installed on the product stream allows operator to monitor the membrane performance and to make the necessary flow adjustment to optimize its operation.
Membrane comes in two most common forms, hollow fiber and spiral wound. Hollow fiber has strength limitation but its construction maximizes surface area per unit volume of membrane. The common materials for constructing membrane are cellulose acetate derivatives, polyimide, polyamide and polysulfon.

<table>
<thead>
<tr>
<th>TYPES OF MEMBRANE</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
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<tbody>
<tr>
<td>Hollow fiber</td>
<td>• Greater amount of membrane surface area within a given volume.</td>
<td>• Limited maximum operating pressure.</td>
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<td></td>
<td>• Ability to operate effectively in the presence of heavy hydrocarbons</td>
<td>• Strength reduces with increasing CO2 concentration</td>
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<tr>
<td>Spiral wounds</td>
<td>• Able to withstand relatively high pressures</td>
<td>• Hydrocarbon condensation may not be easily removed and liquid accumulated inside reduces the productivity of membrane</td>
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<td></td>
<td>• Minimum permeate pressure drop</td>
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Meanwhile, the use of membrane is also more promising if compared to liquid solvent technologies. Some justifications the statements above are as follows:

- Membrane technology requires lower energy to operate than chemical absorption process leading to saving in one or more turbo generator units.
- Membrane technology has less rotating equipment resulting in less manning and maintenance requirement.
- The treated gas from membrane is dehydrated and can be exported directly into the sales gas pipeline. Amine treated gas is water saturated and requires additional equipment for drying the gas. Membrane treated gas is very dry (unlike gas dehydrated by TEG system) with no risk of corrosion in the gas export pipeline.
- There is no solvent and chemical make-up that will require additional space on platform for chemical handling and storage. The need to replenish solvent and chemicals will add to logistics and transportation costs.
- Membrane units are simpler to operate with low operator intervention and have no foaming and corrosion problems.
- Membrane systems occupy less platform space than amine systems leading to smaller platform resulting in significant cost saving.
• Membrane systems avoid the need to have a fire source on the platform which is a potential source of ignition in a hazardous situation involving the release of hydrocarbon gases. The low heating duties can be supplied by hot oil heating medium recovering waste heat from the turbo generator exhaust gas.

• Single stage membrane is more economical than the chemical absorbent system. The high cost of the chemical absorbent system is attributed to the need for an additional offshore structure to locate the future 3rd compression train. A larger flare support structure to locate the thermal oxidizers and waste heat recovery units partly contribute to the overall cost.

IV. CHALLENGES FOR CO2 REMOVAL

The application of CO$_2$ treatment plant on offshore platforms is not very common for the last 10 years. Therefore there is lack of feedback on the optimum choice of process treatment in term of design and operation.

For offshore operation, weight and space are the main constraints need to be addressed. Looking at traditional CO2 removal technology within the industry (e.g Amine) required a lot of processing equipment in order to meet sale specification. Furthermore the technology is able to reduce CO2 for less than 15%. Installing a complex system with many equipment and utilities to support its operation is against the trend in the offshore industry to reduce manning levels for safety and logistic reasons. High energy, utilities demand and issues concerning environmental protection and logistics of replenishing chemicals and solvents losses are among the other issues need to be considered.

V. PROJECTS UNDERTAKEN

PETRONAS had started facing all the challenges in offshore CO$_2$ removal by participating in Joint Development Area (JDA) fields' projects. The JDA projects have answer to the gas shortage issue in Malaysia and Thailand.

Cakerawala (Fig 2) platform an offshore processing facility in Block A18 of the Malaysia – Thailand Joint Development Area in the Gulf of Thailand, installed semi permeable membranes for CO2 removal after evaluating several other technology options. The Cakerawala production platform (CKP) which uses NATCO/Cynara semi permeable membranes was successfully commissioned in December 2004 and is currently continuing to operate. Carigali Hess Operating Co. Sdn. Bhd., a joint venture of PETRONAS Carigali Ltd. and Hess Oil Co. of Thailand Ltd., operates the plant, 150 km offshore for the Malaysia-Thai Joint Authority. Raw untreated inlet gas to CKP with about 37% CO2 has a sales-gas specification of less than 23% CO2 before being delivered to the buyer’s pipeline.(1)
After successfully installed the first acid gas removal system utilized membrane as a technology for removing CO2, there is no turning back for PETRONAS. The second project with high CO2 gas field undertaken by PETRONAS is joint venture project with Talisman located offshore Peninsular Malaysia. The Acid Gas Removal System uses spiral wound membrane to process raw gas at 44% of CO2 down to 8% of CO2. The third project undertaken by PETRONAS is CPOC project which processing raw gas containing CO2 as high as 45% reduce to 23%. The project is located at Gulf of Thailand. In 2006 another project with high CO2 gas field had been developed by Petronas Carigali Sdn Bhd located offshore Peninsular Malaysia. In this project membrane technology had been utilized to remove CO2 from 34% to 8% from hydrocarbon gas and expected to be on stream by fourth quarter 2010. Both project are using CYNARA/NATCO semi permeable membranes to remove CO2 in the raw gas stream.

VI. WAY FORWARD

With current technology and in house capability, PCSB was able to develop offshore fields with CO2 content as high as 45%. However, developing gas field containing more than 60% CO2 content which will definitely give greater challenges are still waiting for PETRONAS and other players in the world to extend beyond the current limit of monetization.

References

1. A. Callison, G. Davidson Offshore processing plant uses membrane for CO2 removal, Oil and Gas Journal (May 2007)