CHALLENGE
Design an acid gas removal system (AGRS) for an onshore processing facility to efficiently address variations in feed gas composition (12- to 25-mol% CO₂ and H₂S) and flow rate and deliver product gas with <8-mol% CO₂.

SOLUTION
Use CYNARA PN-1* dual-zoned acid gas removal membrane technology to achieve the required product gas specification with a system fabricated in multiple modular trains to efficiently manage dynamic swings in flow rate.

RESULTS
- Delivered system on time.
- Eliminated need for liquid chemicals (weight, transportation, storage, and disposal).
- Reduced installation (capex) and operating cost (opex) by USD 180 million.
- Enhanced operational flexibility to deliver stable outlet gas.
- Exceeded designed hydrocarbon separation quality by 100%.
- Exceeded designed flow capacity by 20%.

Variations in flow rate and acid gas concentration present challenges at gas processing plant
Petronas Gas Berhad needed to design onshore gas processing facilities at the Terengganu gas terminal (TGAST) with the capability to process CO₂-rich gas from offshore production and achieve the product gas specification of <8-mol% CO₂. Significant variations in flow rate and acid gas concentration (12- to 25-mol% CO₂ and H₂S) in the feed gas streams required a technology that could dynamically handle wide swings in the feed gas conditions.

The Schlumberger OneSurfaceSM reservoir-integrated production system team (formerly Cameron Process Systems) provided conceptual design scope for the CYNARA PN-1 dual-zoned acid gas removal membrane system. An economic comparison study of the proposed CYNARA PN-1 membrane technology versus conventional solvent-based processes showed that the former had 50% lower installation cost, more than 60% reduction in plot space, and 20-year estimated operating cost savings of more than USD 180 million. In 2013, Schlumberger was awarded the contract to complete the detailed design, fabricate, deliver, and provide site support of the proposed CYNARA PN-1 dual-zoned acid gas removal membrane system.

CYNARA acid gas removal membrane systems reduce installation and operating costs and increase efficiency
CYNARA* acid gas removal membrane systems efficiently and selectively permeate acid gases to separate them from produced gas streams that contain 5- to 95-mol% acid gas. The membrane systems are compact, largely self-contained, and mounted on skids, which reduces installation costs. The use of these membrane systems also reduces operating costs by eliminating the need for liquid chemicals and the logistics of their transport, storage, and disposal.
The unique CYNARA PN-1 dual-zoned acid gas removal membrane system, which was jointly developed with Petronas, works on the principle of diffusion and solubility-based separation. It combines two different membrane cores in a single 30-in-diameter membrane element, with each membrane optimized to selectively permeate different concentrations of acid gas endemic to the feed gas. The CYNARA PN-1 membrane permeates the highest concentrations of inlet acid gas in Zone 1 and directs lower concentrations of acid gas into Zone 2 to efficiently optimize the treatment of gas streams with irregular levels of CO$_2$ and H$_2$S.

Prior to deployment, the technology was tested and validated for three years at a Schlumberger-operated gas processing facility in Texas. During evaluation, it was demonstrated that the dual-core technology offers 8% to 10% more CO$_2$ removal and throughput compared with standard 30-in single-core membranes and provides approximately four times higher CO$_2$-removal capacity compared with 16-in membranes.

The Schlumberger OneSurface team designed the gas plant’s AGRS to treat up to 700 MMcf/d of raw gas containing up to 25-mol% CO$_2$ and to deliver product gas with <8% CO$_2$, C$_3$ = RSH (mercaptans), and C$_4$ – RSH content. The system comprises two pretreatment trains of 350-MMcf/d nominal capacity, followed by five modular CYNARA PN-1 membrane sections that remove CO$_2$ from inlet gas to produce the product gas (nonpermeate). The overall design of the CYNARA PN-1 acid gas removal membrane system was tailored for operation flexibility to address variations in feed gas composition and flow rate. With technical support of the Schlumberger global team of experts, the entire system was fabricated and delivered to Petronas by 2015, was installed and commissioned on time in 2016, and began operation in early 2017.

Performance of the CYNARA PN-1 acid gas removal membrane system exceeds design expectations

Operations data verified the anticipated significant flow rate swings in inlet gas. The modular design of the system easily addressed this such that, after stabilization of operations, only three trains need to be used full time. Trains 4 and 5 are reserved for periods of increased flow rate.

In addition to the economic advantages derived from reduced installation costs and separation efficiency, data demonstrate stable performance of the membranes, consistent yield of product gas that meets required specification, and excellent overall performance that exceeds design expectations. Data from one of the five primary membrane trains, PM-1, shows overall flux capacity is at 120% and hydrocarbon separation performance is at 200% relative to design basis. There is no evidence of decline in capacity or loss of separation quality. The design of the CYNARA PN-1 membrane system successfully meets the Petronas CO$_2$ specification while retaining maximum hydrocarbons in the product gas.