



Small Scale,



Big Benefits

Christopher Elko, Daniel Harajda, and Amanda Witmer, Air Products, assess the flexibility and versatility of small scale LNG in the future LNG industry.

As the world seeks energy security in the face of the energy transition and geopolitics, demand for clean fuels, such as LNG, continues to rise. Safe and reliable energy supply to an ever-widening consumer base remains critical, while increasingly stringent environmental regulations have mandated tighter control over fugitive emissions and reduced carbon intensity. The LNG industry has risen to the occasion to meet this need, offering production that ranges from large scale export facilities to small scale facilities that support local pipeline distribution. Even the smallest of these facilities leverage world-class technology that is tailored for the highest efficiency, superior performance, and lowest total overall cost of ownership.

Small scale LNG plants are a versatile solution for optimising a facility's geographic location to better serve consumers. Whether located at a wellhead, the end of a pipeline, or even used within an existing facility to reliquefy boil-off gas, small scale LNG plants feature a small footprint, thus making them suitable for greenfield or brownfield installations. Although smaller in scale, the plants utilise proven process technologies. For example, Air Products' nitrogen-based refrigeration cycles are derived from well-referenced liquefaction technology spanning decades of operating experience in the industrial gas industry:

- Brazed aluminium heat exchangers (BAHX) housed within an insulated cold box.

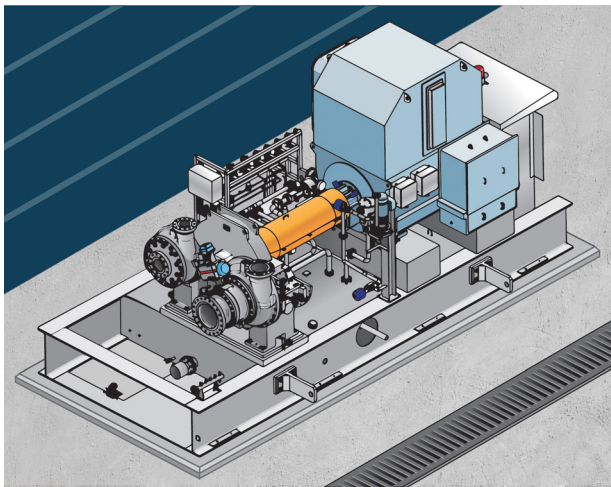


Figure 1. Fully packaged integral gear nitrogen recycle compressor enables a high degree of project certainty by reducing field work.

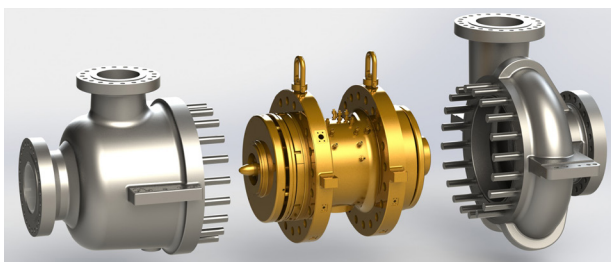


Figure 2. Modular compander rotating assembly designs offer a small footprint and easy maintenance.

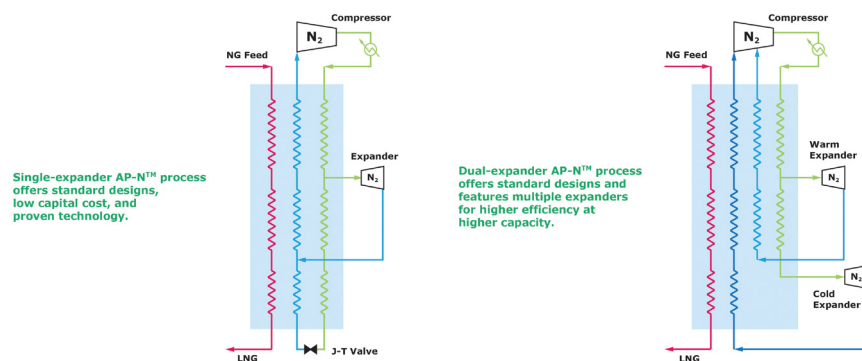


Figure 3. The AP-N™ LNG Process presents options to optimise liquefaction over a variety of plant configurations.

- Packaged, integrally geared refrigerant compressors with robust, cost-effective performance.
- World-class cycle efficiencies and stable operation realised through the use of compressor-loaded turboexpanders (also known as 'componders') for reliable refrigeration across a wide operating range.
- Highly modularised equipment packages enabling reduced field execution scope and faster times to first drop.

Purpose-built process

The AP-N™ LNG Process is Air Products' nitrogen expander liquefaction process that is used for the company's small scale LNG product offerings, and currently offers a single-compander cycle and a dual-compander cycle to cover a broad range of liquefaction capacities. Optimised equipment selections are designed to suit small scale LNG plant production ranging from 140 – 450 tpd and higher. This process offers benefits that include:

- High efficiency and reliable turndown capability.
- Simple start-up and shutdown procedures with short cold or warm start-up periods.
- Non-flammable and environmentally benign nitrogen refrigerant that is safe and widely available.
- Low equipment CAPEX and low maintenance cost due to lower equipment and process complexity and well-referenced components.

Productisation – standardisation plus value-added customisation

Adaptability in plant configuration is the basis of the equipment design for Air Products' small scale LNG product offerings. To accommodate variations in feed gas composition and flow, all static and rotating equipment is designed with flexibility in mind to cover a wide range of operating conditions and production capacities. Furthermore, site environmental conditions and availability of utilities may dictate additional constraints to the equipment selection. By deploying a standardised major equipment set with engineered-to-order

performance attributes, customers can realise reduced CAPEX while achieving target capacity.

The company takes a meticulous approach to product development, utilising decades of engineering and design experience to successfully productise small, mid, and large scale plants across the air separation and hydrocarbon industry – including natural gas liquefaction. Productised small scale LNG liquefier scope includes a complete, pre-engineered liquefaction system featuring core process equipment and piping runs designed for minimal footprint,

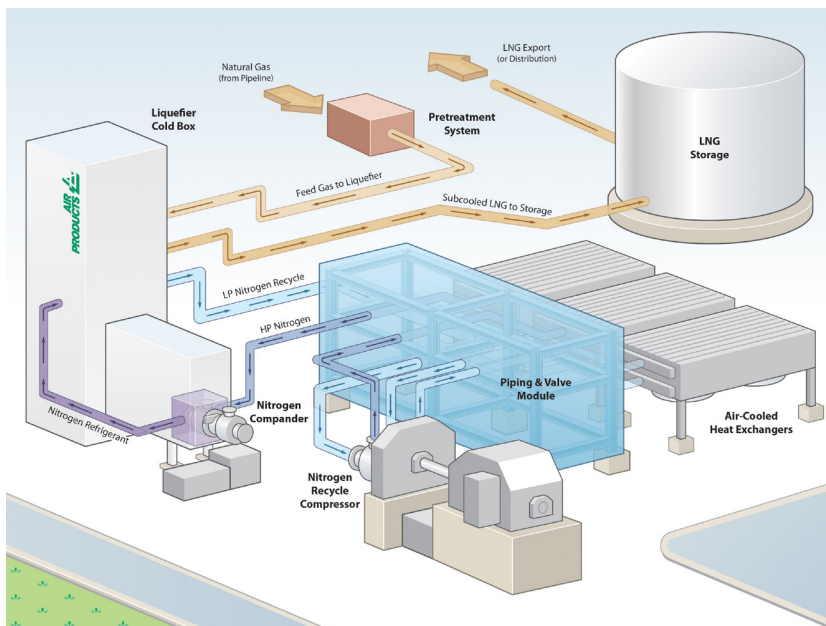


Figure 4. A peak shaving facility featuring the AP-N LNG Process, fully equipped with each core system integral to safe and reliable liquefaction.



Figure 5. Cold boxes being manufactured at Air Products' Caojing manufacturing facility in Shanghai, China.

low pressure drop, and enhanced plot plan flexibility. Major pieces of equipment include cold box and crossover box, control valve module, nitrogen recycle compressor, and compressor-loaded turboexpander (componder).

Cold box and crossover box

The insulated cold box can be considered the heart of the AP-N process. Its internals include the main liquefaction BAHXs, cryogenic control valves, and heavy hydrocarbon removal drum. The main liquefaction BAHXs are sized to accept a wide variety of feed compositions and ambient conditions. The crossover box provides an insulated duct integrating the componders into the cold box; it also features pre-installed piping and valves for reduced field execution scope.

Control valve module

This pre-packaged module provides safe, convenient personnel access to all non-cryogenic control valves integral to liquefier operation. Keeping all critical valves

in one location minimises the time spent making online adjustments or performing offline maintenance. The module also acts as a pipe rack, supporting large-bore piping that runs between the nitrogen recycle compressor and air-cooled heat exchangers.

Nitrogen recycle compressor

Selecting a single compressor frame size with a flexible aerodynamic design enables the product development team to accommodate a wide range of nitrogen refrigeration duties without affecting critical tie point coordinates. The modular aerodynamics allow the compressor's performance to be optimised for maximum efficiency for each opportunity, accommodating variations in cooling medium and process conditions.

Compressor-loaded turboexpander (componder)

Air Products' offerings include the Rotoflow® EC series componder featuring a compact, single-shaft design with adjustable expander inlet nozzles to fine-tune the performance for project-specific conditions. Deploying active magnetic bearings (AMB) and a seal-free mechanical assembly in each EC componder used in a small scale LNG product translates into a small footprint, no lubrication requirement, and zero refrigerant loss from the componder. This hermetically sealed and intrinsically safe design was developed specifically for the LNG industry.

All major pieces of equipment are supplied as either skid-mounted packages, cold boxes, or pre-assembled modules including piping, instrumentation, and valves. This significantly reduces field installation scope and schedule. Cold box equipment is manufactured and assembled in Air Products' specialised manufacturing facilities around the globe that have supported cryogenic air separation and LNG technology for decades.

Safety and environmental impact

The use of nitrogen as a refrigerant yields substantial safety and regulatory benefits compared to hydrocarbon-based liquefaction cycles. Most importantly, the risk to personnel and property due to the flammable nature of hydrocarbons is mitigated. Additionally, the use of a nitrogen-based cycle eliminates the need to control fugitive emissions, thus avoiding costly environmental permit compliance related to refrigerant containment. By deploying oil-free componders, circulating lubricant inventory and storage requirements are dramatically reduced compared to oil-flooded models. This further reduces the site's lifecycle carbon intensity, while lowering the risk of an environmental release and potentially reducing permitting requirements based on location and agency jurisdiction.

With sources of renewable and decarbonised electrical power such as solar, wind, and hydro on the rise, customers who choose an electrically driven main refrigerant compressor reap the added benefit of future-proofing their liquefaction facility and immediately minimising their operational carbon impact. For those customers in more remote locations and without access to a local grid or provision for on-site power generation, a gas turbine driver for the refrigerant compressor can be specified; this option opens the door for pre-combustion carbon reduction solutions, such as hydrogen co-firing provided by AP-BlueLNG™ liquefaction technology.

Field support experience – peak shavers

Existing infrastructure and geographic location may present limitations for import capacity during peak seasons. The shift from heavy fuel oil to clean-burning natural gas for heating, combined with residential sprawl from existing city centres into more remote locations, further compounds the challenge for natural gas utilities. Multiple North American small scale LNG facilities that utilise Air Products' liquefaction technology have been in operation for decades, with the latest onstream as of early 2023. For small scale LNG peak shaving applications, despite the cyclic, seasonal nature of their operation, Air Products-designed liquefiers have proven to be robust, easy to start up, and reliable with high on-stream availability when running.

The most recently commissioned peak shaver featuring the AP-N LNG Process has already proven to be a

boon to the reliability of the critical Northeast US residential and commercial grids. Initially established as a liquid import and distribution facility, this plant now has the ability to liquefy gas from the local pipeline during off-peak, warm-weather months and store the liquid to be vaporised and deployed during peak, cold-weather demand.

In addition to the process technology and equipment, initial start up and field support are key to maximising plant efficiency and reliability. Air Products offers extensive field support during the construction, commissioning and start up, and process optimisation phases of each peak shaver's lifecycle. The small scale LNG product engineering team leverages the comprehensive experience of each site start up to further refine product offerings for improved reliability and user-friendliness. This direct line of feedback shortens the product development cycle and results in the best possible offerings for each customer.

Conclusion

To meet the global demand for LNG, production facilities must be designed with agility in mind to offer options that range from mega scale to small scale liquefiers. Although smaller by nature, small scale LNG marries Air Products' process and cryogenic technology expertise with the necessary efficiency, reliability, and safety requirements to suit widespread applications and user-friendly operation. In addition, the flexibility of these small scale LNG designs provides options to meet production capacity, variations in operating conditions, and geographic location requirements. **LNG**