



Up for the challenge

Ethan Eiswerth, Christopher Elko, and Sarah Farnand, Air Products and Rotoflow, US, consider the obstacles of today's dynamic LNG industry, and offer ways to overcome these difficult scenarios.

Demand for clean fuels such as LNG is on the rise. Demand for technologies to improve efficiency is on the rise. Reliable energy supply remains critical. Air Products and Rotoflow, an Air Products business, have been partnering for decades to solve the LNG industry's most pressing challenges.

Small scale LNG

One challenge is that the demand for clean fuel for power generation or transport exceeds internal natural gas capacity. Increasingly stringent environmental regulations and the industry's ability to identify ever more methods of natural gas consumption require a safe, efficient, and

environmentally conscious means by which to expand natural gas availability to a wider consumer base.

A solution to this is liquefaction, which provides a convenient means by which to store or transport the clean energy of natural gas.

Small scale LNG (ssLNG) plants can be located near a wellhead, at the end of a pipeline, or anywhere in between – even on a floating vessel. Their small footprint requires very little plot space compared to gargantuan baseload export facilities, thus broadening opportunities to optimise a facility's geographic location to better serve consumers. Air Products' ssLNG product line offers nitrogen-based refrigeration cycles derived from well-referenced and proven liquefaction technology, and Rotoflow turboexpanders play an integral role in achieving cycle efficiencies and reliable operation. Optimised machine selections from Rotoflow's product portfolio are designed to suit a variety of ssLNG plant capacities ranging from 200 tpd - 400 tpd using a single compander (or two companders for even higher natural gas liquefaction and subcooling performance).

The use of nitrogen as a refrigerant yields substantial safety and regulatory benefits as compared to hydrocarbon-based cycles. The risk to personnel and property due to the flammable nature of hydrocarbons

and the need to control fugitive emissions are eliminated when using nitrogen-based cycles. Rotoflow machines feature good process seal leakage rates – even when equipped with labyrinth seals – that help to mitigate refrigerant inventory anxiety and reduce costs for remote locations where nitrogen deliveries may be difficult.

Another challenge is that high, localised natural gas demand for power generation and heating during cold winter months puts a strain on existing supply infrastructure and drives consumer prices up. 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.

One solution is to leverage excess pipeline capacity during warmer, off-peak months to build a liquid inventory for peak shaving. Multiple North American LNG peak shavers that marry Rotoflow turboexpanders with Air Products liquefaction technology have been in operation for several decades, with the latest scheduled to come onstream in mid-2022. Despite the cyclic, seasonal nature of their operation, these plants have proven to be robust and reliable with high onstream availability. Because the liquefier must accommodate variations in feed gas composition and flow, all static and rotating equipment must be designed with flexibility in mind to cover a wide range of operating conditions. Proper refrigeration balance can easily be established under these transient conditions thanks to the compander's ability to adjust speed and flow with the integration of variable expander inlet nozzles.

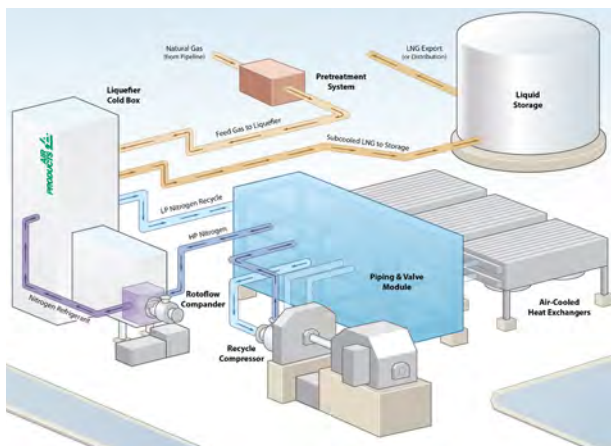


Figure 1. The Rotoflow compander is an integrated refrigeration source for each AP ssLNG product offering. Whether for peak-shaving duty or export, Rotoflow machines have the operational flexibility to meet demand and keep liquefaction processes running efficiently and reliably.

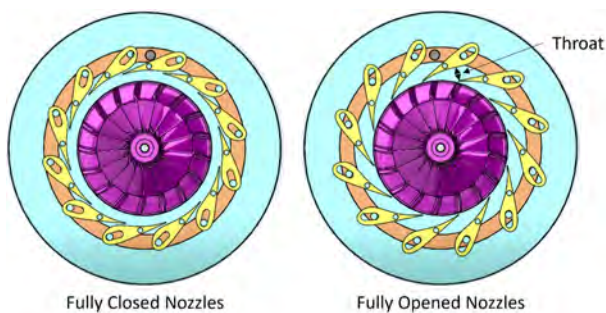


Figure 2. Open and closed positions of the adjustable inlet nozzles.

Hydraulic turbines

One obstacle is the increasingly stringent environmental regulations that make it necessary to extract as much energy from processes as possible.

However, a solution to this is the integration of a hydraulic turbine in an LNG process, as this provides additional process benefits that can be used to improve liquefaction plant performance in numerous ways. One option is to use the additional refrigeration that a hydraulic turbine provides to increase LNG production. As an example, for a nominal 4.5 million tpy facility, the production increase is 4.0% – nearly an additional 500 tpd. That additional refrigeration can also be used to reduce refrigeration power. For the same 4.5 million tpy facility, refrigeration power decreases 4.5% when leveraging the energy recovery of the hydraulic turbine. Furthermore, increased refrigeration affords reduced end flash by subcooling the LNG to a colder temperature. This equates to a 30% reduction in end flash for the 4.5 million tpy facility, which leads to lower auto-consumption and ultimately more liquid in the tank.

Because hydraulic turbines are, fundamentally, generator-loaded expanders, they convert potential energy that is recovered from the process into electricity. The total estimated electrical power generated by the LNG and MRL turbines for the example 4.5 million tpy plant is 2.3 MW – this electricity can be used to balance site power demand or exported to a local grid.

Advancements in hydraulic turbine design affect both performance and reliability of the machine. A new offering from Rotoflow, an Air Products business – a fixed-speed hydraulic turbine with adjustable inlet nozzles – can greatly benefit the LNG industry.

Adjustable inlet nozzles

The new offering incorporates adjustable inlet nozzles to increase the flow range. The inlet nozzles direct the flow of the process fluid into the expander impeller. By adjusting the throat or the distance between the adjacent nozzles, the flow through the expander can be controlled while maintaining the inlet and outlet pressures of



Figure 3. Combination journal and thrust tilting pad bearing.



Figure 4. The Rotoflow product line provides cryogenic turbomachinery for refrigeration and energy recovery in a wide range of plants. This 16R has found its home in some of the world's largest existing liquefaction facilities.

the turbine. The nozzle position is typically controlled by the DCS via an electric actuator.

Adjustable inlet nozzles change the amount of flow (and thus power) that the machine produces (power = mass flow * enthalpy drop). This permits the machine to operate over a wide range of plant production levels without the need for a machine bypass or the complex electrical circuitry required with a VFD. Turn down capability can be greater than 50% of flow for some applications, making the new hydraulic turbine offering capable of continuous operation over a wide range of production capacity.

Integrating well-referenced components

The new offering intentionally includes conventional component designs – including the generator, seals, and bearings – that have extensive use in hundreds of machine installations. Combining well-referenced components in a unique arrangement improves reliability and performance.

For example, the new turbine offering employs combination journal and thrust tilting pad bearings, which are well referenced in compressors, gas and steam turbines, pumps, turboexpanders, turbochargers, and gearboxes. Some motors and generators have also incorporated tilting pad bearing designs. Tilting pad bearings are well-suited for hydraulic turbines, which operate at high-speed and load. The bearings' tight clearances maximise efficiency by enabling close operating clearances between the rotating impeller and stationary shroud. These bearings are well-referenced in turboexpander applications that operate at similar conditions with thousands of installations in operation worldwide.

Warm start-up

Typical hydraulic turbines used in the LNG industry require a gradual cooldown procedure prior to start-up. Hydraulic turbine parts have small clearances because they improve performance and efficiency. If the turbine is cooled too quickly, the clearances may disappear and the mechanical parts may touch, leading to mechanical damage. To avoid the large temperature differences, a soak-in-place cooldown is used. This means incrementally filling the pressure vessel to a pre-determined level and holding while the mechanical components cool, typically over a 12- to 24-h period.

The Rotoflow design uses a significantly different machinery arrangement that permits starting the turbine from a warm condition without the need for any cooldown period. This is accomplished, in part, because the mechanical components that have small clearances are separated from the cryogenic process fluid while the wetted components that contact the process fluid are designed to handle rapid temperature transients.

Eliminating the cooldown increases hydraulic turbine availability by 72 to 144 h/y, increasing revenue by US\$360 000 - US\$720 000 over conventional hydraulic turbines, based on the following assumptions:

• One startup every two months for a single turbine.

• US\$5/million Btu LNG price (approximately US\$250/h/t).

• 20 tph production increase when running the hydraulic turbine.

Aftermarket service

Another hurdle is that operational excellence can only be realised when owners and operators understand the process and equipment. Even in a fast-paced market, there are clear advantages to embracing performance and reliability as core objectives. An LNG organisation that sharpens its focus in these areas can uncover enormous potential. However, it is critical to understand that even the best technology and equipment must be supported by the appropriate processes, systems, and expertise.

Maintaining a partnership with owners to provide comprehensive training and technical consulting throughout the entire lifecycle of the operating plant is a way of resolving this. As one of the world's only OEMs in both the manufacturing and operation of turbomachinery, Rotoflow knows both the equipment and the process. In partnering with LNG organisations, the support Rotoflow provides applies not only to application-specific rotating equipment and its incorporation into cold boxes (or any other type of cryogenic heat exchanger), but also to the optimisation of those processes in which the company's equipment's best performance is critical. The company can plug into new plant installations to provide vital start-up and commissioning services and work with owners and

operators to retrofit expansion and energy recovery equipment into existing plants. For customers in the LNG industry, further integration with process cycles from the Air Products ssLNG product line allows for expansion of remote monitoring and operations support through AP-OptiPlus™, an advanced computational programme that guides operators and engineers through troubleshooting and performance optimisation of the liquefaction unit of an LNG plant. Collectively, this allows Air Products to help its partners to get the most production out of their units.

The real value-add is that when it comes to the integration of Rotoflow equipment, the company can cater the extent of mechanical condition monitoring to each customer's needs while ensuring that all rotating equipment assets maintain a high level of reliability and availability. Comprehensive condition monitoring can catalyse the transition to a condition-based maintenance programme from a periodic maintenance regime, ultimately yielding cost savings through reduction of operational expenses and overhead.

Whether maintenance activities are planned or unplanned, the company's field service engineers are prepared to offer personalised, site-based support for equipment repair or replacement, while the centres in Houston, Texas, US; Bethlehem, Pennsylvania, US; and Dharan, Saudi Arabia, are equipped to rebuild turbomachinery precisely and swiftly to minimise downtime exposure. [LNG](#)

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