

COVER STORY

Keeping it simple

Jonathan Berg, Christopher Elko, Christopher Ott, and Colton Schrettner, Air Products, consider liquefaction trains for modern LNG facilities.

Today's LNG market is motivated by critical demand for worldwide energy security and the rapid transition to fuels and manufacturing facilities with ever-decreasing carbon intensity. These demands require liquefaction trains with high efficiency and availability, coupled with construction methods that offer reduced CAPEX and the shortest time between final investment decision and first shipment of product. With the trend toward highly-modularised liquefaction trains rising to meet those project delivery objectives, the LNG industry is turning its attention to electrically-driven liquefaction plants to achieve custom-tailored, low-carbon production capacity.

Electrically-driven processes in conjunction with more widespread modularisation capability enables more freedom to 'right-size' a liquefaction plant's production

capacity. With more degrees of design freedom than ever before, one size rarely fits all. EPCs and owners may wonder, "what is the best way to configure modules for optimal plant production for baseload facilities?" A configuration that is simple, elegant, and efficient at one capacity can become complicated, cumbersome, and inefficient at other sizes.

Mid-size liquefaction facilities

Single mixed refrigerant (SMR) processes have gained popularity in recent years due to their simplicity: in its most basic form, an SMR liquefaction unit consists of one refrigerant compressor and one main cryogenic heat exchanger. Besides straightforward scalability over a wide range of production capacities, this equipment can be easily modularised for quick installation at site, relative to



traditional stick-built facilities. Figure 1 shows the elegance of this solution.

The AP-SMR™ liquefaction process is well-proven with decades of reliable operation. This simple process is a natural fit for facilities exporting up to a nominal

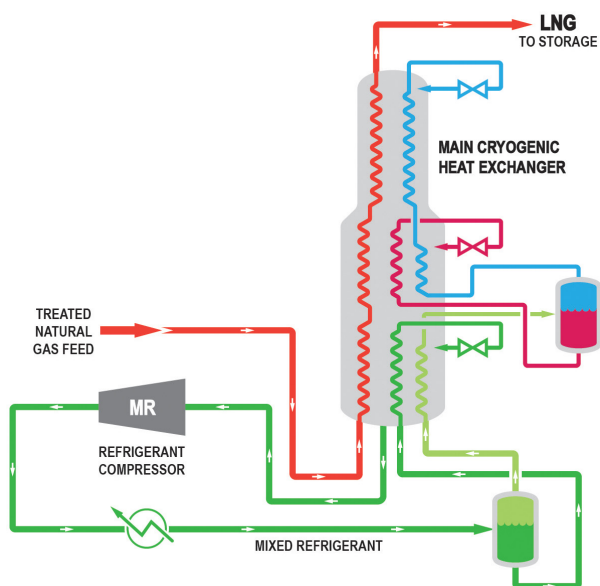


Figure 1. The AP-SMR Process pairs low per-train equipment count with proven coil-wound heat exchanger technology.

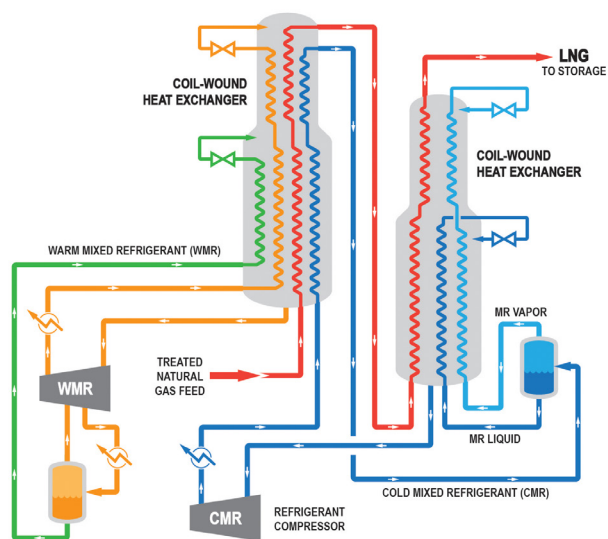


Figure 2. The AP-DMR Process employs integrated pre-cooling to improve thermal efficiency by 10 – 12% over AP-SMR.

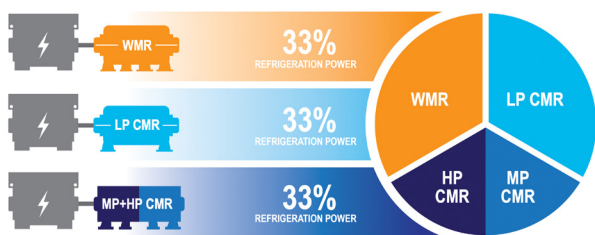


Figure 3. An ideal “equal-third” power split using three identical drivers for the AP-DMR refrigeration compressors.

1.5 – 1.7 million tpy of LNG. High liquefier availability and enhanced performance is achieved over a wide operating range by integrating a robust, well-referenced coil wound heat exchanger. Air Products’ experience in offering fully dressed, modularised exchangers directly translates into reduced field execution time – enabling shorter line of sight to first drop. This technology is proven at both small and mid-sized scales, with over 40 years of field operation. This is also the basis of the company’s AP-1M™ LNG module, a 1 – 1.4 million tpy AP-SMR modularised product offering.

Similarly, because AP-SMR liquefaction processes targeting approximately 1.5 million tpy of production require a refrigerant compressor driver size in the 50 – 60 MW range, they can leverage well-referenced frames from a variety of electric motor manufacturers. Note that for optimal compressor aerodynamic performance in this size range, a speed-increasing gearbox is often employed to increase shaft speed when a single-speed, synchronous driver is used. Additional lube oil circulation for thermal management of the gearing translates into a larger accessory skid. However, the additional capital impact of the gear box and nominal increase in package footprint actually decrease compressor casing size while improving liquefaction cycle efficiency – thus reducing carbon intensity for a given production capacity.

Larger liquefaction facilities

To minimise CAPEX, simple solutions are desirable for capacity below 1.5 million tpy. However, what is simple at 1.5 million tpy may not necessarily remain simple as capacity is scaled larger. In addition, larger capacity plants will require more power and produce more greenhouse gas (GHG) emissions. Therefore, reduced carbon intensity will be of higher value. For example, three AP-SMR liquefaction trains can achieve a capacity of 4.5 million tpy, but other liquefaction technologies can provide a more efficient option.

Simply put, precooled liquefaction processes are thermodynamically more efficient than single refrigerant processes. Dual mixed refrigerant (DMR) processes can improve the overall economics of a large scale facility with fewer trains. Shown in Figure 2, the AP-DMR™ liquefaction process offers 10 – 12% better efficiency than the AP-SMR liquefaction process; that means that for a given electric driver size, the AP-DMR process produces approximately 10 – 12% more LNG than the AP-SMR process. This in turn reduces specific power and improves project economics, making the AP-DMR process the cycle of choice for reducing carbon intensity.

Figure 3 depicts an optimal machinery arrangement for the AP-DMR liquefaction process that leverages an equal-third power distribution: three equally sized electric motors are used to drive the entire liquefaction process. In this configuration, one motor powers the warm mixed refrigerant (WMR) compressor, the second motor powers the first stage of cold MR compression, and the third motor powers the final two stages of cold MR compression. Note that for a nominal 4.5 – 5 million tpy of production, each of these is the same 50 – 60 MW motor used in the nominally 1.5 million tpy AP-SMR

process example. In this case, speed-increasing gearboxes are generally not required when combined with synchronous-speed motors because the refrigerant duties contribute to satisfactory compressor aerodynamic performance when directly driven. This shrinks the compressor package footprint and reduces the lubricant circulation requirement, thus reducing capital expenditure, operating expenditure, and plot space.

The AP-DMR process also employs Air Products' coil wound heat exchanger technology for the pre-cooler and main cryogenic heat exchanger (MCHE). These exchangers can be just as easily modularised for rapid integration at site to fit even the most aggressive project schedules and – most importantly – they have already been successfully applied in onshore and floating applications of the AP-DMR liquefaction process (Figure 4).

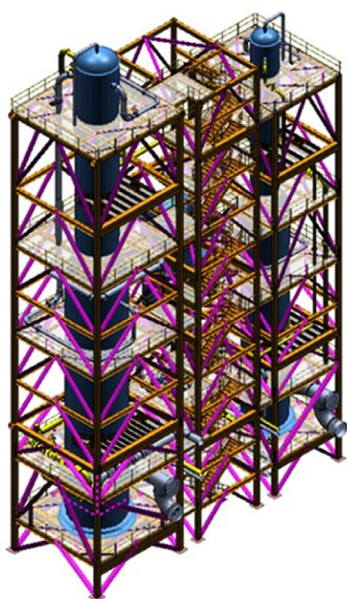


Figure 4. A fully dressed and module-ready coil-wound pre-cooler and MCHE saves valuable field execution time.

Table 1. SMR vs DMR				
	Hardware	AP-SMR Process	AP-DMR Process	Advantage
	Number of trains	3	1	–
Machinery	60 MW e-motor or GT drivers	3	3	–
	Speed-increasing gearboxes	3	0	AP-DMR
	Compressor casings	3	3	–
	Anti-surge valves	6	5	AP-DMR
	Coil-wound heat exchangers	3	2	AP-DMR
Liquefier	Coil-wound bundles	9	4	AP-DMR
	JT valves	12	4	AP-DMR
	Separator vessels	9	3	AP-DMR
	LNG production (million tpy)	4.5	5	AP-DMR

Equipment count comparison

While the use of a pre-cooled liquefaction process, such as the AP-DMR process, increases the equipment count and CAPEX compared to the AP-SMR process, this logic is only valid on a per-train basis. For larger quantities of the LNG production, it is important to look at the larger picture and evaluate the CAPEX, plot space, and execution schedules per unit of production. For the production target of 4.5 million tpy, the AP-DMR process is more efficient and has the lower overall equipment count. Lower equipment counts generally translate to lower overall CAPEX, as well as reduced plot space. If the plant will be modularised, less plot space is particularly attractive as this reduces the module size and cost. This illustrates that one train size does not necessarily fit all projects.

While a single AP-SMR liquefaction train will have the shortest construction schedule and produce LNG quickest, any common infrastructure (such as pretreatment, loading jetty, storage tanks, etc.) is likely to eliminate that benefit. For the full liquefaction capacity, the AP-DMR process is expected to have the shortest construction schedule given that it contains fewer pieces of equipment, as illustrated in Table 1.

Besides the performance benefits inherent to the AP-DMR liquefaction process at this train size, the reduced equipment count directly reduces carbon intensity by decreasing the number of potential hydrocarbon leak paths. Fewer valves – with less stem packing to wear out and fail – and fewer overall flanged connections reduce the probability of fugitive greenhouse gas emissions escaping into the atmosphere.

Making the right choice

The evolving landscape of the LNG market demands innovative solutions that balance efficiency, reduce carbon intensity, and provide flexibility in plant design. For mid-size and smaller liquefaction facilities, the simplicity and scalability of processes such as the AP-SMR process can offer an elegant solution. For larger liquefaction facilities, options like the AP-DMR

process provide enhanced efficiency and reduced overall equipment count, cost, and schedule. These processes leverage Air Products' proven coil wound heat exchanger technology for reliable operation, supporting the global demand for LNG. As the LNG sector navigates the path towards cleaner, more efficient production, the company's commitment to innovative technology and modularisation continues to shape a future where 'right-sized', low-carbon LNG facilities are the standard. **LNG**

References

- OTT, C., SCOTT, K., ELKO, C., and KRETZ, C, 'Turning LNG Greener; LNG Liquefaction Using Electric Drive', *Gastech Exhibition & Conference Proceedings*, (2022).
- OTT, C., BERG, J., and KRETZ, C, 'Large or Small: Which is Better?', *LNG2023 Proceedings*, (2023).