Standardized, Modular Liquefaction Equipment and Technology

The world leader in LNG equipment and technology brings vast expertise to the small and mid-scale LNG market.

Standardized and modular LNG plant designs with capacities in the small-scale range of 100 – 500 MTPD through the mid-scale size of up to 2.0 MTPA provide developers a means of managing project risks, costs and schedule.

Depending upon the particular project criteria, developers of both greenfield and brownfield projects are evaluating new execution strategies that may provide a competitive advantage to the overall project. That's why choosing the most experienced provider with the best performing LNG process technology and equipment is paramount to your project's success. Air Products is the world's leader, having more than 50 years' of experience in supplying customers with the most proven LNG technology, equipment and services for all size LNG plants.
Choosing the best equipment and technology in the LNG industry

Air Products has contributed to the success of more LNG operations than any other company. Our LNG engineering and manufacturing team has been involved in the majority of LNG projects deployed around the world. As a result, our technology and equipment is successfully integrated into most of the LNG traded globally today. Air Products’ proprietary cryogenic heat exchanger technology and equipment has industry recognition for being the most proven and reliable units built with the utmost quality.

Unmatched LNG experience

No other company has over 50 years of experience in LNG engineering and process design. Only Air Products has a proven track record of having successfully commissioned over 100 heat exchanger units with 85 LNG trains in operation today, all of which successfully passed their performance test the first time. Air Products’ in-house team of highly-skilled LNG specialists developed our proprietary liquefaction processes. We have the unique ability to efficiently integrate the liquefaction process design and critical liquefaction equipment that leads to an optimization of performance, costs, operability and reliability that has become the benchmark of the LNG industry. Air Products is committed to helping our customers achieve their bottom line objectives, every step of the way.

Standardized equipment and technology for smaller capacity requirements

Marketplace dynamics naturally changed over the past years and will undoubtedly continue to evolve. More recently, owners and developers have been actively pursuing the monetization of smaller natural gas resources to meet their LNG project objectives. As a result, Air Products developed a novel suite of standardized processes and equipment. These offerings can accommodate a wide liquefaction range within the small and mid-scale markets.

No matter how small your capacity requirements, maintaining production is key to a profitable project. Air Products’ proprietary standardized offerings are robust, reliable, compact, and efficient. You can trust Air Products to deliver the best product solutions.
Standardized designs of small-scale liquefier units

For small plant capacities, Air Products offers our proprietary standard designs at nominal 200-400 TPD capacities using simple to operate nitrogen refrigeration systems. (see figure 1)

The AP-N™ nitrogen system skid is highly modularized to minimize field construction cost.

Benefits of nitrogen expander cycles for small-scale plants:

- **Reduced operating costs/improved revenue**
  - proven, established refrigeration technology with low capital expenditure

- **Simple operation**
  - easy start-up and shutdown,
  - can vent nitrogen refrigerant, and
  - cold or warm start-up periods are short.

- **Efficient turndown**
  - by 50% or more allowing for a quick ramp up or down.

- **No expensive refrigerant to manage or store**
  - only nitrogen is required

- **Improved low-cost efficiency**
  - newer designs that allow incorporation of multiple cryogenic expanders

- **Use of non-API machinery**
  - simple, inexpensive, and easily integrated

- **Safe and environmentally friendly**

Small-scale plant features suitable for:

- electric motor or gas turbine drive
- modular/skidded equipment
- adaptable for varying feed gas compositions
- adaptable to most global locations and design codes

**Figure 1: Air Products’ AP-N™ Configuration with Single Compander can Produce up to 500 TPD.**
Standardized designs for mid-scale liquefaction unit coil wound heat exchangers

For mid-scale plants, Air Products offers our proprietary single mixed refrigerant process (AP-SMRTM). (see figure 2)

Air Products’ robust coil wound heat exchangers (CWHE) are the heart of the liquefaction process and adaptable to multiple cycle configurations. (see figures 3)

Figure 2: CWHE Suitable for the Mid-Scale Range

Air Products’ CWHE’s are the heart of the liquefaction process

Figures 3: CWHE Suitable For Multiple LNG Plant Configurations:

Air Products’ AP-SMR™ (Air Products Single Mixed Refrigerant Cycle) configuration with front end pre-treatment, designed for simplicity while delivering lower unit costs.

Air Products’ AP-SMR™ configuration incorporating HHC removal with integrated TSA and stripping*; nitrogen rejection with stripping column.

Air Products’ AP-SMR™ configuration incorporating HHC removal with front end TSA and stripping*; nitrogen rejection with dedicated CWHE circuit*.

*Air Products patented process
**Mid-scale plant features suitable for:**
- electric motor or gas turbine drive
- varying feedgas compositions
- limited plant fuel requirements
- integration of heavy hydrocarbon removal
- integration of nitrogen rejection

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**Table 1: Benefits of Air Products’ Mid-Scale Coil Wound Heat Exchanger Units (CWHE):**

<table>
<thead>
<tr>
<th>Features</th>
<th>Description</th>
<th>Benefits/Advantages</th>
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<tbody>
<tr>
<td>High Availability &amp; Reduced Downtime</td>
<td>CWHE with external containment allows continuous operation even in the unlikely situation of tube leaks thus delaying any necessary repair to a scheduled shutdown.</td>
<td>Reduce OPEX</td>
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<td>Reduced plugging risk</td>
<td>CWHE design and tubing reduces the probability of plugging/blockage.</td>
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<td>High Efficiency</td>
<td>Refrigeration system with multiple cooling streams increases overall liquefaction efficiency. Closely matched temperature profiles within MCHE provide high performance and efficiency.</td>
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<tr>
<td>High Adaptability</td>
<td>Proprietary thermo data base facilitates a design whereby the selected refrigerant mixture/components provide flexibility to accommodate fluctuations in feedgas composition. Depending upon plant configuration, refrigerant components can be extracted from feedgas or sourced locally.</td>
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<tr>
<td>High Operational Flexibility</td>
<td>Multiple cooling streams increase operational flexibility, especially for fluctuating feedgas composition, daily and seasonal ambient temperature change. Ease of turndown with stability during shortage of feedgas.</td>
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<tr>
<td>High Robustness &amp; Reliability</td>
<td>CWHE with tube-in-shell design provides high resistance to thermal stresses/shock and ensures good vapor-liquid distribution.</td>
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<tr>
<td>External Protection</td>
<td>CWHE with external pressure shell provides added measure of protection in the event of an unlikely natural gas leak thus mitigating unnecessary releases into the atmosphere.</td>
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<td>Multi-Bundle Design</td>
<td>CWHE multiple bundle design (e.g. pre-cooling, liquefaction, and sub-cooling) can ease transportation constraints.</td>
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Flexible supply offerings to accommodate optimal project execution strategies:

Depending upon the project criteria, Air Products’ standardized offerings can be supplied to support a contractor’s preferred execution strategy whether it be modularized or field-erected.

**Modularized or field-erected mid-scale LNG train**

- **CWHE-multiple bundle configuration in a module**
- **Ningxia, China, 1000 TPD SMR trains**
- **Coil Wound Heat Exchanger-single shell unit**
- **Indonesia, 2.1 MTPA train** (Photo courtesy of Donggi-Senoro LNG)

**State of the art manufacturing facility located in Port Manatee, Florida**

The 300,000-square foot LNG heat exchanger manufacturing facility has ready access to port services, which facilitate global shipping of the equipment.

- **Typical standardized modular and compact designs**
- **Heat exchangers may consist of one, two, or three bundles**
Simple equipment integration

Air Products’ designs are readily adaptable to a wide range of feedgas compositions. This flexibility allows for an easy integration with the heavy hydrocarbons removed, as well as rejection of lighter components such as nitrogen.

<table>
<thead>
<tr>
<th>Table 2: Example Feedgas Composition</th>
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<tr>
<td>Mole %</td>
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<tr>
<td>--------</td>
</tr>
<tr>
<td>N2</td>
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<tr>
<td>C1</td>
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<td>C2</td>
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<td>C3</td>
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<td>C4</td>
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<td>C5</td>
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<td>C6+</td>
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<tr>
<td>Benzene</td>
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<td>Toluene</td>
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<tr>
<td>Xylenes</td>
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<tr>
<td>CO2</td>
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<tr>
<td>Total</td>
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Figure 4: Typical 0.5 MTPA LNG Plant Flow Diagram and Facility Layout

Technical services

Air Products can provide technical services from concept phase through operations:

- **Engineering studies:**
  - Feasibility, pre-feed and feed

- **Engineering review services for feed and EPC phases:**
  - Liquefaction area process design
  - Project development PFD, P&ID review, dynamic simulation
  - Plot plan, 3-D modeling, transportation and lifting

- **Engineering services during project execution phase:**
  - Participation in P&ID, HAZOP, model reviews, and control systems staging

- **Field technical advisory services:**
  - During transportation, construction, start-up and performance testing
  - LNG operations technical training

- **Technical operation services for new and existing plants:**
  - Debottlenecking studies, operations improvement, and optimization

- **LNG performance guarantee**
Before you decide on an LNG technology and equipment provider, consider this . . .

When exploring your options for investing in a small or mid-scale LNG facility, it’s important to understand the bottom line objectives for a successful project. Even though the planned individual train capacity may be smaller than the typical capacity of a baseload train in the past, the magnitude of the overall investment itself still warrants appropriate due diligence to guarantee a successful return over the life of your plant.

Ask your potential process licensor and contractor:

• How many LNG plants have you successfully started-up using your technology?
• What is your engineering team’s dedicated LNG plant experience?
• What start-up and operating issues have your customers experienced?
• How much design and engineering do you outsource on your LNG projects?

These are but a few of the questions that should be answered in the early stages of project development to ensure the overall investment of time and resources is properly managed.

Safety

Safety is our #1 priority. Air Products’ performance is consistently among the leaders in our industry, thanks to our teams’ efforts around the world to prevent injuries and send people home as safely as they arrived at work. Air Products is also committed to reducing the environmental impact by consuming fewer resources and lowering emissions. We’ve set aggressive reduction goals in energy, greenhouse gases, water, waste, emissions, and fleet emissions.

About Air Products

Air Products is a world leading industrial gases company celebrating 75 years of operation. The company’s core industrial gases business provides atmospheric and process gases and related equipment to manufacturing markets, including refining and petrochemical, metals, electronics, and food and beverage. Air Products is also the world’s leading supplier of liquefied natural gas process technology and equipment.