

## Saving Energy with Closed-Cycle Air Refrigeration

*Air Products and Chemicals' Energy-saving Cooler Reduces Emissions and Uses 75 Percent Less Space*



Air Products and Chemicals' Closed-Cycle Nitrogen Refrigeration (CCNR) compresses, cools, and condenses liquid natural gas that would otherwise be lost to the atmosphere during transport.

**The Challenge**—Conventional liquid refrigerants (which contained chlorofluorocarbons and hydrochlorofluorocarbons) damage the ozone layer. Researchers were attempting to find safer refrigeration technologies. In 1995, Air Products and Chemicals, Inc. and its joint venture partner, Toromont Process Systems, Inc., proposed to develop a high-risk, ultra-cold refrigeration technology called closed-cycle air refrigeration (CCAR). CCAR was based on using benign air at high pressure (82 atmospheres of pressure) as the refrigerant. ATP funding allowed Air Products to develop environmentally friendly cooling technology.

**The Economic Outcome**—Although Air Products achieved most of its technical goals, the food processing industry did not implement CCAR as expected, because of the high investment cost. Nevertheless, some of the processes are being commercialized in other areas:

- Air Products continued developing the technology with large air-separation units. The company sells approximately \$2 billion in liquid oxygen and nitrogen annually, one of the top U.S. liquid nitrogen suppliers. The ATP-funded compander saves approximately 3 percent in energy costs compared with existing air-separation units.

- As of 2005, Air Products was marketing a modified air-cycle refrigeration application to reliquefy and recapture evaporating natural gas lost during marine transportation. During transport on specially constructed tanker ships, liquid natural gas (LNG) is condensed 600 times to a liquid form and cooled to -250 F. Some of the gas evaporates, about 0.15 percent of cargo volume per day. The Air Products Liquid natural gas recovery system, based on the ATP-funded CCAR technology, is 75-percent smaller than comparable systems, a significant advantage on a ship where space is at a premium. Global LNG consumption has increased from approximately 40 quadrillion British thermal units (Btus) in 1970 to 100 quadrillion in 2004, and growth in demand is expected to continue.

**The Technical Outcome**—Air Products demonstrated key technical advances to facilitate closed-cycle refrigeration, including: 1) a single-stage compander (a compander is a [com]pressor and ex[pander] mounted on one shaft); 2) high pressure (1,200 pounds per square inch gauge, or psig), temperatures below -150°F, and compander shaft speeds of 30,000 revolutions per minute (rpm); and 3) low-leakage dry gas seals.

<b>Partnering Organization:</b>	Air Products and Chemicals Inc., Allentown, PA and Toromont Process Systems Inc., Houston, TX
<b>Project Duration:</b>	8/1/1995–1/31/1999
<b>Project Cost:</b>	\$2.1M ATP cost-share; \$4.3M industry cost-share
<b>Project Brief:</b>	<a href="http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=95-01-0150">http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=95-01-0150</a>
<b>Project Status Report:</b>	<a href="http://statusreports.atp.nist.gov/reports/95-01-0150.htm">http://statusreports.atp.nist.gov/reports/95-01-0150.htm</a> Research conducted December 2005
<b>Economic Case Study:</b>	<a href="http://www.atp.nist.gov/eao/gcr_819.pdf">http://www.atp.nist.gov/eao/gcr_819.pdf</a>