

Air Separation Technology— Ion Transport Membrane (ITM)

- > Lower unit costs for oxygen and syngas*
- > Reduced capital costs*
- > Excellent integration with power generation cycles*
- > Small footprint for greater flexibility*

“Ion Transport Membrane technology will change the way oxygen is separated and reacted. This breakthrough would significantly reduce costs for generating syngas, hydrogen and oxygen for gasification, clean energy, GTL and other markets.”

Ted Foster, Director, Business Development, Advance Gas Separation



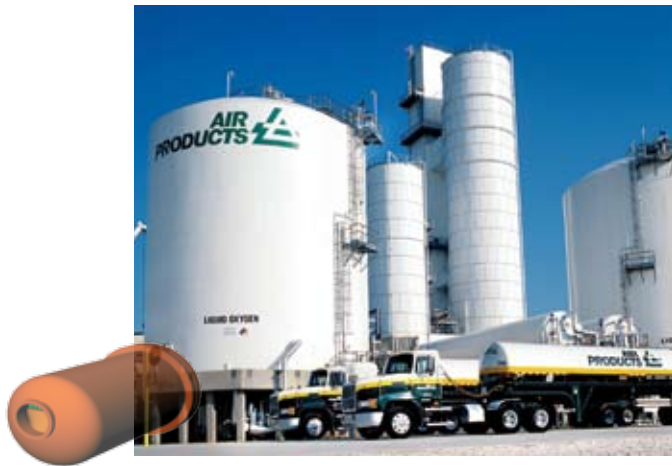
Background: Tonnage oxygen product with step-change reductions in capital and operating costs

In the face of rising oil, natural gas and electricity costs, gas-to-liquid (GTL) and gasification are increasingly attractive options for providing affordable, clean energy. The economics of providing oxygen and syngas impact the widespread commercialization of these processes. For instance, a cryogenic air separation unit represents approximately 15% of an integrated gasification combined cycle (IGCC) capital cost and requires a large fraction of the plant internal energy consumption. Air Products has a deep commitment to helping customers reduce their industrial gas cost in use. Working with our associates, Air Products has developed Ion Transport Membrane (ITM) technology, a groundbreaking way to provide reliable, cost-effective oxygen supply for high-volume applications, including GTL, IGCC, oxy-fuel, coal/carbonaceous feeds-to-liquids (CTL, XTL), hydrogen, SNG, carbon capture energy processes and others. ITM also can produce syngas for GTL and clean fuels at lower unit costs.

ITM can offer multiple benefits:

- 25%–35% reduction in capital requirements over conventional cryogenic oxygen plants
- 30% reduction in capital requirements for syngas plants
- 30% reduction in operation costs for oxygen
- 35%–60% reduction in power consumption (depending on product pressure) up to 1000 psig
- Consumes no net electricity
- Uses syngas, natural gas or other fuel
- Can be integrated with other high-temperature processes to produce electrical power and/or steam from depleted air
- Substantial reduction in cooling water consumption
- Compact, modular design has significantly smaller footprint than cryogenic ASU plant or the syngas plant

ITM's very high oxygen flux leads to compact designs and drives costs down. Here, a scale drawing of a 2000 TPD ITM oxygen vessel is shown in comparison to a 2000 TPD cryogenic separation unit.



Description: A revolutionary technology using ceramic membranes

ITM is a technology for gas separation that works by transporting an ionized gas through a ceramic membrane. The crystalline metal oxide structure of our proprietary membranes incorporates oxygen ion vacancies, through which the oxygen ions diffuse. ITM's very high flux and very high selectivity contribute to reductions in both capital and operating costs. ITM Oxygen membranes are 100% selective for oxygen, delivering a high-purity oxygen product. ITM Syngas membranes combine air separation and methane partial oxidation into a single-unit operation, resulting in significant cost savings for syngas production.

ITM Oxygen

Membrane wafer: Proprietary mixed conducting, nonporous ceramic planar membranes

Feed stream: Compressed air (150–500 psig/10–34 bar) heated to 800–900°C (1470–1650°F)

Products: Pure oxygen (99+%), power and/or steam

ITM Syngas

Membrane wafer: Proprietary mixed conducting, nonporous ceramic planar membranes, different from the ITM Oxygen membranes

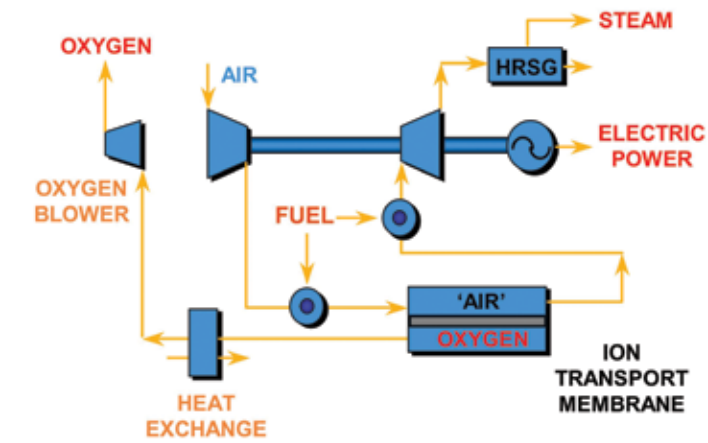
Feed streams: Natural gas, low-pressure air (20+ psig/1.4+ barg) heated to approach reactor inlet temperature, and steam

Products: Synthesis gas (hydrogen and carbon monoxide) for ultraclean liquid fuels, hydrogen and/or chemicals

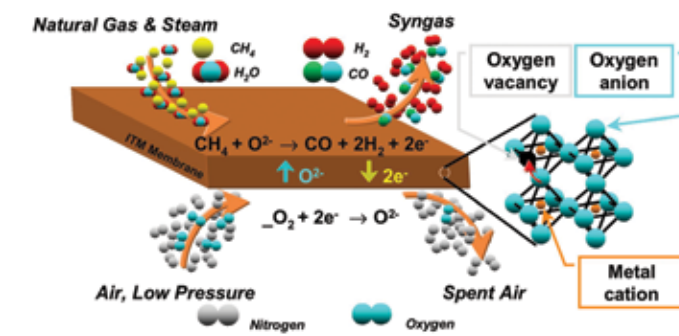
Compare: ITM Oxygen has excellent economic performance in many applications

Application	Product		Savings (% of Cryo ASU)	
	Oxygen (sTPD)	Power (MW)	Capital for Oxygen	Power for Oxygen
IGCC	3200	458	35%	37%
Decarbonized Fuel†	2400	300	35%	36%
Enrichment*	1500	260	27%	69%
Oxy-fuel†*	8030	500	48%	68%
GTL	12,500	n/a	20+%	n/a

†Enables carbon capture
*Uses existing gas turbine offerings



ITM Oxygen integrates well with power generation cycles. Steam and electric power can be generated from the depleted air stream.



Air Products' ITM ceramic membranes have high oxygen flux and high selectivity for oxygen, making them ideal for tonnage oxygen and syngas production.



Commercialization: Realizing the dream

Along with the U.S. Department of Energy and other associates, Air Products accelerated ITM research and development in 1997 and thereafter. Since then, Air Products has established the feasibility of producing commercial-scale ITM modules, developed a ceramic processing development infrastructure and operated prototypes with commercial-size membranes.

Pathway for ITM Oxygen

- Successfully operating 5 TPD sub-scale engineering prototype test plant since 2005
- Scale-up development plant to 150 TPD
- Develop additional commercialization partnerships
- Build first small commercial-size test unit in 2010+ (100s TPD)
- Build first large commercial-size test plant in 2012+ (1000s TPD)
- Ready to serve industrial markets near the end of the decade
- Serve large plant, hydrogen, clean power and IGCC markets in 2013+

Pathway for ITM Syngas

- Increase pilot plant size during 2008–2010 with engineering prototype for 1 million std. cu. ft./day (SCFD) syngas plant sufficient for 40 barrel/day Fischer-Tropsch (BPD F-T) liquids
- Develop additional commercialization partnerships
- Build first commercial-size test plant in 2010–2012 with 20–125 million SCFD syngas sufficient for 800–5000 BPD F-T liquids
- Build first commercial-size plant for large syngas and hydrogen applications, including single-train 100–500+ million SCFD syngas sufficient for more than 18,000 BPD F-T liquids

Acknowledgement

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For More Information

Air Products is currently in the third phase of a three-phase, 11-year, \$148 million program with the goal of reducing the cost of oxygen by one-third. We are also progressing to the end of the second phase of a three-phase, 16-year, \$163 million program with the goal of reducing the syngas plant cost by more than 30%. In these precommercial development phases, we seek additional partners and pilot sites for ITM Oxygen and ITM Syngas. To learn more about how you can be a part of the development of this revolutionary technology, contact us at one of the locations listed below.

ITM in the Americas

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