ILC Cryogenic Plants
Large Helium Refrigeration Plant Operating Experience
ILC--International Industrial Forums

Particle Accelerator Conference 2007
Albuquerque, NM

Richard Nolte, Jr.
June 28, 2007
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- Supplying the Refrigeration Services vs. Supplying Refrigeration Equipment
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AP/Linde Team Formed to Offer Cryogenics Own/Operate to ILC

- AP/Linde team provides refrigeration services
  - Distinct from sale of cryogenic equipment
  - Proven industrial way to lower cost and increase reliability

- Air Products as the prime contractor brings helium supply and refrigeration system operation

- Linde as the subcontractor brings refrigerator/liquefier equipment
ILC Cryogenic Team
Fast Facts

Air Products

- $10 B global gases, chemicals, equipment and services provider
- Serving technology, energy, healthcare and industrial markets
- Large global helium supplier
- Operations in more than 30 countries
- >20,000 employees worldwide
- Known for our innovative culture and operational excellence
- Corporate safety, environmental and quality commitment to all stakeholders

Linde Group

- $17 B global gases, process plants, equipment, and services provider
- Serving technology, energy, healthcare and industrial markets
- Large global helium supplier
- Operations in more than 70 countries
- >53,000 employees worldwide
- Leading process technologies
- Corporate safety & quality commitment to customers and employees
# Linde - Equipment Capabilities

## Main activities

<table>
<thead>
<tr>
<th>Category</th>
<th>Services/Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Solutions</td>
<td>Purifiers, Liquefiers, Reliquefiers, Refrigeration System</td>
</tr>
<tr>
<td>Hydrogen Solutions</td>
<td>Purifiers, Liquefiers</td>
</tr>
<tr>
<td>Storage &amp; Distribution Solutions</td>
<td>Distribution Systems, Storage Tanks, Dewars</td>
</tr>
<tr>
<td>Special Solutions</td>
<td>Special Cryogenic Plant Engineering</td>
</tr>
<tr>
<td>Customer Service Solutions</td>
<td>Installation, Maintenance, System Operation, Spare Parts</td>
</tr>
</tbody>
</table>
Air Products Brings Complementary Operating Capabilities

- Operates a third of world’s liquefiers associated with helium production
- Designed and installed majority of crude helium extraction plants
  - e.g., Cliffside, TX (USBLM)
- CERN particle accelerator liquefier operating and management experience
  - Liquid helium and nitrogen supply
  - 20 people assigned to manage cryogenic services
- Currently managing GE’s Florence, SC MRI manufacturing product supply and helium recovery
  - Liquid helium
  - Dewar helium
- Gardner Cryogenics (an APCI division) is the world’s leading developer, designer and manufacturer of liquid helium storage and related equipment
- Built and operated the refrigeration system for General Dynamics’ Hammond, LA facility for the SSC project
Air Products Worldwide Helium Network
Linde - Fabrication Facilities

Fabrication Facility Tulsa, USA
- A total of approx. 97,000 m² of floor space
- Approx. 400 skilled craftsmen and engineers

Fabrication Facility Schalchen, Germany
- A total of approx. 80,000 m² of floor space
- More than 740 skilled craftsmen and engineers

Several Fabrication Facilities by local suppliers
Linde Helium Solutions: USA

- World’s largest industrial helium liquefier at Liberal, Kansas (Air Products)

  **Capacity:**
  
  • 3,500 l/h @ 4.4 K, with LIN pre-cooling

  **Power input:**
  
  • ~2,600 kW
APCI designs, constructs and operates our own helium production facilities in U.S. and Algeria
Linde Helium Solutions: CERN

Large Scale Helium Refrigerator
18 kW for CERN - LHC

Cooling of superconducting magnets and cavities

Installed Operating Mode
• 4,400W @ 4.5 K isothermal
• 20,700W @ 4.5-20 K cold compr.
• 55,400W @ 20-280 K current leads
• 33,000W @ 50-75 K radiation shield

Power input:
4,100 kW, approx.

Expected He-Liquefaction with LN2-support is 5,800 l/h
Linde CERN Reliability

C169/LHC SERVICE CONTRACT

- Routine Operation
- Preventive / Corrective maintenance
- New Plants Commissioning

18KW PLANT
PM18 operation for LHC Cryomagnets tests 2002-2006

Production [H]

Availability

Downtime [H]

2002 2003 2004 2005 2006

Downtime [H]

Water / Air

EL

OP + Control

THE LINDE GROUP
APCI equipment helps safely deliver our products to the point of use . . .
Gardner Cryogenics Container

- Outer Carbon Steel Shell
- Super Insulation
- Nitrogen Shield
- Super Insulation
- Inner Stainless Steel Shell
- Vacuum
Air Products and Linde: The Global Leaders in Helium

- #1 production capacity share
  - least dependent on 3rd party purchases
- #1 manufacturer of helium production equipment
  - APCI and Linde
- #1 manufacturer of LHe containers
  - Gardner Cryogenics
- #1 manufacturer of LNG heat exchangers
  - allows early insight into future helium availability

Production Capacity Shares
Remote monitoring with Air Products
Conceptual Approach for Supplying Refrigeration Services (Own/Operate)

- Extension of our operating philosophy used at our own facilities
- Applications of these principles at our own plants has earned AP one of the best overall on-stream performance and safety records in the industry
- Applied at customer-owned facility with same results
APCI Plant Reliability is 99+%  

Statistical Data from Air Products owned and operated plants

<table>
<thead>
<tr>
<th></th>
<th>Lost Production (days/year)</th>
<th>Outages Frequency (# / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled Outages</td>
<td>4.3 (1.2%)</td>
<td>1</td>
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<tr>
<td>Unscheduled Outages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6 hours</td>
<td>0.5</td>
<td>4</td>
</tr>
<tr>
<td>24-72 hours</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>24-72 hours</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Total Unscheduled</td>
<td>3.0 (0.8%)</td>
<td>7.8</td>
</tr>
<tr>
<td>Total Outages</td>
<td>7.3 (2%)</td>
<td>8.8</td>
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</table>

APCI Plant Reliability is 99+%
## APCI Helium Equipment Experience

<table>
<thead>
<tr>
<th>CUSTOMER</th>
<th>LOCATION</th>
<th>DESCRIPTION</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAS GAS/QATAR GAS</td>
<td>QATAR</td>
<td>HELIUM RECOVERY FROM LNG</td>
<td>2006</td>
</tr>
<tr>
<td>CLIFFSIDE REFINERS, L.P.</td>
<td>AMARILLO, TX</td>
<td>HELIUM ENRICHMENT UNIT</td>
<td>2001</td>
</tr>
<tr>
<td>BROOKHAVEN NL (RHIC)</td>
<td>BROOKHAVEN, NY</td>
<td>TRANSFER LINES</td>
<td>2000</td>
</tr>
<tr>
<td>DUKE ENERGY</td>
<td>BORGER, TX</td>
<td>CRUDE PLANT</td>
<td>2000</td>
</tr>
<tr>
<td>AIR PRODUCTS</td>
<td>LIBERAL, KS</td>
<td>LIQUID PLANT</td>
<td>1999</td>
</tr>
<tr>
<td>PIONEER NATURAL RESOURCES</td>
<td>FAIN, TX</td>
<td>CRUDE PLANT</td>
<td>1997</td>
</tr>
<tr>
<td>HELIOS</td>
<td>ARZEW, ALGERIA</td>
<td>LIQUID PLANT</td>
<td>1995</td>
</tr>
<tr>
<td>CRYOR</td>
<td>ORENBURG, RUSSIA</td>
<td>LIQUID STORAGE</td>
<td>1994</td>
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<tr>
<td>AIR PRODUCTS</td>
<td>LIBERAL, KS</td>
<td>LIQUID PLANT</td>
<td>1992</td>
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<tr>
<td>DUKE ENERGY</td>
<td>LIBERAL, KS</td>
<td>CRUDE UPGRADE</td>
<td>1990</td>
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<tr>
<td>AIR PRODUCTS</td>
<td>SHERMAN, TX</td>
<td>LIQUID PLANT</td>
<td>1985</td>
</tr>
<tr>
<td>AIR PRODUCTS</td>
<td>SHERMAN, TX</td>
<td>GAS/LIQUID PLANT</td>
<td>1982</td>
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<tr>
<td>INTERNATIONAL</td>
<td>RED ROCK, AZ</td>
<td>GAS/LIQUID PLANT</td>
<td>1980</td>
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<tr>
<td>CITIES SERVICE</td>
<td>ULYSSES, KS</td>
<td>GAS/LIQUID PLANT</td>
<td>1968</td>
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<tr>
<td>USBLM</td>
<td>EXELL, TX</td>
<td>CRUDE PLANT</td>
<td>1967</td>
</tr>
<tr>
<td>PHILLIPS PETROLEUM</td>
<td>SHERMAN, TX</td>
<td>CRUDE PROCESS ONLY</td>
<td>1963</td>
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<tr>
<td>KERR McGEE</td>
<td>NAVAGO, AZ</td>
<td>GASEOUS PLANT</td>
<td>1962</td>
</tr>
<tr>
<td>PHILLIPS PETROLEUM</td>
<td>DUMAS, TX</td>
<td>CRUDE PLANT</td>
<td>1962</td>
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<tr>
<td>NORTHERN NATURAL GAS</td>
<td>BUSHTON, KS</td>
<td>CRUDE PLANT</td>
<td>1962</td>
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<tr>
<td>CITIES SERVICE</td>
<td>ULYSSES, KS</td>
<td>CRUDE PLANT</td>
<td>1962</td>
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<tr>
<td>USBLM</td>
<td>KEYES, OK</td>
<td>GASEOUS PLANT</td>
<td>1959</td>
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# Major APCI Service Agreements

<table>
<thead>
<tr>
<th>Plant</th>
<th>Location</th>
<th>Type of Agreement</th>
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</thead>
<tbody>
<tr>
<td>560 TPD O2 plant</td>
<td>AZ, USA</td>
<td>Technical Services Package</td>
</tr>
<tr>
<td>75 TPD O2 plant</td>
<td>Orange County Ca, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>Helium</td>
<td>Algeria</td>
<td>Operations and Maintenance assistance</td>
</tr>
<tr>
<td>Helium Purifier</td>
<td>Amarillo, TX</td>
<td>Technical Services Package</td>
</tr>
<tr>
<td>Helium liquefiers</td>
<td>CERN Switzerland</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>N2 generator</td>
<td>UK</td>
<td>Maintain</td>
</tr>
<tr>
<td>220 TPD O2 / 100 TPD N2</td>
<td>NV, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>N2 Generator</td>
<td>UK</td>
<td>Preventative Maintenance</td>
</tr>
<tr>
<td>1100 TPD O2</td>
<td>NV, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>1400 TPD O2</td>
<td>NV, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>4 x Nitrogen Generators</td>
<td>Netherlands</td>
<td>Agreed rates</td>
</tr>
<tr>
<td>160 TPD O2</td>
<td>Houston TX, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>180,000 SCFH N2</td>
<td>CO, USA</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>2800 TPD O2</td>
<td>Trinidad</td>
<td>Operate and Maintain + Admin services</td>
</tr>
<tr>
<td>Nitrogen generator</td>
<td>UK</td>
<td>Quarterly Audit</td>
</tr>
<tr>
<td>2100 TPD Oxygen Generator</td>
<td>Republic of South Africa</td>
<td>Operate and Maintain</td>
</tr>
<tr>
<td>1200 TPD Oxygen Generation</td>
<td>Malaysia</td>
<td>Technical Services Package</td>
</tr>
<tr>
<td>650 TPD Oxygen plant</td>
<td>AZ, USA</td>
<td>Operations and Maintenance Assistance</td>
</tr>
<tr>
<td>Oxygen generator</td>
<td>Shipboard generator</td>
<td>Operations and Maintenance Assistance</td>
</tr>
<tr>
<td>1600 TPD O2 Plant</td>
<td>Punta Arenas, Chile</td>
<td>Technical Services</td>
</tr>
<tr>
<td>3 N2 generators</td>
<td>NY, USA</td>
<td>Operate and Maintain</td>
</tr>
</tbody>
</table>
Own/Operate Approach

- Remote Monitoring

- Operate/maintain facility at minimum cost with maximum reliability

- Continuously improve overall plant performance

- Capital improvements to increase efficiency and/or production

- Safety is our 1st priority
Need for an Industrial ILC R&D Program

DOE/NSF Review: May 2007

Goal of this review... was to evaluate the R&D plan, milestones and resource needs for FY2007 and beyond, and to plan for U.S. activities relating to development of test infrastructure and industrial partnerships...

Gerry Dugan
GDE Americas Regional Director

Report of the ICR Committee: June 14, 2007

...essentially no funds have been available so far for industrial R&D...which will be a very important input for validating the costs assumed for a significant fraction of the ILC components. Also, industrialization can lead to competition and further cost savings....

International Cost Review Committee
ILC
Suggested Plan of Action for ILC Cryogenics

- Begin early dialog (funded R&D engineering) with the industrial gas industry
- Utilize industry’s experience/resources to move from reference design to engineering design
- Engage industry to refine current cost estimate
APCI - Linde Value Added Summary: Our Team Brings Unique Capabilities

- Linde Turbines and Cold Compression Equipment, Fabrication and Helium Solutions
- APCI Global Operations Organization
- Remote monitoring improves up-time
  - 12 year management experience with 6000 assets
  - Fully staffed 24/7 real time data collection center
- Best operating practices
  - Helium conservation measures
  - Power conservation
  - Optimize manpower requirements
  - Maximize on-stream
- Safety best practices
- Helium supply backup
- Financing expansions or upgrades
  - Engineering, design and build skills
To Conclude

The Own/Operate industrial gas model:

- A proven way to lower
  - capital costs
  - operation and maintenance costs

- A proven way to increase
  - plant reliability and backup supply
  - safety best practices
Thank you
tell me more

www.airproducts.com