Flexible Aerogel Insulation for Power-Generation Applications

August 2009
Presentation Outline

• Product Overview
• Application
• Reference Projects
• Questions
What Is An Aerogel?

- Aerogels are nanoporous solids invented in the 1930’s
  - Aerogels are created when silica is gelled in a solvent
    - *When the solvent is removed, what remains is “puffed-up sand”, with up to 99% porosity*
  - Nanopores cage the air molecules, retarding heat flow
  - Long molecular chains increase the solid path-length through the silica, reducing thermal conductivity

- Twin innovations helped move aerogels from lab curiosity to industrial product
  - Supercritical CO₂ extraction reduces cycle times from months to hours
  - Casting the wet gel into a fibrous batting provides mechanical integrity

**The Aerogel Advantage:**
Superinsulation performance in a flexible blanket form
Aerogel Thermal Performance – With the Flexibility of a Blanket

• Start with a non-woven blanket
  – Typically polyester, glass, carbon, or ceramic fiber
• Fill that blanket with a wet gel
• Remove the solvents via supercritical CO₂ extraction
• Roll the blanket onto a spool

**Step 1:** Fill fibrous batting with a liquid-solid solution

**Step 2:** Extract solvents with supercritical carbon dioxide

**Step 3:** Resulting dry, fiber-reinforced aerogel blanket
Aspen’s Aerogel Manufacturing Process

Silica Sol → Catalyst → Dopants → Casting → Gelation → Dry fiber blanket → Drying → Supercritical extraction → Rolls packed for shipment
Aerogel Factory In East Providence, RI

- Casting
- Extraction
- Drying
- Tank farm
Heath and Safety Aspects of Aerogels

- Aerogels are an amorphous (non-crystalline) silica with 97% of particles larger than 45μm
  - Only the pores are nano-scale (~0.01 μm)
  - Aerogel particles are much larger
- Amorphous silicas have been studied by OSHA, EPA, and the OECD, concluding:
  - “Demonstrated lack of toxicity, mutagenicity.”
  - “Is not expected to pose a carcinogenic risk.”
  - “Silicas are inert when ingested, and unlikely to be absorbed through the skin.”
  - “No concerns for human health.”
- Typical dust loading in fab-shop is <5 mg/m³
  - OSHA limit for amorphous silica is 80 mg/m³

Recommended PPE is paper dust mask, work gloves, and safety glasses
Aerogels Are Nanoporous, Not Nanoparticles

Air sampling in an aerogel fabrication shop reveals that 97% of dust particles are larger than 45 microns.

Particle Count Histogram

- 0 to 45 µm: 3%
- 45 to 75 µm: 11%
- 75 to 150 µm: 33%
- >150 µm: 53%

Particle size (microns)

Cutting or installing Pyrogel or Cryogel does not generate “nanoparticles”
Aspen’s Industrial Products Span the Temperature Range

**Cryogel Z (5 and 10 mm)**
-460°F to 200°F (-273°C to 90°C)
- 2 to 3 times lower $k$-value than cellular glass or PUR/PIR foams
- Fast, simple installation is insensitive to workmanship or site conditions
- Excellent durability and fire resistance
- Available with integral vapor barrier:
  - Single-step installation
  - Multiple plies provide system redundancy

**Pyrogel XT (5 and 10 mm)**
-40°F to 1200°F (-40°C to 650°C)
- 3 to 5 times lower $k$-value than perlite, calcium silicate, cellular glass, or mineral/glass fiber
- Excellent productivity, especially on towers, vessels, and large pipe
- Water repellant
- Resists mechanical abuse and thermal degradation
Aerogels Have the Lowest $k$-Value of Any Industrial Insulation
Traditional Insulation Thickness Ratios vs. Pyrogel XT

Ratios provide equal resistance in planar configurations.

Does not account for geometric effects of pipe cover.
Pyrogel XT enables lighter designs at the same level of thermal protection, reducing loads on pipes, shoes and hangars.
Pyrogel Resists the Enemies of Insulation: Water, Heat, and Abuse

**Damage Tolerant**
Cryogel and Pyrogel easily withstand most impact or compressive loading events (e.g., footfalls, tool strike), and will spring back to the original performance even at loads > 100 psi. Further, because there is no brittle failure mechanism (its a flexible blanket), damage remains local and will not propagate.

**Water Repellant**
During Katrina, an aerogel-insulated pipe was flooded with sea water. Afterward, the pipeline was drained, dried, and retested with no degradation. That pipe was then sealed, and is now in service off the coast of Africa.

**Thermally Stable**
Aspen Aerogel’s products do not use organic binders, so will not crumble or sag in hot service.
Aerogels Will Not Promote Corrosion Under Insulation (CUI)

• Pyrogel and Cryogel are durably water repellent, even at high temperatures
• The open-cell nature of Aspen’s Aerogel blankets allows any water that gets around or beneath the insulation to evaporate out
• Aerogel pH is engineered to be > 7

Pyrogel is super-hydrophobic, yet also...

Water droplet with contact angle >150°
Hot Applications
Pyrogel XT Has Many Benefits On Hot Process Equipment

- Industry’s best $k$-value saves energy with 2-5X less material
  - Greater space efficiency
- Installation productivity
  - Shop- or field fabrication
  - Very fast in 1 & 2 ply designs
  - Single-man installs
  - Good in difficult-access areas
- Greater in-service durability
  - Durably hydrophobic
  - Will not crack, crumble, or sag
- Reduces jacketing, banding, and vapor barrier costs
- Packed volume reduced 5-10X
  - Less scrap, trucking, storage
- Single part number simplifies logistics, planning
- Excellent fire protection

All four designs provide the same level of thermal protection

6” pipe at 600°F (315°C)

Ambient conditions = 65°F, 2 mph wind, 0.1 emissivity
Installation of Flexible Aerogel Blankets Is Fast and Intuitive

Pyrogel blanket wraps over the pipe

Cladding & banding provide mechanical and weather protection

Butt joints (staggered if using multi-ply construction)
Flat-Pack Elbows Ship Easy and Install fast

Pre-kitted “lobster tail” elbows ship flat for better packing efficiency

Multi-layer lobster tails are quickly layed up on the elbow and taped in place

Subsequent layers are installed with a staggered joint pattern

The finished elbow is covered with a vapor barrier and jacketed with metal
A Full Line of Complimentary Products Is Available

- Aerogel elbows & jacketing
- Pre-jacketed V-groove for small-bore pipe
- Removable covers
- Panel systems
- Inspection ports
## Pyrogel Enables Increased Pipe Density

<table>
<thead>
<tr>
<th>Insulation Material</th>
<th>Pyrogel</th>
<th>Rigid Pipe Cover</th>
</tr>
</thead>
</table>
| **2” Pipe:**  
56% more on a rack | ![Pyrogel Diagram](image1) 
5.38 in. | ![Rigid Pipe Cover Diagram](image2) 
.838 in. |
| **6” Pipe:**  
44% more on a rack | ![Pyrogel Diagram](image3) 
10.13 in. | ![Rigid Pipe Cover Diagram](image4) 
14.63 in. |
| **12” Pipe:**  
28% more on a rack | ![Pyrogel Diagram](image5) 
2 in.  
16.25 in. | ![Rigid Pipe Cover Diagram](image6) 
20.75 in. |

*Assumes 2 inch clearance space*
Aerogel Offers Simplified Inventory Management and Logistics

- Results of a trade study of a typical new-build plant insulation project…

<table>
<thead>
<tr>
<th></th>
<th>Rigid Pipe Cover</th>
<th>Pyrogel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distinct Part No.’s</strong></td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Insulation only</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Distinct Parts</strong></td>
<td>36,000 pieces</td>
<td>790 rolls</td>
</tr>
<tr>
<td>45:1 ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Packed Volume</strong></td>
<td>5,700 m³</td>
<td>930 m³</td>
</tr>
<tr>
<td>6:1 ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Packed Footprint</strong></td>
<td>53 m x 53 m</td>
<td>22 m x 22 m</td>
</tr>
<tr>
<td>2 m stack height</td>
<td></td>
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Pyrogel can reduce the material handling and inventory management required on big jobs.
Pyrogel Reduces Local Portage of Insulation Materials

- A 3” pipe at 300°F can be insulated with 1” of fiberglass or ¼” of aerogel
- Under many workplace rules, one person can lift no more than 40 lbs
- A 40 lb box of 3x1 fiberglass weighs 40 lbs, and insulates 27 lineal feet
- A 40 lb roll of aerogel would insulate 188 lineal feet
- Using aerogel instead of fiberglass reduces manual portage by 7X
Economics On 1000 m of 30” Pipe (North America)

[Bar chart showing total installed cost for Pyrogel, Calcium Silicate, and Mineral Wool, with breakdowns for Logistics, Other Materials, Labor, and Insulation.]
Binder Burnout Is a Major Cause of Mineral Wool Heat Loss

- Initial region of binder decomposition
- Insulation sags due to weak fiber consolidation
- Burnout zone spreads upward, resulting in further sag and heat loss

Pristine

Initial sag

Final sag
Mineral Wool-Over-Pyrogel for Temperatures Above 250°C

- Mineral over Pyrogel saves space by using the materials where they’re most effective
  - PGXT at high temperatures
  - MW at low temperatures
- The cost of the Pyrogel is minimized by using it at the smallest diameters
- The burnout of the mineral wool binders is minimized by limiting its exposure to the highest process temperatures
  - This should increase the mechanical durability and overall longevity of the system
Mineral Wool Over Pyrogel XT Can Be the Low-Cost Solution

All seven designs have equivalent heat loss.
Reference Projects
14 MW Biomass-Fueled Power Station

• **Location:** Flixborough, UK
• **Scope:** 200 feet of 6” pipe
• **Date:** Oct-Dec, 2006
• **Process Temp.:** 800-900°F
• **Design Goal:** Heat conservation
• **Insulation:** 30 mm Pyrogel
• **Other Factors:** Old mineral wool delivered insufficient superheat

• **Results:**
  – Material performed better than predicted
  – Unsafe touch temperatures brought back under 120°F
Steam and Condensate Piping

• **Location**: La Porte, TX
• **Scope**: 10,900 feet of pipe
• **Date**: Oct-Dec, 2006
• **Process Temp.**: 180-500°F
• **Design Goal**: Heat conservation
• **Insulation**: 1½” Perlite → 1 layer of ¼” Pyrogel
• **Other Factors**: T&M contract
• **Results**:
  – Insulation “drag race” on adjacent 8” lines showed 5:1 productivity advantage
  – Remainder of job was converted to Pyrogel 6350
  – Job finished ahead of schedule and 26% under the original perlite bid
Condensate Tank

- **Location**: La Porte, TX
- **Scope**: 20’ x 40’ tank
- **Date**: November, 2006
- **Process Temp.**: 180°F
- **Design Goal**: Heat conservation
- **Insulation**: 1½” Perlite → 1 layer of ¼” Pyrogel
- **Other Factors**: Heavy weather during installation

**Results:**
- Entire tank was insulated in one day
- Despite heavy rain fall, the aluminum jacketing was left off for a week; the insulation experienced no damage or water absorption
Hot Air Ducts for Industrial Dryers

• **Location**: Marshall, MN, USA
• **Scope**: 100’s of meters of ductwork for an industrial dryer at a corn-processing facility
• **Date**: May, 2009
• **Process Temp.**: 175-650°F
• **Design Goal**: Heat conservation
• **Insulation**: 20-70 mm of Pyrogel XT
• **Results**:
  – Original mineral wool had become water-logged, heavy, thermally inefficient, and corrosive
  – Pyrogel XT installed on the ground in a fraction of the time required for mineral wool
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Municipal Steam Tunnels In Baltimore, MD

- **Scope**: Removable covers for manholes, steam tunnels
- **Date**: November, 2007
- **Process Temp.**: 150-450°F
- **Design Goal**: Personnel protection, heat conservation, reduced blanket weight
- **Other Factors**: Tunnel flooded shortly after installation
- **Results**:
  - After the tunnel was flooded for 10 days during a winter storm, the blankets were inspected and found to be “good as new”
Heat Exchanger Modules

• **Location**: Northern Alberta
• **Scope**: Three pre-insulated heat exchanger modules
• **Date**: Mar, 2007
• **Process Temp.**: 250-400°F
• **Design Goal**: Heat conservation
• **Insulation**: 2” mineral wool → ¾” Pyrogel
• **Other Factors**: Modules insulated in Kansas City; transported to Alberta
• **Results**:
  – Insulation survives the abuse of long-distance road transport
  – Thinner profile reduced interference near inlets, outlets, and structural supports
Heat Exchanger Insulation Survives Transport and Handling

03/07/2007

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Heat Exchanger Insulation Survives Transport and Handling
SCR Duct, Billings, MT

- **Location**: Millings, MT
- **Scope**: 10-14’ SCR ducting
- **Date**: June, 2008
- **Process Temp.**: 750°F
- **Design Goal**: Heat conservation
- **Other Factors**: Insulated the duct-work on the ground
- **Insulation**: 50 mm of Pyrogel
- **Results**:
  - Fast, high-quality install
  - Has now become the standard worldwide specification for SCR ducting
Bridge Crossing Near Ft. McMurray, Alberta

- **Scope:** 800 m of 24” pipe, pre-insulated in Edmonton and trucked 6 hours to remote site
- **Date:** Summer 2007
- **Process Temp.:** 149°C (300°F)
- **Design Goal:** 7-day cool-down to 60°C (140°F)
- **Insulation:** 3½” minwool w/ electric heat trace ➔ 3.3” Pyrogel, no heat trace
- **Other Factors:** Eliminate electric heat tracing, transformers, and utilities
- **Results:**
  - Saved $330K in heat tracing and $100K per year in O&M costs
Pyrogel Enables Pre-Insulation, Transport of Pipe & Equipment
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Unique Application: Pre-Insulated Sweep Elbow
Aerogel Blankets Are Durable with Good Compression Resistance
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Summary and Conclusions

• Efficiency
  – Most efficient insulation materials in the world
  – Saves energy
  – Reduces touch temperatures

• Productivity
  – Flexible blanket form for increased productivity
  – Streamlined planning, supply chain, and logistics
  – Better space efficiency
  – Enables pre-insulation of piping and equipment

• Durability
  – Resistance to damage by water, heat, and mechanical abuse
  – Will not promote corrosion under insulation
  – Exceptional fire protection
Thank You

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NANOTECHNOLOGY AT WORK