Reduction of Energy Usage Through Insulation Selection & Design

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Morgan Thermal Ceramics
Outline

New Insulation Options

• Microporous Insulation
  • History and Theory
• RFC, Bio-Persistence, EH&S and Regulation
  • Superwool Alternatives

Insulation Design Techniques

• Material Selection
Microporous Insulation

Theory and Application
A “New” Type Insulation

1930s – Theory of microporous insulation is conceptualized

1950s – Manville develops into a viable product ideal for aerospace applications

1980s – New techniques in raw material manufacturing allowed for cost effective use in industrial applications

1990s – Exclusive use of microporous insulation in Flight Data Recorders

Current – Continued expansion of material usage into commercial applications
What is microporous insulation?

• A low density powder comprised of heat resistant particles (metal oxides / inorganic opacifiers) and high temperature fibers compressed to form a microporous structure
  • See ASTM C1676-08 for detailed information
• Most efficient insulation commercially available that controls all three modes of heat transfer
  • Radiation
  • Conduction
  • Convection
Microporous Insulation

- Trapped Air
- Opacifiers
- Fumed Silica
Microporous Insulation

Opacifiers scatter IR resisting transfer by radiation

Heat Source

Heat Source
Microporous Insulation

Minimal points of contact and low intrinsic thermal conductivity prevent conduction
Microporous Insulation

Micro voids between particles prevent convection currents from forming.
Thermal Conductivity

![Graph showing thermal conductivity of fiberglass mat as a function of temperature.](image-url)
Thermal Conductivity

Temperature (F)

Thermal Conductivity (BTU-in/hr-ft²-F)

- Mineral Wool Board
- Fiberglass Mat
Thermal Conductivity

- Mineral Wool Board
- Fiberglass Mat
- Vermiculite Board
Thermal Conductivity

The graph shows the relationship between thermal conductivity (BTU-in/hr-ft²-F) and temperature (°F) for different materials:

- **Mineral Wool Board**
- **Fiberglass Mat**
- **Vermiculite Board**
- **RCF 8 pcf Blanket**

The graph indicates that as the temperature increases, the thermal conductivity increases for all materials, but at different rates.
Thermal Conductivity

![Graph showing thermal conductivity vs. temperature for different materials like Mineral Wool Board, Fiberglass Mat, Vermiculite Board, RCF 8 pcf Blanket, and AES 8 pcf Blanket.](image-url)
Typical Product Types

Board
- Rigid material encapsulated in thin plastic
- Lowest thermal conductivity of all product types

Panel
- Core material encapsulated in high temperature cloth
- Lower dust than board

Flexible
- Core material encapsulated in high temperature cloth and quilted
- Flexible for round or contoured shapes
Mechanical Properties

Temperature Use Limit

- Core always good up to 1800 F
- Standard cloth has a lower temperature rating
  - Cloth can be sacrificial depending on application

Compression Resistance

- Dependent on density
- Similar to vermiculite board

Shrinkage

- Less than 1% up to 1700 F
- Approximately 3% at 1800 F
RCF and Superwool

Review and Introduction to Superwool Plus and HT
TC’s commitment to a healthy environment

- Increasing concern over the health effects relating to RCF has caused Thermal Ceramics to develop alternative fibre products, these come under the brand name “Superwool®”.
- TC has been proactive in studying the health aspects of RCF for more than 20 years.
- TC has helped to lead the work in the USA and in the EU in the fields of:
  - Epidemiological (human) studies
  - Toxicological (animal and *in vitro*) studies
- The studies have been carried by independent scientists and organisations and are used as references by regulators.
Why are regulators concerned about RCF?

- History shows that fine asbestos fibres inhaled into the lungs may cause cancer.
- RCF is not asbestos.
- However, RCF has a higher biopersistence than most glass wools and mineral wools.
- Animal testing of RCF in the early 1990s showed signs of carcinogenicity.
- Human epidemiology has shown
  - reduction in lung function among smokers exposed to RCF.
  - a correlation between pleural plaque development and cumulative RCF exposure.
Bio-Persistence

• **Definition**: The ability of fibers to resist removal from the lungs by natural mechanisms (i.e., dissolution and breakage).

• **How Measured?**: It is measured by the time it takes for half of the fibers induced to disappear from the lungs.
Short fibers and fragments, whether inhaled or produced by breaking long fibres, are cleared from the lungs like other dusts encountered in everyday life.
Bio-Persistence Results

Half Life of Various HTIW via Intertracheal Instillation

40 Days = EU Exoneration Limit for Intertracheal Instillation

(1.) Source: Biopersistence by Intertracheal Instillation from Fraunhofer Reports For Superwool and from BIA-Report for RCF: (2/98: Fasern - Tests zur Abschätzung der Biobeständigkeit und zum Verstaubungsverhalten)
## RCF Regulation by Country

<table>
<thead>
<tr>
<th>Permissible or Recommended Exposure Limit (PEL or REL))</th>
<th>European Union</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 0.1 to 1.0 fibers/cc</td>
<td>• 0.2 to 1.0 f/cc <strong>mandatory</strong> PEL (Canada)</td>
<td></td>
<td>• 0.5 f/cc <strong>voluntary</strong> REL (U.S.)</td>
</tr>
<tr>
<td>• PEL is typically <strong>mandatory</strong></td>
<td><strong>Examples for Canada:</strong></td>
<td></td>
<td>• 0.2 f/cc <strong>mandatory</strong>, Regulated in California, August 3, 2010</td>
</tr>
<tr>
<td></td>
<td>• 0.5 f/cc PEL (Ontario, CN)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 0.2 f/cc PEL (British Columbia and Alberta, CN)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>RCF’s Status</th>
<th>European Union</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Class 2 Carcinogen</td>
<td>• Possible Carcinogen</td>
<td></td>
<td>• Possible Carcinogen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regulatory Control</th>
<th>European Union</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>All aspects of RCF use are controlled by regulation including:</td>
<td>• Regulated</td>
<td></td>
<td>• Not regulated in U.S.</td>
</tr>
<tr>
<td>• Workplace cleanliness,</td>
<td></td>
<td></td>
<td><strong>Exception:</strong> As of August 2010, <strong>Cal OSHA</strong> regulated PEL of 0.2 f/cc for RCF</td>
</tr>
<tr>
<td>• Disposal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Obligation to use alternatives if possible</td>
<td></td>
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</tbody>
</table>
### Superwool® Regulation by Country

<table>
<thead>
<tr>
<th>Classification of Superwool Family</th>
<th>European Union (EU)</th>
<th>United States and Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Alkaline Earth Silicate (AES)</td>
<td>• Alkaline Earth Silicate (AES)</td>
</tr>
<tr>
<td></td>
<td>• Not RCF</td>
<td>• Not RCF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Superwool Status</th>
<th>European Union (EU)</th>
<th>United States and Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Fully exonerated from any carcinogen classification in the European Union under the Provisions of Directive 97/69/EC</td>
<td>• Viewed as a nuisance dust</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• May cause temporary, mild mechanical irritation to the eyes, skin, nose and/or throat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PEL/Regulatory Control</th>
<th>European Union (EU)</th>
<th>United States and Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• No PEL</td>
<td>• No PEL</td>
</tr>
<tr>
<td></td>
<td>• Not Regulated</td>
<td>• Not Regulated</td>
</tr>
</tbody>
</table>

The Superwool Family of Products are Alkaline Earth Silicate (AES) fibers; Not RCF
RCF Alternatives

Superwool Plus and Superwool HT
Superwool – why it is an alternative to RCF?

• Man-made vitreous silicate fibres (MMVF) containing >18% alkali and alkaline earth oxides are classified as Carcinogen 3 in Europe.

• These fibres may be exonerated from classification as a carcinogen if one of the specific criteria described under nota Q of Directive 97/69/EC are met.
  • The animal tests at RCC which lead to the classification of RCF also included X607; however animals exposed to X607 did not develop excess tumours. This fulfils the exoneration criteria under Nota Q.
  • Superwools have shown <40 days half-life in IT tests on rats which also provides complete exoneration under Nota Q.

• This European regulation is the only official system that exonerates MMVFs (including Superwools) from classification as carcinogens.
RCF and Superwool on a chart showing the EU 18% oxides rule for vitreous silica fibres.

- Alkali and Alkaline Earth oxides
- Aluminium and Zirconium oxides

18% divide

Silica

Fibres with more than 18% soluble oxides avoid the C2 classification. Animal testing is needed for complete exoneration.

RCF

SW HT: 74% Silica/23% Cao/3% Other
SW Plus: 64% Silica/30% Cao/6% MgO
Superwool® Plus and RCF

<table>
<thead>
<tr>
<th>Property Comparison of Superwool Plus vs. RCF Blanket</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>HP RCF</td>
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<tr>
<td>---------</td>
</tr>
<tr>
<td>Continuous Use Temperature Limit (° F)</td>
</tr>
<tr>
<td>Classification Temperature Limit (° F)</td>
</tr>
<tr>
<td>Thermal Conductivity (BTU-in/hr-ft²-° F) @ 1000° F</td>
</tr>
<tr>
<td>8 lb/ft³ Blanket @ 1800° F</td>
</tr>
<tr>
<td>8 lb/ft³ Blanket @ 2100° F</td>
</tr>
<tr>
<td>Over Temperature Cushion</td>
</tr>
<tr>
<td>Bio-Persistence, Half-Life (days)</td>
</tr>
</tbody>
</table>

Key Advantages of Superwool Plus over HP RCF:
- Low Bio-Persistence
- Low Shrinkage up to Classification Temperature
- Low Thermal Conductivity
Thermal Conductivity – vs. HP RCF

Thermal Conductivity (ASTM C-201)
HP RCF 8 lb/ft³ vs. Superwool Plus 8 lb/ft³ Blankets

Heat Loss (BTU/ft²/hr): 3” thick at 1500° F
- HP RCF = 352
- Superwool Plus = 277
- Difference = 75 (23.9%)

Superwool® Plus 8 lb/ft³ blanket has a thermal conductivity that is more than 15% lower than HP RCF 8 lb/ft³ blanket at mean temps >800° F
Superwool® Plus 8 lb/ft³ blanket has a thermal conductivity that can be significantly lower than Fiberglass Mat and is binder-free.
Superwool® 607® HT

Key Characteristics of Superwool 607 HT

Low Biopersistence
- First low biopersistent fiber with a classification temperature of 2372°F (1300°C)
- Disposable in standard landfills

Excellent Physical Properties
- Lowest shrinkage of any comparable insulation up to its classification temperature
- Continuous use temp of 2102 to 2300°F (1150 to 1260°C) depending on product
- Short-term exposure limit that is 90°F (50°C) higher than standard RCF

Proven Track Record
- In use in Europe since the end of 2005
- Proven(2) reliability for applications such as:
  - wall boilers
  - tunnel kilns
  - glass pre-heating furnaces
  - mold wrap for steel industry

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(1) Available in blanket, paper, board, bulk, modules, mastics and vacuum formed shapes
(2) As demonstrated in Europe and/or U.S. sales trial
# Superwool® 607® HT vs. HP RCF

## Property Comparison of Superwool 607 HT vs. HP RCF Blanket

<table>
<thead>
<tr>
<th>Property</th>
<th>HP RCF</th>
<th>Superwool 607 HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Use Temperature Limit (°F)</td>
<td>2150</td>
<td>2102</td>
</tr>
<tr>
<td>Classification Temperature Limit (°F)</td>
<td>2400</td>
<td>2372</td>
</tr>
<tr>
<td>Thermal Conductivity (BTU-in/hr-ft²-°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 1000° F</td>
<td>0.93</td>
<td>0.83</td>
</tr>
<tr>
<td>@ 1800° F</td>
<td>2.05</td>
<td>2.11</td>
</tr>
<tr>
<td>@ 2100° F</td>
<td>2.49</td>
<td>2.75</td>
</tr>
<tr>
<td>Over Temperature Cushion</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Bio-Persistence, Half-Life (days)</td>
<td>50</td>
<td>≤ 10</td>
</tr>
</tbody>
</table>

**Key Advantages of Superwool 607 HT over HP RCF:**
- Low Bio-Persistence
- Low Shrinkage up to Classification Temperature
Thermal Conductivity (ASTM C-201)
HP RCF vs. Superwool® 607® HT vs. Magnesium Silicate 8 lb/ft³ Blanket

Mean Temperature (° F) vs. k-Value (BTU/in/hr-ft²-° F)

- **HP RCF**
- **Superwool 607 HT**
- **Magnesium Silicate**

<table>
<thead>
<tr>
<th>Mean Temperature (° F)</th>
<th>HP RCF</th>
<th>Superwool 607 HT</th>
<th>Magnesium Silicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>0.44</td>
<td>0.35</td>
<td>0.56</td>
</tr>
<tr>
<td>1000</td>
<td>0.93</td>
<td>0.83</td>
<td>1.31</td>
</tr>
<tr>
<td>1500</td>
<td>1.61</td>
<td>1.66</td>
<td>2.48</td>
</tr>
<tr>
<td>1800</td>
<td>2.05</td>
<td>2.11</td>
<td>3.38</td>
</tr>
<tr>
<td>2100</td>
<td>2.49</td>
<td>2.75</td>
<td>4.33</td>
</tr>
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</table>
Energy Savings Through Insulation Selection and Design

How to use the “new” insulation types
Typical Selection Criteria

• Thermal Efficiency
• Space Constraints
• Maximum Use Temperature
• Durability
• Ease of Fabrication
• Fire Situations
• Cost
  • Short Term and Long Term
Thermal Efficiency

• Regulations and consumer market push for more energy efficient designs
  • New regulations outlining energy efficiency requirements
  • CA and FL leading the nation
  • Market also demanding more energy efficient solutions
• How to meet this demand?
  • Use more efficient insulation materials
Theoretical Case Study – Heater Box

- Standard water heater box for pool / spa application
- Gas Firing Box
- Water Coils Above
- Flame temps at 2000°F
# Theoretical Case Study – Heater Box

<table>
<thead>
<tr>
<th>Current Style Designs</th>
<th>Optional Design</th>
<th>Optional Design</th>
<th>Optional Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1.5” RCF Board</td>
<td>• Outer Temperature - 379°F</td>
<td>• Outer Temperature - 384°F</td>
<td>• Outer Temperature - 244°F</td>
</tr>
<tr>
<td>• Outer Temperature - 384°F</td>
<td>• Heat Loss - 536 BTU / SF / Hr</td>
<td>• Heat Loss - 993 BTU / SF / Hr</td>
<td>• Heat Loss - 427 BTU / SF / Hr</td>
</tr>
<tr>
<td>• Heat Loss - 1015 BTU / SF / Hr</td>
<td>• Energy Savings ~$90 annually</td>
<td>• Energy Savings - None</td>
<td>• Energy Savings ~$165 annually</td>
</tr>
</tbody>
</table>

- Half the thickness for the same insulating properties
- Over twice as efficient as standard design
Options

Limitless Options
• Multiple options exist with these types of insulation to add value to your products and reduce the energy usage of the heater units

Energy Usage
• Reduce energy loss through the insulation lining
• Reduce energy usage by lowering set point temperatures

Space
• Reduce the unit footprint by lowering the thickness requirement of the insulation lining
Items to Consider

These material are options to aid in design
• Another tool for your designs

The larger the area, the larger the impact
• Larger Boilers will have more annual savings

Understand the materials and environment
• Not every material type is appropriate for every situation

Ask for assistance
• There are multiple experts in insulation materials that can assist

Don’t let insulation be the energy drag in your systems
• Options are available to allow for maximum efficiency!
QUESTIONS??

• *Thanks for your attention*

• The information presented in this presentation (and all documents linked) can be confidential and legally protected. They are exclusively for the present audience or readers to whom it has been presented.

• All the properties given are typical values and should not be considered as a specification.
Thank you