• **UF Resin Definition, Raw Materials, Reactions**

• **Typical Resin Requirements and Applications**

• **Process Matrix in Nonwovens**

• **Resin Modifications, Cure Speed, Flexibility, Binder Allocation**

• **UF Resin Aging, Stability and Emissions**
• **Urea-Formaldehyde Resin (UF)** is a class of synthetic resin obtained by chemical combination of urea and formaldehyde

• **UF** is a type of *thermosetting adhesives*:
  » Polymerizes to a permanently solid and infusible state upon the application of heat
  » Acid curing
  » Good water tolerance
  » High cross-linking ability
  » High degree of versatility
  » Inexpensive
  » Used in a wide variety of applications
• **Formaldehyde** ⇔ **Gas** ⇔ **37- 56% solution**
  • **Natural gas** (methane – \( CH_4 \)) ⇔ **Methanol** (\( CH_3OH \))
  • **Methanol** ⇔ **Formaldehyde** (\( CH_2O \))

• **Urea** – **white crystalline powder, prills**
  • **Natural gas** ⇔ **Ammonia** (\( NH_3 \))
  • **Ammonia** (\( NH_3 \)) + **Carbon Dioxide** (\( CO_2 \)) ⇔ **Urea** (\( CH_4N_2O \))
Two Major Stages in Urea - Formaldehyde Reaction:

1. Methylolation (Electrophilic Substitution)
   - Initial reaction from mixing urea with formaldehyde
   - First step in the resin manufacturing process
   - *Exothermic* part of the resin manufacturing process
   - Not much MW or viscosity build

2. Condensation
   - Secondary reaction from mixing urea with formaldehyde
   - MW and viscosity build during this stage
   - Water is lost with the formation of ether or methylene linkages
   - Ether linkages are more water soluble, methylene linkages are not
   - The higher MW, the lower resin water dilutability
Methylolation

Formation of mono-, di- and trimethylolureas

\[
\text{CO} \quad \text{NH}_2 \quad + \quad \text{CH}_2\text{O} \xrightarrow{\text{H}^+ \quad \text{OH}^-} \quad \text{CO} \quad \text{NH} \quad \text{CH}_2\text{OH}
\]

Methylol Group
Condensation of methylolureas

\[
\text{urea} \xrightarrow{\text{CH}_2\text{O}} \text{mmu} \xrightarrow{\text{CH}_2\text{O}} \text{dmu}
\]

\[
\text{Condensation of methylolureas}
\]

\[
\text{ether of methylolureas}
\]

\[
\text{Ether Linkage}
\]
Condensation

trimethylolurea + mmu → branched resin polymer

Methylene Linkage
A chemical compound formed by the union of two molecules of a monomer.

A polymer intermediate containing relatively few structural units.

A chemical compound formed by polymerization, and consisting essentially of repeating structural units.

<table>
<thead>
<tr>
<th>Monomer</th>
<th>Dimer</th>
<th>Oligomer</th>
<th>Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A compound that can undergo polymerization</td>
<td>A chemical compound formed by the union of two molecules of a monomer</td>
<td>A polymer intermediate containing relatively few structural units.</td>
<td>A chemical compound formed by polymerization, and consisting essentially of repeating structural units.</td>
</tr>
</tbody>
</table>
Factors Affecting Resin Characteristics

- Resin Technology / Composition
- Temperature
- pH
- Molar Ratio
- Viscosity (Advancement and Solids)
- Additives
- Limit on Free Formaldehyde
UF Production

The Production Operator

Resin reactor

Formaldehyde
urea

Cooling water
Steam

Condensate

Additives

Distillate receiver

Condenser

Scales

Storage tank

Transportation/packaging

Happy Customer

6/1/2010
• **UF resins are designed for the underlying application, and usually for a specific customer**

• **Majority of UF is used in wood applications - composites, particleboards, etc.**

• **Big volume is also used in glass mat / nonwovens production. Resin could be used:**
  - Alone
  - As a major component of a binder system
  - As a minor component/cross linker in the binder with thermoplastic resins for specialty applications
Chemical binders are essential raw materials for non-wovens added to the web already formed or to the batt of fibers in forming stage.

Functions of a binder:
- Primary – to hold fibers in pre-determined form
- Secondary – to improve web properties
Glass fiber produced in various grades, diameters, lengths w/wt sizing

Type of white water system – HEC, PAA, AO and additional additives

UF Resin

Latex – SBR, SBA, Acrylics, VA, etc.

Chemical Binder

Process
Factors Impacting the Product Strength

- **Substrate**

- **Binder**

- **Interactions between substrate and binder**
• Stability and adequate shelf life
• A wide operating window
• Tack characteristic associated with the plant and process conditions
• Cure speed appropriate for the process
• Targeted physical properties – tensile, tear (flexibility / rigidity)
• High water dilutability
• Emissions – level and type
• Compatibility with process water
• Compatibility with additives – latex, defoamer, etc.
• Low cost
The binder is selected for defined application based on different aspects:

- **Cure speed**
- **Physical attractive forces between polymer chains (e.g. reaction and/or compatibility with process additives)**
- **Chemical crosslinking**
- **Film formation**
- **Wetting ability**
- **Binder allocation**
1. **Molar Ratio**
   - MR range in UF is 0.6 – 2.0
   - The higher MR, the faster cure
   - The higher MR, the higher emissions

2. **pH**
   - Resin buffer capacity
   - Catalyst system
   - Additives in the system – e.g. latexes

3. **Molecular size**
   - In general, larger molecules, faster cure
   - Size of molecules has impact on viscosity

4. **Additives**
The main factors:

1. Formation of ether and methylene linkages 
   \( (\text{MR, pH, } T) \)
   - ether linkages – clear resin
     \[ \text{CH}_2 \quad \text{O} \quad \text{CH}_2 \]
   - methylene linkages – opaque
     \[ \text{CH}_2 \]

2. Used additives
3. Cooking time
Major factors affecting resin flexibility / rigidity

- MR
- Cross-linkers
- pH
- Additives
Compatibility with Latex

UF chemist can make resin more compatible with latex by adjusting:

• Resin's Molecular Weight

• MR

• Selecting components and additives

• Designing the right buffer capacity of the resin to match or enhance the latex properties
• An even binder coverage over the whole fiber

• The binder concentrated at the fiber cross-points
Wetting Ability

Different resins composition, different wetting properties
• Aging mechanism of U-F resins depend on the
  • Final Formaldehyde/Urea molar ratio,
  • Storage pH
  • Free urea in the resin

• Aging of U-F resins involve
  • Changes in resin structure
    • Initial increase in linear methylol groups
    • Subsequent decrease in linear methylol groups
    • Corresponding increase in linear methylene groups
    • Minor changes in branched methylol and methylene groups
    • Decrease in free urea

  • Increase in bulk viscosity
  • Decrease in absolute molecular weight
  • Decrease in cure speed
  • Decrease in ultimate bond strength
Functional Group Changes upon aging

NMR data over 25 day period

- Linear Methylene
- Branched Methylene
- Linear Methylid
- Branched Methylid
- Linear Ether
- Branched Ether

Number of Days

Percentage
- Although bulk viscosity is an important parameter used to monitor process ability of the resin, it does not provide a measure of resin performance upon aging.

- The increase in bulk viscosity as resins age probably results from associative forces such as hydrogen bonding.

- Decrease in cure speed is related to decrease in molecular weight and methylol content rather than an increase in methylene content.
Resin Stability

25°C

Days

pH

Viscosity (cps)

35°C

Days

pH

Viscosity (cps)

45°C

Days

pH

Viscosity (cps)

Resin Stability
Emissions and Curing By-Products

- Water
- Formaldehyde
- Methanol
- Low molecular weight compounds
Ammonia modified UF resin at >400°C:

- Decomposition products of UF part: CH2O, HCl, HCN, COx, SOx, NOx, Na₅Ox, sodium carbonate & other organic compounds

- Ammonia-flammable, will flash off

- Low flashpoint amines - will flash off with heat with the presence of characteristic ammonia odor, decomposition products include COx, NOx
Acknowledgements

I would like to thank Teong Tan, Mark Anderson and Reggie Mbachu for their help and valuable advices
Agenda

- What is a Latex Binder?
- Designing a Latex Binder
- Nonwoven Performance
Latex in Glass Mat Products -

3 distinct functions

1. **Additives** to UF
   (Roofing mat, up to 12wt%)

2. **Sole Binders** (Specialty mat)

3. **Coatings**
Latex as Glass Mat Binder (x500)
Latex Binders

- Water Borne

- Versatile
e.g. UF Modifier or Sole Binder or Coating

- Tailor properties: Flexibility
  Hydrophobicity
  UV, Solvent resistance
Latex made by **Emulsion Polymerization:**

- Polymerization occurs in each particle
  *monomer migrates through H2O to particle*
  *(100-1000 nm diameter)*

- Polymers (& most monomers) are **NOT**
  water soluble.

- Polymer particles are stabilized by
  surfactants & colloids
Viscosity vs. Molecular Weight

Water soluble Polymer vs. Latex

Viscosity (cp) vs. Mw (1000s) for 50% solids.
The Life of a Latex Particle…

- **Formation & Growth of Polymer Particle**
  variable composition, Mw, particle size

- **Particles (wet) deposited** onto substrate
curtain coater, spray, roll coat

- **Film Formation Process:**
  Individual particles → Coalesced polymer film
  
  *Coalescents?*
  
  *Heat? Time?*
Film Formation

Aqueous Dispersion

Water Evaporation Water Evaporation

Close Pack Spheres

Polymer Deformation

Continuous Polymer Film
**Dried Latex v. Water Soluble Polymer**

**Latex**
- St/acrylic latex + polyol, Tg=130°C

**Aquaset 600**
- Polyacid + polyol
Nonwoven Performance:

- Tensile Strength (rigidity)
- Tear Strength
- “Elasticity” (extensability)
- Hand or “feel”
- Hydrophobicity
Latex Product Development

**Monomer Selection**
- Tg
- Functionality
  - Adhesion
  - Mechanical Stability
  - Water Resistance
  - Post crosslinking
  - Solvent Resist.
  - Hydrophobicity
  - UV Resistance

**Process Parameters**
- Molecular Weight Crosslink Density
  - Film Strength
  - Cohesive Strength
  - Heat Resistance
  - Tack
- Physical
  - %Solids
  - pH
  - Viscosity
  - Surface Tension
- Particle Size Distribution
  - Mechanical Stability
  - Viscosity response
  - Cohesive Strength
  - Flow and leveling
  - Coalescence

- Film Rheology
- Hand
- Film Strength
- Heat Resistance
- Adhesion
- Mechanical Stability
- Water Resistance
- Post crosslinking
- Solvent Resist.
- Hydrophobicity
- UV Resistance
- %Solids
- pH
- Viscosity
- Surface Tension
- Mechanical Stability
- Viscosity response
- Cohesive Strength
- Flow and leveling
- Coalescence

- Image of monomer droplet
- Image of aqueous medium
- Image of polymer particles

- = Surfactant
- = Monomer
- = Initiator Radical
- = Propagating Radical
Composition Guidelines

- **Acrylics** (BA, EA, EHA, MMA) for UV resistance.
  - MMA exceptional.
  - EHA for water resistance.

- **Styrene** (St) for Water/alkalai Resistance (hydrophobic)
  - Degrades over extended exposure to UV.

- **Acrylonitrile** (AN) for Solvent Resistance (hydrophillic)
  - Discolors under UV (unsaturation).

- **Vinyl Acetate** (VA) Low Cost
  - Hydrolyzes
  - Degrades under UV
Backbone Composition

Vinyl Monomer

\[ \text{C} = \text{C} \]

Vinyl Polymer

\[ \cdots - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \cdots \]
Acrylates

Ethyl Acrylate

\[ R: \quad C \quad \text{—} \quad \text{OC}_2\text{H}_5 \]

\[ \text{H} \quad \text{H} \]

\[ \text{C} \quad \text{—} \quad \text{OC}_2\text{H}_5 \]

\[ \text{H} \quad \text{C} \quad \text{—} \quad \text{OC}_2\text{H}_5 \]
Methacrylates

H: CH₃  R: \( \text{C} = \text{O} \rightarrow \text{CH}_3 \)

Methyl Methacrylate
Acrylic Copolymer

Ethyl Acrylate/Methyl Methacrylate Copolymer
**Rigidity:** affected by Tg

\[ Tg = f(\text{monomer choice, crosslinking}) \]

---

**Thermoset:**
- Rigid, No creep

**Latex**

---

**Modulus (log)**

- High Crosslinking
- Low Crosslinking
- High MW

---

**Temperature**

---

\[ G'(\text{rubbery plateau}) \sim \frac{1}{Me} \sim \text{Crosslink density} \]

---

# Monomer Choice – Guidelines

*Hydrophobicity independent of Rigidity*

<table>
<thead>
<tr>
<th>Monomer</th>
<th>Tg (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most Hydrophobic</strong></td>
<td></td>
</tr>
<tr>
<td>2-EHA</td>
<td>- 85</td>
</tr>
<tr>
<td>Styrene</td>
<td>+ 105</td>
</tr>
<tr>
<td>Butyl Acrylate</td>
<td>- 52</td>
</tr>
<tr>
<td>Methyl Methacrylate</td>
<td>+ 105</td>
</tr>
<tr>
<td>Ethyl Acrylate</td>
<td>- 21</td>
</tr>
<tr>
<td>Methyl Acrylate</td>
<td>+ 8</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>+ 130</td>
</tr>
<tr>
<td>Vinyl Acetate</td>
<td>+ 29</td>
</tr>
<tr>
<td>Acrylic Acid</td>
<td>+ 103</td>
</tr>
<tr>
<td><strong>Most Hydrophilic</strong></td>
<td></td>
</tr>
</tbody>
</table>
Crosslinking Chemistry #1: **Amides**

Acrylamide (AM)  
N-Methylol Acrylamide (NMA)

- Acid/Heat-catalyzed Crosslinking $\rightarrow$ methylene bridge

\[
\begin{align*}
\text{CH}_2=\text{C} & \quad \text{H} \\
\text{C} & \quad \text{NH}_2 \\
\text{O} & \\
\text{CH}_2=\text{C} & \quad \text{H} \\
\text{C} & \quad \text{NH} \\
\text{O} & \quad \text{CH}_2 \\
\text{N} & \quad \text{O} \\
\text{HCH}_2 & \\
\text{NCHO} & \\
\end{align*}
\] $\Delta$  

\[
\begin{align*}
\text{CNH}_2 & \quad \text{HO} \\
\text{O} & \quad \text{CH}_2 \\
\text{NC} & \quad \text{H} \\
\text{H} & \quad \text{NC} \\
\text{H} & \quad \text{O} \\
\text{CH}_2 & \\
\text{O} & \\
\end{align*}
\] $\Delta$  

\[
\begin{align*}
\text{CN} & \quad \text{H} \\
\text{H} & \quad \text{NC} \\
\text{CH}_2 & \quad \text{O} \\
\text{O} & \quad \text{CH}_2 \\
\end{align*}
\] $+ \text{H}_2\text{O}$  

$+ \text{CH}_2\text{O}$
Crosslinking Chemistry #2: Acid/Polyol

\[
\text{poly(AA)} \quad \text{polyol} \quad \text{poly(AA)}
\]

Heat Catalyst

Ester Crosslinks + H\(_2\)O

\(\text{CH}_2\text{O-free}\)

Aquaset LT\(^\text{TM}\)
Nonwoven Performance:

- Tensile Strength (rigidity)
- Tear Strength
- “Elasticity” (extensability)
- Hand or “feel”
- Hydrophobicity
**Tensile Strength: Latex-Modified UF**

**Dry Tensile Strength**

10% Modifier in UF, Cured 2.5min/204C
95% confidence intervals (pooled, n=15 from 3 mats)

<table>
<thead>
<tr>
<th>Material</th>
<th>Wet Tensile Strength (lb/in)</th>
<th>Dry Tensile Strength (lb/in)</th>
<th>Average % Strength Retention (wet/dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UF</td>
<td>72</td>
<td>58</td>
<td>63</td>
</tr>
<tr>
<td>UF/LatexA</td>
<td>35</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>UF/LatexB</td>
<td></td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>UF/LatexC</td>
<td></td>
<td>35</td>
<td>70</td>
</tr>
</tbody>
</table>
Tear Strength: Latex-Modified UF

Tear Strength
10% modifier in UF, cured 2.5min/204C
95% confidence interval (n=12 from 3 mats)
Crosslinked Latex (sole binder):

High strength & high temperature flexibility

17% LOI on glass mat, cured 2min/200C (no pre-dry)
Crosslinked Latex (sole binder):  
**Excellent Tear Strength**

Tear Strength: Crosslinked Latex vs. Modified UF (10% modifier)  
1 inch glass, 17% LOI

![Bar chart showing tear strength comparison between UF/ModA, Latex, Tg=72C, and Latex, Tg=55C.](chart.png)
THANK YOU

Jean Brady
The Dow Chemical Company
Spring House, PA 19477
215-619-5438
Novel Formaldehyde Free Technology For Glass Fibers: Hycar® FF 26920 & Hycar ® FF26921

Building and Industrial Mat Meeting 5/19-5/21
Dennis P. Butcher – Technical Market Manager
Lubrizol Advanced Materials
Formaldehyde Free Technology For Glass Fibers

- Wet-laid
  - Fiberglass/Industrial Mats
  - Duct Liner
  - Carpet Tiles

- Saturation Application
  - Filtration
Drivers for Formaldehyde Free Technology

- The Clean Air Act
- California Proposition 65
- ACGIH lists formaldehyde as suspected human carcinogen
  - American Conference of Governmental Industrial Hygienists
- IARC Group 1 Human Carcinogen
  - International Agency for Research on Cancer
- Free formaldehyde level permissible is continuously being reduced by various regulations globally
- European Union, California, New England States are forefront in reducing the limits on free formaldehyde on various substrates
  - California Air Resources Board – Wood Products
- Reducing formaldehyde may allow potential of “Green Branding” for products using alternative technologies
  - US Green Building Council – LEED Certification
What does a binder need to do in industrial mat applications?

- **Bind fibers**
- **Provide structural integrity**
  - Dimensional stability and strength
    - Initially during manufacturing of mat product
    - In final composite
- **Provide processability and product integrity**
  - Resistance to:
    - Solvents
    - Plasticizers
    - Petroleum based materials
- **Provide application appropriate feel**
  - Stiffness
  - Flex
How do we measure binder performance?

- Dry Tensile Strength
- Hot Dry Tensile Strength
  - Thermal Stability
- Hot Wet Tensile Strength
  - Wet Strength
- Plasticizer Resistance Tensile Strength
  - Mat Chemical Resistance
Overall Physical Performance Targets

Achieve similar or improved properties of crosslinked industry leading acrylic with a formaldehyde free system.

Overall Performance of leading acrylic + 2.5 pph melamine formaldehyde

- High Dry Tensile Strength
- Good Hot-Dry Tensile Strength
- Hot-Wet Tensile Strength
  - Good wet/dry ratio
- Plasticizer Resistance Tensile Strength
# Conventional Benchmark

<table>
<thead>
<tr>
<th>Product</th>
<th>Tg°C</th>
<th>Solids</th>
<th>pH</th>
<th>Viscosity</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading Acrylic</td>
<td>+29</td>
<td>49.0</td>
<td>5.5</td>
<td>60 cP</td>
<td>Can Modify with MF or UF Resin to Improve: Hot Dry Tensile Strength Hot Wet Plasticizer Resistance</td>
</tr>
</tbody>
</table>

Product commonly used in construction products alone and with crosslinking resins

**Key Properties**
- Dry Tensile
- Hot Dry Tensile Strength
- Hot / Wet Tensile
Procedures for Testing Binders

**Substrate:** Whatman® Microfiber GF/A

**Test Conditions:**
- Target LOI: 25%
- Dry/Cure Conditions: 2 minutes at 375°F
- Sample Conditioning: Samples conditioned for 24 hours at 70±1°F and 50±2% RH
- Crosshead speed for tensiles- 1”/min.
- Avg. of 4 specimens
- Tensiles recorded in lbs./in.

**Dry Tensile**
- 1x 6 Sample
- Gauge length – 4”

**Hot-Dry Tensile**
- 1"x9" Sample - die cut
- Gauge length - 7”
- Samples placed in hot slot and tested after 1 minute at 375°F

**Hot-Wet Tensile**
- Samples immersed 10 minutes in H₂O at 180°F
- Tested using same parameters as dry tensile

**Plasticizer Soak**
- Samples immersed 2 minutes in Diisononyl Phthalate (DINP) at RT
- Tested using same parameters as dry tensile
Glass Fiber Saturation Test Procedure

- Substrate- Whatman Microfiber Grade: GF/A
- Saturate substrate sheets with latex on Padder
- Dry sheets in oven at 190°C/ 2 min.
- Cut sample into strips and measure tensile properties
Dry Tensile

System Summary on Whatman Microfiber GF/A
25% Binder Level

<table>
<thead>
<tr>
<th>Material</th>
<th>Dry Tensile (lbs/in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading Acrylic</td>
<td>11.45</td>
</tr>
<tr>
<td>Leading Acrylic + 2.5 pph MF</td>
<td>11.37</td>
</tr>
<tr>
<td>Hycar® FF 26920</td>
<td>11.48</td>
</tr>
<tr>
<td>Hycar® FF 26921</td>
<td>11.60</td>
</tr>
<tr>
<td>Hycar® FF 26921 + 2K</td>
<td>11.91</td>
</tr>
</tbody>
</table>
Hot Dry Tensile

System Summary on Whatman Microfiber GF/A
25% Binder

Tensile (lbs/in.)

- Leading Acrylic: 3.9
- Leading Acrylic + 2.5 pph MF: 5.2
- Hycar® FF 26920: 5.8
- Hycar® FF 26921: 6.7
- Hycar® FF 26921 + 2K: 5.5

28% Improvement
System Summary on Whatman Microfiber GF/A
25% Binder

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile (lbs/in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading Acrylic</td>
<td>2.2</td>
</tr>
<tr>
<td>Leading Acrylic + 2.5 pph MF</td>
<td>2.9</td>
</tr>
<tr>
<td>Hycar® FF 26920</td>
<td>2.3</td>
</tr>
<tr>
<td>Hycar® FF 26921 + 2K</td>
<td>5.8</td>
</tr>
</tbody>
</table>

65-100% Improvement
Plasticizer Soak Tensile

System Summary on Whatman Microfiber GF/A
25% Binder

<table>
<thead>
<tr>
<th>Plasticizer Tensile (lbs/in.)</th>
<th>Leading Acrylic</th>
<th>Leading Acrylic + Hycar® FF 26920 2.5 pph MF</th>
<th>Hycar® FF 26921</th>
<th>Hycar® FF 26921 + 2K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.9</td>
<td>11.9</td>
<td>11.9</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.7</td>
</tr>
</tbody>
</table>
Composite Tensile Results

System Summary on Whatman Microfiber GF/A 25% Binder

- Leading Acrylic
- Leading Acrylic + 2.5 pph MF
- Hycar® FF 26920
- Hycar® FF 26921
- Hycar® FF 26921 + 2K

Performance equaled or exceeded control in all cases
Based upon initial development work, additional studies were performed to better understand application properties and property development

1. Attempt to better quantify wet tensile improvement
2. Examine wet tensile strength development as a function of time
3. Examine tensile strength development as a function of temperature
Wet and Dry Tensile – 2 min cure @ 190ºC

Dry and Wet Tensile with % Retention

35-60% improvement in wet/dry tensile ratio

Sample ID

- Leading Acrylic + 2.5 MF
- Hycar® FF 26920
- Hycar® FF 26921
- Hycar® FF 26921 FF Xlink #1
- Hycar® FF 26921 FF Xlink #2

% retention wet/dry
Better wet tensile properties at equal or lower curing duration
Cure Temperature Study – 2 min.

CURE STUDY - Wet Tensile on Whatman GF/A 25%LOI

- Leading Acrylic + 2.5 MF
- Hycar® FF 26920
- Hycar® FF 26921
- Hycar® 26921-FFXlink #1
- Hycar® 26921-FFXlink #2

Wet tensile strength improved under normal comparable drying conditions

Control
Findings ........

1. Formaldehyde free products showing improved tensile properties on microglass over MF crosslinked Leading Acrylic system
   - Hycar® FF 26920 compared to control
   - Hycar® FF 26921 shows improved hot and wet tensiles compared to control

2. Hycar® FF 26921 demonstrates improved cure response compared to control
   - Opportunity for energy savings?
**Solution Description:**
Hycar FF-26920 is a one component system replacing the use of traditional acrylic emulsion binder and melamine-formaldehyde cross-linker for a non-yellowing binder for most industrial use fiberglass nonwovens.

**Unique Benefits:**
- Formaldehyde Free System
- Unsurpassed Hot Dry Tensile Strength
- Self Cross-linking
- 1K solution to a typical 2K system

**Potential Applications:**
- Wet-laid
  - Fiberglass/ Industrial Mats
  - Duct Liner
  - Carpet Tiles
  - High Tech Filtration

**Value Creation:**
- “Green” implications because of Formaldehyde Free system
- Reduced emissions at substrate manufacturing process
- Extended durability and usage life of substrate because enhanced hot dry tensile strength

**General Specs**
- **Tg:** +29°C
- **Viscosity:** 105 cps (#2 @ 60rpm)
- **pH:** 8 – 9
- **Solids:** 44%
**Solution Description:**

- Hycar FF-26921 is a one component system replacing the use of traditional acrylic emulsion binder and melamine-formaldehyde cross-linker to be used as a binder for most industrial use fiberglass nonwovens.
- For unsurpassed performance, additional non-formaldehyde component can be added

**Unique Benefits:**

- Formaldehyde Free System
- Unsurpassed Hot Wet Tensile Strength
- Self Cross-linking

**Potential Applications:**

- Wet-laid
  - Fiberglass/ Industrial Mats
  - Duct Liner
  - Carpet Tiles
  - High Tech Filtration

**Value Creation:**

- “Green” implications because of Formaldehyde Free system
- Reduced emissions at substrate manufacturing process
- Extended durability and usage life of substrate because enhanced hot wet tensile strength

**General Specs**

- Tg: +29°C
- Viscosity: 65 cps (#2 @ 60rpm)
- pH: 8 – 9
- Solids: 44%
Thank You!

Acknowledgements
Ashok Makati
Jamel Lawrence
Matt Sciulli
Prachur Bhargava
Gary Anderle
The Impact of Product Variability on Profitability

B&IM Spring Meeting 2010

Paul Frost
P J Associates
Product Variability

- The term “product variability” refers to both the amount of variability in product that meets specification along with out-of-spec product.

- This characteristic is also important in hidden, or non-delineated specifications.
A Fundamental Problem

- Most roll goods manufacturers use the concept of product “in-spec” as compared with product “in control.”

- There are several problems with this philosophy:
Internal Problems

1. The entire spec (and more) is used to ship product to customers.
2. Assignable causes are not usually recognized until bad product is made.
3. Current inspection acceptance procedures assure that some level of out-of-spec product will be shipped.
4. Current inspection techniques are nearly always statistically invalid.
External Problems

1. Shipment-to-shipment variability
2. Doff-to-doff variability
3. Within doff variability
4. Out-of-specification product
Key Drivers of Profitability

1. Customer satisfaction and loyalty
2. Internal costs
Hidden Customer Factors

- Product/Service dissatisfaction not communicated
- Hidden specifications
- Changing markets/processes
- 2nd sourcing
Customer Communication

Dangerous perceptions

1. If I deliver product that meets specification, my customers will be happy.

2. If I provide poor product or poor service, my customers will tell me.
Customer Complaints

- 50% of all customers experiencing a problem never complain to anyone.

- Of those who complain, 45% complain only to frontline personnel who either fail to escalate the problem up to management and/or mishandle solving the problem.

- Only 5% voice the problem to management

  - TARP & Goodman and Ward
Hidden Specifications

- Virtually every customer has product expectations that are not covered in the specification; however, “they know it when they see it.”

- Nearly every manufacturer is capable of producing a “new and exciting” defects with potential “Shut Down” capabilities.
Changing Markets/Processes

- New or modified production processes at the customer/supplier facility may impact product quality perceptions.

- Changing markets and/or consumer needs may impact product specifications.
2nd Sourcing

- SOP for many customers
  - Raw material costs
  - Quality
  - Unions
  - Good business practice
  - Shutdown Hedge
Hidden Manufacturing Factors

- Operator variability
- Machine variability
- Critical Raw materials
- Changeovers
- Operating procedures
- Bottlenecks
- Lean Waste
- Environment
Operator Variability

- Training
- Habit
- Attitude
- Union
- Operating procedures
- Maintenance
- Communication
Machine Variability

- Design
- Maintenance
- Wear
- Set-up
- Start-up
- Steady state variability
- Effect of environment
- Comparisons
Critical Raw Materials

- Within lot
- Lot-to-lot
- Environment
- 2nd source comparisons
Changeovers

- Time
- Frequency
- Product effect
- Standardized procedures
Cost of Quality

- Reports
- Calculations
Non-Traditional Reports

- Effect of variability on product quality
  - Process average location & range
  - MD/CD patterns of variability
- Intangibles
  - Covert customer dissatisfaction
  - Poor company image
  - Unknown/underestimated competitor advantage
- Impact of quality & service on revenue
- Taguchi Quality Loss Function
Roll Goods vs. Piece Parts Overview

1. Product variability is *integrated* in both the cross and machine directions.
2. Test values may be correlated in the cross and/or machine directions.
3. Multiple populations may well be manufactured over time.
Where Does Roll Variability Analysis Add Bottom Line Value?

- The Entire Supply Chain
  - Raw Materials
  - Mat
  - Coating
  - Converting
  - Customer
Conclusions

- Profitability is more important than ever.
- There are many hidden factors influencing profitability.
- Controlling overall product variability and patterns of variability is critical to minimizing cost.
- There are a number of specialized tools to help us.
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Glass Fiber Mat Reclamation Process

- Patent Information
- Process Highlights/Summary
- Process Footprint
- Fiber Reuse
- Trial Work
- Savings
Patent Information

- Patent Number
  - 6,793,737
- Plant Location
  - Aiken, South Carolina

J. W. Yount Fiberglass Reclaimers Corporation
Process Highlights

• Material Handling
Process Highlights

- Process Washer Unit

J. W. Yount Fiberglass Reclaimers Corporation
Process Summary

- 200 Degree Wash Cycle
- Rinse
- Dry/Spin – approximately 15% moisture
- Packaged
Process Footprint

• Relatively Small Footprint
• Range from Inexpensive Batch Equipment to Automated Continuous Washer Unit
• Training
Glass Fiber Mat Reclamation

• Fiber Reuse
  • Glass Fiber Mat
  • Other Glass Fiber Products
• Trial Work
• Savings
  • Economic – Raw Material Costs
  • Environmental – Landfill Issues
GOING GREEN

Environmental efficiency is actually the hottest trend in development. The challenge is creating demand among tenants.

REAL ESTATE FINANCE

Building ‘green’ reaches a new level

Real Estate’s Latest Movement

The New York Times

Editorial

Build Green, Make Green

The New York Times

The Greening of America’s Campus

It’s Easy Being Green

It’s Easy Being Green

It’s Easy Being Green

It’s Easy Being Green
U.S. Building Impacts:

- 12% water use
- 39% CO₂ emissions
- 65% waste output
- 71% electricity consumption
<table>
<thead>
<tr>
<th>The Average Green Building Saves:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY SAVINGS</td>
</tr>
<tr>
<td>30%</td>
</tr>
<tr>
<td>CO2 SAVINGS</td>
</tr>
<tr>
<td>35-50%</td>
</tr>
<tr>
<td>WATER USE SAVINGS</td>
</tr>
<tr>
<td>35-50%</td>
</tr>
<tr>
<td>WASTE COST SAVINGS</td>
</tr>
<tr>
<td>50-90%</td>
</tr>
</tbody>
</table>
What is green building?
Design and construction practices that meet specified standards, resolving much of the negative impact of buildings on their occupants and on the environment.
The Triple Bottom Line

Improved Bottom Line.

- 30-70% Energy Savings
- Verified Performance
- Enhanced Productivity
- Increased Value
- Reduced Liability & Improved Risk Management
A $4 investment per square foot in building green nets a $58 benefit per square foot over 20 years.
Improved Bottom Line.

30-70% ENERGY SAVINGS

REDUCED LIABILITY & IMPROVED RISK MANAGEMENT

INCREASED VALUE

REDUCED ABSENTEEISM

PRODUCTIVITY

ENHANCED RECRUITMENT

IMPROVED EMPLOYEE MORALE

REDUCED LIABILITY & IMPROVED RISK MANAGEMENT
Average Productivity Gains

High-performance lighting enhances productivity by 6.7%.

Individual temperature control enhances productivity by 3.6%.
Green benefits go beyond cost savings:

**Increased Productivity**

- **Schools**: 20% Better Test Performance
- **Hospitals**: 2 ½ Day Earlier Discharge
- **Retail**: Increase in Sales per Square Foot
- **Factories**: Increased Production
- **Offices**: 2-16% Productivity Increase
Occupants and tenants perceive value of working in a green building to be:

- Reduced energy consumption
- Increased productivity
- Lower operating costs
- Positive marketing and promotion
- Overall environmental benefit
Health gains from improved Indoor Air Quality
As indicated by reduced symptoms for flu, asthma, allergies, respiratory infections, headaches, and colds.
An Oven Explosion –
Lessons Learned on PSM Concepts
(or “PSM: It’s not just for breakfast anymore”)

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PSM Concepts & Applicability

- Should some concepts of PSM be applied in all industries?
- Are codes enough?
- Should we accept the notion that suppliers always know their process and equipment better than us?
- Should we view combustion as something more than a mundane, ubiquitous process?
The Event

- September 15, 1998: Difficulties starting up new line.
- Once started, operations ramps up to full speed. Ovens ramp up to high fire settings.
- Within 12 minutes of ramp initiation, an explosion, heard for 6 miles, takes place.
Evolution or Managed Change?
Evolution or Managed Change?

Societal Need

Process A

Proc. C

Proc. B, Mod 2

Proc. B, Mod 1

Proc. A, Mod 2

Proc. A, Mod 1

Process B

Societal Need

Human Evolution
5 million years ago to the Present
Vertical Scale in Millions of Years

Proc. A, Mod 1
Proc. B, Mod 1
Proc. B, Mod 2
Proc. A, Mod 2
Proc. C
Sequence of Changes

- Orders a machine capable of X feet/minute
- Changes order to 1.5 X feet/minute
- Machine manufacturer changes burner requirements
- Burner manufacturer uses same burner, but increases gas flow to get higher rating
- No one changes combustion air fan capability
Sequence of Changes

• **Start up problem:** Unstable low fire flame
• **First Solution:** Weighted Pressure Relief Valve on Combustion Air – Too Noisy!
• **Second Solution:** Combustion Air Trim Damper
Flow could be anywhere in this box and satisfy the interlock

Low Combustion Air Set Point
Same $dP$ at Two Different Flows Possible

Trim Damper Affect on Fan Curve
The Burner
The Incident

21:15 Line shut down due to quality; burner at low fire
21:34 Line re-started, 12 minute ramp up to maximum speed. Burner demand set to high-fire
21:39 Leakage alarm – calculated number indicating pressure is high within oven. Operators should smell binder fumes. No smell reported. Thermal oxidizer temperature begins rising
The Incident


21:45:33 Operator clears alarm

21:46:04 Explosion occurs (pressure disturbance in Zone 1)
Explosion Venting

- **Recommended by FM & NFPA**
  - Only for ovens regardless if flammable vapors are generated or not
  - Does this mean we do not trust combustion safeguards?
- **Venting not provided**
Investigation

- Identified, secured and tested the low combustion air pressure switch
- Confirmed valve positions and determined failure mode – Combustion air trim damper was “fail last”
- Found water in instrumentation lines
- Preserved lines and tested for effect of water on dPT
## Affect of Water in the Instrumentation Line

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Amount of Water</th>
<th>dP Applied (in. WC.)</th>
<th>dP from DPT (in. WC.)</th>
<th>Error (in. WC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 ml.</td>
<td>4.1</td>
<td>4.1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5 ml.</td>
<td>4.8</td>
<td>6.0</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>10 ml.</td>
<td>4.1</td>
<td>5.9</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>15 ml.</td>
<td>4.12</td>
<td>6.17</td>
<td>2.05</td>
</tr>
<tr>
<td>5</td>
<td>20 ml.</td>
<td>4.3</td>
<td>5.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Conclusions

• **Failure to manage change:**
  – Upsized burner from 30 MM to 40 MM BTU
  – Never increased fan rating
  – Original specification of 14:1 air/fuel ratio
  – Actual ability at high fire was 10:1
Conclusions

- **Failure to manage change:**
  - Due to flame instability at low fire, dP was reduced first by relief valve, then by trim damper
  - Fan curve truncated resulting in multi-point dP
  - Allowed trim damper to seek low flow position
Conclusions

- **Failure to properly install:**
  - *Instrument locations changed to become accessible without building ladders/platforms*
  - *Tap points were higher than instruments*
  - *Condensate filled lines*
  - *Induced error*
  - *Corroded switch contact closed*
Conclusions

• Questionable design of burner
  – Seemed to meet code, but high fire flame was not monitored
  – Low fire flame monitored and stayed lit
  – Became ignition source of explosion
Conclusions

• **We are not measuring meaningful parameter**
  – *Combustion air pressure limits do not mean we have sufficient air for combustion!*

• **We assume linkage will not slip or bind**
  – *Linkage slip has happened!*
Conclusions

• Should we measure air and fuel flow instead?
  – Ratio control and interlock systems?

• How about measuring combustibles in the exhaust?

• Can we make them reliable enough to preclude the need for venting?
  – ASME Code Case 2211?
  – SIL 1 or 2 needed?
Glass Mat Industry Safety Group

Phil Halpin, GAF-ELK
Glass Mat Industry Safety Group Member

TAPPI Building & Industrial Mat Meeting
May 28, 2010
Glass Mat Industry Safety Group

GOAL

Keep anyone from getting hurt in our plants
Background

- Followed a fatal accident at a member company
- Appeal to join forces to eliminate injuries
- 2007 Ashley Safety Summit
- Website Developed: www.glassmatsafety.org
- 2008 Benchmarking visit Verso Paper
- Monthly Conference Calls
Monthly Calls

- Safety Shares
- Best Practices
- Equipment
- Safety Training & Systems
- Post on www.glassmatsafety.org
“Future Focus” sub-team developed and plans to meet in Q3 to work on the following:

- Structure of the group to ensure effectively meeting the original vision of the safety group
- Development of a rotational leadership plan
- Development of a strategy that will ensure this group stays together and committed to providing the glass mat industry an avenue for sharing safety best practice, etc., as company representatives change
- Development of a plan to increase involvement/participation to include a plan to get Senior Leaders in the industry to assure their companies’ commitment to this Group’s purpose.
Glass Mat Industry Safety Group

Please join us......

Send your contact information to: PHalpin@GAF.com