Spray Polyurethane Foam Chemistry and Physical Properties

What is SPF?
A Cellular Plastic
- Dispersion of a gas in a solid polymer
- 97% gas by volume
- Gas thermal properties
- Polymer mechanical & chemical properties

Raw Materials
What is Isocyanate- “A”?
- Highly reactive organic chemical
  - \( R - (N=C=O)X \) ISOCYANATE or sometimes called MDI
- Almost all rigid foams use polymeric methylene bis diphényl isocyanate (PMDI) which is blend of PMDI and MDI
- Not all the same
  - Variations in viscosity and reactivity differentiate products
- Health issues READ YOUR MSDS SHEETS
  - Sensitizer - can cause asthma like reaction to some persons
- Reacts with moisture/water to form gas (\( \text{CO}_2 \))
  - Keep dry!!! Use drum drier
  - Make sure substrate is dry
  - If drums get wet will generate gas in drum!!!!!
Raw Materials

What is Resin – “B”?

Mixture of 5 components:

1. Polyols
   - Reacts with Isocyanate
   - Made from variety of materials
   - Glycerin, sugar, soy beans, petroleum, recycled plastics
   - Foam physical properties and application environment dictate what polyols are used. Often a blend contains more than 1 type of polyol

2. Surfactants
   - Controls the cell size and structure
   - Helps keep all components in solution

Formulated by Material Manufacturer / System House

©SPFA

Mixture of 5 components cont.

3. Flame retardants
   - Used to reduce foam combustibility
   - Necessary to meet many building code requirements
   - 2 types-
     - Reactive (changed in the foam reaction)
     - Unreactive- stays same during reaction

4. Catalysts
   - Controls chemical reaction- and reaction time- often amine based-changed depending on season
   - 2 types-
     - Initiating- starts exothermic reaction- generates heat
     - Curing- speeds the completion of the reaction

©SPFA

Mixture of 5 components cont.

5. Blowing Agents
   - 97% volume of the foam is blowing agent (cell gas)- It determines thermal properties of the foam
   - 2 types of blowing agents
     - Physical
       - Vaporize during the reaction causing bubbles (cells) to form
         - Common types- Fluorocarbons (HFC-245fa), hydrocarbons
     - Reactive
       - React with raw material to generate a gas
         - Common type- water- reacts with PMDI generates CO2

©SPFA
Blowing agent for ocSPF

- Generally the blowing agent or expansion gas used for open cell foams is referred to as "water" or CO₂ blown.
- The water reacts with the part-A (isocyanate) and generating CO₂ causing the foam to expand.
- It is commonly referred to as water blown foam.

Blowing Agent for ccSPF

- Generally 245fa or a HFC blowing agent is used for closed cell foams.
- It is a physical blowing agent. The heat from the reaction causes the blowing agent to vaporize and expands the foam.
- Often there is a combination of blowing agents in a formulation.

Types of Spray Foam

Classified and defined by:
- Density
- Closed/Open cell content

These traits impact:
- Foam Characteristics
- Foam Performance
- Foam Application
**Defining Density Types of SPF**

**Density** - Measure of weight of a specific measured foam sample

- **Low density** (~0.5 pcf) - used primarily as an insulation and air seal/considered non-structural. (traditionally open cell foam)

- **Medium density** (~2 pcf) - used traditionally in wall applications as an insulation/air seal and vapor barrier - can be used internally or externally/considered structural (traditionally closed cell foam)

- **High density** (~3 pcf) - used traditionally in roofing applications as an insulation/air seal and vapor barrier - considered structural to support foot traffic and bear weight loads - can be used internally or externally (traditionally closed cell foam)

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**Defining Open/ Closed Cell Types of SPF**

**Closed Cell Content**
- Defined as amount of cell windows that are not open
- Typically closed cell foam has closed cell content >90%

**Open Cell Content**
- Defined as amount of cell windows that are open
- Open cell foam has a closed cell content <10%

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**Types of SPF**

- **Low Density** (~0.5 pcf) - used in BE insulation
- **Medium Density** (~2 pcf) - usually roofing
- **High Density** (~3 pcf) - (usually roofing in roofing applications)
SPF Properties

The table below compares the physical properties of cured SPF. *

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open</th>
<th>Closed</th>
<th>Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use</td>
<td>Building envelope internal</td>
<td>Building envelope internal &amp; external</td>
<td>Roof Insulation</td>
</tr>
<tr>
<td>Density</td>
<td>0.45-0.7</td>
<td>1.7-2.3</td>
<td>2.4-3.1</td>
</tr>
<tr>
<td>R-value/in</td>
<td>3.8</td>
<td>6.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Closed cell content, %</td>
<td>&lt;10</td>
<td>&gt;90</td>
<td>&gt;90</td>
</tr>
<tr>
<td>Compressive strength, psi</td>
<td>0.7</td>
<td>23-28</td>
<td>45-80</td>
</tr>
<tr>
<td>Vapor gaps</td>
<td>10-12</td>
<td>2-3.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Water absorption, g/cc</td>
<td>26</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* Represents industry average(s) taken from manufacturer literature.

SPF: THE REACTION

Reaction of two basic chemical ingredients

\[
\text{R} - (\text{N} = \text{C} = \text{O})_X \quad \text{ISOCYANATE} + \quad \text{R} ' - (\text{OH})_Y \quad \text{POLYOL}
\]

Isocyanate “A”

basic component

Polish “B”

catalyst

heat

Exothermic reaction

consists of at least five components:
- Polyols
- Surfactants
- Catalyst
- Blowing Agents
- Fire Retardants

Making Foam

The Manufacturing Process

• “A” side and “B” side are pumped through a heated proportioning pump
• Pass thru heated hoses separately
• “A” & “B” mix at gun and react
• Applied to substrate
• Blowing agent vaporizes
• “Solid” foam plastic
Monitoring the Reaction

Its about reaction time…..

- **Cream Time:**
  - Brown liquid turns cream color.
  - Important for speed of reaction &
  - Do not to spray unreacted chemicals on top of reacting chemicals.

- **Gel Time:** When polymer forms – string formation

- **Tack-Free Time:** SPF is dry to touch.

- **Cure Time:** Time required for SPF to reach maximum physical properties. (80% 1st hour)

*Applicator aware of times……..Look for changes*

Making it Right

Physical properties depend on properly proportioned and properly mixed materials.

*Applicator watch :

- Material temperatures and pressures
  - Mixing ratio: 1:1 by volume (+/- 2%)
  - "A" & "B" have different viscosities and specific gravities drums may not empty at the same time.
  - Temperature ranges of material when considering speed. (considering reactivity)

*Applicator monitors temperatures…
Look for changes…
The reaction and product depends on it*

Making it Right

Physical properties depend on properly proportioned and properly mixed materials.

*Application considerations:
1. Application ambient temperatures
2. Humidity- Dew point
3. Surface types
4. Surface temperatures and conditions

Applicator to match foam to specification and conditions.
*Always consult the manufacturer first.*

*Applicator monitors temperatures………..
Look for changes…..
The reaction and product depends on it*
Making it Right
The foam doesn’t look right?

What to look at………

Surface texture …..
• Too fast surface texture will change- rougher/ may see more pinholes

Off Ratio………..
• Too much iso or “A” rich
• Glassy structure causing brittle/friable foam
• Too much Resin or “B” rich
• Soft/Spongylower density foam

Other Physical Property Tests

Compressive Strength:
• This test measures how much load a foam sample can take before it compresses by 10%

Dimensional Stability:
• ASTM D-2126- This test measures how much a foam sample will change when exposed to environmental conditions such as hot/humid, cold or hot.

Vapor Permeance:
• This test measures the ability of vapor to pass thorough a foam sample.

Review

1. SPF systems have good thermal insulation properties. This is partly due to _______ encapsulated in the material.
   a. Water
   b. Blowing agents
   c. Helium
2. In the SPF industry "A" generally represents the ______ component, and "B" generally represents the ______ component.
   a. "A" represents: Isocyanate, "B" represents: Resin blend
   b. "A" represents: Fire Retardant, "B" represents: Surfactant
   c. "A" represents: Fluorocarbon, "B" represents: Catalyst

3. When "A" and "B" components are mixed under recommended conditions, what type of chemical reaction occurs?
   a. None
   b. Nuclear
   c. Endothermic
   d. Exothermic

4. How will the finished product be affected if the components are mixed "A" or iso-rich?
   a. Soft/Spongy
   b. Orange Peel
   c. Brittle/Friable
   d. Popcorn
Review

5. How will the finished product be affected if the components are mixed "B" rich?
   a. Soft/Spongy
   b. Orange Peel
   c. Brittle/Friable
   d. Popcorn

Review

6. Speed of reaction is important when applying SPF systems. If the speed is too fast for the ambient and substrate temperature, ______ will be affected
   a. Color
   b. Mixing ratio
   c. Pressure gauges
   d. Surface texture

Review

7. When dealing with SPF systems, your first source of information is ________:
   a. Another applicator
   b. SPFA
   c. The public library
   d. The material manufacturer
8. The blowing agent for open cell spray foam insulation is ________:
   a. HFC-245fa
   b. water
   c. HCFC-141b
   d. freon

9. The blowing agent for closed cell spray foam insulation is ________:
   a. HFC-245fa
   b. water
   c. HCFC-141b
   d. freon

10. What types of SPF are usually used in BE insulation applications?
    a. Flotation foams
    b. “High Density” and “Medium Density, Closed cell” foams only
    c. “Surfactant” foams
    d. “Low Density, Open cell” and “Medium Density, Closed cell” foams