FUNDAMENTALS OF SPF FOR THE INDEPENDENT BUILDING ENVELOPE INSPECTOR

CHAPTER 1

SPRAY POLYURETHANE FOAM CHEMISTRY AND PHYSICAL PROPERTIES

ACCREDITATION
SPFA
EXCELLENCE THROUGH EDUCATION

CONTENTS PAGE

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INTRODUCTION

More than 50 years ago in Germany, Dr. Otto Bayer discovered the chemical reaction that gave birth to the modern SPF industry. Since then, SPFs, particularly those that can be sprayed in place, have gained wide acceptance in the construction industry. This is especially true of those SPFs that are now used as insulation and components of today's roofing systems.

To provide a properly installed sprayed-in-place polyurethane foam system, a contractor must have:

1. A commitment to good workmanship.

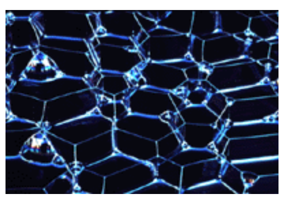
But equally important, if an applicator is to apply any spray-in-place system correctly, he must know the system's

2. Chemical and physical properties
3. Handling characteristics

This CHAPTER will provide that information and advise you on how to obtain any other information you should know about SPF Roofing systems.

CHEMICAL AND PHYSICAL PROPERTIES

By definition, SPF is a cellular plastic. It is a dispersion of gas in a solid polymeric matrix and derives properties from both phases. The foam is 97% gas by volume. The gas phase contributes mainly to thermal insulation properties; the polymeric structure affects the mechanical and chemical properties.



Close up view of spray foam

SPRAY POLYURETHANE FOAM: THE COMPONENTS

SPF is the product of two basic chemical ingredients: Isocyanate and resin blend.

Isocyanate, designated in most instances by the letter "A", is a highly reactive organic chemical containing one or more isocyanate (-N = C = O) groups, and is a basic component in SPF chemical systems and some polyurethane coating systems. The isocyanate currently used for most rigid spray foam systems is polymeric MDI.

Since most system manufacturers use a similar isocyanate, the difference in SPF systems comes mainly from the second chemical component of polyurethane, the resin blend. Resin blend (or polyol blend) usually designated by the letter "B", consists of at least five components: polyols, surfactants, catalysts, blowing agents and fire retardants. Polyols react with isocyanate to form the main building blocks of the polyurethane matrix. Polyols are made from base ingredients such as glycerin, polyether, and polyesters.

Surfactants, or surface active agents, allow "A" and "B" components to correctly blend with one another. They also assist in developing cell structure and surface texture.

Catalysts are chemicals that control the chemical reaction rate for initiation and cure of SPF. There are at least two types of catalysts in the resin blend: an initiating catalyst starts the exothermic reaction that generates heat, and a curing catalyst allows the reaction to continue to its completion.

Blowing agents form the gas the fills the SPF cells. Since 97% of the foam by volume is gas this is an important component of the foam. There are two types of blowing agents, physical and chemical. Since the SPF reaction generates heat (>200 F) the physical blowing agents actually vaporizing during the reaction causing the cells (bubbles) to form expanding the polymer and making a foam. Common physical blowing agents include fluorocarbons and hydrocarbons. The second type of blowing agent is a chemical blowing agent. It reacts with one of the other raw materials during the foaming reaction to generate a gas. A typical chemical blowing agent is water which reacts with the isocyanate to form carbon dioxide (CO_2) gas.

Fire retardants are chemicals used to reduce the combustibility of SPF and meet certain flammability standards* established within the building codes.

***NOTE:** When references are made to flame spread ratings, these numerical flame spread ratings are not intended to reflect hazards presented by these or any other materials under actual fire conditions.

TYPES OF SPRAY FOAM

There are a variety of types of SPF available for installation based upon the application that it is being used in. The types of foam are based upon 2 factors, density and closed (open) cell content. These two physical properties impact the characteristics and performance of foam and thus the application of the materials.

Density will impact the strength or ability of foam to support weight. SPF is sold in 3 general density categories, low density (LD), medium density (MD), and high density (HD). Low density foams (~0.5 pcf) is used traditionally internally in the building envelope. It is not designed to support weight. Medium density foams (2pcf) area is used in the building envelope. It can be used both internal and external to the structure. High density SPF (3 pcf) is traditionally used on the roof deck It is designed to handle foot traffic and bear weight loads.

Closed cell content has a significant impact on the performance and characteristics of foam. Foams with a closed cell content of >90% are referred to as closed cell foam. Foams with a closed cell content of <10% are referred to as open cell foams.

OPEN CELL
Although the types of chemicals used to make open cell and closed cell foam are the same, the specific chemicals used differ. The blowing agent for open cell spray foam is water. The water reacts with the isocyanate to create carbon dioxide gas which is used as the blowing agent to expand the foam. However, since the cells are open no gas is retained in the foam. It is a porous polymer material. It is therefore not as rigid a material as closed cell foam. Since it retains no insulating gas it traditionally has a lower R-value. Its open cell composition allows the material to absorb sound better than closed cell foam.

CLOSED CELL
Closed cell foam is made from a combination of blowing agents and a small amount of water but the primary blowing agent is a physical blowing agent. Today SPF is made with a fluorocarbon blowing agent. The retention of this gas in the closed cells is the reason for the higher R-values. The closed cell content also makes a more rigid foam providing greater load bearing capabilities to the foam.

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

Characteristic*			
Type	Open	Closed	Closed
Use	Building envelope internal	Building envelope Internal & external	Roof Insulation
Density	0.45-.7	1.7-2.3	2.4-3.1
R-value/in	3.8	6.4	6.5
Closed cell content, %	<10	>90	>90
Compressive strength, psi	0.7	23-26	45-60
Air infiltration			
Vapor perm	10-12	2-3.0	1.9
Water absorption g/cc	26	0.02	0.02

* Represents industry average taken form manufacturer literature.

SPRAY POLYURETHANE FOAM: THE REACTION

To apply SPF, the isocyanate (“A”) and the resin blend (“B”) are pumped through a proportioning pump and heated. These components pass through heated hoses to a mixing spray gun and are spray-applied to a substrate (e.g., a roof surface or stud wall cavity). The mixed components (“A” and “B”) react with each other generating heat (an exothermic reaction). The heat of reaction and/or the reaction itself generates or vaporizes the blowing agent. The blowing agent gas forms bubbles while the polyol and isocyanate react to form the polyurethane matrix. When all is done, the result will be a solid foam plastic having the desired properties needed for an insulation or roofing material.

The physical properties of SPF depend on properly proportioned and properly mixed SPF components. It is important that the manufacturer's recommendations be followed regarding (1) material temperatures and pressures as controlled by the proportioning equipment; (2) application ambient temperature and humidity; and (3) substrate types, temperatures and conditions. The next chapter discusses this further.

WARNING: Isocyanate will react with any moisture present before it reacts with the resin blend. The chemical reaction of isocyanate and water results in carbon dioxide (CO_2) gas being generated as a by-product. When SPF is applied to moisture laden substrates poor cell structure of the SPF may result. The severity of the poor cell structure varies with the amount of moisture present and the SPF formulation. Therefore, it is important to apply this product to a dry surface, and to keep moisture out of the "A" component even while still in the drum. **Do not** spray within five degrees of the dew point. **Do not** leave drums out in the rain.

TIME FACTORS

When mixing polyurethane systems, several time factors are significant.

1. Cream Time: This gets its name from the brown liquid turning a creamy color. This designates when the reaction begins. It is important for two reasons:

   a. To determine the speed of reaction at varying ambient temperatures, i.e., cold/ warm weather, when the SPF is being applied;

   b. To insure that the applicator does not spray unreacted chemicals on top of the reacting chemicals.

2. Tack-Free Time: This is the time when the SPF is dry to the touch. It then can be sprayed over with another layer of mixed chemicals, and, with some care, be walked on. Foam is no longer sticky.

3. Cure Time: This refers to the time required for the SPF to reach its maximum physical properties. SPF, within the first hour, will reach 90% of its cure and will have obtained at least 90% of its maximum physical properties. As the exotherm subsides, the cure time slows down considerably, and it takes an additional 23 to 72 hours for a complete cure, depending on the ambient temperatures.

MIXING RATIO

Another important factor to consider is the mixing ratio of a SPF system. Most SPF systems in use today have a mixing ratio of one-to-one, or one part resin blend (B) to one part isocyanate (A) by volume. Most equipment for spray systems has fixed mixing ratios of one-to-one by volume. However, since the "A" and "B" components of the SPF have different specific gravities and viscosities, the drums of isocyanate and resin blend may not empty at the same time. There are several factors that can distort this ratio within the equipment, and they will be discussed in CHAPTER 3. Slight variations in density will result from mechanical tolerances of the spray equipment. However, the SPF formulation will generally provide proper results as long as the ratio of the "A" and "B" components are within ± 2% by volume.

The applicator should be aware that an off-ratio mix will produce undesirable results. If the mix is lacking B-component (“A” or iso-rich), the resulting SPF may have a glassy cell structure, causing brittleness or friability. The density of an SPF lacking B-component will typically be higher than the manufacturer's specifications.

If the mixture is lacking A-component (“B” rich), then the resulting SPF will generally be soft and spongy, and lower in density than the manufacturer's specifications.

NOTE: Positive displacement pumps of the type used with SPF equipment are incapable of producing "excess" material; they can only "lack" material. (See Chapter 3)

APPLICATION CONSIDERATIONS

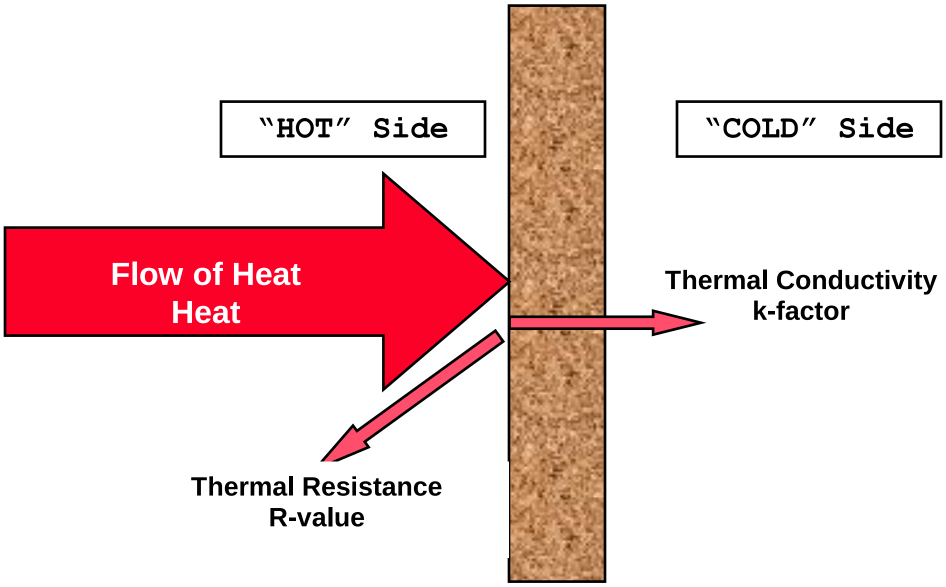
Many manufacturers supply more than one reactivity (speed) of a system to be used in different temperature ranges. The correct reactivity for the conditions is required to produce the desired surface texture and cell structure.

PHYSICAL PROPERTIES

It is important to understand the tests and physical properties of the foams that you are installing. The test methods for measuring properties are standard through the foam industry. Many are agreed upon and published by the ASTM (American Standard Test Method). Anyone who is a member of ASTM can participate in developing or changing test procedures. There are a few key methods and properties that one needs to understand. These are reviewed below.

Density is a measurement of the weight of a measured foam sample. It is reported as pound foam vs size or pound per cubic foot (pcf).

Thermal performance- measurement of heat flow



K-factor- ASTM C-518- Amount of heat that passes through a unit thickness of material over a unit area in one hour if the temperature differential between the "hot" and "cold" sides is one degree

R-value- Amount of heat that does not pass through a unit thickness of material over a unit area in one hour if the temperature differential between the "hot" and "cold" sides is one degree. R-Value - 1 / k-factor
The k-factor of foam is traditionally measured after it has been aged for 180 days at room temperature. The FTC has guidelines on what and how R-value is to be reported to a residential home owner. Please consult these before selling foam to homeowners.

Closed cell content- ASTM D-6226. This test measures the open cell content of a foam sample. The number is than converted to the closed cell content. It describes the porous nature of the foam.

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. Since it is done on a core form not an adhered form it

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

Surface burning characteristics: ASTM E-84, In this test a foam samples is placed in a long chamber and exposed to a flame source. The local state and national building

codes reference this test. The values are reported in the distance the burner flame extended down the chamber and the smoke that was developed during this time for a specified thickness of foam.
Example: The Foam Thickness – 4”, Flame Spread $\leq$ 25, Smoke Development $\leq$ 450

SUMMARY

In review, the major points covered in this Chapter are:

1. SPF has good thermal insulation properties. This is due to the blowing agents encapsulated in the material and the seamless monolithic nature of spray polyurethane foam.
2. When isocyanate ("A") and resin blend ("B") are mixed under recommended conditions, an exothermic reaction occurs.
3. If the materials are not mixed at the proper ratio, the following may occur:
    - If the SPF is “A” or iso-rich, the SPF may be brittle, friable and high in density.
    - If the is “B” rich, the foam may be soft, spongy and low in density.
4. Speed of reaction is important when applying SPF systems.
    - If the speed is too fast or too slow for the ambient and surface temperature, the following may be affected:
        - Cell Structure
        - Density
        - Adhesion to the substate
        - Surface texture
        - Tensile and compressive strength
        - Adhesion between passes
5. The material manufacturer is the first source for information when dealing with SPF systems.

6. The characteristics of open and closed cell insulation.

7. The physical properties for open cell and closed cell insulation.

8. The blowing agent for open and closed cell foam.

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SELF-QUIZ
SPRAY POLYURETHANE FOAM CHEMISTRY, PROPERTIES AND SAFETY

Please circle the ONE best answer for each question.

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

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

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

7. When dealing with SPF systems, your first source of information is:

   a. Another applicator
   b. SPFA
   c. The public library
   d. Your 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

To find out the correct answers, please turn to CHAPTER 6.