Review
Polyurethane Foam

4 types of polyurethane foam

1. Polyurethane foam caulking (tube)
2. Single-component foam sealant (cans)
3. Two-component foam insulation/sealant kits
4. Spray-applied/injected foam insulation (SPF/IPF)
   - Open-cell vs. closed-cell foam
   - Spray vs. injection
   - Molded

The History of Polyurethane foam

History

- Polyurethanes were originally developed in the late 1930s in Leverkusen, Germany (Otto Bayer).
- The technology arrived in the US after World War II (Mobay Chemical Company).
- Flexible foams (furniture) were prevalent before their use as acoustic and thermal insulations.
- Rigid Foam, medium density
  - Spray applications first began in 1950 in North America
  - 1970 - beginning of current significant level of use in construction
  - Daily field-installed cavity-fill applications began in 1982

The History of Polyurethane foam

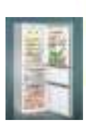
The size of the industry


The following table shows how polyurethanes are used (US data from 2004)

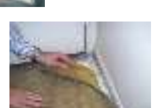
Application	Amount of polyurethane used (millions of pounds)	Percentage of total
Building & Construction	1,459	26.8%
Transportation	1,298	23.8%
Furniture & Bedding	1,127	20.7%
Appliances	278	5.1%
Packaging	251	4.6%
Textiles, Fibers & Apparel	181	3.3%
Machinery & Foundry	178	3.3%
Electronics	76	1.4%
Footwear	39	0.7%
Other uses	558	10.2%
Total	5,444	100.0%

Common uses








Common Uses of Polyurethanes	
Type	Product
Rigid and semi-rigid foam	Refrigerators, freezers, hot water storage tanks, process equipment
	Building insulation Conventional and cold-storage building insulation, SIPs Marine flotation
Flexible foam	Furniture cushions, car seats
	Packaging materials, foam-in-place packaging
Urethane coatings	Marine & wood finishes
High-density molded polyurethanes	Wood-look TV & appliance cabinets Automobile bumpers

SPF Chemistry Fundamentals

Two component liquid systems manufactured in plant
- A-Side: MDI – Isocyanate
- B-Side: Proprietary Resin (polyols , catalysts, fire retardants, blowing agents, etc.,…)
- A+B = spray polyurethane foam

Sold to insulation contractors – Processed and installed on site
- A+B components are heated, pressurized and pumped through hoses and mixed at spray gun just before contacting the surface

Polyurethane foam

A-Side

The A-side is typically a mixture of approximately 50% methylene diphenyl diisocyanate (MDI) and 50% polymeric methylene diphenyl diisocyanate (pMDI). A-side chemicals are very reactive and reactions can result from improper mixing with water; acids; inorganic bases (such as sodium hydroxide), ammonia, and amines; magnesium, aluminum and their alloys; other metal salts, especially halides (such as tin, iron, aluminum and zinc chlorides); oxidizing agents (such as bleach or chlorine); or polyols.

A-side chemicals have a musty odor, but because of the relatively high odor threshold, most people cannot smell A-side chemicals when present in concentrations equal to applicable occupational exposure limits. As a practical matter, this means that if you smell MDI (musty odor), you have probably exceeded the exposure limits.

Courtesy: Center for the Polyurethanes Industry (CPI) of the American Chemistry Council

Polyurethane foam

B-Side

Figure 1: Typical Composition of Polyol Resin Systems

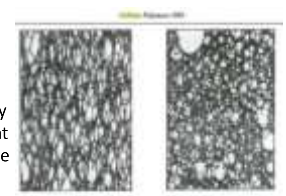
Component	Low Density, Open Cell [illegible]	Medium Density, Closed Cell [illegible]
Polyols	[illegible]	20-40%
Blowing Agents	[illegible]	[illegible]
Catalysts	[illegible]	[illegible]
Flame Retardants	[illegible]	20-40%
Surfactants and Glycerin	[illegible]	[illegible]

Additives determine:
1. Cell size and R-value
2. Speed of the chemical reaction
3. Fire resistance
4. Flexibility and dimensional stability

Courtesy: Center for the Polyurethanes Industry (CPI) of the American Chemistry Council

Polyurethane foam

The Material
- The bubbles or hollow cells are created by introducing "blowing agents" into the plastic resin.
- Blowing agents are primarily low-conductivity gases or water. These boil at atmospheric pressures from the heat of the exothermic reaction to form the bubbles.
- Without blowing agents, urethanes are hard plastics (urethane varnish, molded furniture parts)
- Blown foams vary in density in proportion to the amount of blowing agent used in the formulation



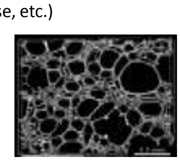
Polyurethane foam

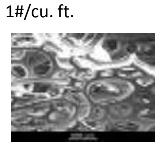
Cell types
- <u>Closed-cell foams</u> with low-conductivity gasses in the bubbles have higher R-values, high resistance to air and vapor flow, and are very strong. Closed-cell foams will be at least 1.85#/cu. ft. There are closed-cell foam products that are not filled with low-conductivity gasses.
- <u>Low density</u> foams with open cells, usually water-blown, have R-values typical of other insulation materials with air in the interstitial spaces. They are permeable to vapor transmission, and are non-structural. They can, however, have a high resistance to air flow. Open-cell foams are usually less than 1#/cu. ft.

**Handout – FAQ response from BES Website –"What is the difference between open-cell and closed-cell urethane foams?"*

Polyurethane foam

Cell types
- <u>Low-density open-cell foams</u>
  - are usually water-blown,
  - have R-values typical of other insulation materials with air in the interstitial spaces (fiberglass, cellulose, etc.)
  - are permeable to vapor transmission
  - are non-structural
  - have a high resistance to air flow
  - are <u>not</u> water tolerant
  - are usually less than 1#/cu. ft.





Open-cell PUF at different magnifications

SPF properties

Table 1: Summary of SPF properties

	Sealant	Low Density or ocSPF	Medium Density or ccSPF	Roof SPF
Density (pcf)	[illegible]	0.4 - 0.7	1.7 - 2.3	2.5 - 4.0
Thermal Resistivity (R/in)	not reported	3.6 - 4.5	5.8 - 6.8	5.8 - 6.8
Air Impermeable Material	✓	✓ (≥5.5")	✓ (≥1")	✓ (≥1")
Integral Air Barrier System		✓	✓	✓
Class II Vapor Retarder			✓ (≥2")	✓ (≥2")
Water Resistant			✓	✓
Cavity Insulation		✓	✓	
Continuous Insulation		✓	✓	✓
Low Slope Roofing				✓
Structural Improvement			✓	✓

I would add closed-cavity low slope insulation to this with a check in the center two boxes. These are the only code compliant materials for this application.

Courtesy of The Center for the Polyurethanes Industry and the Spray Foam Coalition - American Chemistry Council (ACC)

Polyurethane foam - Physical Properties

In-place physical properties are not the same as in the lab

- Density
- Physical strength (compression, tension, shear)
- R-value
- Water permeability
- Air permeability
- Vapor permeability
- Bond Strength

Foam blowing agents

GWP ratings

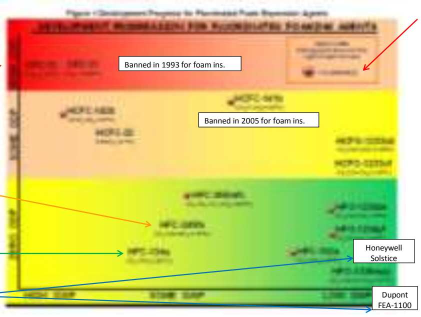
ODP ratings: All current products are zero ODP

My first foam job (1971) Who knew?

The current technology (2003)

F-T SUPERGREEN FOAM (1993)

The next generation (2013)



Source: Dupont Formacel 1100 paper

Processing and installing polyurethane foam

Delivery systems for field-processed materials

- Low-output (3 to 10 #/minute) pressurized portable units (Kits and Cans)

Kits and Cans

Two-component kit foam (Kits and cans)

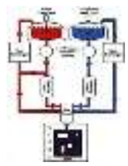
Processing and installing polyurethane foam

Delivery systems for field-processed materials

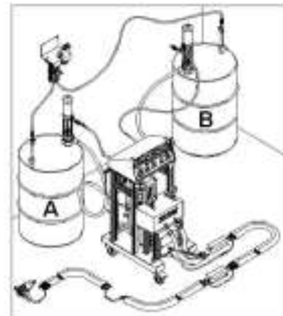
- High-output (6 to 100 #/minute) pressurized or pumped bulk equipment (Low-tech and high-tech machine processing equipment)

Bulk foam – Pump systems

Mobile Spray Rig (Bulk foam)



Bulk foam



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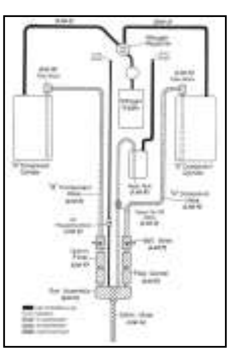
Field Processed & Field Applied

Pressure vessel system



Pressure vessel system

No pumps or open drums

Static mix method

Spray guns

Advantages

Open-cell foam

1. Lower cost even though it usually requires trimming and waste disposal
2. Dimensional stability is not an issue
3. One-step convection, diffusion, and conduction control

Advantages

Lower cost even though it usually requires trimming and waste disposal

Advantages

Closed-cell foam

1. Higher R-values are possible in smaller existing framing cavities
2. Will not be damaged by roof leaks, foundation leaks, or condensation
3. Can function as a drainage plane
4. Not prone to weather damage
5. Has structural capabilities
6. One-step convection, diffusion, and conduction control
7. Self supporting

Advantages

Not prone to weather damage

Advantages

Self supporting

Better depth control

Advantages

Below grade application

Advantages

Unvented roof application

Advantages

Drainage planes