IPUA
INDIAN POLYURETHANE ASSOCIATION

TECHNICAL MANUAL

A GUIDE TO ENERGY SECURITY

WORKING WITH SPRAY POLYURETHANE FOAM

Spray Foam Alliance of India

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CHAIRMAN'S NOTE

It is my pleasure to write this note of commendation for the Spray Foam Alliance of India, which is yet another brainchild of the IPUA.

Energy security is the need of the day for India. The projections for India's energy demands in the next decades are astronimical. However, insulation is a game-changing factor which needs to be fully brought into the proper implementation and taken advantage of. Simply put, heat transfer losses are reduced 70% to 90% by building envelope insulation. Only under an aggressive roll out plan will our country be able to have a realistic approach to meeting the demands.

The Spray Foam Alliance of India (SFAI) has been created to address two important issues.

First, to bring into effect one of the simplest and most effective forms of insulation – Spray Polyurethane Foam. Second, to generate and train the crucial link in the industry chain - the applicator . There is a dearth of both aspects. The SFAI hopes to take up the Herculean task of bringing about the much needed transformation.

In this process, we have ensured to capture the knowledge and expertise from across the globe: we already have the presence of perspectives from the USA, Middle East and China supporting us now.

Looking forward, the SFAI hopes to be a model for other countries in the region to emulate, as we take courageous steps in the promotion, practice, product stewardship and proliferation of Spray Polyurethane Foam.

MUKESH BHUTA

Chairman

Indian Polyurethane Association

PREFACE

It is a defining moment in history when industry stalwarts get together and decide to change the game in alignment with the needs of the consumer, going beyond the capacity and skill limitations of their immediate customer.

At the outset, we wish to thank the Executive Committee members of the IPUA who have extended moral and visionary support to this project. The IPUA was instrumental in the creation of the India Insulation Forum. Now, it is stepping up the pace in the race for the energy security of the country by creating the SFAI, an Alliance of the System Houses to promote safely and expertly the use of Spray Polyurethane Foam (SPF).

SPF has unique advantages which are very well suited for the country like India which is struggling to prove the business case for Insulation. The biggest advantage is that of achieving both insulation and air sealing in one stroke.

We believe that the skill development for SPF is the vital cog in the wheel which should not be left in the hands of a handful of enterprises. With the involvement of the chemistry and technology of the suppliers of systems who are colloborating with each other, we are sure the safe and proper use of SPF will transform the insulation landscape of the country.

The topics covered range from the reasons behind using insulation, its relation to architecture in the midst of growing acknowledgement of its benefits by the practitioners, chemistry and application process. Special attention is given to retrofitting SPF and most importantly, Health and Safety aspects.

Honestly, we have taken baby steps to tackle a very complex problem. Our commitment is in our investments and we believe in continuous learning and improvements.

To this end, we look forward to comments and feedback from the readers and users.

SFAI FOUNDERS

Indian Polyurethane Association

ACKNOWLEDGEMENTS

The SFAI is grateful to the vision of the IPUA leadership in supporting the initiative taken by the System houses, especially Chairman Mukesh Bhuta, Secretary Ramamurthy and Jt. Secretary Murali Mohan.

The members Dr. Ashok Mhatre (Expanded Polymer Systems), Sachin Bedmutha (BASF), Govind Gupta & Thomas Nesamani (Dow Chemicals) and Isaac Emmanuel (Covestro) ably supported by Sachin Bansal of Graco have been working relentlessly over the past 6 months to bring together the content and roll out of the SFAI in a relatively short time.

We are also grateful for the support extended by Sr. Director Salamone Lee of the CPI, ACC, USA who has been devoted time along with her team to support the SFAI not only by way of content edition and contribution, having permitted us to use the resources of the CPI but by personally traveling for the event launch all the way from the USA.

Neeva Candelori of Covestro Global Advocacy has been an able mentor to the team, having initially guided us through sharing her experiences in the USA at the early stages, which helped us speed up the formation process.

Needless to say, the experience of working together with the utmost compliance has been enriching, fulfilling and disciplined for which we thank all who have cooperated and contributed their time, energy and resources.

This is the beginning of a new journey on the road less travelled. We look forward to the continued support as we take bold steps in contributing to the Energy Security of India.

SFAI Founders

THE NEED FOR BUILDING INSULATION

Buildings are responsible for more than 40 % of global energy use. Industry and society require Low-emission buildings, Energy-efficient architecture, sustainable solutions and modular systems.

There is a growing demand for sustainable materials. Such materials ought to have the potential to be re-invented; must make significant contribution to its saving effects on energy and its resources and should have the properties of being the best insulator, besides being lightweight and durable.

With some elaboration, they ought to have the scientific basis as covered below:

Figure 1 Desirable Properties of a Sustainable Material - Polyurethane has it all

But, what is Sustainable Development?

Sustainability is an abstract concept subject to interpretation. A good definition of sustainable development would include

1. Sustainability is an attribute of a system.
2. Sustainability is achieving commercial success through solid business models in a way that meets the needs of our employees, society, and protects the environment and natural resources.
3. Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

At the 2005 World Summit it was noted that sustainability requires the reconciliation of environmental, social and economic demands - the "three pillars" of sustainability[1]. This view has been expressed as an illustration using three overlapping ellipses indicating that the three pillars are not mutually exclusive and can be mutually reinforcing.

What we know:

Fossil fuels are a finite source of energy. Burning fossil fuels emit greenhouse gases. Energy efficiency in buildings conserves resources such as fossil fuels. By conserving energy, we can slow down the depletion of fossil fuel, giving time to develop long-term solutions to meet energy needs for the future.

- Insulating our homes and buildings conserves the fossil fuels needed to heat and cool them.

[1] Source: Johann Dreo - Sustainable development 2006

- Buildings insulated with spray polyurethane foam will typically use 30 per cent less energy for heating and cooling compared to buildings insulated with traditional fibrous insulation material[2].

Life Cycle Assessments (LCA) for some individual chemical product applications, including insulation, were calculated in the ICCA[3] report. The life cycle assessment is a recognized multi-step, well-structured methodology that performs environmental impact analysis (based on ISO 14044:2006). LCA assess energy and environmental impacts of a material in a specified application from cradle to end-of-life. LCA results support decision-making on new projects and compare the energy and environmental impact of different products with quantitative data factoring in all the life cycle phases.

LCA performed on insulation products have demonstrated that energy savings during the use phase far outweigh energy associated with manufacturing the raw material, formulating components, transporting, installing and managing at end-of-life. LCA calculations show that the highest values obtained with an increase of insulation can contribute substantially to energy efficiency improvement. Insulation contributes to fossil fuel conservation and GHG reduction.

Why should I insulate?

- Lower energy losses; avoid the danger of oversized heating or cooling systems that work hard to compensate for the heat or cold losses through the building envelope.
- Effective insulation lowers heating or cooling bills, thus no longer being affected by rising energy costs.
- minimize air-borne sound transmission,
- impede entry of insects and pests,
- reduce air infiltration that can generate condensation and result in mold growth,
- increase the comfort of occupants.
- Future legal requirements. Energy certification anticipated.

Why Polyurethane insulation?

- SPF insulation reduces the amount of energy required for heating and cooling, thus also cutting CO2 emissions.
- An investment in improving energy efficiency of your building with SPF insulation is far more profitable and sustainable than a conventional capital investment.
- SPF insulation is effective even in renovation of buildings.
- SPF insulation provides insulation + air sealing in one product and step

How should I insulate?

- Appropriate expertise is required when planning a building project due to the huge number of building materials, the multitude of technical options, the legal regulations relating to thermal protection and tight deadlines.
- Cost-effective, state-of-the-art integrated solutions are needed.

[2] Source DOE Airsealing

[3] International Council of Chemical Associations - Innovations for Greenhouse Gas Reductions July 2009

- The most important criterion for the effectiveness of an insulating material is its thermal conductivity. **The lower the number, the better the material's insulating properties.**

Why SPF insulation?

- Low energy and heating/cooling costs.
- Optimum thermal protection. Thin is in.
- Greater comfort and a more pleasant room climate throughout the year
- A significant increase in the value of your property
- Reliable compliance with all legal requirements.

PU insulation have thermal conductivity and low mass compared with solid walls or ceilings and are not good at retaining heat.

Where should I insulate?

- Roofs
- Walls
- Floors

Why SPF insulation?

- High compressive strength.
- Lightweight & thin
- Maximizing space utilization
- Quick and easy to install
- Architecture appeal

ARCHITECTURE AND ENERGY-SAVINGS

Architecture is our 'third skin' (after skin & clothing). Buildings have a direct effect on healthy living. Poor ventilation, High heat transfer coefficient of building materials lead to condensation & structural Damage. Coupled with the oil crises leading to regulations; reserves & resources are limited; pledge to reduce fossil fuel consumption & CO_2 emission, Energy efficiency – its saving and optimum usage – closes the gap between future supplies & increasing demand

Thermal insulation measures pay for themselves through energy savings.

A Building is an Energy System: a Balance of Energy is inherent in the system. This calls for a new standard for architecture and architects, not a special method of construction or design. Greatly reduced heating / cooling requirement compared to the norm.

The technical challenge comprises of satisfaction in all the below areas:

- Compact design: surface-area-to-volume ratio
- Energy-efficient construction: minimizing the U-values, avoiding thermal bridges
- Excellent thermal insulation in the external components: high insulating efficiency per unit area
- Wind-tight and air-tight building shell
- Mechanical ventilation (heat recovery in some cases): limit the relative air humidity
- Rapidly controllable heat / cold distribution: adaptability

The architectural challenge comprises of

- Synthesis of technically perfect construction
- Correct use of materials
- Sensible utilization
- Efficient production planning

Effectively, it boils down to giving the design processes a specific direction governed by external factors:

- **Conservation of resources**
- **Climate protection**
- **Energy efficiency**
- **Develop a new aesthetic**

With the new role play of Architects as stylists and engineers, their responsibilities widen to

- **Create** appropriate architectural designs from it. Not simply "Form follows U-value".
- **Author** New developments, e.g., in the styling of facades of large, complex buildings
- **Design** an energy system, a "power station", a "living system" that can respond to changes in the environment
- **Turn** the technical requirement to a style challenge

Architecture has always been closely linked to social requirements and social change. Energy efficiency in architecture would be inconceivable without the use of insulating materials. Optimum energy efficiency can be achieved with high-performance insulating materials such as polyurethane rigid foam. A building and its shell constitute a system with a long life and a correspondingly long-term energy-saving effect. Rapid wear is inherent in cooling systems and therefore short renovation cycles. In the long term, a building with a low heating or cooling requirement is in any case "equipped" for the anticipated energy shortage.

Integrated planning and realization is the key to eco-friendly & cost efficient construction. Unless sufficient time and energy is spent in the Analysis & Planning stage, the benefits of the exercise will not be realized fully.

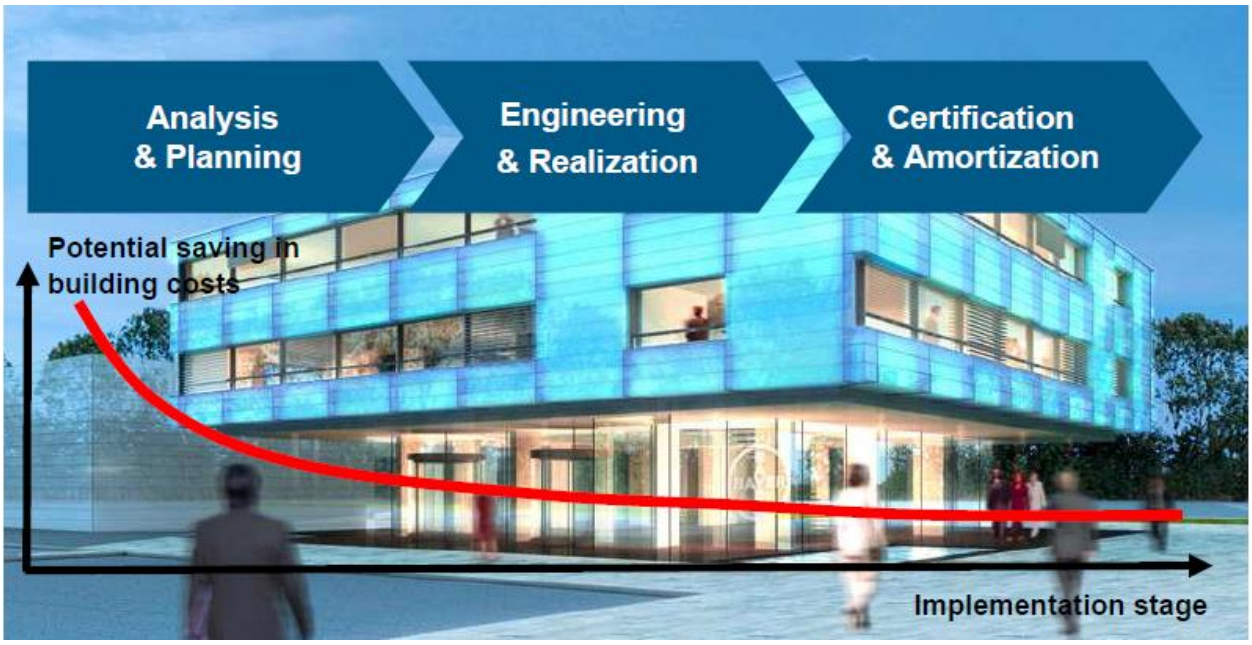


Figure 2 The more time you spend at the Analysis & Planning stage, the more effective your chances of achieving your goals.

Therefore, a holistic approach to building envelope with energy-saving materials is important. The goal is 'towards zero emission'.

THE CASE FOR SPRAY POLYURETHANE FOAM

The case for an example such as polyurethane is extremely strong due to its extreme simplicity – just a combination of polyol and iso - and ease of application. Thus it is a widely accepted solution whenever energy efficiency is talked about. To begin with, the "K-factor" a key indicator of a material`s ability to insulate is lowest for Polyurethane (<.023, the lower the better) in comparison to materials like XPS (<.028) and EPS (<.041). It has excellent thermal, gas barrier and water proofing properties. Moreover, it`s self-adhesion property is clear add on over other materials which require adhesive for making panels, e.g..

There are virtually no cavities between the insulation and the base which is not the case with other material (almost 50%-60% cavities). Unlike others the versatility (of processing) offers a seamless insulated surface in case of PU-spray insulation. Also, Polyurethane offers exquisite shaped wall construction. It also excels over other materials when "chemical stability" and "construction efficiency" are the decisive parameters. With just 1-2 days of "stability period" after construction it is ready for use. With fire safety norms being extremely important, SPF supports compliance with all state and local fire codes. Extreme caution is needed during application, till the foam insulation is suitably covered by dry wall or other protection.

The polyurethane can operate in a much wider range of temperature. It can be exposed to -30^{o}C-90^{o}C in a longer run and 90 ^{o}C – 250 ^{o}C for short duration. Others start softening at 75 ^{o}C and melt at 90 ^{o}C.

When it comes to enhancing the performance of a given building design, not many construction materials can compare to **SPF** insulation. SPF is an ideal insulation material when energy efficiency and code compliance related to thermal performance are important. SPF technologies provide not only an effective thermal layer but also an air control layer as an integral part of the building envelope. The air sealing properties, low thermal conductivity, and design flexibility make SPF the all-in-one solution for architects and builders responsible for insulating any kind of building - residential, commercial, institutional, military and industrial buildings.

When you're looking at various types of insulation for your home, you will inevitably come across spray foam insulation as an option. There are many differing views about spray foam, however, and it can sometimes be difficult to separate fact from fiction. That's why, at the outset, we should address two of the most commonly asked questions about spray foam insulation:

What is spray foam insulation?

Spray foam like Polyurethane is made when two sets of unique liquid chemicals are combined at the site of the installation. This creates rapidly expanding foam that helps to seal any gaps and holes, as well as insulate wherever it is applied. Spray foam comes in two different densities, which are used where appropriate for different locations and scenarios within the home.

Is spray foam insulation energy efficient?

The short answer is, "Yes." Spray foam insulation creates an air seal on your home wherever it is applied, helping to mitigate the air loss your home experiences. A reduction in air leakage means a decreased workload for your HVAC equipment, which can lead to lower monthly heating and cooling bills.

It’s obvious that people living in a colder climate are in need of an effective insulation for their homes, but what about if you live in a warm climate? Does the quality of your insulation really matter then? The answer is, resoundingly, yes.

Spray Foam for warm climates?

If you’ve been asking yourself, “How can I make my home cooler?” then an effective, high quality insulation like Polyurethane spray foam is the ideal choice for your home. Polyurethane doesn’t just insulate your home; it creates an air barrier wherever it is applied, to help minimize air loss in your home, which can lead to more efficient use of your air conditioning equipment.

If you’re wondering how to reduce your monthly cooling bills, look no further. Polyurethane spray foam insulation can help do exactly that by helping to minimize conditioned air from escaping, through the air seal that it creates, wherever it’s applied. With less air escaping, your cooling equipment doesn’t need to work as hard to keep your home cool enough for you to be comfortable.

Further to this, Polyurethane is also not a food source for mold which, in warmer, more humid climates, is a significant issue, when it comes to your insulation. And if you live in a disaster-prone area, it is well to know that in the US, closed cell spray foam is considered by FEMA to be flood-resistant material.

THE ADVANTAGES OF SPRAY POLYURETHANE FOAM

There are clear arguments for the construction value chain to choose SPF. Let us check them out one by one.

For architects, meeting both the local building codes as well as the budget of the project is an ever-present challenge. They would need to incorporate unique design features in commercial buildings which require more design-friendly materials. SPF is the most suited answer technically and aesthetically.

For the general contractor, the crucial factor of time is well addressed by the fast and easy process of SPF, apart from other features like reduced initial building costs.

First, a comparison with other materials in the intrinsic value of thermal conductivity coefficient shows SPF a clear winner.

Insulation Material	Thermal Conductivity Coefficient
Spray Polyurethane Foam	**0,023 W/mK**
Expanded Polystyrene EPS	**0,030 - 0,047 W/mK**
Extruded Polystyrene XPS	**0,029 - 0,037 W/mK**
Mineral Wool	**0,033 - 0,044 W/mK**

Figure Comparison with other insulating materials

To list them out, SPF exhibits

- ✓ The best thermal conductivity
- ✓ Prevention of thermal bridges/no joints
- ✓ Installation by trained professionals
- ✓ Fast installation. It is possible to apply up to 600 m2 of foam per day. Other insulation materials generally do not exceed 200 m2 per day.
- ✓ Adhesion to the substrate: The product is self-adhesive and stays fixed to the substrate, preventing any possible detachment, common with other types of insulation.
- ✓ Adapts to the shape of the substrate. Due to the nature of the application, the foam adapts itself and reproduces the shape of the substrate. As a result, it is easy to insulate difficult areas such as columns, waved roofs, or covers for blinds.
- ✓ Mobility: Easily portable equipment
- ✓ Air tight. The continuous application of spray foam, without joints, means that the product is airtight. This gives important energy savings, highly valued in most countries. According to some studies, up to 40% of energy can be saved, creating

an airtight wall. To reach a passive house construction, air tightness is absolutely necessary.

- ✓ Water Impermeability. Due to its closed-cell structure and its continuous application, the product is impermeable to water. This results in the following advantages**.**
- ✓ Moderate vapour permeability. The balanced values permits working without a vapour barrier in most cases, permitting the surface to "breathe". Only a small possibility of internal condensations.

Moreover,

- SPF combines superior insulation R-value with near-zero air permeability,
- SPF insulation is a tested & certified air barrier at an application of 1.0 inch thickness. It does not allow air flow around/behind/through insulation system.
- SPF increases energy efficiency, longevity, occupant comfort & indoor air quality of building.
- SPF reaches insulation effectiveness by forming a **fully adhered, seamless insulation and air barrier system.**

Figure 3 SPF offers seamless insulation

THE CHEMISTRY OF SPRAY POLYURETHANE FOAM

SPF insulation is a cellular thermoset[4] plastic material.

Two generic types make describe most of the SPF market.

- Open Cell is very low density, around 10 to 20 Kg cubic meter and can easily be crushed between thumb and fingers.
- Closed Cell is about 4x higher density than OC, around 38 to 42 Kg per cubic meter. It is more rigid and difficult to crush.

In open cell foam the gas inside the cells is air. In closed cell foam the gas inside the cells is mostly made up of blowing agent called "HCFC 141b", "245fa", "CO2 (Water blown)"[5].

THE CHEMICALS INVOLVED

The A-Side or "Resin" is a mixture of many components.

Polyols

Water and Blowing agents

Catalysts

Fire retardants

Surfactants and miscellaneous additives

The B-Side consists of just one component.

"Polymeric Methylene Diphenyl Diisocyanate" is often abbreviated as "PMDI", and is also commonly referred to as "MDI", "Iso", or "Isocyanate".

Chemical reactions between Side A and B create a lot of heat. This is called an **exothermic reaction.**

Polyols - React with PMDI to form solid urethane

Blowing agents (3)

1) Water – Called a chemical blowing agent because it creates CO_2 by a chemical reaction with PMDI.
2) 245fa – called a physical blowing agent because it is already present in the A-side and unaffected by the reaction between A-side and B-side. It boils at 60F, so becomes a gas during foaming.
3) 141b – similar to above 245fa

[4] "Thermoset" means the material does not melt when heat is applied, it degrades and burns without liquefying (like wood).

[5] Common names for 245fa are "blowing agent", "HFC", and "hydro fluorocarbon".
245fa does not degrade the Earth's ozone layer.
245fa is the main reason closed cell foam has higher R-Value than open cell foam. It is more insulating than air.

Open cell foam blowing agents are carbon dioxide (chemical) and water (physical). Closed cell foam blowing agents are carbon dioxide (chemical) and 245fa (physical).
Catalysts - Catalysts are chemicals that accelerate chemical reactions. The presence of catalysts allows Side A and B to react to form solid urethane foam in seconds, instead of minutes or hours. Some catalysts are reactive, and become part of the solid urethane.

Fire retardants - Foam still burns when fire retardants are present. These additives just make it more difficult for fire to start and spread.

Surfactants - Like soap or dishwashing detergent, surfactants keep liquid bubbles from bursting before they become solid

THE CHEMICAL REACTIONS INVOLVED

Essentially, the physics of polyurethane foam is the dispersion of gas within a polymer. In fact, the foam is 97% gas. The gas provides the thermal properties while the mechanical and chemical properties are provided by the polymer.

- PMDI reacts with polyol in the A-Side to make urethane.
- PMDI reacts with water in the A-Side to make gaseous carbon dioxide and a solid by-product called urea, which becomes part of the urethane.
- The heat from the reaction causes the Physical blowing agent to vaporize and expands the foam while Chemical Blowing Agent (H2O) reacts with Isocyanate to generate CO2 gas and expands the foam
- Often there is a combination of blowing agents in a formulation.

CAUTION:

- PMDI can also react with water vapor in the air to generate carbon dioxide and solid urea. The hard urea particles can clog filters and spray guns.
- Always use a sealed container with a desiccant dryer in the vent, or top off with a nitrogen atmosphere before sealing. Never store ISO in an open container.

GETTING THE REACTIONS RIGHT

Physical properties depend on properly proportioned and properly mixed materials.

The Applicator must be alert to 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

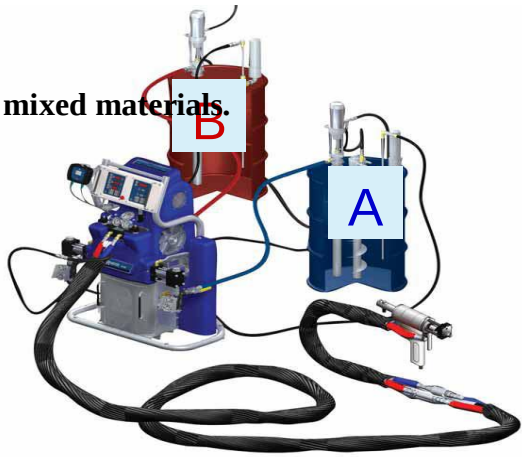


Figure 4 The heart and lungs of the SPF machine

- Mixing is by impingement – i.e., A & B streams collide at high velocity in order to achieve mixing.
- The spray gun creates a fine mist that exits the gun in a symmetrical pattern (typically conical)
- Within seconds the mixture foams and reacts to form a tack-free urethane foam.

CAUTION:

Proper pressure and temperature at the spray gun are critical to insure good mixing of A&B. These two factors are in the applicator's control!

Viscosities of A & B reduce with increasing temperature making them easier to pump and flow.

Example:

Viscosities of A&B

B-Side PMDI	170 to 230 cPs	25 °C
A-Side Polyol	170 to 200 cPs	25 °C

Viscosities of common materials

Water	0.9 cPS	25 °C
SAE 10 Motor oil	65cPs	25 °C
SAE 40 motor oil	319 cPS	25 °C
Molasses	5,000 – 10,000 cPs	25 °C

FOAM PROCESSING AND PROPERTIES

SPF typical properties normally listed include:

- Density
- Compressive Strength
- Tensile Strength
- Dimensional stability
- Thermal Conductivity
- Cell Structure – % closed cell

If SPF is not processed correctly it will not achieve the listed physical properties.

We will examine each of them and some more below:

Certain **time**-based parameters are to be kept in mind. They are

1. Cream Time - brown liquid turning a creamy color (typical range 1-4 sec)
2. Tack-Free Time / Gel Time – SPF is not tacky to the touch (typical range 5-10 sec)
3. Rise Time - the time until the foam has completely risen (typical range 9-16 sec)

All these times will vary as a function of system type, A&B temperature, air temperature, and substrate temperature. Colder climate / Winter grades are designed to react faster. They determine the reactivity of the chemicals.

Density is a demanding factor. It is normally measured in kg/m^3.

- Core (or nominal) density - weight from center of sample
- In place density – sample with points of adhesion, knit lines, skins
- Density in technical data sheets refers to core density. In place density is substantially higher, and can vary greatly with application and environmental conditions.
- One cubic meter of water weighs 1 Kg / 1 Ltr.

NOTE: Higher altitudes reduce the density of foam systems due to lower atmospheric pressure.

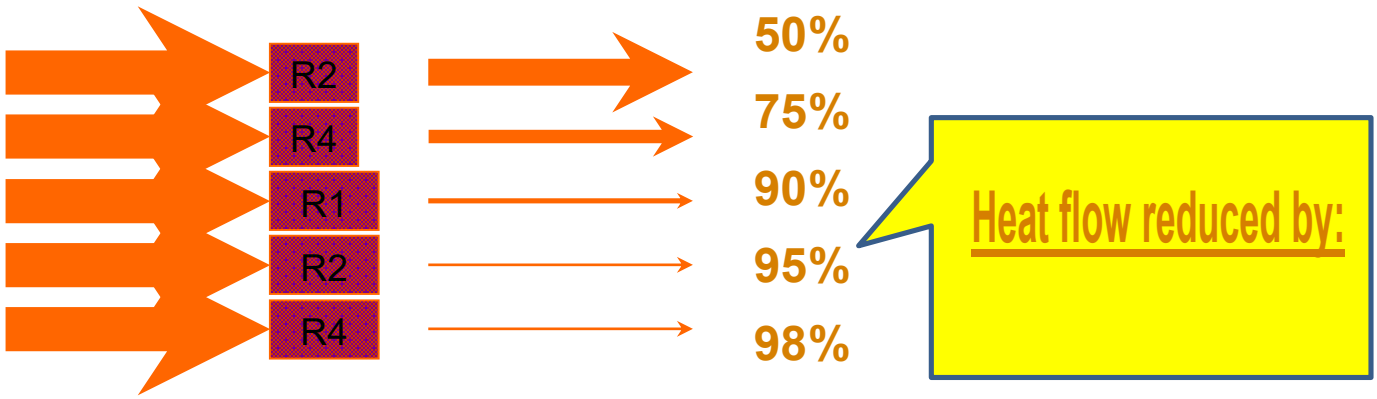
R-Value is a measurement of resistance to heat flow.

- Insulating materials have higher R-Values than thermally conductive materials
- R-value is not always linear with thickness. The ECBC Reports list R-Value at multiple thicknesses.
- For thicknesses not listed use interpolation.

Building Material	R-Value per inch
steel	0.004
concrete	0.1
wood	1.0
Open Cell Spray Foam	3.7
Closed Cell Spray Foam	6.9

Figure 5 R-Value comparison with other materials

Figure 6 There is a diminishing return on heat flow reduction with higher R value. 3% difference between R20 and R40



Compressive Strength is a measure of the resistance of the foam to deformation under a load.

- Closed cell foam has much higher compressive strength than open cell foam.

Dimensional Stability is a measure of the ability of the foam to keep its shape when exposed to extreme environmental conditions.

- The foam is subjected to wide and frequent temperature and humidity swings in a laboratory environment
- Changes in dimension are reported as a percent of the original dimension.

A note on the supplier side quality control measures will be in place here.

- ✓ A-Side is made by a batch process. Each batch is tested by a chemist or technician prior to drumming to confirm reactivity and density are acceptable.
- ✓ Every A-side and B-side drum has a Lot Number listing on the drum. The lot number is important for tracking when product issues arise.
- ✓ A-side and B-side have shelf life limits, typically 6 months. Check the technical data sheet. The lot number indicates the manufacturing date.

TIPS:

- If the SPF contractor believes there is a problem with the SPF system he must collect the information required on the Customer Complaint Information Request from the Supplier.
- The Tech Service representative needs this information to initiate an investigation.
- Lot numbers for the A- and B-side are important, required information.
- SFAI recommends that all contractors utilize a daily log sheets for the lead applicator to fill out at the job site.

- In the event of a quality issue this recordkeeping helps to reconstruct events and clarify the situation.
- A sample Daily Log Sheet is included in the appendix of the AIP notebook for review and discussion at this time.

CAUTION:

- Long-term storage between 18-25 °C. Storing below recommended temperatures can lead to seeding in side B and increased viscosity in both side A & B.
- Store drums at 20-25 °C for 48 hrs. before spraying.

APPLICATION PROCESS

A step-by-step checklist should be thoroughly adhered to for every job. They are as follows:

Substrate Preparation

Metal surfaces should be dry and free of scaling, rust, grease & oil

Concrete should be clean and dry, moisture content should cured for 28 days and free surface moisture.

Wood should be free of standing water; moisture content should be less than 18%.

Many substrates are candidate for priming. Priming substrates can help increase yield, enhance adhesion, and allow application in colder ambient temperatures. Contact supplier Technical Service for a recommendation.

Substrate Temperature

Check the drum label for recommended temperature ranges. Cold surface temperature will reduce the reactivity of the foam and reduce yield. Hot surface temperature can cause the foam to react too quickly

Higher mass substrates like concrete or heavy metal can absorb large amounts of heat or cold and are referred to as “heat sinks”.

If a cold substrate can’t be warmed up with a heater, etc. A common approach is to first seal off the substrate with a pass of approx. ½”. This adds insulation to the substrate.

Use proper grade formulation for varying substrates.

The Process

Before you even start the mixing, ensure that all lines are thoroughly flushed when switching between SPF systems, or when converting between products from different manufacturers. Do not assume compatibility.

Start from the Drum and Work Forward to Achieve the Desired Temperature and Pressure at the Spray Gun as depicted in Fig. 9.

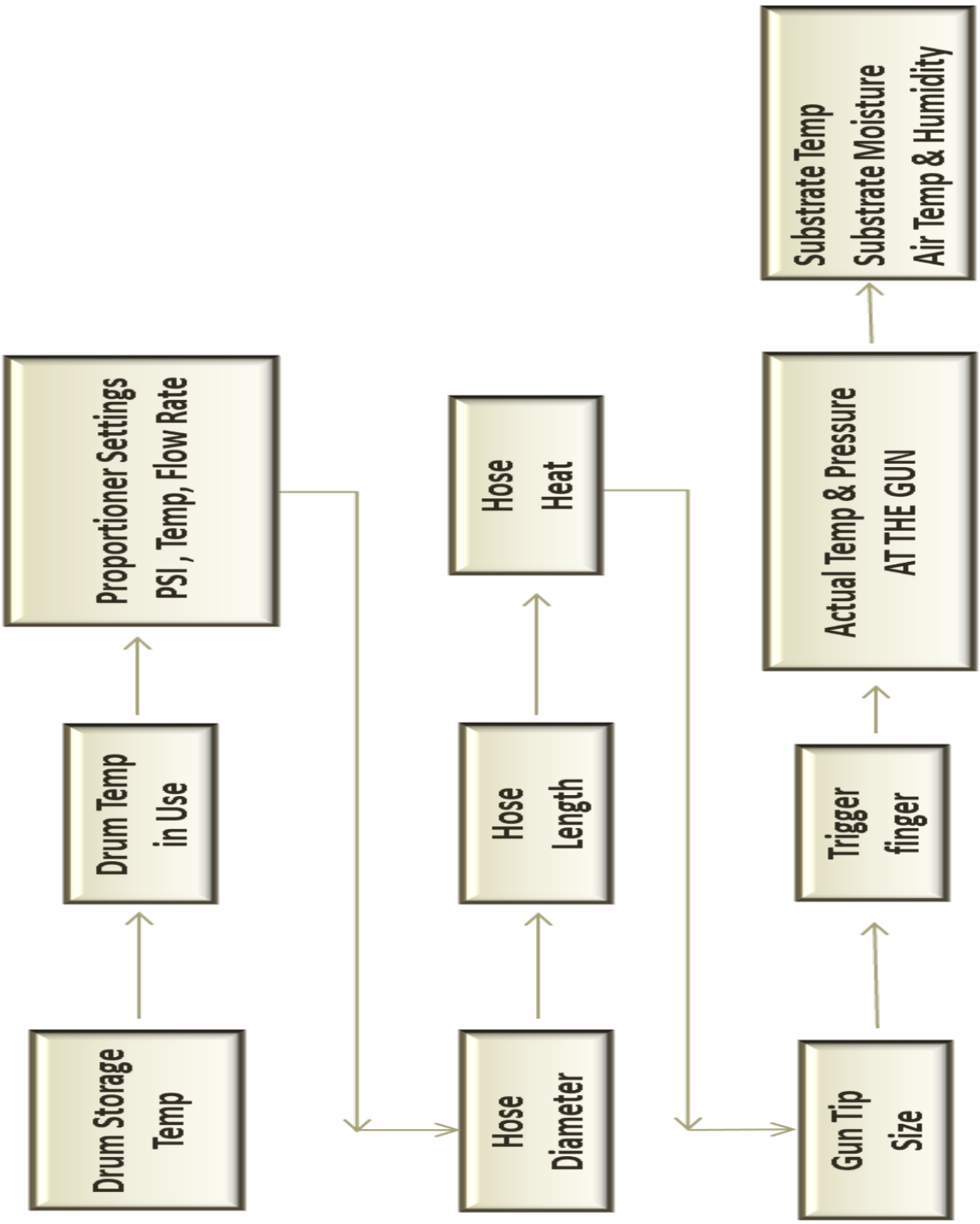


Figure 7 Process Flow

TIPS:

Yield is impacted by the Equipment and Process Settings

- **Material temp too low will lead to poor reactivity, poor mixing**
- **Material temp too high will lead to SPF too fast, less yield**
- Transfer pumps and feed hoses undersized (cavitation)
- Preheater undersized (low $\Delta T \Rightarrow$ poor mixing, low reactivity)
- Hose >150 ft. length or <0.5 inch i.d. not recommended
- Transfer pump - stick pump OK , no diaphragm, no gravity feed
- Lacking insulation on hoses
- Improper gun and/or tip size (yield $\Downarrow$)

Yield is impacted by the Equipment and Process Settings

- **Air temperature (too cold, yield $\Downarrow$)**
- **Substrate temperature (too cold, yield $\Downarrow$)**
- **Wet substrate (yield $\Uparrow$, poor adhesion to substrate)**
- Substrate type (OSB, concrete, gypsum board, metal panel)
- Humidity (impacts substrate moisture content)
- Surface contaminants
- Altitude and Wind (yield $\Downarrow$)

Yield is impacted by Applicator Skill and Experience

- **Overall foam thickness consistency, control of lift thickness (primarily applies to closed cell)**
- **Recognition of issues (off ratio, shrinkage, voids, contamination, etc.)**
- **Ability to optimize equipment settings to existing conditions**
- **Spray technique**
- Improper material transition
- Management of drum residual

CAUTION:

Do not be surprised. Exotherm in closed cell foam can create very high temperatures if not adequately managed, which can cause foam degradation. Lift thickness of closed cell foam must not exceed supplier recommendation of 18 to 22 mm per pass.

Successive two-inch lifts must not be applied until the foam core cools to less than 38 to 40 °C or ambient temperature (if ambient is above 38 °C).

Incomplete reaction leaves unreacted chemicals in the SPF. Off-ratio can result in A-rich or B-rich streaks in the foam, and incomplete reaction between A&B.

Low pressure or low temperature can lead to inadequate mixing of A&B, resulting in incomplete reaction

DON'TS

Do not Attempt to Cover Bad Foam with Good

REMOVE

- Off-ratio foam
- Transitional material
- Streaky foam
- Overly thick lifts of closed cell SPF

SPRAY FOAM FOR RETROFIT

The ability to both **insulate AND air seal** with a single product offers one of the easiest and most effective ways of weatherizing existing buildings.

Most people understand that adding insulation will improve the energy efficiency of a home.

However, many people don't understand that eliminating air leakage is extremely important to achieve energy efficiency, and helps prevent mold and moisture in the building envelope by eliminating condensation surfaces.

The most readily available energy resource to the nation today is energy avoidance through efficiency measures.

Becoming part of a larger work team, partnering with an Energy Smart Contractor to take care of the energy modelling and HVAC sizing, e.g., enables bundling of services to broaden the offering to the customer is a winner in the marketplace.

In this chapter, the following essential topics will be covered.

- Locations for Spray Foam in Retrofit
- Benefits of the Unvented space
- SPF Installation in the Space.
- Converting from Conventional to Unvented space.

Locations for Spray Foam in Retrofit

It goes without saying that SPF installation can be done with ease in any area and it specially helps in areas that are difficult to seal and insulate. Some such areas are

- **Space - convert to unvented: SPF can be utilized to convert a vented space to an energy efficient unvented space.**
  - Vented attics typically have lots of air leakage. Converting to unvented seals the space and eliminates leakage.
  - When the HVAC and air handler unit are in the attic, sealing the space puts them within conditioned space, where they operate more efficiently.
  - By moving the thermal boundary up to the roof deck, the entire space moves to within a few degrees of the interior of the home.
- **Crawlspace or Basement - seal vertical walls or underside of floor**
- **Rim joists**
- Cantilever (overhang) structures
- Floors of rooms over garage

Benefits of unvented space are important.

They eliminate air leakages; when HVAC and air handler are in the attic, sealing the space creates a conditioned space where they can operate more efficiently; by moving the thermal boundary up to the roof deck, the entire space moves to within a few degrees of the interior of the home.

Pre-Inspection

Identify pre-existing conditions before undertaking work. If you do not identify these issues before commencing a project they can become safety hazards, and they may be attributed to you after job completion.

Possible issues include:

HVAC Sizing

When retrofitting an existing attic to an unvented attic, the existing HVAC system may become oversized in relation to the new, reduced demand.

- In warm and humid / Coastal climate zones HVAC also functions to reduce and/or manage moisture levels of the building.
- When HVAC becomes oversized, the system may begin to short cycle, limiting it's ability to control humidity.
- Short cycling may have negative impacts on the comfort and efficiency of the building.

Utilize an HVAC consultant when retrofitting an attic with spray foam insulation to determine of the HVAC unit needs replaced.

Moisture:

Look for

- Evidence of damage due to moisture intrusion or vapor/condensation damage
  - Existing or prior water leak from Exterior
  - Mold - Mold has a fuzzy appearance and can be an orange, green, black, brown, pink or purple in color.
  - Mildew - Mildew could be downy or powdery: Downy mildew starts as yellow spots that first become brighter in appearance and then the color changes to brown. Powdery mildew is whitish in color and that slowly turn yellowish brown and then black.

Figure 8 Moisture is tough sabotager & has to be dealt with firmly

- Moisture Content
  - All wood substrate materials should be checked to ensure it is below 18%.
  - Use of a hand held moisture meter is recommended.

Figure 9 Well measured is half the problem solved

Dangerous Wiring:

- **Knob and Tube** - The fire safety of knob and tube wiring relied on the fact that the wires were generally routed through air, suspended by knobs and protected by a heavy ceramic tube where passing through wood. Wiring of this type must be replaced before SPF application.
- **Bare wires** - need to be replaced before installing spray foam insulation

Figure 10 Wires can be fire spots

Pest infestations:

Look for evidence of existing or prior pest infestations.

Figure 11 Nature's hazards

Combustion Safety Issues:

Check efficiency and ventilation requirements of all combustion appliances. Open combustion heating systems and hot water tanks are routinely located in conventional attics. Similarly, open flames cause a fire hazard during construction and should be carefully avoided.

Moving the thermal envelope to the roofline places the open flame inside the thermal envelope and creates the possibility of back drafting carbon monoxide or other combustion by-products into the occupied space.

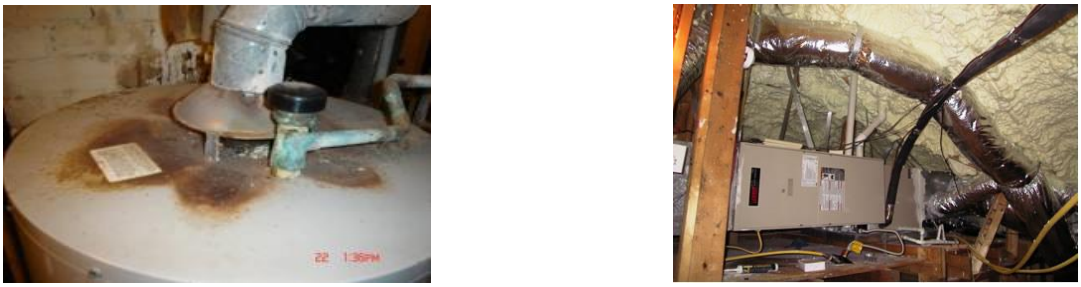


Figure 12 Open flames inside a sealed space will emit dangerous gases

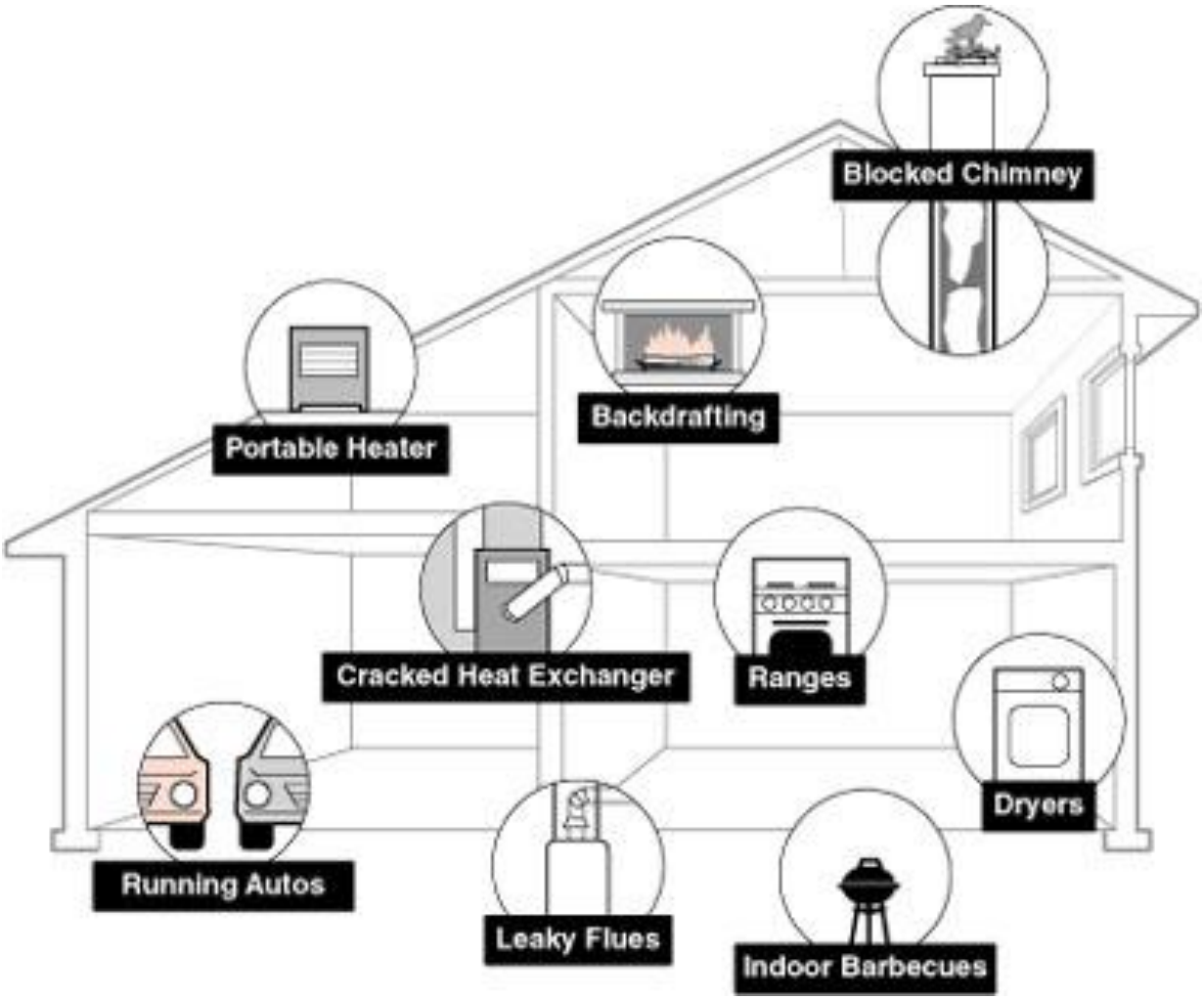


Figure 13 A meticulous study of the home layout has many benefits

Miscellaneous:

a. Look for recent changes to the house such as modifications to the structure that could affect the thermal or moisture performance.

Figure 14 Note the modifications, utilizations & contaminations

b. Look for evidence of utilization of the attic space for storage.
c. Look for contaminants on the surfaces that will be insulated with spray foam. Surfaces must be clean, dry, and free of dust, dirt, debris, oil, and solvents.

SPF Installation

Working in retrofit situations can be more hazardous or risky than in new construction.

Nothing is worth getting hurt for!

Access to areas where foam must be applied may be extremely tight. No matter how tight the space, required PPE must be worn. Never work alone

Wrap rafters of joists to achieve a continuous layer of SPF

Deal carefully with Direct Combustion Appliances

Construct a sealed equipment room with combustion air supplied from the exterior.

Install high-efficiency, closed combustion appliances with the combustion air ducted directly to the units from the outside of the building.

Ductwork

Ensure all duct systems are in good condition and securely connected to the register boots and plenums

Take care not to damage ductwork when dragging hoses, electrical cords and lines over them.

Check for damage, cracks, or improper connection of the ductwork and repair. Failure to repair may lead to buildup of odors.

Figure 15 Ductwork should not be damaged during the SPF application process

Remove Existing Insulation

Whenever the concept of moving the thermal envelope from the floor to the roof line is applied, it dictates that the thermal insulation on the floor is no longer functional.

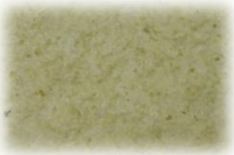
Old insulation can contain years of accumulated dust, mold or mildew, and dead insects and rodents. It is also advisable to remove it from a hygienic perspective

The existing floor insulation should be removed prior to installing SPF on the roof deck and walls.

SPF TROUBLESHOOTING

Several factors affect the typical yield, properties, performance and appearance of the foam application. Please study the below table. It is important to keep in mind that the skill and experience of the operator is critical to achieving the optimum application.

Table 1 Troubleshooting Guide

S. No.	Condition	Possible Causes	Remedies
1	Higher density; poor yield; poor foam quality	Low ambient and substrate temperature Wind Thin passes Loss of blowing agent from "A" component Off ratio (high on "B" component) Insufficient mix	Take suitable corrective action.
2	Imbalanced pressure 	Higher pressure in Iso side Higher pressure in Polyol side	Check the screen of gun Check the screen of machine Check the chamber Check hose Check the machine and hose heater
3	Soft foam, Low Density 	Off-ratio due to Polyol rich	Correct the ratio accordingly
4	Bright/Coarse cell structure Brittle foam High density Dark brown colour 	Off-ratio due to Iso-rich	Correct the ratio accordingly

5	Blisters  blister	Bad mixture; Off ratio; Insufficient pressure; Wind; Humidity; other contaminants on the surface of substrate; Too much thin layers will result in more blisters. High temperature.	Ensure right ratio Ensure output under machine limit Substrate should be clean and free of moisture.
6	Pinholes 	Insufficient pressure in the gun. Bad mixture; Low material temperature; Low substrate surface temperature; Off ratio; Wind.	Ensure sufficient mixture; Ensure material temperature

HEALTH AND SAFETY

In this chapter, we will learn in detail the following topics which are of utmost importance in the SPF industry:

1. Hazards of SPF Application
2. Effects of Exposure and First Aid
3. Personal Protective Equipment (PPE)
4. Disposal
5. Communication to Building Owner and Occupants of Existing Home Evaluation and SPF Install Details
6. Worksite Ventilation for SPF Applications
7. Basic Ventilation Design Principles
8. Enclosures
9. Re-occupancy

Before that, let us have a quick recap of the basic chemicals and what we must be aware of them.

As already explained, SPF is a thermoset plastic insulation material formed by the combination of MDI and a polyol blend. The reaction between the two materials is quick, releases heat, and within a few minutes, foam is formed and tack-free.

Consequently, installation of SPF does present safety and health hazards requiring protective measures due to chemicals used.

***Cured Foam is essentially inert and non-hazardous when properly installed*.** SPF is combustible, and therefore care must be taken to avoid exposing the foam to extreme heat or open flame**.**

Table 2 A & B Components Physical & Chemical Reactivity

A Side or Isocyanate (ISO) Known as polymeric MDI or pMDI	**B side or Polyol Blend**
ISO part A component **does not** contain cyanide	Consists of several chemicals: Polyol(s) Catalysts (amine compounds) Blowing Agent (can be water and/or hydrofluorocarbon or HFC) Flame Retardants Surfactants
Brown liquid	Amber liquid
Virtually Odorless	Slight ammonia/fishy odor
Evaporates Slowly	Evaporates slowly
Does not dissolve in water; reacts with water slowly to form polyurea and carbon dioxide (CO2) gas	Dissolves slightly in water

ISO is a health hazard if not used or handled properly	Some of the additives do present safety and health hazards

Chemical Handling and Storage

Proper storage is important before and during use on the job site. Improper storage condition can make the components unusable.

Keep A and B-side drums dry and at proper temperatures to prevent bulging.

Storage temperature for SPF material should be as per recommendation of supplier.

It is important to maintain a **tight seal on MDI (B-side)** containers to protect against moisture or direct contact with water.

When opening A **-side drums, open the bung slowly** to help release any built-up pressures. This is due to presence of HFC blowing agent which can expand if the drum is exposed to high temperatures.

Figure 16 B-side with water contamination

Hazards of SPF application

To reiterate, IF NOT HANDLED PROPERLY, SPF chemicals pose a hazard.

Hazard Communication Requirements

- According to Globally Harmonized System (GHS) of Classification and Labelling of Chemicals Hazard Communication Standard, **all employers are required to inform employees** of the safety and health hazards of the chemicals they may work with on the job. Requirement of this law include:

- Worker Training

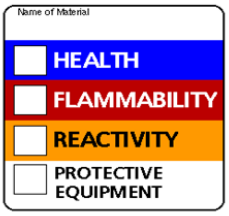


Figure 17Checklist

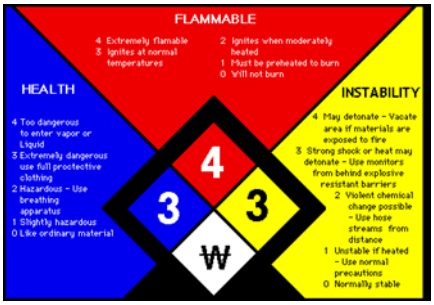
- 

Figure 18 Label sample

- SDS(s)
- Labels

- Hazard communication should be available in more than one form (for example, placards, labels or SDS's).
- Hazard communication should include hazard statements and precautionary statements.
- Hazard communication information should be easy to understand and standardized.
- Hazard communication phrases should be consistent with each other to reduce confusion.
- Hazard communication should take into account all existing research and any new evidence.

Effects of exposure and first aid

Personnel Safety

It is important to know the ways in which exposure leads to potential health effects. Of even more importance is the communication of this information.

Table 3 SPF Chemical Exposure

Routes of Exposure • Inhalation • Skin • Eye Contact • Ingestion	**Possible ways of Over Exposure** • Improper Use or Fit of Respirator • Allowing Skin/Eye Contact • Used in a confined/poorly ventilated space • Overheating chemical • Burning foam
Signs of Over Exposure • Sore Throat • Coughing • Chest tightness • Shortness of breath • Reddening, Itching, Rash on skin	**Potential Health Effects of Over Exposure** • Short term irritation • Long term lung effects • Sensitization – allergic reaction

The first aid action plan should be in place as per the exposure mode:

In the case of **Inhalation Exposure:**

- Breathing vapors/mist of Side A or Side B should be avoided at all times.
- Remove individual from area if person is affected by inhalation and seek immediate medical attention.

In the event of **Skin contact Exposure**:

- Wash with soap and water or shower to cleanse the skin. Contaminated clothing should be removed and discarded.
- For cuts or abrasions caused by pressurized fluid, seek immediate medical attention.

When **Eye Exposure** happens,

- Flush the eye(s) immediately for at least 15 minutes with large amounts of lukewarm water. After flushing, protect eyes with a loosely tied bandage if victim cannot tolerate light. Seek immediate medical attention.
- Contact lenses are not recommended during spray application.

If there is **Ingestion Exposure**,

- Do not induce vomiting. Seek immediate medical attention.

Personal protective equipment

SFAI Requires Respiratory Protection during SPF Application Work

Air monitoring studies across the globe have shown that airborne MDI concentrations often are above the occupational exposure limits for the applicator, and sometimes for helpers working on the same floor or near the SPF application area. It is also seen that it is common to find airborne concentrations of amine catalysts and blowing agent in the spray area.

Moreover, Indoor SPF applications usually result in much higher airborne concentrations of SPF chemicals than outdoor applications. For Indoor SPF applications: supplied-air respirators are recommended while Outdoor SPF applications: air-purifying respirators may be adequate

Recommended Respirator Use

Spray Foam Applicator (Required by SFAI)
A full-face or hood-type supplied-air respirator (SAR) operated in continuous flow or positive pressure mode. Use SAR during post-spray activities (e.g., trimming foam, clean-up, etc.) if this work is performed within one hour after application.

Figure 19 Full Face SAR

Helpers

Air-purifying respirator (APR) with combination organic vapor/particulate (P100) cartridges generally acceptable unless they work in the immediate spray area for extended periods of time, then use SAR.

Figure 20 APR

Liquid Chemical Handling in Spray Rig When handling liquid product that has been heated, use an air-purifying	respirator (APR) with combination organic vapor/particulate (P100) cartridges.

Key Requirements of a Respiratory Protection Program include but are not limited to:

1. Written Respiratory Program established by employer demonstrating compliance
2. Medical Evaluations (medical approval that employee physically capable of wearing)
3. Annual Fit Tests (required for employees provided air-purifying respirators or a tight-fitting supplied air respirator such as a full face (FF) or half mask respirator)
4. Limitations on Facial Hair (applied to employees provided FF or ½ mask respirators)
5. Cartridge Change-out Schedule (must be clear to employee when to change cartridges; cartridges needed for APRs are organic vapor or charcoal with a P100 pre-filter)
6. Employee Training (employee must be trained on how to properly wear the respirator, do daily fit checks and inspections, perform routine cleaning and maintenance)

Eye Protection helps prevent splashes of chemicals, overspray, aerosols and particulates present in spraying, sanding, and grinding operations

Types of Eye Protection include Safety goggles, Safety goggles with face shields and Hooded or full face respirator

Contacts are not recommended while spraying

A portable eyewash station should be available in the work area.

Figure 21Safety Goggles & Full face respirator Figure 22 Safety Goggles

Clothing

- Appropriate protective clothing is necessary whenever there is a possibility of direct skin contact with SPF component chemicals
- Disposable coveralls are typically worn to keep spray mist from contacting employees' skin and personal clothing.
- To ensure proper skin protection, wear PPE in such a manner that no skin is exposed.

Gloves

- Nitrile, neoprene, butyl or PVC gloves generally provide adequate protection against A side and B side material. Fabric gloves coated in these materials provide the best protection when spraying or handling hoses due to heat associated with the SPF process.
- A good fit is essential. Too large or too small may not provide adequate protection from dermatitis, skin sensitization, toxic build up and skin oil extraction.

Figure 23 Gloves

Other Safety Hazards

Precautions: SPF Equipment (High Pressure Systems)

Pressurized fluid can be very dangerous.

Never use a damaged hose. Check hoses for cuts, leaks, abrasions, bulges or damage. Replace hose if any of these are present. **DO NOT TRY TO REPAIR**.

Check for movement of the hose couplings. Tighten all fluid connections securely before each use

Fluid injection injuries can cause serious damage. Seek immediate medical attention if such injury occurs.

Figure 24 SPF Machine

Precautions Electrical

Electrical equipment used should be equipped with Ground Fault Circuit Interrupters (GFCI) to prevent electrical shock or electrocution.
Ground or bond all process equipment and container of flammable materials (i.e. cleaning solvents) Note: plastic containers used to transport solvents cannot be grounded.
Do not plug in or unplug any power supply cords in the spray/dispersing area when there is a chance of igniting vapors still in the air.

Electric power lines near a work site can be a source of ignition and other extreme hazards. Never let equipment touch or come close to overhead electric lines or to other sources of electricity.

Precautions: Confined Space and Fall Protection

Confined Spaces

Some attics and crawlspaces could fall within the definition of "confined spaces. Full face or hood type supplied air respirators are recommended for attic and crawlspace applications.

Fall Protection

Employees should receive training in the following areas prior to work assignments

- Nature of fall hazards in the work environment
- Correct procedures for erection, maintaining, disassembling, and inspecting fall protection systems.
- Role of each employee in a safety monitoring system while in use
- Correct procedure for handling and hoisting of material and equipment

Precautions: Fire

Open flames, cutting and welding torches, lighted pipes, cigars and cigarettes are prohibited in and adjacent to chemical storage and installation areas.

Post warning signs in all spray areas so that they are clearly visible.

Do not expose SPF to flames or to sources of intense heat (> 75°C).

Fire extinguishing equipment must be provided at both storage and installation sites.

Figure 25 It is essential to make familiar with the operation of the fire extinguisher

Disposal

Waste insulation should be disposed of daily in a designated location with due regard for its combustible characteristic.
Large buns of closed cell waste insulation should be cut open, doused with water and allowed adequate time to cool prior to disposal to minimize the risk of a fire.
Follow local Pollution Control guidelines for disposal of waste

Precautions: SPF Chemicals - Waste Disposal

Wastes, including empty drums, require proper handling and disposal.
Do not re-use drums (especially A-side or ISO drums). Do not expose drum to open flame or cut with torch.
In general, there are 2 options for disposing of drums:

Arrange for pick-up by a drum re-conditioner, a scrap metal dealer, or an approved landfill. The drum must meet the definition of empty and check with vendor on how to prepare the drum for pick-up.

A preferred method for disposing of empty drums is to contract with an approved drum re-conditioner. If not re-claimed, empty drums should be thoroughly decontaminated with a neutralizing solution prior to disposal. A mixture of 90% water, 3-8% ammonium hydroxide or concentrated ammonia, and 2% liquid detergent. (refer to MSDS).

Communication to building owner and occupants of existing home evaluation and SPF install details

It is critical that building occupants and owner (if different) have a complete understanding of the project.

Prior to commencement or work schedule a meeting with the building occupants and owner that includes:

- **EXISTING HOME EVALUATION** – Discuss issues pertaining to the building before project begin.
- **SPF INSTALL**– Discuss all issues related to the installation of SPF.

Communication – Site Evaluation

A checklist should include the following and fully documented.

- Pre-existing Conditions: Explain all identified pre-existing conditions. Leaks, pest infestations, condensation damage, equipment malfunctions, etc., should all be resolved by you or another professional.
- Combustion Appliance: Combustion equipment in the attic must have proper ventilation or must be replaced.
- Venting
- Existing Duct Work: Sections may need to be replaced if they are extremely leaky, or if insulation is falling off.

- HVAC: Discuss your HVAC evaluation. Explain that making the house more efficient may impact humidity control.
- Insulation Removal: To avoid the potential for attic moisture issues, existing insulation and vapor barriers should be removed from the attic floor.
- Attic Storage: If attic is to be used for storage or occupancy, then the SPF must be separated from the attic space with an approved thermal barrier.

Communication – Installation Plan

- Review Installation Plan: Review project details and timing.
- Building Specific Details: Special approaches may be necessary to insulate poorly or un-insulated areas in the house (Such as porches, knee walls)
- Vapor Retarder Requirements: Information on types of vapor retarders and locations where should be located.
- Unvented Attic Retrofit: All attic vents including soffit, ridge, turbine, electric fans, must be completely sealed or removed.
- Safety Precautions: Review the safety precautions that will be employed: closing off air intakes, isolation and quarantine of the work area, proper ventilation during and after install, installers wear appropriate personal protective equipment, blower door testing before and after (if deemed necessary), and other measures.
    - Vacating During Application
- Re-occupancy Times: Discuss for building occupants and other trades. 12 hours for trades, 24 hours for occupants, per SFAI.
- Home Ventilation: In the case of extremely tight houses it may be necessary to install mechanical ventilation after the SPF installation to ensure the home has sufficient ongoing air changes to meet ASHRAE 62.2.

Worksite ventilation for SPF applications

Manufacturers may have specific ventilation instructions. Below are essential guidelines.

Ventilation is a method of controlling work exposure to airborne hazardous chemicals or flammable vapors by exhausting contaminated air away from the work area and replacing it with clean air.

There are two basic types:

General Exhaust Ventilation

- Dilutes contaminated air by mixing it with cleaner room air.
- Generally consists of an exhaust fan mounted in ceiling or wall.
- Pulls air out of the room and discharges it outdoors.
- Replacement air is brought in by natural means (window, door, etc.) or a separate make-up air fan, duct

work, and air registers that provide clean air to the room.

Figure 26 General exhaust system is NOT RECOMMENDED as the sole source of ventilation when hazardous vapors or mists are present, because they do not immediately remove contaminants from the work space.

Local Exhaust Ventilation

- Local exhaust ventilation systems remove chemicals and other contaminants at their source.
- Exhaust duct or vent is placed as close as possible to where the work is performed to capture and remove contaminants before they mix with the rest of the air in the room
- Recommended for controlling hazardous vapor, mists, dusts, and particulates because they remove the contaminants before workers are exposed.

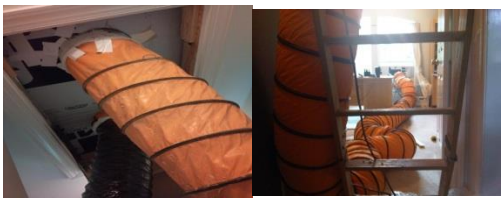
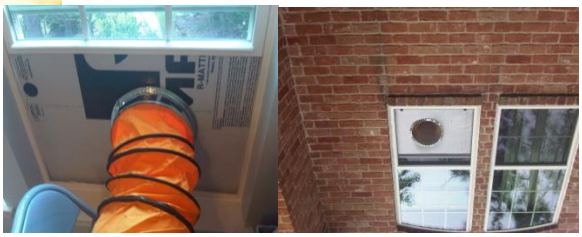


Figure 27 Local Exhaust Ventilation System



Basic ventilation design principles

A **local exhaust system** would be appropriate ***during*** the application process to capture vapors mists, dusts, and particulates at the source as they are emitted during the spraying and trimming processes.

A **general exhaust system** would be appropriate ***after*** the insulation is applied to ventilate the entire work area and building before other workers or occupants enter the area

Enclosures

Establishing enclosures around the work area serves two purposes:

- Prevents migration of contaminants to other areas of the building.

- Improves the efficiency and effectiveness of the ventilation system by minimizing the size of the area to be ventilated.

TIPS:

Remember to place warning signs on entrances to the enclosure or work area to alert other workers of the hazard and prevent them from entering the area. Where possible, remove residents and pets from buildings during application

Maintain a negative pressure in the work area or enclosure. If you use passive supplied air, your exhaust fan alone should be sufficient.

With a negative pressure in your room or enclosure, air will be drawn into the room from any opening.

Avoid openings that will short circuit your ventilation system. Poorly placed openings can short-circuit your air flow and create dead spaces

Remember to shut down and seal off HVAC openings in the work area. Unseal and restart the HVAC system prior to re-occupancy after the SPF has fully cured and the work area has been ventilated and cleaned.

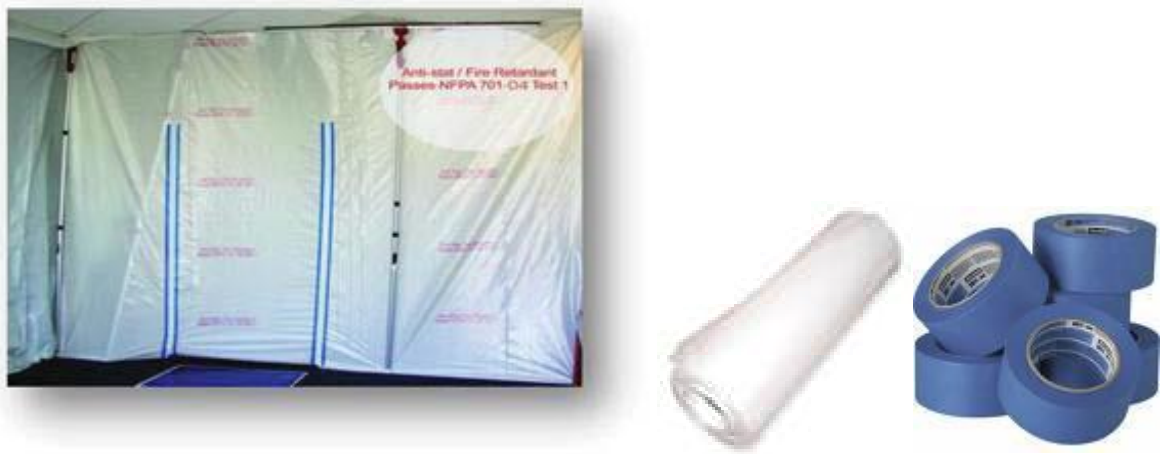


Figure 28 Separators & seals

Direct Exhaust to a Safe Location

Always remember to direct exhaust to a safe location outside the building, away from areas where other workers or people are or could be present. If the exhaust is at ground level, establish a control zone using warning signs and physical barriers.

Be aware of where direct air intakes are exhausting and not on neighboring buildings, cars etc.

Particulate exhaust filters should be used to remove SPF dusts and mists from the exhaust air. Helps to minimize hazardous air contaminants in the exhaust air and prevent SPF from settling on nearby vehicles or properties.

SPF can build up on exhaust fan blades, reducing the fan's efficiency over time. Place filter in front of fan

Figure 31 Direct exhaust to a safe location

Re-Occupancy

- Continue ventilating the area following application until the material had fully cured, off-gassing has stopped and vapors have been removed.
    - Worker reentry should be kept to a minimum and should only include those with appropriate respiratory protection.
    - Occupant re-entry should only occur after the building is fully ventilated.
- The SFAI Re-occupancy Guidance for SPF installations is normally 24 hours for all installations. Some manufacturers may recommend less.
- Refer supplier guidelines for more details

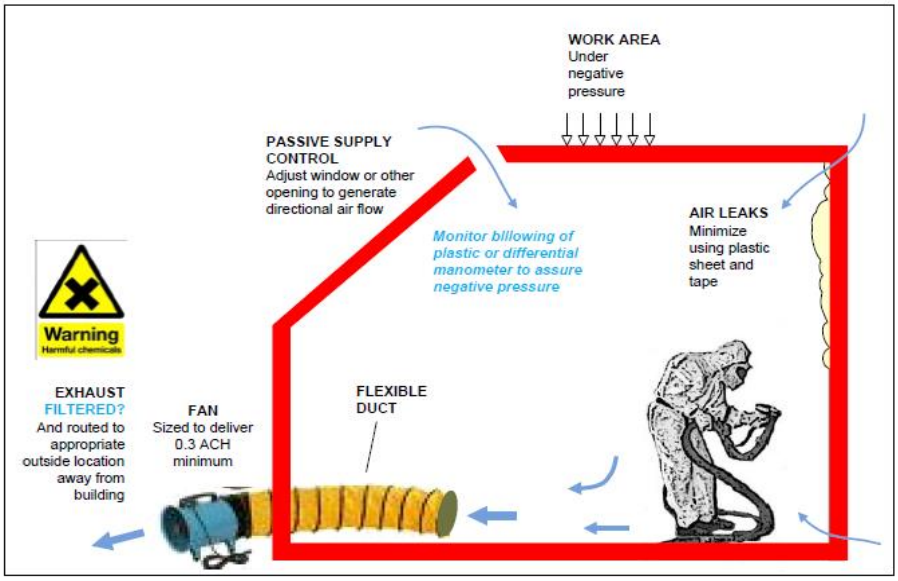


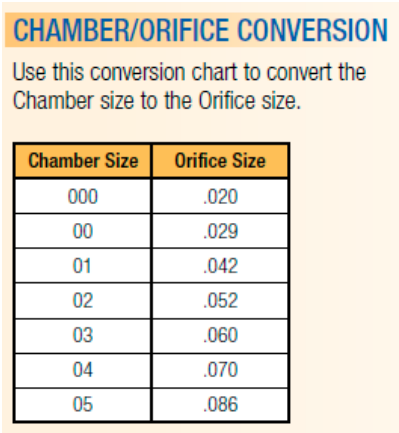
Figure 29 An Ideal SPF operation

EQUIPMENT COMPONENTS

We will cover here briefly but really leave the detailed instruction on application practices, machinery, job site safety, and other critical advice to the spray foam applicators groups and machinery suppliers. Always, manufacturers or equipment manufacturers can be more specific.

As in all cases, begin with an understanding of the controls of the equipment. In the SPF, the relevant ones are the controls for the electric reactor, temperature and pressure/motor. Each of them error codes which you will do well to familiarize yourself with.There are 6 major components which comprise the Spray Foam machines, which may be compressed air driven or electric or hydraulic.

1. **Proportioner**: A Proportioner is a system to secure proportions in a mixture. Normally, it consists of a body, jet, throat and metering orifice.



Chamber Size	Orifice Size
000	.020
00	.029
01	.042
02	.052
03	.060
04	.070
05	.086

2. **Heated Hose**
3. **Heated Whip Hose**
4. **Spray Gun:**

   The commercially available ones are easy-to-use, lightweight and ergonomic. They have features which reduce tip clogging and downtime and maintenance. Some also have quick-shot grease port which enables end-of-day maintenance in seconds. Solvent resistant O-rings means that entire gun can be soaked in gun cleaner

   The day-to-day maintenance of the gun centered on the gun safety mechanism is be conducted for trouble free and prolonged life.

5. **Drum Feed System**
6. **Agitator**

Effects that could influence yield

- This list is not exhaustive but helps to improve our understanding.
- Optimum thickness between 1/2" and 1"
- Too thin of a pass will raise the product density because of multiple product skins.

- Too thick of a pass could create thermal degradation, which could create scorched / burned foam.
- Over spraying an area too thick without allowing time to cool can damage the internal cell structure, which could cause slight shrinkage
- Material in drums **is** lower than the recommended storage temperature.
- Material – Type & Temperature
- Transfer pump - Pressure output & flow capacity
- Transfer hose - diameter and length
- Filtration
- Proportioner pump
- Size, common drive type and speed
- Pressure output setting
- Temperature settings & primary heat capacity
- Heated hose system
- Diameter, length & whip
- Gun Flow rate capacity is determined by the mixing chamber and gun configuration

One cycle = 2 strokes

Cycles are tracked on most proportioners and used to calculate volume used

Knowing the volume (Ltr) per cycle you can estimate

Cycles per Ltr

Total Ltr used per number of cycles

- ❑ Troubles are caused normally by Starvation, Cavitation or Restriction
- ❑ Troubleshooting can be effected by way of reading the pressure gauges correctly.

Below is an example of understanding the readings from the Pressure Gauges:

Lacking “A” Material 

We are dispensing product when all of a sudden we only have “B” component coming out of the gun. The first thing we do is, “**STOP**” .

We get to the proportioner and we see the “A” gauge is high while the “B” gauge is low. We know we have “B” component coming out of the gun so we **only** look at the “A" side of the equipment.

With the “A” gauge being high we know we are getting “A” component to the proportioner because it is pumping it up, (high pressure gauge). We look at for the problem to be from the proportioner to the end of the gun. Most likely place would be at the smallest orifice. The problem would be in the “A" side of the gun.

Below figure attempts to give a pictorial representation of the spray pattern vs. temperature and pressure. Knowing what is coming out the gun will tell you where to look for the problem. If you know you have “A” component being dispensed, you know you have lack of “B” component, you would look at the “B” side of the equipment for the problem.

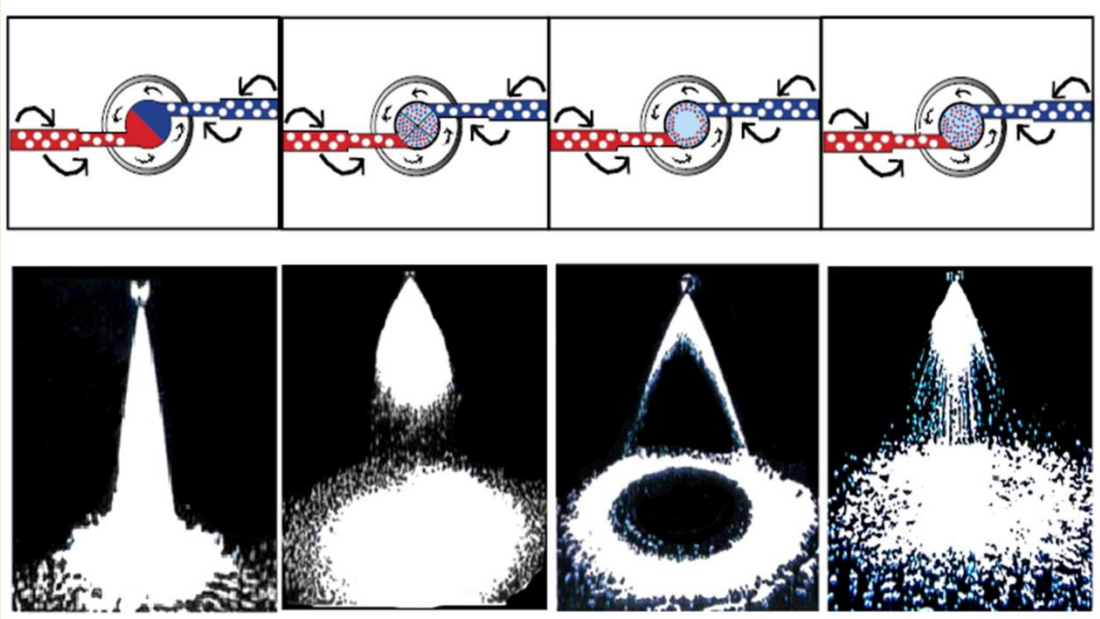


Figure 30 Spray pattern vs temperature & pressure**Potential Skin Injection Hazard**

High-pressure fluid from leaks can potentially inject fluid into the body. High-pressure fluid from dispensing devices, hose leaks, or ruptured components could pierce skin. This may look

like just a cut, but it can be a serious injury in need of immediate medical attention. The following safety tips can help avoid injury, including possible amputation.

• In case of skin injection, get immediate medical treatment.

• Inspect hose before each use for cuts, bulges, kinks, or any other damage. Replace damaged hose immediately.

• Check hoses and couplings daily. Replace worn or damaged parts immediately.

• Engage trigger lock when not dispensing.

• Do not point dispensing device at anyone or at any part of the body.

• Do not put your hand over the fluid outlet.

• Do not stop or deflect leaks with your hand, body, glove, or rag.

• Follow the Pressure Relief Procedure when you stop dispensing and before cleaning, Checking, or servicing equipment.

• Tighten all fluid connections before operating the equipment.

• Keep clear of leaks.

• Follow hose maximum pressure or temperature ratings.

• Use chemicals that are compatible with the hose materials you are using.

Equipment (Low Pressure Products): When working with low pressure products, avoid kinking or folding the hoses and secure all fittings before use. Keep the outlet ports of the dispensing unit free from any dust, dirt, or chemical that can affect the proper sealing of the nozzles. Also, keep outlet ports pointed away from persons while opening outlet port valves and leave chemical in the hose for storage.

Electrical

Electric power lines near a worksite can be a source of ignition and other extreme hazards, including shock and electrocution. If you notice downed power lines in the area, secure all ignitable materials and evacuate personnel until the lines are repaired. Never let equipment touch or come close to overhead electric lines or other sources of electricity.

For work near energized equipment, follow the GHS to properly lock out or tag out machines and equipment during repair or servicing activities. Ground any electrical equipment used as part of the SPF application to prevent electrical shock or electrocution. This is especially important when working near water or on damp or wet floors and roofs. Ground or bond all process equipment and containers of flammable materials (e.g. cleaning solvents). Remember that plastic containers used to transport solvents cannot be grounded. Use non-sparking tools (such as those made of brass or aluminum) where flammability may be a concern. Employers on construction sites are required by GHS to use either ground fault circuit interrupters (GFCI) or an Assured Equipment Grounding Conductor Program (AEGCP) to protect employees from the risk of electrocution or shock. There are several different means of employing a GFCI: (a) as an attachment to an appliance cord, (b) installed at the breaker panel, or (c) provided at the receptacle. Extension cords are considered to be temporary wiring; therefore, consider using ground fault protection with all extension cords on construction sites. All 120-volt, single-phase

15-ampereand 20-ampere receptacle outlets on construction sites that are not a part of the permanent wiring of the building or structure and which are in use by employees need to have approvedGFCIs for personnel protection. Your local electrical code will have detailed grounding and bonding instructions for your area and type of equipment. Consult the equipment manufacturer’s instructions for specific instructions.

BIBLIOGRAPHY

www.spraypolyurethane.org This website is CPI's main health and safety website for SPF (safe handling of SPF chemicals). The content is divided into professionals, homeowners, "Do It Yourselfers," and weatherization professionals (renovation mostly). Under Professional, at the link called "Resources," is a huge repository of guidance documents, posters, etc. The online health and safety training programs are accessed through this website.

https://polyurethane.americanchemistry.com/Spray-Foam-Coalition/Guidance-Documents This is a section of the CPI main website with systems house guidance on SPF, how to use SPF to meet building codes and other information. The "Best Practices" document might be of particular interest. It has some checklists and information on equipment as well.

www.whysprayfoam.org This website is a marketing website for SPF. It contains fact sheets, videos, documents, and case studies that promote the use of SPF as an energy efficient product.

https://spraypolyurethane.org/Main-Menu-Category/Weatherization-Contractors/Resources/Personal-Protective-Equipment-Sheet.pdf

https://polyurethane.americanchemistry.com/Resources-and-Document-Library/11365.pdf

https://polyurethane.americanchemistry.com/Resources-and-Document-Library/Disposal-of-Empty-Drums-Containing-Polyurethane-Chemicals.pdf

The CPI Spray Foam Coalition has a dedicated guidance document for designing ventilation for interior applications of high-pressure spray foam. Consider requesting permission to translate the existing guidance document. https://polyurethane.americanchemistry.com/Spray-Foam-Coalition/Guidance-on-Ventilation-During-Installation-of-Interior-Applications-of-High-Pressure-SPF.pdf

Please also refer to the manufacturer's brochures and literature available directly from them.