Protected membrane roofing’s breakthrough contribution to flat roof technology was the incorporation of an “upside-down” approach to insulating the roof: placing the insulation on top of the waterproof membrane to improve the membrane’s effectiveness and the insulation’s efficiency.

This advancement was made possible in large part by the use of STYROFOAM™ Brand Extruded Polystyrene (XPS) Foam Insulation, whose closed-cell, water-resistant qualities have proven to be a key component in protected membrane roof (PMR) systems.

A conventional roof places the membrane on top of the insulation, leaving the membrane vulnerable to extreme temperature changes, freeze-thaw conditions and physical abuse from heavy foot traffic (Figure 1).

The PMR system places the insulation on top of the membrane, protecting the roofing membrane from extreme temperature changes and physical abuse (Figure 2).

The main difference between PMR and conventional roofing is the sequence in which the materials are applied. The key to the PMR system is that the insulation is placed on top of the waterproof membrane, resulting in excellent long-term performance and durability.
Advantages of PMR
All flat roof assemblies consist of the same basic elements assembled in a seemingly logical order: a deck (composed of wood, metal or concrete), covered with insulation and topped with a waterproofing membrane. A protected membrane roof can employ the same elements, but the membrane is positioned under the insulation, offering exceptional long-term performance and durability.

PMR assemblies:
- Maintain the membrane at a nearly constant temperature, close to the temperature of the building’s interior; this minimizes the stresses on the membrane by reducing the harmful effects of freeze-thaw cycling, thermal cycling and excessive heat
- Protect the membrane from weathering, foot traffic and other types of physical abuse – both during and after construction
- Allow year-round construction since the roof is waterproofed first, then insulated
- Permit easy removal and re-installation of the ballast and insulation for making repairs or for constructing additional stories. In addition, a protected membrane roof provides an environmentally preferred option to reuse the insulation
- Allow for a range of ballast options – stone, precast paving slabs, soil and plantings for a vegetative roof, interlocking stone or concrete – depending on use and aesthetic considerations
- Are compatible with a range of membrane types
- Eliminate the need for a separate vapour retarder

Provide Durability and Protection
With the membrane positioned under the insulation, the choice of insulation becomes an important consideration. The insulation must be able to withstand wet environments (without sacrificing insulation performance) and foot traffic during and after construction, while continuing to perform over time.

Because of its durability and excellent moisture-resistant qualities, STYROFOAM™ Brand Extruded Polystyrene Foam Insulation delivers exceptional performance in roofing and plaza applications.
- Provides excellent moisture resistance and long-term R-value (RSI)*
- Offers exceptional durability to extend the life of the plaza or roof
- Protects the membrane against weathering, physical abuse and damage
- Maintains the membrane at a relatively constant temperature
- Controls dew point location

Terms:
- Absorption: the ability of a material to absorb quantities of gases or liquids, such as moisture.
- Accelerated Weathering: an experimental test where a material is exposed to a controlled environment to various elements (heat, water, condensation or light) to magnify the effects of weathering. The material’s physical properties are measured before and after the test to identify any detrimental effects of weathering.
- Aggregate: rock, stone, crushed stone, crushed slag or waterworn gravel used for ballasting a roof system.
- Aging: the effect on materials exposed to an environment for a defined time.
- Alligatoring: the cracking of the exposed bitumen on a built-up roof, producing a pattern of cracks similar to an alligator’s hide.
- Asphalt: a dark brown or black substance left as a residue when processing crude oil or petroleum. Asphalt may be further refined to conform to various roofing grade specifications.
- Asphalt Emulsion: a mixture of asphalt particles and an emulsifying agent, such as bentonite clay and water.
- Ballast: an anchoring material, such as stone or precast concrete pavers, used to hold insulation and/or roof membranes in place.
- Base Ply: the bottom ply of roofing in a roof membrane or roof system.
- Base Sheet: an impregnated, saturated or coated felt placed as the first ply in some multi-ply built-up and modified bitumen roof membranes.
- Blocking: sections of wood built into a roof assembly, usually attached above the deck and below the membrane or flashing, used to stiffen the deck around an opening, act as a stop for insulation, support a curb or to serve as a nailing for attachment of the membrane and/or flashing.
- Built-up Roof (BUR)Membrane: a continuous, semi-flexible multiply roof membrane, made up of plies or layers of saturated felts, fabrics or mats with bitumen in between.
- Cant Strip: a beveled or triangular shaped strip of wood or other suitable material used to transition from the horizontal surface of a roof deck or rigid insulation to a vertical surface.
- Caulking: sealing and making weather-tight the joints, seams or voids between adjacent units using a sealant.
- Compatible Materials: two or more substances that can be mixed, blended or attached without separating, reacting or affecting the materials adversely.
- Condensation: the conversion of water vapour or other gas to liquid state as the temperature drops or atmospheric pressure rises. (Also see Dew Point.)
- Counterflashing: formed metal sheeting secured on or into another surface used to protect the upper edge of the membrane or underlying metal flashing and associated fasteners from exposure to the weather.
- Curb: a raised roof location relatively low in height.
- Dead Load: permanent nonmoving load that results from the weight of a building’s structural and architectural components, mechanical and electrical equipment, and the roof assembly itself.
- Deck: a structural component of the roof of a building designed to safely support the design dead and live loads, including the weight of the roof systems, and the additional live loads required by the governing building codes. Decks are either non-combustible (e.g., corrugated metal, concrete or gypsum) or combustible (e.g., wood plank or plywood) and are the substrate used to apply the roofing or waterproofing system.
- Design Load: load specified in building codes or standards published by federal, provincial, county or city agencies, or in owners’ specifications to be used in the design of a building.
- Dew Point: the temperature where water vapour condenses in cooling air at the existing atmospheric pressure and vapour content. Cooling at or below the dew point will cause condensation.
- Dynamic Load: any load that is non-static, such as a wind load or a moving live load.
- Fabric: a woven cloth or material of organic or inorganic filaments, threads or yarns. Can be used as a reinforcement in certain membranes and flashings or used in a protected membrane roof application to reduce the ballast requirements.
- Flashing: materials used to weatherproof or seal the roof system edges at penetrations, penetrations, walls, expansion joints, valleys, drains and other places where the roof covering is interrupted or terminated.
- Gravel Stop: a low profile, upward-projecting metal edge flashing with a flange along the roof side, usually formed from sheet or extruded metal. Installed along the perimeter of a roof to provide a continuous finished edge for roofing material.
Glossary

Humidity: the amount of moisture contained in the atmosphere. Generally expressed as percent relative humidity (% RH). It is the ratio of the amount of water vapour actually present in the air, compared to the maximum amount that the air could contain at the same temperature.

Inverted Roof Membrane Assembly (IRMA): same as protected membrane roof (PMR) assembly, where a closed-cell insulation (e.g., STYROFOAM™ Brand XPS Foam Insulation) and ballast are placed over the roof membrane.

Live Load: temporary load that the roof structure must be designed to support, as required by governing building codes. Can include people, installation equipment, vehicles, wind, snow, ice or rain, etc.

Loose-laid Membrane: membrane that is not attached to the substrate except at the perimeter of the roof and at penetrations. Typically, a loose-laid membrane is held in place with ballast.

Mechanically Fastened Membrane: membrane that is attached at defined intervals to the substrate, using various fasteners and/or other mechanical devices.

Membrane: a flexible or semi-flexible material that waterproofs (excludes water) a roof.

Parapet Wall: that part of a perimeter wall immediately adjacent to the roof, which extends above the roof.

PMR: protected membrane roof.

Positive Drainage: the drainage profile of a deck, considering the roof slope and loading deflections to ensure the roof deck drains within 48 hours of rainfall during ambient drying conditions.

Ridge: highest point on the roof where two roof area intersect.

Roof Assembly: an assembly of interacting roof components (includes the roof deck, vapour retarder [if present], insulation and roof covering).

Roof Slope: the angle a roof surface makes with the horizontal. Typically expressed as a ratio of rise to run, such as 4:12, or as a percent.

Square: 100 ft² (9.29 m²) of roof area.

Substrate: the surface on which the roofing or waterproofing membrane is applied (e.g., the structural deck or insulation).

Vapour Retarder: a material that restricts the movement of water vapour.

Wind Uplift: the force caused by the deflection of wind at roof edges, roof peaks or obstructions, causing a drop in air pressure immediately above the roof surface (e.g., suction). Uplift may also occur from air movement from underneath the roof deck, causing the membrane to balloon and pull away from the deck.

Function

Provide thermal properties: STYROFOAM™ Brand Extruded Polystyrene Foam Insulation has a high aged thermal resistance (R-value or RSI) when compared with competitive roof insulations.

Provide membrane protection: By installing the insulation over the membrane, the membrane is kept at a relatively constant temperature year-round and protected from weathering, mechanical damage and abuse.

Specification

The insulation shall meet CAN/ULC S701 Type 4. Install required thickness of STYROFOAM™ Brand Extruded Polystyrene Foam Insulation bonded over the roof membrane. Install a slip or separation sheet over the membrane if the membrane is coal tar or Type 1 or 2 asphalt, or if required by the membrane manufacturer.

Burr boards tightly together with a maximum 3/8” (9 mm) gap between boards, staggering end joints. The recommended stagger between each board is 4. However, in cases where boards have been cut to fit, maximize the stagger where possible. At a minimum, each board should have at least an 8” (200 mm) stagger.

Bevel edges to fit closely to cant slopes.

FIT around protrusions and obstructions with a maximum 3/4” (19 mm) gap to minimize heat loss.

Multi-layer foam installation:

- The bottom layer of insulation the layer directly on the membrane) must be at least 2” (50 mm) thick.
- The bottom layer must be the thickest or, at minimum, equal to the top layer (e.g., 3” (75 mm) bottom and 3” (75 mm) top).
- Lay successive layers of insulation unbonded or unadhered.
- Stagger or offset all joints from those of the underlying layer.

Description

STYROFOAM™ Brand Extruded Polystyrene (XPS) Foam Insulation is a rigid, closed-cell insulation, ideally suited and designed for PMR installations. Because of the properties imparted during the extrusion process combined with the hydrophobic nature of polystyrene, STYROFOAM™ Brand Insulation has a high resistance to both water and water vapour. Providing a demonstrated long-term mechanical and thermal performance. The boards are available in a range of thicknesses, densities and edge treatments.

Components

STYROFOAM™ Brand EXTRUDED POLYSTYRENE FOAM INSULATION

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Drainage</td>
<td>The drainage profile of a deck, considering the roof slope and loading deflections to ensure the roof deck drains within 48 hours of rainfall during ambient drying conditions.</td>
</tr>
<tr>
<td>Roof Assembly</td>
<td>An assembly of interacting roof components (includes the roof deck, vapour retarder [if present], insulation and roof covering).</td>
</tr>
<tr>
<td>Roof Slope</td>
<td>The angle a roof surface makes with the horizontal. Typically expressed as a ratio of rise to run, such as 4:12, or as a percent.</td>
</tr>
<tr>
<td>Square</td>
<td>100 ft² (9.29 m²) of roof area.</td>
</tr>
<tr>
<td>Substrate</td>
<td>The surface on which the roofing or waterproofing membrane is applied (e.g., the structural deck or insulation).</td>
</tr>
<tr>
<td>Vapour Retarder</td>
<td>A material that restricts the movement of water vapour.</td>
</tr>
<tr>
<td>Wind Uplift</td>
<td>The force caused by the deflection of wind at roof edges, roof peaks or obstructions, causing a drop in air pressure immediately above the roof surface (e.g., suction). Uplift may also occur from air movement from underneath the roof deck, causing the membrane to balloon and pull away from the deck.</td>
</tr>
</tbody>
</table>

Installation Notes

Protect insulation from physical damage. Handle boards carefully to prevent damage during installation. Always wear protective eyewear and gloves when handling and cutting insulation.

Do not leave STYROFOAM™ Brand Extruded Polystyrene Foam Insulation exposed to direct sunlight for more than 90 days. Consult a Dow representative if exposure is expected to be longer than 90 days. Prolonged exposure to ultraviolet radiation may cause the surface of STYROFOAM™ Brand Extruded Polystyrene Foam Insulation to become faded and dusty. The surface degradation will have no measurable effect on the insulating value of the plastic foam unless the deterioration is allowed to continue until actual foam thickness is lost. Since the dust would impair the performance of adhesives and finishes, dusty surfaces should be brushed off before these products are applied. A light-colored, opaque protective covering should be used if excessive solar exposure is expected. When stored outdoors, keep insulation boards tarped or covered to protect from weather and weighted down to prevent boards from being blown away by the wind. Store above standing water.

Always check the compatibility with other products that may come in direct contact with the insulation, particularly those containing solvents. Preventive care must be taken, such as allowing the solvents to evaporate, providing a slip sheet or painting the surface of the insulation with white latex paint. Always brush off any surface dust before applying white latex paint on the insulation.

STYROFOAM™ Brand Extruded Polystyrene Foam Insulation is combustible and may constitute a fire hazard if improperly used or installed. The insulation contains a flame-retardant additive to help inhibit ignition from small fire sources. During shipping, storage, installation and use, this material should not be exposed to open flames or other ignition sources.
**Components**

**FABRIC**

**Description**
Ballast reduction fabric, commonly known as filter fabric, is used in PMR installations between the ballast and insulation. This water-permeable material must have proven long-term weather resistance, be strong enough to withstand traffic abuse and prevent displacement of the insulation under flotation conditions.

**Function**
- Prevent fines from penetrating between insulation boards
- Raft the insulation together to prevent wind scorching
- Extend the fabric up the roof perimeter
- Ensure that dark-coloured products, such as black plastic drainage boards, are not exposed. Dark-colored fabric is over the insulation. To prevent this phenomenon during hot air temperatures, increasing the potential for distortion of rigid foam boards. Where STYROFOAM™ Brand Extruded Polystyrene Foam Insulation is exposed, it is critical that the membrane is properly attached to the deck when using 10 lb/ft² (50 kg/m²) ballast and a suitable filter fabric to prevent the possibility of any ballast falling under the membrane during times of ponding and air infiltration. Areas of extra ballasting: Extra ballast, required to overcome high wind loads and restrain insulation during heavy rainstorms, should be considered in the following locations:
  - Perimeter edge – 4 (1.2 m) wide band running along the perimeter edge of the roof insulation.
  - Penetrations through the insulation – 2 (0.6 m) wide band around any roof penetration greater than 4' (1.2 m) in any direction (e.g., skylights, equipment pads, etc.).

**Specification**
- Apply fabric unbounded and shingle fashion over the installed insulation (Figure 3).
- Extend the fabric up the roof perimeter cants and roof protrusions by at least 3” (75 mm) above the top level of the ballast (typically about a 6” (150 mm) upturn) and place it loose under the metal counterflashings (Figure 5).
- Fabrics, such as Fabrene V.I.E.®, should meet or exceed the guidelines listed in Table 1. For a complete list of acceptable filter fabrics, contact a Dow representative.

**Installation Notes**
- Adhered membrane (e.g., membrane attached to deck): When a suitable UV-resistant filter fabric is used over a membrane attached to the deck, the amount of required ballast is 10 lb/ft² (50 kg/m²) regardless of the insulation thickness, except around the perimeter and penetrations, and in areas of high winds. See Table 2 for amount of ballast required for perimeters and penetrations, as well as PMR assemblies installed without a fabric.
- It is critical that the membrane is properly attached to the deck when using 10 lb/ft² (50 kg/m²) ballast and a suitable filter fabric to prevent the possibility of any ballast falling under the membrane during times of ponding and air infiltration. Areas of extra ballasting: Extra ballast, required to overcome high wind loads and restrain insulation during heavy rainstorms, should be considered in the following locations:
  - Perimeter edge – 4 (1.2 m) wide band running along the perimeter edge of the roof insulation.

**Supporting Documentation**
Blueprint 501a: “Protecting STYROFOAM™ Brand Insulation Below Dark Roofing Membranes and Fabrics”

**Ballast**

**Description**
Crushed stone or washed, rounded riverbed rock, with a 1” (25 mm) clear size, free of fines or stones smaller than 5/8” (15mm) or larger than 1-3/8” (35 mm). Most stones should be 3/4” to 1-1/4” (19 mm to 32 mm) size.

**Function**
Prevent uplift and prevent flotation: Ballast is required to prevent negative flotation and is based on the total thickness of STYROFOAM™ Brand Extruded Polystyrene Foam Insulation and the type of membrane used.

**Table 1: Specification Guidelines**

<table>
<thead>
<tr>
<th>Unit Weight</th>
<th>Test Method</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notch CD MD</td>
<td>ASTM D2629</td>
<td>lb/yd²</td>
<td>4.0 (max)</td>
</tr>
<tr>
<td>Tenaciously Grabbed CD MD</td>
<td>ASTM D1682</td>
<td>lb</td>
<td>70 (min)</td>
</tr>
<tr>
<td>Elongation @ break</td>
<td>CDMD</td>
<td>%</td>
<td>60 (min)</td>
</tr>
<tr>
<td>UV Resistance</td>
<td>ASTM D1682</td>
<td>%</td>
<td>Approved for outdoor use</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td>Woven polyolefin preferred to promote run-off</td>
</tr>
</tbody>
</table>

**Table 2: Required Ballast Around Perimeters and Penetrations, and for Standard PMR (Without Fabric)**

<table>
<thead>
<tr>
<th>Insulation Thickness, inch (mm)</th>
<th>Required Weight of Ballast, lb/ft² (kg/m²)</th>
<th>Approximate Thickness of Ballast, inch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (100)</td>
<td>22 (108)</td>
<td>5 (125)</td>
</tr>
<tr>
<td>6 (150)</td>
<td>32 (156)</td>
<td>6 (150)</td>
</tr>
<tr>
<td>8 (200)</td>
<td>42 (204)</td>
<td>8 (200)</td>
</tr>
<tr>
<td>Up to 2 (50)</td>
<td>12 (60)</td>
<td>1-1/2 (40)</td>
</tr>
<tr>
<td>3 (75)</td>
<td>17 (84)</td>
<td>2-1/4 (60)</td>
</tr>
<tr>
<td>5 (125)</td>
<td>27 (132)</td>
<td>3-1/2 (90)</td>
</tr>
<tr>
<td>7 (175)</td>
<td>37 (180)</td>
<td>4-1/4 (105)</td>
</tr>
<tr>
<td>9 (225)</td>
<td>47 (228)</td>
<td>5-1/2 (140)</td>
</tr>
</tbody>
</table>

**Support Prevent UV degradation of the insulation:** Most PMR applications use a filter fabric that typically incorporates a UV stabilizer. However, if no fabric is used, the insulation must be totally covered by the ballast to prevent UV degradation. The quality of the ballast is critical in these types of applications. Too small fines (not more than 10 percent of mix) and the stones may work into the insulation joints or be blown inbound by about 4’ (1.2 m) and piled up on the filter fabric, creating additional weight. In these instances, concrete parapets should be considered. See “Pavers” on page 12 for additional information.

**Provide a Class A fire-resistant roof cover:** Class A roof covering, as defined by UL1057, UL790 and ASTM E108. (See “Fire and Wind Ratings” on page 20 for details.) The requirements for Class A roof construction cover the performance of roof assemblies and roof covering materials when exposed to a fire originating from sources outside a building. The stone ballast provides the Class A fire rating.
**Components**

**BALLAST**

**Specification**
Sound, hard, washed stone or gravel, freeze-thaw resistant, with a 1” (25 mm) clear size, free of fines or stones smaller than 5/8” (15 mm) or larger than 1-3/8” (35 mm). Most stones should be 3/4” to 1-1/4” (19 mm to 32 mm) size.

**PMR (without fabric):** Spread stone ballast uniformly over installed insulation to provide minimum weight or thickness (Table 2).

**PMR (with fabric):** Spread stone ballast uniformly over installed fabric and insulation to provide minimum weight of 10 lb/ft2 (50 kg/m2) or 1-1/2” (38 mm) thickness.

**Note:** Use either weight or thickness, but not both.

Spread additional ballast around the roof perimeter for a width of 2’ (0.6 m) to increase ballast weight or thickness. Refer to Table 2 for either weight or thickness, depending on the thickness of insulation installed.

Spread additional ballast around any penetration for a width of 2’ (0.6 m) if the penetration is greater than 4” (1.2 m) in any direction.

**Installation Notes**
Make sure that proper provisions have been specified to seal openings in the roof deck and any perimeter blocks. This will prevent air from getting below the roofing membrane and billowing it.

For PMR installations without a fabric, ensure that the ballast does not contain too many small stones (fines not more than 10 percent of mix) as they may work into the insulation joints or be moved by the wind. Conversely, too many large stones may not provide adequate cover to protect the insulation from UV light where a fabric is not used.

**Note:** Additional ballast should be placed around the perimeter in a PMR design. Depending on the design, pavers can be installed instead of conventional stone ballast.

Spread additional ballast uniformly over installed fabric and insulation to provide minimum weight of 10 lb/ft2 (50 kg/m2) or 1-1/2” (38 mm) thickness.

**Installation Notes**
Make sure that proper provisions have been specified to seal openings in the roof deck and any perimeter blocks. This will prevent air from getting below the roofing membrane and billowing it.

For PMR installations without a fabric, ensure that the ballast does not contain too many small stones (fines not more than 10 percent of mix) as they may work into the insulation joints or be moved by the wind. Conversely, too many large stones may not provide adequate cover to protect the insulation from UV light where a fabric is not used.

**Note:** Additional ballast should be placed around the perimeter in a PMR design. Depending on the design, pavers can be installed instead of conventional stone ballast.

Spread additional ballast around the roof perimeter for a width of 2’ (0.6 m) to increase ballast weight or thickness. Refer to Table 2 for either weight or thickness, depending on the thickness of insulation installed.

Spread additional ballast around any penetration for a width of 2’ (0.6 m) if the penetration is greater than 4” (1.2 m) in any direction.

**Supporting Documentation**
National Research Council of Canada report by Kind and Wardlaw. Report on PMR assemblies using a 30° x 30° (9 m x 9 m) wind tunnel, with various ASTM gradation/sizes of ballast. (See reports NRC LTR-LA 269, NRC LTR-LA 234, NRC No. 15544.)


ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction

ANSI/ASCE 7 Minimum Design Loads for Buildings and Other Structures (includes Basic Wind Speed Map)

**Description**
Concrete slab pavers or interlocking pavers can be used to supplement or replace conventional stone ballast. They can be used to create a surface for rooftop decks, walkways, terraces, gardens, and similar applications. In many cases, the pavers must be raised from the surface of the fabric and insulation. See “Installation Notes” for details.

**Specification**
Concrete pavers shall be manufactured from minimum 3,000 lb/ft2 (18.64 kg/cf) concrete with a minimum weight of 18 lb/ft2 (88 kg/m2).

Pavers shall be placed on pedestals to ensure a “diffusion open” design. The pedestal can be:

- 1” (25 mm) thick insulation cut into 6’ (1800 mm) square blocks and placed under the four corners of the paver (limited to 108 lb/ft2 [59.7 kg/m2] live loading)
- Preformed pavers with at least a 1” (25 mm) foot in each corner or ribbed undersurface
- Paver pedestal of injection molded, weathering-grade plastic, installed under each corner (e.g., PAVE-EL by Envirospec Inc., Terra-Tabs by Wausau Tile, etc.)
- Layer of pea gravel 1” (25 mm) (min.) free of fines

**Note:** This air space is not required if the pavers are covering only a limited area (less than 10 percent of roof area), such as corners or narrow roof walkways.

**PAVERS**

**PAVER STRAPPING AND FASTENERS (IF REQUIRED):** Straps shall be of 22 gauge galvanized or stainless steel, 3” (75mm) wide and 1/2” (13mm) long. Fasteners shall be 1/4” x 1-1/4” (6 mm x 32 mm) corrosion-resistant metal anchors, expanded in pre-drilled holes (e.g., Zamac Nailin #2814 by Powers Fasteners, Inc).

**Installation Notes**
Pavers should be placed on pedestals. In colder climates, the air space will minimize any freeze-thaw spalling on the concrete and moisture buildup in the insulation due to vapour drive from the inside.
Components

ALL OTHER COMPONENTS

Description

MEMBRANES
The membrane is the flexible or semi-flexible waterproofing layer on the roof deck. In a PMR application, the membrane is sandwiched between the roof deck and the insulation. Membranes fall into three general categories: built-up roof (BUR), two-ply modified bitumen, single-ply (sheet) or liquid membranes.

Note: PMR assemblies should be installed with adhered membranes only.

BUR membranes are semi-flexible, multi-ply roof membranes, consisting of plies or layers of saturated felts, coated felts, fabrics or mats between alternate layers of bitumen, either asphalt or coal tar based.

Modified bitumen membranes are similar to BUR membranes, but instead are manufactured in a production facility, using asphalt modified with various additives. The membrane is fully adhered and the seams overlap to provide an uninterrupted waterproof layer.

Sheet or single-ply membranes are prefabricated sheets of polymer-based material, such as thermoplastic (e.g., PVC), elastomeric (e.g., EPDM) or modified bitumen with polymer modifiers. Single-ply roofs can be:

• Fully or partially adhered: The membrane is fully or partially adhered to the underlying substrate with a flood coat.
• Loose-laid: The membrane is not attached to the substrate except at the perimeter and at penetrations. In a PMR assembly, the loose-laid membrane is held in place with full ballast. (See “Ballast” on page 10 for details.) Care must be taken to ensure that air infiltration underneath the membrane is prevented.

Liquid membranes are applied in situ as a liquid that hardens or sets into a continuous, monolithic membrane over the substrate. These liquids are generally applied by spraying or with rollers and include:

• Hot-applied rubberized asphalts, a blend of asphalt, mineral fillers, elastomers, virgin or reclaimed oil. Some versions consist of two coats of rubberized asphalt with a polyester mat in between (fully reinforced or two-ply system).
• Cold-applied liquid compounds consist of emulsions and solutions of resins, elastomers (e.g., polyurethane, silicones, acrylics, etc.) and bitumens and/or modified bitumens

FLASHINGS
Flashings are materials used to weatherproof or seal the roof system edges at penetrations, walls, expansion joints, valleys, drains and other places where the roof covering is interrupted or terminated. For example, membrane base flashing covers the edge of the field membrane, and cap flashings or counterflashings shield the upper edges of the base flashing.

ROOF DECK
The roof deck (including drains and gutters) is the structural component of a building’s roof. The deck must be capable of safely supporting the design dead and live loads, including the weight of the roof systems and the additional live loads required by governing building codes. Decks are either non-combustible or combustible (e.g., corrugated metal, concrete or gypsum) or combustible (e.g., wood plank or plywood), and provide the substrate to which the roofing or waterproofing system is applied.

Note: With some membranes, manufacturers may recommend a slip sheet (e.g., 4-mil polyethylene film) over the membrane to prevent adhesion of the foam to the membrane or plasticizer migration (e.g., chemical attack) to the STYROFOAM™ Brand Extruded Polystyrene Foam Insulation. Consult the membrane manufacturer for recommendations.

Function

The roof deck should:

• Provide structural support to accommodate both live and dead loads without significant deflection.
• Provide dimensional stability by forming a stable substrate not affected adversely by cyclical thermal- and moisture-induced movement.
• Provide fire resistance as determined by the building type and intended use.
• Provide a substrate for the roof system.
• Accommodate building movement. Where necessary, building expansion joints and roof area dividers should be designed and installed.
• Provide for drainage (either by sloping the roof deck or using tapered insulation or both). The roof surface should be sound and should drain water freely within 48 hours following a rain. Every effort should be made to isolate and correct the causes of any standing water or ponding on the roof. CRCA recommends a minimum slope of 1/4” (6 mm) per foot (2 percent). However, if the roof is designed to allow ponding, ensure the insulation is not adhered to the membrane and a filter fabric is used.
• Provide suitable roof drains and gutters. Care should be taken to prevent ballast from entering the drains and/or gutters by using perforated collars or paving stones. When concerns exist, a drainage assessment should be conducted per Sheet Metal and Air Conditioning Contractors’ National Association guidelines.
• Extend well above the expected high water level (typically 8” [200 mm] minimum).

Specification

General: The overall system (including membrane and insulation) should be designed so that the dew point is located above the membrane. The system should be designed so that freezing will not occur at the membrane level. Where required, an adequate thermal barrier should be provided between the insulation and the interior of the building. The thermal barrier may consist of the deck, a ceiling assembly or an underlayment board equivalent to 1/2” (13 mm) gypboard or.composite.

Membrane: Refer to membrane manufacturer’s literature for details. The manufacturer or supplier of the membrane shall be responsible for determining compatibility of the membrane with STYROFOAM™ Brand Extruded Polystyrene Foam Insulation.

Roof deck and flashing: Refer to general roofing specification for details

Installation Notes

Components

ALL OTHER COMPONENTS
Cold Rain Phenomenon

**THE ISSUE**

“Cold rain phenomenon” (or “cold water wash”) occurs during periods of cold rain and/or melting snow or when the ambient condition is 33°F to 50°F (1°C to 10°C). In these conditions, the deck temperature may be temporarily reduced. The issue is that there may be additional heat loss, and in buildings with high humidity, such as pulp and paper mills, the likelihood of condensation increases.

**DISCUSSION**

Increased heat loss: Heat loss studies have shown that extra heat loss in PMR systems during periods of “cold rain” is a temporary phenomenon, occurring only during the short time of cold rain in a heating season. In fact, cold rain in the cooling season creates a cooling advantage for a PMR system. Studies, comparing a conventional versus PMR assembly show only a 1 percent overall heat loss disadvantage for the PMR assembly.

High temperature/high humidity buildings: According to NRCA, a building with 45 percent RH is considered high moisture occupancy. Other buildings, such as pulp and paper mills, textile mills and natoriums, can have an even higher internal humidity. Combining high humidity with a higher than normal operating temperature results in a “high temperature/high humidity” building environment that requires special design consideration.

The severe operating conditions of high temperature/high humidity buildings are particularly problematic for conventional roof systems. The high temperatures drive the high humidity up into the roof system, resulting in severe condensation and premature deterioration of the insulation and roof deck.

A PMR system offers an inherent design solution for this moisture problem. The waterproof roof membrane is an excellent vapour retarder. With the membrane directly on the roof deck and the insulation above the membrane, the membrane effectively blocks water vapour from reaching the roof deck and the insulation above the membrane, the membrane blocks water vapour from reaching the roof deck and the insulation above the membrane. If the insulation is sandwiched between a vapour retarder on the roof deck and the insulation above the membrane, the membrane and the insulation above the membrane, the membrane will absorb the vapour and the insulation value will be reduced.

**CONCLUSION**

The effect of “cold rain phenomenon” is temporary and does not have a significant overall effect on the performance of a PMR assembly. Generally, thicker amounts of insulation are not required to counteract the negative effects of cold rain.

In high humidity and high temperature applications, sandwiching the membrane between two layers of insulation, coupled with a vapour retarder on the roof deck will address condensation problems in high humidity roofing systems. Remember that the thicker insulation layer should be above the membrane to ensure the dew point is above the membrane.

Moisture Absorption

**THE ISSUE**

STYROFOAM™ Brand Extruded Polystyrene Foam Insulation will absorb water and the insulation value will be reduced.

**DISCUSSION**

In a PMR design, it is critical that any insulation installed above the membrane can perform in a wet environment without any detrimental effects on its long-term performance. STYROFOAM™ Brand Extruded Polystyrene Foam Insulation has a unique closed-cell structure that provides excellent moisture resistance and long-term R-value.

Nine PMR systems were monitored over a period of 22 years and the insulation properties assessed. The average moisture content of the insulation was 0.9 percent on a percent by volume basis, with a retained R-value of 96 percent.

In plaza deck designs, it is important that a drainage layer be created above the insulation, allowing precipitation to drain off the top surface of the insulation, creating a “diffusion open” assembly. If the insulation is sandwiched between a vapour barrier (e.g., pavers) and the roof deck, vapour cannot escape so it is driven back into the insulation. To create a “diffusion open” layer, ensure impermeable roof coverings (such as pavers) have a ventilating air space. This could be a layer of fine-free gravel or a 3/16” (5 mm) minimum air space. See “Pavers” on page 12 for additional details. In addition, if the wearing surface is installed in direct contact with the insulation, moisture may become trapped and freeze-thaw cycling could cause spalling on the bottom of the wearing surface.

Always ensure that the roof deck has proper drainage; if the PMR system has significant ponding (e.g., standing water), the insulation will not be “diffusion open.” Follow roofing association guidelines for drainage recommendations.

**CONCLUSION**

STYROFOAM™ Brand Extruded Polystyrene Foam Insulation offers demonstrated long-term performance in a PMR assembly.

Vegetative Roof Design

**THE ISSUE**

Can PMR assemblies be used for vegetative roof designs?

**DISCUSSION**

In a “green roof” design, the ballast in a PMR assembly is essentially replaced with vegetative soil and plantings – plus a drainage layer directly on top of the insulation (Figure 6). Replacing conventional ballast with vegetation can limit storm water runoff and, by filtering the runoff through the plants, also improve the quality of the runoff. The plantings not only ballast the insulation, they can, depending on the configuration, also add additional R-value (KSI) to the roof assembly. Vegetative roofs provide habitat for insects and other wildlife and are often considered in buildings applying for USGBC or CAGBC Leadership in Energy and Environmental Design (LEED) certification.

Many materials may be suitable as ballast, provided they are compatible with the insulation, prevent flotation, shield ultraviolet light and provide a Class A fire-resistant roof finish.

The roof structure must also be designed to accommodate the dead load from the additional weight of the plantings (including when they are fully saturated by rainfall and covered in several feet of snow), plus any live load from traffic, if applicable. It is also important to design the roof slope and drainage system to accommodate rain runoff.

PMR assemblies are ideal for vegetative roof designs:

- The membrane is protected under the insulation.
- Because STYROFOAM™ Brand Extruded Polystyrene Foam Insulation comes in a range of compressive strengths, the insulation layer can be designed to withstand the higher dead loads.
- STYROFOAM™ Brand Insulation is proven to outperform in a moist environment.
- STYROFOAM™ Brand Insulation has a high modulus of elasticity, allowing the system under long-term live or cycle loading. Maximum recommended dynamic (live) load is 1/10 of the rated compressive strength for 1,000,000 repetitions to address creep and fatigue guidelines.

Typically, a drainage layer is placed over the insulation to direct runoff to the drains, as well as keep the top surface of the insulation “diffusion open.” (See “Moisture Absorption” on page 16 for details.) This drainage layer usually includes a fabric over the insulation to protect the joints and keep them open for drainage. Any stone used for this drainage layer must be clean and have a low percentage of fines. In some cases, a drainage mat combined with a filter fabric has also been used successfully to create the necessary air space.

For additional information on vegetative roof design, see: Design Guidelines for Green Roofs, by Steven Peck and Monica Kuhn, B.E.S., B. Arch., OAA, an OAA and CMHC publication, available at http://www.cmhcschl.gc.ca

**CONCLUSION**

PMR assemblies are ideally suited to vegetative roof designs.
Conditions, Issues and Ratings

SPECIAL CONDITIONS AND ISSUES

Finding Leaks in a PMR

THE ISSUE
Is it more difficult to locate a leak with a PMR or conventional roof assembly?

DISCUSSION
Building upon years of in-field experience, the majority of roof leaks in PMR systems occur at flashing as opposed to the interior field area. The field area is protected from physical abuse, UV attack and thermal cycling – all factors that are the primary causes of roof failures – by both the insulation and ballast over the membrane. However, sometimes interior field leaks do occur.

Concrete decks: For PMR installations on concrete decks, generally the membrane is fully adhered to the deck. This simplifies leak detection because the leak is localized. For example, the leak in the interior will be exactly where the hole in the membrane is located. If the membrane is not adhered, the water can run under the membrane for many feet before entering the building – just like in a conventional roof.

Steel decks: For PMR installations on steel decks, a layer of insulation is fastened to the deck and then the membrane is placed on the “warm side” – or the exterior in a conventional roofing application.

Wood decks: On wood decks with a PMR installation, the membrane is typically a felt layer and two or three plies mopped on top. In a conventional installation, the insulation is fastened to the deck and then the membrane is applied. Both of these approaches will allow the water to run to the deck joints prior to entering the building.

CONCLUSION
Not only do PMR assemblies have fewer leaks in the first place, PMR assemblies over concrete decks with bonded membranes have definite advantages when isolating any leaks that do occur. Both conventional and PMR roofs over steel or wood decks require the same leak detection strategies. In addition, because PMR roofs are easier to repair and typically all of the original materials can be reused (ballast and insulation), this environmentally friendly feature can save money.

Low Temperature Applications

THE ISSUE
PMR assemblies should not be used in low temperature applications because of the potential adverse effect on the STYROFOAM™ Brand Extruded Polystyrene Foam Insulation.

DISCUSSION
In a low temperature application (e.g., freezers), the interior space has a low temperature and low water vapour pressure (humidity). In contrast, the warm outside temperature and higher water vapour pressure causes a vapour drive toward the interior space. Unless addressed, this vapour can condense in the insulation and lower the R-value (RSI) of the system. It can also condense on the membrane and freeze, gradually forming a layer of thick ice.

In low temperature applications, the membrane is placed on the “warm side” – or the exterior in a conventional roofing application.

CONCLUSION
In low temperature applications (e.g., freezers), a conventional roof may offer performance benefits.

High Temperature Installation

THE ISSUE
In high temperature locations, PMR assemblies should not be covered with a dark fabric prior to laying the ballast because of the potential adverse effect on the STYROFOAM™ Brand Extruded Polystyrene Foam Insulation.

DISCUSSION
Like many insulations, higher temperatures may cause permanent distortion and/or long-term creep. The maximum use temperature for STYROFOAM™ Brand Extruded Polystyrene Foam Insulation is 165°F (74°C) for continuous use, with short-term exposure up to 190°F (88°C). Typically, this concern arises in warmer locations (e.g., southern U.S.) when STYROFOAM™ Brand Insulation is placed underneath a dark fabric prior to laying the ballast. Given the right conditions, the temperature on the top of the insulation may reach close to the upper limits for polystyrene insulation and cause some distortion. Experience has shown that when STYROFOAM™ Brand Insulation is exposed to both direct sunlight and an outdoor air temperature over 90°F (30°C), distortion can occur in as little as 30 minutes when a dark fabric is installed over the insulation. To prevent this phenomenon during hot weather, temporarily place white opaque polyethylene film on the insulation until the ballast is laid (or use a white filter fabric).

In addition, reflective surfaces such as glass or metal wall panels can substantially increase surface temperatures. When combined with a dark fabric, extremely high surface temperatures can occur, increasing the potential for distortion of rigid foam boards. Follow the same precaution as mentioned above.

CONCLUSION
In high temperature locations, the temporary use of white opaque polyethylene film laid on the insulation until the ballast is laid will prevent any distortion of the insulation (or use a white filter fabric).

Membrane Seam Failure

THE ISSUE
Failures at the seams in thermoset membranes may be worse with PMR because the membrane stays damp.

DISCUSSION
Thermoset membranes (such as EPDM and neoprene) were historically sealed with a contact adhesive. Seam failure due to moisture intrusion or other contaminant was a concern for this type of membrane because the membrane stays damp in a PMR, potentially resulting in an increase in seam failure. In fact, Dow never received a complaint about this perceived concern.

In today’s EPDM system, a seam tape is used. This tape has exhibited excellent performance and this is no longer an issue.

CONCLUSION
There are no documented cases of seam failure related to the PMR application.

Plant Growth on PMR Assemblies

THE ISSUE
Periodically, plant growth will occur on PMR and other low-sloped roofs. Can this be avoided?

DISCUSSION
At times, grass, weeds or small trees may grow on both PMR and conventional roofs. Good roofing practice should include a maintenance program that includes periodic inspection for this type of growth. Any plant growth should be pulled out and, if required, the area treated with a weed killer. Roots from plant growth can sometimes damage the membrane if left unchecked. With a PMR system, there is less chance of this happening since the membrane is protected by the insulation, fabric and ballast.

CONCLUSION
A preventive maintenance and inspection program should include inspection and removal of any plant growth.
Overview
Fire and wind ratings are required to meet building code requirements. Typically, a PMR assembly, including roof deck, membrane, insulation and ballast, is tested in exactly the same configuration as would be constructed in the field. No deviation from the component specification is allowed. Underwriters Laboratories Inc. (ULI), Underwriters Laboratories Canada (ULC) and Factory Mutual (FM) have developed test methods to rate the fire and wind performances of assemblies. For the most current listings, contact Dow at 1866-583-BLUE (2583).

Test Methods
FIRE RESISTANCE RATING – FIRE WITHIN A BUILDING
Both ULI and ULC test roof assemblies based on the type of fire exposure. For fires originating within a building, roof assemblies are assessed using either ANSI/UL 263 or CAN/ULC S101M.

When testing for fires originating within a building, a full-scale roof system is exposed to a controlled fire in order to assess a construction/assembly that can contain a fully developed fire. The Fire Resistance Rating represents the time it takes for the temperature on the unexposed side of the assembly to increase by 250°F (121°C).

A sample measuring approximately 14' x 17' (4.3 m x 5.2 m) is used, including the decking material, any suspended ceiling, hangers, insulation, etc. The sample is then exposed to a fire with temperatures reaching 1,000°F (537°C) at five minutes and then 1,700°F (927°C) for a specified time. During the test, a load is applied to the roof to represent the maximum load the joists are designed to support.

EXTERIOR FIRE PERFORMANCE OF A ROOF ASSEMBLY
The fire resistance performance of roof coverings exposed to simulated fire source originating outside a building is conducted in accordance with ULI 790 (ASTM E108) or CAN/ULC S107-M. Three classifications are available.

Class A roof covering:
• Effective against light fire test exposures
• Provides a light degree of fire protection
• Not expected to produce flying embers
• Does not slip from position during the test

Class B roof covering:
• Effective against moderate fire test exposures
• Provides a moderate degree of fire protection
• Not expected to produce flying embers
• Does not slip from position during the test

Class C roof covering:
• Effective against light fire test exposures
• Provides a light degree of fire protection
• Not expected to produce flying embers
• Does not slip from position during the test

Note: PMR assemblies ballasted with a minimum of 9 lb/ft² (44 kg/m²) of stone ballast (or pavers installed with a maximum gap of 1/4" [6 mm]) achieve a Class A rating.

FM TESTS FOR WIND PERFORMANCE
Factory Mutual approved roof assemblies are only required when the building is insured by FM Global. Building code authorities may recognize some FM standards; however, they do not require the use of FM approved or accepted products and systems.

FM 4450. “Approval Standard for Class I Insulated Steel Deck Roof,” and FM 4470, “Approval Standard for Class I Roof Covers,” are two recognized laboratory test methods for determining the wind-uplift resistances of roof assemblies. FM 4450 and FM 4470 are the basis of FM’s 1-60, 1-90, 1-120, etc., approvals. For example, a Class I-60 design resists a 60 lb/ft² (2.88 kPa) uplift pressure for one minute without loss of pressure.

Dow has a PMR system rated FM 1-90 that adheres STYROFOAM™ Brand Extruded Polystyrene Foam Insulation to a BUR assembly with asphalt. This system can be used on both steel and concrete roof decks. Loose-laid single-ply roof membranes with ballast are not listed in the FM approval guide since there are not methods to test these systems for wind uplift. Loose-laid systems can be “accepted” by FM if the assembly is ballasted in accordance with FM Loss Prevention Guide 1-29 and reviewed by the local FM engineering office.

REQUIREMENTS FOR BALLASTED ROOF ASSEMBLIES
PMR assemblies should be ballasted according to the requirements listed in “Ballast” on page 11.

Conditions, Issues and Ratings

FIRE AND WIND RATINGS

Assembly # | Rating (hrs) | Description
--- | --- | ---
P-225, P-226, P-235 (New PMR) | 1, 1-1/2 | Steel deck 1/2" or 5/8" (13 mm or 16 mm) Type X gypsum (various) Bar joists Suspended ceiling
P-404 (New PMR) | 1-1/2 | Steel deck 1/2" or 5/8" (13 mm or 16 mm) Type X gypsum (various) Bar joists Suspended ceiling
P-801, P-805 (Retrofit PMR) | 1, 1-1/2, 2, 3 | Steel deck Mineral or fiberboards Spray fiber fireproofing Beam construction
P-803 (Retrofit PMR) | 1, 1-1/2, 2, 3 | Steel deck Mineral or fiberboards Spray fiber fireproofing Bar joists
P-811 (New PMR) | 1, 1-1/2, 2, 3 | Steel deck 5/8" (16 mm) Type X gypsum Spray fiber fireproofing Beam construction Suspended ceiling
P-813 (New PMR) | 1, 1-1/2 | Steel deck 5/8" (16 mm) Type X gypsum Spray fiber fireproofing Bar joists
P-908 | 2 | Steel deck 3-5/8" (97 mm) vermiculite concrete Beam construction

Note: Always refer to the actual listing for complete details, including maximum load the joists are designed to support.

ULC Hourly Fire Resistance Ratings for PMR – Metal Deck

Assembly # | Rating (hrs) | Description
--- | --- | ---
P-227, P-507, P-908 (New PMR) | 1, 1-1/2 | Steel deck 2" (50 mm) poured gypsum deck Bar joists Suspended ceiling

FM Hourly Fire Resistance Ratings for PMR

Assembly # | Rating (hrs) | Description
--- | --- | ---
RC-227 (New PMR) | 1 | Steel deck 1/2" (13 mm) Type X gypsum Gypsum board coating
RC-264 (New PMR) | 1 | Steel deck 1/2" (13 mm) Type X gypsum Suspended ceiling

ULC Hourly Fire Resistance Ratings for PMR – Concrete Deck

Assembly # | Rating (hrs) | Description
--- | --- | ---
P-904, P-909, P-912, P-915 (Retrofit PMR) | 2 | Precast concrete units Mineral fiberboard
P-904, P-909, P-912, P-915 (New PMR) | 2 | Precast concrete units 1" (25 mm) gypsum board

FM Class 1 Fire and Wind Uplift

Class | Description
--- | ---
1-60, 1-90 | Steel deck 1/2" (13 mm) (StrataGuard) or 5/8" (16 mm) DensDeck™ (mechanically fastened) 3-ply BUR

Note: Control the ballast weight and location with commercial-assembled ballasting systems. FM Loss Prevention Guide 1-29 provides accepted ballasting requirements.
Illustrations are not intended to replace the need for design by appropriate professionals such as architects or engineers.

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STYROFOAM™ Brand Extruded Polystyrene Foam Insulation

CAUTION: This product is combustible. Protect from high heat sources. A protective barrier or thermal barrier may be required as specified in the appropriate building code. For more information, consult MSDS, call Dow at 1-866-583-BLUE (2583) or contact your local building inspector. In an emergency, call 1-989-636-4400 in the U.S. or 1-519-339-3711 in Canada.

WARNING: Rigid foam insulation does not constitute a working walkable surface or qualify as a fall protection product.

Building and/or construction practices unrelated to building materials could greatly affect moisture and the potential for mold formation. No material supplier including Dow can give assurance that mold will not develop in any specific system.