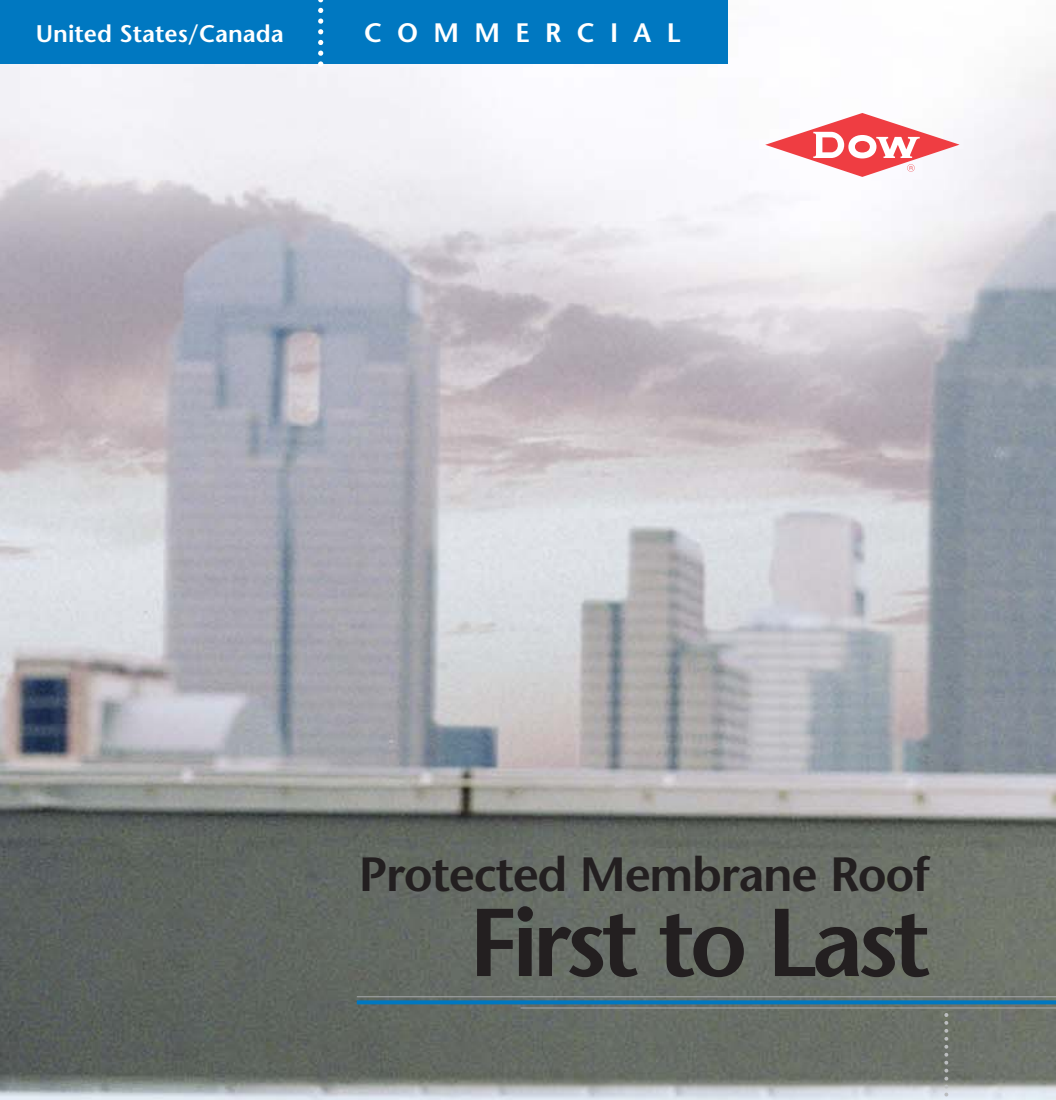
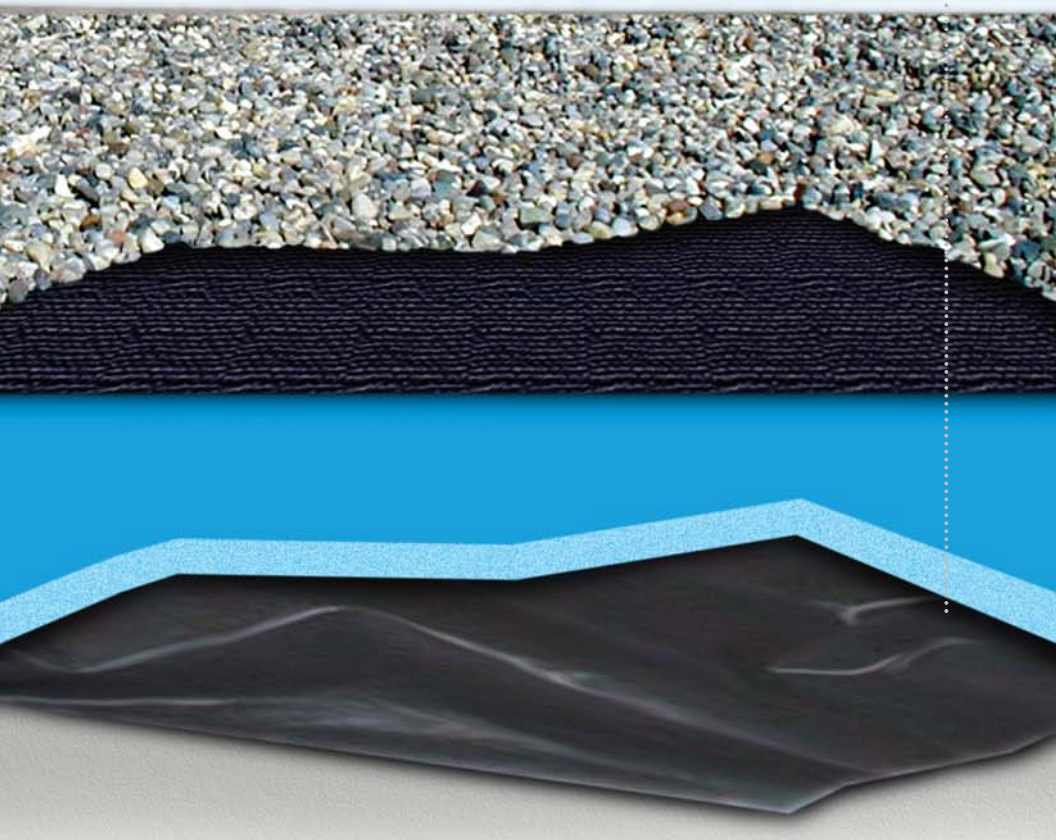
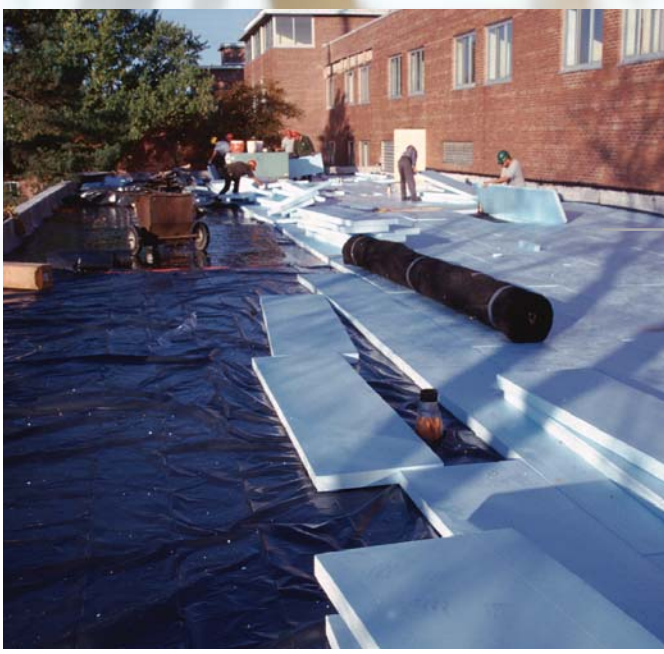


Protected Membrane Roof

First to Last





How a Breakthrough Idea Revolutionized the Roofing Industry

Nearly 40 years ago, some roofing experts from The Dow Chemical Company took a completely new look at the ways roofs are designed. Quite literally, they turned the industry *upside down*.

The protected membrane roof (PMR) has represented the best in flat roof technology since it was developed in 1970. The PMR concept was simple yet radical. A PMR incorporates an "upside down" approach to insulating the roof: placing the insulation on top of the waterproof membrane. While experts believed this design would improve the membrane's effectiveness and the insulation's efficiency, few could have foreseen the dramatic results that PMR assemblies have delivered to building owners: Some of these original roof membranes remain in exceptional condition, nearly 40 years after installation.

Why did this breakthrough take so long to happen? Easy: because no insulation had ever proven durable enough to withstand exposure to the environment like STYROFOAM™ extruded polystyrene insulation. Once it began to be used as a roof insulation, roofing experts saw the possibility for a new, effective technology.

And the protected membrane roof was born.

In a protected membrane roof assembly, the insulation is placed on top of the membrane, improving the performance and longevity of the roof system.

Taking "Cost-Effective" to a New Level

A protected membrane roof is cost-effective. It is an assembly that performs year after year – and the longer a roof can be kept in use, the more it contributes to the overall sustainability of the building by delaying the impact of eventual tear-off.

Building owners must consider the time value of money over the life of the building – not just the up-front construction costs. Using a PMR can reduce annual maintenance costs and increase the life of the roof. For example, deferring a roof replacement by 10 years – which is often the incremental difference between the life spans of PMR and conventional roofs – can save hundreds of thousands of dollars.

In commercial roofing, maintenance costs can be significant if patching, cleaning or rejuvenating is required. When PMR assemblies are installed, the membrane is usually not visible, and is not subject to any of the prime forces of deterioration. In independent studies, PMR systems have been shown to have significantly lower maintenance costs than conventional low slope roofs. For a 50,000 ft^2 (4,645 m^2) roof, reducing the maintenance costs from 3 percent of initial roof cost to 1 percent of initial roof cost provides a significant cost savings that can be invested in the lower-maintenance roof. The investment is paid back in less than seven years, after which the savings in maintenance costs continue to help the operations budget.

Long-Term Performance? Try 30 years (or more)

Consider the conventional roof, which may last 15 years. At the end of its useful life, it will be disposed in a landfill. This process is costly for the building owner, who pays for the tear-off of the old roof and the installation of a new system, and also costly for society, where concern over the environmental costs of the construction industry is growing. A true life-cycle cost decision will include all of these factors in its final analysis.

By contrast, a PMR assembly that lasts 25 to 30 years (or longer) helps to alleviate many of those costs. Or, at the very least, greatly reduces the frequency of tear-offs – a benefit to the building owner as well as to the environment.

WHY PMR IS PERFECT FOR MSU

By any standard, Michigan State University in East Lansing, Mich., is a massive place. In terms of the sheer number of students and the size of the campus, MSU is one of the nation's largest universities.

Established in 1855, Michigan State is, obviously, here to stay. That's why MSU places long-term performance and durability as a top priority for its many buildings.

Some of the earliest protected membrane roofs were installed on MSU buildings in the late 1960s, and many more have followed in the past 40 years – a total of 161 buildings on campus.

"We are very happy with the inverted (PMR) roof," says Budd Pulver, Michigan State University's roofing supervisor. For Pulver and the rest of the staff who maintain MSU's extensive infrastructure, PMR provides a number of benefits:

DURABILITY: Some roof decks are used as plazas, which means the roof must support foot traffic.

STRENGTH: Construction projects are constantly carried out on campus. This means equipment and building materials are often placed on top of PMR assemblies during the construction phase. "Protected membrane roofs provide protection during construction of new additions," Pulver says.

LONGEVITY: "Some of the PMR assemblies will probably last 50 years," says Pulver without hesitation.

WIND RESISTANCE: "When a roof deck is 100 feet off the ground, a 20 mph wind can feel more like 80 mph," says Pulver. With a conventional roof, the wind sweeps across the unprotected membrane. But with a PMR, the wind simply sweeps across the stone, and the membrane stays protected.

MEMBRANE PROTECTION: Given Michigan's climate, temperatures vary widely throughout the year. This up-and-down variation can degrade an exposed membrane that endures rain and sunlight, frigid cold and blistering heat; but thanks to the inverted structure of PMR, the membrane is kept away from the damaging effect of weather. The benefit for MSU is a decrease in maintenance and repair costs on many of its roofs.

Photo courtesy of University Relations, Michigan State University

Questions About PMR?

DOW HAS THE ANSWERS

Building decisions are not made lightly. And although you may agree that a PMR assembly is a great choice, you likely have additional questions. Let's address some of the common questions that are asked about PMR.

Q: Is a PMR too heavy for my building?

A: PMR systems require a minimum ballast of 10 lb/ft² (50 kg/m²) when used with a Fabrene* scrim sheet. Additional ballast is required at perimeter areas, curbs, pony walls, etc. For a lighter-weight PMR, consider using a T. Clear system with Lightguard** in the U.S.

Q: Is a PMR too expensive?

A: Actually, a PMR will save money in the long run. Consider these advantages of a PMR, which directly impact your bottom line:

- The building can be weatherproofed faster, allowing interior trades to start work quicker. This gives greater flexibility in the construction timetable.
- The insulation is laid after the membrane – and can be laid in any weather.
- Greater quality control is possible, as the membrane can be inspected or flood-tested before insulating and ballasting.
- Because the PMR system uses fewer components than many conventional roof systems, the overall labor costs and material costs may be reduced.
- Life-cycle cost analyses show a higher initial capital cost for a PMR, but lower maintenance and longer roof life span offset these initial costs.

Q: Will my PMR roof blow off?

A: No, because pressure equalization offsets the effect of wind uplift. In a lightweight PMR – with insulation loose-applied on the membrane and covered with 10 lb/ft² (50 kg/m²) of ballast – external pressures due to wind are mostly applied to the membrane.

The membrane will withstand the National Building Code calculated pressure if it is properly attached to the deck. In the case of a loose-applied membrane, it is important to prevent any air infiltration underneath the membrane. When air infiltration is restricted, any movement of the membrane will create a vacuum that will neutralize the uplift forces and keep the membrane on the deck.

*Fabrene is a registered trademark of Fabrene, Inc., a wholly owned subsidiary of Polymer Group, Inc.
**Lightguard is a registered trademark of T. Clear Corp.

Q: Will my insulation float (and reduce my R-value† or RSI)?

A: The insulation, ballast and approved scrim sheet are intended to float temporarily after periods of heavy rain, or if control flow drains are required in your area. The Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Corps of Engineers studied the reduction of R-value due to ponding on a PMR. Their report found an R-value or RSI reduction during periods of cold rain, but the report went on to point out that the same effect reduces heat gain during air conditioning periods.

Q: Will my insulation get wet?

A: Remember: STYROFOAM™ extruded polystyrene insulation has the lowest moisture absorption of any insulation in the marketplace today. If any insulation can handle moisture, it's STYROFOAM.

It is also true that all insulation, including Dow products, can become saturated if a "diffusion closed" situation occurs. This happens when the insulation is sandwiched between the vapor barrier and the roof deck (such as when pavers are placed directly on the foam, preventing vapor from escaping so it is driven back into the foam). Constant ponding can also lead to this condition. To avoid diffusion closed situations, provide for a good slope to drain in your roof design (a minimum of 1/4" slope per foot) and ensure impermeable roof coverings, such as pavers, are installed on pedestals so that vapor can escape.

Q: Is it difficult to find a leak in a PMR system?

A: In loose-laid membrane systems, it is true that water can enter the building far from the actual location of the leak. However, if the membrane is fully bonded to the deck, this water remains at the location of the leak. And in the case of a leak, the PMR is far easier to repair, because all of the original materials can be reused – an environmentally friendly feature that will save you thousands of dollars.

†R means resistance to heat flow. The higher the R-value or RSI, the greater the insulating power.

Sustainability in the Roofing Industry

WHY PMR IS THE ANSWER

In the 21st century, sustainable building practices are more important than ever. And many North American cities are making sustainability a *requirement,* rather than an option. In a number of ways, the PMR assembly helps building owners meet the goal of sustainable construction – including contributing to the achievement of LEED†† points.

SUSTAINABILITY OBJECTIVE	PMR BENEFIT
Reduce the total energy consumption of the building (life-cycle costing)	**PMR performs year after year – and the more a roof can be kept in use, the more it contributes to the overall sustainability of the building by delaying the impact of eventual tear-off.**
Reduce global warming impact from excessively using energy sources (reduce)	**A PMR using a rigid, extruded polystyrene insulation, with one of the highest R-values per inch, will realize reductions in utility bills, year after year. By reducing HVAC loads, this will lower pollution emissions from burning fossil fuels.**
Reduce the downstream waste during construction, maintenance and demolition phases (reuse, recycle)	**Because the insulation, fabric and ballast are loose-laid in a PMR, many times these components can be reused after maintenance or major construction.**
Offer recycled content and/or environmentally friendly reusable products (recycle)	**Dow incorporates recycled materials into its finished goods. For example, Dow has been internally recycling trimmings from the production of STYROFOAM™ extruded polystyrene for more than four decades. Scrap, such as cuttings from board edge treatments, is recycled back into finished products, reducing waste and storage and landfill costs.**

®™Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

††The U.S. Green Building Council, a nonprofit coalition promoting high-performance green building design, has developed Leadership in Energy and Environment Design (LEED), a voluntary, consensus-based standard. The LEED rating recognizes the life-cycle costing of construction.

From Green Buildings to Green Roofs

PMR is the perfect partner

The protected membrane roof provides the ideal foundation for a sustainable building solution. Whether you are seeking to obtain LEED points, or are planning an earth-friendly green roof, a roof that leaves the membrane protected is an essential component.

GREEN ROOF BEGINS WITH PMR

Situated on 10 acres in downtown Salt Lake City, The Conference Center is an imposing presence. Completed in 2000, the Center seats more than 21,000 people and is the world's largest religious auditorium.

One of its most striking features is its 70,000 ft^2 (6,500 m^2) rooftop meadow – a massive re-creation of the wild landscape of Utah mountains featuring 21 types of Utah grasses and 300 varieties of native wild flowers.

The rooftop meadow helps Salt Lake City battle the "urban heat island" effect that is common to large cities. One remedy is to add vegetation to downtown areas; "urban forests" like green roofs keep cities cool because a large portion of solar energy is required to evaporate water from vegetation and soil. As a result, asphalt absorbs less energy and increases in temperature are smaller.

The foundation for The Conference Center's remarkable urban garden is a protected membrane roof, featuring STYROFOAM™ extruded polystyrene insulation from Dow. STYROFOAM extruded polystyrene is an ideal component of any green roof project, providing the water resistance and compressive strength necessary to support the heavy soil loads of this environmentally friendly assembly.

Photos courtesy of American Hydrotech, Inc.

The Need for a Better Roofing System

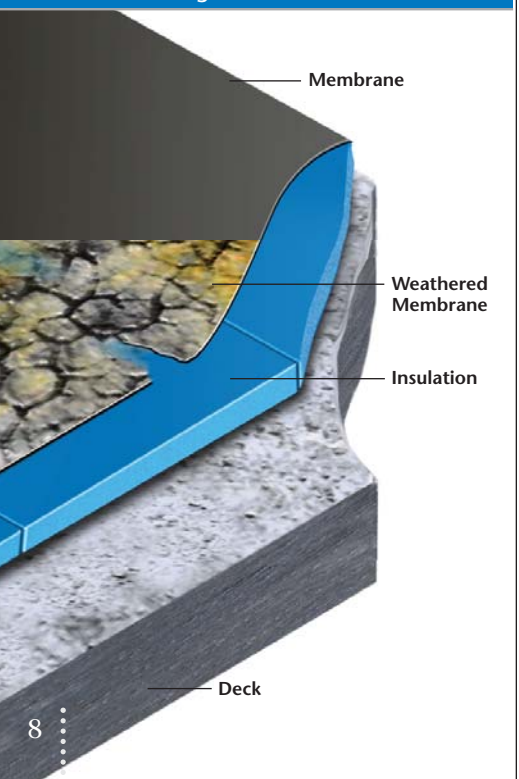
PMR VS. CONVENTIONAL ROOFS

To understand why PMR represents such an important step forward, it helps to look at how it differs from a conventional roof.

Conventional roofs have always been constructed the same way: with the membrane placed on top of the insulation. With the conventional arrangement of roofing materials – roof deck, vapor retarder, insulation, waterproof membrane – the insulation is protected from the exterior environment; however, in this arrangement the membrane is separated from the roof deck. Because it is no longer kept within a moderate temperature range that is near the building's temperature, the membrane is subject to a new set of conditions and stresses.

A conventional roofing arrangement can leave the sensitive membrane vulnerable to extreme and often sudden temperature changes, high summer roof temperatures, lower winter temperatures, freezing puddles, ultraviolet rays, interior moisture that could penetrate the insulation, and physical abuse from heavy foot traffic and routine maintenance. Exposure to all of these elements weakens the integrity of the membrane. Once the membrane is compromised, moisture will eventually enter the insulation and cause a loss in its thermal efficiency.

Figure 1: Conventional Roof



Temperature Variation on a Conventional Roof is Extreme – and Extremely Damaging

On a sunny winter day, the temperature of a roofing membrane can experience a one-day change of 100°F (55°C). Here's how: In cold areas of North America, the temperature of a roof will mirror the air temperature in the pre-dawn hours. But during the course of a clear, cloudless winter day, sunlight can drive the membrane's temperature up – much warmer than the air temperature. This extreme freeze-thaw cycling – which repeats many times in a typical year – can take a heavy toll on the roofing membrane in a conventional roof. The result is a series of cracks, blisters and an "alligatoring" pattern of damage on the membrane.

PMR 101: How the Elements of PMR Work Together

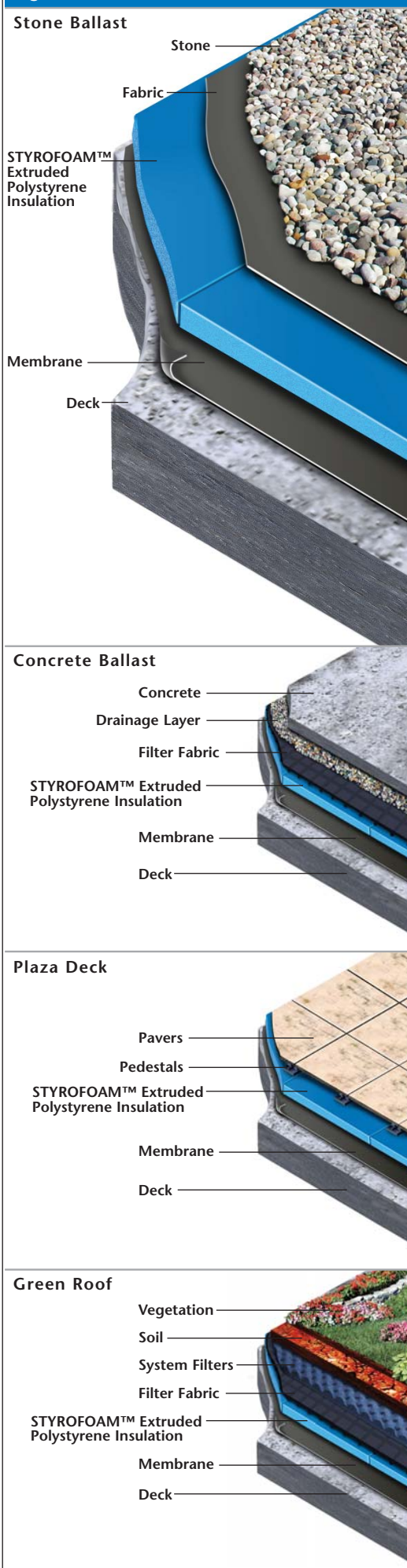
All conventional flat roof assemblies consist of the same basic elements, which are assembled in a seemingly logical order: a deck (composed of wood, metal or concrete) covered with insulation and topped with a waterproofing membrane (see Figure 1).

While protected membrane roof assemblies often employ the same elements, the order is changed. The membrane is positioned UNDER the insulation, which protects the membrane and thus provides superior long-term performance and durability (Figure 2).

With a PMR assembly:

- The membrane is maintained at a nearly constant temperature – close to the temperature of the building's interior. This reduces the harmful effects of freeze-thaw cycling and excessive heat.
- The membrane is protected from weathering, foot traffic and other physical abuse, during and after construction.
- The roof is waterproofed first and insulated second – which allows for year-round construction.
- Removal and re-installation of the ballast (for repairs or to construct additional stories) and insulation is easy. And insulation can be reused.
- Many ballast options – such as stone, precast paving slabs, green roof, interlocking stone or concrete – can be used in conjunction with a PMR. And PMR assemblies are compatible with a range of membrane types as well.

Figure 2: PMR Roof Assemblies



Dow Products are Key to PMR Performance

With the membrane positioned under the insulation, the choice of insulation becomes a key consideration. The insulation in a PMR assembly must be able to withstand wet environments (without sacrificing insulation performance) and foot traffic.

That's why durable, moisture-resistant STYROFOAM™ extruded polystyrene insulation is the ideal choice for PMR.

STYROFOAM extruded polystyrene insulation has a closed-cell structure, which means water is inhibited from penetrating the insulation and reducing its thermal efficiency. The impressive physical properties of STYROFOAM extruded polystyrene insulation products (see Tables 1 and 2) help to ensure the long-term reliability of a PMR.

TABLE 1

Physical Properties of STYROFOAM™ Extruded Polystyrene Insulation, U.S.

Property and Test Method	Value
Thermal Resistance, typical 5-year aged R-value, ASTM C518, $ft^2 \cdot h \cdot °F/Btu$	5.0
Coefficient of Linear Thermal Expansion, ASTM D696, in/in•°F	3.5×10^{-5}
Compressive Strength, ASTM D1621, psi, min.	
STYROFOAM™ ROOFMATE™	40
STYROFOAM™ Ribbed ROOFMATE™	40
STYROFOAM™ PLAZAMATE™	60
STYROFOAM™ Highload 40	40
STYROFOAM™ Highload 60	60
STYROFOAM™ Highload 100	100
Water Vapor Permeance, ASTM E96, perm, max.	0.8
Water Absorption, ASTM C272, % by volume, max.	0.1
Maximum Operating Temperature, °F	165

TABLE 2

Physical Properties of STYROFOAM™ Extruded Polystyrene Insulation, Canada

Property and Test Method	Value
Thermal Resistance, typical 5-year aged R-value (RSI), ASTM C518, C177 $ft^2 \cdot h \cdot °F/Btu$ ($m^2 \cdot °C/W$)	5.0 (.88)
Coefficient of Linear Thermal Expansion, ASTM D696, in/in•°F (mm/m•°C)	3.5×10^{-5} (6.3×10^{-2})
Compressive Strength, ASTM D1621, psi (kPa), min.	
STYROFOAM™ ROOFMATE™	35 (240)
STYROFOAM™ ROOFMATE™ DC	35 (240)
STYROFOAM™ Highload 40	40 (275)
STYROFOAM™ Highload 60	60 (415)
STYROFOAM™ Highload 100	100 (690)
Water Vapour Permeance, ASTM E96, perm (ng/Pa•s•m^2), max.	0.8 (46)
Water Absorption, ASTM D2842, % by volume, max.	<0.7
Maximum Operating Temperature, °F (°C)	165 (74)

Built on Science
Styrofoam

INSIDE INSULATION

To insulate is to prevent the transfer of heat. Insulation is formed by trapping air in a material. But not all insulating materials are created equal. The more compartments of air across a given span of material, the greater the thermal resistance (R-value or RSI).

Insulating sheathing from Dow contains thousands of tiny pockets of trapped air in every square inch of material. Proprietary formulations and manufacturing processes ensure that these closed cells are consistent in size.

An insulation's performance is greatly reduced when the trapped air is able to circulate or move freely. This happens primarily through air infiltration or convection. Insulation performance is also reduced when the trapped air is displaced, which can happen through compression or moisture uptake.

Rigid foam insulation from Dow has a closed-cell structure. The ability of air to infiltrate and circulate is greatly reduced within the boards, and they resist compression and moisture. So the trapped air stays trapped … and the insulating value remains high.

A microscopic view of rigid foam insulation reveals thousands of closed cells that effectively trap air.

We Have the Ideal Product for Your PMR Project

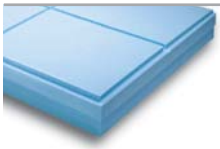
Dow has designed products that fit a wide variety of roofing needs. No matter what kind of PMR application you have planned, we have an insulation product that fits the bill.

STYROFOAM™ extruded polystyrene insulation products for PMR are available in 2' x 8' and 2' x 4' boards. Nominal thicknesses range from 1" to 4" (25 mm to 100 mm), depending on the product.

STYROFOAM™ Extruded Polystyrene Insulation Products Recommended for PMR Applications(1)

STYROFOAM™ ROOFMATE™
An extruded polystyrene foam insulation with drainage channels on the bottom long edge. Provides excellent moisture resistance, durability and long-term R-value. Ideal for installation above waterproofing or roofing membranes in PMR applications.

STYROFOAM™ Ribbed ROOFMATE™
An extruded polystyrene foam insulation board with 1/4" x 1/2" drainage channels on the bottom long edge of each board. Top surface of the board has ribs that form corrugations in the long dimension of the board. Designed for installation above waterproofing or roofing membranes in PMR applications that use pavers as ballast. Pavers can be installed directly over the ribbed foam surface without needing pedestals.



STYROFOAM™ ROOFMATE™ DC (Canada only)
A series of 1/2" x 1/2" grooves on the bottom of the board provide additional drainage on roofs where little or no slope is present.

STYROFOAM™ PLAZAMATE™ (U.S. only)
A high-density extruded polystyrene foam insulation board designed for installation above waterproofing or roofing membranes in most plaza deck applications.

STYROFOAM™ Highload 40, 60, 100
An extruded polystyrene foam insulation board with high compressive strength developed specifically for in-ground application and freezer floors. The products are also well-suited for plaza and protected membrane roofs that must withstand heavy traffic.

(1)Note: Not all products are available in all regions. Consult a Dow representative about product availability in your area.

Let the Industry Leaders Help You Enjoy the Benefits of PMR

STYROFOAM™ extruded polystyrene insulation is crucial to the protected membrane roof. But a PMR requires more than great insulation – and that's where Dow's partners can help you. Dow works in conjunction with the top names in the roofing industry to deliver the world's best-performing roof.

We can help you design a solution that is just right for your building. Call us today to discuss PMR in greater detail.

A 30-year reuse warranty is available. Ask your Dow representative for details.

DOW

BUILT ON SCIENCE

STYROFOAM™ extruded polystyrene insulation from Dow is the only rigid insulation product built on the scientific expertise of The Dow Chemical Company, a leading global supplier of chemical, plastic and agricultural products and services.

Nearly 60 years ago, Dow pioneered STYROFOAM extruded polystyrene insulation, which revolutionized insulation science. Our commitment to innovation continues. Drawing on the vast research, development and technological resources of Dow and an open exchange of information with building professionals, STYROFOAM building products offer proven thermal envelope solutions for every application.

THE DOW CHEMICAL COMPANY • Building Solutions • 200 Larkin • Midland, MI 48674
FOR TECHNICAL INFORMATION: 1-866-583-BLUE (2583)
FOR SALES INFORMATION: 1-800-232-2436

DOW CHEMICAL CANADA INC. • Building Solutions • Suite 2200
250 – 6th Ave. SW • Calgary, AB 2TP 3H7
FOR TECHNICAL INFORMATION: 1-866-583-BLUE (2583) (English); **1-800-363-6210** (French)
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