TPO Roofing Technology in the United States

By David Collette

The popularity of thermoplastic polyolefins (TPOs) for use in roofing applications has increased tremendously in the U.S. during the past decade. While TPO technology has been around the roofing industry – here and abroad – for over a decade, TPO technology which has been adopted for the North American marketplace is not the same as that which currently exists in other parts of the world. In fact, the U.S. TPO roofing technology is greatly improved and far better.

TPO-based products used in exposed or outdoor applications have been common in the U.S. since the 1970s. On a global basis, hundreds of millions of pounds of TPOs are used in a variety of applications ranging from automotive components (bumpers, side panels, air intake ducts, wheel well liners, and interior trim), to recreational applications (golf cart bodies, snowmobile belly pans, bodies for inline roller skates), to construction applications (roofing, geomembranes and as insulation and corrosion protection on billion dollar gas and oil transmission lines).

TPO technology was first brought to the roofing industry in the mid-1980s but was not widely used for single-ply roofing until the early 1990s, when Stevens Roofing Systems introduced its Stevens EP™ membrane. Today, TPOs represent the fastest growing polymer technology in the commercial roofing industry single-ply segment. One manufacturer of TPO roofing has well over 400 million square feet of material installed worldwide.

Nearly all of the TPO roofing polymers used in the United States are supplied by Montell USA, a unit of the Royal Dutch/Shell Group. Montell manufactures raw TPO polymers and supplies them to various companies for further manufacturing/compounding into a finished product. Montell also sells ready-compounded materials to some membrane manufacturers.

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As a technology group, TPOs are considered the "next generation" of roofing membranes, combining the best attributes of today's most popular flexible single-ply membranes – EPDM and PVC. They offer the advantages of traditional EPDM in terms of weather resistance and cold temperature flexibility while providing the welded seam capability of PVC roofing systems.

The original olefinic thermoplastic elastomers were created by blending polypropylene (PP) and ethylene-propylene rubber (EPR). The EPR soft phase would modify the PP hard phase to yield a finished polymer blend with unique properties. However, the technology has evolved such that today Montell uses an "in-reactor blending" of monomers (called the Catalloy process) to synthesize the polymers. This method blends the polymers at the point where the propylene is polymerized simultaneously along with the ethylene-propylene phase. This creates a uniformly dispersed heterophasic polymer that combines the tough properties of the PP phase along with the inherent flexibility of the EPR phase[1]. The resulting polymer is compounded into a finished roofing membrane with exceptional weathering resistance, flexibility and low temperature properties gained from the EPR compound, along with the heat weldability, tear-, puncture-, abrasion- and chemical-resistance properties from the PP polymer. Because the olefinic polymer is completely thermoplastic, it can be fabricated and hot-air welded throughout its rooftop life.

Furthermore, unlike PVC sheets, TPO membranes sold in the United States do not contain any plasticizers, internal or external, to achieve flexibility. By definition, plasticizers are a secondary addition of low molecular weight materials to a polymer to separate molecular chains for modification of flow, stiffness and crystallinity during the end-product manufacturing process. The known problem with plasticizers is their tendency to migrate and volatilize, thus causing the end-product to become brittle or shrink. TPOs from the Catalloy process do not require plastification. In fact, the EPR phase is very high in molecular weight, and delivers the high melt strength required for good processability along with the outstanding low temperature properties without the need for plasticizers. The high melting point of polypropylene allows TPO membranes to be produced in darker colors without the worry of sunlight exposure causing the membrane to soften and shrink.

[1] "Polypropylene Handbook;" edited by Edward P. Moore, Jr., 1996. Hanser/Gardner Publications.

Today, there are several brands and a rainbow of colors of TPO membranes available in the commercial roofing industry. Each manufacturer's products have a unique formulation – no two TPO membranes are exactly alike in look, feel or in their physical properties. One of the most obvious visible physical property attributes of any TPO sheet currently available is its relative stiffness. Some TPOs feel relatively soft and flexible, while others feel more "boardy" or rigid. Additionally, some TPO membranes require additional installation steps such as seam cleaning prior to welding even "fresh-out-of-the-bag" sheets. As a group however, TPO membranes exhibit strong physical property characteristics including resistance to UV degradation, heat aging, cold temperature flexibility, puncture resistance and tear strength. In addition, TPO materials are highly resistant to a wide variety of chemicals, including animal fats, some hydrocarbon oils and vegetable oils. As such, TPO roofing membranes are suitable for direct contact with aged roofing materials such as EPDM, CPE, CSPE, PVC, NBP, EIP, Neoprene and even asphalt BUR in reroofing applications. TPO roofing membranes can also be installed directly over polystyrene insulation without the need for a protection barrier as required by PVC sheets.

Although TPO materials are not inherently fire resistant like halogen-containing PVC roofing materials, TPO roofing membranes can be made both fire-resistant and highly weather-resistant during manufacture. The TPO polymer is heated and mixed with UV stabilizers, pigments, and a flame retardant (FR) package to yield a finished product that will meet all of the requirements of a single-ply roofing system. Sophisticated hindered-amine type stabilizers have been developed, which have a regenerative property (i.e. during the stabilization process, new stabilizer radicals are produced, not consumed). Due to possible interactions between these stabilizers and the other

TPO-based systems are suitable for most commercial roofing applications, such as this food processing facility.

Table 1. *Accelerated Weathering Testing*

ACCELERATED WEATHERING TESTING		
Test Method	Criteria	Result
ASTM G-26, Xenon Arc 80°C black panel, 4000 hours.	Inspect sample at 10% strain, 7X magnification. No cracks, craze.	PASS
ASTM G-90-85, EMMAQUA, 4 million Langleys	Inspect sample at 10% strain, 7X magnification. No cracks, craze.	PASS

additives in the compound, these systems must be carefully developed and tested. FR systems are added to enable the membrane to pass Underwriters Laboratory and Factory Mutual fire test standards.

One of the most significant manufacturing breakthroughs by at least one U.S. manufacturer is in blending FR and stabilizer systems to achieve a material that meets both fire codes and long-term weathering standards. The inherently high acid level in most halogenated FR packages (such as chlorine and bromine), or alkaline levels in non-halogenated FR materials (such as hydroxides and phosphate ions), can create a conflict with higher alkaline UV stabilizers. However FR systems and stabilization packages can work in synergy if developed correctly[2]. Using the proper combination of flame retardant and UV stabilizers, certain U.S. manufacturers have been able to produce TPO roofing membranes which meet UL and FM fire standards and demonstrate outstanding long-term weathering performance – a feat which has yet to be accomplished among European TPO manufacturers. This weather resistance has been demonstrated both on the rooftop, and as evaluated by various (i.e. RMA-1, ASTM) accelerated weathering test methods (*see Table 1*). As a result, roofing applications for TPO technology in North America need not be limited to ballasted-type applications. Properly formulated, an exposed TPO roofing membrane in a mechanically attached or fully adhered roofing system will weather as well as or better than other single-ply membranes.

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From an environmental standpoint, TPO roofing is manufactured in one of the most environmentally friendly processes available today. TPO membranes containing halogenated fire retardants have far lower percentages of halogen by weight than PVC sheets. If incinerated, a halogenated TPO sheet would generate less acid-gas-producing species on a weight basis than PVC. The real environmental appeal of TPO roofing products, however, is the possibility of offering either halogenated or non-halogenated FR systems. In geographies which rely heavily on incineration for disposal of construction materials (e.g. Europe and Japan) there is now the option to provide a non-halogenated solution. In countries where landfill disposal is most common, such as in North America, the type of flame retardant used in the sheet is a non-issue with regard to disposal. Additionally, some TPO materials have been specifically tested and approved for landfill disposal per the EPA's Toxic Characteristic Leachate Procedure.

Today's TPO roofing membranes are manufactured by either a calender or an extrusion process. With either process, the inherent short- and long-term dimensional stability is quite good due to the fact that plasticizers are not used in the compound in any way. As with most single-ply membranes, a fabric reinforcement is incorporated for long-term dimensional stability and improved puncture and tear resistance. Due to the TPO polymer's tensile strength, high-ply adhesions and welded seam strengths are achieved by the reinforced membrane. When coupled with sophisticated mechanical fastening systems, this provides for some of the highest windstorm classification ratings available in the industry today. Additionally, installation of these membranes has been made easier for the roofing contractor due to a wide "welding window" provided by the thermoplasticity of these membranes and the fact that a strong weld can be achieved in a wide variety of weather and welding conditions.

TPO-based systems are ideally suited for most commercial roofing applications. They can be installed on flat and low-sloped decks and, under certain circumstances, TPO membranes can be installed on high slopes – even vertical surfaces – and still provide a UL Class A fire rating. Most reinforced TPOs are mechanically attached, however, they can be fully adhered, stone or paver ballasted, or installed as a vented roofing system. In fact, Stevens currently has a TPO with fleece and a TPO specifically engineered for ballasted applications in addition to its mechanically attached TPO.

Manufacturers also offer a full line of accessories specifically designed for TPO systems including non-reinforced flashing, molded pipe boots, pre-fabricated corners, bonding adhesives, sealants and fasteners.

TPO membranes are inherently resistant to microbial attack and will not support growth of micro-organisms. This is very important in ballasted applications where moisture and lack of light can create ideal conditions for microbial growth. Depending on the pigments used, the membranes are colorfast, and do not fade, hold dirt, or chalk excessively. The membranes perform very well as a "pure white" material, allowing for maximum reflective energy savings in hotter climates where air-conditioning is a major cost[3] (*see Table 2*). Additionally, TPO membranes exhibit excellent cold temperature properties and hail resistance, again as a result of the base polymer.

On the rooftop, the TPO polymer provides a flexible and tough membrane that has demonstrated years of outstanding performance. For many U.S. single-ply manufacturers, TPO roofing systems are no longer considered to be "emerging." They have arrived in force and are taking their place at the top of the list of specified flexible membrane choices. More important, in a relatively short period of time, TPO roofing membranes have gained significant recognition and acceptance among roofing contractors, consultants, architects, and building owners alike.▲

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TPO is also ideally suited for high-slope applications such as sports arenas and domes.

Table 2. *Albedo and Emissivity for Selected Surfaces*

MATERIAL	ALBEDO	EMISSIVITY
Concrete	0.3	0.94
Red brick	0.3	0.90
Tar paper	0.05	0.93
White plaster	0.93	0.91
Bright galvanized iron	0.35	0.13
Bright aluminum foil	0.85	0.04
White pigment	0.85	0.96
White single-ply roofing*1	0.78	0.90
Black EPDM roofing*	0.045	0.88
Grey pigment	0.03	0.87
Green pigment	0.73	0.95
White paint on aluminum	0.80	0.91
Black paint on aluminum	0.04	0.88
Aluminum paint	0.80	0.27-0.67
Gravel	0.72	0.28

Data Source: "Implementation of Solar-Reflective Surfaces; Materials and Utility Programs," Lawrence Berkeley Laboratory, June 1992, for all materials except the white single-ply membrane and the black EPDM membrane.

* White Stevens EP membrane and a generic black EPDM membrane were tested at DSET Laboratory, Phoenix, AZ, May 1997, in accordance with ASTM E 903 reflectivity test protocols and ASTM E 408 emissivity test protocols. These values are not part of the Lawrence Berkeley Laboratory data.

1. Conclusion: White plaster followed by white pigment (paint) second and white single-ply roofing third are the most efficient at not absorbing heat (albedo) and at emitting (emissivity) back into the environment what heat they do absorb.

[2] *"Polypropylene Handbook;" edited by Edward P. Moore, Jr., 1996. Hanser/Gardner Publications.*

[3] *"The Protocols of White Roofing" James I. Seeley, The Construction Specifier, November 1997.*