

# Thermographic Anomalies in Roof Membranes: Wet Insulation or False Indications

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## ABSTRACT

Nondestructive investigation utilizing infrared thermographic techniques to locate wet insulation in roof structures is not new in the thermographic community. Not surprisingly, as new roofing processes and materials have been developed, new wet insulation indications have emerged. The development of accepted national standards has addressed methodology for performing roof studies. The invention of focal plane arrayed radiometers has eased thermographic imaging application. Given the best of both worlds, questions still arise as to whether thermographic anomalies found in roof membranes are wet insulation or merely false indications.

How to proceed? When insulation becomes wet in types of roofing structures such as the standard built up roof (BUR) there are thermographic anomalies that can be expected. Torch-down or chemically adhered membranes, on the other hand, produce thermographic anomalies that are unique to their application. Another type of roofing system that is difficult at best to image, is rubber membrane with ballast.

This paper presents case studies performed by the author on various new and standard roofing systems. Example thermograms and methodologies employed are presented to show techniques, standards and equipment used to complement the thermographic imaging survey.

**Keywords:** ASTM, membrane, radiometers, roof inspections, wet insulation.

## 1. INTRODUCTION

Infrared thermography as a tool for locating wet membrane in commercial roof systems has gained wide acceptance in the last twenty-five years. The “standard” commercial roof system twenty-five years ago was the Built-Up-Roof (BUR). The Built-Up-Roof is still a popular roofing system, however, new state of the art systems have emerged on the market.

In the beginning, successful thermographic analysis on roof systems was difficult and more considered an art than a science. Fortunately, for today’s practicing thermographers this is no longer the case. We are reaping the benefits of the hard work produced by our seasoned professional colleagues. Through their diligence, documentation and research, refined thermographic technique and industry standards in this realm have been developed. Moreover, and again to our benefit, recognition of many indications found in roof membranes is not only common place, but cataloged and provided in various references for the beginning practitioner.

*ASTM C 1153- Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging* is one of the benefits of our colleagues’ hard work. It is the primary standard used by the thermographic community. It is also the standard used by the author while performing “ground-based” surveys on the roofing systems shown in the figures below.

ASTM C 1153 has several “required conditions” that are based primarily on micrometeorology, environmental conditions of the roof being examined and minimum performance parameters of the radiometric equipment used. It also addresses the minimal acceptable size of any indications found and the distance the radiometer should be from those indications. Thermographers should familiarize themselves with this standard and the reference documents it lists.

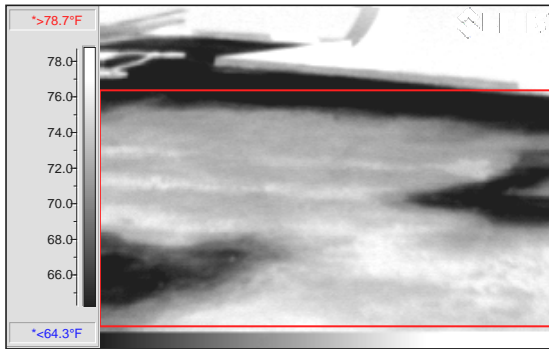
Presented in this paper are examples of Built-Up-Roofs, Sprayed Polyurethane Foam Roofs, EPDM membranes (torch down and chemically adhered) and finally Ballasted Rubber Membrane Roofing systems. It should be noted that the roof systems discussed here are classified as low-sloped.

## 2. BUILT-UP-ROOFING MEMBRANES (BUR)

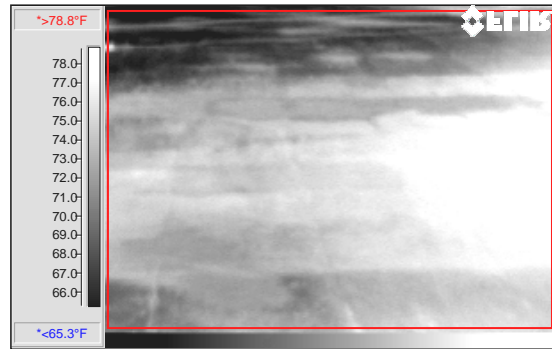
The most common roofing system in the industry is the Built-Up-Roof (BUR). It is a roof that is built with as many as three to five plies of roofing felts, adhered to each other with hot asphalt and capped with an asphaltic membrane and gravel ballast. The indications in Figures 1 and 2 are common to asphalt and gravel type BURs. Figure 1 displays an irregularly shaped anomaly referred to in ASTM C 1153 as “amorphous”. Figure 2 displays a combination of amorphous and poorly defined “board-stock” type anomalies.

Figure 3 is a thermogram of a tar and gravel BUR. that was damaged during Hurricane Andrew. In this case, the roof was initially damaged by the storm and emergency repairs were made. Five years later the roof still had no follow-up repairs or restorations. All of the roof except for the initial repaired areas had deteriorated to the point that the only good spot on the roof was the dark “picture-frame” indication viewed in the middle of the image.

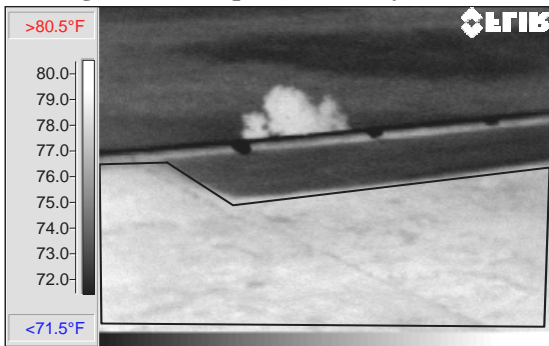
Figure 4 is a detail of a common Built-Up-Roof system.



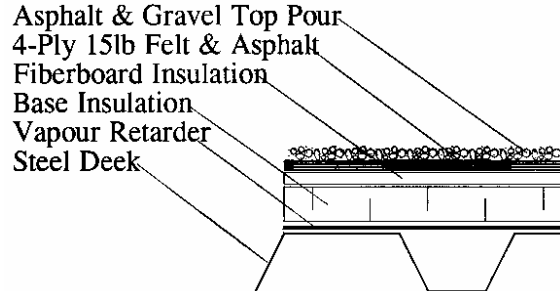
**Figure 1. Amorphous anomaly on BUR**



**Figure 2. Combination of anomalies**



**Figure 3. Roof damaged by Hurricane “Andrew” with only the upper “dark frame” undamaged**



**Figure 4. Cross-section detail of Built-up Roof**

### 3. SPRAYED POLYURETHANE FOAM MEMBRANES (SPF)

Sprayed Polyurethane Foam (SPF) is a combination of isocyanate and polyol. The two components are fed through a device called a proportioner which heats up and then pumps the two separate components to a spray gun. Here they are mixed and sprayed onto the substrate. Because it is sprayed onto the roof in a liquid state, it forms a single continuous seamless structure. To protect the foam an elastomeric base coat is applied to the surface followed by a topcoat. The base-coat and topcoats are usually sprayed on as well. A detail of this kind of membrane is provided in figure 10. The finished product often looks like a lunar landscape. See figure 9.

The SPF roof system can be identified thermographically by the apparent lack of detail on the surface of the roof. Everything looks blended together or somewhat smooth. Water intrusion indications in this kind of membrane are very irregular and stand out brightly. See figures 5, 6 & 7.

There are certain factors to keep in mind when surveying SPF roofs and caution must be exercised when identifying anomalies. The foam membrane is prone to damage from Ultraviolet breakdown, water encapsulation during installation, and normal wear from foot traffic. Birds also reek havoc on SPF roofs. They will peck at the membrane until an opening is produced. Certain species of birds will nest in the membrane. Another scenario that must be dealt with is small pockets of ponding water. Once water ponds an anomaly had begun. As the sun evaporates the pool, a breakdown of the topcoat starts. If this cycle is repeated over a season, the foam membrane will start to compact and trap dust, particles and leaves. Of course, this changes the emissivity of the surface of the roof and false calls can happen. See figure 8.

As part of the author's standard operating procedure, a good visual exam of the membrane is performed during daylight hours to help eliminate any after dark confusion. If an anomaly has been identified as "highly suspicious", further proof is required to verify that the membrane is actually wet. A relative-reading moisture meter is utilized or core samples are taken.

Presented below are thermograms showing indications found in a sprayed polyurethane foam roof system.



Figure 5. Water saturation pattern on SPF roof



Figure 6. Water saturation pattern on SPF roof

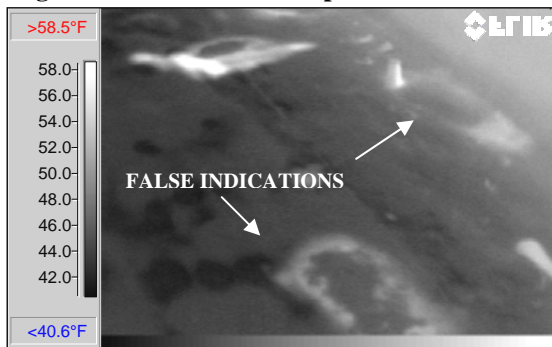
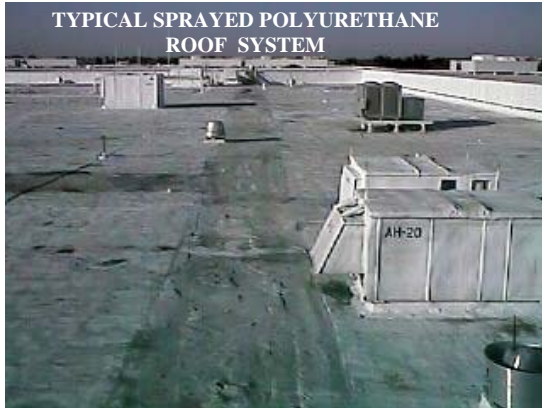


Figure 7. Real and false saturation indications



Figure 8. "False call" due to weatherization



**Figure 9. Typical SPF roof system**



**Figure 10. Construction detail of SPF roof system**

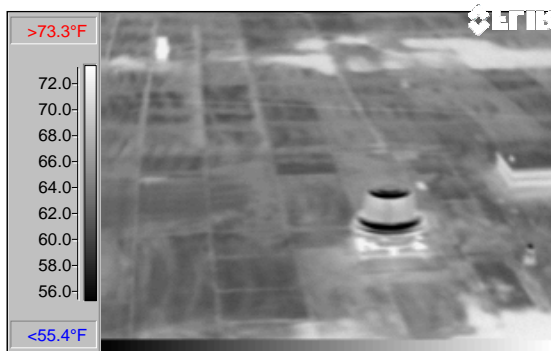
#### 4. MODIFIED BITUMEN MEMBRANES

Polymer modified bitumen membranes have been in use in the United States since 1975. The modifying compounds add flexibility and elasticity, and improve cohesive strength, and toughness. Modified bitumen sheets may be self-adhered or may be installed with hot asphalt or by heating the membrane with a propane torch. The seams are sealed by torch-welding or by using hot asphalt. The membrane may be surfaced with liquid coatings, metallic laminates, ceramic or mineral granules to enhance ultraviolet resistance and fire resistance.

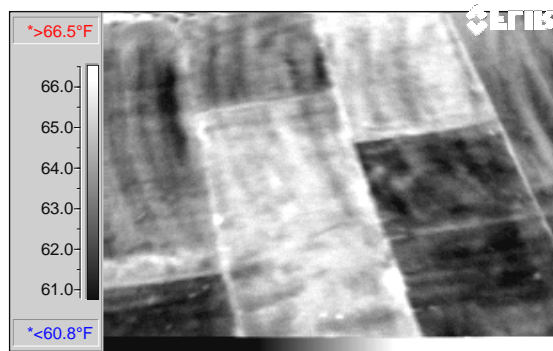
From the description provided above, there is a wide range of variables available to building owners using modified bitumen products. Also there are other outstanding variables, such as geological location or code compliances that “factor in” when choosing this type of roofing system. As one can see, with all the given variables here (and there are more) an infrared thermographic survey on any of modified bitumen membrane roofing systems can present challenges to interpretation.

Shown below is a modified bitumen “torch down” roof.(Figures 11 and 12). Board-stock and amorphous anomalies are present . While this roof system was being installed, the edges of the individual sheets were over heated during the welded-seam process. The seams did not bind and water penetration was the end result.

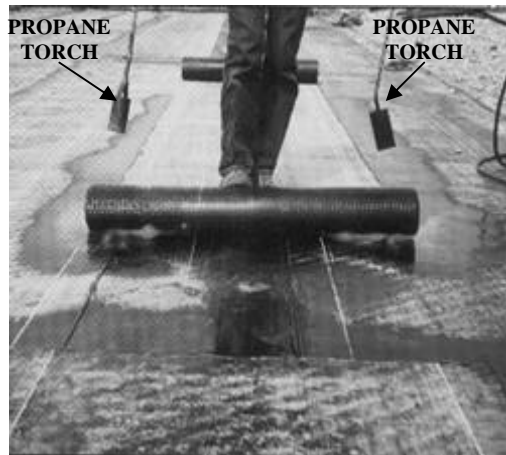
Figure 13 shows a roofing technician using propane torches to weld the seams of the membrane together.



**Figure 11. Water penetration anomalies on a “torch-down” roof caused by installation defects**



**Figure 12. Water penetration anomalies on a “torch-down” roof caused by installation defects**

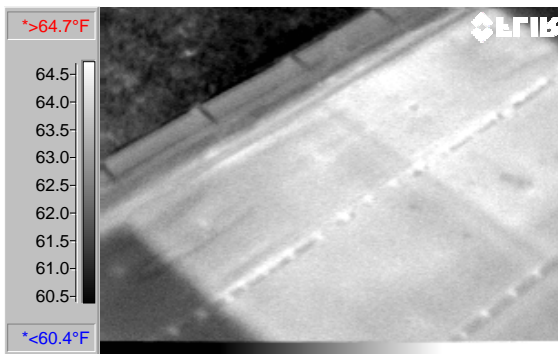


**Figure 13. A roofing technician uses propane torches to weld the seams of the membrane together.**

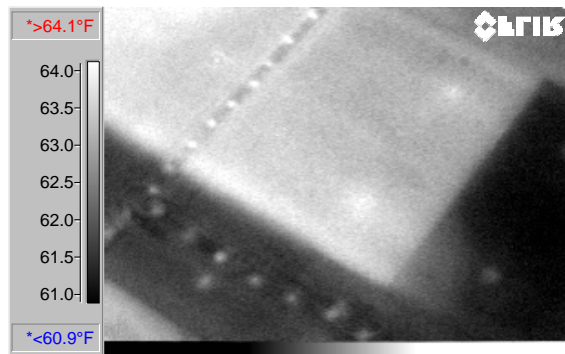
## **5. ETHYLENE PROPYLENE DIENE MONOMER (EPDM) SINGLE PLY MEMBRANES**

EPDM is an elastomeric compound synthesized from ethylene, propylene, and a small amount of diene monomer. It is generally used for roofing as a vulcanized material, although it can be produced as non-vulcanized. This type of membrane has been used in the United States since the early 1960s. EPDM single-ply membranes have a high degree of ozone, ultraviolet, weathering and abrasion resistance and good low-temperature flexibility. Again as with modified bitumen membranes there are a wide range of variables that can have an effect on thermographic interpretation.

Figures 14 and 15 are an EPDM single-ply membrane that have a chemically adhered cap sheet over a nailable deck. The insulating material is a closed cell extruded polystyrene and is much like a brittle sponge. This is why the membrane looks wet but also appears to hold its original shape.



**Figure 14. EPDM single-ply membrane with a chemically adhered cap sheet over a nailable deck (closed-cell polystyrene insulation)**

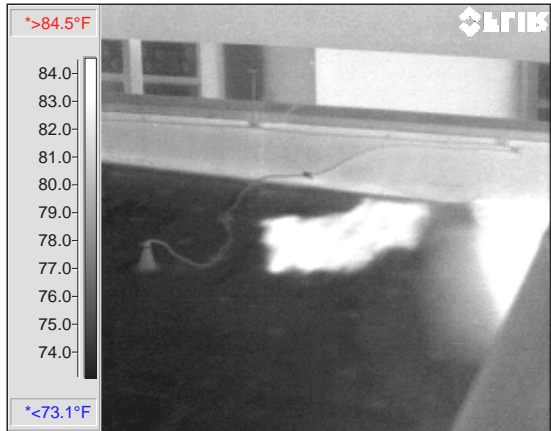


**Figure 15. EPDM single-ply membrane with a chemically adhered cap sheet over a nailable deck (closed-cell polystyrene insulation)**

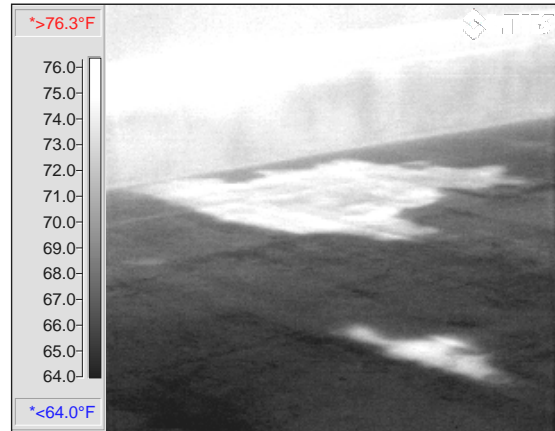
Figures 16 and 17 are also chemically adhered EPDM single-ply membrane however the insulating material is mineral-fiber board. The mineral fiberboard is the reason for the amorphous type indication versus the board type indications found in figures 14 and 15.

Figure 18 is also EPDM single-ply membrane fully adhered membrane only this membrane is mechanically fastened. The mechanical fasteners can readily be seen through out the thermographic image.

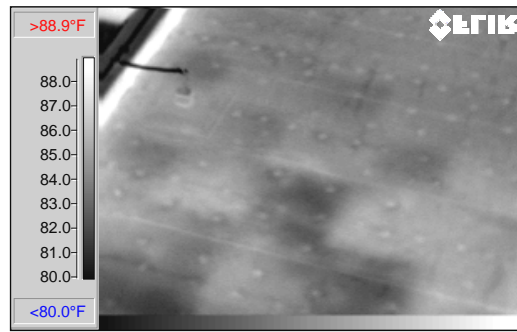




**Figure 16. EPDM single-ply membrane with a chemically adhered cap sheet (mineral fiberboard insulation)**



**Figure 17. EPDM single-ply membrane with a chemically adhered cap sheet (mineral fiberboard insulation)**



**Figure 18. . EPDM single-ply membrane system with the membrane mechanically-fastened**

The photograph and images in figures 19, 20 and 21 are also EPDM membranes. The main difference between the EPDM membranes above and the one below is that this particular membrane is laid out as a large rubber or vinyl sheet. This particular roof membrane is installed as “loosely-laid”. This means that the membrane is just laid on top of the deck and insulation and then ballasted with aggregate.

There are several limitations for the owner of such a roof system. One of the main limitations is that the membrane should be able to breathe, dry from the bottom or be vented to allow evaporation to take place. Another limitation is building height and wind restrictions. The aggregate is usually river-washed stone. In some geographical locations, this kind of aggregate is not allowed. The individual stones make wonderful projectiles during high wind situations. Then there is the load to the roof deck itself. The aggregate on average adds 10 pounds per square foot of dead load over the structure.

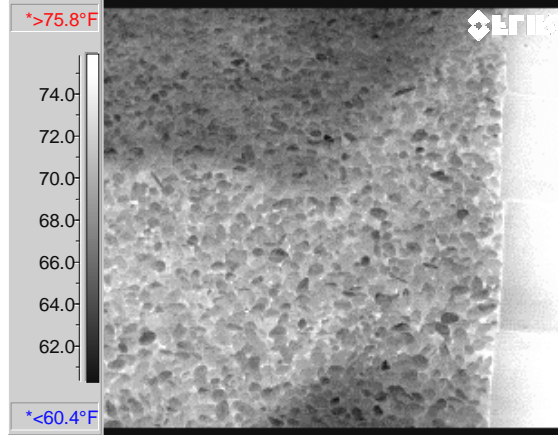
From a thermographic point of view, this type of roof is difficult to survey and interpret. To begin, aggregate ballasted rubber membranes should be shot from an elevated height. Another point is that there should be enough difference between the outside temperature and the temperature of the space under the deck to make any anomalies show. One other simple point to make here is that if an anomaly is spotted in this kind of roof system, be sure to look at the anomaly during daylight hours. The anomaly may be nothing more than a thicker than normal pile of aggregate.

ASTM C 1153 addresses the issues specifically. This standard should be reviewed before beginning a survey on this kind of roof system.

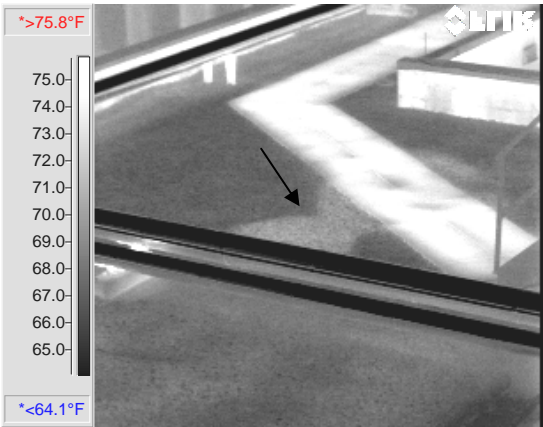
Figure 19 is a photograph of a partially exposed EPDM membrane. Figure 20 is a first view of a suspect anomaly and figure 21 is the same anomaly re-shot from an elevated vantage point. The author and the owner’s representative of this roof went to perform verification of the anomaly. To do this an invasive type moisture meter was used. When the membrane was punctured by the pins on the meter a small geyser developed. Special note should be made here. Never do invasive testing on a roof system without the roof manufacturer’s and/or owner’s permission. Any existing warranties left on the roof may be voided when you break the membrane. Also, be sure to repair any opening in the membrane created by the invasive test.



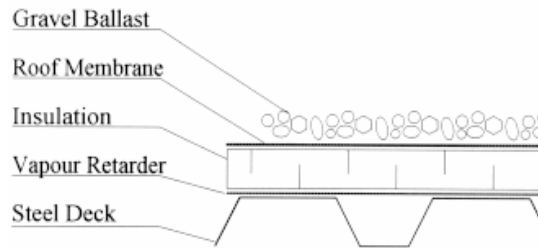
**Figure 19. photograph of a partially exposed EPDM membrane**



**Figure 20. first view of a suspect anomaly**



**Figure 21. Anomaly detected in Figure 20, seen from an elevated vantage point**



**Figure 22. EDPM structural cross-section**

## 6. CONCLUSION

Nondestructive investigation utilizing thermographic techniques is a great tool for locating wet insulation and although infrared imaging is almost commonplace today, there are certain steps that practicing thermographers should take to ensure the accuracy of their reports.

Following accepted industry standards and guidelines will help ease the burden of knowing what is expected from a thermographer and/or thermographic survey. It will also make reproducing anomalies found easier because a set of guidelines was followed to perform the initial study. It stands-to-reason that if you follow a roadmap to a location once, you should be able to use that road map again to return to that same location.

Understanding the roof system that is to be surveyed is another great start. Look at the drawings if any are available. Talk to the owner or facility representative about the age of the roof, any problems they are having with it and what type of roof it is. Do a visual examination of the roof prior to start. At the very least look at the roof again once the survey is complete to visually see if any anomalies found were real or just built up dirt, leaves or a tar patch. A few minutes of background work will save you hours.

Finally, as recommended in ASTM C-1153, a second means of verification of the roofs anomalies using cores samples and/or moisture meters will add validity to the report. It is important that thermographers ensure the accuracy of their data. As the infrared imaging industry continues to grow, it is vital that thermographic analysis remains science and not just creative interpretation.

## DEFINITIONS

APP	Atactic polypropylene. Modified bitumen membrane.
Ballast	The ballast system uses a single ply roof membrane, held in place with gravel. Loose-laid modified bitumen systems require the use of ballast to provide resistance against wind-uplift forces. This ballast consists of rounded stone, such as washed river gravel. The amount of ballast needed will vary with the location and height of the building. Concrete pavers may be substituted for rounded stone ballast, provided the roof membrane is protected from the abrasive surface of the paver.
Built-Up-Roof (BUR)	Built-Up-Roofing is a roof that is built with more than three to five plies of roofing felts, typically adhered to each other with hot asphalt. This system is often perceived as the standard roof system, and is sometimes referred to as a "Pitch" or "Tar and Gravel" roof. It is still the most common type of roof installed, although it is steadily losing ground to single ply roofing.
EPDM Membrane	Ethylene Propylene Diene Monomer. EPDM is a thermostat synthetic rubber membrane (commonly referred to as plastomeric) and is available in single ply sheets. It is usually black or white in color and can be loose laid, ballasted, mechanically-fastened or full-adhered.
Mechanically Fastened	The mechanically fastened system uses a single ply membrane, where the membrane is fastened in place with screws and stress plates.
Modified Bitumen	Also Modified Bitumen Asphalt (MBA). Is made of a rubberized asphalt mat reinforced with fiberglass and surfaced on one side with mineral granules. The modifying compounds such as SBS and APP, add flexibility and elasticity, and improve cohesive strength, resistance to flow at high temperatures and toughness. Modified bitumen sheets may be self-adhered or may be installed with hot asphalt or by the membrane with a propane torch.
SBS	Styrene Butadiene Styrene. SBS is a modified bitumen membrane.
Single-Ply membrane	Single-ply membranes are prefabricated sheets consisting of a single material, or several materials, designed to resist water penetration.
SPF	Sprayed Polyethylene Foam. The SPF roofing system is commonly referred to as a closed cell roofing and insulating membrane that is "sprayed-in-place" on site. The foam membrane is then coated with an elastomeric coating to help protect the foam.
Torch Applied	Modified Bitumen membrane systems installed using this technique are shipped from the manufacturer with a factory-applied coating of modified asphalt on the underside of the sheet. This modified asphalt coating is generally protected by a laminated polyethylene sheet to prevent the sheet from sticking in the roll. This protection sheet is peeled away or melted during application. A propane torch is used to melt the underside coating of asphalt on the roll, which adheres the sheet. The same procedure is used for the lap joints. For some systems, a base sheet is first mechanically fastened to the deck to serve as an underlayment.

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