5.4.4 Intrusion Discovery

Once it was determined through water testing where the approximate location of the roof leak was, roof tiles were removed to examine the underlayment and roof sheathing. By following the water visible below the underlayment, the source of the intrusion was found. Two nails were discovered that had been dropped onto the roof sheathing, then covered by the underlayment and having punctured the underlayment. Since the roofing tiles prevent water from entering the underlayment it was important to determine how the water got under the roofing tiles to begin with. Further exploration of the roof revealed a debris dam at the valley of the roof. Roofing codes in the area required the tiles to be installed without a gap at the roof valley. This allowed debris to accumulate in the valley eventually damming the valley causing water to spill over onto the underlayment.

As the roof water test continued, the water intrusion increased, moving to the front wall of the living room.

Fig. 15 indicates the location of the water within the wall as it moves behind the wall, surfacing at the top and bottom of the window. At this point of the test water was dripping from the window header on to the floor of the living room. Water testing continued with the spray rack positions at different locations. As the rack moved away from the valley of the roof the water intrusion decreased, finally stopping with the completion of the water testing.

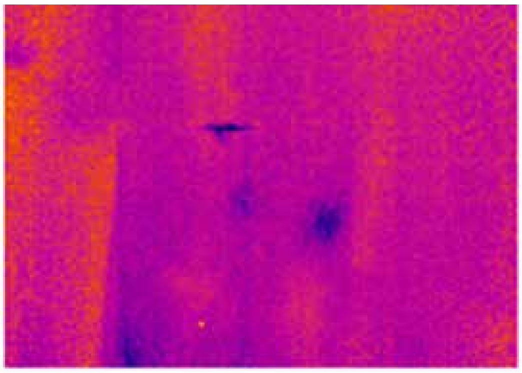


Fig. 15: Thermogram showing the beginnings of the water intrusion

(Source: Non Invasive Roof Leak Detection Using Infrared Thermography by Scott Wood, Four Star Cleaning and Restoration, Inc.)

6.0 Conclusion

The thermal imaging method is the most advanced technique to trace the leakage path. This technology is available in India and is being used by many consultants to detect water leakages as well as many other common defects in buildings.

Membrane Integrity Testing & Electronic Leak Detection by Vector Mapping and Case Studies

[Source: http://leak-detection.com/about-ild/case-studies/case-study]

1.0 Introduction

Electronic Field Vector Mapping (EFVM) is a cutting edge technology that is redefining the art of leak detection and quality assurance in low-slope roofing and waterproofing systems. Vector mapping pinpoints breaches in the roof membrane by tracing the flow of an electric current across the membrane surface. One can get virtually 100% testing on roofing and waterproofing membranes with ELD Fusion®, with an advanced combination of High and Low Voltage Electronic Leak Detection methodologies.

2.0 Importance of Integrity Testing

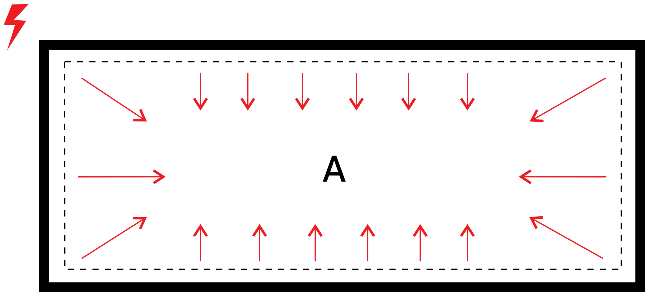
Small punctures, membrane splits or mechanical damage to a waterproofing membrane will result in wet insulation, mold, and costly interior damage. Leaks can go unnoticed and the water exit location might not correspond with the point of entry. Previously, lengthy and costly leak investigations were necessary to locate a membrane breach, especially in protected roof membrane assemblies, garden roofs, or parking and plaza decks. Vector mapping eliminates the dangers and potential damage inherent in traditional flood testing. Unlike the interpretive process of water, flood, infrared, or nuclear testing, vector mapping detects membrane faults directly.

3.0 How Does EFVM Work?

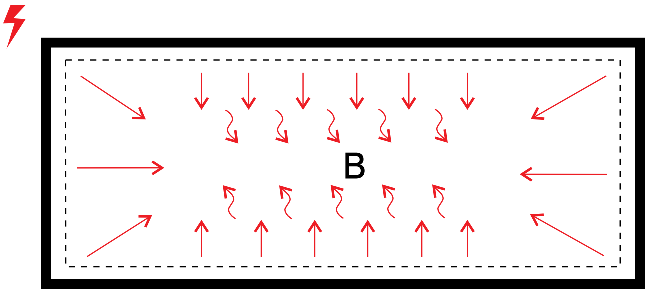
An electric field is created by applying water on the surface of the membrane and using the water as a conductive medium. The EFVM equipment delivers a low voltage pulsating electrical charge between the non-conductive waterproofing membrane and the conductive structural deck. A watertight membrane will isolate the potential difference, while breaches in the membrane will cause an electrical connection to occur. The directional flow of the current is read with a potentiometer to locate the point of entry with pinpoint accuracy.

The vector mapping conductive mediums are created to test non conductive substrates. Three different conductive mediums allow for accurate EFVM testing results:

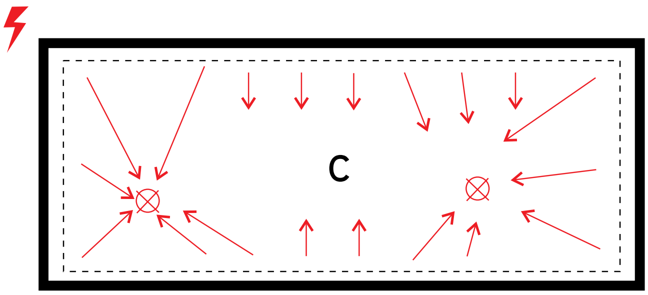
Vector mapping grid (VMG): A welded stainless steel mesh which can be utilized on the fully-adhered systems. This mesh is a non-corrosive material that prevents aging deterioration within the roofing system.



A: Small electrical pulses are directed onto the membrane. The electricity searches for a ground connection



B: If the membrane is watertight, the electricity is isolated and does not find a ground connection



C: If the membrane is not watertight, the electricity makes a ground connection and is pulled toward positive poles.

Vector mapping mesh (VMM): A fine aluminum screen that is utilized in loosely-laid membrane systems.

Vector mapping felt (VMF): A non-abrasive conductive fabric that can be utilized under a loose laid or mechanically fastened roof assembly and embedded into hot liquid membrane systems.

The conductive mediums are placed under the waterproofing material and connect to a contact plate, via a prefabricated cable to the contact box. The Vector-9 conductor wire on top of the membrane delivers direct current tension to the surface. Even in the case of minimal contact with moisture, the system closes the electrical circuit. Moisture penetration can be located quickly and then be cost-effectively repaired.

The test is completed by conducting a visual inspection of all wall junctions, perimeter details, and membrane penetrations. All breaches are numbered to allow for repairs by the waterproofers onsite and are retested to confirm watertightness. A report follows with picture documentation of every breach and a detailed drawing noting the wire placement and breach locations. The various EFVM methods are discussed as follows:

3.1 Low Voltage Method

In low voltage vector mapping (Fig. 1), the surface of the roof membrane is moistened (not flooded) to create an electrically conductive medium.

A conductive wire loop is laid out on the membrane around a section of the area to be tested. One lead from a pulse generator is connected to this wire perimeter. The other lead from the generator is connected to a ground, either the structural deck or a GroundScreen™ conductive mesh installed in the system. Leaks or breaches in the membrane are detected when the electric current flows across the moistened membrane and through the breach to the deck, completing the circuit. The technician uses two probes connected to a receiver to determine the direction of the current flow and to precisely locate the breach (Fig. 1).

Fig. 1: In Low Voltage Vector Mapping (wet testing) the technician uses metal probes on a wet surface to pinpoint membrane breaches

3.2 High Voltage Method

Unlike the low voltage method, high voltage testing is performed on a dry horizontal or vertical surface using a very small current at a relatively high voltage for safe and reliable testing (Fig. 2).

Fig. 2: High Voltage ELD (dry testing) is ideal for testing flashings and other vertical surfaces

One lead from the portable current generator (charger) is grounded to the conductive roof deck (either metal or concrete) or a GroundScreen™. The other lead is attached to a special electrode brush made with highly conductive metal bristles. As the technician "sweeps" the brush electrode over the surface of the roof membrane, electricity will flow through any breach in the membrane.

This completes the circuit between the brush and the ground, and immediately pinpoints the location of the fault. Where there are no breaches, the membrane acts as an insulator and prevents the flow of current to the deck.

3.3 ELD Fusion Method

ELD Fusion combines traditional Low Voltage Vector Mapping (wet testing) on large horizontal areas with High Voltage ELD (dry testing) on vertical surfaces, transitions, and other areas not tested with the low voltage technique (Fig. 3). ELD Fusion gives 100% coverage, and a 100% efficient leak free test.

Fig. 3: ELD Fusion method of membrane integrity testing

3.4 Vector Mapping Benefits

- Pinpoints membrane defects for efficient repairs
- Repairs can be immediately retested
- Most green roofs can be tested with soil overburden in place (low voltage method)
- Less expensive, faster, safer, and more reliable than flood testing
- Sloped roof systems and flashings can be quickly and efficiently tested (high voltage method)
- Enables direct (non-interpretive) detection of membrane breaches
- Wet weather tolerant (low voltage method)

3.5 Vector Mapping Applications

- Insulated and non-insulated low-slope roof systems (excluding metal-coated and carbon black EPDM membranes)
- Ballasted roofs (low voltage) Ponded and flooded roofs (low voltage)
- Green roofs
- Plaza decks
- Quality assurance
- Warranty verification
- Membrane integrity testing
- Pools, parking garages, liners
- Horizontal and vertical waterproofing membranes

3.6 Advantages of EFVM Testing

- Pinpoint accurate, quality-control testing method
- Non-destructive integrity and troubleshooting testing
- Ability to test sloped decks and vertical walls
- Defects can be repaired and retested the same day
- Limited use of water required to conduct test
- Inclement weather will not hinder the test (wet conditions are preferred for electrical flow)
- Overburden installed immediately after the EFVM test
- Eliminates unnecessary removal of overburden to locate a breach when doing a visual inspection
- Membrane can be tested prior to the expiration of the warranty or after traffic has occurred on the membrane

3.7 Limitations of EFVM Testing

- Not capable of testing most black EPDM membranes (ability to test white & grey EPDM)
- Steel-reinforced concrete topping slabs can affect the EFVM readings due to the conductivity of the metal within the topping slab (fiber-reinforced concrete is suggested for retesting capabilities)
- Metal projections protruding through the membrane must be isolated with membrane to allow for retesting

4.0 Case Studies

4.1 EFVM Testing vs. Flood Testing

A hospital project in Cincinnati, Ohio, USA utilized EFVM testing for final watertightness verification of a hot-rubber membrane approximately 25,000 sq. ft. in size. Due to the occupied hospital space below and the elaborate paver system above, ensuring 100% waterproofing was the highest priority. The consultant on the project requested that a flood test and an EFVM test be completed prior to the overburden installation.

Fig. 4: EVFM and flood testing for watertightness

Once the waterproofing was completed, a 48-hour flood test was performed and the area was deemed watertight. A testing agency was called in immediately after the flood test in March 2011 to complete the EFVM testing (Fig. 4). After the EFVM test, over 50 breaches (Fig. 5 & 6) were located within the membrane, which were found to be mainly due to mechanical damage. Unlike a flood test that only shows a membrane's ability to hold water, the EFVM test is a pinpoint-accurate test that confirms watertightness, or, in this case, a test that located potential active leaks.

Fig. 5: Breach no 19 as detected by EFVM test

Fig. 6: Breach no 5 as detected by EFVM test

EFVM testing gives an exact location, making repairs simple and quick without any additional inspections required from the contractor. A report was issued to the roofing contractor listing all breach locations and a plan drawing as well for reference. Once all repairs had been made and retested, all of the overburden was put in place and the plaza deck was completed (Fig. 7).

The Vector-9 conductor wire remained in place to allow for future testing, should any damage occur prior to the expiration of the waterproofing warranty. The same pinpoint testing will be possible through the pavers and miscellaneous vegetation in the future.

Fig. 7: View of plazadeck after the repair with overburden

4.2 EFVM Testing through Overburden

A water treatment plant in Lorton, Virginia, USA was in the process of completing the installation of an 85,000 square foot lid covering a clean water storage tank. During this process, it was discovered that ground water was leaking into the tank. Over $2^{1/2}$ feet of soil was already in place on top of the tank and it would have cost the contractor more than $1 million to locate and repair the breaches, with no guarantee they would have all been found. A testing agency was contacted in hopes that the EFVM test would locate the breaches in a more cost-effective and timely manner.

Fig. 8: Pinpointing the leakage location and further removal of overburden for remedial treatment

Since the vector wire was not installed prior to the dumping of soil, the technician had to weave a temporary wire through the soil around the lid area. Because the soil acted as a conductor, the EFVM test could be conducted and the readings obtained were strong. The technician was able to locate multiple breaches. Once a breach was located, the technician placed numbered landscape flags to allow for excavation of the soil (Fig. 8) and subsequent sheet membrane repair. The contractor made the repairs (Fig. 9) and the areas were retested to confirm watertightness. Since the completion of the test, the fresh water tank has remained free from ground water contamination. A view of overburden after repair and installation of waterproofing system is shown in Fig. 10.

Fig. 9: Remedial waterproofing at leakage point

Fig. 10: View of overburden after repair and installation of waterproofing system

4.3 EFVM Testing on a Vertical Surface

One notable project which contained multiple areas of vertical waterproofing is an indoor botanical garden located in Alberta, Canada. Opened in the late 1970's, the original gardens contained more than 20,000 plants, waterfalls, bridges, ponds and sculptures by local artists, showcased as a permanent art exhibition. In 2008, a renovation of the 100,000 sq. ft. gardens began. One major component of the renovation was the installation of a new cold applied waterproofing membrane for the horizontal and vertical applications, which allowed for a seamless installation throughout the project.

To verify the installation of both horizontal and vertical applications, a testing agency was retained to conduct an EFVM test to ensure a watertight installation. Beginning in late June 2011, began testing the newly-installed waterproofing membrane. The membrane appeared to be intact and watertight, but EFVM testing found areas of damage (Fig. 11) that were not visible to the naked eye. Until the advent of EFVM technology in the mid 1990's, there was never a successful testing method for the verification of vertical waterproofing installations. With millions of square footage of vertical waterproofing being installed every year, a method of vertical testing was conducted and accordingly remedial waterproofing (Fig. 12) was made.

Fig. 11: Breaches identified by vector mapping test on vertical surfaces of the membrane

Fig. 12: Remedial waterproofing at leakage point

4.4 EFVM Testing of Uneven Surfaces

The Kansas City State House was in the process of installing a concrete layer of stairs that had a hot liquid waterproofing membrane. The contractor suggested an EFVM test due to the fact that an 8,000 square foot area was installed the previous year. Although there was no damage visible to the naked eye, the contractor wanted to ensure the area was 100% watertight before the stairs were completed. Flood testing was not an option due to the inability to build dams around the stairs.

The EFVM test discovered numerous breaches. Repairs were not economically viable and the area was reinstalled. The EFVM test was used again to verify the new membrane's integrity and the Vector-9 wire was left in place to allow for future retesting after the concrete was installed.

5.0 Conclusion

The EFVM test method is the most advanced technique and precisely pinpoints the leakage points in a waterproofing system. Though the technology is rarely available in India at present, once introduced, sooner or later, it will be the most preferred system for leakage detection.