Risk Mitigation and Loss Control Using Electronic Leak Detection

By David Vokey, PEng, and Shaun Katz, CSI

SOME EXPERTS ESTIMATE that 75% to 80% of all construction-defect disputes are related to roof failures, and that more than 70% of construction litigation involves water intrusion.[1,2] These issues are particularly concerning for low-slope roof systems, which are typically installed on large commercial and residential buildings. Even the most carefully constructed roof systems can suffer damage, which often leads to water penetration into the building interior. The costs associated with the roof repair can be significant, and water damage to the contents in the building, particularly if it involves priceless artifacts or expensive critical equipment, can be staggering.[3,4]

There are several reasons that a roof system can leak. These include:

- Design: Errors and omissions; conflicting codes and guidelines
- Execution: Poor contractor quality of work, inadequate training, and lack of quality control
- Materials: Sequencing, storage, and manufacturer quality control errors
- Maintenance: Operating deficiencies, maintenance oversights, and gaps in technical knowledge
- Natural events: Heavy rain, hail, and snow

Historically, flood testing (**Fig. 1**) was the traditional method of testing the integrity of a roofing membrane.[5] Over 25 years ago, an international standard (ASTM D5957[6]) was developed to provide a guide for flood testing horizontal waterproofing installations. While providing some assurance of watertightness, this type of testing is often difficult to perform and should only be used on waterproofing membranes that are installed directly on top of a structural deck. Membrane breaches that allow water to reach the deck but do not leak past the deck will not be detected by flood testing. However, that type of membrane breach could become a leakage problem during the service life of the roof system.

The National Roofing Contractors Association[7,8] and Canadian Roofing Contractors Association[9] do not recommend flood testing of conventional low-slope roofs because there is a risk of structural failure due to the weight of water required. The Canadian Roofing Contractors Association also states that flood testing a roofing membrane is not a reliable quality assurance method and that the risks associated with flood testing far outweigh any potential benefits.

During the last few decades, several methods of detecting potential leaks in roofing and waterproofing membranes using electronic testing equipment commonly referred to as "electronic leak detection" (ELD) have rapidly been gaining acceptance.[5,10,11] The four methods used for locating membrane breaches are described in the ASTM D7877, *Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes*.[12] These four ELD methods are low-voltage scanning platform, low-voltage vertical roller, low-voltage vector mapping, and high-voltage ELD (also known as spark/holiday testing).

The four ELD testing methods operate using the same physics and basic requirements. For valid testing in new construction, each ELD method requires the following:

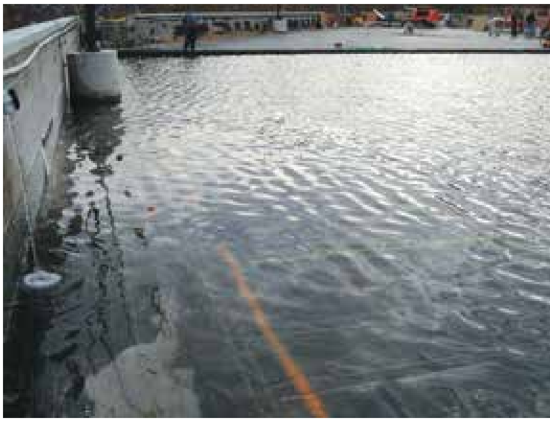


Figure 1. Flood testing a roofing membrane.

- A conductive substrate directly under the membrane to serve as a ground return path for the test currents. Conductive substrates are structural concrete, metal, or a conductive medium designed to facilitate testing.
- A ground connection to the conductive substrate. Typical ground connections include metallic penetrations in direct contact with the conductive substrate.
- An exposed membrane. The principle of ELD is the establishment of an electrical potential

between the membrane and underlying conductive substrate. Electrically insulating layers above the membrane interrupt any electrical path/leak-locating signal.

- An electrical path from the surface of the membrane to the conductive substrate. Low-voltage ELD methods wet the surface of the membrane. Water used during the test carries the electrical current to the conductive substrate. High-voltage ELD requires a dry testing area and a direct vertical air gap for the electrical path to travel through the membrane to the conductive substrate.

While all four ELD methods employ the same science (**Fig. 5**), they have different testing procedures and limitations.

THE FOUR ELD METHODS FROM ASTM D7877

Low-Voltage Scanning Platform and Vertical Roller

The low-voltage scanning platform and low-voltage vertical roller units were created in the early 2000s to simplify the ELD testing process. Both the platform and roller are included in a kit. These methods were designed specifically for quality control testing of roofing and waterproofing membranes.

In 2017, the scanning platform was modified to "drown out" the conductivity of a membrane, enabling the ability to test semiconductive membranes such as black ethylene propylene diene terpolymer (EPDM). This new ability and technical advancement are reflected in ASTM D8231-19, *Standard Practice for the Use of a Low Voltage Electronic Scanning System for Detecting and Locating Breaches in Roofing and Waterproofing Membranes*,[13] which provides a more detailed description of both units. Additionally, in 2022, the platform and roller became the first and only FM-approved ELD methods (**Fig. 2**).[14]

To test horizontal surfaces, the area is wetted down. The scanning platform applies a low-voltage electrical current to the wet membrane. For vertical surfaces, the roller sensor is moistened and applied to the surface of the membrane. The electrical current flows from the equipment, through the water to the conductive substrate below, resulting in an audible and visual alert.

The primary limitation of the low-voltage scanning platform is that it only works on a horizontal surface, and the surface must be wet. Excessive water on the membrane may cause a false positive if the water has a continuous path from the platform to an electrically grounded penetration such as a drain.

The roller attachment is used on nonconductive areas where the scanning platform cannot be used (such as transitions and verticals). Excessive water from the moistened sensor to a grounded object may cause the equipment to alarm.

Low-Voltage Vector Mapping

Electric field vector mapping (**Fig. 3**) was created in Germany in the 1970s. This method was originally developed to test pond liners and geomembranes. This method was later adapted for use on nonconductive roofing and waterproofing membranes.

The low-voltage vector mapping method requires a perimeter wire (also known as conductor cable) loop to be installed around the perimeter of an area to be tested. Metal penetrations and drains must also be isolated by looping a separate cable around them and then connecting these isolating cables to the main perimeter wire. The membrane area within the perimeter wire must have a continuous layer of water. A generator is connected to the perimeter wire, charging the area with up to 40 volts. A pair of handheld probes are used to track the leakage current to the breach.

There are some limitations with vector mapping. Vector mapping method requires a continuous layer of water on the membrane within the perimeter wire, and any gaps in the water coverage can result in missed breaches. On new membranes, water tends to bead and pool, which can often impede the formation of a continuous water path. Some vector mapping testing agencies will mix dish soap with the water to assist with creating the required continuous film, but this approach can cause safety concerns.

Compared with the other ELD methods, vector mapping has a lengthy setup process. This is the only method in which the testing area and all grounded objects must be isolated before testing is performed. This isolation area also eliminates the ability to test critical areas such as transitions and details. Testing verticals is also challenging and is

Figure 2. Low-voltage scanning platform (left) and roller (right).

Figure 3. Low-voltage vector mapping.

not something that is recommended by the equipment manufacturer.[15] Most ELD testing agencies use either high-voltage ELD or the low-voltage vertical roller for testing verticals. Vector mapping cannot test semiconductive membranes such as black EPDM.

Some ELD testing agencies that use vector mapping claim that it can be used to test through overburden. Additional layers such as insulation, drain mats, and root barriers can interrupt the leak-locating signal because these layers are electrically insulating and block the tips of the probes from contacting the actual membrane.[16] The presence of the left-in-place perimeter wire does not guarantee future successful testing with overburden.[17,18]

The vector mapping equipment manufacturer in the United Kingdom does not support the claim of testing through overburden, but some ELD testing agencies continue to promote its use. While the equipment might be used as a troubleshooting feature, it is important that expectations are managed and that all parties should be made aware of the requirements and limitations of testing through overburden.

High-Voltage ELD

High-voltage ELD (**Fig. 4**), also known as spark/holiday testing, was created in Europe in the 1960s. This method was originally used for locating breaches in coatings on pipes and later adapted for testing roofing and waterproofing membranes.

High-voltage testing is performed on a dry, nonconductive horizontal or vertical surface, and uses up to 40,000 volts. This method uses either a broom or brush electrode apparatus made of conductive metal bristles. The unit is swept over the surface of the membrane. At the location of a breach, an electric arc will jump from the electrode. The arc requires a direct vertical air gap to spark. Because of this requirement, seam void detection is more suitable with low-voltage ELD.

The most notable limitation of high-voltage ELD is that the testing can only be performed on a dry membrane surface. Any moisture on the membrane such as dew or frost will cause the equipment to alarm (a false positive). This method is also not capable of testing semiconductive membranes such as black EPDM. Additionally, excessive voltage can cause damage to the membrane if the equipment is not calibrated for the correct mil thickness. It is suggested that this equipment should not be used in combustible areas as it could result in an explosion; also, individuals with electronic implants should avoid using this method.[16]

Figure 4. High-voltage spark/holiday testing.

Detecting and repairing membrane breaches (**Fig. 6**) during construction is critical for the long-term viability of the roofing system. ELD locates breaches in the membrane during construction and for the life of the building. ELD can be performed on nearly all membranes, including thermoplastic olefin membrane (TPO), polyvinyl chloride (PVC), EPDM, styrene-butadiene-styrene (SBS) modified bitumen, hot fluid waterproofing, and cold fluid waterproofing coatings, traffic coatings, high-density polyethylene (HDPE) liners, and geomembranes.

CONDUCTIVE MEDIUM

ELD requires a conductive substrate directly below the membrane for a valid test; therefore, some assemblies require the addition of a conductive medium to enable testing. Nonconductive substrates such as cover board, insulation, wood, or lightweight insulating concrete require this specially developed conductive medium to provide the return path for the test currents. Conductive media come in numerous forms, such as an electrically conductive primer or metal grid (**Fig. 7**). The sole purpose of these products is to create the required conductivity directly below the membrane to enable valid and reliable ELD quality control testing. Placement of a conductive medium below cover board or insulation will interrupt the electrical path, resulting in an invalid test.[19,20]

The conductive medium used should comply with appropriate building codes and industry standards such as the Florida Building Code, ASTM, UL listings, or FM Approvals. The membrane manufacturer and type of assembly (for example, adhered, fastened, torched) will determine which conductive medium can be used.

CONTINUOUSLY MONITORED SYSTEMS

ELD has further evolved in the form of embedded roof-monitoring systems. These systems are installed in the roof assembly during construction and are often specified for critical roof structures on facilities such as hospitals, data centers, and museums. Monitored systems can include sensors arranged in a grid array (typically 15 × 15 ft [4.6 × 4.6 m]) to form leak detection zones (**Fig. 8**).

Monitoring systems provide continuous status of the watertightness of the roof system and will alert the responsible personnel of any developing moisture-related problems (**Fig. 9**). Because a monitoring system can detect potential moisture problems long before significant wetting of the roofing components occurs, prompt corrective action can be taken, thereby avoiding costly property damage.

To monitor a conventional roof, temperature and humidity sensors can be placed strategically in the assembly. The monitoring software will then automatically calculate the potential for condensation within the roof assembly and within each zone. The monitored system detects any areas where moisture is located, typically at the vapor barrier or vapor retarder, and provides a time frame. Once moisture is detected, the building owner can take action to determine the source of moisture intrusion and arrange for removal of moisture from the assembly.

In July 2022, FM Approvals updated standard FM 7745[14.21] to include requirements for products designed to prevent and mitigate potential damage due to roof leaks. This document requires that products and services meet specific performance conditions ensuring consistency and reliability to assist with risk mitigation and loss control.

SUMMARY

Leaks occur. With the advent of ELD, valid and reliable quality control testing and monitoring can be performed to locate breaches, holes, and

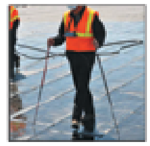
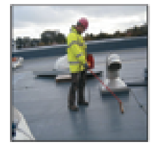
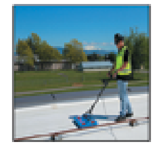
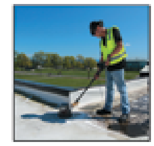
	Vector Mapping	High Voltage	Scanning Platform	Vertical Roller
COMPARE				
Tests Inverted Assemblies*	✓	✓	✓	✓
Tests Conventional Assemblies	✓	✓	✓	✓
Tests in Dry Conditions	✗	✓	✗	✗
Tests in Wet Conditions	✓	✗	✓	✓
Pinpoints Breaches	✓	✓	✓	✓
Tests Horizontals	✓	✓	✓	✓
Tests Verticals, Transitions & Details	✗	✓	✗	✓
Time Efficient	✗	✓	✓	✓
Good for Seam Void Detection	✓	✗	✓	✓
Tests Conductive Membranes	✗	✗	✓	✗
FM Approved	✗	✗	✓	✓

Figure 5. Electronic leak detection comparison chart.

Note: Membrane testing prior to installation of inverted roof components or overburden.

Figure 6. A breach is located and repaired.

Figure 7. Examples of conductive medium.

Figure 8. Moisture detection sensors being installed on a vapor barrier and a vapor retarder.

seam voids. While each ELD method has its pros and cons, the key to successful ELD is ensuring that valid testing is part of the commissioning process. Best practice is to perform ELD in new construction on exposed membranes, which provides a valuable option for risk mitigation and loss control.

ELD quality control testing and continuously monitored systems provide real-time data, analytics, and insight required to help maintain the health of the roof. This advanced technology is critical to realize both the environmental performance and design life of the roof while avoiding preventable losses caused by roof failures and moisture damage.

REFERENCES

1. Seward, A. 2011. "When It Leaks It Pours." *Architect*. https://www.architectmagazine.com/technology/when-it-leaks-it-pours_o.
2. Hoch, J. 2016. "Water Intrusion Is the Largest Generator of CDL Claims and Insurance Losses" (Tech Alert blog post). QualityBuilt. https://www.quality-built.com/resources/tech-alert-water-intrusion-is-the-largest-generator-of-cdl-claims-and-insurance-losses.
3. Benoy, D. D., P. Jergenson, and G. C. Patrick. 2020. "Low-Slope Roofs Are Rotting: Case Study Resolution." *IIBEC Interface* (January): 25–34.
4. Patterson, S. L., and M. Mehta. 2018, "Roof Drainage Design, Roof Collapses, and the Codes." In: *Proceedings 33rd RCI International Convention and Trade Show, March 2018*, 121–131. https://iibec.org/wp-content/uploads/2018-cts-patterson-mehta.pdf.
5. Smith, T. L. 1995. "Flood Testing Roof Systems." *Professional Roofing* (February): 42. https://www.nrca.net/Technical/PDF?id=65374&k=449903.
6. ASTM International. 1998. *Standard Guide for Flood Testing Horizontal Waterproofing Installations*. ASTM D5957-98. West Conshohocken, PA: ASTM International.
7. Wilen, J. P. 2012. "The Art and Science of Electronic Leak Detection." *Professional Roofing* (November): 24–29. https://www.professionalroofing.net/Articles/The-art-and-science-of-electronic-leak-detection--11-01-2012/2170.
8. Crowe, J. P. 2006. "Water, Water Everywhere." *Professional Roofing* (February). https://www.professionalroofing.net/Articles/Water-water-everywhere--02-01-2006/800.
9. Canadian Roofing Contractors Association. 2009. "Bulletin: Flood Testing." *Roofing Canada* (November). https://roofingcanada.com/bulletin/flood-testing.
10. IIBEC. 2021. *Technical Advisory: Electronic Leak Detection*. IIBEC-TA-018-2019 (updated 2021). https://iibec.org/publication-post/iibec-technical-advisory-no-018-2019-electronic-leak-detection.
11. Western States Roofing Contractors Association (WSRCA). 2021. *A Guide for Electronic Leak Detection of Roofing and Waterproofing Membranes*. Technical Bulletin No. 2021-WC1. Morgan Hill, CA: WSRCA.
12. ASTM International. 2014, *Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes*. ASTM D7877-14. West Conshohocken, PA: ASTM International.
13. ASTM International. 2019, *Standard Practice for the Use of a Low Voltage Electronic Scanning System for Detecting and Locating Breaches in Roofing and Waterproofing Membranes*. ASTM D8231-19. West Conshohocken, PA: ASTM International.
14. FM Approvals. 2021. *Examination Standard for Liquid Leak Detectors*. FM Approval Class 7745. Norwood, MA: FM Approvals.
15. Hoverman, C. 2021. "Roof Leak Detection Inspection" (webinar). LDM Buckleys. https://youtu.be/FhV2G3oKpXwm.

Figure 9. Moisture detection sensors (before roofing is completed) and a monitoring center.

16 "Electronic Leak Detection High vs Low Voltage." *Waterproof! Magazine.* October 13, 2013. https://www.waterproofmag.com/2013/10/electronic-leak-detection-high-vs-low-voltage.

17 Brooks, P. 2017. "Electronic Leak Detection: Sound Science, Not a Magic Wand." *RCI Interface* (July): 20–24. https://iibec.org/wp-content/uploads/2017-07-brooks-2.pdf.

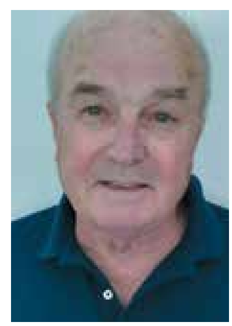
18 Sika Corp. 2015. "Electronic Leak Detection Testing Limitations." Technical Bulletin 15-8 (August 11, 2015). https://usa.sika.com/dms/getdocument.get/74f5300e-f397-4850-96d5-cd063ef213ee/15-8-eld-testing-limitations.pdf.

19 Baskaran, B., and D. Lefebvre. 2019. "Good Codes vs. Durable Roofs—Which Is the Missing Link? Where Is the Sweet Spot?": Presented at the RCI International Convention, Orlando, FL, March 17, 2019.

20 Sika Corp. 2017. "Electronic Leak Detection Testing on Roofing Projects." Technical Bulletin 17-09 (August 2, 2017). https://usa.sika.com/dms/getdocument.get/3f21a134-bdf5-47ee-aed8-684a8fb422a1/ELD-Testing-Limitations-15-8.pdf.

21 FM Approvals. 2022. "Updated Standard: FM 7745, Liquid Leak Detection" (news release, July 18, 2002). https://www.fmapprovals.com/product-alerts-and-news-events/news/updated-standard-fm-7745.

ABOUT THE AUTHORS



DAVID VOKEY, PEng

David Vokey, PEng, *is a founder, president, and CEO of Detec Systems. He graduated from the University of Manitoba with a bachelor of science in electrical engineering in 1973 and master of engineering from the University of Manitoba in 1984. Prior to co-founding Detec Systems, he worked for Siecor Corp. (now Corning Cable Systems) as the manager of R&D for cable development, responsible for the design and development of fiber optic cables. He holds over 40 patents worldwide relating to fiber optic cables and moisture detection in building envelopes. He is a member of IEEE, IIBEC, ASTM, and the Association of Professional Engineers and Geoscientists in both British Columbia and Manitoba.*

SHAUN KATZ, CSI

Shaun Katz,CSI, *has over 20 years of experience in customer service and business administration. He has assisted contractors, architects, engineers and consultants, manufacturers, facility/property managers, and building owners with forensic leak investigation, as well as leak detection in new construction. He is a member of IIBEC and CSI.*