TITLE: Electronic Leak Detection

DESIGNATION: IIBEC-TA-018-2019 (updated 2021)

OBJECTIVE: To provide information on the methods and qualifications for electronic leak detection testing used for installed roofing and waterproofing systems.

BACKGROUND

With the desire to improve the service life of roofing and waterproofing systems, a need has arisen to improve both quality control (QC) and trouble-shooting techniques of these systems. The introduction of nondestructive electronic leak detection (ELD) testing has provided additional options to meet this demand. Since QC is an increasingly important aspect in today's construction projects, ELD is becoming a commonly specified and utilized procedure to determine watertightness in roofing and waterproofing assemblies. The introduction of ELD technology occurred around 20 years ago in the North-American market and has led to increased confidence in the performance of roofing and waterproofing systems. In recent years, questions have arisen regarding differences in technology and training required to provide accurate results using ELD. This technical advisory will provide information related to ELD on the following:

- History and development of equipment currently utilized
- Current ASTM standards and how they apply
- Basic principles needed to conduct testing
- Characteristics and limitations of the different technologies
- Training and proper implementation
- Recommendations

DIFFERENT TECHNOLOGIES

The origins of ELD began with high-voltage (holiday) testing equipment. This equipment was originally designed to test corrosion-resistant coatings applied on metallic pipes and was later modified to test geomembranes, waterproofing membranes, and low-slope roofing assemblies.

Moving into the 1990s, low-voltage testing made its way slowly into the German market as a means of troubleshooting existing roofing assemblies. It quickly became evident that low-voltage equipment was also suitable for integrity testing on exposed membranes.

Low-voltage electric field vector mapping also has the ability to assist with the troubleshooting of roofing and waterproofing through different types of overburden covering the membrane, although these tests are much more difficult and challenging than testing exposed membranes and have significantly reduced reliability.

In the 1990s, low-voltage testing—electric field vector mapping—was introduced in the North American market. While ELD was first promoted as a troubleshooting tool, as it was in Europe, it quickly became apparent that many individuals in the industry were interested in using the technology as a QC tool during installation of roofing and waterproofing systems.[i] Several developments have been made in the equipment over the years to allow for QC on numerous types of roofing and waterproofing systems. Within the last ten years, conductive grids, conductive primers, and other materials have also been introduced into the market to act as alternative grounds. These are incorporated into systems to allow for testing conventional insulated roofing systems. ASTM D7877–14, *Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes*, specifies that the alternative ground be installed directly under the membrane when the electrical path to the conductive deck is interrupted.

While there are several forms of equipment utilized for ELD—such as high-voltage broom, scanning platforms, electric field vector mapping—the basic electrical theory of either high or low voltage is similar.

ASTM D7877-14

ASTM D7877[ii] was introduced in 2014 and specifically explains the various pieces of equipment in use and the conditions required to perform a test. While this standard outlines the terminology and methodology associated with current electronic test methods and equipment variations, it does not address training and experience of the individual performing the tests.

Equipment Addressed in the Standard[iii]

ASTM D7877 outlines two methods of low-voltage ELD for horizontal surfaces, one method of low-voltage ELD for vertical surfaces, and one method of high-voltage ELD for horizontal and vertical surfaces, further described in the following.

Low-Voltage Methods of Electronic Leak Detection

- Low-Voltage Membrane Horizontal Scanning Platform Method (performed with wetted membrane)
    - This equipment utilizes direct current contained within a wheeled scanning platform that reads a field between two different “sweeps” making contact with the membrane. This is utilized for testing membranes on horizontal substrates only.

- Electric Field Vector Mapping Method (performed with wetted membrane)

  - This equipment utilizes two poles which read a direct current field being placed across the membrane via a looped conductor wire at the membrane perimeter. This is utilized for testing membranes installed on horizontal and vertical substrates.

- Low-Voltage Vertical Membrane Surface Scanning Method (performed with wetted membrane)
  - Similar to the platform utilized for horizontal applications but the equipment is designed to be handheld and utilized for testing membranes installed on vertical substrates.

High-Voltage Method of Electronic Leak Detection

- High-Voltage Membrane Testing Method (performed with dry membrane)
  - This is a broom like device with electrodes at the head and is "swept" across a dry membrane locating punctures in the membrane. This is utilized in testing membranes on horizontal and vertical substrates.

BASICS REQUIRED FOR ELECTRONIC LEAK DETECTION

The basics required for either high- or low-voltage ELD are very similar even though the results are achieved through different methods. In either method of testing, electrical principles apply, and the testing cannot work without meeting specific conditions.

The first thing that needs to be verified is that the membrane being tested will not allow electrical flow to pass through. Most fluid-applied and sheet membranes in the roofing and waterproofing market are suitable candidates for performing ELD. However, there are several membranes that are conductive or semi-conductive, with black EPDM being one of the most commonly employed conductive membranes.

Although ASTM D7877-14 primarily describes methods for using ELD testing to locate breaches in non-conductive waterproofing membranes, it also provided initial guidance on testing electrically conductive membranes, such as black EPDM. Sections 6.3, 6.5, 8.5, and 9.3 specified that the high- and low-voltage technologies available at the time when ASTM D7877 was developed were not suitable for testing conductive membranes.

In the case of EPDM, due to the carbon-black content in this material, the proper electrical isolation needed for testing cannot be created with the black membranes themselves. If the membrane is electrically conductive, such as black EPDM, specialized membrane primers or adhesives may be required in conjunction with testing equipment that is designed or calibrated specifically to the primer or adhesive used.

Subsequently published in 2019, ASTM D8231, *Practice for the Use of a Low Voltage Electronic Scanning System for Detecting and Locating Breaches in Roofing and Waterproofing Membranes*, describes a low-voltage, dual-sweep scanning method using ELD to locate breaches in waterproof membranes. It also includes procedures for testing non-conductive and semi-conductive membranes. Testing of black EPDM requires the use of a conductive primer in conjunction with approved adhesives. All methods of ELD require the substrate immediately below the membrane to be conductive and have the ability to carry an electrical charge.

Acceptable substrates are steel-reinforced, cast-in-place concrete (CIP); steel-reinforced precast concrete (such as double tee sections); metal decks; and conductive materials specifically manufactured to be incorporated into the system and installed directly under the membrane to act as a grounding medium.

If the necessary conditions indicated herein are present, then either a low- or high-voltage ELD method can be successfully performed. If any of these necessary conditions are not present, then the testing firm must present options to the project personnel for creating conditions that will result in a successful test once final membrane installation is complete. In all cases, it is prudent to review the entire assembly design prior to installation for other potentially limiting factors, such as adhesives, vapor barriers, overburden components, and the like.

ADVANTAGES AND LIMITATIONS OF EACH TECHNOLOGY

Low Voltage

The most notable shortcoming of electric field vector mapping is the difficulty with testing black EPDM or other electrically conductive membranes, as described previously. Care must be taken in the roofing design to allow for proper testing, if black EPDM is used. ASTM D8231-19 is a standard practice for testing conductive and semi conductive membranes, such as black EPDM utilizing low-voltage platform scanning technology.

Scanning platforms must make direct contact with the membrane. Therefore, they cannot be used on assemblies with overburden, such as pavers, garden or vegetation, ballast, or similar that cannot be readily removed. In these cases, another method of low-voltage testing, such as electric field vector mapping, is more appropriate. Note that these tests are much more difficult and challenging than testing exposed membranes and require significantly more experience.

High Voltage

High-voltage ELD cannot be used to test black EPDM single-ply membranes for reasons indicated previously. Another issue that can affect the high-voltage test results is varying membrane thickness in fluid-applied membranes. The equipment should be calibrated on each project to perform the test based on a consistent fluid-applied membrane thickness. Care must also be taken to minimize the possibility of false "positive readings" in areas where the membrane thickness is less than the test standard. Seams in the membrane and flashings in both fluid- and sheet-applied products can also influence the test readings. Seams in the membrane can also pose challenges as voltage will not travel laterally through a void within a seam to the underlying conductive substrate. This has been addressed in ASTM D7240 section 2.3.[iv] "Unless the conductive geomembrane has been installed with the conductive layer sufficiently broken in the fusion weld, this method cannot be used to test fusion-welded seams."[v] Although this was stated in a standard applicable to geomembranes, the same basic science is applied to roofing or waterproofing membranes.

TRAINING AND PROPER TEST IMPLEMENTATION:

As with any other specialized trade in the construction industry, both low- and high-voltage ELD require significant training for technicians to have the appropriate knowledge and experience to properly implement the test. In the last few years there have been several companies beginning to offer ELD services with technicians with little to no training. It is important for industry stakeholders to understand the qualifications of companies and personnel offering ELD services and their ability to provide accurate and reliable test results. Currently there are no independent educational or training opportunities being offered for either low- or high-voltage ELD testing. Nor are there industry recommendations for minimum training requirements for ELD technicians.

The following items are important questions when establishing testing firm and technician qualifications:

- Knowledge of roofing materials, components, and systems
- Length of time providing ELD service
- Experience with the equipment and testing method utilized
- Type and duration of technician training
- Approvals from roofing or waterproofing manufacturer for testing firm and method being used
- A list of references of the technician providing testing on similar projects

RECOMMENDATIONS

It is important when specifying ELD testing to ensure membrane and assembly compatibility as well as manufacturer acceptance. Consulting with a firm knowledgeable in ELD technology during the design phase is also critical to achieving a successful roofing or waterproofing project. In several assembly designs, ELD testing cannot be considered as an afterthought, if a conductive medium is to be incorporated within the assembly. It is important to remember that test results can only be accurate when the correct ELD technology is employed, and proper procedures are followed by trained and experienced technicians. ELD testing when appropriate does not replace visual QC and other best-practice inspection requirements and should not be relied on as the sole means of QC. Metal flashings, drains, and other components require different inspection techniques and all these components combined are what form a successful installation.

REFERENCES

[i] Roberts, Keith, The Electrical Earth Leakage Technique for Locating Holes in Roof Membranes, Proceedings of the Fourth International Symposium on Roofing Technology, September 1999.

[ii] ASTM International, ASTM D7877-14, Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes, 2014.

[iii] Refer to ASTM D7877 for photographs of equipment.

[iv] Section number may change. When this Technical Advisory was published, section 2.3 was current.

[v] ASTM International, ASTM D7240-18, Standard Practice for Electrical Leak Location Using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive-Backed Geomembrane Spark Test), 2018.