Electronic Leak Detection Methods for Locating Leaks in Waterproofing Membranes

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ABSTRACT

This paper presents the new ASTM D7877 standard, which addresses the need for a systematic procedure to test, verify, and monitor the integrity of waterproof membranes using electronic conductance measurement methods to locate leaks in exposed or covered waterproof membranes. The methods described are used on both conventional and protected roofs and are particularly useful for roof designs that incorporate a waterproofing membrane under a green roof, wear course, or topping slab, where direct inspection of the roof membrane is difficult or impossible.

SPEAKERS

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DAVID VOKEY, PEng, is a founder, president, and CEO of Detec Systems, LLC. He graduated from the University of Manitoba with a BS degree in electrical engineering in 1973, and a master of engineering degree from the University of Manitoba in 1984. Prior to cofounding Detec Systems, he worked for Siecor Corporation (now Corning Cable Systems) as the manager of research and development, responsible for the design and development of fiber optic cables. David holds over 35 patents worldwide relating to fiber optic cables and moisture detection in building envelopes. He is a member of IEEE, RCI, ASTM, and of the Association of Professional Engineers and Geoscientists in both British Columbia and Manitoba.
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BACKGROUND
Historically, architects and other designers have often called for a flood test to be carried out on horizontal waterproofing systems when the membrane is under a green roof, wear course, or topping slab where direct inspection of the roof membrane is difficult or impossible. ASTM D5957, Standard Guide for Flood Testing Horizontal Waterproofing Installations, is typically referenced for the test. Flood testing takes between 24 and 48 hours and is often considered inconclusive; as a result, the National Roofing Contractors Association (NRCA) and the Canadian Roofing Contractors Association (CRCA) do not recommend conducting flood tests as part of a routine quality control or quality assurance program for a new roof system.

The first low-voltage electronic conductance method to test waterproofing membranes was developed in Europe in the early 1980s and were patented by H. Geesen. The method, which is a derivation of a technique used to locate cable sheath faults in buried telephone cables, was subsequently called electric field vector mapping. Several new electronic leak detection (ELD) methods have been developed in the past 20 years or so, and they fall into two main categories: low-voltage (48V or less) and high-voltage (600V or more) conductance testing. Although ELD testing has been in use for several decades, no standard describing the methods and limitations has been developed to guide the industry.

INTRODUCTION
The new ASTM D7877 standard serves as a guide describing current methods for using electrical conductance testing procedures to locate leaks in exposed or covered waterproofing membranes. It addresses the need for a systematic procedure to test and verify the integrity of waterproofing membranes; however, it is not intended to replace visual, infrared, or other methods of evaluation. It is to be used in conjunction with other methods of roof inspection when specified. The methods described include testing procedures designed to provide an important part of the quality control during membrane installation.

ELD can be used on waterproofing membranes installed on roofs, plaza decks, pools, water features, covered reservoirs, and other waterproofing applications. The procedures are applicable for membranes made of materials such as polyethylene, polypropylene, polyvinyl chloride, bituminous material, and other electrically insulating materials.

While this guide provides a general description of the equipment and methods for locating membrane breaches using electric conductance, it is important that an operator refer to the manufacturer’s instructions for the proper operation and use of the equipment. It is also recommended that the leak location equipment, procedures, and survey parameters used be calibrated to meet established minimum leak detection sensitivity. The leak detection sensitivity calibration should be verified on a regular basis according to the manufacturer’s recommendations.

The electric conductance methods described in this guide require a conductive substrate under the membrane to serve as a ground return path for the test currents. In roof assemblies where the membrane is installed over an electric insulating material such as insulating foam and/or a protection board, the electric path to any conductive deck is interrupted. This situation can be remedied by placing a conductive surface directly under the membrane. The conductive surface provides the return path for the test currents.

SUMMARY OF CONDUCTANCE LEAK LOCATION
The leak location methods in this guide describe the electrical conductance techniques used to detect and locate membrane breaches. These methods—while accurate and effective—are subject to certain noted limitations. Electric conductance leak location requires that the deck material directly below the membrane be sufficiently conductive for the test method employed. In most instances, a concrete substrate is sufficiently conductive to allow this method. In certain membrane assemblies where the substrate is nonconductive, it may be possible to install a wire mesh or other conductive layer directly under the membrane to facilitate testing.

Application of the leak detection and location methods in this guide, in conjunction with construction quality control and quality assurance programs, can provide a higher level of confidence that the membrane is leak-free. This quality control process can minimize the risk of membrane breaches during construction and leaks during the service life of the membrane.

The principle of the conductance leak location method is the establishment of an electrical potential between the electrically insulating waterproof membrane and the underlying substrate.

For test methods employing a low-voltage electrical potential (48V or less), a controlled covering of water on the surface forms the conductive path horizontally across the membrane to any membrane breach (Figure 1). At a breach location, an electrical path to the deck is formed through the water leaking to the deck below. A sensitive receiver detects the leakage current and alerts the operator.
For test methods using a high voltage potential (600V or more), an electrode is swept across the surface of the membrane. The electrode is charged to a high potential relative to the deck below. At a breach location, an electrical arc occurs from the electrode to the deck below. The arc discharge is electronically detected and the operator alerted.

**LOW-VOLTAGE HORIZONTAL MEMBRANE SCANNING PLATFORM**

The principle of the scanning platform method is to establish a voltage potential between the platform and the roof deck and to track any leakage current passing through the membrane. This is accomplished by wetting the surface of the membrane, applying a voltage with respect to the deck, and then locating areas where electrical current flows from the platform through membrane breaches to the deck.

The basic circuit and application of a dual sweep-scanning platform is shown in Figure 2. The platform is constructed with two sets of metal sweeps, which make continuous electrical contact with the membrane surface. The outer sweep forms a continuous perimeter around the platform with the inner sweep contained within the perimeter of the outer sweep. The positive terminal of the generator is attached to the building electrical ground or the roof (concrete or metal) deck/substrate, and the negative terminal connects to the conductive sweep of the platform through the measuring and indicator unit. Since the majority of roofing/waterproofing membranes are nonconductive (excluding high-carbon, black-loaded materials such as certain types of EPDM), the electrical potential applied to the platform sweeps provides a path through the water over the wetted area of the membrane to any breach, thus completing the circuit to the substrate and back to the generator.

During the membrane scan (Figure 3), a light spray of water is applied to the membrane in front of the advancing platform. The outer sweep responds to and displays any leakage current in the test area.

The inner sweep, which is electrically shielded by the outer sweep, will detect a leakage current when the sweep platform is directly over the membrane defect. This will result in a noticeable deflection on the inner sweep meter accompanied by an audible alert. This is precisely the location where moisture is penetrating the membrane.

**Limitations** – The conductance leak locate method using the scanning platform cannot be carried out on conductive membranes such as EPDM. The deck material directly below the membrane must be sufficiently conductive for the purposes of this test method (concrete decks typically meet this criterion). Drains and other grounding penetrations can cause a false reading if not isolated from the applied water spray. See the equipment manufacturer’s instructions on avoiding these unintended grounding problems.

Note: Certain scanning equipment designs provide built-in isolation of the sweep from drains and other grounds, thereby minimizing the potential for false readings.

**LOW-VOLTAGE HORIZONTAL MEMBRANE ELECTRIC FIELD VECTOR MAPPING**

The electric field vector mapping technique employs an electric potential gradient across the membrane surface, along with a sensitive voltmeter and probes to locate membrane leaks. As illustrated in Figure 4, a conductor cable loop is installed around the perimeter of the area to be tested. A signal generator is connected to the loop cable and the building ground. The area within the loop is covered with a spray of water to form a continuous conductive surface in the test area. Since most roofing/waterproofing membranes are nonconductive, the electrical signal from the perimeter cable loop looks for an electrical path over the wet area of the roof to any breach within the wetted area, thus completing the circuit to the substrate. The resulting current from the breach location to the perimeter cable sets up a voltage gradient in the water within the perimeter. A sensitive voltmeter and a pair of handheld electrical probes long enough to reach
the membrane surface are used to detect, measure, and track the leakage current to its source at the breach.

A signal generator is connected to the building ground or concrete roof deck and the perimeter cable that is placed around the area to be tested. Metal penetrations and drains must be isolated by looping a separate cable around them and then connecting these isolating cables to the perimeter cable. The meter response is read at an initial location within the perimeter area, and the operator carefully moves the pair of probes left or right while reading the signal level (Figure 5) to the probe positions that result in the maximum meter reading. The probes are then repositioned towards the indicated direction and the process is repeated. The location of maximum signal strength will coincide with the breach location.

Limitations – The proper operation of the electric field vector mapping system requires a continuous layer of water on the membrane where water beading occurs, thereby impeding the formation of a continuous wet surface. Protected waterproof membrane roof systems covered with additional layers—including insulation, root barriers, and drainage mats—can interrupt the locating signal. These layers form an electrical insulating layer that can interrupt the locating signal or cause offset errors in the leak’s identified position. Operator skill and knowledge are important factors in obtaining the accurate results.

LOW-VOLTAGE VERTICAL MEMBRANE SURFACE SCANNING

Vertical surface leak location is a leak testing and locating system that picks up where horizontal scanning methods leave off. The vertical test method provides leak testing on vertical surfaces, corners, foundation and parapet walls, seams, etc., ensuring that difficult-to-inspect details are watertight.

As illustrated in Figure 5, the vertical leak locate system employs a sensitive receiver, water-moistened sensor, audible alert, and ground lead. The receiver supplies the power source referenced to ground for testing the membrane integrity.

In operation, the moistened sensor, which is connected through a cable to the voltage source in the receiver, is pressed against the surface under test. This action forces water onto the membrane surface and into any breaches. A leakage current will flow from the ground connection through the breach location, returning to the receiver through the moistened sensor. The receiver will register a deflection on the signal level meter, accompanied by an audible alert.

The vertical surface leak locator is used to test the membrane integrity of corners, parapet walls, and seams.

Limitations – The vertical surface leak locating method cannot be carried out on conductive membranes such as EPDM or heavy carbon-black-loaded material. The material directly underneath the membrane must be sufficiently conductive for the purposes of this test method.

HIGH-VOLTAGE MEMBRANE TESTING

Unlike the low-voltage method, which is carried out on a wet membrane, high-voltage testing is performed on a dry horizontal or vertical surface using a limited current at relatively high voltage. One lead from the portable current generator is grounded to the roof deck (either metal or concrete). The other lead is attached to a special electrode brush made with conductive metal bristles. The brush electrode is then swept over the surface of the roof.
membrane (Figure 7). An electric arc will jump from the electrode through any breach in the membrane, thereby completing a circuit between the brush and the roof deck. Where there are no breaches, the membrane acts as an insulator and prevents the flow of current to the deck.

Using a voltage source of approximately 40 kV, a membrane up to a maximum thickness of 26 mm can be tested. For the test to be effective, the membrane must be adhered to a conductive deck or have a conductive backing.

Limitations – The test can only be carried out on nonconductive roof membranes that have a conductive substrate. The surface must be dry when the testing procedure is carried out. The thickness of the waterproof membrane must be known so that the test voltage can be calculated. The operator must be isolated and protected from the voltage source.

RECORDKEEPING AND REPORTING

Daily field notes should be written with entries describing the areas scanned; the number and location of any breach; and weather conditions, date, and name of scan operator. It is recommended that the field notes include a plan view drawing of the total area to be scanned. At the end of each day, the scanned area should be marked on this drawing with crosshatching or shading.

If the entire area to be scanned cannot be completed in one day, the area scanned each day should be identified on the membrane. This identification should be made with a clearly visible mark drawn on each corner with a compatible marker.

The operator should copy and submit daily field notes to the designated receiver. The information on this document will be transferred to a periodic field report for submittal and storage.

A periodic field report should describe the work performed, persons contacted on the site, items discussed, and any additional remarks. The report should include the project information, weather conditions, and date of the report and should be submitted digitally by the end of the following day.

The operator should maintain a breach location and repair log that records a running tally of the breaches located and repaired. Information on this log should include the breach identification numbers, date located, date of repair, notes, and square footage of area scanned.

CONCLUSIONS

Electronic leak locating methods for locating breaches in waterproofing membranes have been in use for several decades. The new ASTM Standard D7877, Electronic Leak Detection Methods for Locating Leaks in Waterproof Membranes, provides a guideline to the industry on the application and use of ELD. In particular, it helps specification writers to better understand the capabilities and limitation of the various test methods so that the most accurate results can be realized in every case.