Knowing whether or not a new or existing roofing or waterproofing assembly is watertight and being able to successfully identify leakage sources in these assemblies can be a challenging and often humbling experience. Leakage problems have plagued builders since antiquity. Today, an entire industry has, through trial and error, prior experience, and scientific development, progressed to help answer these questions in a variety of ways. Those of us in the fields of design, specification, installation, and inspection of building envelope weatherproofing assemblies derive our livelihood responding to watertight integrity issues. The historical and traditional, as well as state-of-the-art, cutting-edge testing methods available to answer these questions will be summarized in this article.

Investigation and identification of leak sources, primarily in horizontal building systems, can sometimes be a daunting task. Some of the techniques and methods employed to find leak sources may appear similar to the practice of dowsing for water in the earth. Some individuals utilize their knowledge of roofing and waterproofing design principles, membrane system strengths and weaknesses, deck construction and common workmanship deficiencies, as well as a great deal of logic and common sense. After a lot of time, energy, and practice, they are often successful in identifying potential leak sources through deduction and reasoning.

Analytical methods and techniques used to detect or identify leak problems and sources in roofing and waterproofing applications are available to assist designers, specifiers, installers, and investigators. Until recently, there have been five general testing methods: spray testing, flood testing, capacitance (impedance) testing, nuclear metering, and infrared (IR) thermal imaging. Recently, two relatively new methods of testing have revolutionized the leak detection and integrity testing industry. These methods utilize electricity and a simple electric circuit to detect and identify problem conditions in roofing and waterproofing systems. These are generically referred to as “Low Voltage” and “High Voltage” test methods. It is not the intent of this article to explain or address all the principles and subtleties of how each testing method should be done to provide accurate results. This article will focus on highlighting the testing methodologies and principles, and their advantages and limitations.
This testing method is definitive and not interpretive, meaning that the test will pinpoint the precise location of any existing breaches in the membrane. Once the breach has been identified, it can then be isolated on the outside of the copper loop and excluded from the test area, and testing for additional breaches may continue in the same test area. Low voltage testing can find breaches invisible to the human eye as well as be able to detect a breach in the membrane system that has wet building components but which have not yet presented themselves at the building’s interior as visible leaks. This test method has its limitations. In order for the breach to be detected, water must be in the system to complete the circuit. The application of the light spray of water at the membrane’s surface will usually not be enough to complete the circuit in an insulated assembly if water is not already in the assembly. This means that the system has to be exposed to the weather or flooded with water prior to the testing. Due to the low voltage, planters with soil depths greater than six feet may need some or all contents removed to allow the testing to function properly. Also, when a vapor retarder is installed below the membrane, it may function as an additional insulator and will not allow the circuit to be completed unless it has been penetrated with mechanical fasteners.

Difficulties may also arise when large vertical or irregular surfaces are encountered. While simple vertical base flashings and penetration flashings can be tested with this method, it is impractical to test large or irregular areas. Also, the extent of the damaged or wet building components is not quantified, requiring additional investigation to determine their condition.

High Voltage Testing

The concept of high voltage testing is similar to that of the low voltage and is depicted in Diagram 2. The difference between the two test methods is that instead of laying out a conductive loop and...
causing the entire membrane surface to become positively charged, the positive charge is concentrated to a small area the size of a broom head. See Photo 2. The power source is again grounded to the conductive deck and creates a high potential difference with an extremely small current. When the broom head, made of copper bristles, is swept over a breach in the membrane surface (which functions as an isolator in the circuit), the circuit is completed, allowing current to flow and the power source then emits an audible tone to alert the test operator. The area where the broom head was located when the tone was heard is then carefully swept again with the corner of the broom head to pinpoint the exact location of the breach. This process is continued until all areas of the membrane have been tested, including vertical base flashings and penetration flashings.

The lack of water, as well as the speed of testing, make the use of high voltage testing preferable to low voltage, provided the limitations described below do not preclude the use of the high voltage testing equipment.

The high voltage testing method is also definitive and not interpretive. It will identify the precise location of breaches in the membrane and, because no water is used, allows their immediate repair and retesting. As with low voltage testing, high voltage testing can find breaches invisible to the human eye, as well as detect a breach in the membrane system that has wet building components, but which have not yet presented themselves at the building's interior as visible leaks.

There are limitations with this method. These include the requirement that the membrane be smooth (i.e., no aggregate surfaced/ballasted roofs), completely exposed to view, dry, and relatively clean. Due to the extremely high voltage, the electricity will arc approximately 3/4"; however, if excessive dirt exists, this will act as an insulator, possibly obscuring a membrane breach.

As with the low voltage testing, the extent of the damaged or wet building components is not quantified, requiring additional investigation to determine conditions.

**Capacitance Testing**

Capacitance testing utilizes an electric field to determine the relative moisture content of a membrane assembly. An electric field is created, and a sensor then reads the strength of the electric field when the meter is placed over the membrane. The strength of the field and sensitivity of the sensor can be changed based upon the substrate being tested in order to obtain readings that provide greatest variation while staying within the limits of the analog read-out or digital display. This type of meter calibration at each jobsite provides the most accurate survey the equipment will allow.

Readings are generally taken in a grid pattern with a hand-held unit and recorded, although it is possible to take continuous readings with some meters that are mounted with wheels. See Photos 3A and 3B.

This testing method is interpretive and not definitive in that it does not specifically identify the location of the membrane breach,
rather it locates areas of elevated moisture content, which in most instances can be assumed to contain the breach. Once the metering of the test area in question is complete, test cores should be taken at the high and low reading locations and their moisture content precisely established by laboratory measurement after controlled drying. This technique will provide a correlation between the meter readings and the absolute moisture content of the assembly. Removing additional samples at locations of intermediate meter readings will provide more precise correlations from meter reading to actual moisture content.

The preparation and calibration required for the testing described above may seem lengthy and cumbersome. Survey results are not available until after laboratory moisture content results are provided. A skilled technician, however, can quickly calibrate the electric field and sensor in order to get relative readings providing information to allow areas with elevated moisture content to be mapped out before leaving the test location. Knowing the areas of elevated moisture content provides areas that should be inspected with the purpose of finding the breach in the membrane.

There can be instances in which the capacitance testing will provide elevated readings that are not due to leakage. Condensation within a roof insulation system is a typical example in which the capacitance meter readings will be elevated with no associated roof leak as a cause of the elevated readings.

This testing technique requires that the test membrane be dry, the assembly be uniform in materials and their thicknesses, and that water be in the system to provide differential readings at relative dry and wet areas.
Infrared Thermography (IR)

Infrared thermography is an interpretive testing method that is based upon the principle that wet and dry building components have differing rates of heat gain and retention. Wet materials have significantly more mass and have slower rates of heat transfer, meaning that they gain and lose heat more slowly than a dry sample of the same material. This physical characteristic is used in the same manner as in the capacitance testing described earlier in order to quantify the location of wet building components. The testing equipment used is generally a hand-held IR camera with the ability to have recording devices connected or contained within the unit to allow the information to be retained and presented at a later time in a report. See Photos 4 and 5.

The most common use of IR imaging is after a sunny day when the exterior of a building gets warmer than the surrounding air temperature, due to solar radiation. The amount of this temperature difference has a direct relationship to the color and reflectivity of the surface. The darker and less reflective the surface, the greater the temperature difference; or the lighter in color and greater the surface reflectivity, the less the temperature difference will be.

As described above, the rate of thermal gain upon initial exposure to the sun and the rate of thermal loss upon setting of the sun will vary between two areas of the same material that have different moisture content. If the IR imaging is done after sunset, exposed roof and wall areas that have elevated moisture content will retain significantly more heat than surrounding dry areas that can readily be detected in the IR scan. Areas of elevated temperature within a homogenous roof and wall assembly are assumed to be due to the presence of moisture. Laboratory drying of test cuts removed from areas with low, medium, and high temperatures will allow calibration of the IR image to absolute moisture content of the building materials.

As with capacitance scanning, a skilled investigator can utilize the areas of elevated temperature detected by the IR equipment, assume it to be due to elevated moisture content, and thereby concentrate visual inspections in these areas in order to isolate the source of the leak.

As with the capacitance meter, an IR scan will outline areas of wet insulation that could be due to condensation or problems other than a roof membrane breach.

The obstacles to the use of IR in the location of leaks are that the scans are typically done at dusk or in the early evening and should be done when weather conditions are favorable. Once the areas of suspected elevated moisture have been identified, the visual inspection for the membrane breach must be done the following day in the daylight hours. Also, assumptions must be made with respect to items such as the homogeneity of the materials, thicknesses, and interior building temperature of the scanned areas.

Nuclear Meter

Nuclear meter testing is also an interpretive test method that utilizes relative readings that are interpreted to locate areas of identical substrate materials with differing moisture contents.

A nuclear meter emits a stream of high velocity neutrons that collide with hydrogen atoms and give up some energy and then rebound to the metering device at a slower speed. One point to remember is that each molecule of water is made of two hydrogen and one oxygen atoms. The meter then records these slower speed neutrons and provides a digital reading on a pre-set calibrated scale. Readings generally take from seven to sixty seconds each and are done in a grid pattern that varies from three feet to ten feet on center. See Photos 6 and 7.

Again, as with the other interpretive test methods, the testing equipment should be calibrated at each jobsite as well as for different roof assemblies and thicknesses within a single site for accurate results. The relative readings can again be utilized by a skilled investigator to locate areas of suspected wet materials to limit the bounds of a detailed visual inspection to determine the source of the leak.

Unlike the IR scanning method, the nuclear testing can be done in the daytime hours to allow immediate inspection, identification, and repair of the suspected leak source(s).

The difficulties with this testing technique are that the transportation of radioactive materials contained within the meter has become much more difficult and overhead intensive since September 11, 2001, and the use of a metering device that contains radioactive material can be troublesome due to perceived danger on the part of the public and building occupants. As with IR and capacitance testing, the source or sources of the leak must be found visually within the area determined to contain the elevated readings after the nuclear testing is completed.

Flood Testing

Flood testing is the most basic of testing methods available. It can also be one of the most effective. An in-depth understanding of structural systems and their safe load-carrying capacity is imperative prior to employing this method. The drainage system is temporarily sealed or blocked, and the area in question is covered with water – typically for 12-48 hours. Simultaneously, during this period, the underside of the test area is inspected for any evidence of water infiltration. The depth of the water can vary; however, a minimum of 2’ is common to provide a sufficient hydraulic head to
force the water into any small breaches that may occur within the timeframe of the test. See Photo 8.

The difficulty with flood testing is the time required to fill, test, and then drain the sometimes tens of thousands of gallons of water required to properly test an area. When the area to be tested has a slope greater than 1/4” per foot, the depth of the water needed to test that area increases dramatically. On occasion, the depth of the water required can exceed the safe load-carrying capacities of the structural frame or deck and may require that the area be broken down into multiple smaller sections by the construction of water retaining dams. Once the test is complete, the water must be safely removed from the membrane. If the water depth is sufficient and the drains are simply opened completely to drain the area, catastrophic results, such as blowing out elbows in drain piping, can allow all of the test water to enter the building interior, causing significant damage.

**Spray Testing**

Spray testing is the use of controlled water flow deposited on building components in a manner that simulates normal to severe weather conditions. ASTM method E-1105 is a good overall method commonly used to test exterior walls, sloped glazing, and shallow pitched roofs to help identify leak sources. This ASTM procedure utilizes a calibrated spray rack with specific water pressures, nozzles, and distances to wet a wall with water at the rate of five gallons per square foot per hour. A pressure differential that simulates wind is created between the interior and
exterior of the building, and the interior is inspected for any leaks.

Less formal spray testing can be done on horizontal and vertical areas with similar results, provided the water spray is controlled to wet only the areas intended to be tested. The spray testing is started at the point of lowest elevation of a suspected area of leakage and then the spray is directed at progressively higher building components with the wash water running over the components at a lower elevation that have already been tested.

This type of procedure can be particularly effective when testing by any of the other methods is difficult due to access or assembly composition limitations. These might be when ponding water for a flood test is not practical or the presence of multiple metal penetrations makes electrical testing difficult. See Photo 9. Also, spray testing is ideally suited for fast and easy results, as the materials and techniques are quite basic and can be learned fairly quickly.

The limitations of spray testing are that during periods of cold weather the use of water may be impractical or the addition of more water to a sensitive leak may not be tolerated by the building occupants. In addition, spray testing may not replicate all the conditions — i.e., direction, pressure differential, etc., necessary in order to recreate a leak.

**Conclusion**

As with most investigative tools, the test method selected is only as good as the experience of the person used to perform the test. Knowledge of all the test method options is only the first step. Knowing the benefits, and more importantly, the limitations of each system will assist a knowledgeable individual to quickly and cost effectively locate and repair all breaches within the membrane.