

# ELECTRONIC LEAK DETECTION

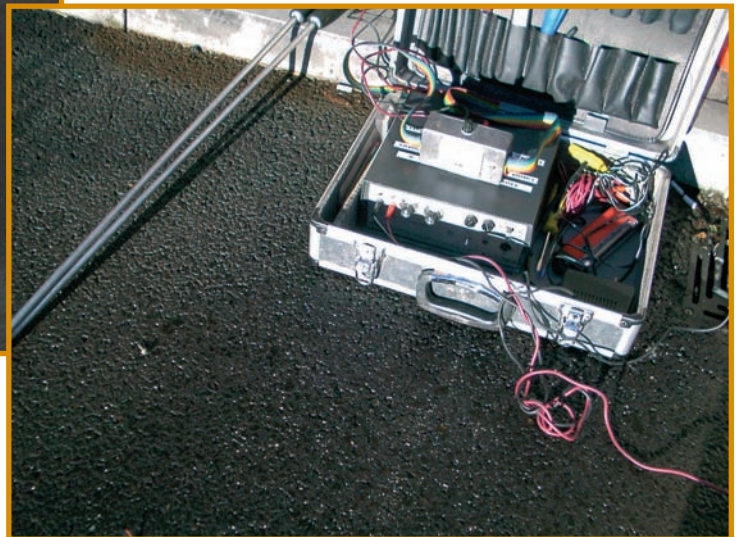
BY STEVEN THORNTON

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Above: Conducting the test with surface probes connected to the detector unit worn around the neck of the test engineer.

Right: Test equipment showing the large pulse generator and the smaller detector unit.



## Introduction

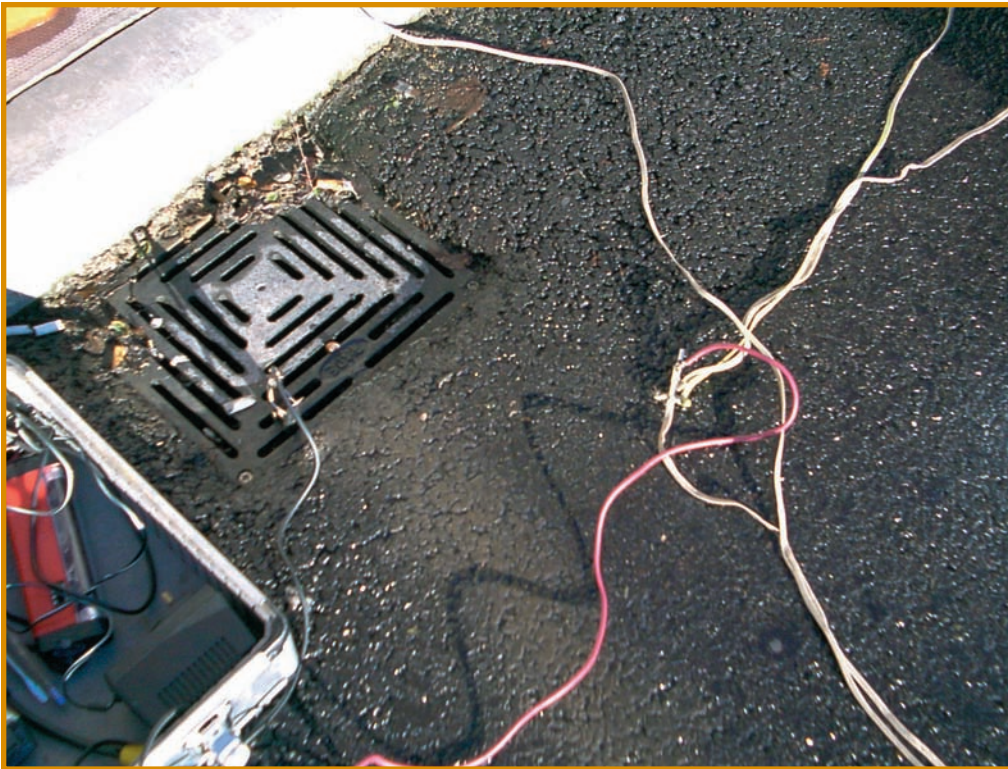
With the advent of high performance roof membranes and systems in the 1970s, it soon became clear that their performance was being compromised by poor design, workmanship problems, or damage following completion. This situation was further exacerbated by a trend toward burying membranes in plaza decks, concrete car parks, and roof gardens.

Added to this was the fact that, in the United Kingdom, at least, the roof was being held to blame for all manner of leaks which, more often than not, originated in detailing the superstructure above roof level. Improved diagnostic methods were thus needed; and so was born electronic leak detection in flat roof and structural waterproofings. The introduction of electronic leak detection to the UK in the late 1980s coincided with major advances in quality assurance (QA) controls in construction. As a result, the electronic diagnostics test was rapidly perceived as being an extremely useful method of confirming the integrity of new waterproofings in a much more defined and efficient way.

There is a distinct preference between testing for leaks and testing for no leaks (i.e., integrity testing). When testing for leaks, we know already that there is a water path from the source into the structure, so an electric circuit is being made. When testing for absence of leaks, however, we must bear in mind that, although the waterproofing membrane may be breached, water entering through it may be recent and not have moved very far, or it could be held back by the vapor retarder, thus preventing the circuit from being made. We thus have to be extremely careful when assessing the suitability of a given roof for quality assurance testing. This will include assessing such factors as the type of decking, whether a vapor retarder could hold back water, the type of membrane used, the age of the roof, and weather conditions since installation.

## Electronic Leak Detection

The term "electronic leak detection" is perhaps a misnomer in the context of this paper. The technical term used in the UK is "Earth (ground) Leakage Detection." This allows us to categorize the test into two distinct functions:



Left: Connections between the pulse generator and the conductor loop/ground.

- Leak detection in roof and other waterproofing membranes.
- QA integrity testing of new waterproofing applications.

We originally set up our leak detection service back in 1987 with the purpose of tracing leaks. However, its use as a quality control tool rapidly outgrew this function and is now well established—not just as the viable alternative to flood testing—but as a superior stand-alone test in its own right.

Perhaps at this stage the word “leak” should be defined. We refer to leaks as water manifesting into buildings, which is clearly what leak detection is all about. In terms of QA or integrity testing, however, a leak might be referred to as “water penetrating through the membrane and not necessarily reaching the inside of the structure or manifesting internally.” In that respect, we have tended to refer to holes in the membrane as breaches rather than leaks. This certainly helps our clients in distinguishing one from the other, so it will be used from now on in this paper.

To describe the benefits of electronic testing, I propose to use one contract in the UK as an example—Broadgate in the city of London, which we came across in 1987, not long after starting up the leak detection service.

Broadgate was at the time—and probably still is—the largest single office development in Europe. That said, it is probably dwarfed by many similar projects in the United States. In this project, 4 million square feet of office space were built in the old marshaling yards associated with Liverpool Street Railroad Station. The project started in the mid 1980s and continued until around 1993. We became involved during building of Phase 3 of a total of 12. The project included roofs, plazas, bus and taxi decks, gardens, water features, and an ice rink over underground accommodations. These included restaurants, a shopping

mall, automobile parking, and railroad tracks. At that time, the contract was beginning to accelerate and reached its peak around 1990. The entire accent was on speed and, at its peak, some 20,000 square feet of office accommodation were being completed per week.

In 1987, however, the regime for testing waterproofing membranes as set down by the architects was for a 14-day flood test, followed by close inspection underneath. Following trials in mid 1987, the architect decided to reduce the time for flood test to seven days, following which the areas were to be electronically tested. So successful was this operation in detecting flaws in the membrane (against everybody's expectations), that the flood test was eventually eliminated altogether in favor of the electronic test. One of the reasons was that, during the course of testing, we were able to demonstrate that, by employing certain preparatory techniques, the

exposure time to water could be reduced to around five minutes, in which time any defects in the membrane would be sought out by the electronic test.

### Test operation

The test relies on two basic parameters:

- The slab or decking onto which the membrane or roof system is laid is electrically conductive—usually metal or concrete.
- The membrane itself is an electrical insulator.

As water is the conductive medium, an electric path can be created from the surface breach to the deck along the line of water flow. There must, therefore, be a moisture path from the breach in the membrane surface to ground for the test to function. This is not the case with all decks and all membranes, as shall be described later.

When water enters a breach in the membrane and passes through to make contact with the deck, an electrical path is created along which current will flow. Once made, this path will remain in place permanently. Depending upon roof build-up and the membrane type, one of two tests can be employed to detect it.

The first is a low voltage wet test which we have been operating since 1987. The test is now recognized in the UK as the method of testing waterproofing membranes and is specified or used by architects, construction companies, and waterproofing contractors alike. It is also incorporated as a standard in the National Building Specification (NBS), which is sponsored by the Royal Institute of British Architects (RIBA).

It uses water as the conductive medium on the roof surface. In the same way as an automobile uses ground as one of the ter-

minals for all electrical equipment, so, too, do we use ground. For the other terminal we connect to a special wire loop laid on the roof surface. This has two distinct functions: it defines the area of test and eliminates earth leakage from components such as outlets, lightning conductors, etc. The area within this loop is thoroughly wetted to form an electric "plate." The roof deck or slab below it may be referred to as the other electrical plate, while the membrane separating the two acts as the insulator.

When we change the electric potential between these two plates, current will flow through any holes or breaches via the water path described earlier. Because current is vectored, or directional, it will flow across the wet surface in all directions, thus creating an electric field—or, in the case of multiple holes—a series of electric fields, some of which interfere with each other. The task of the test engineer is to tap into this field or fields by means of a pair of surface probes connected to a sensitive meter. Taking one single leak as an example, this is how it works:

Starting at a reference point (normally at a corner of the looped area), we touch our probes onto the surface approximately three feet apart. At this point, direction does not matter, although, for reference purposes, it is best to work parallel with one of the sides. If there is a breach, current will flow across the probes. Through a sensitive meter connected to the probes, we obtain an electric signal which tells us from which direction that flow is coming. We then move across the roof following this direction until we reach a point at which we are perpendicular to the hole. At this point, there is zero current flow. As we move past it, the current flow reverses. Here, we change direction through 90° and follow until we again pass the perpendicular. By a series of turns, and moving the probes closer together, we can eventually home in on the precise point. Once we are there, we can hold one of our probes on the suspected hole and the other approximately an inch or two away. No matter where the second probe is, flow will always be toward the one which is over the hole, therefore allowing it to be identified with pinpoint accuracy.

Once detected, the hole can be isolated by drawing the conductor loop around it. This eliminates the electric field created by that particular hole. In the case of multiple holes, we normally find first the ones with strongest current flowing from them. By a process of detection and isolation, we can ultimately locate all such defects.

Although this test operates within a conductor loop as explained, it is possible to work outside it, for example at perimeter curbs, provided that the membrane at the top of the upstand is dry, as the current will otherwise ground out. In this way, the most vulnerable details can be properly tested.

The other test—high voltage dry—is not so commonly employed as it requires more exacting circumstances. It uses air as the conductive medium between the roof surface and water in the leak hole. It is simply a contact method using the same basic principles as the low voltage electron-

ic test. In this case, however, there is no need to set up an electric field on the roof surface, as current will arc through any small holes in the membrane, which sets off a discharge in the transformer/generator. This, in turn, produces an audible signal. The test is a surface contact method of test on dry membranes and, as such, varies substantially from the wet test.

### So why use electronic testing?

It has a number of distinct advantages over flood testing and certainly over doing nothing at all, including visual inspections. The main points are:

- Environmental – no large volumes of water wasted.
- Speed of test – hours rather than days or weeks.
- Ability to home in precisely on defects, enabling precise repair.
- Ability to re-test repairs immediately.
- Certification of roof systems, enabling faster hand-over and, for contractors, earlier release of payment.
- Cost efficiency.
- Loading, especially on lightweight roof structures.

### So, why do we have two tests?

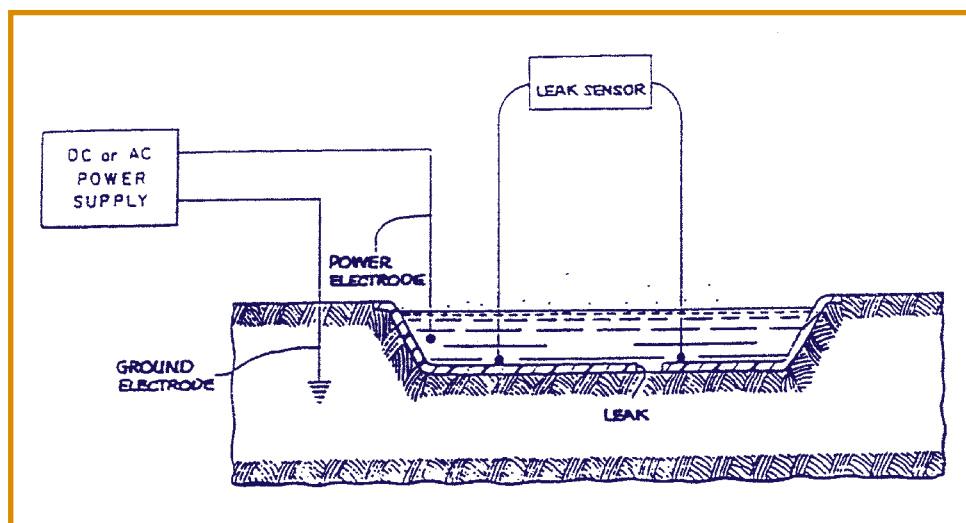
The answer is quite simple. As with many testing procedures, none is perfect for all eventualities. The following are typical limitations of each test.

#### General limitations

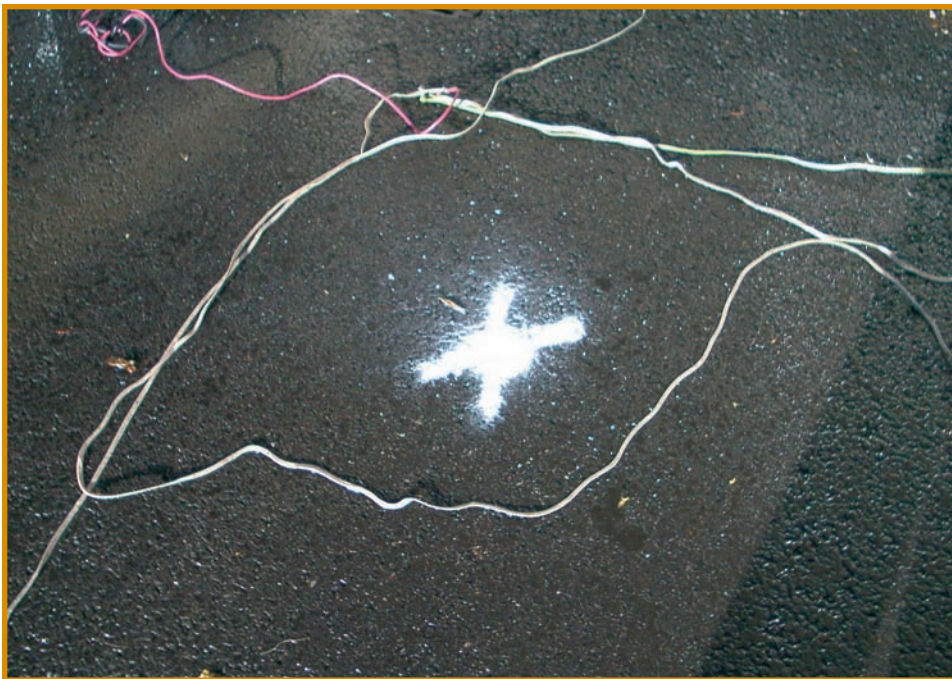
- Cannot test EPDM membranes or metal-faced felts. The carbon in EPDM renders it electrically conductive.
- Unable to test sealed warm roofs without mechanical fixings.
- Inorganic decks (i.e., non-conductive) need special preparation. Not suitable for QA testing.

#### Low voltage wet test

- Difficult to work sloping roofs or in windy conditions.
- Single ply is difficult to keep wet in large areas.
- High sun can also affect ability to maintain continual wet conditions.



*Leak detection for geomembranes.*



*Isolation of defect traced by drawing the conductor loop around it.*

### High voltage dry test

- Not really suitable with asphalt-based products – i.e., felts.
- Cannot trace lap defects.
- Needs water exposure before being employed.
- Cannot function on buried or inverted roofs.

### Testing of warm (insulated) roofs

These are defined as thermally insulated roofs where the insulation is above the deck and is sandwiched between waterproofing layers to prevent leakage from above and condensation from below.

To repeat the parameters necessary for the test to function, the following are required:

- The need for an electrically conductive deck.
- Membrane to be an insulator.
- A water path to be developed from the surface to the deck.

With warm roofs, there can be a problem in obtaining the necessary moisture path. It is perfectly possible for water to enter the breach in the membrane and actually fill the voids of the roofing system without it penetrating the vapor barrier. Under these circumstances, the test is unlikely to function properly.

With mechanically-fixed roofs, however, where the fixing is either through insulation or membrane into the deck or both, we can obtain the necessary conductivity through the fixing itself (although some of these now have plastic washers and/or sleeves).

Should there be a need to integrity test a warm roof without fixings, we can install what I term an “earth loop” within the build-up as work progresses. It would be too complex at this stage to go into the details of this system.

### IRMA or buried roofs

In this type of construction, the membrane system is not visible, being buried under insulation and ballast, paving, or earth. It is not really suitable for this type of membrane to be integrity tested as part of a QA process, as the sensitivity of the test is diminished somewhat, depending upon finishes. Even for detection of breaches, testing is difficult and can only be undertaken by someone with considerable experience, while results can never be guaranteed.

The main problem here is that, as the conductor loop cable can only be laid on the top surface, signals can ground out through the finishes, which will inevitably contain sufficient water to conduct electricity. To overcome this, “channels” need to be dug in the finishes to expose a band of membrane. This will then eliminate the unwanted ground leakage.

In conclusion, electronic leak detection has now become widely approved as the way for assessing integrity of new membranes, as proven in many thousands of tests over 14 years. It has also gained widespread acceptance as a diagnostics tool for determining the location of holes in membranes or even for proving the membrane, thus allowing investigations to progress to other elements of the building envelope or mechanical services.

It must be used with care, however, and in this respect there is no substitute for experience.

Quality assurance testing, in particular, cannot be just a matter of guessing and hoping, as there is often no second chance. In inexperienced hands, therefore, there is great potential for disastrous consequences. In particular, where membranes are to be buried, there is no realistic alternative, but there is only one chance to get it right. ■

## ABOUT THE AUTHOR

**Stephen Thornton** has been involved in the roofing industry in the United Kingdom since 1992. Since then, he has worked in product development, quality control, plant management, technical services, and sales for major manufacturing and contracting companies. In 1986, he formed Thornton Consulting Group, Ltd., in West Sussex, UK. His first project was an assessment and refurbishment of the H.J. Heinz UK Headquarters building. He later moved into the fields of leak detection and quality integrity testing. Mr. Thornton has spoken at RCI Building Envelope Symposia.



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