THE ELECTRICAL EARTH LEAKAGE TECHNIQUE FOR LOCATING HOLES IN ROOF MEMBRANES

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This paper sets out the principle of the electrical earth leakage technique for locating holes in roof membranes and goes on to describe the equipment and method. Site experiences from using the technique on different types of roof construction are included. The paper is written from the perspective of a practicing roofing consultant based in the United Kingdom (UK), giving both the advantages and disadvantages of this nondestructive test method, which potentially could be used more widely.

KEYWORDS

Leak detection, nondestructive testing, waterproofing.

INTRODUCTION

One of the challenges of the twenty-first century will be to monitor the performance of roof systems using objective and reliable techniques.

Traditionally, flooding a roof and monitoring any fall in water level has been the preferred method for testing the integrity of a waterproofing membrane, but there are real practical problems in setting up the test. If the membrane doesn't hold water, then the roofing substrate could become saturated and permanently damaged. After the water is drained off, the punctures still have to be located.

During the construction of new buildings, it is common to find damage to roof membranes caused by other tradesmen working on the roof after the waterproofing has been completed and often before the handover of the building. The client's inspector is in a difficult situation: he can see some visible signs of puncture damage and mark them for repair, but how can he be sure that *all* of the tears, splits, and holes are identified? There is a clear need for an objective test method to identify any leak paths through the membrane such that at the handover, the parties are assured of a watertight roof.

The widespread concern of specifiers who have been in this unsatisfactory position before is one of the underlying reasons why waterproofing systems in the UK have recently lost market share to low-slope metal watershedding systems. Thus, it is also in the interests of the waterproofing manufacturers to address the issue of how to locate holes in roof membranes.

During the past ten years, the electrical earth leakage technique has become popular in the UK and is now probably the most widely used test method for detecting leaks in membrane roofs. Although the test method is also common in parts of Europe, it is understood that it is less well-known in North America. Little has previously been published about the practical aspects of this technique, which potentially has many uses.

OBJECTIVES

The objectives of this paper are to describe the electrical earth leakage technique for locating holes in roof membranes and to set out both the advantages and disadvantages of the method as seen from the perspective of an independent roofing consultant working in the UK and Ireland.

PRINCIPLE OF OPERATION

In a leaking roof, rainwater passes through a hole in the membrane down into the roof substrate. Water is a good conductor of electricity.

An electrical potential difference is set up between the roof surface, which is wet, and the roof deck, which is earthed or grounded. If there are any leaks, then a small electric current will flow across the roof surface and down through the hole to the earthed roof deck. The electric current will flow directly to the hole. Using an ammeter connected to two probes, the direction of the current can be identified and, thus, by moving the probes, any puncture can be pinpointed (Figures 1 and 2).

Because of the high electrical resistance through the roof, the magnitude of the electrical current is relatively small. Thus, variations in construction affect the distance from which a hole can be identified. However, what is of greater importance is not the *magnitude* of the current, but the *direction* in which it flows, leading the technician to the hole.

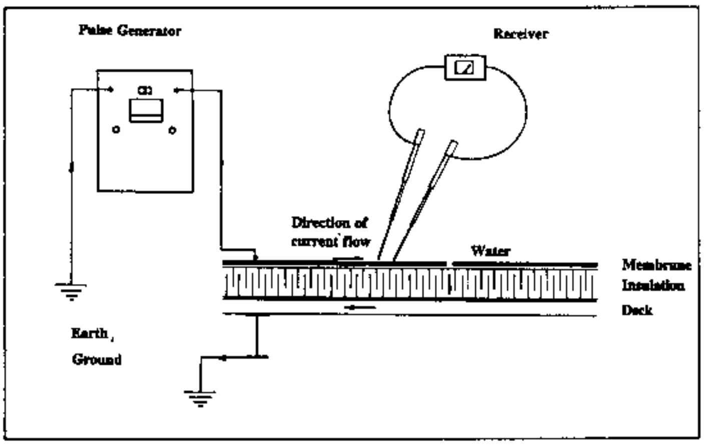

Figure 1. Diagram showing principle of operation.

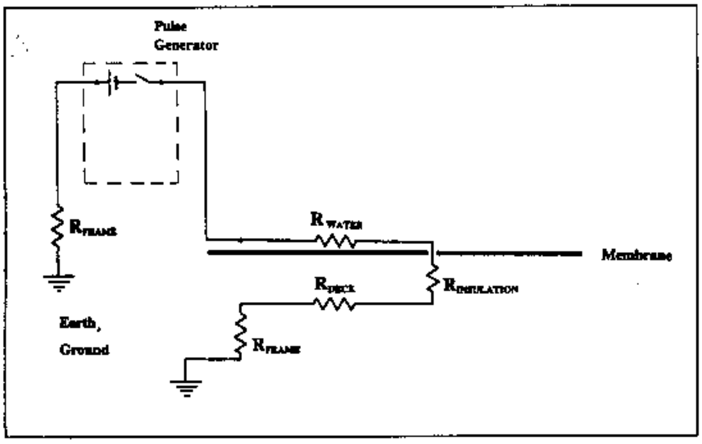

Figure 2. Simplified circuit diagram.

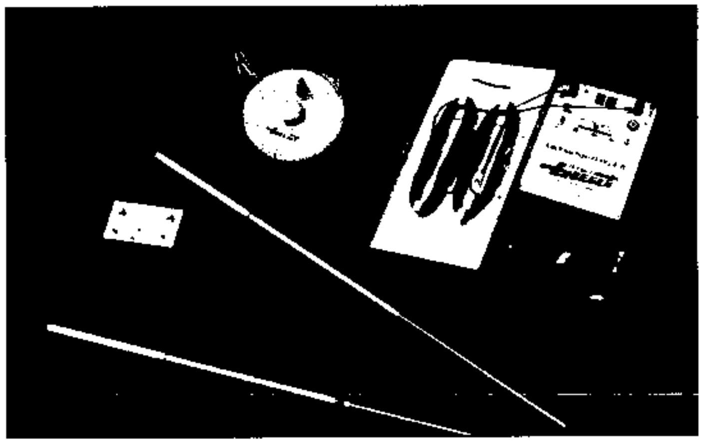

Figure 3. Photograph of electrical earth leakage equipment.

Throughout its development, the method has been given various names in the UK, including "the electrical conductance technique," "the electronic flat roof leak detection system," and "the sparks test." However, it is understood that these methods all use similar equipment, the Geesen Flat Roof Leak Detector, a patented system manufactured in Germany.

EQUIPMENT

The equipment, which is portable, is shown in Figure 3 and comprises the following:

- **Electric Pulse Generator.** The electric pulse generator, which weighs approximately 10 kg (22 pounds), has a rechargeable battery and, when switched on, delivers a 40-volt potential for a period of approximately 1 second once every 3 seconds. The voltage is low so that there is no risk of the technician being electrocuted while operating the equipment on the wet roof.
- **Coils of Wire.** Several reels of multistrand cord with braided wire are used to conduct the electricity across wide areas of roofing. A second wire is provided for connecting the pulse generator to the earthed, or grounded, deck. Often, small weights are provided to hold the wire in place.
- **Receiver.** The receiver houses an ammeter in a lightweight carrying case with neckstrap. Two metal probes are connected to the left- and right-hand terminals each side of the receiver. The ammeter has a central zero position and half-scale deflection of the order of 0.1μA.

METHOD

Before setting up the test equipment, it is essential that the roof surfaces are thoroughly soaked with water. If it is not raining at the time of the test, then water needs to be sprayed from a hosepipe over all of the surfaces to be tested. If the roof is sloped and free-draining, the water supply needs to be continuous. For new roofs, it is advisable to leave the roof to be subjected to wet weather for at least a month prior to testing, allowing rainwater to seep into the roof construction to improve the electrical conduction.

The fully charged electric pulse generator is taken up onto the roof, and one of the terminals is connected to the structure of the building. This could be the steel framework, a metal rainwater outlet, or a handrail bolted to the deck.

The other terminal is connected to the long length of wire, which is set out in a rectangular loop around the area to be tested. The pulse generator is switched on, a green light starts to flash, and a regular clicking noise is heard. The technician with the receiver and two metal probes then steps into the field to be tested and places the two probes onto the roof surface 1.5 m (5 feet) apart. The zero control is adjusted so that the ammeter is in the central position when there is no current flowing (Figure 4).

If there is a hole, the dial will move either to the left or right, indicating the direction of current flow. The technician then moves the probes in the direction indicated, with the strength of the current increasing closer to the hole. By a series of iterations, the direction of current flow shown on the receiver leads the technician to the leakage point. When one of the probes is over the hole, the strongest reading is given. At this stage, the technician can normally identify visually some mark or feature on the roof surface, such as a scuff or a side lap, which can then be ringed in wax crayon for reporting and repair.

Having identified one hole, it is important that the local area is isolated by either laying an isolation loop or by temporarily sealing the puncture with adhesive tape. If this is not done, other smaller holes nearby could remain undetected. It is also prudent at the start of a test program to cut a few core samples to check and confirm that the electrical earth leakage points are indeed punctures and that water is present

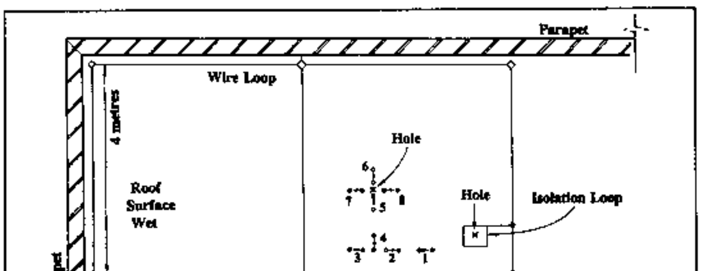

Figure 4. Roof plan showing area under test.

within the roof construction directly below.

It is essential that the technician adopts a methodical approach, systematically working across all of the roof areas. For relatively open roofs with little damage, a technician can test more than 1,000 m² (10,000 square feet) in a day. However, for a typical roof, it would be more realistic to anticipate a rate of 500 m² (5,000 square feet) per day. What is important is that an unhurried approach is adopted; otherwise, holes can be missed.

APPLICATIONS

It is important to recognize that the technique does not work on all types of roofs; in particular, the membrane being tested must not be a conductor of electricity. For example, black EPDM membranes with a high carbon black content are known to conduct electricity, and the technique will not work on these roofs.

In contrast, the materials below the membrane, notably the insulation and decking, need to be good conductors of electricity. For example, foil-faced insulation boards work well, especially if they are mechanically fixed to a metal deck.

In the UK, it has become normal practice for the specialist testing house to undertake a site trial of a small area to check the effectiveness of the method on the actual roof construction before progressing to a full survey. Table 1 summarizes the current understanding of the different constructions where the method either will or will not work, based on the experiences of using the electrical earth leakage technique over the past six years.

Situations where new roofs overlay earlier constructions can present difficulties because the path of the electric current becomes longer, creating greater electrical resistance and reducing the strength of the current on top of the roof. A reduced current means that the technician needs to be closer to the puncture before he picks up a reading on his receiver, and thus, there is a greater risk of missing a hole.

The technique will work on roofs covered with loose-laid stone ballast, although concrete paving slabs or walkway pads would need to be lifted to gain access to the membrane surface to locate holes if there is an electrical current. Any metal passing through the roof, such as pipe penetrations, handrails, fixed plant or gutter outlets, also offer an earth path and should not be assumed to be an active leak. Instead, the loop of wire should be passed around the penetration to isolate it.

One of the benefits of the technique is that it will work in the rain because the test is less weather-dependent than other roof moisture survey techniques, such as infrared thermography. This is of particular importance in countries with maritime climates, such as the UK and Ireland.

	Membrane	Insulation	Deck
Will Work	PVC Single-Ply EP Single-Ply Bitumen Felts Asphalt Liquid Coatings	Mineral Wool PUR / PIR Cork	Metal
Marginal		Polystyrene Cellular Glass	Concrete Timber Woodwool
Won't Work	Metal-Faced Felt EPDM Single-Ply		

Table 1. Suitability of different roof constructions.

CASE STUDIES

Study No. 1: New EP single-ply membrane roof

Construction:
- white EP membrane, mechanically fixed
- polyurethane thermal insulation
- polyethylene vapor control layer
- galvanized steel deck

The EP single-ply roof membrane had been completed, but before the factory building was handed over, other trade contractors started working above the roof without adequate protection and caused puncture damage to the membrane.

The technique successfully identified more punctures, often hidden below muddy debris (Figures 5 and 6). The tests also found local points where the heat-welded side laps were not continuous. Thus, the technique is an alternative to the physical test where a blunt screwdriver is drawn along the edge of a welded side lap to identify any incomplete welds.

One of the reasons why the tests were particularly successful in this case study was because the membrane was laid directly over a foil-faced insulation, which, in turn, was screw-fixed through to the metal deck. Thus, the foil facing acted as an excellent earth, or ground, with a strong electrical current flowing over the roof surfaces, enabling the technician to be drawn to the leak point from a distance of up to 3 m (10 feet).

Study No. 2: Over roof

Construction:
- thermoplastic single-ply membrane, fully adhered
- polyurethane thermal insulation
- original multilayer bitumen felt roofing
- fiberboard
- channel-reinforced cementitious wood particle decking

The original built-up felt roof of the residential home had been overlaid with insulation and single-ply membrane. The

Figure 5. Case study No. 1: Technician using the receiver and two metal probes to search for punctures in a single-ply roof membrane.

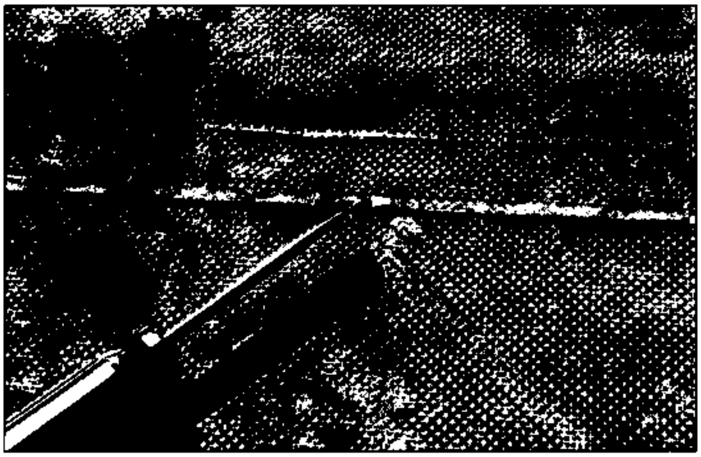

Figure 6. Case study No. 1: Point of leakage path identified at incomplete welded side lap.

roof leaked, and there was a need to locate all of the holes.

The testing was not successful because the electrical resistance of the full depth of the roof construction was too great, so that the current was very low (Figure 7). Thus, the probes needed to be very close to the puncture, for example, less than 0.3 m (1 foot), before there was any reading on the receiver.

Study No. 3: Aged PVC gutter linings

Construction:
- PVC single-ply membrane, fully adhered
- aluminum support plate
- polyurethane thermal insulation
- coated steel internal face

Over a period of years, the gutters above a large exhibition hall had been used as walkways, and scuff damage had been caused. Also, the membrane gutter lining had torn at some of the joints between the aluminum support plates because of differential thermal movement (Figures 8 and 9).

The testing identified a large number of punctures, which were later subdivided into two groups—"scuff damage" and "thermal movement"—enabling liability for the cost of the repairs to be allocated. The gutter linings were subsequently repaired, and the long-term rainwater leakage problem solved.

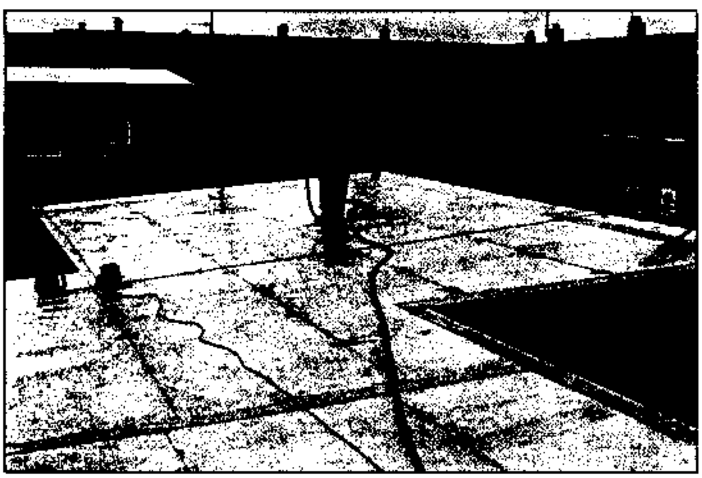

Figure 7. Case study No. 2: General arrangement of test.

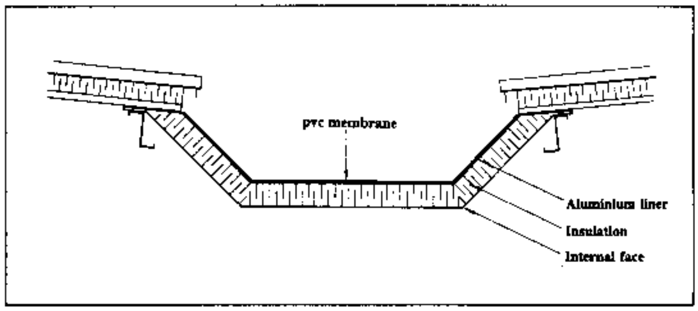

Figure 8. Cross section through insulated gutter with PVC lining.

Figure 9. Case study No. 3: Testing of gutters in progress.

Study No. 4: Aged multilayer bitumen felt roof

Construction:
- mineral-surfaced multilayer bitumen felt roofing
- cork thermal insulation
- original asphalt roofing
- lightweight insulating screed, saturated with water
- vapor control layer
- concrete deck

As part of a condition survey of an aged built-up felt roof over a hotel, the technique was used to test an area of 300 m^2 (3,000 square feet). It was found that there were 57 holes, notably around penetrations and at the base of a low upstand wall. The technique worked on the vertical faces of the upstand, provided that there was a continuous flow of water (Figure 10). One of the lessons learned from the case study was that the technique locates everything, right down to a pinhole.

It was later discovered that the screed had been wet since the time of the original construction twenty years before, when flood testing had resulted in the substrate becoming saturated; this contributed to the underperformance of the roof.

THE TECHNICAL COORDINATOR'S ROLE

A common experience is that new test techniques don't always seem to work and the results are confusing. Sometimes, this viewpoint is well-founded and is the result of a missing link: a technical coordinator who has an overview of the performance of the whole roof system.

Who the technical coordinator should be is dependent upon national and regional working practices. It may be a consultant, a contractor, or a specialist test house. What is important is that the named person is competent, diligent, and experienced in using the test methods. Technical input is necessary at three stages:

- **Stage 1: To identify the need for testing and the appropriate test method.** In carrying out a condition survey of a waterproofing membrane, it is right to consider alternative nondestructive test techniques, which may include the use of an infrared camera, a nuclear densimeter, a capacitance meter, and electrical earth leakage testing. Each method has its appropriate applications, and it should be the responsibility of the technical coordinator to advise on the optimum technique for the given situation. It is the author's view that a combination of methods is often desirable and sometimes needed in piecing together a reliable assessment of the condition of the roof.
- **Stage 2: To administer the testing.** The completeness of the testing in identifying all of the punctures is heavily dependent upon the thoroughness of the technician, who should methodically work across the roof in discrete bays, isolating the holes as he finds them. The technical coordinator has a duty to check random areas on behalf of his client and satisfy himself that the test is not being hurried.
- **Stage 3: To interpret the results.** This is probably the most important task of all: to deduce the correct conclusions and decide on an appropriate course of action, specifying the appropriate remedial works to the roof.

CONCLUSIONS

The electrical earth leakage technique for locating punctures through roof membranes is a practical alternative to flood testing low-slope roofs and is a useful tool for the roofing industry. Applications of the nondestructive test method include checking the integrity of new membrane roofs as part of a quality control procedure and assessing the condition of aged roofs.

Figure 10. Case study No. 4 : Testing an aged built-up felt roof.

The method cannot be used on all types of membrane roofs, and site trials are often the best way to establish the suitability of the technique. The roofing consultant and contractor have an important role in identifying the appropriate test method, in administering the testing, and, finally, in interpreting the results.

The greater and more widespread usage of the electrical earth leakage technique as an objective method for positively identifying holes in membrane roofs, is likely to contribute to the restoration of public confidence in low-slope membrane roofing in the twenty-first century.

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