# Ultimate Quality Assurance on Liner Installation by Using State of the Art Electric Leak Location Technologies

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**ABSTRACT**

The requirement for the protection of the environment and public health is increasing at tailings dams and heap leach facilities.

The installation of a geomembrane liner provides an additional level of safety and facilitates community and regulatory approval, since the liner is perceived as a guarantee of a low permeability barrier.

However, even under a strict CQA protocols, installed liners may contain defects, which may not be detectable by visual observation or traditional field test, like vacuum tests.

By incorporating electrical leak location (ELL) using the arc testing method (ASTM D7953-14) as an additional layer of quality control into the CQA protocols, liner defects as small as 1 mm may be detected and repaired.

This technology increases the safety of the facility by several orders of magnitude, both from an environmental and a stability point of view, by eliminating leaks and potential future differential settlement or even collapse of the lined facility.

Based on real case field data, the authors will demonstrate the results that can be obtained with this technology.

**Keywords:** Arc Testing, Electric Leak Location

## INTRODUCTION

Tailings storage facilities (TSFs) are some of the largest structures geotechnical engineers construct.

For a world inventory of 18,401 mine sites, the failure rate over the last one hundred years is estimated to be 1.2%. This is more than two orders of magnitude higher than the failure rate of conventional water retention dams that is reported to be 0.01%. (ICOLD, 2001).

The mining industry has experienced several significant dam failures in recent history: Merriespruit (South Africa), 1994; Omai (Guyana), 1994; Los Frailes (Spain), 1998; Baia Mare (Romania), 2000; and Aitik (Sweden), 2000; Buena Vista (México), 2014; Mount Polley (Canada), 2014. (Rico M, 2007)

An acute societal concern over such events has resulted in enforcing stringent safety criteria at mining operations in some parts of the globe (Azam S, 2010).

In this context, mining companies increasingly invest many thousands of dollars on Construction Quality Assurance (CQA) during tailing dam construction and/or expansion in order to install a high quality geomembrane liner free of defects or leaks.

### Reducing Leakage and Reducing Risk:

It is impossible to quantify the leakage through a single-lined containment facility, which is typically specified for most very large-scale geomembrane lined facilities. Once groundwater is contaminated or a failure occurs, then the leakage is noticed, but by then it is too late.

One way to quantify leakage through installed geomembranes is to measure the amount of leakage reported to the leak detection layer for double-lined containment facilities. The Action Leakage Rate (ALR) is defined as the amount of leakage that is allowable through the primary geomembrane of a double-lined containment facility. Sites are prescribed ALRs by environmental regulators and the ALR is dependent on the type of waste that is contained in the facility. In New York State, the ALR for landfills is 189 liters per hectare per day (20 gallons per acre per day). A statistical analysis of leakage through the primary geomembrane of landfills constructed using best practices for geomembrane installation and high quality CQA oversight is shown in Figure 1. As implied by the Figure, applying a leak location survey, especially both a bare geomembrane survey before cover soil placement and a covered geomembrane survey after cover soil placement (if applicable), tremendously reduces the risk of exceeding the New York State ALR. The risk reduction resulting from applying these technologies would be applicable to any site where leakage through the geomembrane is of concern.

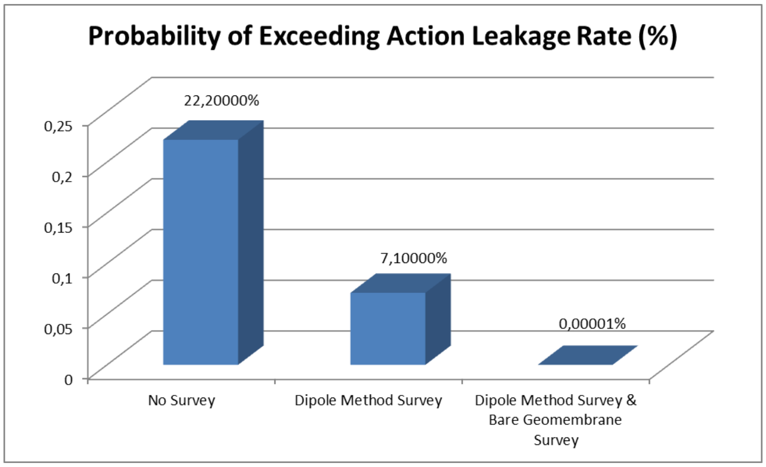


**Figure 1** Probability of Exceeding ALR (Beck, 2012)

The complexity of new installations is increasing, especially in the Andes region, increasing the corresponding risk of failure and/or leakage. The size of the facility required to dispose of the tailings is increasing and the topography of the area is a challenge to design engineers, generating new TSFs with slopes steeper than 2.5 h to 1 v, requiring the need to utilize new materials like Geosynthetic Clay Liners (GCL) underneath the geomembrane liner. Water is already a scarce resource and health and safety has become a top priority for mine sites, especially during construction phases.

An electrical leak location (ELL) technique called the arc testing method is available for locating leaks in exposed geomembrane liners (ASTM D 7953). The arc testing method has been proven to be a reliable and cost effective tool to check 100% of the exposed geomembrane for leaks, which can then be repaired before operations begin. However, the arc testing method is not typically used as part of tailings dam construction and CQA. The general practice is for a QC person to conduct limited tests on welds and for a CQA person to "walk and observe" the geomembrane liner surface, basically visual inspection from a 6" distance, on a quick walk. Therefore, small leaks, knife slices, leaks on welds or under overlap flaps, or any other hard to identify section of the facility, will likely go undetected.

Moreover, since there is no cover material placed on top of geomembrane liners at most TSFs, then other ELL methodologies such as the dipole method (ASTM D7007) cannot be applied.

In this paper, the authors share their experience applying the Arc Testing methodology, following the ASTM D7953 standard at two different TSF facilities. Applying the method resulted in increasing the safety and integrity of the sites and preventing environmental impacts and liabilities associated with potential leaks through the geomembrane liner that would have otherwise occurred if the survey had not been conducted.

## METHODOLOGY

The principle of this electrical leak location method is to introduce a high voltage between a leak detection test probe and the conductive medium underneath the geomembrane. The area is then swept with a test probe to locate points where the current completes the circuit through a leak. A visible electrical arc is formed when the current completes the circuit and the current flow is also converted into an alarm (audible, visual or other, which confirms leak detection and location) (ASTM Subcomittee 35.10, 2014).

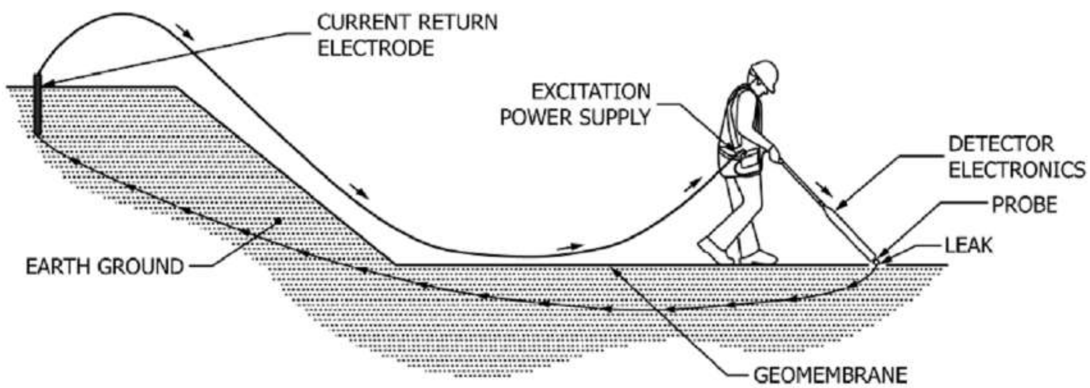


**Figure 2** Arc Testing Method Diagram

Testing must be performed on geomembrane liners that are generally clean and dry. Proper field preparations and other measures are implemented to ensure an electrical connection to the conductive material directly below the geomembrane liner to successfully complete the leak location survey.

A sufficiently conductive material is required below the geomembrane being tested. Under proper conditions and preparations, geosynthetic clay liners (GCLs) can be adequate as conductive material.

Measures should be taken to perform the leak location survey when geomembrane wrinkles are minimized. The maximum arc length for the site conditions can be determined during equipment calibration. Any hole located on wrinkles with a height exceeding the maximum arc length will likely not be detected.

This survey methodology is advantageous to sites with restrictions such as limitations on water availability, multiple leaks in the same area, and slopes steeper than 2.5 h to 1 v.

## SYSTEM CALIBRATION

Before beginning a leak survey, the equipment must be checked to ensure it is in working order. A trial test must be performed. A puncture (deliberate defect) is introduced in a test piece of geomembrane liner.

The deliberate defect is no greater than 1 mm in diameter. The test piece of geomembrane must be of sufficient size to enable movement of the testing probe at normal testing speed over the deliberate defect without touching the edges of the test piece.

At a minimum, the equipment is checked before testing begins and after any shut down of an hour or more. In the event a test reveals the equipment is not working properly, the entire area arc tested since the last passing check of the equipment must be retested to assure it was arc tested with working equipment.

## FIELD TESTING PROCEDURE

Field testing may be performed by marking a predetermined grid, or another acceptable method, and performing the survey within that grid at the same speed as the sensitivity test was performed.

During an ELL survey, wrinkles should be minimized in order to avoid false negative results.

The operating voltage should be adjusted between 6,000 and 30,000 volts, based on site conditions and sensitivity test.

The survey should be performed over 100% of the geomembrane liner.

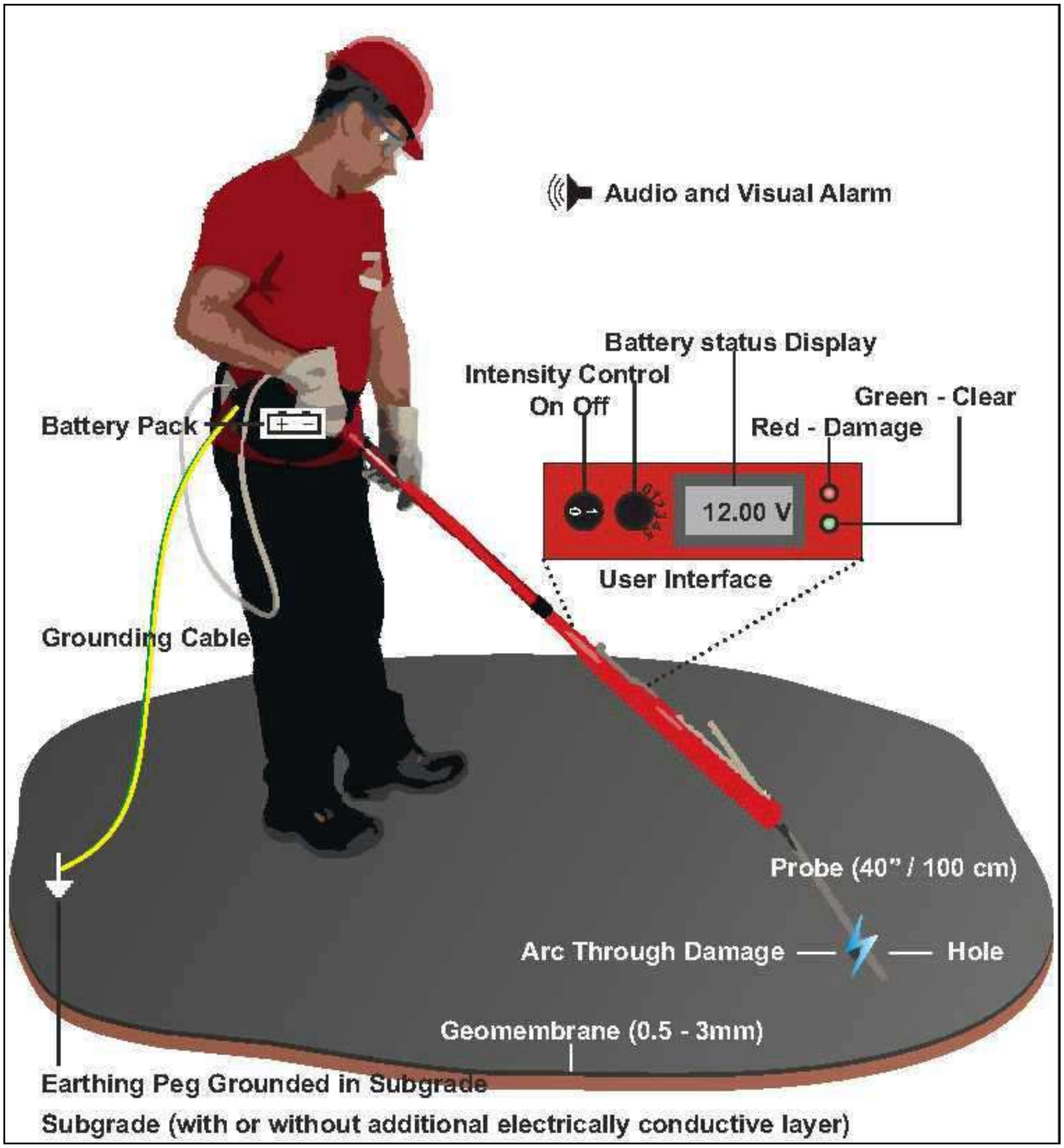


**Figure 3** Arc Testing Typical Set Up

**Case Study # 1 – Site Description**

This site is a gold leach pad located in the Andes Mountains, at 4,400 m above sea level (masl). Figure 4 shows the area general overview. Weather at this site is generally dry, with a rainy season from December through February. The geomembrane liner area to be surveyed was 190,000 $m^2$, with a schedule restriction of 90 days to finalize the project. The maximum slope was 2.5H: 1V

A 2.0 mm LLDPE geomembrane single liner was installed over a 30 cm soil liner (1.3 E-07 cm/s) layer.

**Figure 4** Site # 1 General View of exposed geomebrane liner to be surveyed, perimeter berms and previous phases

**Figure 5** Site #1 Perimeter Berm and Soil Line, prior to liner installationr

**Case Study # 2 – Site Description**

Project # 2 is tailings dam located in the Andes Mountains, at 4,000 m above sea level (masl). Tailings from a silver mine processing unit are stored in this facility. Figure 6 shows the area general overview. Weather at this site was generally dry, sunny, and windy with temperatures ranging from 7 C to 19 C. The geomembrane liner area to be surveyed was 77,000 $m^2$,. The maximum slope was 1.5H: 1V

1.50 mm HDPE geomembrane single liner was installed over Geosynthetic Clay Liner (GCL).

**Figure 6** Site # 2 General View or Tailings Deposit to be surveyed

**Figure 7** Site #2 Geomembrane liner and GCL installation

**Table 1** Summary of Sites Basic Data

| Site | Site # 1 | Site # 2 |
|---|---|---|
| Total Area surveyed ($m^2$) | 190,000 | 77,000 |
| Geomembrane Liner Specifications | 2.0 mm LLDPE single side textured | 1.5 mm HDPE smooth |
| Material placed underneath the liner | Soil liner | GCL |
| Single or double lined | Single | Single |

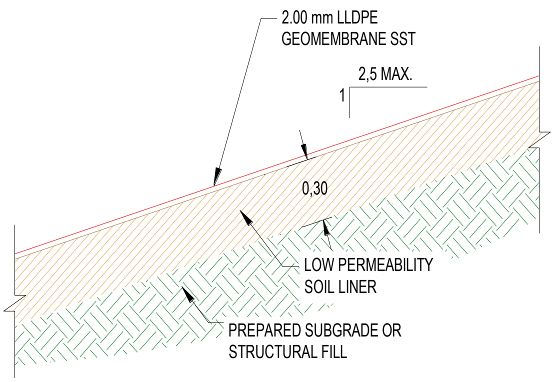


**Figure 8** Site # 1 Typical Cross Section

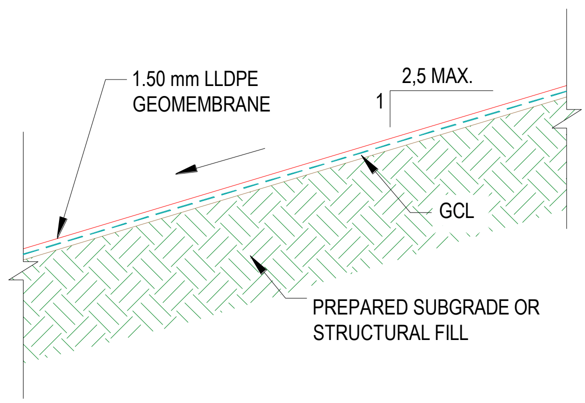


**Figure 9** Site #2 Typical Cross Section

## RESULTS AND DISCUSSION

Electric Leak Location was successfully completed at both sites within the project schedule using state of the art arc testing equipment. In compliance with ASTM D7953, equipment verification was conducted daily, ensuring quality of the reported results.

**Figure 10** Site # 1 Field Survey

**Figure 11** Site #2 Field Survey

In both sites several small (1 cm) to very small leaks (0.5 mm) were detected, improving the quality of the system's construction. Most of these leaks were not visually detectable.

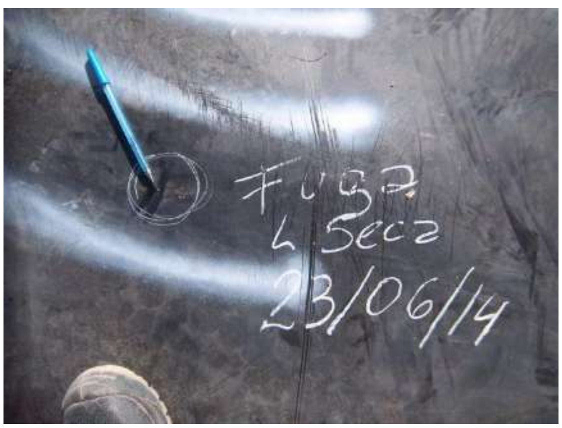


**Figure 12** Site # 1 Small Leak

**Figure 13** Site #2 Small leak

**Table 2** Summary of Survey Results

| Description | Site # 1 | Site # 2 |
|---|---|---|
| Total surveyed area ($m^2$) | 188,633 | 77,000 |
| Survey time (working days) | 67 | 17 |
| Survey speed ($m^2$ / day) | 2815 | 4500 |
| Number of leaks detected | 13 | 24 |
| Minimum leak size detected ($mm^2$) | 1.0 | 0.8 |
| Number of leaks detected per ha | 0,8 | 3,1 |
| Stones per ha | 35,8 | 16,1 |
| Damages per ha (excluding burns) | 13,3 | 17,9 |
| Burns detected on the geomembrane liner per ha | 0,9 | 1,7 |
| Water underneath a patch per ha | 0 | 0,6 |
| Other anomalies per ha | 1,9 | 0,6 |

Notes:

- **Stones**: Number of stones (smaller than 1.25 cm diameter) detected underneath the geomembrane liner
- **Damages**: number of scratches, shallow, medium and deep punctures that do not penetrate the geomembrane liner, therefore, they were not leaks at the time of the survey, but could potentially generate a leak in the future during operational phase.
- **Burns**: burns detected on the geomembrane liner possibly originating from welding equipment or by cigarettes.
- **Water underneath the patch**: water accumulated on the primary liner not drained before the patch was installed.
- **Other anomalies**: other anomalies includes sand bags placed underneath the geomembrane liner and irregular soil surface

Based on field observations and collected data, the main causes for the identified leaks were:

- Puncture by oversized stones underneath the geomembrane.
- Improper geomembrane welding
- Damage incurred by equipment/tool use

## CONCLUSION

Arc Testing was successfully applied at both sites, detecting leaks over 1.0 $mm^2$, and even smaller in some cases.

At the same time, since the equipment operator was a qualified geomembrane liner CQA technician, a detailed and thorough visual inspection was conducted during the survey, where a significant number of damages were detected, ranging from minor scratches to severe punctures, that could eventually generate a leak in the future.

Had the ELL survey not been performed; neither the actual leak, nor the damages would have been detected.

Arc Testing ELL presents multiple advantages compared to the water-based ELL methods:

- Arc Testing sensitivity complies with ASTM standards at sites with geomembrane liners placed on top of GCL.
- Arc Testing was able to detect multiple leaks in the same area, avoiding interference or "shadow" effect which is common during the application of the water-based ELL methods.
- Since no water is used during the arc testing survey, Health and Safety risks are minimized, especially while working on steep slopes.
- Water-based ELL runoff water is not generated, therefore there´s no interference with other subcontractors may work downhill from the ELL survey area, (e.g. installation or repair of other sections of the geomembrane liner).
- Leaks were detected on part of wrinkles of the geomembrane that were less than 2 cm separated from the GCL.
- No water consumption is required for the survey, which in turns avoids the need for rain flap installation and reduces the need for support logistics (water tank, generator, water pump, etc.).
- Arc Testing ELL is applicable to slopes steeper than 2.5 H to 1 V, since it is not dependent on water travelling through the leak location.

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