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1.0 HANDBOOK INSTRUCTIONS

This handbook is intended for use by design engineers, regulatory agencies, construction quality assurance agencies, and any individuals seeking a basic knowledge of liner integrity surveys. It is not a comprehensive guide for the performance of liner integrity surveys. It describes the most commonly used mobile liner integrity / leak location methods.

For more specific information related to your project, contact Abigail Beck, TRI Environmental Director of Liner Integrity Services, at abeck@tri-env.com, 512-623-0511. TRI Environmental is a world-wide educational and service platform for liner integrity and leak location surveys. TRI performs liner integrity surveys, provides liner integrity survey equipment, refers liner integrity companies world-wide, and provides technician training and certification.

2.0 BARE GEOMEMBRANE SURVEYS

References:
ASTM D7002: Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System
ASTM D7703: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance System
ASTM D7240: Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)

2.1 Water Puddle Method (ASTM D7002)

The water puddle method is generally the preferred method for bare, non-conductive geomembrane due to its speed and sensitivity, but it becomes less sensitive on extreme side slopes. When slopes are steeper than 2H:1V, the water lance method should be used. The minimum sensitivity is a 1 mm diameter leak.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the subgrade underneath the geomembrane. An ammeter in series with the circuit converts the increase in voltage to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal).

2.2 Water Lance Method (ASTM D7703)

The water lance method is generally the preferred method for bare, non-conductive geomembrane when slopes are steeper than 2H:1V, but it can also be used on flat areas. The minimum sensitivity is a 1 mm diameter leak.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the subgrade underneath the geomembrane. An ammeter in series with the circuit converts the increase in voltage to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal).

2.3 Conductive Geomembrane Spark Testing Method (ASTM D7240)

The conductive geomembrane spark testing method is generally preferred for bare conductive
geomembranes, since no water is required to perform the test. The minimum sensitivity is a 1 mm
diameter leak per current ASTM but pinholes can be found.

A high voltage pulsed power supply charges a capacitor formed by the underlying conductive layer, the
non-conductive layer of the geomembrane and a coupling pad. The area is swept with a brush-like test
wand to locate points where the capacitor discharges through a leak. When the system senses the
discharge current, it is converted into a visible spark and an audible alarm.

The surface of the geomembrane must be clean and dry. Unless the conductive geomembrane has been
installed with the conductive layer sufficiently broken in the fusion weld, this method cannot be used to
test fusion-welded seams.

2.4 Arc Testing Method (ASTM in development)

The arc testing method is generally preferred for bare geomembranes, since no water is required to
perform the test and equipment is available with an optional GPS-based data acquisition system. The
minimum sensitivity is a pinhole leak.

A high voltage power supply is applied to a test wand above the geomembrane and is grounded to the
underlying conductive layer. The area is swept with a test wand and an electrical arc is formed in the
presence of a leak. When the system senses the discharge current, it is converted into visual and
audio alarms. The test wand can be custom sizes and shapes for specific applications.

This type of test requires that the geomembrane is in contact with the subgrade. If the separation
distance is greater than 3 cm, the instrument is not likely to arc. In addition, no water can be present on
top of the geomembrane.

The surface of the geomembrane must be clean and dry.

3.0 COVERED GEOMEMBRANE SURVEYS

References: ASTM D7007: Standard Practices for Electrical Methods for Locating Leaks in
Geomembranes Covered with Water or Earth Materials

3.1 Dipole Method – Soil Covered Geomembrane (ASTM D7007)

This dipole method is used for geomembranes covered with earth, gravel, concrete, sand or any other
conductive medium. The sensitivity of the survey depends highly on site conditions and the lining system
materials. The suggested minimum sensitivity for earthen materials less than 0.6 meters thick is a 6.4
mm diameter leak, though adverse site conditions can decrease the sensitivity.

A high voltage is applied to the cover material with a positive electrode. The power source is grounded to
the subgrade underneath the geomembrane. Voltage measurements are taken in a grid pattern
throughout the survey area using a dipole instrument. Leak locations cause a sine wave pattern in the
voltage measurements as the dipole instrument travels across a hole location.

The survey area must be electrically isolated from the surrounding ground. Generally, a perimeter
isolation trench surrounds the survey area, with the geomembrane exposed. Any conductive objects
such as access roads, metal sump pipes, or standing water must be removed before the survey can be
performed.

Leaks can be located in real time as the survey progresses, or the data can be recorded quickly and
downloaded into computer software for analysis. Currently, the ASTM requires the data to be recorded
but does not specify how it is analyzed. Data can be analyzed two-dimensionally or three-dimensionally.
Two-dimensional data analysis displays the data as voltage slices of the survey area, as graphed in
software such as Excel. Three-dimensional data analysis shows the voltage measurements in plan view
of the survey area. An example of data taken in a small test cell and shown graphically using both data
analysis methods is shown in Figure 1.
A sensitivity test is performed before beginning the survey using either a real or an artificial leak. An artificial leak is essentially a metal disk of a given diameter to mimic an actual leak. The metal disc is grounded to the conductive layer underlying the geomembrane. The distance from the artificial leak ground and the power source ground should be an adequate distance to mimic an actual leak. The sensitivity test protocol requires that the magnitude of the sine wave signal produced by the real or artificial leak be at least three times that of the background voltage oscillations as measured when the leak is not there. This is known as the signal to noise ratio. A sample of sensitivity test results are shown in Figure 2.

Once a leak is located by the survey, it must be excavated and the leak cleaned off and removed from the electrical circuit so that the area around the leak can be checked for leaks in the surrounding area, since large leaks can mask smaller adjacent leaks.
Figure 1: Two-Dimensional (top) and Three-Dimensional (bottom) Data Analysis of a Small Survey Area. The obvious leak location is shown as a sine wave pattern on slice number three of the two-dimensional data and can be seen in plan view as a negative (red/blue) circular peak next to a positive (green/yellow) circular peak separated by tight voltage potential lines in the three-dimensional data plot. A second, much smaller leak signal can be seen on slice number 1 of the three-dimensional plot (center of slice), but cannot be distinguished from the background voltages on the two-dimensional plot.
<table>
<thead>
<tr>
<th>Method</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Real-Time Leak Location    | -Does not require sophisticated data recording software                                         | -Requires high level of operator skill  
-Requires high level of operator skill  
-Survey progresses slowly  
-No quality control documentation  
-Relies on string lines for measurement accuracy  
-to be in accordance with current ASTM, must record data by hand or other method even though it will not be evaluated |
| Data Recording: 2-D Data Analysis | -Does not require high-precision GPS  
-Faster than real-time leak location  
-Provides quality control documentation  
-Does not require high level of operator skill with senior review of data | -Quality control documentation not meaningful  
-Difficult to relocate leak locations from data because there are imprecise spatial references  
-Relies on string lines for measurement accuracy |
| Data Recording: 3-D Data Analysis | -Faster than real-time and 2-D data analysis  
-Measurement locations highly accurate due to GPS-guided grid lines  
-Leak locations highly accurate due to high-precision GPS  
-Provides meaningful quality control documentation  
-Does not require high level of operator skill with senior review of data | -Requires high-precision GPS and sophisticated data recording software |
Figure 2: A Sensitivity Test, also known as a Calibration Curve. The graph shows the sine wave pattern produced by an artificial leak. In this case, the signal to noise ratio is 12.

3.2 Dipole Method – Water Covered Geomembrane (ASTM D7007)

This survey setup and methodology is essentially the same as the soil-covered survey method. The same data recording and analysis techniques can be used, but the ASTM does not require data recording for water-covered geomembranes. The minimum sensitivity for water-covered geomembrane is a 1.4 mm diameter leak. Although the ASTM specified minimum sensitivity of this method is lower than that specified for the water puddle and water lance methods, this method is typically more sensitive than the aforementioned methods due to the hydraulic head over leak locations, which provides better hole contact.

Rather than taking voltage measurements at discrete points throughout the survey area, the voltage is continuously measured by an analog-based voltmeter. When the voltage increases beyond a given threshold, with either a positive or negative magnitude, an audible tone alerts the operator. The equipment is swept along the survey area in lines throughout the survey area.

The sensitivity test consists of finding the “minimum detectable distance” that the equipment can be swept by the artificial or actual leak with the target diameter. This minimum detectable distance dictates the spacing of the survey lines. No signal to noise ration calculation is required.
It should be noted that a dipole survey in a highly conductive solution such as brine or with poor boundary conditions that cannot be changed is considerably more complicated than in fresh water with good boundary conditions and requires more advanced geophysical survey methodology.
BLIND ACTUAL LEAK PROTOCOL
**BLIND ACTUAL LEAK PROTOCOL**

**Definition of Blind Actual Leak** – A hole created through the geomembrane in the survey area by a site owner, CQA agency or design engineer to check the effectiveness of the liner integrity survey.

Leak detection is dependent upon the site conditions at each leak. Site conditions that affect leak detection sensitivity (particularly for surveys with earth materials on the geomembrane, to some degree with surveys on bare geomembranes) include:
- having adequate moisture throughout the overburden material and near-subgrade,
- moisture in the leak,
- the presence of dry insulating materials such as geotextile or geonet in contact with the leak,
- contact of the geomembrane with the overburden and subgrade,
- degree of isolation of the overburden from earth ground or the conducting material under the geomembrane, and
- the composition of the material in contact with the liner (large stones may bridge a leak).

Because of these varying site conditions, detecting a leak of the same size as the actual leak used to determine the leak detection sensitivity (calibration) as specified in the ASTM standards could be problematic. Better leak detection sensitivity will be obtained at some locations, and worse leak detection sensitivity will be obtained at other locations. It should be noted that for knife slits which fold back together and thus create a “barrier” the likelihood for leak detection during the leak detection survey is relatively small.

**Guidelines for installing blind actual leaks**

1. The blind actual leaks are to be installed in accordance with the relevant ASTM standard for the type of geomembrane leak location survey being performed. Specifically, the blind actual leak is constructed by drilling a hole in the installed bare geomembrane that is to be tested. The hole shall be drilled, and the drill bit moved forward and backward in the hole so the geomembrane material is removed rather than just displaced.
2. The blind actual leaks should be installed as early as practical before the geomembrane leak location survey is performed so the blind test leak will be exposed to the same conditions of rainfall, condensation, consolidation, and equilibrium as the rest of the geomembrane in the installation. If the blind actual leaks cannot be installed during geomembrane installation, it is strongly recommended that the diameters of the blind actual leak are increased to twice the suggested minimum diameter.
3. The locations of the blind actual leaks are documented using appropriate land surveying methods so the blind actual leaks can be located for future repair.
4. The blind actual leaks shall be put in realistic locations and not on wrinkles, areas of bridging, or other areas where the geomembrane is not in contact with the subgrade, or within 15 m of the edge of the liner. If conductive geomembrane is used, the blind actual leak can be located in a poor contact situation.
5. The blind actual leaks shall be backfilled with a compaction representative of the rest of the installation. Ensure that any cavity made by the drill in the subgrade under the blind actual leak is filled with soil, unless conductive geomembrane is being tested.
6. The number of placed blind actual leaks should be reasonable. The Owner or owner’s representative should consider the cost of installing, surveying, documenting, and repairing the blind actual leaks and the fact that a repair weld or patch of inferior integrity will replace an unflawed geomembrane.
7. In summary, for the leak location survey to successfully detect the intentionally placed blind actual leaks, the blind actual leaks should have conductivity through the openings otherwise it may not be detected. If the owner or owner’s representative has their own independent leak location equipment, the blind actual leaks could be verified as they are being placed.
8. As a courtesy to the leak location survey contractor the owner or owner representative should mention at the start of the survey that a blind actual leak has been placed in accordance with this guidance document.

**Guidance if the blind actual leak is not detected**

If the leak location survey contractor does not detect a blind actual leak after surveying an area where the blind actual leak was placed, then the owner or owner representative should mention that a blind actual leak was not detected. The leak location survey contractor shall review the survey data to determine if the blind actual leak signal is indicated in the survey data. In addition, the leak location survey contracto shall confirm that the survey successfully completed the leak detection sensitivity tests (calibration) per the corresponding ASTM procedure and that the survey was performed according to the ASTM procedure.

Assuming the blind actual leak was not detected (even after review of the survey data) then the following potential limitations should be considered for each missed blind actual leak:

- Subgrade restrictions (conductivity, moisture content, etc.),
- Proximity to survey boundary,
- Geosynthetics underneath or above the geomembrane,
- Uncovered material restrictions (waves, wrinkles, etc.),
- Cover material restrictions (conductivity, water saturation, etc.),
- Water requirement (depth necessary, quantity of water needed, bottom slope), and
- Proximity to protruding/penetrating accessories (pipes, steel bars, access platforms, ladders, etc.).

If any of the preceding conditions apply, the blind actual leak was not placed per the procedures of the relevant ASTM standard.

If it can be demonstrated that the placed blind actual leak was not detectable because of the above considerations or other limitations and a detailed check with the leak location equipment shows that there is no electrical conductivity through the blind actual leak then the blind actual leak was in fact never detectable with that particular leak detection setup and indicates a limitation of the leak location survey.

If the leak location survey contractor locates leaks before and after missing a blind actual leak and the located leaks are smaller than the blind actual leak then it is assumed that site conditions at the blind actual leak location are not optimal. The leak location survey contractor shall potentially recommend to the owner or their representative what site conditions can be improved or changed so detection of the blind actual leaks can be improved.

If the survey is ongoing for multiple days, it is recommended to review relevant ASTM procedures to assure that the leak detection sensitivity test (calibration) was implemented correctly. For example the survey spacing could be optimized in accordance with relevant ASTM standards. Alternatively, the size of the placed blind actual leak for the remainder of the survey can be increased to account for poor site conditions.
DESIGNING FOR LINER INTEGRITY
SURVEYS
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1.0 HANDBOOK INSTRUCTIONS
This handbook is intended for use by design engineers and earthworks and liner installer contractors. It does not contend to be comprehensive. An experienced liner integrity contractor should review project specific construction plans and specifications.

2.0 BOUNDARY CONDITIONS
The four critical boundary conditions in order to conduct a liner integrity or leak location survey are:

1. Conductive material over geomembrane (unless the geomembrane is bare)
2. Conductive material below geomembrane
3. Good contact of material above and below geomembrane through leak
4. Material above and below geomembrane are only in contact through leak locations

The following sections describe how these four conditions must be addressed during the design and construction of a facility where a liner integrity survey is specified.

3.0 MATERIAL SPECIFICATIONS

3.1 Geomembranes
Geomembranes must be electrically insulative. Polyethylene, polyvinyl chloride, polypropylene, chlorosulfonated polyethylene and bituminous geomembranes are sufficiently electrically insulative. Excessive leakage in terms of number or size of holes in the geomembrane will compromise the sensitivity of a liner integrity survey. Any locations of poor hole contact (wrinkles, subgrade depressions) will decrease the sensitivity of a survey and possibly result in undetected leaks. Material and placement methods should minimize the production of wrinkles and areas of trampolining.

If survey sensitivity is a high concern, conductive geomembrane should be specified. When a material is referred to as “conductive geomembrane”, it refers to an insulative geomembrane, with a conductive layer beneath the insulative layer, manufactured specifically to assist liner integrity surveys. The conductive backing allows leak detection on poor hole contact scenarios and also increases overall leak detection sensitivity. Conductive geomembrane installation requires a specialty welder and special installation protocol. GSE’s Leak Location Liner fulfills these requirements.

In a double-lined impoundment, a conductive layer must be present under the primary geomembrane. In the absence of a conductive layer (i.e. geocomposite only), conductive geomembrane should be specified.

3.2 Geocomposites
Geocomposites alone are not conductive, but the application of water to the geocomposite will enable a liner integrity survey. Water can be added to the geocomposite during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geocomposite. With hole contact being an important parameter in survey sensitivity, it can be expected that a geocomposite may increase the minimum detectable hole size.

A conductive geotextile can be specified as the geotextile portion of the geocomposite directly in contact with the geomembrane to be tested in order to enable leak detection.

If a non-conductive geomembrane is used as the primary geomembrane in a double-lined impoundment and a geocomposite is present in the leak detection layer, the leak detection layer must be flooded with water to perform the survey.

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3.3 Geotextiles

Geotextiles alone are not conductive, but the application of water to the geotextile will enable a liner integrity survey. Water can be added to the geotextile during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geotextile. If a geotextile is adjacent to moist soil material and covered, the moisture tends to wick through the geotextile, thus enabling a survey. Geotextiles can be left intact in perimeter isolation trenches as long as they are dry. In the case of rainfall, it is typically necessary to wait for dry weather for the geotextile to dry out before performing a survey.

A conductive geotextile can be specified to be placed underneath the primary geomembrane in a double-lined impoundment in order to enable leak detection. The conductive geotextile/geomembrane interface may still have contact problems unless the leak location is wet or dirty.

3.4 Geosynthetic Clay Liners (GCL)

The high quality clay component of a GCL is highly conductive, however due to the discrete clay granules surrounding by geotextiles, the moisture content of a GCL must be fairly high in order to perform a liner integrity survey. The minimum moisture content of a GCL required to perform a liner integrity survey can be estimated at 8%, though this value will vary for different GCL products. A single composite liner with GCL does not require any special preparation; moisture will easily wick into the GCL from the subgrade, since it is extremely hydrophilic. Encapsulated GCL, however, will tend to stay at the moisture content that it was placed at. In arid climates where GCL panels are left uncovered and allowed to desiccate before being covered with the primary liner, the product can desiccate within one working shift. In arid climates, it is advisable to either rehydrate the GCL before covering with the primary liner, or specify a conductive geomembrane as the primary geomembrane. Encapsulated GCLs can also have problems with electrical conductivity over the panel overlaps, especially in arid climates. It is advisable to place a bare copper wire in a network under the GCL. The concept of the layout is to run the network of wires so that each and every panel is connected to at least one wire. The wire is then made accessible to the liner integrity surveyor by running it out through the anchor trench. At least two discrete wires should be placed, in order for the liner integrity surveyor to check the conductivity through the bulk of the GCL panel.

Figure 1: Hypothetical copper wire layout for encapsulated GCL. Copper wire is shown as a red line. Copper wire must be accessible to liner integrity surveyor.
3.5 Cover Material

The material covering the geomembrane should always be moisture conditioned, unless the project is located in a wet climate and the material is already sufficiently moist. Highly porous material such as gravel does not require moisture conditioning, since the material will require watering during the leak survey regardless. This is only true for large gravel particles (greater than approximately 5 cm). All other materials should have moisture within the mass of the cover layer. Surficial watering directly in front of the liner integrity survey may be required regardless.

3.6 Subgrade Material

Subgrade conductivity will not be a problem with a compacted clay liner. However, if there is no design requirement for a compacted clay liner and onsite soils are used, there is a small chance that the material will be either too dry or contain a mineral content that is not sufficiently conductive. In that case, the subgrade material must be watered before placement of the geomembrane. Subgrade conductivity testing should be performed in the case of questionable site soils, or a conductive geomembrane should be specified as the geomembrane type.

Geomembrane rub sheets should not be allowed to remain under the geomembrane.

4.0 CONSTRUCTION SEQUENCING

4.1 Dipole Method – Soil Covered Geomembrane (ASTM D7007)

An isolation trench must be specified as part of construction sequencing around the perimeter of the survey area. In climates with spells of extreme rain events, a rain flap should also be considered. Rain flaps are welded in the isolation trenches and propped up by soil so that in the case of extreme rain where the trench will fill up with water, electrical isolation will still be provided by the rain flap. The rain flap must be welded to the base geomembrane.

Access roads can typically remain in place, as long as there is a strip of geomembrane or rain flap bisecting the access road, creating electrical isolation.

4.2 Dipole Method – Water Covered Geomembrane (ASTM D7007)

Consideration for the installation of any grounded objects should be given with respect to the construction sequencing. The survey should be performed before any necessary grounded objects are installed.

If a double-lined impoundment lacks a conductive geomembrane for the primary geomembrane or lacks a conductive geotextile underneath the primary geomembrane, the leak detection layer must be flooded in order to survey the primary geomembrane. There must be ballast over the primary geomembrane, or the impoundment must be filled with water at the same rate that the leak detection layer is filled (or before).

4.3 Water Puddle and Water Lance Methods (ASTMs D7002 and D7703)

Consideration for the direction of flow should be given for bare geomembrane survey methods using water as a conductive medium. If water is allowed to flow freely out of the survey area, an electrical short will be created. Interim rain flaps can be used where necessary to contain the water within the survey area.

5.0 GROUNDED OBJECTS

Objects that will provide a source of electrical grounding should be carefully designed, or the construction
sequence modified to enable a liner integrity survey. For example, a metal pipe penetrating the liner system should have a plastic boot so that water sprayed on the geomembrane or soil covering it will not touch the metal pipe. For pond applications, concrete inlet or outlet structures, including metal batten strips, will ground out the survey. In some cases the design cannot be modified, but a rain flap can be welded as an interim measure to intercept water flowing to a grounded object.

6.0 SPECIFYING METHODS

The appropriate survey method will depend on the condition of the geomembrane during the survey in terms of whether it is bare or covered, whether it is the primary geomembrane or the secondary geomembrane, and whether the geomembrane has a conductive backing or not. The “Liner Integrity Survey General Guide” covers the various methods and their general applications.

The primary geomembrane of a double-lined impoundment can be surveyed using the dipole with soil as cover if there is ballast material over the primary geomembrane. In that case, the primary geomembrane must be conductive or have a conductive geotextile underneath it, or the leak detection layer must be flooded up to the level of the top of the ballast layer. In order to survey the side slopes, or if there is no ballast material over the geomembrane, the impoundment must be completely filled with water and a dipole with water as cover method must be performed. Alternatively, conductive geomembrane can be specified as the primary geomembrane and subsequently any method can be performed on it.

A survey can be conducted either before or after cover material placement, or both. The minimum sensitivities of each method, as described in the “Liner Integrity Survey General Guide” should be considered. For geomembranes that are to be covered by earthen materials, a survey should be performed both directly after liner installation and after cover material placement. This will result in the maximum leak detection sensitivity. If small holes are not a concern and only one method can be specified due to cost constraints, then a dipole survey should be performed after placement of the cover materials, since this method will locate the major leaks caused by placement of the cover material. The only exception to this is if the geomembrane is covered by gravel and the gravel layer can be flooded during the survey, resulting in the increased sensitivity of a water-covered survey.

If a dipole survey is specified, the method of data analysis can be specified. The advantages and disadvantages of each method of data analysis is described in the “Liner Integrity Survey General Guide”.

6.1 Specifying Leakage Rates

It is impossible to construct a “leak free” lining system, since even in the absence of breaches through the geomembrane, diffusion occurs through a geomembrane. Thus, setting an allowable leakage rate should be attainable with the existing available technologies. Setting an allowable leakage rate too low to achieve with existing technologies is simply a recipe for failure.

By using the Bernouilli and Giroud equations, one can calculate the anticipated leakage of a facility. Parameters such as the head over the liner and the hole contact factor can be informed by the geomembrane application and the geomembrane type. The minimum survey method sensitivity and an assumed undetected leak frequency can be used to inform the number and size of leaks contributing to leakage.

With currently available technologies, the lowest level of potential leakage can be achieved by specifying specialty conductive geomembrane installed per GSE’s Leak Location Liner installation procedures, performing a bare geomembrane survey directly after geomembrane installation, and then performing the dipole method after the installation of cover material, if applicable. It is technically possible to install a geomembrane without breaches with this prescription, since, if installed and surveyed correctly, it eliminates the known sources of errors in the liner integrity survey technologies. However, room should always be granted for human error to avoid a specification that cannot be met.
6.2 Minimum Experience Qualifications

The various methods vary significantly in how much skill is required to perform them. It is therefore reasonable to set the minimum experience qualifications according to which method is used.

Spark testing has been historically performed by liner installers. Very little training is required and no minimum experience in terms of square footage of the method completed is usually required. Once an operator learns to use the spark tester, very little can go wrong in terms of site conditions and instrument set up.

The arc tester evolved from spark testing technology, but is even easier to use. In less than one hour, an operator can be competent at performing the arc testing method.

The water-based bare liner testing is a little more complicated in terms of setting up the survey, adjusting the equipment sensitivity and controlling the site conditions so that they do not adversely impact the sensitivity of the survey. It is therefore advisable to set some minimum number of projects and square footage where this method has been performed. A reasonable minimum for the water puddle and water lance methods would be 1-2 projects and a minimum area of 10 hectares.

The dipole method is more closely related to advanced geophysical methods, which require a thorough understanding of the method, the equipment, and the site conditions. Many site conditions can adversely impact the sensitivity of a survey. It is therefore advisable that the highest level of minimum experience qualifications be applied to a dipole survey. A reasonable minimum for the dipole method would be 4-5 projects and a minimum area of 50 hectares. The minimum qualifications should apply to the lead operator onsite directing the survey and not the survey company.

ELIS Operator certification is available, which can be substituted for the required minimum experience level. The operator certification program requires than an individual performing ELIS methods be evaluated for competency by a third party.
ATTACHMENT 3

ELECTRICAL LINER INTEGRITY SURVEY
OPERATOR CERTIFICATION
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1.0 OPERATOR CERTIFICATION BACKGROUND

The operator certification program intent is to uphold industry standards and provide a way of ensuring that operators are performing the electrical liner integrity survey (ELIS) methods correctly and per ASTM standard methodology. As the world-wide demand for ELIS grows, the certification program provides a tool for emerging ELIS consultants to gain proficiency and credentials. It also provides a tool for site owners and project engineers and managers to evaluate the capabilities of ELIS providers and establish minimum criteria for the demonstration of competency in the applied ELIS methods.

An ELIS Steering Committee was assembled to advise the contents of the operator certification. The ELIS Steering Committee consists of professionals who have worked closely with ELIS methods in different roles, especially in method application. Members of the ELIS Steering Committee who specialize in the application of the ELIS methods are qualified to oversee the field portion of the Level 2 certification exam.

2.0 THREE-TIERED STRUCTURE

The operator certification program is broken down into three tiers of certification. The intent of the three tiers is to distinguish between the levels of education and practice required in order to illustrate different levels of competency. The certification encompasses both bare and covered ELIS methods.

2.1 Level 1 Certification

The first tier of certification illustrates that an individual:

1. Is qualified to specify ELIS for projects
2. Understands how boundary conditions affect ELIS
3. Understands how the ELIS methods are applied
4. Is qualified to review ELIS for conformance to ASTM standards

2.2 Level 2 Certification

The second tier of certification illustrates that an individual:

1. Has passed a written exam on the application of ELIS methods
2. Has passed a field exam on the application of ELIS methods
3. Can competently perform ELIS methods per current ASTM standards

2.3 Level 3 Certification

The third tier of certification illustrates that an individual:

1. Has satisfied the Level 1 and 2 certification criteria
2. Has a proven track record of ELIS method performance
3. Maintains certification through a minimum level of annual field experience

3.0 LEVEL 1 CRITERIA

The first tier is an educational component. An individual shall receive at least six (6) hours of classroom education (or equivalent) in the following subject areas:

1. ELIS terminology, history, background
2. Electrical Basics
3. Bare and covered ELIS methodology
4. Criteria for specifying ELIS
5. Current ASTM methods for ELIS
6. Boundary conditions affecting ELIS performance
7. Site safety

An individual shall receive at least four (4) hours of field training in the following subject areas:
1. Operating equipment for bare and covered ELIS methods
2. Performing a sensitivity test for bare and covered ELIS methods
3. Locating leaks in bare and covered geomembranes
4. Setting up a ELIS circuit for bare and covered ELIS methods

4.0 LEVEL 2 CRITERIA

The second tier is a demonstration that the Level 1 education and field training can be applied by an individual. The Field Exam can be conducted to a production survey by an individual.

4.1 Written Exam
The written exam, which is administered through a third-party, shall test an individual’s ability to:
1. Interpret plans and specifications for ELIS
2. Understand electrical measurements
3. Perform methods per ASTM standards
4. Troubleshoot field difficulties
5. Effectively collect and interpret data
6. Identify poor boundary conditions
7. Understand method limitations

4.2 Field Exam
The field exam shall be proctored by a qualified member of the ELIS Steering Committee. The proctor shall observe an individual in the field as the individual performs an ELIS method and without interfering shall document:
1. Which method is being performed
2. Where electrodes are placed
3. Where artificial leak is placed and grounded, if applicable
4. What voltage is used for the method
5. Survey set up procedures
6. Equipment set up and calibration procedures
7. Sensitivity test procedures
8. Procedures for locating leaks
9. Procedures for recording and analyzing data, if applicable
10. Any ASTM procedures lacking during field observation

The field exam is method-specific. The documentation of the field exam shall be provided to the ELIS Steering Committee. The ELIS Steering Committee shall deliberate on whether the individual has demonstrated the ability to locate actual leaks in the field using the applied methodology. If an individual demonstrates the ability to locate actual leaks, but some aspect of the ASTM procedure is lacking, the ELIS Steering Committee shall evaluate whether that lacking procedure was crucial for locating leaks and performing a thorough survey. The actual location of leaks shall weigh more heavily on the Committee’s pass/fail decision than the following of the ASTM standard.

The results of the field exam, including critiques and comments from the ELIS Steering Committee, shall be submitted to the examinee(s) along with a Level 2 certificate if applicable.

The ELIS Steering Committee shall maintain a list of all individuals who have passed the written and field examinations and keep on file a copy of the actual examination documentation.

5.0 LEVEL 3 CRITERIA

The third tier is a demonstration that the individual can competently perform the ELIS method(s) and has a proven track record of doing so. Although not necessary to show that an operator can successfully perform the methods, an owner or design engineer might opt for this level of experience to reduce project liability. The minimum level of experience is method-specific. The experience for a given method would be called out for a specific project employing that method.

For Level 3 certification, the individual must maintain a minimum level of ELIS method performance on an average annual basis as follows:

1. Bare geomembrane arc testing method: 1 project and 0.4 hectares (1 acre)
2. Bare geomembrane spark testing method: 1 project and 0.4 hectares (1 acre)
3. Bare geomembrane water puddle method: 1 project and 2 hectares (5 acres)
4. Bare geomembrane water lance method: 1 project and 2 hectares (5 acres)
5. Water-covered geomembrane dipole method: 2 projects and 4 hectares (10 acres)
6. Soil-covered geomembrane dipole method: 2 projects and 25 hectares (25 acres)

An excess of survey experience one year can carry into the next year, but no longer than three years past the date of the qualifying experience.

In order to receive level 3 certification, an individual must submit documentation of the aforementioned experience requirements to the ELIS Steering Committee. The documentation required shall consist of:

1. The name of the project
2. The method applied
3. Sensitivity test set up and results
4. Number and size of located leaks

The ELIS Steering Committee shall maintain an actively updated list of all individuals who maintain current level 3 certification, and which method the certification applies to.