Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

GRI White Paper #3

- on -

Providing Flexibility in Destructive Seam Sampling/Testing

by

Robert M. Koerner and George R. Koerner
Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033 USA

Phone (610) 522-8440
Fax (610) 522-8441

E-mails:
robert.koerner@coe.drexel.edu
gkoerner@dca.net

February 13, 2003

International Association of Geosynthetic Installers

White Paper

on

"Providing Flexibility in Destructive Seam Sampling/Testing"

by

Robert M. Koerner, Ph.D., P.E., NAE
Director – Geosynthetic Institute
Folsom, PA 19033
robert.keorner@coe.drexel.edu

George R. Koerner, Ph.D., P.E., CQA
Associate Director – Geosynthetic Institute
Folsom, PA 19033
gkoerner@dca.net

This White Paper is intended to provide technical guidance information that allows, *with confidence*, a decrease in the amount of destructive geomembrane seam samples and the associated shear and peel testing. In addition to providing insight into the many advances in seaming and nondestructive testing made over the past 25-years, it focuses on two alternative statistical sampling methods; attributes and control charts. Both methods allow for gradually increasing sampling distances when acceptable destructive seam tests result and for gradually decreasing sampling distances when unacceptable destructive seam tests result. Thus, good seaming is rewarded and poor seaming is penalized. Other strategies for providing flexibility for destructive seam sampling are also mentioned, e.g., certified welders, taped edges, automatic welders and emerging NDT methods.

Lastly, the paper encourages the testing of the entire system, i.e., all seams and the completely installed sheets, after the geomembrane is covered using an electrical leak location surveying method. This method is considered by the International Association of Geosynthetic Installers (IAGI) to be a major diagnostic method to assure an environmentally safe and secure geomembrane liner system.

<u>Background</u>

There has evolved over the years many methods to fabricate geomembrane seams in the field. The installation industry began with adhesive tape and/or adhesively bonded seams on elastomeric geomembranes like butyl, neoprene and EPDM. This was followed by a vulcanizing tape, i.e., a hot bonding method. The technology also included solvent and bodied solvent seams on PVC, CPE and CSPE geomembranes. With the introduction of HDPE in the 1980's (which could not be adhesively or solvent seamed) the technology moved to extrusion flat and extrusion fillet seams on HDPE, as well as LLDPE and eventually fPP. After patent issues were sorted out, the technology segued into thermal fusion seams using a hot wedge (single track and dual track) which are applicable to all types of thermoplastic geomembranes. Hot air and ultrasonic thermally fused seams can also be made in single and dual track configurations. Table 1 gives the current status of the seam types available for various geomembranes.

Table 1 –Field Seaming Methods for Various Geomembranes

Type of Seaming Method	Type of Geomembrane					
	HDPE	LLDPE	fPP	PVC	CSPE-R	EPDM-R
extrusion (fillet and flat)	A	A	A	n/a	n/a	n/a
thermal fusion (hot wedge and hot air)	A	A	A	A	A	n/a
solvent (solvent and bodied solvent)	n/a	n/a	n/a	A	A	n/a
adhesive (chemical and contact)	n/a	n/a	n/a	n/a	n/a	A

Note: A = method is applicable
n/a = method is "not applicable"

At this point in time, AIGI strongly encourages that all geomembrane seaming be done by dual track thermal fusion seaming. This applies to all thermoplastic geomembranes and constitutes almost the entirety of the geomembrane market. (The exception to this is EPDM which has seen recent advances in seaming which appear promising). Dual track thermal fusion seaming is clearly the premier method of joining all thermoplastic polymers due to (i) the automatic nature and control of the welding device, and (ii) the fact that an air channel remains between the dual tracks for subsequent air channel testing. Figure 1 shows a photograph and schematic of a hot wedge welding device, the split wedge itself, and a cross section of the resulting seam.

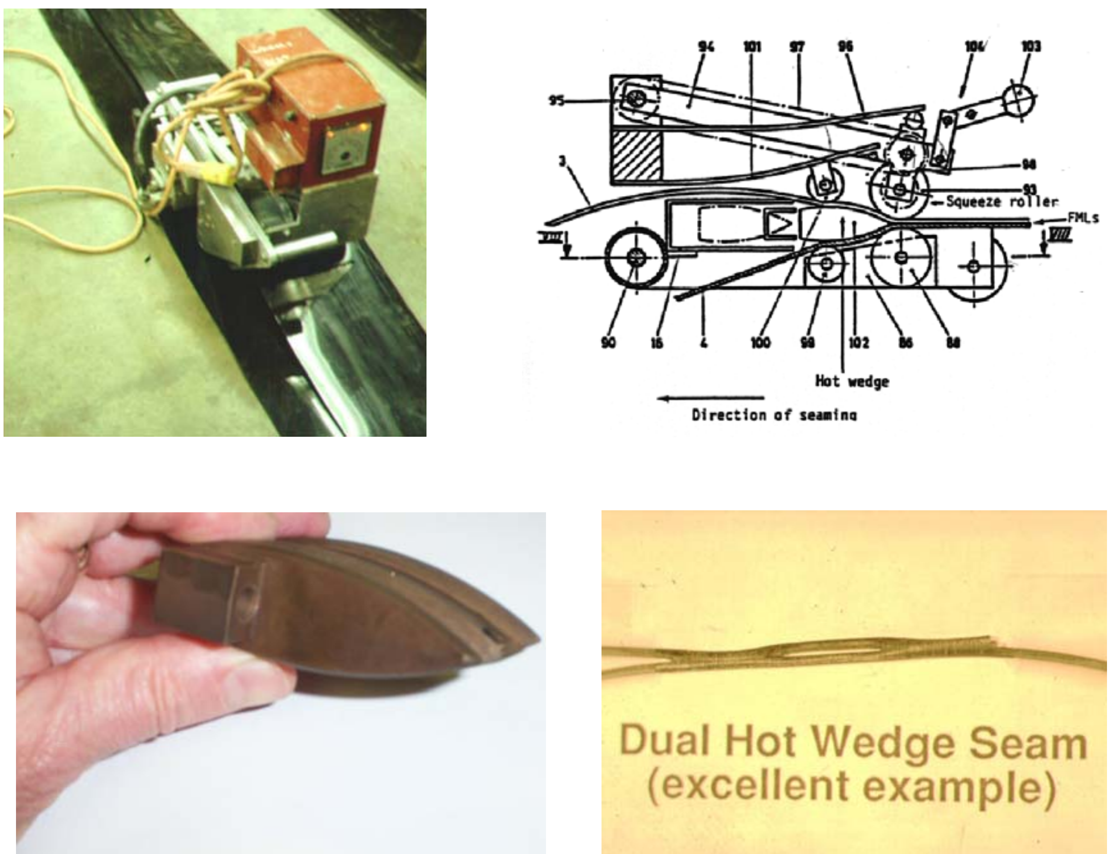


Figure 1 – Photographs of Wedge Welding Device, Dual Track Wedge and Cross Section of Subsequent Seam

As with the progression of the various seaming methods just described, so has the progression of nondestructive testing methods occurred. From the early days of pick testing and high pressure air lancing, the technology moved to embedded electric wires and vacuum box testing. Currently, with dual track thermal fusion seaming, the central air channel can be inflated and used as an excellent nondestructive test (NDT) air channel test. Figure 2 shows a cross section of a dual track weld and a set of photographs of needle insertion, pressurizing and monitoring the performance of air pressure in the channel. Procedures for such air channel testing area available from a number of organizations including ASTM D 5820, the Geosynthetic Institute (GRI-GM6) and the PVC Geomembrane Institute. Recent work with PVC geomembranes at higher than usual pressures in the air track shows that this NDT test can provide a possible alternative to destructive peel tests. This holds promise for other geomembranes as well, e.g., HDPE, LLDPE, fPP, CSPE and EPDM.

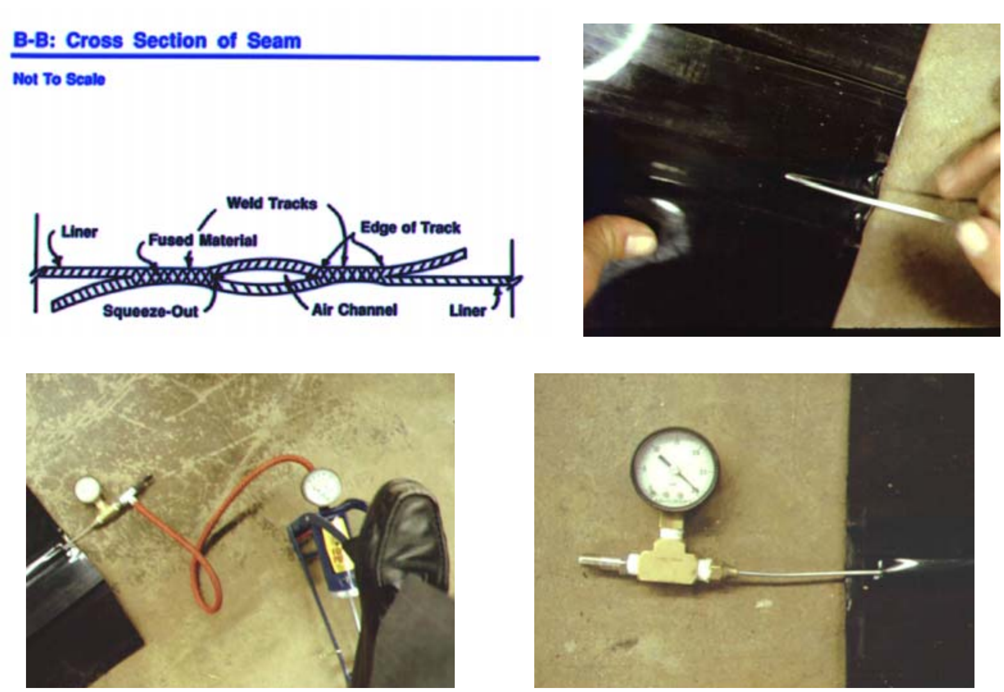


Figure 2 – Various Steps in Setup and Performance of Air Pressure Test on a Dual Track Hot Wedge Seam

Thus, with dual channel thermal fusion seaming and its subsequent air channel test as an NDT evaluation process, the industry is well positioned but left with the dilemma of a fixed spacing for sampling and subsequent destructive testing. The sampling interval was set as one destructive sample per 500 feet (150 m) approximately 25-years ago and has remained intransigent until today. It is toward challenging and indeed changing this practice and mindset that this White Paper is directed.

Statistical Sampling Methods

There are many sampling methods available which are based on credible statistical procedures. Testing of large populations of almost everything (including elections and political policy) is a widespread activity. With respect to geomembrane seam sampling two statistical procedures have been developed; attributes and control charts. They are based on pass/failure performance of the destructive seam tests which were taken from field sampling.

Note: ASTM nomenclature is used herein. A "sample" is a section of seam removed from the field. Seam sample lengths vary from 12 in. (300 mm) to 36 in. (900 mm). From the sample, individual test "specimens", typically five for shear and five for peel, each being 1.0 in. (25 mm) wide, are tested in a laboratory to failure. Using a specification like GRI GM19, the results are used to declare that the entire sample has either passed or failed. This white paper and the two sampling methods to be described are written around *samples* passing or failing; not individual test specimens.

Both statistical sampling procedures that follow have the very desirable feature of rewarding good seaming by allowing for gradually increasing sampling intervals and penalizing poor seaming by requiring gradually closing sample intervals. Furthermore, both procedures can start the process at the traditional spacing of one sample per 500 feet (150 m).

Method of Attributes – Utilization of the method of attributes requires the initial establishment of a seam sample failure rate and a initial sampling interval. The initial failure rate should come from the installers past historical records and, even more specifically, from the particular welding technician/hot wedge device's past historical records. Using such values as a 2% failure rate and one sample per 500 ft. (150 m) as starting values, the project begins and when a statistically valid number of destructive tests have been evaluated (at least thirty sample test results are required), the average failure rate is calculated. If the project failure rate is lower than the initially set value, the interval is opened from the initially set value, e.g., open to 1 per 750 ft. (225 m). If the project failure rate is higher than the initial value, the interval is decreased from the initially set value, e.g., closed to 1 per 250 ft. (75 m). If the project failure rate is essentially the same as the initial value, the interval remains the same, i.e., 1 per 500 ft. (150 m). This process is repeated for the next batch of 30± samples until the project is complete. The method has been formalized as GRI-GM14 and is best suited for relatively large projects.

Control Chart Method – Utilization of a control chart to determine sampling intervals can be done on projects of any size; large or small. The method follows a procedure identical to that used in the manufacturing quality control of geomembranes or any other manufactured product. Whenever the process goes beyond an arbitrarily set upper control limit (UCL) or lower control limit (LCL), a corrective action must be addressed. The corrective action is a variation in sampling interval. Such limits could be a 5% and 3% sample failure rate, respectively. Seam failures above the UCL require decreased the sampling interval, while seam failures below the LCL allow for increased the sampling interval. Sample failure rates within the UCL and LCL suggest that the sampling interval remain at the previously set value. The method is being formalized as GRI-GM20 (Draft) and can be utilized on the smallest of projects.

Improvements Leading to the Initial Setting of Increased Sampling Intervals

There are several improvement which should lead directly to increased destructive seam sampling intervals. These are not statistically related, but clearly show advances in seaming technology and represent an advanced state-of-the-practice. Depending on the regulator, owner, designer and CQA organization of a specific project, these improvements should allow for initial, or start-up, sampling intervals greater than one in 500 ft (150 m).

IAGI Certification – The International Association of Geosynthetic Installers (IAGI) certification process signifies that the installation company and/or its welding technicians have passed a rigorous "hands-on" examination showing welding proficiency. Further, this proficiency is exhibited on the same type of geomembrane that is being installed in the project. Such pro-active steps taken by the installer should be acknowledged and rewarded. A listing of certified installation companies and/or certified welders is available from IAGI. A strategy could be to set the interval for a project with IAGI Certified Welders to one sample in 1000 ft. (300 m) and then to use a statistical method as described previously for the remainder of the project.

Taped/Protected Edge Strips – It has been shown by IAGI that 50% of seam failures are due to moisture or dirt in the area to be seamed. For the longitudinal edge seams (which represent 95% of all seams), the surfaces to be seamed can be completely protected by having a 6.0 inch (150 mm) tape placed over top and bottom on both edges of the sheet in the factory. Such tapes are then stripped off the adjacent sheets immediately in front of the wedge welder thereby assuring that the area to be bonded is completely moisture and dirt free, see Figure 3. Of course, there is a premium in the cost of the geomembrane but this is readily offset by increasing the initial destructive seam sampling interval. A strategy could be to set the interval for a project with protected geomembrane edges to one sample in 1000 ft. (300 m) and then use a statistical method as described previously for the remainder of the project.

Figure 3 – Taped Edges for Protection of Areas to be Seamed and Removal Directly in Front of Hot Wedge Welding

Automatic (Robotic) Wedge Welders – As used in some European countries, automatic wedge welders monitor the sheet temperatures and set the speed of the wedge welder accordingly. In this regard they are truly robots doing the work that is done manually using conventional wedge welders, see Figure 4. Even further, some have data acquisition systems with print-out of ambient, sheet and wedge temperatures, speed and station of the precise location being welded, see U.S. EPA, 1993. While these devices are both expensive and quite heavy, their use by the installer should be partially compensated for by an initially increased sampling interval. For example, the initial interval could be set at one destructive sampler per 1000 ft. (300 m) and the use of statistical method as described previously for the remainder of the project.

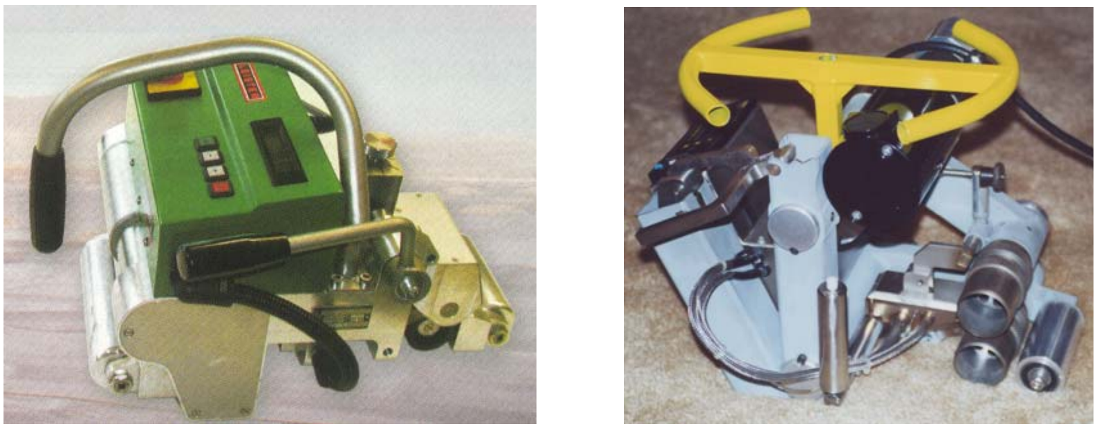


Figure 4 – Two Variations of Automatic Wedge Welding Devices (compliments of Leister Inc. and Fred Struve)

Infrared or Ultrasonic Methods – There are several established NDT methods that can be used for seam evaluations (in addition to air channel testing). They are based on infrared sensing technology (Peggs, et al. 1994) and ultrasonics (Peggs, et al., 1985 and Koerner, et al., 1987). With varying degrees of success the latter has three variations; pulse echo, impedance plane and shadow method. If these techniques are used, the initial sampling interval could be increased to one sample in 1000 ft. (300 m) and then use a statistical method as described previously for the remainder of the project.

Total System Monitoring; Electrical Leak Location Survey

It has been shown by electrical leak location surveys that the majority (50% to 83%) of the leaks in a covered geomembrane lined facility are in the sheet itself rather than being seam failures. Conversely, in exposed geomembranes most of the leaks are in the seams. In large part, this is a result of soil backfilling by the earthwork contractor.

Surveying stakes penetrating through the underlying geomembrane are notorious in this regard, as are all-sized gouges from bulldozer blades. This issue is absolutely critical insofar as a total leak free facility is concerned. The technique that has emerged as being preferred in such a total system monitoring procedure is the electrical leak location survey technology.

The electrical leak location survey method applies a high voltage across the geomembrane and detects locations where electrical current flows through leaks in the insulating geomembrane. Figure 5 illustrates the technique which can be used on both single and double lined facilities. Most importantly, it can be performed after the covering soil has been placed over the uppermost geomembrane. As shown, the electrodes are connected to a high energy power supply with data taken and sometimes recorded on a portable data logger. Numerous references are available and the method is being finalized within ASTM.

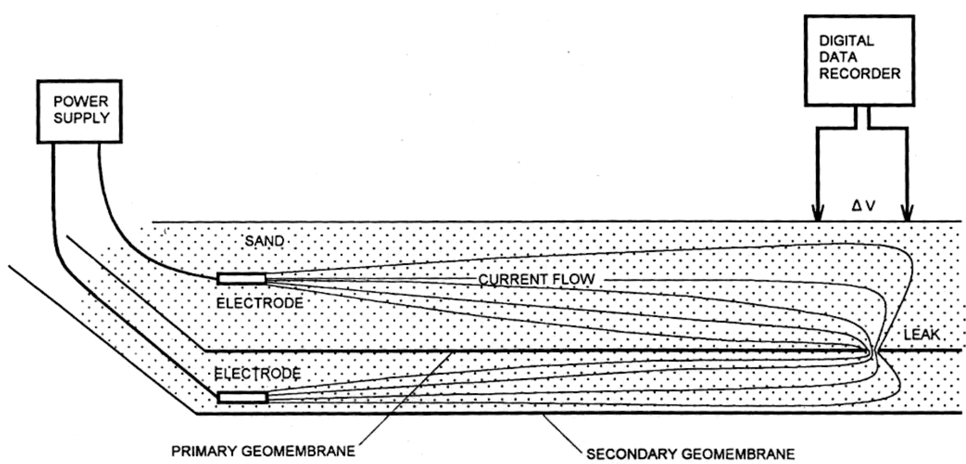


Figure 5 – Principle of the Electrical Leak Location Method for Sand-Covered Geomembrane Liners, after Laine and Darilek (1993) and Darilek and Miller (1998)

Summary and Conclusions

This IAGI White Paper is purposely focused on changing the long embedded mindset of taking destructive seam samples at one per 500 feet (150 m). This criterion was set approximately 25-years ago and yet both seaming technology and NDT methods have advanced tremendously since that time. The patching of the locations where such destructive test samples have been taken by fillet extrusion welding is universally agreed upon as being inferior to the dual track hot wedge weld of the original seam. That is, the replacement of an extrusion fillet seam for the original hot wedge fusion seam is a step backward in the completed facility. Thus, the sampling interval must be flexible within the confines of good (or poor) seaming. To stay with a fixed interval of sampling is essentially saying that all installation organizations and all of their seaming crews and equipment are identically equal. This is simply not the case and this paradigm must be broken. *Good installation organizations and seaming crews should be rewarded, and poor installation organizations and seaming crews should be penalized.* The best way to achieve these objectives is by opening destructive seam sampling intervals for the good, and tightening them for the poor. This paper is focused on providing information so as to achieve this goal. *The tacid assumption throughout the paper is that the seam itself has been made using a dual track hot wedge or dual track hot air welding device and has had a successfully completed air channel test.* IAGI endorses this method as the only primary seaming method that should be used. This white paper is predicated on that assumption.

More specifically, statistical sampling strategies (attributes and control charts) should be routinely used. This provides for the classical “carrot and stick” approach and is completely justified within all quality control guidelines and concepts.

Furthermore, the setting of the initial sampling interval should be increased over the traditional value by using (i) IAGI certified organizations/welders, (ii) taped edge strips, (iii) automatic welders and/or (iv) use of modern NDT methods in addition to air channel NDT evaluation. Upon setting an opened initial sampling frequency, e.g., one in 1000 ft. (300 m), one of the statistical methods (attributes or control charts) should be used to adjust the spacing over the course of the project.

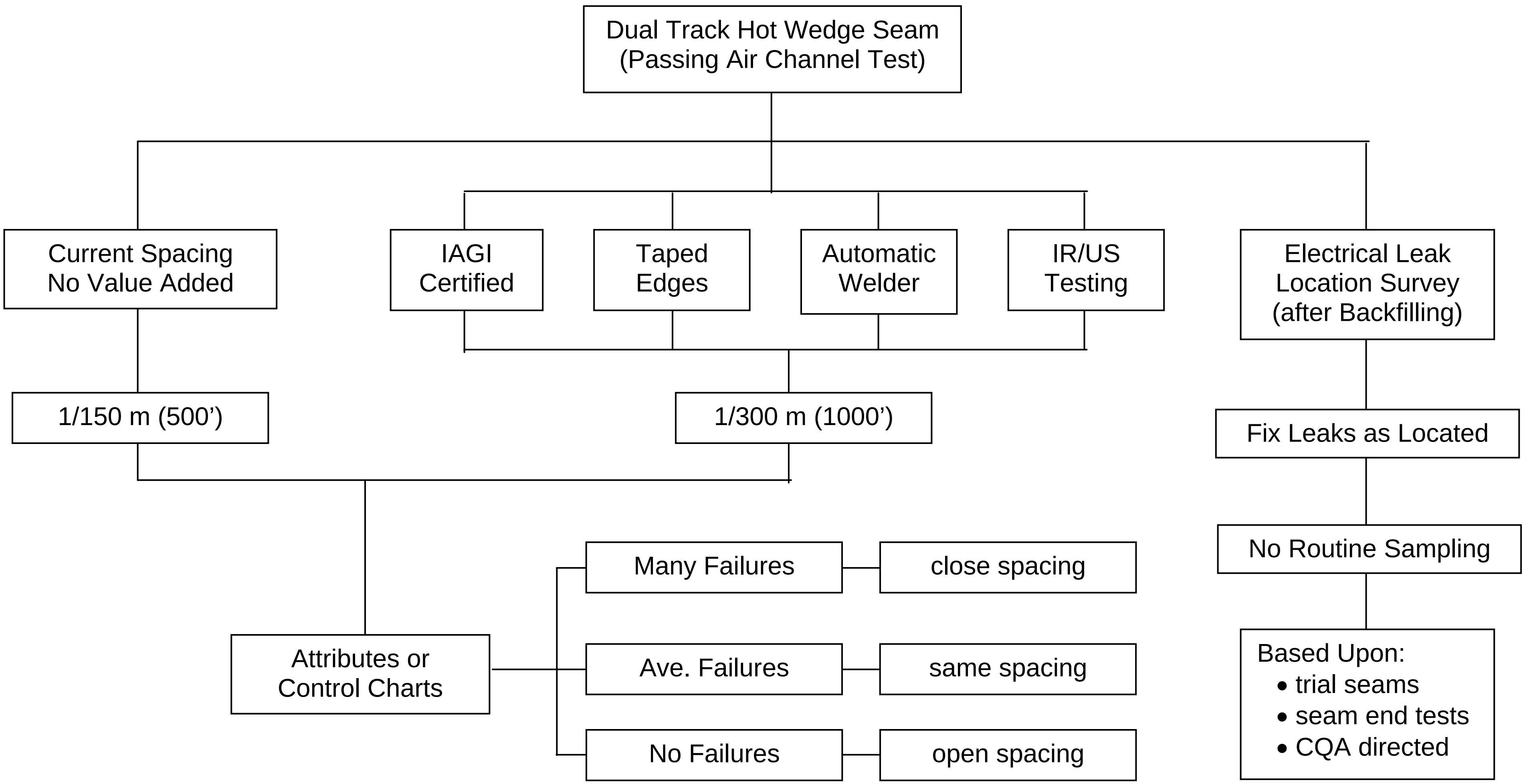
Lastly, the entire paradigm can be shifted if one uses electrical leak location surveys after the soil backfill has been placed over the geomembrane. This method challenges not only the seam but the entire sheet areas between seams; the latter constituting 99% of the total facility's footprint. Use of this technique should completely obviate the necessity of destructive test sampling except for the following;

(i) test strips or trial seams,
(ii) at each end of the dual track wedge weld no matter what its length, and
(iii) wherever the CQA monitor feels that a potential flaw, e.g., a burnout, necessitates a destructive sample… this option must always be available

This is, of course, a bold proposal but one which IAGI feels is justified. Electrical leak integrity surveying has been field validated and should be viewed accordingly. It is a modern, viable and justifiable quality control procedure. It should be used as suggested herein and furthermore it should be implemented as a separate bid item in the installer's proposal. In this way it can be identified and associated with its own benefit/cost analysis.

The suggested strategy embodied in this entire white paper is given in the flow chart that follows. In our opinion it represents a transition from the current destructive seam sampling strategy of one sample per 150 m (500 ft.) to a nondestructive testing strategy for the entire facility and, most importantly, after the covering soil has been placed.

Suggested Strategy for Destructive Test Sampling



References

ASTM D 5820, Standard Practice for "Pressurized Air Channel Evaluation of Dual Seamed Geomembranes."

Darilek, G. T. and Miller, L. V. (1998), "Comparison of Dye Testing of Electrical Leak Location Testing of a Solid Waste Liner System," Proc. 6th International Conference on Geosynthetics, IFAI, pp. 273-276.

GRI-GM6, Standard Practice for "Pressurized Air Channel Test for Dual Seamed Geomembranes," GSI, Folsom, PA.

GRI-GM14, Standard Guide for "Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes," GSI, Folsom, PA.

GRI-GM20, Standard Guide for "Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts," GSI, Folsom, PA.

Koerner, R. M., Lord, A. E., Jr., Crawford, R. B. and Cadwallader, M. (1987), "Geomembrane Seam Inspection Using the Ultrasonic Shadow Method," Proc. Geosynthetics '87, IFAI, New Orleans, LA, pp. 493-504.

Laine, D. L. and Darilek, G. T. (1993), "Locating Leaks in Geomembrane Liners Covered With a Protection Soil," Geosynthetics '93, IFAI, Vancouver, British Columbia, Canada, Vol. 3, pp. 1403-1412.

Peggs, I. D., Briggs, R. and Little, D. (1985), "Developments in Ultrasonics for Geomembrane Seam Inspection," Proc. Canadian Geotechnical Conference, pp. 153-156.

Peggs, I. D., Miceli, G. F. and McLearn, M. E. (1994), "Infrared Thermographic Nondestructive Testing of HDPE Geomembrane Seams," Proc. 5th International Conference on Geosynthetics, Singapore 5-9 September, pp. 941-944.

U.S. EPA, 1993, Proceedings of the Workshop on Geomembrane Seaming: Data Acquisition and Control, EPA/600/R-93/112, June, 64 pgs.