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GRI GEI GII GSI GAI GCI

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GRI-GM32*

Standard Practice for

"Geomembrane Seaming Using Data Acquisition Hot Wedge Welding Devices"

1. Scope

1.1 This standard practice provides guidelines for hot wedge welding devices that continuously record temperature, speed and pressure of geomembrane production seams as they are prepared in the field.

Note 1: The practice applies to all thermoplastic geomembranes in typical thicknesses of 0.30 to 3.0 mm (12 to 120 mils).

Note 2: This practice applies to all homogeneous geomembranes, but can be used for scrim reinforced and spread coated geomembranes as well.

Note 3: The hot wedge device itself can make a single track or dual tracks; the latter with an air-space between the tracks for subsequent use as a nondestructive air pressure test method.

1.2 The need for the practice is to acknowledge that customary wedge welding devices used globally leave the ongoing adjustment of temperature, speed and/or pressure up to the experience and knowledge of the device's operator. This particular standard, leading to a data acquisition hot wedge welding device, allows for the continuous monitoring and recording of these three variables. Thus, the operator can make adjustments based on the appropriate recorded values for seaming with that specific device.

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*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This practice will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

1.3 This standard practice <u>does not address</u> closed loop control technology leading to device feedback and automatic adjustment of the three mentioned hot wedge variables.

> Note 4: Such automatic feedback welders are sometimes referred to as “smart welding devices” and are available but are not the purpose of this particular standard practice. That said, some traditional wedge welding devices currently have electrical circuits for maintaining voltage and speed.

1.4 This practice is field oriented focused on both construction quality control (CQC) personnel performing the actual welding and construction quality assurance (CQA) personnel inspecting the final seam product.

1.5 This standard may involve hazardous operations, equipment and climates. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Reference Documents

2.1 ASTM Standards

D751 Test Methods for Coated Fabrics

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D4439 Terminology for Geosynthetics

D5820 Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

D6392 Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

2.2 GRI Standards

GM6 Practice for Pressurized Air Channel Test for Dual Seamed Geomembranes

GM19a Specification for Seam Strength and Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes/Barriers

GM19b Specification for Seam Strength and Related Properties of Thermally Bonded Reinforced Polyolefin Geomembranes/Barriers

GM29 Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and Nondestructive Testing

2.3 EPA Documents

EPA/530/SW-91/051, "Inspection Techniques for Fabrication of Geomembrane Field Seams"

EPA/600/R-93/182, "Quality Assurance and Quality Control for Waste Containment Facilities"

EPA/530/SW-91/051, "Inspection Techniques for the Fabrication of Geomembrane Field Seams"

EPA/600/R-93/112, "Proceedings of the Workshop on Geomembrane Seaming, Data Acquisition and Welders," June, 1993, 64 pgs.

2.4 References

Bullock, A. M. (2019), "The Future of Geomembrane Installation: Utilizing Smart Technology and Data Acquisition to Enhance Installation Standards, Project QC/QA and Reporting," Geosynthetics Conference, Houston, TX (IFAI Publ.), pp. 937-944.

Daniel, D. E. and Koerner, R. M. (2007), "Waste Containment Facilities: Guidance for Construction Quality Assurance and Construction Quality Control of Liner and Cover Systems," ASCE Press, Reston, VA, 352 pgs.

Donaldson, J. J. and Kolbasuk, G. M. (1994), "Summary of Experience with NSC Data Acquisition Welders," Proc. GRI-7, Geosynthetic Liner Systems: Innovations, Concerns and Designs, Publ. by IFAI, St. Paul, MN, pp. 1-8.

Koerner, R. M. (2012), "Designing With Geosynthetics," 6^{th} Edition, Xlibris Publ. Co., 914 pgs.

3. Terminology

3.1 Definitions of <u>General Terms</u>

3.1.1 *field seams* - The seaming of geomembrane rolls or panels together in the field thereby making a continuous liner system; also referred to as *production seams.*

3.1.2 *trial seams* - Trial seams are made from spare pieces of geomembrane that are field seamed and tested immediately to establish welding device settings of temperature, pressure and speed. Such information applies to the specific welding device under the specific set of atmospheric conditions, as well as the specific welding operator.

3.1.3 *thermal fusion seams* - A seam which involves the temporary thermally induced reorganization in the polymer structure at the surfaces of two opposing geomembranes which, after the application of pressure and the passage of a short amount of time, results in the two being joined together.

Note 5: Thermal fusion seams can be made using a hot wedge (single or dual track) or a hot air device.

3.1.4 *nondestructive test* – A test performed on geomembranes in the field to verify integrity and completeness of the seam without taking physical samples and testing them to failure.

3.1.5 *destructive test* – A test performed on geomembrane samples cut from a field installation or test strip to verify specification performance requirements. In this regard, shear and peel tests of geomembrane seams are destructive tests in which the specimens are tested to failure.

3.1.6 *seam shear test* - A destructive test in which two seamed sheets or panels on opposite sides of the seam specimen are pulled in tension such that the seam is placed in a shear mode of stress.

3.1.7 *seam peel test* - A destructive test in which two seamed sheets or panels on opposite or same sides of the seam specimen are pulled in tension such that the seam is placed in a tension (or peel) mode of stress.

3.1.8 *Construction Quality Control (CQC)* - A planned system of inspections that is used to directly monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics installer and is necessary to achieve quality in the constructed or installed system. Construction quality control (CQC) refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project. (See EPA/600/R-93/182)

3.1.9 *Construction Quality Assurance (CQA)* - A planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design. Construction quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance (CQA) refers to measures taken by the CQA organization to determine if the installer or contractor is in compliance with the plans and specifications of the project. (See EPA/600/R-93/182)

3.2 Definition of Specific Terms

3.2.1 Hot Wedge Welding Device – A field operated device for joining overlapped geomembranes using a hot wedge device to melt the opposing surfaces followed by immediate roller pressure which upon cooling reestablishes the molecular structure of the now temperature equilibrated seam.

Note 6: Hot air welding devices act similarly but use hot air instead of a hot wedge to melt the opposing geomembrane surfaces.

3.2.2 Data Acquisition Welding Devices – A hot wedge or hot air welding device which has the capability of continuous monitoring and recording of the temperature of the hot wedge (or hot air), the speed of the device, and the pressure being applied by the opposing nip or squeeze rollers. This recorded and preserved data can be transmitted to other devices for analysis and reporting purposes.

3.2.3 Automatic Feedback and Adjustment Welding Devices – A hot wedge (or hot air) welding device equipped with data acquisition which then transfers wedge temperature, speed and pressure to a smart phone, tablet or computer so as to automatically adjust the welding device to the original or other designated values. Such systems can be computer controlled using preset algorithms for various field conditions.

Note 7: This type of automatic welding device is sometimes called a "smart data acquisition, or process control, welder".

3.2.4 Seaming Bubble (or Seaming Window) – A conceptual depiction of a three-dimensional graph of temperature, speed and pressure within which acceptable seams are being made and beyond which they are unacceptable.

Note 8: If only two of the three variables are being considered one sometimes refers to a "seaming window".

3.2.5 The bubble or the window is defined by the geomembrane installer for the specific material, the specific welding machine and the site-specific conditions. Trial seams are tested to prove/confirm these details and are under the CQA inspector's control.

4. Summary of Practice

Contrary to relying entirely on the intuition and experience of the welding device operator during production seaming to monitor and/or adjust the welding device variables, data acquisition welders continuously monitor and record the three variables of temperature, speed and pressure. Thus, by observation of the continuous signal output of each variable the operator can make periodic and timely adjustments. In so doing, it is expected that the seaming process stays within the material specific and site-specific acceptable seaming bubble or seaming window. Such recordings also show continuity of seams without gaps or other anomalies.

Data acquisition welding devices significantly assist the intuition of the operator by giving visual data of the three variables on a continuous basis. Response to changes in any or all of the outputs can be gradual or sudden, and is generally accomplished by varying the device's speed or stopping the process entirely until the situation is remedied.

5. Significance and Use

The goal of such data acquisition welders, as just described, is to document the seaming parameter data and identify deficiencies or lack thereof (as typically assessed by nondestructive or destructive seam tests). This is done by using data to verify positive seam quality and/or deficiencies. More informed destructive testing can be performed as a result, leading to the eventual relaxation and/or abandonment of the “one destructive test every 150 m (500 ft.)” of product seeming. See GRI-GM29 Standard Practice for Field Integrity Evaluation in this regard.

6a. Procedure with Conventional Welding Devices

The hot wedge seaming method (hot air seaming is also appropriate but used comparatively less frequently and will not be discussed further) consists of an electrically heated element in the shape of a wedge that travels between the two sheets to be seamed together. As it melts the surface of the two opposing sheets being seamed, a shear flow occurs across the upper and lower surfaces of the wedge. Opposing roller pressures are applied as the two sheets converge at the tip of the wedge to form the final seam. See Figure 1 (left). Hot wedge units are controlled by variables of temperature, speed, and amount of pressure as applied by the device’s operator. A standard hot wedge creates a single uniform-width seam, while a dual (or *split*) hot wedge forms two parallel seams with a uniform unbonded space between them. See Figure 1 (right) for cross sections of such seams. This air space is used to evaluate seam quality and the continuity of the seam by pressurizing the unbonded space with air and monitoring any drop in pressure that may signify a leak in the seam. *The dual hot wedge seam is considered to be the preferred seaming method for all thermoplastic geomembranes* (ref. Koerner, 2012).

> Note 9: It should be recognized that hot air seams parallel the above statement and are seeing increased interest and use.

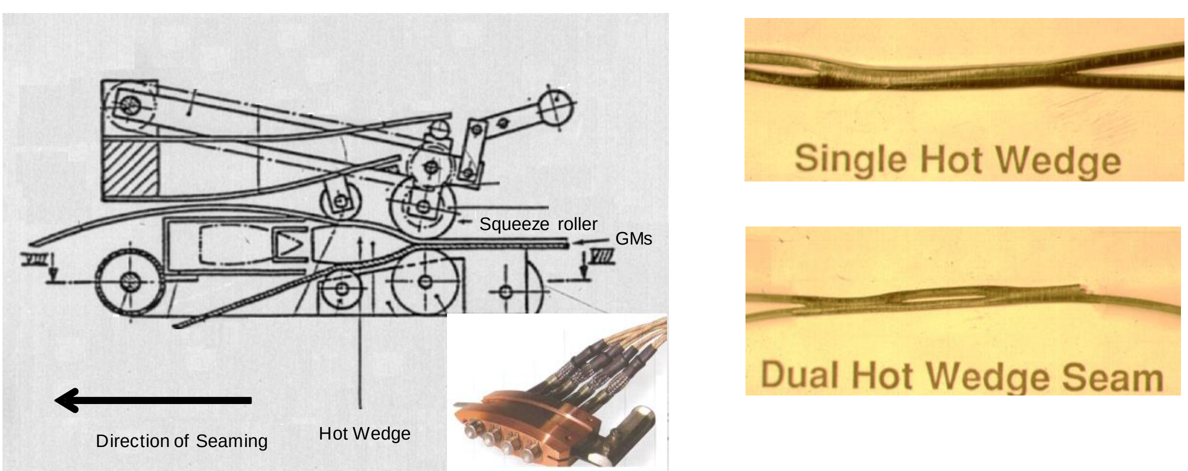

Figure 1. Hot wedge welding device (U.S. patent 4,146,419, March 27, 1979-now expired), a dual or split wedge photograph (inset), and resulting single and dual track geomembrane seams, the latter with an open air channel for pressure testing.

Regarding the concept of a seaming window, or better a seaming bubble, wherein acceptable seams are being made, the operator can visualize a hypothetical two-dimensional space of speed versus temperature or pressure versus temperature. However, the three variables together will form a three-dimensional space, or bubble, as shown in Figure 2. Some limited data is available in the literature defining the actual size and shape of such seaming patterns but it is sparse data and is only applicable for site-specific equipment and operator-specific situations, see Donaldson and Kolbasuk (1994).

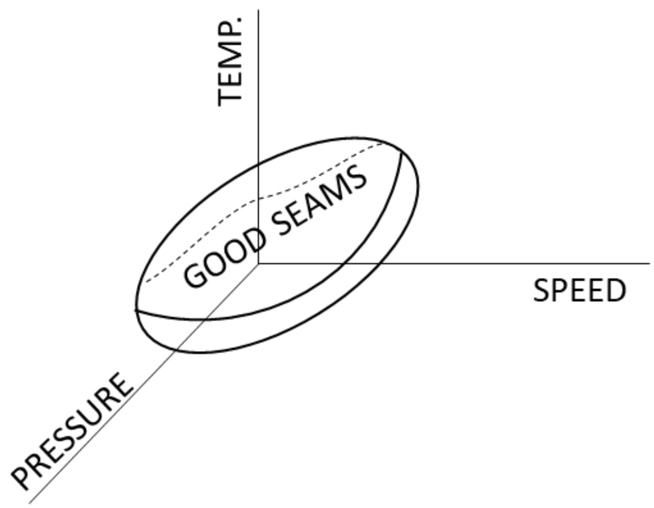

Figure 2. Concept of a Three-Dimensional Bubble for Controlling Seaming Variables Leading to Consistently Good Seams
(R. M. Koerner, Overview of EPA Workshop on Geomembrane Seaming, EPA/600/R93/112, June, 1993)

Generally, the operator adjusts the three controls (temperature, speed, and pressure) to suit the specific conditions of the site, its personnel and the welding equipment being used and is initially set on seamed test strip results. The device, operator and related equipment (generator, power cords, etc.) then proceed to make production seams. The operator is at liberty to adjust those controls during production based on experience and intuition. The quest for the operator is to stay at, or near, the center of the acceptable window or bubble as possible.

The issue with such conventional welding devices is that an operator never precisely knows where the outputs are within the window or bubble. Is one variable at one boundary ready to move out of it due to inadequate or excessive speed, or at another boundary ready to move out of it for higher or lower temperature, or are the variables right in the center where considerable tolerance and variation in all these variables may still be acceptable? This concept of a seaming window or bubble is very conceptual but one would like to stay as close to the center as possible in order to obtain high quality and consistent seams.

6b. Procedure with Data Acquisition Welding Devices

With a data acquisition hot wedge welding device adapted to continuously monitor temperature, speed and pressure, continuous graphs of the three variables can be obtained. See Figure 3 for such outputs. Here it is seen that for a 1350 ft. long seam, wedge temperature (upper graph) is constant throughout, the speed of the device (middle graph) is constant throughout, but that the pressure (lower graph) is erratic at the 970 ft. and 1130 ft. stations (lower graph). As noted, a physical investigation of the completed seam at these stations was required and a leak was confirmed in the seam. Even if a leak was not physically observed, the region could justify the taking of a destructive sample for testing at the CQA inspectors' discretion.

Note 10: Critical in the proper functioning of such welding devices is to have initial and ongoing "machine calibration" practices. The device manufacturer's instructions must be rigorously followed.

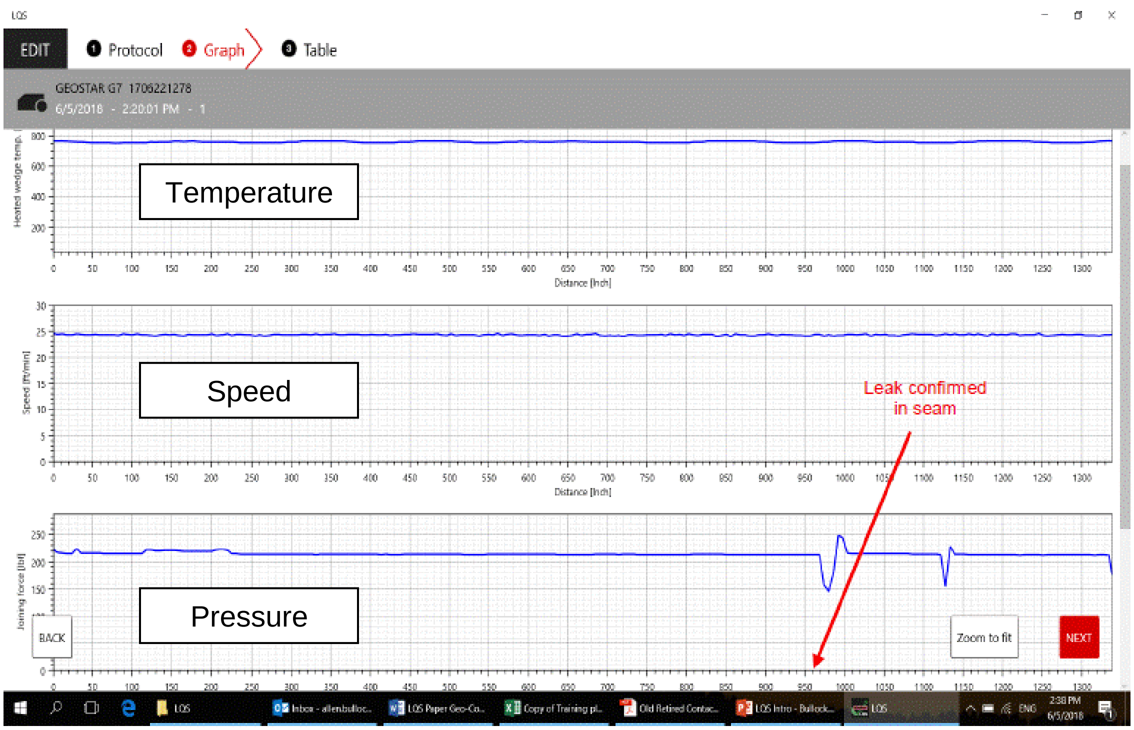

Figure 3. Example from seam evaluation showing anomaly with welding pressure.
(ref. A. M. Bullock, IFAI Conf., Houston, 2019)

7. Summary

Conventional hot wedge welding of geomembrane seams has seen major improvements since first introduced in 1979. Rates of seam failures have reduced over time from quite high percentages (10% or more) down to approximately 2% based on laboratory testing of destructive seam samples (recent IFAI data). Clearly, a major improvement over extrusion seaming, solvent or adhesive seaming, etc. has been achieved using such devices. That said, operator dependency and equipment consistency is an ongoing challenge which is required to bring seam performance even better than at present. It is felt, and is the focus of this standard practice, to further enhance overall geomembrane seaming performance by the use of data acquisition welding devices. By having ongoing quantified data of the three critical welding variables (temperature, speed and pressure) a visual indication of anomalies is readily seen. This will certainly aid the wedge welding device operator to implement a gradual, or even abrupt, modification of any one of the control variables. By so doing, the cumulative result of temperature, speed and pressure should be kept within the appropriate seaming window or seaming bubble leading to acceptable seams throughout the project.