

# Polyethylene Geomembrane Product Specifications

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## **PART I PURPOSE**

This manual addresses the quality assurance and quality control of the installation of High Density Polyethylene (HDPE) geomembrane liners used by Colorado Lining Construction (CLC) in hazardous waste disposal landfills, surface impoundments or other installations as specified by the owner and/or engineer. This manual delineates the quality procedures and standards for installation.

### **1.1.0 Scope of Quality Assurance**

The scope of this manual includes the quality assurance applicable to shipment, handling, and installation of High Density Polyethylene (HDPE) geomembrane liners also referred to Flexible Membrane Liners (FML's).

### **1.2.0 Units**

In this manual, all properties and dimensions are expressed in English units, with "equivalent" Système International (SI)/metric units in parentheses. It should be noted that the conversion is typically only accurate within ten percent. In cases of conflict or clarifications, the U.S. units shall be deemed to govern. Since most field geomembrane testing equipment manufactured in the United States are equipped to measure in English units, required test result data are tabulated herein with such units.

### **1.3.0 References**

The manual includes references to test procedures of the American Society for Testing and Materials (ASTM), the Federal Test Method Standards (FTMS) and the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF).

## **PART II DELIVERY**

### **2.1.0 Transportation and Handling**

CLC through its own transportation or an independent trucking firm or other party as agreed upon by the Owner will perform transportation of the geomembrane. If the geomembrane arrives on site prior to CLC project personnel, the Owner is responsible for off-loading roll goods and any ancillary items shipped. The material received shall be matched against the freight bill of lading. Any discrepancies shall be immediately reported to CLC before the shipment is signed for. When off-loaded, geomembrane and any ancillary items should be placed on a smooth, well drained surface, free of rocks or any other protrusions which may damage the material. No special covering is necessary for geomembrane.

The following should be verified prior to and during off-loading geomembrane:

Handling equipment used on the site is adequate and does not pose any risk or damage to the geomembrane and that personnel handle the geomembrane with care. If slings are provided, the material should be lifted with such. In any event, materials shall be offloaded in a safe manner whereby the rolls are properly balanced and no personnel or property are at risk of being injured/damaged should loss of control of any roll(s) of material occur.

Upon arrival at the site, CLC shall conduct a surface observation of all rolls for

defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. CLC shall indicate any damage to the Owner's Representative. The Owner shall immediately report to CLC any damage known to exist prior to delivery or that may have occurred during off-loading/handling.

### **2.2.0 Storage**

The Owner shall provide storage in location (or several locations) such that on-site transportation and handling are minimized. Storage space should be protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined.

### **2.2.1 Special Consideration for Welding Rod or GCL Liner**

Should any welding rod or geoclay (GCL) liner be delivered to the site prior to CLC arrival, such materials shall be immediately secured in a sheltered/dry condition and maintained in such condition until deployed by CLC personnel.

## **PART III SITE PREPARATION & INSPECTION**

### **3.1.0 Anchor Trench Systems**

All Anchor Trench Systems shall be excavated by others (unless otherwise specified) to the lines and widths shown on the design drawings, prior to geomembrane placement.

### **3.2.0 Site Inspection**

Immediately prior to installation, the subgrade shall be jointly inspection walked by the Owner's Representative and CLC personnel to determine it's worthiness to accept the specified lining system. The decision to repair cracks, if any, should be made only by the Owner's Representative. Once properly prepared, CLC will sign acceptance of the surface condition of the subgrade. The integrity of the underlying soil shall remain the responsibility of the owner/earthwork contractor.

#### **Subgrade Preparation Recommendations:**

No liner shall be placed on surfaces not previously found acceptable by the CLC supervisor or his agent.

Surfaces to be lined shall be compacted, smooth, and free of all rocks greater than 3/8" in diameter, sharp angular stones, sticks, vegetation, roots, sharp objects, gravel, or debris of any kind. The surface shall provide a firm, unyielding foundation for the lining system with no sudden, sharp or abrupt changes or breaks in grade or geometry.

## **Part IV PANEL DEPOLYMENT AND TRACKING**

### **4.1.0 Weather and Site Conditions**

Panel placement shall not take place during precipitation, or in the presence of excessive winds (unless wind barriers are provided). In addition, deployment shall not take place in any areas of ponded water.

### **4.2.0 Panel Identification**

Panels are portions of roll stock membrane that are field cut to size as required for



fitment and overlapped/welded in situ. In larger projects, a panel may consist of an entire uncut roll.

At the time of installation, the CLC Field Supervisor shall give each field panel an "identification code" (Number or letter-number). This field panel identification code shall be as simple and logical as possible.

#### **4.3.0 Panel Placement**

Panels are located by the CLC Field Supervisor in a manner consistent with the specification and best suited to existing site conditions. Field Panels shall be placed one at a time and each shall be seamed immediately after its placement for protection against wind action or rainwater infiltration.

CLC shall record the identification code, location, and date of installation of each geomembrane field panel.

#### **4.4.0 Precautions During Panel Placement**

CLC shall ensure that:

Any equipment used will not damage the geomembrane by handling, trafficking, excessive heat, leakage of fluids, or other means.

The prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately prior to liner placement.

Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.

All personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane.

Methods used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil.

Methods used to place the panels minimize wrinkles (especially differential wrinkles between adjacent panels).

Adequate temporary ballast is placed over deployed lining panel edges to prevent wind uplift and is not likely to damage the geomembrane. In the event of high winds, continuous loading such as sandbags shall be placed end to end along edges of panels to minimize risk of wind effects.

Direct contact with the geomembrane is minimized. Geotextiles, extra liner or other suitable materials shall be used as protective buffers in areas where excessive traffic may be expected.

#### **4.5.0 Damaged Material**

CLC shall inspect the geomembrane after placement and prior to seaming for damage. Any damaged membrane that cannot be reasonably repaired shall be removed and replaced. Repairs to geomembrane shall be made according to procedures described in section 8.2.0.

### **PART IV SEAMING**

#### **5.1.0 Required Weather Conditions for Seaming**

No seaming shall be conducted during periods of excessive moisture, blowing dust, or in the presence of excessive winds (unless wind barriers are provided). Seaming shall not take place in an areas of ponded water.

High temperature limits for welding are dependent upon crew safety and membrane material limits. Elevated temperatures can create conditions whereby seam strength may be compromised and an inferior installation may result. When elevated temperature conditions exist over 95° F/35° C, weld quality shall be closely monitored during seaming operations.

No seaming shall be conducted during rain or snow, unless the seam is covered with an enclosure permitting favorable seaming conditions.

No seaming shall be attempted at ambient temperatures below 5° F without proper pre-heating of material promoting favorable seaming conditions.

In all cases, geomembrane shall be dry and protected from wind.

CLC shall verify that favorable weather conditions exist and advise the Owner's Representative if they are not favorable.

#### **5.2.0 Seaming and Related Equipment**

Unless otherwise specified, all field seaming procedures shall be limited to two methods: extrusion welding and fusion (via hot wedge/"wedge welding"). The bulk of all panel to panel seaming shall be performed using the wedge weld technique. Extrusion welding shall limited to areas where wedge welders cannot practically be deployed such as patching and pipe penetration sealing. These machines typically require gas or diesel fueled generators as power sources.

Each extrusion welding apparatus shall be equipped with gauges giving the temperature of the apparatus at the nozzle and extruder barrel.

Each wedge welding apparatus shall be equipped with gauges giving the applicable temperatures.

Although welding over a frozen, wet or muddy subgrade is generally not encouraged, fusion welding may be possible under such conditions by deployment of a movable plastic slip-sheet placed directly below the overlapped membranes being seamed. Properly designed and deployed slip-sheets serve to prevent moisture buildup between the sheets being welded while providing conditions whereby wedge welding machines may be propelled at an uninterrupted rate of speed.

### **5.2.1 Equipment Preparation**

Generator(s) shall be fueled outside the extents of the lining system and be inspected for fluid leakage and mechanical damage that may result in damage to the lining system. Should it be necessary to place the generator over the lining system a suitable buffer strip shall be placed between the tires and the membrane. Generators without inflated rubber tires shall not be introduced over the lining system. Tires shall be pre-inspected to be free of foreign matter that may damage the membrane. Generators shall be positioned within close proximity of the seaming region and have adequate extension cords to complete an entire seam without the necessity to move the machine.

Wedge welders shall be calibrated for ambient conditions and the material type/thickness to be welded. The front part of the seaming device should be inspected for sharp corners and irregular details, which may damage the liner. The major point for inspection is that no sharp edges should exist where FML sheet surfaces must pass over the heated wedge element. If a dual, or split, hot wedge seam is being made, the recessed space for the air track should be examined. Knurled pressure rollers shall be inspected for sharp surfaces. All wedge welder adjustments shall be checked daily. Cleaning of machine should be done at least daily.

Extrusion welders shall have an initial inspection before warm up to confirm that the insulation and covers are in good condition and that the welding nozzles (or Teflon shoes) are correct for the FML to be seamed. Teflon shoes should be checked for proper weld bead geometry and excessive wear and replaced if necessary. They shall then be heated to the correct welding temperature for thickness of the material to be welded and then purged of all heat-degraded resin from within the barrel. During the purge process temperature controllers shall be monitored for proper function and that the welding rod feed systems and rotating tips are operating properly.

### **5.2.2 Trial Seams**

Before any welding is performed by either method on the actual membrane lining system, trial seam welds must first be performed yielding passing results.

CLC shall prepare trial seams made with test strips of the actual membrane being installed to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period (start of the day and midday) for each seaming apparatus used. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be approximately 3 feet/1.0 m long by 1 foot/0.3 m wide (after seaming) with the seam centered lengthwise. Seam overlap shall be nominally 4 inches/10.2 cm, 3 inches/7.6 cm minimum.

Unless otherwise specified, five (5) seam sample coupons each measuring 1"/25mm wide x 6"/150mm long shall be cut from the trial seam sample in increments to span its length. The specimens shall be tested in peel (3 ea.) and shear (2 ea.) modes using a field tensiometer. No seaming apparatus shall be used for seaming until deficiencies are corrected and two consecutive trial welds are successfully achieved.

### **5.3.0 Seam Layout**

In general, seams should be oriented parallel to the line of maximum slope, in the direction of slope, not across the slope (horizontal to slopes). Horizontal to slope seams should be no less than 5 feet (1.5 m) from the toe of the slope or areas of potential

stress concentrations unless otherwise approved by The Owner's Representative. When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel end is cut at an angle greater than 45° to minimize seam stress. In corners and areas of irregular geometry, the number of seams should be minimized.

A seam numbering system compatible with a panel numbering system shall be employed.

#### **5.4.0 Panel Overlap for Seaming**

Controlled overlapping of adjacent sheets shall produce approximately 3 inches of overlap for extrusion welds and 4 inches of overlap between sheets for wedge welded seams.

#### **5.5.0 Seam Preparation**

CLC shall verify that:

Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material, and seams are aligned with the fewest possible number of wrinkles or "fishmouths".

All areas to receive extrusion welds shall first be lightly/evenly ground with a hand held grinder with a 60 or 80 grit disc to roughen the surface while removing all surface shine. The grinding is performed parallel to the seam and controlled such that grinding marks do not extend more than 0.25 inches outside the area of the weld bead area. Sixty mil or thicker liners should have the edge of the top sheet beveled by grinding to approximately a 45° angle. This grinding preparation shall be completed no more than one (1) hour prior to extrusion welding. Grinding preparation does not apply to wedge welding.

#### **5.6.0 Wedge Welder Seaming Procedure**

A smooth insulating plate or fabric is shall be placed beneath the hot welding apparatus both before and after usage.

Unless otherwise specified, the general seaming procedure used by CLC shall be as follows:

The rolls of geomembrane shall be overlapped by approximately four inches (100 mm) for fusion welding and three inches for extrusion welding.

Welding can occur once the panels to be joined have been brought into their exact plan position for final installation.

"Fishmouths" or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut "fishmouths" or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions.

Power to the drive motor shall remain switched-off off when positioning the machine to make a seam.

When starting a new weld, the machine shall be manually placed into the overlapped sheet of material. The sheets shall then be guided between the idlers and the wedge element, and into the drive/nip rollers.

When starting a weld in the middle of two sheets, the material must be loaded from the sides. The machine is to be picked up a few inches, loading the bottom sheet first and top sheet second.

As soon as the wedge is in position and the nip rollers are engaged, the drive motor should be energized and the hot wedge moved into position and locked.

Welder alignment and temperature shall be monitored during the seaming process and any adjustments be made as necessary.

Should the machine tend to bulldoze the subgrade due to soil conditions, the operator shall take some of the weight off the front of the machine by lifting it slightly. Alternatively, a base for the machine to travel on could be provided consisting of strips of geotextile or geomembrane.

To avoid damaging membrane material, once the end of a seam is reached the drive and/or pressure rollers shall be immediately disengaged before the material runs completely out of the machine. The machine shall be withdrawn as quickly as possible to avoid damaging the membrane.

Seaming shall span the full panel length extend well into the anchor trench.

All cross seams or "T" intersections are to be extrusion welded where they intersect. The top flap of geomembrane shall be removed in the area to be extrusion welded and the weld area is ground prior to welding.

### **5.7.0 Extrusion Welder Seaming Procedure**

A smooth insulating plate or fabric is shall be placed beneath the hot welding apparatus both before and after usage.

Using a hot air welders or hand held heat guns with seam rollers the overlapping materials to be welded must first be pre-bonded to hold the materials in place before actual extruding.

Welding operations should be observed to assure that the machines are properly aligned resulting in weld beads that are centered over the edges of the top FML sheets and that weld bead appearances are smooth and uniform.

## **PART VI**

### **Non-Destructive Seam Continuity Testing**

CLC shall non-destructively test all field seams over their full length using a vacuum test unit, air pressure testing, or other approved method. The purpose of non-destructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

#### **6.1.0 Vacuum Box Testing**

This test method is almost exclusively used for evaluating extrusion weld bead quality. In areas where vacuum boxes cannot practically be deployed, the welds shall be visually inspected and manually probed over their full length to check adhesion.

The equipment shall be comprised of the following:

A vacuum box assembly constructed from clear transparent plastic with a soft neoprene gasket attached to the bottom and a gauge to indicate vacuum chamber pressure.

A vacuum motor capable of creating a vacuum of 2.5 to 3 psi.

A bucket and wide brush, mop or spray assembly.

A soapy solution.

**Procedure:**

Wet a strip of geomembrane approximately 12 inches by 48 inches (0.3 m by 1.2 m) with the soapy solution;

Place the box over the wetted area.

Energize the vacuum apparatus; confirm 2.5 to 3psi.

Ensure that a leak tight seal is created.

For a period of approximately 5 to 10 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.

All areas where soap bubbles appear shall be marked and repaired in accordance with Section 3.4.

If no bubbles appear, the vacuum shall be disengaged and the box indexed to the next test area with a minimum 6" overlap between indexes, and the process repeated.

Vacuum tested seams are recorded on Daily Progress Reports.

**6.2.0 Air Channel Pressure Testing**

This method is only applicable to seam continuity testing of air channels produced using dual track hot wedge welding equipment.

Testing equipment shall be comprised of the following:

An air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa).

A air hose with fittings and connections.

A sharp hollow needle or other approved pressure feed device.

**Procedure:**

Seal both ends of the seam to be tested by tack welding and clamping with Vise Grips;

Insert needle into the air test channel created by the fusion weld.

Inflate the channel as applicable to pressure between 25 and 30 psi (160 and 200 kPa), close pressurized air source valve and monitor air pressure drop for five (5) minutes.

Remove needle or other approved pressure feed device and seal.

If pressure drop exceeds values tabulated herein or does not stabilize, locate faulty area and repair and re-test until defects are corrected and test values are passing.

Pressure tested seams are recorded on Daily Progress Reports.

**TABLE 6.2  
SEAM PRESSURE TEST ALLOWANCE**

<b>Material Thickness</b>	<b>Minimum psi Test Pressure</b>	<b>Maximum psi Test Pressure</b>	<b>Maximum psi Drop Allowed After 5 Minutes</b>
30 mil	24	30	3 PSI
40 mil	24	30	3 PSI
60 mil	27	30	3 PSI
80 mil	27	30	3 PSI
100 mil & Thicker	30	32	3 PSI

#### **6.2.1 Pressure Test Failure**

Should excessive pressure drop occur, both ends of seam shall be checked to insure proper seal and be re-tested. Should failure reoccur, the top fusion seam shall be checked by applying a constant air pressure to the air channel and applying a soapy water solution over the weld length. Any failure or leak will be indicated by continuous bubbles appearing.

If no failure appears in the top fusion seam area the seam shall then be systematically isolated into in one hundred and fifty linear foot sections of seam which shall each be re-tested by pressure testing until the leak is located. Failed seam areas shall be repaired by extrusion welding the outside edge of the top fusion weld between areas of failure. The extruded edge shall be vacuum tested in accordance with this manual.

## **PART VII**

### **Destructive Seam Testing**

Destructive seam tests (if required by the project specification) shall be performed at random selected locations at a frequency of one sample per every 500 lineal feet of seam or as otherwise specified. Seam testing shall be conducted concurrent to the seaming work progress. The Owner's Representative if required, may select locations where seam samples are to be cut. If destructive seam tests are not required, representative seam samples may be substituted at a similar frequency using material samples of the actual material being installed so that no "damage" is done to the actual lining system requiring patching and testing, etc.

#### **Procedure**

Samples shall be cut by CLC as the seaming progresses. CLC shall:

Cut samples.

Assign a number to each sample, which is to be based upon seam and sample number and mark it accordingly.

Record sample location on daily report.

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 8.2.0.

#### **7.1.0 Sample and Coupon Size and Extraction**

Unless otherwise specified, the following sample preparation guidelines shall govern:

Trial, representative or destructive seam samples cut from the installed liner shall measure 12"/30cm in width x 3'/1m in length with the width of the seam centered in the long axis of the sample. Coupons shall measure 1"/25mm wide by 6"/150mm long with the seam centered perpendicular to the length.

Coupon extractions shall occur in three paired locations along the length of the seam sample:

2 coupons at the beginning, 2 coupons in the center and 2 coupons at the end of the sample for a total of six (6) extractions. Coupons may be extracted and evaluated incrementally.

#### **Sample Distribution**

Remnant 12"/30 cm square samples shall be cut into parts, labeled as specified and distributed as applicable:

- One portion for independent geosynthetic laboratory testing if previously specified
- and

- One portion to the Owner for archive storage

#### **7.2.0 Coupon Field Testing**

Coupons shall be tested with a tensiometer and evaluated for bonded seam strength (shear) and peel using methods ASTM D4437. Tensiometer jaw separation rate for bonded seam strength/shear and peel test shall be 2"/minute (5cm/min.)

All shear strength samples shall yield Film Tearing Bond (FTB) as defined in NSF 54 Annex A,

If the initial sample coupon test passes shear analysis yielding a FTB, the sample qualifies for further testing to obtain quantitative results until three (3) each peel samples and three (3) each shear samples are evaluated from the beginning middle and end of each sample.

If more than one (1) of six coupons per sample fails, the seam should be repaired in accordance with Section 7.3.0.



**TABLE 7.2**  
**REQUIRED FUSION AND EXTRUSION SEAM TEST RESULTS**  
 Per NSF 54 1993 Standards

<b>Material Thickness</b>	<b>Minimum Values Required</b> (In Units of Pounds per inch of Width)			
	<b>Peel Extrusion</b>	<b>Peel Fusion</b>	<b>Shear Extrusion</b>	<b>Shear Fusion</b>
30 mil HDPE	35	49	63	63
40 mil HDPE	48	86	86	86
60 mil HDPE	70	98	126	126
80 mil HDPE	92	115	166	166
100 mil HDPE	115	143	207	207
Textured 30 mil HDPE	31	44	56	56
Textured 40 mil HDPE	42	60	76	76
Textured 60 mil HDPE	63	88	113	113
Textured 80 mil HDPE	84	115	151	151
Textured 100 mil HDPE	105	143	189	189

**Notes:** Textured values are applicable to membranes textured on one side of the sheet only.  
 Only the inner weld track is peeled apart in this destructive test. The outer track (directly at sheet edge) is for the purpose of air pressure testing capabilities.

### 7.3.0 Procedures for Test Failure

Should a sample fail a destructive test, the defect may be remedied by:

Capping the respective seam in its entirety as described in this section,

or

If a defect is suspected to be local to a certain area it may be further investigated to isolate the defective are by:

Taking small coupon test samples located 10' on either side of the defective sample seam void area. If these additional samples pass tensiometer testing, then full samples are to be taken. If these samples pass the tests, then the seam is capped between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed. All acceptable seam areas must be bounded by two locations from which samples passing destructive tests have been taken.

Cap stripping of defective seams or isolated areas shall be performed using either wedge or extrusion welding techniques or combination thereof and re-testing the repaired area with applicable methods as described herein. Cap strips shall cover the defective seam by no less than 6"/15cm On either side of the original weld. Wider patches will be required to cover seam sample void areas.

CLC shall document all actions taken in conjunction with destructive test failures; e.g., capping of failed seam area.

## **PART VIII**

### **Defects and Repairs**

#### **8.1.0 Identification**

All seams and non-seam areas of the geomembrane shall be examined by CLC for identification of defects, holes, blisters, un-dispersed raw materials and any sign of contamination by foreign matter.

Defective/damaged materials shall be identified via a deficiency report, either separately or on the Daily Report. Actions taken to resolve or correct the problem will also be recorded on the similar form.

Defects, holes, blisters, un-dispersed raw materials, signs of contamination by foreign matter, unacceptable welds in geomembranes and other unsatisfactory conditions will be identified on the Daily Report form. The repair/corrective action to "fix" the problem will also be recorded on a similar form.

#### **8.2.0 Repair Procedures**

Available methods include:

Patching - used to repair large holes, tears, and contamination by foreign matter.

Grinding and re-welding - used to repair small sections of extruded seams.

Spot welding or seaming - used to repair pinholes or other minor localized flaws;

Capping - used to repair large lengths of failed seams;

Methods for patching lining system defects shall consist of welding patches or caps over such areas using the same membrane lining material as used on the specific project. Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches.

Seaming, preparation and welding equipment deployment procedures previously addressed in this manual shall be adhered to during patching operations.

#### **8.2.1 Verification of Repairs**

Each repair shall be non-destructively tested using the methods described in Section 6 as appropriate. Repairs which pass the non-destructive test, shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and re-tested until a passing test result is obtained.

## **Part IX**

### **Ancillary Items and Final Acceptance**

#### **9.1.0 Pipe Penetrations**

Pipes penetrating through the lined area shall be sealed using pipe boot details that are welded to the lining system via extrusion weld method and sealed the pipe with double stainless steel banding clamps and butyl sealant tape. Pipe boots shall be fabricated from the membrane material being installed and shall fit snugly over the pipe and pipe to grade interface without undue slack or bridging. In instances where piping is

manufactured from HDPE, the pipe boot sleeve may be extrusion welded directly to the pipe foregoing the need for banding clamps.

### **9.2.0 Backfilling of Anchor Trenches**

Anchor trenches, if any, shall be adequately drained by others to prevent ponding or otherwise softening the adjacent soils while the trench is open. The anchor trench shall be back-filled by others or as outlined in the specifications and bid documents.

Since back-filling the anchor trench can affect material bridging at toe of slope, consideration should be given to backfill the liner at its most contracted state; preferably during the cool of the morning or extended period of overcast skies. Care shall be taken when back-filling the trenches to prevent any damage to the lining system.

### **9.3.0 Lining System Acceptance**

Once the lining system is installed and all quality assurance testing has been completed with satisfactory results, and the system is approved by Owner's Representative, the Representative shall sign an acceptance form provided by CLC prior to demobilization.



Promoting Industry Growth • Providing Better Quality Workmanship

*Approved Installation Contractor*

This Certificate Recognizes That

*Colorado Lining International, Inc.*

Has achieved Approved Installation Contractor status through  
the International Association of Geosynthetic Installers.

Valid through July 8, 2010



A handwritten signature in blue ink, appearing to read 'Carl Apicella'.

Carl Apicella

A handwritten signature in blue ink, appearing to read 'Laurie Honnigford'.

Laurie Honnigford  
Managing Director, IAGI

## GSE HyperNet, HF, HS and UF Geonet

GSE HyperNet geonets are synthetic drainage materials manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. HDPE resins are inert to chemicals encountered in most of the civil and environmental applications where these materials are used. GSE geonets are formulated to be resistant to ultraviolet light for time periods necessary to complete installation. GSE HyperNet geonets are available in standard, HF, HS, and UF varieties.

The table below provides index physical, mechanical and hydraulic characteristics of GSE geonets. Contact GSE for information regarding performance of these products under site-specific load, gradient, and boundary conditions.

### Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE <sup>(b)</sup>			
			HyperNet	HyperNet HF	HyperNet HS	HyperNet UF
Product Code			XL4000N004	XL5000N004	XL7000N004	XL8000N004
Transmissivity <sup>(a)</sup> , gal/min/ft (m <sup>2</sup> /sec)	ASTM D 4716	1/540,000 ft <sup>2</sup>	9.66 (2 x 10 <sup>-3</sup> )	14.49 (3 x 10 <sup>-3</sup> )	28.98 (6 x 10 <sup>-3</sup> )	38.64 (8 x 10 <sup>-3</sup> )
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft <sup>2</sup>	200 (5)	250 (6.3)	275 (7)	300 (7.6)
Density, g/cm <sup>3</sup>	ASTM D 1505	1/50,000 ft <sup>2</sup>	0.94	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft <sup>2</sup>	45 (7.9)	55 (9.6)	65 (11.5)	75 (13.3)
Carbon Black Content, %	ASTM D 1603, modified	1/50,000 ft <sup>2</sup>	2.0	2.0	2.0	2.0
Roll Width <sup>(c)</sup> , ft (m)			15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)
Roll Length <sup>(c)</sup> , ft (m)			300 (91)	250 (76)	220 (67)	200 (60)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			4,500 (418)	3,750 (348)	3,300 (305)	3,000 (278)

#### NOTES:

- <sup>(a)</sup>Gradient of 0.1, normal load of 10,000 psf, water at 70° F (20° C), between steel plates for 15 minutes.
- <sup>(b)</sup>These are MARV values that are based on the cumulative results of specimens tested by GSE.
- <sup>(c)</sup>Roll widths and lengths have a tolerance of ±1%.

DS017 HyperNet R01/13/06

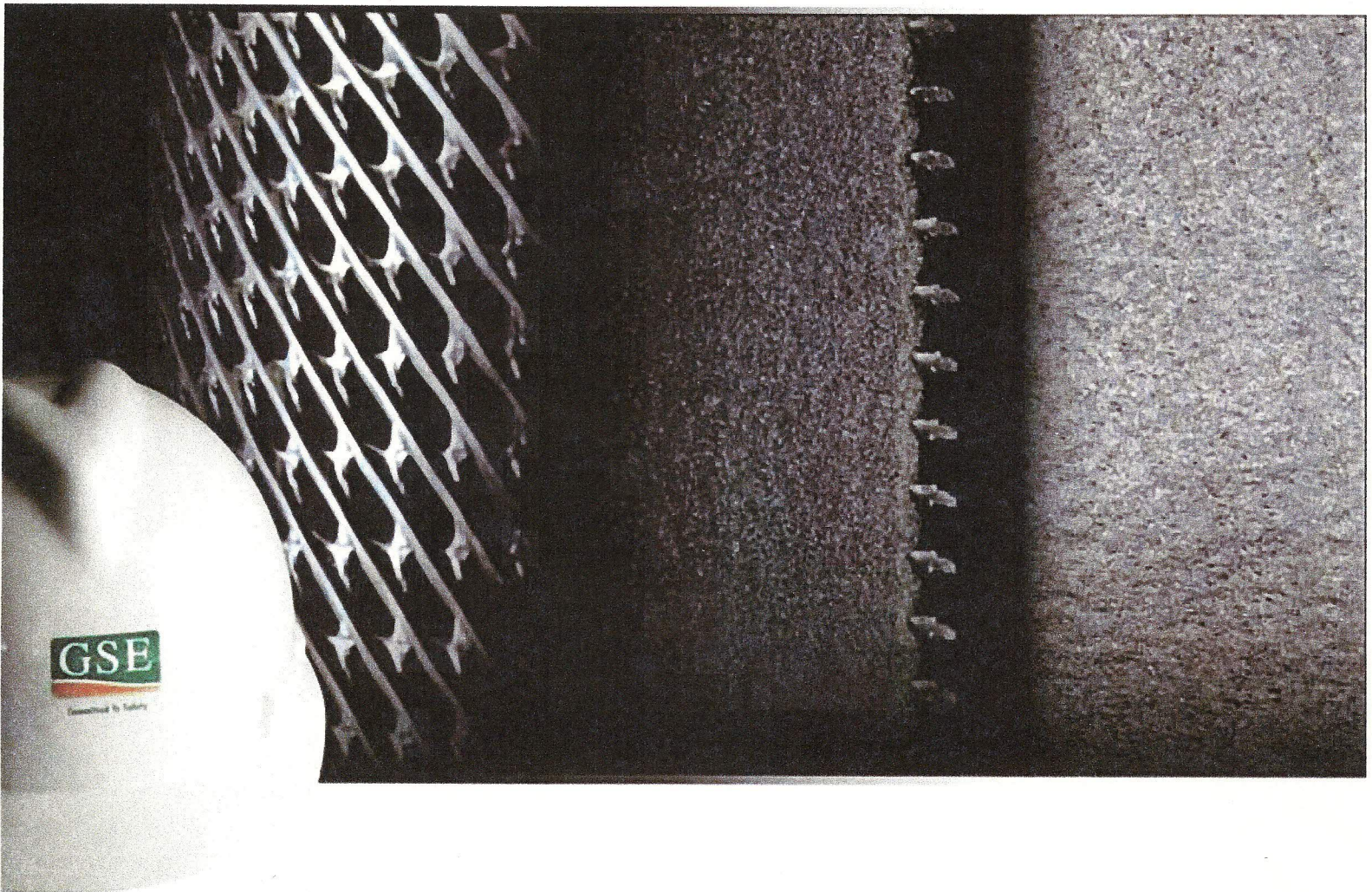
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# Installation Quality Assurance Manual



## Geonet & Geocomposite Products







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### 1.0 INTRODUCTION

This manual provides an overview of the GSE Installation Quality Assurance procedures consistent with industry accepted practices to ensure that the geonet and geocomposite products installed will best perform for its intended purpose. In addition, all installation work will be performed in strict accordance per the customer's specifications. Please read the procedures below completely before you begin. If you need further clarification, contact the GSE Installation Department for assistance. Remember safety first and use safe practices always on every project.

### 2.0 ROLL PACKAGING

GSE geocomposite rolls shall be shipped from the factory in an opaque protective covering to prevent damage and UV degradation. However, GSE geonets do not need to be further protected from UV degradation during shipping or storage.

### 3.0 MATERIAL DELIVERY

- A. Upon arrival on site, QA personnel will inventory all materials on-site.
- B. Roll numbers of the geonet or geocomposite will be logged on the Inventory Check List (Appendix A) and cross-referenced with the Bill of Lading.
- C. Copies of the Inventory Check List and signed Bill of Lading should be sent to GSE corporate headquarters while the on-site QA personnel retains the original copies.
- D. Any visible damage to roll materials should be noted on the roll and Inventory Check List.

### 4.0 UNLOADING & STORAGE PROCEDURES

- A. Rolls of material shall be unloaded with equipment that will not damage the geonet or geocomposite.
- B. Fabric-straps, spreader bars, stinger bars, or other approved equipment shall be used for handling rolls of geonet and geocomposite.
- C. Materials should be stored in a flat, dry and well drained area.
- D. The surface shall be free of sharp rocks or other objects that could damage the materials.

### 5.0 SUBGRADE PREPARATION

The subgrade shall be free of sharp rocks or other objects that could otherwise cause damage to the materials.

### 6.0 DEPLOYMENT

Geonet and geocomposite shall be handled in a careful manner to ensure that it is not damaged in anyway.

- A. On slopes, the material shall be anchored in the anchor trench and then rolled down the slope in such a manner as to continually keep the material under tension.





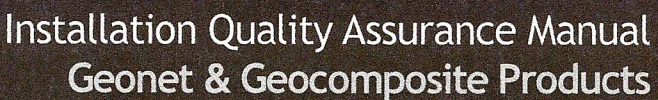
- B. In the presence of wind, the leading edge of the material shall be weighted with temporary ballasting, such as sandbags until the final cover is placed.
- C. Care shall be taken to assure that any underlying layers are not damaged during placement. Low ground pressure machines, such as ATV's to facilitate deployment over the geosynthetic layers is allowed. Low ground pressure machines are machines with a ground pressure less than 8 psi when carrying a driver weighing approximately 150 lbs.
- D. Care shall be taken to avoid entrapment of stones, mud and other materials during placement operations.

### 7.0 OVERLAPS & SEAMS

- A. The recommended geonet overlap in the machine direction is 3.0 in to 5.0 in. The recommended overlap in the transverse direction is 6.0 in to 12.0 in.
- B. On slopes the ends of the materials shall be shingled down in the direction of the slope.
- C. A plastic cable tie should be placed once per every five linear feet in the machine direction and once per every linear foot in the transverse direction.
- D. If the product is a geocomposite, the geotextile on the bottom shall be overlapped and the geotextile on top shall be overlapped, sewn or heat bonded. The exact seaming method or overlap is typically specified in project construction documents.

### 8.0 COVER SOIL PLACEMENT

- A. Prior to placement of cover soil, a Certificate of Acceptance (Appendix B) must be signed by a responsible party and an installer's representative.
- B. Any cover material, such as soil, that is placed over the drainage material shall be placed with care to assure the material is not damaged.
- C. Care shall be taken to minimize any movement of the geonet or geocomposite and to assure that no tensile stress is induced in the material.
- D. Cover soils deployed over the geonet or geocomposite should be free of all sharp objects, sharp rocks and sticks.
- E. Wide track equipment should be used to distribute cover soil over the geocomposite.
- F. A minimum of 12.0 in of cover soil is required to separate the equipment from the geocomposite to prevent damage.



## Appendix A: Inventory Check List

[illegible]





## Appendix B: Certificate of Acceptance

### GSE Lining Technology, LLC

19103 Gundle Road  
Houston Texas 77073  
800-435-2008  
281-443-8564  
281-875-6010 Fax

Job No.: \_\_\_\_\_  
Project: \_\_\_\_\_  
Client: \_\_\_\_\_  
Bill To: \_\_\_\_\_  
\_\_\_\_\_

Job Description: \_\_\_\_\_  
% Complete of Total Job: \_\_\_\_\_

### Certificate of Acceptance

Material	Estimated Square Feet	Final Quantity/Description

I, the undersigned, duly representative of:

Do hereby take over and accept the work described above from the date hereof and confirm to the best of my knowledge the work has been completed in accordance with specifications and the terms and conditions of the contract.

Name	Signature	Title	Date

Certificate accepted by GSE Lining Technology, LLC Representative.

Name	Signature	Title	Date



LINING TECHNOLOGIES

Quality

## CETCO GCL

# MANUFACTURING QUALITY ASSURANCE AND QUALITY CONTROL (MQC) MANUAL

Version 8.0, November 2009

### CONFIDENTIALITY NOTICE

This manual contains confidential company information and is to be distributed exclusively to those personnel who are directly involved with the manufacturing and evaluation of Bentomat. THIS DOCUMENT SHALL NOT BE PUBLICLY DISTRIBUTED WITHOUT THE EXPRESS CONSENT (VERBAL OR WRITTEN) OF COLLOID ENVIRONMENTAL TECHNOLOGIES COMPANY.



## POLICY STATEMENT

The Geosynthetic Clay Liner (GCL) Manufacturing Quality Assurance/Quality Control Manual has been prepared by Colloid Environmental Technologies Company (CETCO), a wholly owned subsidiary of AMCOL International, Inc. This policy states that our primary goal is to achieve optimum productivity while assuring full customer satisfaction. To reach this goal, CETCO is committed to the pursuit of continuous improvement of all processes and materials utilized in the manufacture of GCL.

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## SECTION 1 INTRODUCTION

### 1.1 Definitions

This manual contains objectives and criteria for maintaining CETCO Geosynthetic Clay Liner (GCL) *Manufacturing Quality Control* and *Manufacturing Quality Assurance* as defined below:

**Manufacturing Quality Control (MQC)** refers to a planned system of inspections for directly monitoring and controlling the quality of the GCL product during the manufacturing process. MQC is performed by CETCO to ensure that the specified values for GCLs are achieved.

**Manufacturing Quality Assurance (MQA)** refers to a planned system of activities that provide assurance that the manufactured GCLs product actually meets its specified properties.

The above definitions, provided by Koerner and Daniel<sup>1</sup>, imply that MQC procedures are implemented to control the product *during* manufacture, while MQA procedures are implemented to ensure the product meets specifications *after* manufacture. CETCO GCLs are assembled from three component materials, meaning that there are *four* materials streams (two geosynthetics, the clay, and the finished product) which are subject to either MQA or MQC. Quality control procedures are implemented on those components and finished products which are manufactured by CETCO. Quality assurance procedures are implemented on the components of GCL that are furnished by outside suppliers. Therefore, this manual contains an integrated series of procedures that may be classified as both MQA and MQC, as determined by the source of the component materials.

The organizational structure of the CETCO GCL MQA/MQC Program is depicted in Figure 1-1. The "core" quality personnel are shown in the center of the diagram, with peripheral quality support provided by the other personnel. For each project, the CETCO GCL Sales Manager is the key liaison between the manufacturer and the engineer, and any special MQA/MQC issues which deviate from this manual should be communicated between these two parties prior to production for the project. Figure 1-2 presents the Order Review Process for discrepancies between contract specifications and CETCO standard GCL specifications.

### 1.2 MQA/MQC Objectives

CETCO GCLs are utilized in a wide variety of important environmental and engineering applications which often provide protection of human health and the environment from contaminated soil or water. Accordingly, CETCO GCLs have been designed with certain engineering properties which make it suitable for use in these critical applications. The quality of CETCO GCLs has a direct influence on the degree of environmental protection they provide. It is therefore of paramount importance that the entire manufacturing process for CETCO GCLs is tightly controlled and monitored through the implementation of a comprehensive quality management system.

<sup>1</sup> Koerner, R.M. and D.E. Daniel (1992) *Manufacturing and Construction Quality Control and Quality Assurance of Geosynthetics*. Proceedings of the 6th GRI Seminar: MQC/MQA and CQC/CQA of Geosynthetics, December 10-11, 1992, Philadelphia, PA, pp. 1-14.



CETCO is registered with the International Organization for Standardization (ISO) and follows a quality management system in accordance with ISO 9001:2000. The intent of the quality management system is to ensure that we provide products and services that conform to the requirements of our customers and to deliver them on time and without defects. The Quality Manual and associated quality procedures, work instructions, calibration procedures, test procedures, and records, are saved electronically. The procedures outlined in this MQA/MQC manual are also described in the ISO Quality Manual.

This MQA/MQC manual establishes the manufacturing guidelines and product testing procedures necessary to ensure that CETCO GCLs meet all of their design specifications. Where applicable, established ASTM sampling and testing methodologies and protocols for GCLs or its components are specified for use.

The remainder of this manual is presented in three sections. Section 2 contains test procedures for GCLs and each of its components, and Section 3 describes the record keeping and reporting procedures which will document adherence to this plan and will verify the overall quality of the product. Lastly, Section 4 presents in tabular form an overall summary of the manufacturing QA/QC program.

### 1.3 Revisions

Because one of CETCO's corporate commitments is continual product improvement, the procedures specified in this manual may require some modifications as such improvements occur. Interim revisions to the existing manual will be issued as required, and the manual itself will be updated and reissued on a regular basis to incorporate recent revisions. It is every employee's responsibility to remain abreast of the continued revisions to the quality program.

### 1.4 Audits

Formal internal audits of the GCL manufacturing quality program will be conducted annually by CETCO and by a third-party ISO auditor in order to determine the adequacy of quality procedures and the degree of conformance with these procedures. Informal audits will be conducted on an as-needed basis by plant management.

Results of the audits will be distributed to the CETCO Management Representative, to the Plant Manager, and to corporate management. If the audit reveals that major corrective actions are required to achieve conformance with quality objectives, a quality improvement plan will be prepared and submitted to the CETCO Management Representative. A file of all audits and corrective action plans will be maintained by CETCO. Implementation of the quality improvement plan will be managed by the CETCO Management Representative and/or Plant Manager.

## SECTION 2

### MQA/MQC PROCEDURES

This section of the CETCO GCL Manufacturing QA/QC Manual describes specific procedures carried out to evaluate the quality of each GCL component (top geosynthetic, bottom geosynthetic, bentonite clay), the quality of the actual production process, and the quality of the finished GCL product. This program allows immediate verification of critical production parameters used to monitor production quality, while the laboratory test program will verify the specified engineering characteristics of the GCL.

#### 2.1 Geosynthetic Components

Depending upon the type of GCL the top and bottom geosynthetic components may consist either of a woven geotextile, nonwoven geotextile, or flexible membrane liner laminated to a geotextile. ASTM D5889 states the minimum types of tests and their frequencies for the MQC of the geosynthetic materials used in the GCL.

##### 2.1.1 Woven Geotextile

The woven geotextile is manufactured elsewhere and is delivered to the GCL plant in rolls up to 1,500 yards long, depending on the style being used. CETCO receives and maintains on file manufacturer's certifications stating that the products meet the engineering specifications listed in Table 2-1.

Each geotextile roll is labeled with a lot and roll number, and the date and time at which a roll is placed into GCL production is recorded on a daily operating log. This procedure allows the usage of the woven geotextile to be tracked such that its lot and roll number can be directly determined from the corresponding GCL lot and roll number.

If the overall quality of the of the woven geotextile roll is unknown (e.g., not certified by the manufacturer, lot and roll tag missing, or the data misplaced) full roll-width samples are obtained at a frequency of one per every 200,000 square feet to confirm that the geotextile is acceptable with respect to its required mass per unit area and grab strength values.

##### 2.1.2 Non-Woven Geotextile

The non-woven needlepunched geotextile is manufactured in rolls up to 1,500 yards long by CETCO or elsewhere and is subjected to conformance tests at the plant of origin prior to delivery to the GCL plant. CETCO receives and maintains on file manufacturer's certifications stating that the products meet the engineering specifications listed in Table 2-1.

Each geotextile roll is labeled with a lot and roll number, and the date and time at which a roll is placed into GCL production is recorded on a daily operating log. This procedure allows the usage of the woven geotextile to be tracked such that its lot and roll number can be directly determined from the corresponding GCL lot and roll number.

If the overall quality of the of the woven geotextile roll is unknown (e.g., not certified by the manufacturer, lot and roll tag missing, or the data misplaced) full roll-width samples are obtained at a frequency of one per every 200,000 square feet to confirm that the geotextile is acceptable with respect to its required mass per unit area and grab strength values.

### 2.1.3 Geomembrane/Geofilm Laminated to Geosynthetic

When a geomembrane or geofilm is laminated to the GCL as in the CL Product Series, the geomembrane or geofilm shall be subjected to the MQC testing outlined in Table 2-2 either by the supplier or by CETCO.

## 2.2 Sodium Bentonite

ASTM D5889 identifies the minimum types of tests and their frequencies for the MQC of sodium bentonite prior to incorporation into GCLs. Granular sodium bentonite incorporated into the GCL is supplied by one or more bentonite plants. The bentonite manufacturer provides test data for each shipment received at the GCL plant.

The sodium bentonite is typically railed or conveyed to the GCL plants. Railcars hold approximately 90 tons. The clay testing is therefore performed twice per railcar, but a minimum of every 50 tons. QA procedures for bentonite shipped to the GCL plant primarily involves collecting and maintaining Certificates of Analysis (COAs) issued by the bentonite manufacturer with each bentonite shipment.

The quality parameters for the sodium bentonite are its swell index and fluid loss, which are indicators of GCL hydraulic performance. The clay in CETCO GCLs has a minimum swell index of 24 mL/2g, as determined in accordance with ASTM D5890. The clay in CETCO GCLs has a maximum fluid loss value of 18 mL, as determined in accordance with ASTM D5891. A summary of the bentonite MQA parameters is provided in Table 2-3.

Additionally, shipment COAs indicate moisture content and particle sizing. These properties do not pertain to final GCL quality. They pertain to properties needed for efficient processing of the bentonite into the GCL at CETCO plants. They are **not** part of the ASTM D5889 GCL Quality Control.

The CETCO bentonite COAs are received and retained at the GCL plant, and the accompanying clay lot numbers are recorded in the operations log using procedures similar to those described in Section 2.1 for the geosynthetic components. In order to coordinate the usage of the certified bentonite and the production of GCL, the lot number and the time/date of use is recorded in the daily log. Thus, the daily log allows every roll of GCL to be traced to the bentonite lot number. More information regarding the reporting and record keeping procedures is presented in Section 3.

## 2.3 Production Processes

The machinery utilized for the production of GCLs is highly controlled, and critical production parameters are automatically monitored. Human input into the manufacturing process is critical, however, to the extent necessary to maintain the machinery and the requisite QA/QC information. As described below, quality control procedures during production focus primarily on maintaining the calibration and operation of the production system.

### 2.3.1 Punch Density (Bentomat GCLs Only)

Punch density refers to the number of needlepunched fibers per unit area joining the top and bottom geotextiles of the Bentomat GCLs. The correct punch density has been determined to correspond to various operational parameters, which are maintained during production. Calibration of the needling machinery is performed regularly, and Bentomat peel test results provide a quantitative verification that the punch density meets minimum standards.

### 2.3.2 Lamination (CL/CLT Series)

Lamination refers to bonding a geomembrane or geofilm to the needlepunched geotextile with an adhesive.

### 2.3.3 Roll Length and Width

The dimensions of the GCL panels are directly evaluated. Length measurements are made through continuous monitoring by an electronic linear measuring device connected to the wind-up roll at the end of the production line. When the standard length of 150 feet is reached, the roll is cut and prepared for storage or shipment. Periodically, a GCL roll is manufactured to a length of 153 feet such that a full roll-width QA sample may be taken.

It is noted that shorter rolls are produced when production is temporarily suspended for materials re-supply. These short rolls are often useful for completing the square footage requirements for a particular job. The length of all short rolls is recorded as well. The correct width of either 14.5 or 15 feet is maintained by periodic width measurements are made prior to roll-up using a tape measure placed perpendicular to the machine direction of the GCL.

### 2.3.4 External Markings

GCLs are furnished with two dashed lines ("lap line" at 6 inches and "match line" at 9 inches) on each end of the upper geosynthetic to facilitate its installation. The lines are applied to the finished GCL as it passes by a system of rotating stationary inking devices. The ink reservoirs are checked frequently during each shift to ensure an adequate supply during production. Visual observations of lap line placement are also conducted by the shift supervisor. The system is automated and requires few adjustments, although the locations of the lines are measured at a frequency of at least once per shift. The lines on standard rolls of GCL are located within 1/4 inch of the 6 and 9-inch points as measured perpendicular from each edge.

The GCL product is marked with the word "CETCO" to facilitate product identification.

### 2.3.5 Equipment Inspection

The mechanical equipment and appurtenant devices used in the manufacture of GCL are regularly inspected and maintained in accordance with the overall plant maintenance program.

## 2.4 Finished GCL

This section of the manual describes the sampling and testing procedures implemented to ensure that each roll of GCL has been manufactured to meet its standard design specifications. **CETCO defines a lot of GCL as one week of production of a product at a particular plant.** ASTM D5889 outlines the minimum types of tests and their frequency for the MQC of the finished GCL. Besides the clay mass per unit area, clay moisture content, grab tensile strength and flux listed in ASTM D5889, CETCO also performs peel strength and shear strength testing on its Bentomat products. Based on testing frequency, rolls are identified during production so that their length may be extended by 3 feet in order to accommodate sampling. Table 2-4 presents the finished GCL MQA test specifications.

The bentonite mass per unit area test procedures are performed in accordance with ASTM D5993. It must be noted that an accurate bentonite mass per unit area determination requires that the moisture content of the finished product also be determined. In ASTM D5993, bentonite mass per unit area is defined as the *dried* mass per area of the *bentonite*, as opposed to the mass per area of the entire GCL. In other words, dried bentonite mass per area is calculated by subtracting out the weight of the water in a GCL sample *and* the weight of the geosynthetics. The geosynthetic weights are *typical* values because it is neither possible nor practical to attempt removal of the bentonite entirely from the GCL in order to weigh each component separately. Five test specimens are cut from each full roll-width sample as shown in Figure 2-1. The number of test specimens obtained per sample may be modified as variability data is generated.

The specimens for grab tensile testing are taken from the same full roll width samples at a frequency of one per 200,000 square feet and are tested according to the procedures in ASTM D6768 (grab strength per unit width, reported in lbs/in or N/cm). No fewer than five specimens per sampling event are tested. If requested on a particular project, results may be reported per method ASTM D4632, modified for GCLs with 4-inch grips (total grab strength, reported in lbs or N).

Index flux and hydraulic conductivity testing are performed at a rate of one per production lot (once per week). Index flux is run per ASTM D5887 and hydraulic conductivity is calculated by measuring the thickness and using the formulas presented in ASTM D5887.

Peel testing is performed on Bentomat needlepunched products at a minimum frequency of one per 40,000 square feet. Peel testing is performed following ASTM Method D6496, which reports average peel strength over the sample width, in lbs/in or N/cm. In the peel test, a Bentomat specimen is partly de-laminated by cutting the needlepunched bonds between the geotextiles just enough to allow each geotextile to be separately inserted into the grips of the tensile testing device. If requested on a particular project, results may be reported per method ASTM D4632, modified for GCLs with 4-inch grips (peak peel strength, reported in lbs or N).

Internal direct shear testing is performed per ASTM D5321 (Geosynthetics) or D6243 (GCLs) on Bentomat needlepunched products on a periodic basis, typically annually, at CETCO's Corporate Laboratory in Arlington Heights, IL. The GCL is hydrated under a load of 200 psf for 48 hours and then sheared at 0.004 in./min. Periodic direct shear testing is also performed under higher normal loads (10,800 psf) by an outside GAI-LAP accredited geosynthetic laboratory.

Specimens of finished GCL are archived for 12 months and then are discarded. These samples can be utilized for post-project testing if a dispute arises. However, it is the **purchaser's responsibility** to



ensure that representative samples of the GCL are retained if testing is requested after this one-year period has expired.

## 2.5 Needle Detection and Removal

The production of needlepunch-reinforced GCLs such as Bentomat, involves driving thousands of needles at hundreds of strokes per minute through the bentonite and encapsulating geotextiles. Significant forces are applied to the needles during this process. A few needles will inevitably break, and needle fragments must be removed. CETCO follows a three-part strategy of prevention, detection, and removal, to prevent the presence of needle fragments in the finished product.

Needle breakage is minimized by implementing several measures related to optimization of bentonite particle size, needle type selection, and the operation of the needling loom (including frequent bed plate and stripper plate cleaning). However, even with these measures, some breakage is inevitable. Therefore, a set of powerful magnets is arranged downstream from the loom, across the width of the GCL. Positioned just over the surface of the textiles, the magnets effectively remove needle fragments that break after striking a clay particle. Almost all needle fragments are removed by the magnets, but a few do remain in the product and must be detected and removed.

A system of magnetic metal detectors distributed across the width of the GCL is used to scan the product for needle fragments. Located after the magnets, the detectors divide the roll into discrete segments. If a needle fragment is detected in one of the segments, a production crewperson stops the material in-line and checks for needle fragment(s). Rolling of the material is then resumed and it passes a second metal detector. If metal is still detected, a tag is placed on the outside edge of the roll. Flagged rolls are set aside for a secondary detection and removal process, where a "re-roll station" is used to unroll the GCL to the spot where the tag was placed. This section of the roll is scanned with a hand-held detector and visually inspected until the needle fragment is found. Protruding needle fragments are removed, and the rolls is then wound and packaged. The needle detection and removal process is shown in Figure 2-2.

## 2.6 Plant Storage and Handling

Care is taken at the plant to handle and store the finished rolls of GCL in a manner that prevents damage to the product and its packaging. All handling of the product must be executed with a forklift or other suitable vehicle outfitted with a carpet pole or "stinger." The stinger must be strong enough to support the weight of a full roll of GCL with minimal bending.

GCL storage is limited to stacks no higher than 7 rolls. This provides easy equipment access and minimizes the chance for damage to the roll core and to the GCL itself. The inventories of GCL and its component materials will be rotated for additional protection against potential long-term, storage-related damage.

## SECTION 3

### RECORDING AND RECORD KEEPING

GCL is manufactured from three different raw materials, each requiring its own QA/QC testing and record keeping. The finished GCL product also requires testing, so comprehensive documentation of all GCL manufacturing activities is essential in order to properly manage the large amount of information generated during production. This section of the GCL MQA/MQC Manual lists the quality-related information recorded and provides the procedures for maintaining the records.

#### 3.1 Plant Records

Daily Operations Log. Plant records include both a continuous daily operations log and a log of QA test data. Items included in the daily production log include:

- Current date and shift.
- Current lot and roll number in production.
- Length and width of each roll produced.
- A record of raw material usage, including lot/roll and railcar numbers.
- Documentation of relevant information affecting production.

QA Log. A separate log is maintained at the plant to record information pertaining to test data. Information included in the QA log includes:

- Date, time, lot, and roll number of all tested samples.
- QA test results summarized in tabular form.
- Name of person conducting the tests.
- Actions taken if test results were unsatisfactory.

The QA log may be kept electronically as data is tabulated directly on an available computer or may be kept in writing, at the discretion of the shift supervisor.

For future reference, both of these logs shall be maintained at the plant indefinitely. Copies of test results recorded on the QA log will be provided as required. The daily production log and the QA log are the most important means by which GCL quality is documented; therefore, these logs must be neatly and accurately maintained.

Product Labeling. Adhesive labels are placed on the outer wrap of every GCL roll and on the core. The labels themselves provide the following information:

- Length and width of roll.
- Total weight of roll.
- Product identification (material codes and type designation).
- Lot number and roll number.

Packing Slips. The plant provides the site manager or his designate with a packing slip for each shipment of GCL to the project site. The packing slip includes the following information:

- CETCO order number and customer P.O. number.
- GCL lot numbers, roll numbers, roll dimensions, and roll weights.
- Shipment address.

Copies of the packing slips shall be maintained at the plant.

### 3.2 Supplemental Laboratory Records

CETCO shall maintain complete records of all testing performed at its laboratories or outside laboratories in the event that supplemental MQA testing is required for a particular project. Using standard laboratory record keeping procedures, CETCO shall maintain records, as required for the project, of:

- Results of physical and hydraulic tests on geosynthetic components, bentonite, and GCL.
- Documentation of follow-up action, if any, after evaluation of test data.

### 3.3 GCL Manufacturing Certification Reports

Each shipment of GCL for which MQA/MQC documentation is required will be properly accompanied by a hard copy MQA/MQC Data Package. The package includes a certification statement indicating to the customer that the purchased GCL complies with all of the properties certified by CETCO Lining Technologies Group.

Additionally, as of September 2004, an E-Cert GCL MQC/MQA certification system was implemented. Electronic copies of MQC/MQA Data Packages are posted on the CETCO LT Engineering Web-site (<http://www.cetco.com/LTE/>), for direct retrieval by project technical contacts. The secure website is accessed by customers using a unique password/username, provided to the customer by either the Cartersville or Lovell Quality Assurance Coordinator. Each customer will only have access to their specific projects. The E-Cert packages are streamlined versions of the hard copy MQA/MQC packages – an example is included in Appendix B.



The supplier certifications for the bentonite clay for free swell and fluid loss will be included in the certification reports. Supplier MQA/MQC data on the geotextiles will be included, when required by the project specifications. The GCL MQA/MQC test data reports for bentonite mass per unit area, grab tensile strength and peel strength (for Bentomat orders) will be furnished, as well as the QA tracking forms identifying the raw material lots associated with each GCL lot and roll number for the order. Due to the time required to run the index flux, hydraulic conductivity and internal direct shear testing, this information, when required per the project specifications, will be forwarded under separate cover.

As each roll of material goes through the needle detection and removal system described in Section 2.5, each MQA/MQC package should also include the following needle detection certification statement:

*"CETCO hereby affirms that all Bentomat geosynthetic clay liner material manufactured for this project is continually passed under a magnet for needle removal and then screened with a metal detection device. CETCO certifies Bentomat to be essentially free of broken needles and fragments of needles that would negatively effect the performance of the final product."*

## SECTION 4

### SUMMARY OF GCL MQA/MQC PLAN

This section provides a tabular summary of the MQA/MQC plan for finished GCL and its component materials. Table 4-1 and Table 4-2 serve as convenient references for the overall scope of the plan but should not be used until the plan is read and understood in its entirety. The tables illustrate that the plan is designed to provide comprehensive verification of GCL quality. It is emphasized that the program will be amended as required to conform to future product/process improvement.

FIGURE 1-1  
CETCO GCL MQA/MQC PROGRAM  
ORGANIZATION CHART

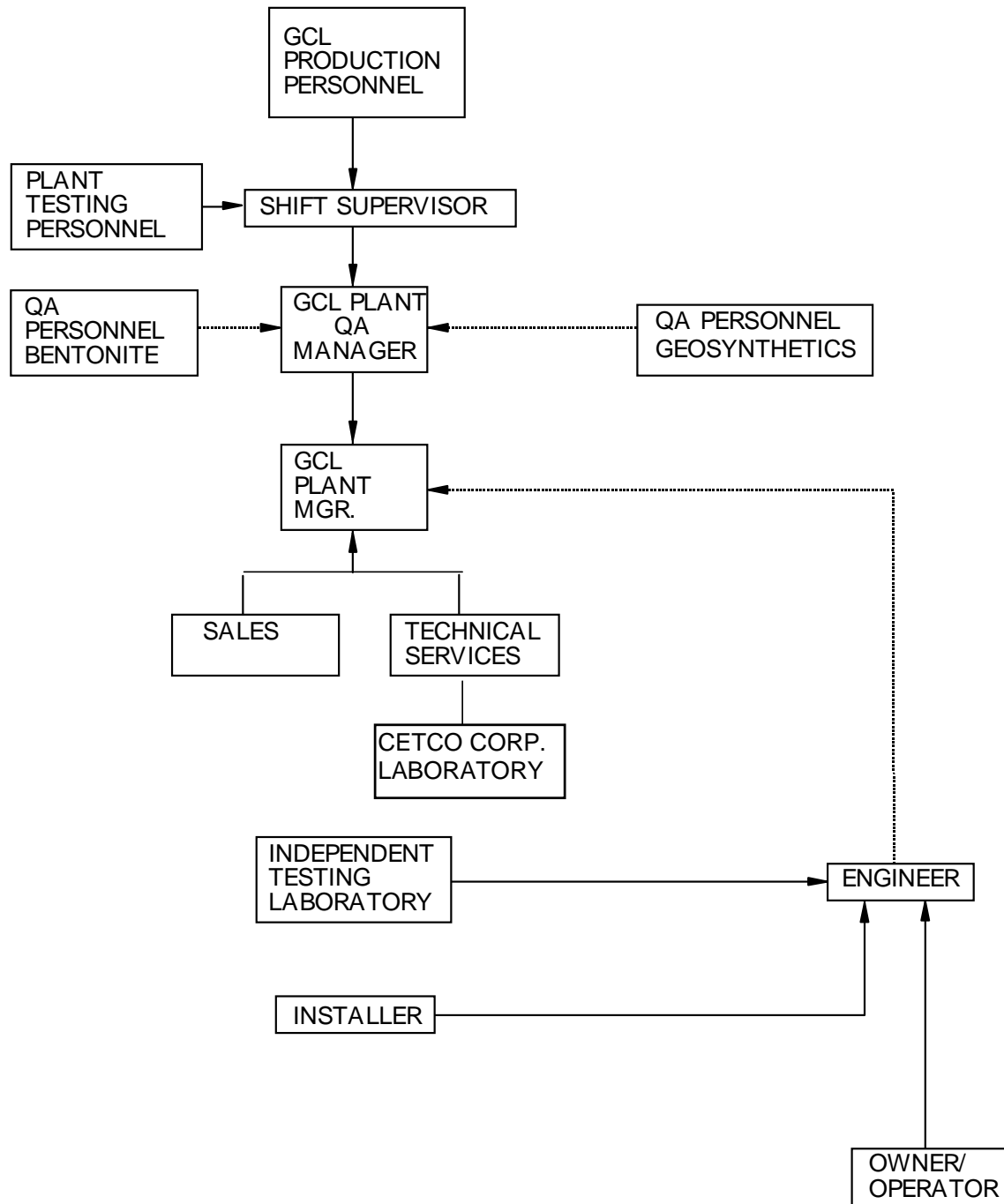
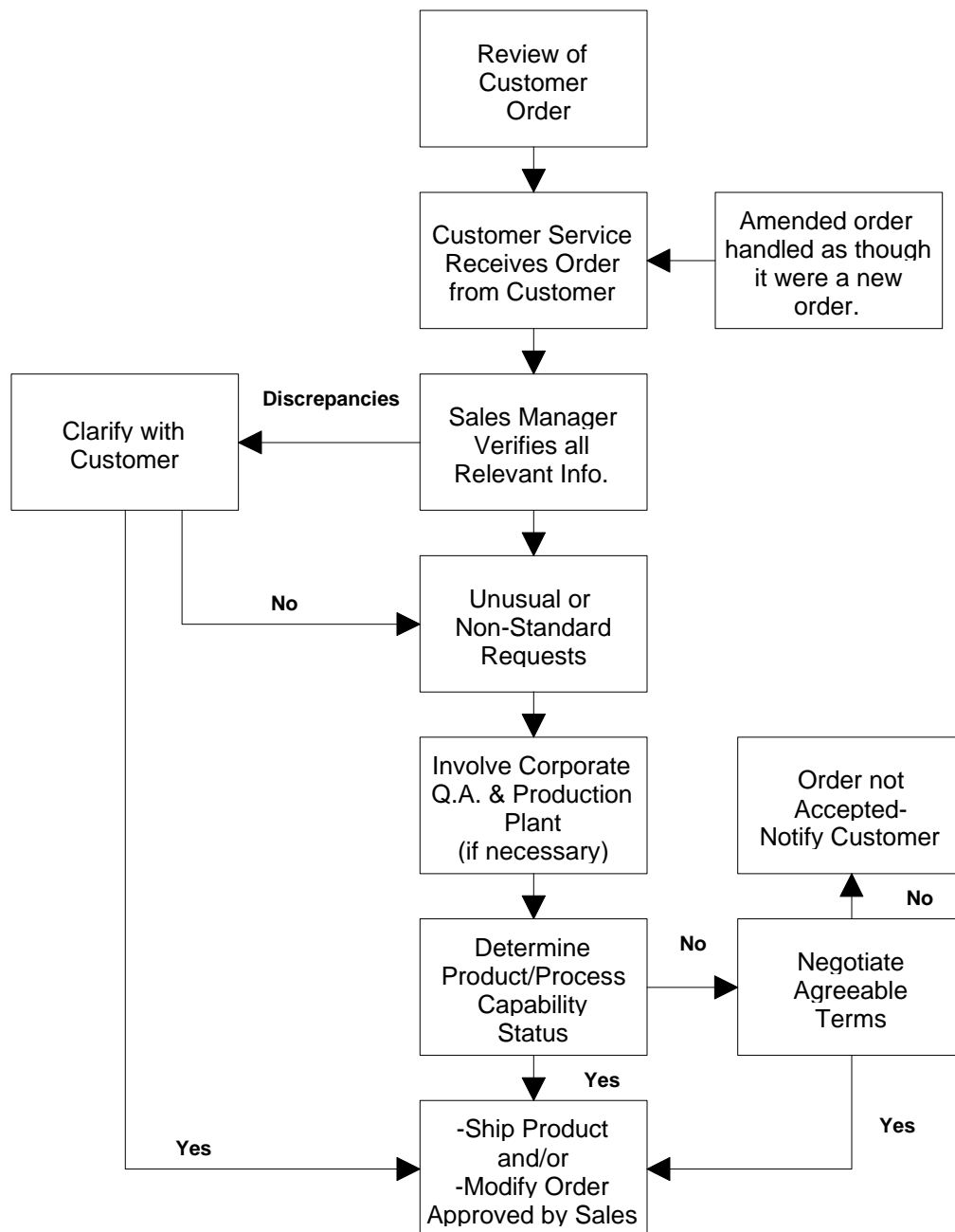
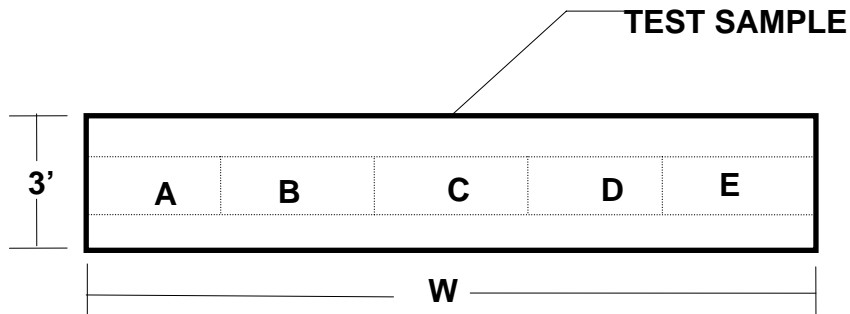


FIGURE 1-2  
CETCO ORDER REVIEW PROCESS



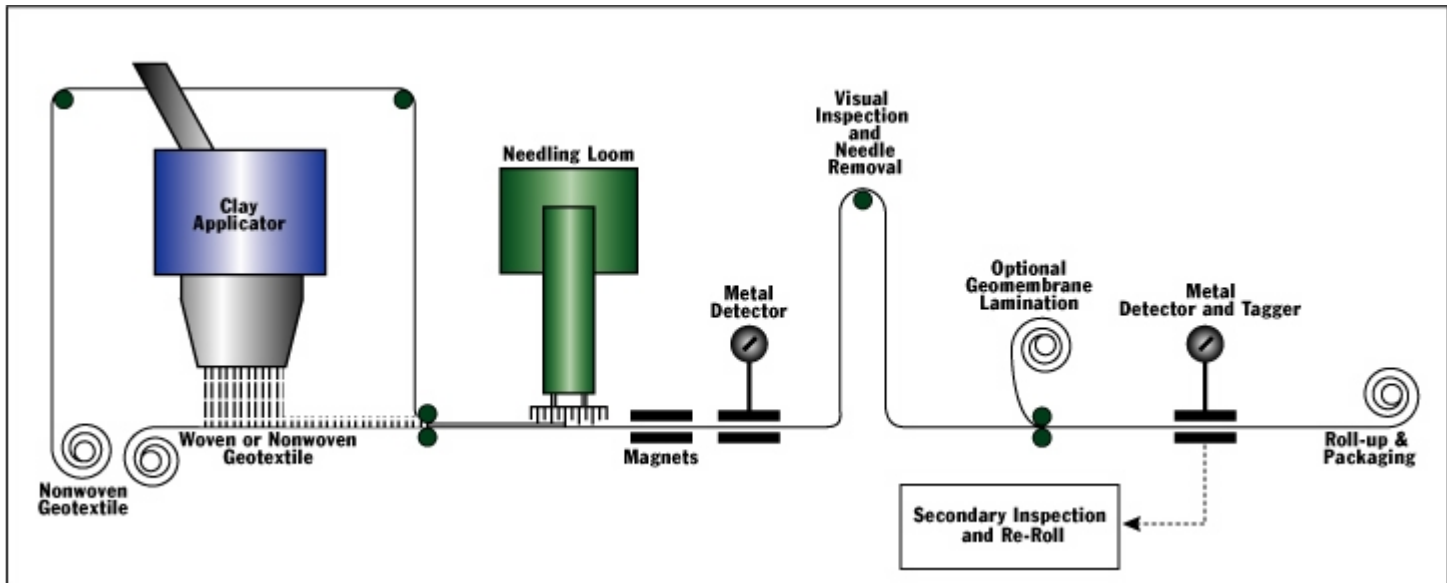
**FIGURE 2-1  
GUIDE FOR OBTAINING SAMPLES  
AND TEST SPECIMENS**



## NOTES

1. Dashed lines represent acceptable "windows" from which test specimens A, B, C, D, and E are cut.
2. The specimens are cut at random locations within each window. For the standard 15-foot wide GCL product, the windows are 3 ft long and for standard 14.5 ft-wide GCL products, the windows are 2.9 ft long.
3. All samples must be cut using a die and hydraulic punch.
4. At least one 1' x 1' specimen is archived (see Section 3).
5. The above figure depicts sampling guidelines for nonwoven geotextile manufactured by CETCO as well as the finished GCL product.

FIGURE 2-2  
SCHEMATIC OF NEEDLE DETECTION  
AND REMOVAL SYSTEM



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**TABLE 2-1**  
**MOA PARAMETERS FOR**  
**GEOTEXTILE COMPONENT OF GCL**

PROPERTY	TEST METHOD	FREQUENCY	RECORDED VALUE <sup>1</sup>
Grab Strength	ASTM D 4632	200,000 sq. ft	Typical and MARV
Mass per Unit Area	ASTM D 5261	200,000 sq. ft	MARV

#### NOTES

1. Values represent geotextile prior to incorporation into GCL.



TABLE 2-2  
MQC PARAMETERS FOR  
GEOMEMBRANE/GEOFILM COMPONENT OF  
CL GCL SERIES

PROPERTY	TEST METHOD	FREQUENCY	RECORDED VALUE <sup>1</sup>
Grab Strength	ASTM D 638 or D 882	200,000 sq. ft	Typical & MARV
Thickness	ASTM D 5199	200,000 sq. ft	Typical & MARV
Mass per Unit Area	ASTM D 5261	200,000 sq. ft	Typical & MARV

#### NOTES

1. Values represent geomembrane/geofilm laminate prior to incorporation into GCL.

TABLE 2-3  
MQA PARAMETERS FOR  
SODIUM BENTONITE COMPONENT OF GCL

PROPERTY <sup>1</sup>	TEST METHOD	FREQUENCY	REQUIRED VALUE
Swell Index	ASTM D 5890	every 50 tonnes	24 mL/2g minimum
Fluid Loss	ASTM D 5891	every 50 tonnes	18 mL maximum
Moisture Content	ASTM D 2216	every 50 tonnes	12% maximum
Particle Size <sup>2</sup>	ASTM C136	every 50 tonnes	100 % typ. - #8 mesh 1 % typ. - #200 mesh

#### NOTES

1. These parameters are for the bentonite incorporated into the GCL and do not necessarily reflect the properties of the bentonite in the finished product. This is especially the case with moisture content.
2. Particle size range based on available bentonite supply. Particle size may change depending on bentonite availability.

**TABLE 2-4**  
**MQA/MQC PARAMETERS FOR FINISHED GCL**

<b>PROPERTY</b>	<b>TEST METHOD<sup>1</sup></b>	<b>FREQUENCY<sup>2</sup></b>	<b>REQUIRED VALUE<sup>3</sup></b>
Bentonite Mass/Area <sup>4</sup>	ASTM D 5993	40,000 sq. ft	0.75 lbs./sq. ft
Tensile Strength <sup>5</sup>	ASTM D 6768	200,000 sq. ft	<b>Product dependent</b> (see Table 4-1 and Table 4-2)
Peel Strength <sup>5</sup>	ASTM D 6496	40,000 sq. ft	<b>For needlepunched GCL only;</b> <b>Product dependent</b> (see Table 4-1 and Table 4-2)
Index Flux <sup>6</sup>	ASTM D 5887	Weekly	<b>Product dependent</b> (see Table 4-1 and Table 4-2)
Permeability <sup>6</sup>	ASTM D 5887	Weekly	<b>Product dependent</b> (see Table 4-1 and Table 4-2)
Internal Shear <sup>7</sup>	ASTM D 5321 ASTM D 6243	Periodic	<b>Product dependent</b> (see Table 4-1 and Table 4-2)

## NOTES

1. ASTM methods are also modified wherever necessary to facilitate the testing of a GCL rather than a geotextile.
2. The test frequency listed is based on ASTM D5889. Actual frequency may vary due to roll dimensions.
3. All values are minimum average roll values (MARVs) unless otherwise indicated.
4. Bentonite mass per unit area is exclusive of the average weight of the geotextiles and is normalized to 0 percent moisture content per ASTM D 5993.
5. Tensile values represent testing with the test specimens oriented in the machine direction. Results reported by D 6768 and D 6496 are in units of lbs/in or N/cm. If requested, results also be reported by D 4632, modified with 4-inch grips, in units of lbs or N.
6. Index flux and permeability with deaired distilled water at 5-psi maximum confining stress and 2 psi head. Frequency is whichever is greater.
7. Internal direct shear sample hydrated for 48 hours at 200 psf normal load and run at 0.004 in/min.

TABLE 4-1  
BENTOMAT MQA/MQC PLAN SUMMARY<sup>1</sup>  
(Version 8.0, revised November 2009)

MATERIAL	QUALITY PARAMETER <sup>1</sup>	TEST METHOD <sup>2</sup>	TEST FREQUENCY <sup>3</sup>	CERTIFIED VALUE <sup>4</sup>
<b>Bentonite<sup>5</sup></b>	Swell Index	ASTM D 5890	50 tonnes	24 mL/2g min.
	Fluid Loss	ASTM D 5891	50 tonnes	18 mL max.
	Moisture Content	ASTM D 2216	50 tonnes	12 percent max.
	Particle Type: Granular <sup>6</sup>	ASTM C 136	50 tonnes	100% typical- #8 1% typical - #200
<b>Bentomat CL/CLT</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	45 lbs/in (CL/CLT)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	3.5 lbs/in (CL/CLT)
	Index Flux <sup>9</sup>	ASTM D 5887	Periodic	$1 \times 10^{-9} \text{ m}^3/\text{m}^2/\text{sec}$ for CL/CLT
	Permeability <sup>9</sup>	ASTM D 5887	Periodic	$5 \times 10^{-10} \text{ cm/sec}$ for CL/CLT
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
<b>Bentomat DN</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	50 lbs/in (DN)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	3.5 lbs/in (DN)
	Index Flux <sup>11</sup>	ASTM D 5887	Weekly	$1 \times 10^{-8} \text{ m}^3/\text{m}^2/\text{sec}$
	Permeability <sup>11</sup>	ASTM D 5887	Weekly	$5 \times 10^{-9} \text{ cm/sec}$
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
<b>Bentomat ST</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	30 lbs/in (ST)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	3.5 lbs/in (ST)
	Index Flux <sup>11</sup>	ASTM D 5887	Weekly	$1 \times 10^{-8} \text{ m}^3/\text{m}^2/\text{sec}$
	Permeability <sup>11</sup>	ASTM D 5887	Weekly	$5 \times 10^{-9} \text{ cm/sec}$
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical

MATERIAL	QUALITY PARAMETER <sup>1</sup>	TEST METHOD <sup>2</sup>	TEST FREQUENCY <sup>3</sup>	CERTIFIED VALUE <sup>4</sup>
<b>Bentomat SDN</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	25 lbs/in (SDN)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	3.0 lbs/in (SDN)
	Index Flux <sup>11</sup>	ASTM D 5887	Weekly	1 x 10 <sup>-8</sup> m <sup>3</sup> /m <sup>2</sup> /sec
	Permeability <sup>11</sup>	ASTM D 5887	Weekly	5 x 10 <sup>-9</sup> cm/sec
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
<b>Bentomat 200R</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	30 lbs/in (200R)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	1.0 lbs/in (200R)
	Index Flux <sup>11</sup>	ASTM D 5887	Weekly	1 x 10 <sup>-8</sup> m <sup>3</sup> /m <sup>2</sup> /sec
	Permeability <sup>11</sup>	ASTM D 5887	Weekly	5 x 10 <sup>-9</sup> cm/sec
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	150 psf typical
<b>Bentomat 600CL</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	30 lbs/in (200R)
	Peel Strength <sup>8</sup>	ASTM D 6496	40,000 sq. ft	1.0 lbs/in (200R)
	Index Flux <sup>9</sup>	ASTM D 5887	Periodic	1 x 10 <sup>-9</sup> m <sup>3</sup> /m <sup>2</sup> /sec for CL/CLT
	Permeability <sup>9</sup>	ASTM D 5887	Periodic	5 x 10 <sup>-10</sup> cm/sec for CL/CLT
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	150 psf typical

## NOTES

- Please refer to the CETCO GCL MQA/MQC manual for additional details regarding this information. Also, the listed values of each parameter are subject to change as manufacturing processes are refined. Contact CETCO for confirmation of this information.
- ASTM procedures modified as necessary to facilitate the testing of a GCL instead of a geotextile.
- The listed test frequency is based on ASTM D 5889 *Standard Practice for Quality Control of Geosynthetic Clay Liners*. Actual frequency of all tests may vary slightly due to varying roll dimensions.
- All required values listed are minimum average roll values (MARVs) unless otherwise indicated.
- These parameters are for the bentonite before it is incorporated into the finished Bentomat/Claymax product.
- All bentonite is granular type. The particle size distribution may vary slightly.
- Mass per unit area of the bentonite component of the Bentomat/Claymax, obtained by weighing an oven-dried sample of known area and subtracting the typical geotextile mass per unit area values. The resulting values are normalized to reference moisture content of 0 percent.
- All tensile testing represent values with the test specimens oriented in the machine direction. Results reported by D 6768 and D 6496 are in units of lbs/in or N/cm. If requested, results also be reported by D 4632, modified with 4-inch grips, in units of lbs or N.
- ASTM D 5887 Index Flux and Hydraulic Conductivity test with deaired-distilled deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 95 gal/acre/day. This flux value is equivalent to a permeability of 5 x 10<sup>-10</sup> cm/sec for typical GCL thickness.
- ASTM D 5321 (geosynthetics) or D 6243 (GCLs) internal direct shear performed on GCL sample hydrated under 200 psf normal load and then sheared at 0.004 in./min.
- ASTM D 5887 Index Flux and Hydraulic Conductivity test with deaired-distilled deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. This flux value is equivalent to a permeability of 5 x 10<sup>-9</sup> cm/sec for typical GCL thickness.

**TABLE 4-2**  
**CLAYMAX MQA/MQC PLAN SUMMARY<sup>1</sup>**

(Version 8.0, November 2009)

<b>MATERIAL</b>	<b>QUALITY PARAMETER<sup>1</sup></b>	<b>TEST METHOD<sup>2</sup></b>	<b>TEST FREQUENCY<sup>3</sup></b>	<b>CERTIFIED VALUE<sup>4</sup></b>
<b>Bentonite<sup>5</sup></b>	Swell Index	ASTM D 5890	50 tonnes	24 mL/2g min.
	Fluid Loss	ASTM D 5891	50 tonnes	18 mL max.
	Moisture Content	ASTM D 2216	50 tonnes	12 percent max.
	Particle Type: Granular <sup>6</sup>	ASTM D 421	50 tonnes	100% typical - #8 1% typical - #200
<b>Claymax 200R</b>	Bentonite Mass/Area <sup>7</sup>	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Tensile Strength <sup>8</sup>	ASTM D 6768	200,000 sq. ft	40 lbs/in
	Peel Strength <sup>8</sup>	ASTM D 6496	N/A	N/A
	Index Flux <sup>9</sup>	ASTM D 5887	Weekly	1 x 10 <sup>-8</sup> m <sup>3</sup> /m <sup>2</sup> /sec
	Permeability <sup>9</sup>	ASTM D 5887	Weekly	5 x 10 <sup>-9</sup> cm/sec
	Internal Shear <sup>10</sup>	ASTM D 5321 ASTM D 6243	Periodic	100 psf

## NOTES

- Please refer to the CETCO GCL MQA/MQC manual for additional details regarding this information. Also, the listed values of each parameter are subject to change as manufacturing processes are refined. Contact CETCO for confirmation of this information.
- ASTM procedures modified as necessary to facilitate the testing of a GCL instead of a geotextile.
- The listed test frequency is based on ASTM D 5889 *Standard Practice for Quality Control of Geosynthetic Clay Liners*.
- All required values listed are minimum average roll values (MARVs) unless otherwise indicated.
- These parameters are for the bentonite before it is incorporated into the finished Bentomat product.
- All bentonite is granular type. The particle size distribution may vary slightly.
- Mass per unit area of the bentonite component of the Bentomat, obtained by weighing an oven-dried sample of known area and subtracting the typical geotextile mass per unit area values. The resulting values are normalized to reference moisture content of 0 percent.
- All tensile testing represent values with the test specimens oriented in the machine direction. Results reported by D 6768 and D 6496 are in units of lbs/in or N/cm. If requested, results also be reported by D 4632, modified with 4-inch grips, in units of lbs or N.
- ASTM D 5887 Index Flux and Hydraulic Conductivity test with deaired-distilled deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. This flux value is equivalent to a permeability of 5 x 10<sup>-9</sup> cm/sec for typical GCL thickness.
- ASTM D5321 (Geosynthetics) or D6243 (GCLs) internal direct shear performed on GCL sample hydrated under 200 psf normal load and then sheared at 0.004 in./min.
- ASTM D 5887 Index Flux and Hydraulic Conductivity test with deaired-distilled deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 95 gal/acre/day. This flux value is equivalent to a permeability of 5 x 10<sup>-10</sup> cm/sec for typical GCL thickness.

## APPENDIX A REFERENCED STANDARDS AND TEST METHODS

ASTM C136	Standard Practice for Sieve Analysis of Fine and Coarse Aggregates
ASTM D422	Standard Test Method for Particle-Size Analysis of Soils
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D2216	Standard Test Method for Laboratory Determination of Moisture Content of Soil and Rock
ASTM D4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D4643	Determination of Moisture Content of Soil by the Microwave Oven Method
ASTM D5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
ASTM D5261	Standard Test Method for Measuring Mass Per Unit Area of Geotextiles
ASTM D5321	Standard Test Method for Direct Shear of Geosynthetics
ASTM D5887	Standard Test Method or Measurement of Index Flux Through Saturated GCL Specimens Using a Flexible Wall Permeameter
ASTM D5889	Standard Practice for Quality Control of GCLs
ASTM D5890	Standard Test Method for Swell Index Measurement of the Clay Mineral Component of GCLs
ASTM D5891	Standard Test Method for Measurement of Fluid Loss of Clay Mineral Component of GCLs
ASTM D5993	Standard Test Method for Measuring the Mass Per Unit of GCLs
ASTM D6243	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method
ASTM D6496	Standard Test Method for Determining Average Bonding Peel Strength Between Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
ASTM D6768	Standard Test Method for Tensile Strength of Geosynthetic Clay Liners





**EXAMPLE**

Date: 11/16/2009  
Purchase Order: 000000000  
ORDER NUMBER: 000000000

ABC Landfill

Example Certification Package

To Whom it May Concern:

Please find enclosed the MQA/MQC test data package for Geosynthetic Clay Liner shipments to ABC Landfill.

The enclosed data package includes results of all the MQC tests required by ASTM D5889, with the exception of index flux/hydraulic conductivity. This test, which is run according to ASTM D5887, is normally performed once per production lot (once per week), unless a higher frequency is required by the project specifications. Because of the GCL's low permeability, this test can take several weeks to complete. The index flux/hydraulic conductivity results associated with this lot of material will be provided under separate cover as soon as they are available.

Although the index flux/hydraulic conductivity test results are not yet available, CETCO accepts responsibility for our GCL should the index flux/hydraulic conductivity tests produce unacceptable results. If, upon delivery and prior to installation, individual rolls of GCL are found to be nonconforming to accepted project specifications, CETCO will replace the nonconforming material at no charge.

Questions regarding this information should be directed to Chris Athanassopoulos, Technical Support Engineer, at (847) 851-1831.

Sincerely,

Quality Assurance Coordinator  
CETCO Cartersville Plant



**GEOSYNTHETIC CLAY LINER  
MANUFACTURING QUALITY ASSURANCE DATA PACKAGE**

***EXAMPLE***

PROJECT NAME: ABC Landfill  
CUSTOMER P.O.: 000000000  
ORDER NUMBER: 000000000  
PREPARED FOR: Example Certification Package

**CONTENTS:**

- Product Certifications
- GCL Order packing list and MQA tracking form
- GCL manufacturing quality control test data
- Bentonite clay certification
- Raw material test results

PREPARED BY: Melanie King  
Quality Assurance Coordinator  
CETCO  
218 Industrial Park

Cartersville, GA 30121  
Telephone: (770) 387-7773  
E-Mail: melanie.king@cetco.com



**EXAMPLE**

## PRODUCT CERTIFICATIONS

PROJECT NAME: ABC Landfill  
CUSTOMER P.O.: 000000000  
ORDER NUMBERS: 000000000  
PREPARED FOR: Example Certification Package

The GCL manufactured for the above-referenced order number(s) is certified to meet the values listed in the tables below:

### GCL PROPERTY SPECIFICATIONS FOR BENTOMAT ST

Test Method	Test Method Property	Test Frequency	Certified Value
ASTM D 5891	Bentonite Fluid Loss	1 per 50 Tons	18 ml Max
ASTM D 5993	Bentonite Mass/Area	40,000 sq ft (4000 sq m)	0.75 lb /sq ft Min
ASTM D 5890	Bentonite Swell Index	1 per 50 Tons	24 ml/2g Min
ASTM D 6768	GCL Grab Strength	200,000 sq ft (20,000 sq m)	30 lbs/in MARV
ASTM D 6243	GCL Hydrated Internal Shear Strength	Periodic	500 psf typ @ 200 psf normal load
ASTM D 5887	GCL Hydraulic Conductivity	Weekly	5.0E-9 cm/s Max
ASTM D 5887	GCL Index Flux	Weekly	1.0E-8 m3/m2/s Max
ASTM D 6496	GCL Peel Strength	40,000 sq ft (4000 sq m)	3.5 lbs/in Min

Bentonite property tests are performed at a bentonite processing facility before shipment to CETCO's production facility. All tensile testing is in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.

### NEEDLE DETECTION AND REMOVAL PROCEDURE

CETCO hereby affirms that all Bentomat<sup>®</sup> geosynthetic clay liner material manufactured for this project is continually passed under a magnet for needle removal and then screened with a metal detection device. CETCO certifies Bentomat<sup>®</sup> to be essentially free of broken needles and fragments of needles that would negatively effect the performance of the final product.

Melanie King  
Quality Assurance Coordinator



**EXAMPLE**

**GCL PACKING LIST AND MQA TRACKING FORM**

Listing of finished and raw materials used to produce certification package number 000000000

GCL								Geotextiles				Clay
CV-BENTOMAT ST								N/W-WHITE			WOVEN	CV-CG 50
Order	GCL Lot #	GCL Roll #	Length	Width	weight	sq ft	Roll # Tested	Cap Lot #	Cap Roll #	Roll # Tested	Base Roll #	Clay Lot #
025672604	200943CV	9383	150	15	2690	2250	9376	200943CV	00004325	00004318	WEA012199-2	934488B
025672604	200945CV	10188	150	15	2792	2250	10183	200943CV	00004191	00004186	F001125849	937006B
025672604	200945CV	10233	150	15	2840	2250	10232	200945CV	00004511	00004507	F001126171	937005A
025672604	200945CV	10234	150	15	2826	2250	10232	200945CV	00004511	00004507	F001126171	937005A
025672604	200945CV	10235	150	15	2832	2250	10232	200945CV	00004513	00004507	F001126171	937005A
025672604	200945CV	10237	150	15	2808	2250	10232	200945CV	00004513	00004507	F001126171	937005A
025672604	200945CV	10238	150	15	2824	2250	10232	200945CV	00004513	00004507	F001126171	937005A
025672604	200945CV	10239	150	15	2840	2250	10232	200945CV	00004513	00004507	F001126171	937005A
025672604	200945CV	10242	150	15	2838	2250	10232	200945CV	00004504	00004497	F001126171	937005A
025672604	200945CV	10246	150	15	2822	2250	10232	200945CV	00004504	00004497	F001126171	937005A
025672604	200945CV	10250	150	15	2830	2250	10247	200945CV	00004490	00004482	F001126171	937005A
025672604	200945CV	10258	150	15	2808	2250	10247	200945CV	00004496	00004492	F001309340	937005A
Total sq ft:							<b>27000</b>	Total Number of Rolls Certified: <b>12</b>				



**EXAMPLE**

### GCL MANUFACTURING QUALITY CONTROL TEST DATA

The following rolls in GCL certification package number 000000000 have been tested in our production facility lab.

Product	Lot # Tested	Roll # Tested	Mass Area	Grab Strength	Peel Strength 6496
ASTM Test Method:			D 5993	D 6768	D 6496
Required Value:			0.75 lb /sq ft Min	30 lbs/in MARV	3.5 lbs/in Min
CV-BENTOMAT ST	200943CV	9376	0.85	40.9	7.3
CV-BENTOMAT ST	200945CV	10183	0.87	37.4	10.6
CV-BENTOMAT ST	200945CV	10232	0.83	37.4	6.2
CV-BENTOMAT ST	200945CV	10247	0.86	37.4	4.8

### BENTONITE CLAY CERTIFICATION

The Bentonite Clay used to produce package 000000000

has been tested by American Colloid Company and yielded the following test results.

Clay Lot #	Moist	Swell	Fluid Loss
ASTM Test Method:	D 2216	D 5890	D 5891
Required Value:	12% Max	24 ml/2g Min	18 ml Max
934488B	10.40	26.00	13.60
937005A	10.40	26.00	14.40
937006B	11.60	25.00	15.20



**EXAMPLE**

## GEOTEXTILE TEST RESULTS FROM MATERIAL SUPPLIERS

The GCL in certification package number 000000000 was manufactured with geotextiles which were tested with the following results.

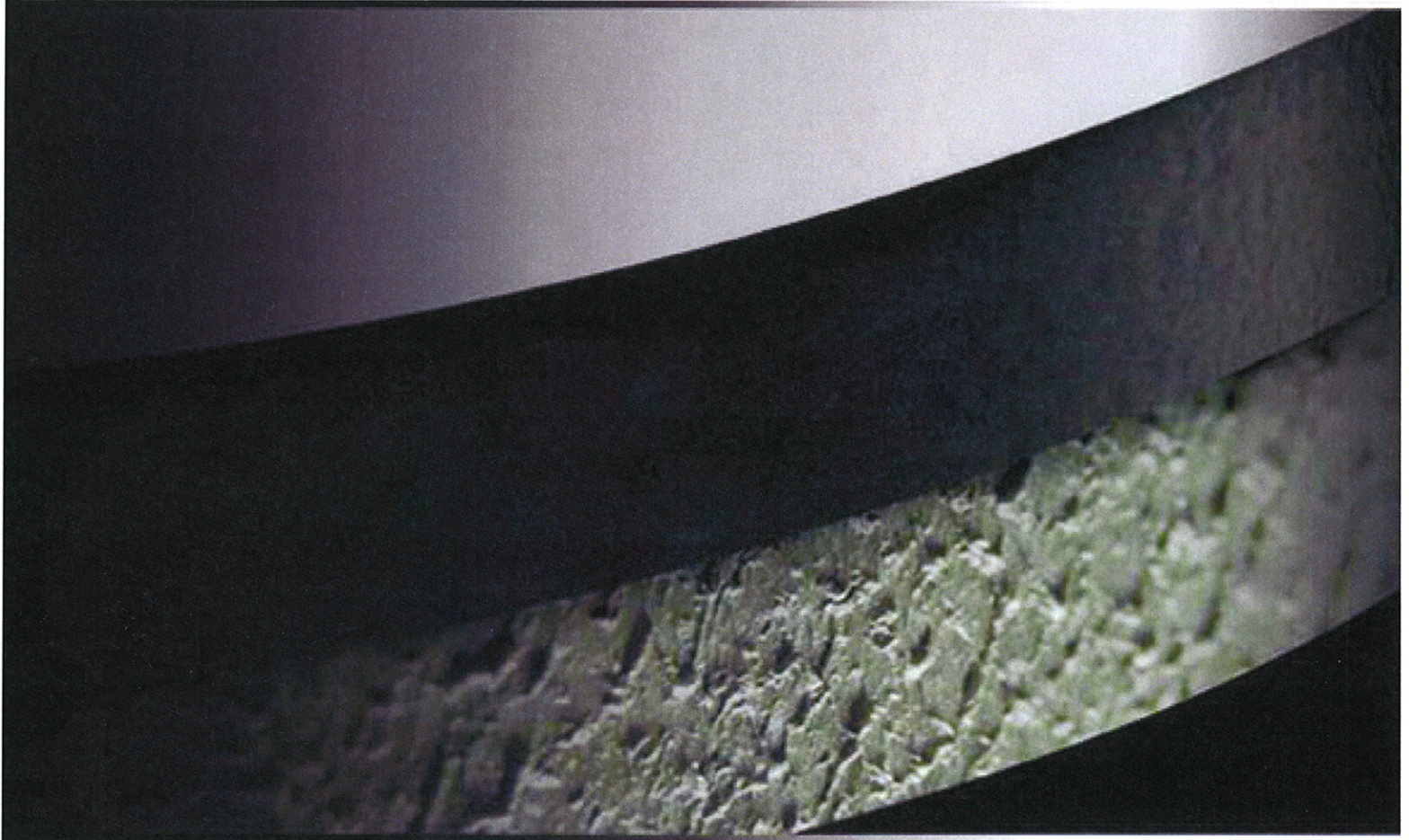
BASE GEOTEXTILE				COVER GEOTEXTILE			
Material	Roll Number	Mass Area oz/yd2	Grab Strength lbs	Material	Roll Number	Mass Area oz/yd2	Grab Strength lbs
Thrace Linq	F001125849	3.3	139.4	CV-NON-WOVEN	00004186	6.6	43.8
Thrace Linq	F001126171	3.3	139.4	CV-NON-WOVEN	00004318	6.3	37.5
Thrace Linq	F001309340	3.3	173.3	CV-NON-WOVEN	00004482	6.4	49.7
MTX 1213	WEA012199-2	3.5	156.0	CV-NON-WOVEN	00004492	6.9	52.0
				CV-NON-WOVEN	00004497	6.6	36.2
				CV-NON-WOVEN	00004507	6.7	52.7

Certifications from our suppliers are on file at our production facility.

An '\*' or 'PT' indicates supplier certifications were unavailable prior to shipping so testing was performed at a CETCO lab.



## **Manufacturing Quality Assurance Manual**



# **Geomembrane Products**







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## 1.0 INTRODUCTION

This manual provides an overview of the GSE Manufacturing Quality Assurance Program for geomembrane products. It is intended for use by GSE's customers to enhance their understanding of the quality system under which GSE geomembrane products are manufactured.

## 2.0 COMMITMENT TO QUALITY

GSE is committed to meeting or exceeding customer's requirements and industry standards. This commitment to quality is established through a documented quality management system, continuous employee training, investment in technology and emphasis on process control. GSE has allocated resources to ensure that this commitment to quality translates into the best products and services for its customers.

## 3.0 MANUFACTURING QUALITY ASSURANCE

GSE has an on-site quality assurance laboratory at each manufacturing facility worldwide. Each facility has a fully equipped, well staffed, dedicated laboratory with strict guidelines to maintain a high level of quality and up-to-the-minute results on GSE's finished products.

GSE has a rigorous set of minimum standards and an effective test program to assure compliance has been established. These procedures and requirements are frequently reviewed and adjusted to assure compliance with current market demands and/or predetermined project specifications. Also raw materials and process parameters are controlled to provide products complying with GSE's minimum characteristics and regulatory standards.

## 4.0 MANUFACTURING QUALITY ASSURANCE ORGANIZATION

GSE quality assurance department assures that only products meeting GSE and/or the customer's requirements are released for shipment. The quality assurance personnel are directly responsible for monitoring, testing, and providing feedback to the manufacturing department ensuring the production of the specified product quality. Each member of the quality assurance team must participate in detailed training that includes factory exposure.

The GSE quality assurance team consists of the manufacturing quality assurance laboratories, engineering staff and manufacturing personnel. The combination of expertise and experience from these groups provide GSE with the proper tools to maintain the highest level of product quality and customer service in the industry.

## 5.0 STAFF & SCHEDULING

The quality assurance laboratories are staffed during any manufacturing run. A continuous communication link is maintained between the laboratory and manufacturing personnel, maximizing production efficiency and product quality.





## 6.0 PRODUCT IDENTIFICATION & DOCUMENTATION

### A. Roll Numbering

Each roll of geomembrane is assigned a unique roll number. The quality assurance laboratory maintains records documenting the raw materials and resulting product quality information.

### B. Approval Procedure

Results for each tested roll of product are checked against GSE and/or customer's specifications for compliance. The quality assurance laboratory approves those materials that meet both of these requirements for shipment.

### C. Non-Conformance

Material that does not meet GSE's minimum standards is given a roll number, but is rejected and separated from the approved material. The rejected material is identified as non-conforming and will not be used. Material that meets GSE's minimum standards, but does not meet a stricter customer's specifications will not be allocated to that customer, but will be placed into inventory as a GSE's standard material.

### D. Documentation

Quality assurance certificates are generated and supplied for each roll of geomembrane product to include all relevant quality assurance information about the material.

## 7.0 RECORDS RETENTION

GSE maintains reports and/or samples for products produced and sold. Records and/or samples are maintained according to GSE's standard retention policy as outlined below.

MATERIAL	ITEM	YEAR
Raw Materials	Resin Supplier Test Reports and Certifications	≥ 2
	GSE Resin Test Reports	≥ 2
	Resin Sample Retain (Archive)	≥ 2
Geomembranes	Raw Test Data (in computer database)	≥ 5
	Quality Control Certificates	≥ 5
	Sample Retain (approximately one square foot)	≥ 5

## 8.0 TESTING CAPABILITIES

GSE maintains high capacity, state-of-the-art laboratory equipment suitable for performing the procedures listed in Appendixes A-H in Houston, Texas. The quality assurance laboratory is accredited by the GALAP Program. The appropriate certificates are maintained for review upon request by authorized parties.

### A. Routine Testing

GSE has developed a strict and thorough quality assurance program, which exceeds all industry's standards and/or customer's specifications including GRI GM13, "Test Properties, Testing Frequency





and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes and GRI GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes. The testing program covers raw materials as shown in Appendix A and the finished goods as shown in Appendixes B-H and is adhered to by all GSE's quality assurance laboratories. The laboratory equipment used by GSE represents the most modern equipment available and meets or exceeds the requirements of all the test standards used.

### *B. Other Testing Capabilities*

In addition to routine testing, GSE laboratories are equipped to perform a wide variety of other tests as required for unusual requests or product development. Further, although the GSE's laboratories are fully equipped and able to perform the most routinely specified tests in the industry, there are some tests that are more economically performed by a dedicated testing facility. GSE believes requirements for such testing should be carefully considered and defined in terms of specific design requirements if they are found to be necessary.

## **9.0 MATERIAL QUALITY ASSURANCE**

GSE has established strict specifications for all raw materials and finished products. Test results must fall within the acceptable limits of GSE and customer's specifications.

### *A. Raw Material*

GSE uses two types of raw materials in the manufacture of geomembrane products: natural resin and masterbatch. Natural resin is the base material that is used to make a geomembrane. It contains stabilizers to prevent degradation from occurring during and after extrusion. Masterbatch is the term referring to the concentrated carbon black material blended with the natural resin to produce the finished product. The natural resin and masterbatch are blended at the appropriate ratio at the manufacturing stage. The masterbatch can contain other additives depending upon the geomembrane product to be produced. GSE verifies the properties of each lot of raw material prior to their utilization.

When natural resin is received, samples are taken and subjected to the tests outlined in Appendix A. All test data are entered into the computer database and checked for accuracy, consistency and compliance with GSE's specifications. The material is not accepted unless all standard test requirements are met and the GSE's test values meet the requirements set forth in the raw material specifications.

Copies of the supplier's certificate of analysis (COA) for each lot of resin utilized in the production of the materials supplied to a specific project are supplied as standard documentation. In addition, the GSE's test results for each lot of resin are provided in a separate report upon request. Virgin resin is normally received in rail car lots. If resin is received by other transport and/or in other quantities, an equivalent suitable sampling procedure is provided (i.e. not less than one sample per shipment or one sample for each 50,000 lb, 23,000 kg).

### *B. Geomembrane Products*





GSE has implemented a strict and thorough quality assurance program for all geomembrane products. The geomembrane product line can be broken into two primary categories: smooth and textured products. The tables contain GSE's minimum properties and test frequencies for all GSE geomembrane products, such as GSE Green (green surface geomembrane), GSE White (light-reflective geomembrane) and GSE Conductive (field spark-testable geomembrane) as shown in Appendixes B-H.

### 1. On-Line Manufacturing Quality Assurance

The quality assurance program for finished product begins during the manufacturing process. Each manufacturing line is equipped with state-of-the-art monitoring devices that provide feedback on the physical quality of the materials being produced. Each geomembrane production line is equipped with both a thickness gauge and spark-testing device.

#### a. Thickness Measurement

As geomembrane is being produced, thickness readings are taken continuously over the length and width of the roll. These data are used to establish the minimum, maximum and average thickness values for each roll and are verified by thickness testing upon sampling of the finished goods.

#### b. Spark Testing

An electrical spark detector is in place on each manufacturing sheet line. This apparatus provides immediate notification of holes in the finished product. If a hole is detected, an alarm is triggered and the hole is identified. Rolls containing holes are rejected from standard product inventory.

### 2. Smooth Geomembrane Materials

Smooth geomembrane products available include high density and linear low density polyethylene materials with 2-3% carbon black. Specialty materials include GSE White, GSE Conductive, and GSE Green geomembranes.

#### a. Sampling

Geomembrane rolls are sampled for QA testing according to the frequencies in Appendix B. An approximate one-foot by roll width sample is cut for quality assurance testing. Test specimens are taken from five positions across the width of the roll. A retain or archive sample approximately 12 in x 12 in (30 cm x 30 cm) is taken one of the five positions on an alternating basis from the laboratory sample. The retain is labeled and kept for future reference.

#### b. Evaluation of Results

All data are entered into a computer database for calculation and comparison to GSE and/or customer's specifications. If materials do not meet GSE's minimum requirements and/or the customer's specifications, the manufacturing personnel will appropriately make the adjustments. Only products meeting GSE's minimums and/or customer's specifications will be approved for shipment.





*c. Reporting*

Every roll of material has a quality assurance roll certificate or Roll Test Data Report (RTDR). This report identifies the standards on which the GSE's approval is based along with the actual test results demonstrated by the material.

**3. Co-extruded Textured Geomembranes**

Textured geomembrane is produced utilizing a round die with co-extrusion technology. The texture is produced in a process in which one or both of the outer layers of a three-layer extrusion are blended with nitrogen gas. Nitrogen bubbles form in the molten resin and escape upon exiting the die, creating a rough, textured surface. GSE standard, GSE White, GSE Green, and GSE Conductive geomembranes are available with co-extruded texturing.

*a. Sampling*

Geomembrane rolls are sampled for QA testing according to the frequencies in Appendixes B-H. An approximate one-foot by roll width sample is cut for quality assurance testing. Specimens for testing are taken from five positions across the width of the roll. Specimens for testing the machine and transverse direction tensile are cut from each of the five positions. A retain or archive sample approximately 12 in x 12 in (30 cm x 30 cm) is taken from the corresponding transverse direction position from the laboratory sample. The retain is labeled and kept for future reference. Evaluation of results and reporting practices are the same as for smooth geomembranes.

**C. Third Party Conformance Sampling**

Some specifications require independent quality assurance and/or conformance testing. GSE can provide assistance with the sampling of products by arranging for the conformance samples to be taken during production. By taking samples during production rather than on-site or after production, the customer can be assured that the samples are clean and available for conformance testing in a timely manner.

GSE encourages customers to audit GSE manufacturing and other manufacturing quality assurance facilities to collect samples and conduct independent conformance testing prior to shipment of materials.

**D. Product Shipping**

It is GSE's policy to ship only products that have been tested and approved. All shipments are packaged according to industry's standard practices and/or customer's specifications. Only approved handling methods are used to move rolls into and out of shipping containers, please see the GSE Installation Quality Assurance Manual for more details.





## Appendix A: Minimum Testing Frequencies and Properties for GSE Raw Materials

TABLE 1. MINIMUM TESTING FREQUENCIES

Property	Test Method <sup>(1)</sup>	Natural Resin
Density	ASTM D 1505	once per rail car compartment
Melt Flow Index	ASTM D 1238 (190/2.16)	once per rail car compartment
OIT	ASTM D 3895 (1 ATM at 200° C)	once per resin lot <sup>(2)</sup>
Carbon Black Content	ASTM D 1603, modified	N/A
Carbon Black Dispersion	ASTM D 5996	NA

**NOTES:**

<sup>1</sup>GSE utilizes test equipment and procedures that enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geosynthetics. All procedures and values are subject to change without prior notification.

<sup>2</sup>OIT for LLDPE/VFPE resin is performed on a representative finished product for each lot of resin rather than on the natural (without carbon black) resin.

TABLE 2. MINIMUM PROPERTIES FOR GSE RAW MATERIALS

Property	Test Method <sup>(1)</sup>	HDPE	LLDPE/VFPE
Density [g/cm <sup>3</sup> ]	ASTM D 1505	0.932	0.915
Melt Flow Index [g/10 min]	ASTM D 1238 (190/2.16)	≤ 1.0	≤ 1.0
OIT [minutes]	ASTM D 3895 (1 ATM at 200° C)	100	100 <sup>(2)</sup>

**NOTES:**

<sup>1</sup>GSE utilizes test equipment and procedures that enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geosynthetics. All procedures and values are subject to change without prior notification.

<sup>2</sup>OIT for LLDPE/VFPE resin is performed on a representative finished product for each lot of resin rather than on the natural (without carbon black) resin.



## Appendix B: GSE HD Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	30 (0.75)	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			27 (0.69)	36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbbell, 2 ipm	20,000 lb					
Strength at Break, lb/in-width (N/mm)			120 (21)	152 (26)	243 (42)	327 (57)	410 (71)
Strength at Yield, lb/in-width (N/mm)			66 (11)	84 (14)	132 (23)	177 (30)	212 (37)
Elongation at Break, %			700	700	700	700	700
Elongation at Yield, %			13	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	21 (93)	28 (124)	42 (186)	58 (257)	73 (324)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	85 (378)	125 (556)	160 (711)	195 (867)
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
TYPICAL ROLL DIMENSIONS							
Roll Length <sup>(2)</sup> , ft (m)			1,120 (341)	870 (265)	560 (171)	430 (131)	340 (104)
Roll Width <sup>(2)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			25,200 (2,341)	19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (711)

#### NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(2)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE HD is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix B: GSE HD Textured Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D 5994	every roll	30 (0.75) 27 (0.69)	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV	20,000 lb					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		66 (11)	75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			68 (11)	90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %	G.L. 2.0 in (51 mm)		100	100	100	100	100
Elongation at Yield, %	G.L. 1.3 in (33 mm)		12	12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	24 (106)	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	16 (0.40)	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load <sup>(2)</sup> , hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>							
Roll Length <sup>(3)</sup> , ft (m)	Double-Sided Textured		830 (253)	700 (213)	520 (158)	400 (122)	330 (101)
	Single-Sided Textured		840 (256)	650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )	Double-Sided Textured		18,675 (1,735)	15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)
	Single-Sided Textured		18,900 (1,755)	14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

#### NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(2)</sup>NCTL for GSE HD Textured is conducted on representative smooth membrane samples.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE HD Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.



## Appendix C: GSE Green Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	30 (0.75)	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			27 (0.69)	36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb					
Strength at Break, lb/in-width (N/mm)			120 (21)	152 (26)	243 (42)	327 (57)	410 (71)
Strength at Yield, lb/in-width (N/mm)			66 (11)	84 (14)	132 (23)	177 (30)	212 (37)
Elongation at Break, %			700	700	700	700	700
Elongation at Yield, %			13	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	21 (93)	28 (124)	42 (186)	58 (257)	73 (324)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	85 (378)	125 (556)	160 (711)	195 (867)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
TYPICAL ROLL DIMENSIONS							
Roll Length <sup>(3)</sup> , ft (m)			1,120 (341)	870 (265)	560 (171)	430 (131)	340 (104)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			25,200 (2,341)	19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (711)

#### NOTES:

- <sup>(1)</sup>GSE Green may have an overall ash content greater than 3.0% due to the green layer. These values apply to the black layer only.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of  $\pm 1\%$ .
- GSE Green is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of  $\pm 2\%$  when tested according to ASTM D 1204 and LTB of  $< -77^{\circ}\text{C}$  when tested according to ASTM D 746.
- \*Modified.





## Appendix C: GSE Green Textured Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D 5994	every roll	30 (0.75) 27 (0.69)	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV	20,000 lb					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		66 (11)	75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			68 (11)	90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %	G.L. 2.0 in (51 mm)		100	100	100	100	100
Elongation at Yield, %	G.L. 1.3 in (33 mm)		12	12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	24 (106)	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	16 (0.40)	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load <sup>(3)</sup> , hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>							
Roll Length <sup>(4)</sup> , ft (m)	Double-Sided Textured		830 (253)	700 (213)	520 (158)	400 (122)	330 (101)
	Single-Sided Textured		840 (256)	650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(4)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )	Double-Sided Textured		18,675 (1,735)	15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)
	Single-Sided Textured		18,900 (1,755)	14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

#### NOTES:

- <sup>(1)</sup> GSE Green Textured may have an overall ash content greater than 3.0% due to the green layer. These values apply to the black layer only.
- <sup>(2)</sup> Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup> NCTL for Green Textured is conducted on representative smooth membrane samples.
- <sup>(4)</sup> Roll lengths and widths have a tolerance of ± 1%.
- GSE Green Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.



## Appendix D: GSE White Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D 5199	every roll	30 (0.75) 27 (0.69)	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV	20,000 lb					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		120 (21)	152 (26)	243 (42)	327 (57)	410 (71)
Strength at Yield, lb/in-width (N/mm)			66 (11)	84 (14)	132 (23)	177 (30)	212 (37)
Elongation at Break, %	G.L. 2.0 in (51 mm)		700	700	700	700	700
Elongation at Yield, %	G.L. 1.3 in (33 mm)		13	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	21 (93)	28 (124)	42 (186)	58 (257)	73 (324)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	85 (378)	125 (556)	160 (711)	195 (867)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>							
Roll Length <sup>(3)</sup> , ft (m)			1,120 (341)	870 (265)	560 (171)	430 (131)	340 (104)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			25,200 (2,341)	19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (711)

#### NOTES:

- <sup>(1)</sup>GSE White may have an overall ash content greater than 3.0% due to the white layer. These values apply to the black layer only.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE White is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix D: GSE White Textured Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	30 (0.75)	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			27 (0.69)	36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb					
Strength at Break, lb/in-width (N/mm)			66 (11)	75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			68 (11)	90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %			100	100	100	100	100
Elongation at Yield, %			12	12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	24 (106)	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	16 (0.40)	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load <sup>(3)</sup> , hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>							
Roll Length <sup>(4)</sup> , ft (m)	Double-Sided Textured		830 (253)	700 (213)	520 (158)	400 (122)	330 (101)
	Single-Sided Textured		840 (256)	650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(4)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )	Double-Sided Textured		18,675 (1,735)	15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)
	Single-Sided Textured		18,900 (1,755)	14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

#### NOTES:

- <sup>(1)</sup>GSE White may have an overall ash content greater than 3.0% due to the white layer. These values apply to the black layer only.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>NCTL for GSE White Textured is conducted on representative smooth membrane samples.
- <sup>(4)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE White Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.



## Appendix E: GSE Conductive Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm	20,000 lb				
Strength at Break, lb/in-width (N/mm)			152 (26)	243 (42)	327 (57)	410 (71)
Strength at Yield, lb/in-width (N/mm)			84 (14)	132 (23)	177 (30)	212 (37)
Elongation at Break, %	G.L. 2.0 in (51 mm)		700	700	700	700
Elongation at Yield, %	G.L. 1.3 in (33 mm)		13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	28 (124)	42 (186)	58 (257)	73 (324)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	85 (378)	125 (556)	160 (711)	195 (867)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(3)</sup> , ft (m)			870 (265)	560 (171)	430 (131)	340 (104)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (711)

#### NOTES:

- <sup>(1)</sup>GSE Conductive may have an overall ash content greater than 3.0%. These values apply to the non-conductive black layers.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE Conductive is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LT8 of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix E: GSE Conductive Textured (Single-Sided) Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D 5994	every roll	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm	20,000 lb				
Strength at Break, lb/in-width (N/mm)			75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %	G.L. 2.0 in (51 mm)		100	100	100	100
Elongation at Yield, %	G.L. 1.3 in (33 mm)		12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load <sup>(3)</sup> , hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(4)</sup> , ft (m)			650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(4)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> , (m <sup>2</sup> ), ft			14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

#### NOTES:

- <sup>(1)</sup> GSE Conductive Textured may have an overall ash content greater than 3.0%. These values apply to the non-conductive black layers.
- <sup>(2)</sup> Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup> NCTL for GSE Conductive Textured is conducted on representative smooth membrane samples.
- <sup>(4)</sup> Roll lengths and widths have a tolerance of ± 1%.
- GSE Conductive Textured Single-Sided is available in rolls weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.



## Appendix F: GSE Conductive White Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbbell, 2 ipm	20,000 lb				
Strength at Break, lb/in-width (N/mm)			152 (26)	243 (42)	327 (57)	410 (71)
Strength at Yield, lb/in-width (N/mm)			84 (14)	132 (23)	177 (30)	212 (37)
Elongation at Break, %	G.L. 2.0 in (51 mm)		700	700	700	700
Elongation at Yield, %	G.L. 1.3 in (33 mm)		13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	28 (124)	42 (186)	58 (257)	73 (324)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	85 (378)	125 (556)	160 (711)	195 (867)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Notched Constant Tensile Load, hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(3)</sup> , ft (m)			870 (265)	560 (171)	430 (131)	340 (104)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (711)

#### NOTES:

- <sup>(1)</sup> GSE Conductive White may have an overall ash content greater than 3.0% due to the white and conductive outer layers. These values apply to the non-conductive black layers.
- <sup>(2)</sup> Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup> Roll lengths and widths have a tolerance of ± 1%.
- GSE Conductive White is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix F: GSE Conductive White Textured (Single-Sided) Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM13.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D 5994	every roll	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV	20,000 lb				
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %	G.L. 2.0 in (51 mm)		100	100	100	100
Elongation at Yield, %	G.L. 1.3 in (33 mm)		12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load <sup>(3)</sup> , hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(4)</sup> , ft (m)			650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(4)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> , (m <sup>2</sup> ), ft			14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

#### NOTES:

- <sup>(1)</sup> GSE Conductive White Textured may have an overall ash content greater than 3.0% due to the white and conductive outer layers. These values apply to the non-conductive black layers.
- <sup>(2)</sup> Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup> NCTL for GSE Conductive White Textured is conducted on representative smooth membrane samples.
- <sup>(4)</sup> Roll lengths and widths have a tolerance of  $\pm 1\%$ .
- GSE Conductive White Textured Single-Sided is available in rolls weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of  $\pm 2\%$  when tested according to ASTM D 1204 and LTB of  $< -77^{\circ}$  C when tested according to ASTM D 746.
- \*Modified.



## Appendix G: GSE UltraFlex Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM17.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.28)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.92	0.92	0.92	0.92
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			170 (29)	240 (42)	320 (56)	380 (66)
Elongation at Break, %			800	800	800	800
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	22 (97)	33 (146)	44 (195)	55 (244)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	70 (311)	100 (444)	130 (578)	155 (689)
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(2)</sup> , ft (m)			870 (265)	560 (171)	430 (131)	340 (103)
Roll Width <sup>(2)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (710)

#### NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(2)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE UltraFlex is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix G: GSE UltraFlex Textured Data Sheet

### Product Specifications

*These product specifications meet or exceed GRI GM17.*

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.28)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.92	0.92	0.92	0.92
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			115 (20)	168 (29)	224 (39)	270 (47)
Elongation at Break, %			500	500	500	500
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	25 (111)	38 (169)	50 (222)	60 (266)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	125 (556)	140 (622)
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(2)</sup> , ft (m)	Double-Sided Textured		700 (213)	520 (158)	400 (122)	330 (100)
	Single-Sided Textured		650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(2)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )	Double-Sided Textured		15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (689)
	Single-Sided Textured		14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (522)

#### NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(2)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE UltraFlex Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LT8 of <-77° C when tested according to ASTM D 746.
- \*Modified.



## Appendix H: GSE UltraFlex White Smooth Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM17.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5199	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.28)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.92	0.92	0.92	0.92
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			170 (29)	240 (42)	320 (56)	380 (66)
Elongation at Break, %			800	800	800	800
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	22 (97)	33 (146)	44 (195)	55 (244)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	70 (311)	100 (444)	130 (578)	155 (689)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(3)</sup> , ft (m)			870 (265)	560 (171)	430 (131)	340 (103)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )			19,575 (1,819)	12,600 (1,171)	9,675 (899)	7,650 (710)

#### NOTES:

- <sup>(1)</sup>GSE UltraFlex White may have an overall ash content greater than 3.0% due to the white layer. These values apply to the black layer only.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE UltraFlex White is available in rolls weighing approximately 3,900 lb (1,769 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.





## Appendix H: GSE UltraFlex White Textured Data Sheet

### Product Specifications

These product specifications meet or exceed GRI GM17.

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.28)
Density, g/cm <sup>3</sup>	ASTM D 1505	200,000 lb	0.92	0.92	0.92	0.92
Tensile Properties (each direction)	ASTM D 6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			115 (20)	168 (29)	224 (39)	270 (47)
Elongation at Break, %			500	500	500	500
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	25 (111)	38 (169)	50 (222)	60 (266)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	125 (556)	140 (622)
Carbon Black Content <sup>(1)</sup> , % (Range)	ASTM D 1603*/4218	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>	Note <sup>(2)</sup>
Asperity Height, mil (mm)	ASTM D 7466	second roll	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140
<b>TYPICAL ROLL DIMENSIONS</b>						
Roll Length <sup>(3)</sup> , ft (m)	Double-Sided Textured		700 (213)	520 (158)	400 (122)	330 (100)
	Single-Sided Textured		650 (198)	420 (128)	320 (98)	250 (76)
Roll Width <sup>(3)</sup> , ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft <sup>2</sup> (m <sup>2</sup> )	Double-Sided Textured		15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (689)
	Single-Sided Textured		14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (522)

#### NOTES:

- <sup>(1)</sup>GSE UltraFlex White Textured may have an overall ash content greater than 3.0% due to the white layer. These values apply to the black layer only.
- <sup>(2)</sup>Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- <sup>(3)</sup>Roll lengths and widths have a tolerance of ± 1%.
- GSE UltraFlex White Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- \*Modified.