CETCO GCL

MANUFACTURING QUALITY ASSURANCE AND QUALITY CONTROL (MQC) MANUAL

Version 7.0, August 2008

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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[1], 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.

[1] 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.

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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.

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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.

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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.

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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.

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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 modified method ASTM D4632 (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 modified method ASTM D4632 (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

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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.

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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:

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- 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.

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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."

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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.

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FIGURE 1-1

CETCO GCL MQA/MQC PROGRAM
ORGANIZATION CHART

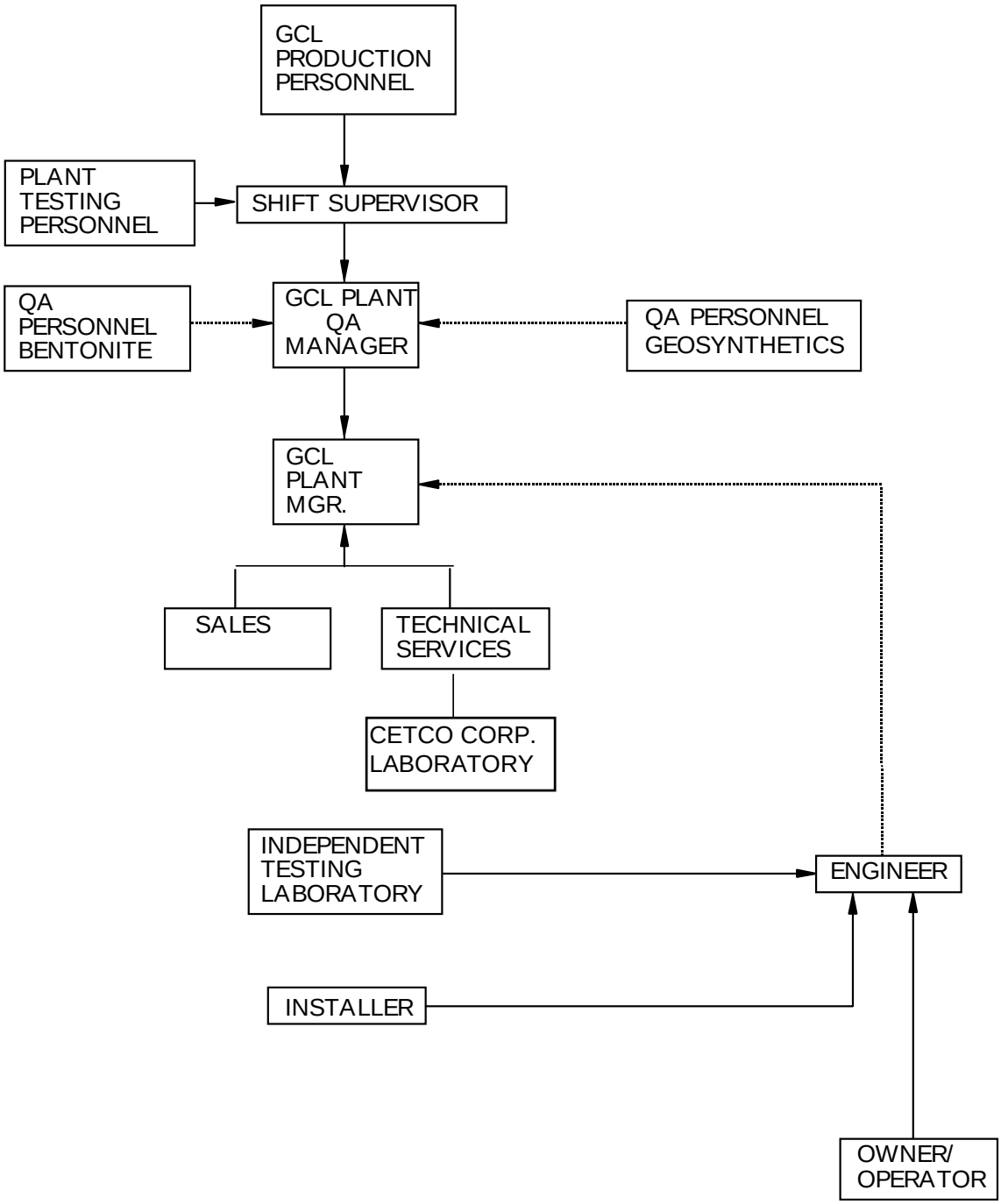

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FIGURE 1-2

CETCO ORDER REVIEW PROCESS

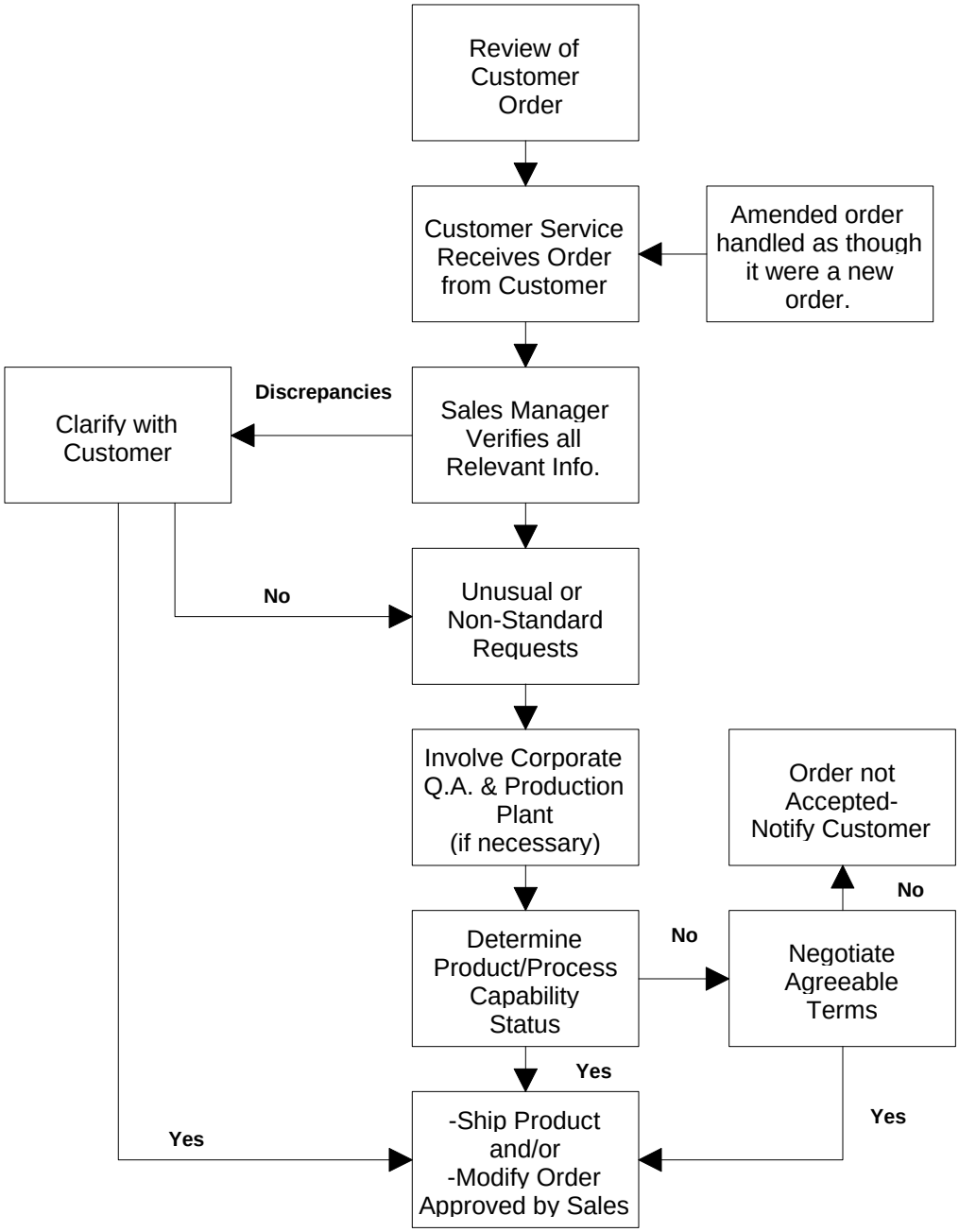

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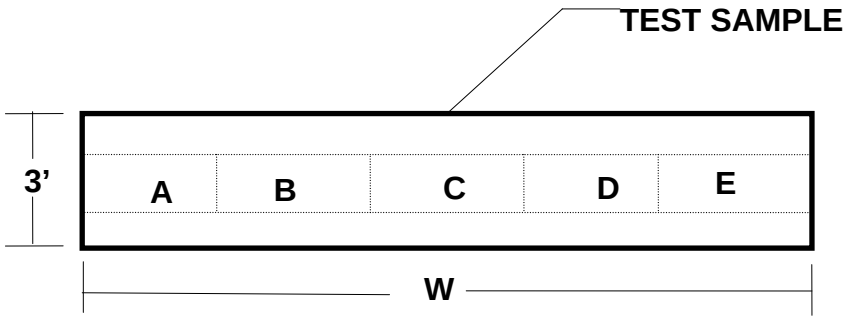
FIGURE 2-1

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.

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FIGURE 2-2

SCHEMATIC OF NEEDLE DETECTION
AND REMOVAL SYSTEM

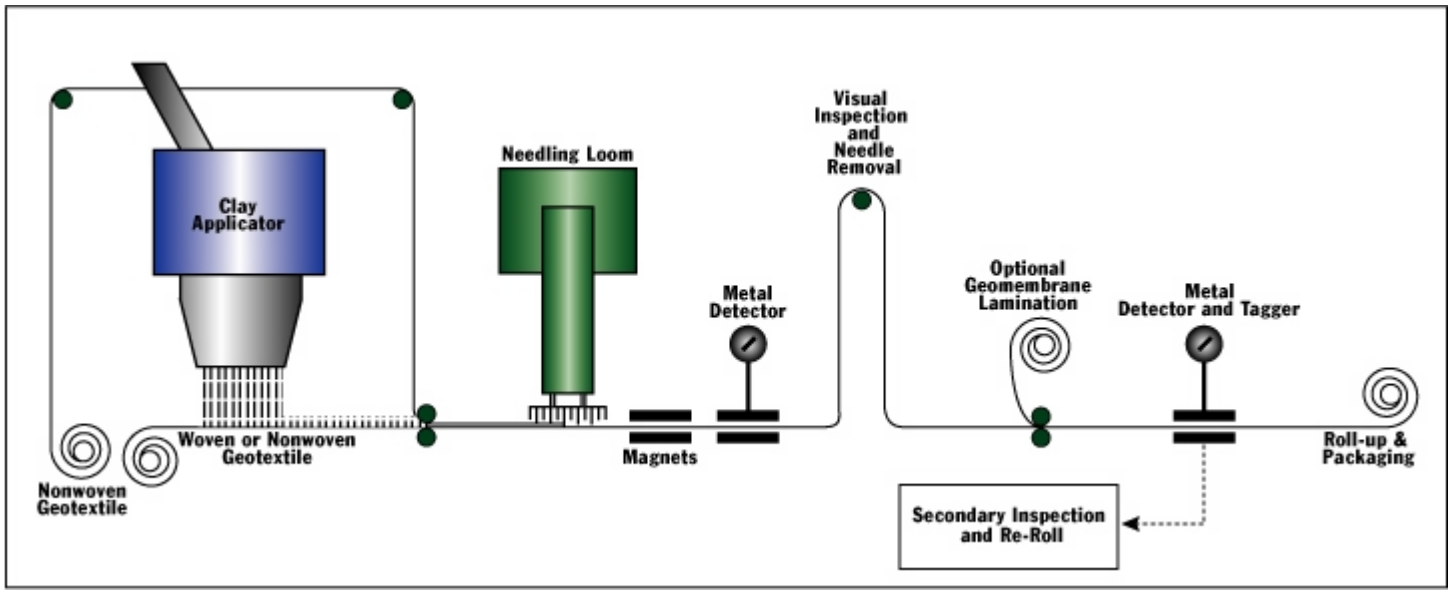

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TABLE 2-1

MQA PARAMETERS FOR GEOTEXTILE COMPONENT OF GCL

PROPERTY	TEST METHOD	FREQUENCY	RECORDED VALUE[1]
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.

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TABLE 2-2

MQC PARAMETERS FOR GEOMEMBRANE/GEOFILM COMPONENT OF CL GCL SERIES

PROPERTY	TEST METHOD	FREQUENCY	RECORDED VALUE[1]
Grab Strength	ASTM D 638 or D 882	200,000 sq. ft	MARV
Thickness	ASTM D 5199	200,000 sq. ft	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.

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TABLE 2-3

MQA PARAMETERS FOR SODIUM BENTONITE COMPONENT OF GCL

PROPERTY[1]	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[2]	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.

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TABLE 2-4

MQA/MQC PARAMETERS FOR FINISHED GCL

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

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TABLE 4-1

BENTOMAT MQA/MQC PLAN SUMMARY[1]

(Version 7.0, revised August 2008)

MATERIAL	QUALITY PARAMETER[1]	TEST METHOD[2]	TEST FREQUENCY[3]	CERTIFIED VALUE[4]
Bentonite[5]	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[6]	ASTM C 136	50 tonnes	100% typical- #8 1% typical - #200
Bentomat CL/CLT	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	45 lbs/in (CL/CLT)
	Peel Strength[8]	ASTM D 6496	40,000 sq. ft	2.5 lbs/in (CL/CLT)
	Index Flux[9]	ASTM D 5887	Periodic	1×10^{-9} m^3/m^2/sec for CL/CLT
	Permeability[9]	ASTM D 5887	Periodic	5×10^{-10} cm/sec for CL/CLT
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
Bentomat DN	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	50 lbs/in (DN)
	Peel Strength[8]	ASTM D 6496	40,000 sq. ft	3.5 lbs/in (DN)
	Index Flux[11]	ASTM D 5887	Weekly	1×10^{-8} m^3/m^2/sec
	Permeability[11]	ASTM D 5887	Weekly	5×10^{-9} cm/sec
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
Bentomat ST	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	30 lbs/in (ST)
	Peel Strength[8]	ASTM D 6496	40,000 sq. ft	3.5 lbs/in (ST)
	Index Flux[11]	ASTM D 5887	Weekly	1×10^{-8} m^3/m^2/sec
	Permeability[11]	ASTM D 5887	Weekly	5×10^{-9} cm/sec
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical

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MATERIAL	QUALITY PARAMETER[1]	TEST METHOD[2]	TEST FREQUENCY[3]	CERTIFIED VALUE[4]
Bentomat SDN	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	30 lbs/in (SDN)
	Peel Strength[8]	ASTM D 6496	40,000 sq. ft	2.5 lbs/in (SDN)
	Index Flux[11]	ASTM D 5887	Weekly	1×10^{-8} m^3/m^2/sec
	Permeability[11]	ASTM D 5887	Weekly	5×10^{-9} cm/sec
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	500 psf typical
Bentomat 200R	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	30 lbs/in (200R)
	Peel Strength[8]	ASTM D 6496	40,000 sq. ft	1.0 lbs/in (200R)
	Index Flux[11]	ASTM D 5887	Weekly	1×10^{-8} m^3/m^2/sec
	Permeability[11]	ASTM D 5887	Weekly	5×10^{-9} cm/sec
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	150 psf typical

NOTES

1. 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.
2. ASTM procedures modified as necessary to facilitate the testing of a GCL instead of a geotextile.
3. 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.
4. All required values listed are minimum average roll values (MARVs) unless otherwise indicated.
5. These parameters are for the bentonite before it is incorporated into the finished Bentomat/Claymax product.
6. All bentonite is granular type. The particle size distribution may vary slightly.
7. 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.
8. 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, in units of lbs or N.
9. 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 5×10^{-10} cm/sec for typical GCL thickness.
10. 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.
11. 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 5×10^{-9} cm/sec for typical GCL thickness.

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TABLE 4-2

CLAYMAX MQA/MQC PLAN SUMMARY[1]

(Version 7.0, August 2008)

MATERIAL	QUALITY PARAMETER[1]	TEST METHOD[2]	TEST FREQUENCY[3]	CERTIFIED VALUE[4]
Bentonite[5]	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[6]	ASTM D 421	50 tonnes	100% typical - #8 1% typical - #200
Claymax 200R	Bentonite Mass/Area[7]	ASTM D 5993	40,000 sq. ft	0.75 lb./sq. ft
	Grab Strength[8]	ASTM D 6768	200,000 sq. ft	40 lbs/in
	Peel Strength[8]	ASTM D 4632 ASTM D 6496	N/A	N/A
	Index Flux[9]	ASTM D 5887	Weekly	1×10^{-8} $m^3/m^2/sec$
	Permeability[9]	ASTM D 5887	Weekly	5×10^{-9} cm/sec
	Internal Shear[10]	ASTM D 5321 ASTM D 6243	Periodic	100 psf

NOTES

1. 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.
2. ASTM procedures modified as necessary to facilitate the testing of a GCL instead of a geotextile.
3. The listed test frequency is based on ASTM D 5889 *Standard Practice for Quality Control of Geosynthetic Clay Liners*.
4. All required values listed are minimum average roll values (MARVs) unless otherwise indicated.
5. These parameters are for the bentonite before it is incorporated into the finished Bentomat product.
6. All bentonite is granular type. The particle size distribution may vary slightly.
7. 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.
8. 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, in units of lbs or N.
9. 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 5×10^{-9} cm/sec for typical GCL thickness.
10. 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.
11. 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 5×10^{-10} cm/sec for typical GCL thickness.

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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

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