



GEOMEMBRANE INSTALLATION SPECIFICATION CQC & CQA



**Safe
Containment
without limits**

Waste Water Mining

Contents

1.0 Scope

Parties Involved	5
Owner	5
Project Manager or General Contractor	5
Design Engineer / Consulting Engineering Firm	5
Manufacturer	5
Geomembrane Installer – Installation Subcontractor	5
Quality Control and Quality Assurance	5

2.0 Submittals

Shop Drawings	7
Additional Submittals (In-Progress and at Completion of the installation)	7

3.0 Project Quality Control

Project Conditions	7
Material Warranty	7
Geomembrane Installation Warranty	7
Delivery, Storage and Handling	7
Installer's Qualifications	9
Source Quality Control	9
Geomembrane Quality Control	9

4.0 Project Quality Assurance Meetings

Geomembrane Pre-Construction Meeting	11
Topics for this meeting shall include	11
Project implementation meetings	11

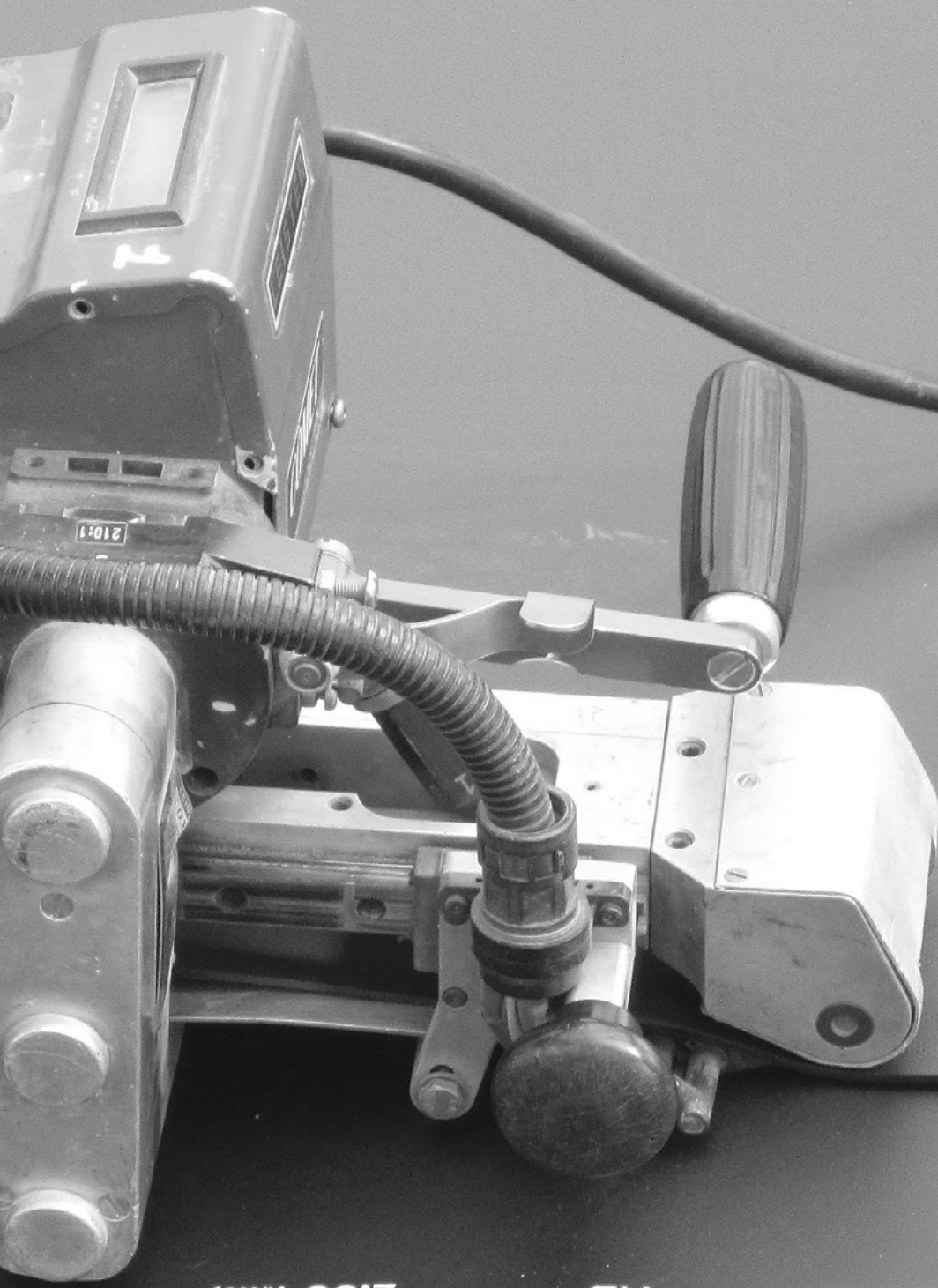
5.0 Field Quality Control

Subgrade Preparation	13
Geomembrane Placement	13
Seaming Procedures	13
Pipe and Structure Penetration Sealing System	14
Welding and testing	14
Prequalification Test Seams	14
Field Seam Non-destructive Testing	14
Destructive Field Seam Testing	16
Identification of Defects	19
Evaluation of Defects	19
Verification of Repairs on Seams	19
Daily Field Installation Reports	19
Liner Acceptance	19
Anchor Trench	19
Disposal of Scrap Materials	19

References

Annex A

References	20
Annex A	22



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ATARFIL

1.0 SCOPE

- 1.1 This document presents quality control for the installation of Atarfil geomembranes, in liquid containment liners systems, water conveyance liners, solid-material liners, landfill cover and closures, wet landfills as well as hydraulic and geotechnical applications.
- 1.2 These specifications focus on installing Atarfil HDPE and LLDPE geomembranes both smooth and textured surface are included.
- 1.3 The information provided uses current international quality control and quality assurance standards within the geomembrane installation industry. It is the exclusive responsibility of the user to define the suitability and use of the information.
- 1.4 This document is based on the installation guidelines provided by the IAGI. More info at www.AIGI.org
- 1.5 The majority of the content from this document was taken from the installation guidelines provided by the International Association of Geosynthetic Installers (IAGI). Additional information can be found at www.IAGI.org.

Parties Involved

- 1.6 As a prelude to this document some introductory information is felt to be necessary. These comments are meant to clearly define the role of the various parties associated with the manufacture, installation and inspection of all components of a total geosynthetic liner system.

Owner

- 1.7 The owner is the final user and the maximum authority on the job site. It is usually the final recipient and user of the installed product.

Project Manager or General Contractor

- 1.8 Owner's representative whose duty is to coordinate the implementation of the construction project with the quality control system. They will coordinate all parties involved in the project.

Design Engineer / Consulting Engineering Firm

- 1.9 Company or person in charge of producing project plan and documents governing the construction. The Designer is responsible for establishing the safe containment system specifications and approving any change that may be

suggested during the construction works. If required by the Project Manager, the Designer will attend the meetings held previously and during the construction works.

Manufacturer

- 1.10 Company which manufactures the geosynthetic materials to be used in the waterproofing system. The manufacturer will be responsible for the geosynthetic materials until they are received on the job site and approved.

Geomembrane Installer – Installation Subcontractor

- 1.11 Company responsible for the installation of the geomembrane. Installation shall be performed under the direction of the field Installation Supervisor who shall be responsible throughout the geomembrane installation, for geomembrane panel layout, seaming, patching, testing, repairs, and all other activities of the Geomembrane Installer.

Quality Control and Quality Assurance

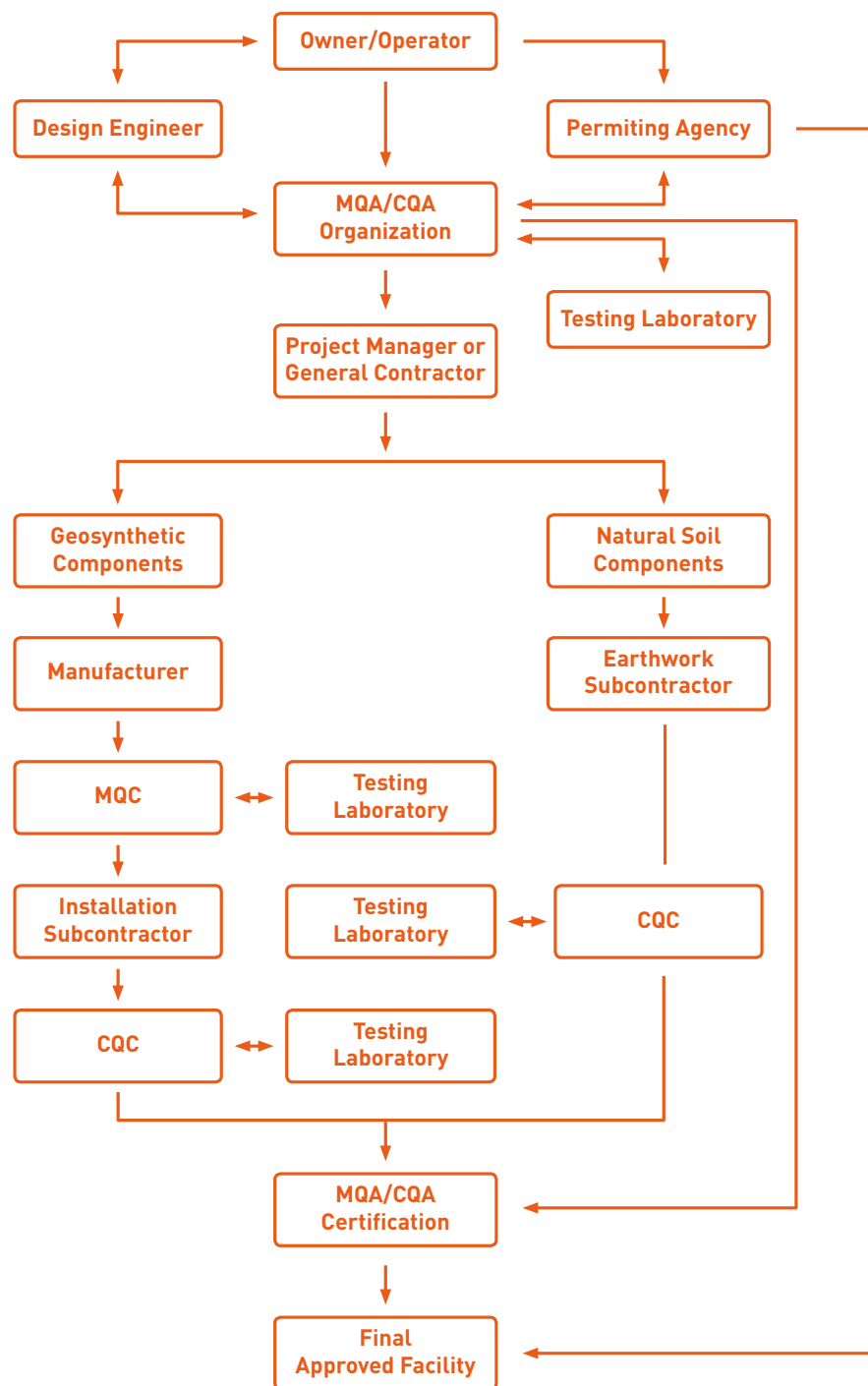
- 1.12 Inspection within a geosynthetic project comes under the dual headings of quality control (QC) and quality assurance (QA). For geosynthetics that are manufactured and constructed a further subdivision of manufacturing and construction is necessary. Thus, it is important to keep four definitions in mind and to understand how the different activities contrast and/or complement one another.

(i) Manufacturing Quality Control (MQC): A planned system of inspections that is used to directly monitor and control the manufacture of a material that is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum, or maximum, specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract plans and specifications.

(ii) Manufacturing Quality Assurance (MQA): A planned system of activities that provide assurance that the materials were manufactured as specified in the certification documents and contract plans and specifications. MQA includes manufacturing and fabrication facility inspections, verifications, audits, and evaluation of the raw materials and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer or fabricator is in compliance with the product certification and contract plans and specifications for the project.

(iii) Construction Quality Control (CQC): A planned system of inspections that are used to directly monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics installer to achieve the highest quality in the constructed or installed system. CQC refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project.

(iv) Construction Quality Assurance (CQA): A planned system of activities that provide assurance that the facility was constructed as specified in the design. Construction quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA refers to measures taken by the CQA organization to assess if the installer or contractor is in compliance with the plans and specifications for the project.



2.0 SUBMITTALS

- 2.1 The following should be submitted to the Engineer or Owner, for review and approval, within a reasonable time so as to expedite shipment and / or installation of the geomembranes:
- (i) Documentation of manufacturer's qualifications. The manufacturer of geomembrane of the type specified or similar product shall have at least five years' experience in the manufacture of such geomembrane.
 - (ii) Manufacturer's Quality Control program manual or descriptive documentation.
 - (iii) A material properties sheet, including at a minimum all properties specified in GRI GM 13 or GRI GM 17, including test methods used.
 - (iv) Sample of the material.
 - (v) Documentation of Installer's qualifications.
 - a. Submit a list of at least ten completed facilities.
 - b. Submit resumes or qualifications of the Installation Supervisor, Master Seamer and Welding Technicians to be assigned to this project.
 - c. Installer's Quality Control Program.
 - (vi) Example Material Warranty and Liner Installation Warranty.

Shop Drawings

- 2.2 Copies of shop drawings should be submitted for engineer's approval within a reasonable time so as not to delay the start of geomembrane installation. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Butt seams or roll-end seams should not occur on a slope unless approved by the Owner's Representative. Butt seams on a slope, if allowed, should be staggered.
- 2.3 Placement of geomembrane should not be allowed to proceed until Owner's Representative has received and approved the shop drawings.

Additional Submittals (In-Progress and at Completion of the installation)

- (i) Manufacturer's warranty.
- (ii) Geomembrane installation warranty.
- (iii) Daily written acceptance of subgrade surface.

- (iv) Low-temperature seaming procedures if applicable.
- (v) Prequalification test seam samples.
- (vi) Field seam non-destructive test results.
- (vii) Field seam destructive test results.
- (viii) Daily field installation reports.
- (ix) Installation record drawing.

3.0 PROJECT QUALITY CONTROL

Project Conditions

- 3.1 Geomembrane should not be installed in the presence of standing water, while precipitation is occurring, during excessive winds, or when material temperatures are outside the limits specified in Section 5 - Seaming Procedures.

Material Warranty

- 3.2 As agreed by project participants.

Geomembrane Installation Warranty

- 3.3 The Geomembrane Installer shall guarantee the geomembrane installation against defects in the installation and workmanship for one year commencing with the date of final acceptance.

Delivery, Storage and Handling

- 3.4 Each roll of geomembrane delivered to the site shall be labelled. The label shall be firmly affixed and shall clearly state the manufacturer's name, product identification, material thickness, roll number, roll dimensions and roll weight.
- 3.5 Geomembrane shall be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.
- 3.6 Rolls shall be stored away from high traffic areas. Continuously and uniformly support rolls on a smooth, level prepared surface.



Installer's Qualifications

- 3.7 The Geomembrane Installer shall be approved Manufacturer's Installer or a contractor approved by the Owner's Representative to install the geomembrane.
- 3.8 The Geomembrane Installer shall have at least three years' experience in the installation of the specified geomembrane or similar. The Geomembrane Installer shall have installed at least 10 projects involving a total of 500,000 m² (5,000,000 ft²) of the specified type of geomembrane or similar during the last three years.
- 3.9 Installation shall be performed under the direction of a field Installation Supervisor who shall be responsible throughout the geomembrane installation, for geomembrane panel layout, seaming, patching, testing, repairs, and all other activities of the Geomembrane Installer.
- 3.10 The Field Installation Supervisor shall have installed or supervised the installation and seaming of a minimum of 10 projects involving a total of 500,000 m² (5,000,000 ft²) of geomembrane of the type specified or similar product.
- 3.11 Seaming shall be performed under the direction of a Master Seamer (who may also be the Field Installation Supervisor or Crew Foreman) who has seamed a minimum of 300,000 m² (3,000,000 ft²) of geomembrane of the type specified or similar product, using the same type of seaming apparatus to be used in the current project. The Field Installation Supervisor and/or Master Seamer shall be present whenever seaming is performed.

All seaming, patching, other welding operations, and testing shall be performed by qualified technicians employed by the Geomembrane Installer.

Source Quality Control

- 3.12 The test methods and frequencies used by the manufacturer for quality control/quality assurance of the above geomembrane prior to delivery, shall be in accordance with GRI GM 13 for HDPE geomembrane or GRI GM 17 for LLDPE geomembrane, or modified as required for project specific conditions.

- 3.13 The manufacturer's geomembrane quality control certifications, including results of quality control testing of the products must be supplied to the Owner's Representative to verify that the materials supplied for the project are in compliance with all product and/or project specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.
- 3.14 The Manufacturer will provide Certification that the geomembrane and welding rod supplied for the project are made from the same material type and are compatible.

Geomembrane Quality Control

- 3.15 The geomembrane shall consist of new, first quality products designed and manufactured specifically for the purpose of this work which shall have been satisfactorily demonstrated by prior testing to be suitable and durable for such purposes. The geomembrane rolls shall be seamless, high density polyethylene (HDPE - Formulated Sheet Density ≥ 0.940 g/cc) or linear low density polyethylene (LLDPE - Formulated Sheet Density ≤ 0.939 g/cc) containing no plasticizers, fillers or extenders and shall be free of holes, blisters or contaminants, and leak free verified by 100% in line continuous testing. The geomembrane shall be supplied as a continuous sheet with no factory seams in rolls.
- 3.16 Material conformance testing by the Owner's Representative, if required, will be conducted using in-plant sampling or as specified for the project.
- 3.17 The geomembrane seams shall meet the property requirements as shown in Table 1 and Table 2 from GRI GM19a attached as annex A or as required by project specifications.



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4.0 PROJECT QUALITY ASSURANCE MEETINGS

Geomembrane Pre-Construction Meeting

4.1 A geomembrane pre-construction meeting shall be held at the site prior to installation of the geomembrane. At a minimum, the meeting shall be attended by the Geomembrane Installer, Owner, Owner's representative (Engineer and/or CQA Firm), and the Earthwork Contractor.

Topics for this meeting shall include

- (i) Health and Safety.
- (ii) Lines of authority and communication. Resolution of any project document ambiguity.
- (iii) Methods for documenting, reporting and distributing documents and reports.
- (iv) Procedures for packaging and storing archive samples.
- (v) Review of time schedule for all installation and testing.
- (vi) Review of panel layout and numbering systems for panels and seams including details for marking on geomembrane.
- (vii) Procedures and responsibilities for preparation and submission of as built panel and seam drawings.
- (viii) Temperature and weather limitations. Installation procedures for adverse weather conditions. Defining acceptable subgrade, geomembrane, or ambient moisture and temperature conditions for working during liner installation.

- (ix) Subgrade conditions, dewatering responsibilities and subgrade maintenance plan.
- (x) Deployment techniques including allowable subgrade for the geomembrane.
- (xi) Plan for controlling expansion/contraction and wrinkling of the geomembrane.
- (xii) Covering of the geomembrane and cover soil placement.
- (xiii) Measurement and payment schedules.
- (xiv) Responsibilities of each party.
- (xv) The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

Project implementation meetings

- 4.2 These meetings will be held at the agreed periods (weekly, daily, etc.) and should be attended by all parties involved in the construction.
- 4.3 The purpose of these meetings is to follow up the construction progress and consider both solved and pending problems, as well as precautions for next stages. Decisions taken on the job site, which may give rise to any modification and the reason and justification of the solutions adopted will be also discussed. The Project Manager must always approve the decisions taken about the subjects considered in these meetings.



5.0 FIELD QUALITY CONTROL

Subgrade Preparation

- 5.1 The subgrade shall be prepared in accordance with the project specifications. The geomembrane subgrade shall be uniform and free of sharp or angular objects that may damage the geomembrane prior to installation of the geomembrane.
- 5.2 The Geomembrane Installer and Owner's Representative shall inspect the surface to be covered with the geomembrane on each day's operations prior to placement of geomembrane to verify suitability.
- 5.3 The Geomembrane Installer and Owner's Representative shall provide daily written acceptance for the surface to be covered by the geomembrane in that day's operations. The surface shall be maintained in a manner, during geomembrane installation, to ensure subgrade suitability.
- 5.4 All subgrade damaged by construction equipment and deemed unsuitable for geomembrane deployment shall be repaired prior to placement of the geomembrane. All repairs shall be approved by the Owner's Representative and the Geomembrane Installer. This damage, repair, and the responsibilities of the contractor and Geomembrane Installer shall be defined in the preconstruction meeting.

Geomembrane Placement

- 5.5 No geomembrane shall be deployed until the applicable certifications and quality control certificates listed in section 2 - Submittals are submitted to and approved by the Owner's Representative within the timeframe specified in the contract documents. If the material does not meet project specifications it shall be removed from the work area.
- 5.6 The geomembrane shall be installed to the limits shown on the project drawings and essentially as shown on approved panel layout drawings.
- 5.7 No geomembrane material shall be unrolled and deployed if the material temperatures are lower than 0 degrees C (32 degrees F) unless otherwise approved by the Owner's Representative. The specified minimum temperature for material deployment may be adjusted by the Owner's Representative. Temperature limitations should be defined in the preconstruction meeting. Typically, only the quantity of geomembrane that will be anchored and seamed together in one day should be deployed.
- 5.8 No vehicular traffic shall travel on the geomembrane other than an approved low ground pressure vehicle or equivalent.

- 5.9 Sandbags or equivalent ballast shall be used as necessary to temporarily hold the geomembrane material in position under the foreseeable and reasonably expected wind conditions. Sand bag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the geomembrane.
- 5.10 Geomembrane placement shall not be done if moisture prevents proper subgrade preparation, panel placement, or panel seaming. Moisture limitations should be defined in the preconstruction meeting.
- 5.11 Damaged panels or portions of the damaged panels which have been rejected shall be marked and their removal from the work area recorded.
- 5.12 The geomembrane shall not be allowed to "bridge over" voids or low areas in the subgrade. The geomembrane shall rest in intimate contact with the subgrade.
- 5.13 Wrinkles caused by panel placement or thermal expansion should be minimized in accordance with paragraph 4 - (xi).
- 5.14 Considerations on site geometry: In general, seams shall be oriented parallel to the line of the maximum slope. In corners and odd shaped geometric locations, the total length of field seams shall be minimized. Seams shall not be located at low points in the subgrade unless geometry requires seaming at such locations and if approved by the Owner's Representative.
- 5.15 Overlapping: The panels shall be overlapped prior to seaming to whatever extent is necessary to affect a good weld and allow for proper testing. In no case shall this overlap be less than 75 mm (3 in.).

Seaming Procedures

- 5.16 Cold weather installations should follow guidelines as outlined in GRI GM9a.
- 5.17 No geomembrane material shall be seamed when liner temperatures are less than 0 degrees C (32 degrees F) unless the following conditions are complied with:
 - (i) Seaming of the geomembrane at material temperatures below 0 degrees C (32 degrees F) is allowed if the Geomembrane Installer can demonstrate to the Owner's Representative, using pre-qualification test seams, that field seams comply with the project specifications, the safety of the crew is ensured, and geomembrane material can be fabricated (i.e. pipeboots, penetrations, repairs, etc.) at subfreezing temperatures.

- (ii) The Geomembrane Installer shall submit to the Owner's Representative for approval, detailed procedures for seaming at low temperatures, possibly including the following:
 - Preheating of the geomembrane.
 - The provision of a tent or other device if necessary to prevent heat losses during seaming and rapid heat losses subsequent to seaming.
 - Number of test welds to determine appropriate seaming parameters.
- 5.18 No geomembrane material shall be seamed when the sheet temperature is above 75 degrees C (170 degrees F) as measured by an infrared thermometer or surface thermocouple unless otherwise approved by the Owner's Representative. This approval will be based on recommendations by the manufacturer and on a field demonstration by the Geomembrane Installer using prequalification test seams to demonstrate that seams comply with the specification.
- 5.19 Seaming shall primarily be performed using automatic fusion welding equipment and techniques. Extrusion welding shall be used where fusion welding is not possible such as at pipe penetrations, patches, repairs and short (less than a roll width) runs of seams.
- 5.20 Fishmouths or excessive wrinkles at the seam overlaps shall be minimized and when necessary cut along the ridge of the wrinkles back into the panel so as to effect a flat overlap. The cut shall be terminated with a keyhole cut (nominal 10 mm (1/2 in) diameter hole) so as to minimize crack/tear propagation. The overlay shall subsequently be seamed. The key hole cut shall be patched with an oval or round patch of the same base geomembrane material extending a minimum of 150 mm (6 in.) beyond the cut in all directions.

Pipe and Structure Penetration Sealing System

- 5.21 Provide penetration sealing system as shown in the Project Drawings.
- 5.22 Penetrations shall be constructed from the base geomembrane material, flat stock, prefabricated boots and accessories as shown on the Project Drawings. The pre-fabricated or field fabricated assembly shall be field welded to the geomembrane as shown on the Project Drawings so as to prevent leakage. This assembly shall be tested as outlined in this document. Alternatively, where field non-destructive testing cannot be performed, attachments will be field spark tested by standard holiday leak detectors in accordance with ASTM 6365.

- 5.23 Spark testing should be done in areas where both air pressure testing and vacuum testing are not possible.
- (i) Equipment for spark testing shall be comprised of but not limited to a hand held holiday spark tester and conductive wand that generates a high voltage.
 - (ii) The testing activities shall be performed by the Geomembrane Installer by placing an electrically conductive tape or wire beneath the seam prior to welding. A trial seam containing a non-welded segment shall be subject to a calibration test to ensure that such a defect (non-welded segment) will be identified under the planned machine settings and procedures. Upon completion of the weld, enable the spark tester and hold approximately 25mm (1 in) above the weld moving slowly over the entire length of the weld in accordance with ASTM 6365. If there is no spark the weld is considered to be leak free.
 - (iii) A spark indicates a hole in the seam. The faulty area shall be located, repaired and retested by the Geomembrane Installer.
 - (iv) Care should be taken if flammable gases are present in the area to be tested.

Welding and testing

- 5.24 The Owner's Representative shall be notified prior to all pre-qualification and production welding and testing, or as agreed upon in the pre-construction meeting.

Prequalification Test Seams

- 5.25 Test seams shall be prepared and tested by the Geomembrane Installer to verify that seaming parameters (speed, temperature and pressure of welding equipment) are adequate.
- 5.26 Test seams shall be made by each welding technician and tested in accordance with ASTM D 4437 at the beginning of each seaming period.
- 5.27 Test seaming shall be performed under the same conditions and with the same equipment and operator combination as production seaming. The test seam shall be approximately 3.3 meters (10 feet) long for fusion welding and 1 meter (3 feet) long for extrusion welding with the seam centered lengthwise. At a minimum, test seams should be made by each technician 1 time every 4–6 hours; additional tests may be required with changes in environmental conditions.

- 5.28 Two 25 mm (1 in) wide specimens shall be die-cut by the Geomembrane Installer from each end of the test seam. These specimens shall be tested by the Geomembrane Installer using a field tensiometer testing both tracks for peel strength and also for shear strength. Each specimen should fail in the parent material and not in the weld, "Film Tear Bond" (F.T.B. failure). Seam separation equal to or greater than 25% of the track width shall be considered a failing test.
- 5.29 The minimum acceptable seam strength values to be obtained for all specimens tested are listed in paragraph 5.41. Four specimens shall pass and the fifth specimen must meet or exceed 80% of the required seam strength for the test seam to be a passing seam.
- 5.30 If a test seam fails, an additional test seam shall be immediately conducted. If the additional test seam fails, the seaming apparatus shall be rejected and not used for production seaming until the deficiencies are corrected and a successful test seam can be produced.
- 5.31 A sample from each test seam shall be labelled. The label shall indicate the date, geomembrane temperature, number of the seaming unit, technician performing the test seam and pass or fail description. The sample shall then be given to the Owner's Representative for archiving.
- Field Seam Non-destructive Testing**
- 5.32 All field seams shall be non-destructively tested by the Geomembrane Installer over the full seam length before the seams are covered. Each seam shall be numbered or otherwise designated. The location, date, test unit, name of tester and outcome of all non-destructive testing shall be recorded and submitted to the Owner's Representative.
- 5.33 Testing should be done as the seaming work progresses, not at the completion of all field seaming, unless agreed to in advance by the Owner's Representative. All defects found during testing shall be numbered and marked immediately after detection. All defects found should be repaired, retested and remarked to indicate acceptable completion of the repair.
- 5.34 Non-destructive testing shall be performed using vacuum box, air pressure or spark testing equipment.
- 5.35 Non-destructive tests shall be performed by experienced technicians familiar with the specified test methods. The Geomembrane Installer shall demonstrate to the Owner's Representative all test methods to verify the test procedures are valid.
- 5.36 Extrusion seams shall be vacuum box tested by the Geomembrane Installer in accordance with ASTM D 4437 and ASTM D 5641 with the following equipment and procedures:
- (i) Equipment for testing extrusion seams shall be comprised of but not limited to: a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft rubber gasket attached to the base, port hole or valve assembly and a vacuum gauge; a vacuum pump assembly equipped with a pressure controller and pipe connections; a rubber pressure/vacuum hose with fittings and connections; a plastic bucket; wide paint brush or mop; and a soapy solution.
 - (ii) The vacuum pump shall be charged and the tank pressure adjusted to approximately 35 kPa (5 psig).
 - (iii) The Geomembrane Installer shall create a leak tight seal between the gasket and geomembrane interface by wetting a strip of geomembrane approximately 0.3m (12 in) by 1.2m (48 in) (length and width of box) with a soapy solution, placing the box over the wetted area, and then compressing the box against the geomembrane. The Geomembrane Installer shall then close the bleed valve, open the vacuum valve, maintain initial pressure of approximately 35 kPa (5 psig) for approximately five (5) seconds. The geomembrane should be continuously examined through the viewing window for the presence of soap bubbles, indicating a leak. If no bubbles appear after five (5) seconds, the area shall be considered leak free. The box shall be depressurized and moved over the next adjoining area with an appropriate overlap and the process repeated.
 - (iv) All areas where soap bubbles appear shall be marked, repaired and then retested.
 - (v) At locations where seams cannot be nondestructively tested, such as pipe penetrations, alternate non-destructive spark testing (as outlined in paragraph 5.22) or equivalent should be substituted.
 - (vi) All seams that are vacuum tested shall be marked with the date tested, the name of the technician performing the test and the results of the test.

- 5.37 Double Fusion seams with an enclosed channel shall be air pressure tested by the Geomembrane Installer in accordance with ASTM D 5820 and ASTM D 4437 and the following equipment and procedures:
- (i) Equipment for testing double fusion seams shall be comprised of but not limited to: an air pump equipped with a pressure gauge capable of generating and sustaining a pressure of 210 kPa (30 psig), mounted on a cushion to protect the geomembrane; and a manometer equipped with a sharp hollow needle or other approved pressure feed device.
 - (ii) The testing activities shall be performed by the Geomembrane Installer. Both ends of the seam to be tested shall be sealed and a needle or other approved pressure feed device inserted into the tunnel created by the double wedge fusion weld. The air pump shall be adjusted to a pressure of 210 kPa (30 psig), and the valve closed. Allow two (2) minutes for the injected air to come to equilibrium in the channel, and sustain pressure for five (5) minutes. If pressure loss does not exceed 28 kPa (4 psig) after this five minute period the seam shall be considered leak tight. Release pressure from the opposite end verifying pressure drop on needle to ensure testing of the entire seam. The needle or other approved pressure feed device shall be removed and the feed hole sealed.
 - (iii) If loss of pressure exceeds 28 kPa (4 psig) during the testing period or pressure does not stabilize, the faulty area shall be located, repaired and retested by the Geomembrane Installer.
 - (iv) Results of the pressure testing shall be recorded on the liner at the seam tested and on a pressure testing record.

Destructive Field Seam Testing

- 5.38 One destructive test sample per 150 linear m (500 linear ft) seam length or another predetermined length in accordance with GRI GM14 or GRI GM20 shall be taken by the Geomembrane Installer from a location specified by the Owner's Representative. The Geomembrane Installer shall not be informed in advance of the sample location. In order to obtain test results prior to completion of geomembrane installation, samples shall be cut by the Geomembrane Installer as directed by the Owner's Representative as seaming progresses.
- 5.39 All field samples shall be marked with their sample number and seam number. The sample number, date, time, location, and seam number shall be recorded. The Geomembrane Installer shall repair all holes in the geomembrane result-

ing from obtaining the seam samples. All patches shall be vacuum box tested or spark tested. If a patch cannot be permanently installed over the test location the same day of sample collection, a temporary patch shall be tack welded or hot air welded over the opening until a permanent patch can be affixed.

- 5.40 The destructive sample size shall be 300 mm (12 in) wide by 1 m (36 in) long with the seam centered lengthwise. The sample shall be cut into three equal sections and distributed as follows: one section given to the Owner's Representative as an archive sample; one section given to the Owner's Representative for laboratory testing as specified in paragraph 5.42 below; and one section retained by the Geomembrane Installer for field testing as specified in paragraph 5.41 below.
- 5.41 For field testing, the Geomembrane Installer shall cut 10 identical 25mm (1 in) wide replicate specimens from the sample. The Geomembrane Installer shall test five specimens for seam shear strength and five for peel strength. Peel tests will be performed on both inside and outside weld tracks. To be acceptable, 4 of 5 test specimens must pass the stated criteria in section Geomembrane Quality Control (3.15 - 3.17) with less than 25% separation. The fifth specimen must meet or exceed 80% of the required seam strength.
- 5.42 If independent seam testing is required by the specifications it shall be conducted in accordance with ASTM 5820 or ASTM D4437.
- 5.43 Reports of the results of examinations and testing shall be prepared and submitted to the Owner's Representative.
- 5.44 For field seams, if a laboratory test fails, that shall be considered as an indicator of the possible inadequacy of the entire seamed length corresponding to the test sample. Additional destructive test portions shall then be taken by the Geomembrane Installer at locations indicated by the Engineer; typically 3 m (10 ft.) on either side of the failed sample and laboratory seam tests shall be performed. Passing tests shall be an indicator of adequate seams. Failing tests shall be an indicator of non-adequate seams and all seams represented by the destructive test location shall be repaired with a cap-strip extrusion welded to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box tested until adequacy of the seams is achieved. Cap strip seams exceeding 50 m in length (150 ft) shall be destructively tested.





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Identification of Defects

- 5.45 Panels and seams shall be inspected by the Installer and Owner's Representative during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter.

Evaluation of Defects

- 5.46 Each suspect location on the liner (both in geomembrane seam and non-seam areas) shall be non-destructively tested using one of the methods described in section Field Seam Non-destructive Testing. Each location which fails non-destructive testing shall be marked, numbered, measured and posted on the daily "installation" drawings and subsequently repaired.
- 5.47 If a destructive sample fails the field or laboratory test, the Geomembrane Installer shall repair the seam between the two nearest passed locations on both sides of the failed destructive sample location.
- 5.48 Defective seams, tears or holes shall be repaired by re-seaming or applying an extrusion welded cap strip.
- 5.49 Reseaming may consist of either:
- (i) Removing the defective weld area and rewelding the parent material using the original welding equipment; or
 - (ii) Reseaming by extrusion welding along the overlap at the outside seam edge left by the fusion welding process.
- 5.50 Blisters, larger holes, and contamination by foreign matter shall be repaired by patches and/or extrusion weld beads as required. Each patch shall extend a minimum of 150 mm (6 in) beyond all edges of the defects.
- 5.51 All repairs shall be measured, located and recorded.

Verification of Repairs on Seams

- 5.52 Each repair shall be non-destructively tested using either vacuum box or spark testing methods. Tests which pass the non-destructive test shall be taken as an indication of a successful repair. Failed tests shall be resealed and retested until a passing test results. The number, date, location, technician and test outcome of each patch shall be recorded.

Daily Field Installation Reports:

- 5.53 At the beginning of each day's work, the Installer shall provide the Engineer with daily reports for all work accomplished on the previous work day. Reports shall include the following:
- (i) Total amount and location of geomembrane placed.
 - (ii) Total length and location of seams completed, name of technicians doing seaming and welding unit numbers.
 - (iii) Drawings of the previous day's installed geomembrane showing panel numbers, seam numbers and locations of non-destructive and destructive testing.
 - (iv) Results of pre-qualification test seams.
 - (v) Results of non-destructive testing;
 - (vi) Results of vacuum testing of repairs.
- 5.54 Destructive test results shall be reported prior to covering of liner or within 48 hours.

Liner Acceptance

- 5.55 Geomembrane liner will be accepted by the Owner's Representative when:
- (i) The entire installation is finished or an agreed upon subsection of the installation is finished.
 - (ii) All Installer's QC documentation is completed and submitted to the owner.
 - (iii) Verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete.

Anchor Trench

- 5.56 Construct as specified on the project drawings.

Disposal of Scrap Materials

- 5.57 On completion of installation, the Geomembrane Installer shall dispose of all trash and scrap material in a location approved by the Owner, remove equipment used in connection with the work herein, and shall leave the premises a neat acceptable manner. No scrap material shall be allowed to remain on the geomembrane surface.

REFERENCES

- (i) Guidelines for Installation of HDPE and LLDPE Geomembrane Installation Specification. November 2019. IAGI.
- (ii) D 638, Standard Test Method for Tensile Properties of Plastics.
- (iii) D 4439 Terminology for Geosynthetics.
- (iv) D 751, Standard Test Methods for Coated Fabrics.
- (v) D 792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
- (vi) D 1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
- (vii) D 1204, Standard Test Method for Linear Dimensional Changes of Non Rigid Thermoplastic Sheeting or Film at Elevated Temperature.
- (viii) D 1238, Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
- (ix) D 1505, Standard Test Method for Density of Plastics by Density Gradient Technique.
- (x) D 1603, Standard Test Method for Carbon Black in Olefin Plastics.
- (xi) D 3895, Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.
- (xii) D 4218, Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
- (xiii) D4437 – 08, Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
- (xiv) D 4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products.
- (xv) D 5199, Standard Test Method for Measuring Nominal Thickness of Smooth Geomembranes.
- (xvi) D 5397, Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefins using Notched Constant Tensile Load Test.
- (xvii) D 5596, Standard Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.
- (xviii) D 5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
- (xix) D 5721, Practice for Air-Oven Aging of Polyolefin Geomembranes.



- (xx) D 5820, Test Method for Air Testing.
- (xxi) D 5885, Test Method for Oxidative Induction Time of Polyolefin.
- (xxii) D 5994, Standard Test Method for Measuring Nominal Thickness of Textured Geomembranes.
- (xxiii) D 6365, Standard Practice for the Nondestructive Testing of Geomembrane Seams using The Spark Test.
- (xxiv) D 5820-95, Pressurized Air Channel Test for Dual Seamed Geomembranes.
- (xxv) D 6392-08, Integrity of Non-reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
- (xxvi) D7002, Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Puddle Method.
- (xxvii) D7007-15, Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials.
- (xxviii) ASTM D7466, Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage.
- (xxix) Designing with Geosynthetics - 6th Edition. Robert M. Koerner.
- (xxx) GRI GM 9, Cold Weather Seaming of Geomembranes.
- (xxxi) GRI GM 10, The Stress Crack Resistance of HDPE Geomembrane Sheet.
- (xxxii) GRI GM 13, Test Properties, Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.
- (xxxiii) GRI GM14 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.
- (xxxiv) GRI GM 17, Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.
- (xxxv) GRI GM19a Seam Strength and Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes/Barriers.
- (xxxvi) GRI GM20 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts.



GRI -GM19a

"Seam Strength and Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes/Barriers"

Table 1 (a) - Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes (English Units)

Geomembrane Nominal thickness	30 mils	40 mils	60 mils	80 mils	100 mils	120 mils
Hot wedge seams ⁽¹⁾						
Shear strength ⁽³⁾ , lb/in.	57	80	120	160	200	240
Shear elongation at break ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , lb/in.	45	60	91	121	151	181
Peel separation, %	25	25	25	25	25	25
Extrusion fillet seams						
Shear strength ⁽³⁾ , lb/in.	57	80	120	160	200	240
Shear elongation at break ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , lb/in.	39	52	78	104	130	156
Peel separation, %	25	25	25	25	25	25

Table 1 (b) - Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot wedge seams ⁽¹⁾						
Shear strength ⁽³⁾ , N/25 mm	250	350	525	701	876	1050
Shear elongation at break ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , N/25 mm	197	263	398	530	661	793
Peel separation, %	25	25	25	25	25	25
Extrusion fillet seams						
Shear strength ⁽³⁾ , N/25 mm	250	350	525	701	876	1050
Shear elongation at break ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , N/25 mm	170	225	340	455	570	680
Peel separation, %	25	25	25	25	25	25

Notes for Tables 1 (a) and 1 (b)

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing
3. Value listed for shear and peel strength are for 4 out of 5 test specimens; the 5th specimen can be low as 80% of the listed values.

INFORMATION TAKEN FROM GM19a/Rev.9: 7/28/2017

Table 2 (a) - Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	30 mils	40 mils	60 mils	80 mils	100 mils	120 mils
Hot wedge seams ⁽¹⁾						
Shear strength ⁽³⁾ , lb/in.	45	60	90	120	150	180
Shear elongation ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , lb/in.	38	50	75	100	125	150
Peel separation, %	25	25	25	25	25	25
Extrusion fillet seams						
Shear strength ⁽³⁾ , lb/in.	45	60	90	120	150	180
Shear elongation ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , lb/in.	34	44	66	88	114	136
Peel separation, %	25	25	25	25	25	25

Table 2 (b) - Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low density Polyethylene (LLDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot wedge seams ⁽¹⁾						
Shear strength ⁽³⁾ , N/25 mm	197	263	394	525	657	788
Shear elongation ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , N/25 mm	166	219	328	438	547	657
Peel separation, %	25	25	25	25	25	25
Extrusion fillet seams						
Shear strength ⁽³⁾ , N/25 mm	197	263	294	525	657	788
Shear elongation ⁽²⁾ , %	50	50	50	50	50	50
Peel strength ⁽³⁾ , N/25 mm	150	190	290	385	500	595
Peel separation, %	25	25	25	25	25	25

Notes for Tables 2 (a) and 2 (b)

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing
3. Value listed for shear and peel strength are for 4 out of 5 test specimens; the 5th specimen can be low as 80% of the listed values.

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