RAVEN

QUALITY CONTROL MANUAL FOR FIELD INSTALLATION OF GEOMEMBRANES

NON-REINFORCED LLDPE AND HDPE GEOMEMBRANES

RAVEN HYDRALINE HDPE AND LLDPE GEOMEMBRANES
LL -SERIES 20 – 120 MIL LAYFLAT LLDPE
HD-SERIES 30 – 120 MIL LAYFLAT HDPE

RAVEN ENGINEERED FILMS

SIOUX FALLS, SD	MADISON, SD	BRANDON, SD
WAYNESBORO, VA	MIDLAND, TX	PLEASANTON, TX

+1 (800) 635-3456

QC MANUAL-INSTALLATION

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TABLE OF CONTENTS

APPENDIX

1.0 INTRODUCTION

1.1 SCOPE

The geomembrane manufacturer is responsible for the production of sheet or roll goods from HDPE or LLDPE polymer for ultimate delivery to the installer. The geomembrane installer is the party responsible for layout and thermal fusion welding of the roll goods delivered to the site. The HDPE or LLDPE material is manufactured in wide 22.5 ft rolls and thus do not require pre-fabrication as with narrow rolls of RPE, for example. All field welding is by double track thermal fusion which allows for air pressure testing of production seams. Extrusion welding is used for detail work and patching. This manual will provide the basic QC procedures for Installation of Raven HydraLine Geomembranes.

1.2 RAVEN HYDRALINE GEOMEMBRANE PRODUCTS COVERED BY THIS MANUAL

The geomembrane products covered by this QC manual include the following Smooth and Textured Geomembranes manufactured in base polymers Linear Low-Density Polyethylene (LLDPE) and High Density Polyethylene (HDPE):

- LL-Series 20 – 120 mil Smooth and Textured LLDPE
- HD-Series 30 – 120 mil Smooth and Textured HDPE

The physical/mechanical properties characteristics for each manufactured thickness of the above are included in the Appendix.

1.3 QUALITY STANDARDS

The manufacturing QC of roll goods (MQC) process shall be in compliance with the provisions of the Geosynthetic Research Institute (GRI) standard specification GRI GM 13 for HDPE and GRI GM 17 for LLDPE. In addition, reference is made to applicable ASTM standards including ASTM, D 5641, D 6392, D 6365, and D 5820 that contain requisite guidelines and required physical/mechanical characteristics, properties, testing methods and frequencies. For the installation of Raven HDPE and LLDPE Geomembranes, reference is made to GRI GM 19 for seam testing and the International Association of Geosynthetic Installers (IAGI) Guidelines for Installation of Geomembranes (IAGI, 2014).

1.4 TERMINOLOGY

The following definitions will be used throughout this document.

Geomembrane Manufacturer — The party responsible for formulating the LLDPE or HDPE sheet or geomembrane.

Geomembrane Installer — The party responsible for placing and/or joining LLDPE or HDPE geomembrane roll goods or sheets in the field or on the job site.

Sample — The piece of liner taken for testing or archival material. It is usually large enough to accommodate multiple specimens for a series of quality tests.

Seam — The completed process of thermal fusion welding.

Specimen — The term applied to an individual part of a sample. Typically, there are 4 to 10 specimens taken from each sample. It is a specific piece of a sample upon which a test can be performed.

Welding — The process whereby two sheets of LLDPE or HDPE are joined together by thermal fusion to form a seam.

2.0 QUALITY CONTROL REQUIREMENTS OF THE GEOMEMBRANE MANUFACTURER

2.1 QC ROLL GOODS OR SHEET MATERIAL

The HDPE or LLDPE sheet material produced must be uniform in color, thickness, and surface texture. The sheet must be free of pinholes, blisters, and undistributed raw materials. Roll goods or sheet material must have uniform edges. The HDPE or LLDPE sheet material shall have minimum property values per GRI Specifications. Testing is done at standard temperature and humidity conditions. A sample from each lot of HDPE or LLDPE geomembrane representing approximately 40,000 pounds is collected for testing. The test sample results must meet the Certified Properties of the GRI GM 13 specification for HDPE Geomembrane or GRI GM 17 for LLDPE.

2.2 MANUFACTURED ROLL GOODS QC TESTING

The Manufacturer of the liner material shall provide certification that the material meets minimum property values as detailed in the Manufacturer's Specifications GRI Specifications and ASTM Specifications. Any lot of material that does not meet minimum specification requirements will be rejected based on testing and verification of the certified values.

3.0 FIELD INSTALLATION OF HYDRALINE GEOMEMBRANES

3.1 PANEL LAYOUT DRAWING

Prior to Installation of Panels, the Installer will provide a panel layout drawing with typical details for seaming and connections. The layout drawing will show the locations of all panels as well as seam orientation in accordance with specifications. In general, seams will be placed parallel to the line of maximum slope. The layout drawing will be submitted to and approved by the Project Engineer prior to the start of panel deployment.

Placement of the HDPE or LLDPE geomembrane rolls will not begin until the proposed panel layout drawing has been approved by the Engineer/Owner, including changes made at the job site. Each roll should be given a unique identification number or letter and labeled with the size of the roll to ensure proper placement during deployment.

3.2 DELIVERY, HANDLING AND STORAGE

HDPE or LLDPE rolls delivered to the job site must be recorded for delivery and confirmed for the specific project being constructed. As a minimum, each roll should be labeled in at least two locations to show:

- Product Type, Thickness and ID
- Rolll Number
- Date of Manufacture
- Dimensions
- Weight
- Special Install Directions

Roll Goods delivered to the job site are off loaded by either forklift (stinger bar only) or cradle style using slings and a handling bar. Chains are not recommended for off load as it can damage the liner.

If the rolls delivered to the site are not to be deployed immediately, the Owner will be responsible for providing storage and on-site security. The geomembrane rolls must be stored so that they are protected from puncture, moisture (ponding water/mud), mechanical abrasions, or other conditions which may cause damage. Rolls should be stacked no more than 3 rolls in height.

3.3 SITE MEETINGS

A Pre-Construction Meeting should be held prior to liner placement. The purpose of this meeting is to identify the responsibility and authority of the various parties involved. Additionally, any changes in the procedures that may be necessary should be discussed at this time. As a minimum, the meeting should be attended by Owner/Engineer Representatives, General and/or Earthworks Contractor, CQA party, and the liner installer's Project Manager/Installation Supervisor.

Progress Meetings should be held from time to time as is necessary to resolve problems and maintain the lines of communication.

3.4 SUBGRADE/SITE PREPARATION

The General Contractor or the Earthwork Contractor shall be responsible for preparing and maintaining the subgrade in a condition suitable for installation of liner. Special care must be taken to maintain the prepared soil surfaces. Any damage to the surface caused by weather conditions or other conditions must be repaired by the Earthwork Contractor. The installer will submit to the Owner/Representative, prior to installing the geomembrane material, written approval of the subgrade surface on which the liner will be installed (Subgrade Acceptance Certificate)

3.4.1 SURFACE CONDITION

All surfaces in contact with the liner must be free of sharp stones, objects over 3/8 inches in diameter, sticks and other debris that can puncture or tear the liner. No standing water, mud, snow, frost/frozen soils, or excessive moisture should be on the subgrade when the liner is deployed. Sub-grade should be constructed of a firm stable smooth base compacted to a minimum 95% standard proctor density. Abrupt changes in grade should not exceed 1 inch and desiccation cracks should not exceed ¼ inch in width.

3.4.2 GROUND WATER ELEVATION

If the liner will be installed at an elevation below the current or possible ground water elevation, the Owner is responsible for providing an adequate under drain system. It is the responsibility of the project engineer to ensure the under drain is appropriate for the project or that ballast (i.e., soil or concrete) is properly designed to prevent hydrostatic uplift.

3.4.3 ANCHOR TRENCHES

The anchor trench shall be excavated by the General Contractor or the Earthwork Contractor prior to geomembrane placement and to the location and dimensions shown on the approved drawings. Anchor trenches excavated in clay soils susceptible to desiccation cracks should be excavated only the distance required for that day's liner placement to minimize cracking of the clay soils. With other classes of soils the anchor trench can be excavated ahead of roll installation leaving an opening for equipment to enter on the highest end of the working area.

It is the responsibility of the General Contractor or Earthwork Contractor to maintain the trench to ensure that it is within the project specifications and drawings.

3.4.4 GAS/AIR VENTING

If there is a possibility of gas or air forming under the liner; a proper venting system must be designed. Specific projects may require different venting systems. It is the responsibility of the Project Engineer to determine if a gas venting system is appropriate for the specific project being constructed.

3.4.5 SOIL STERILIZATION

Sterilize areas containing nut grass, quack grass or other potentially harmful plant life. It is the responsibility of the Project Engineer to check with the manufacturer of the sterilant to ensure that the chemicals used are compatible with the liner material. Apply sterilant according to manufacturers' directions a minimum of 48 hours prior to liner installation.

3.4.6 SUBGRADE ACCEPTANCE AND MAINTENANCE

Prior to installation of the designated geomembrane, the soil surface will be noted by the installer of its current condition. No geomembrane material will be placed on a subgrade surface that has become visibly softened by water, has deep wheel ruts from equipment traffic, or overly dried, until it has been properly reconditioned and/or recompacted. The subgrade/soil surface will be maintained by the Earthwork Contractor until accepted by the Installer.

3.5 GEOMEMBRANE DEPLOYMENT

The HDPE or LLDPE geomembrane rolls will be deployed in accordance with the approved panel layout drawing (refer to section 4.1) and in such a manner as to minimize handling. The liner shall be placed in a relaxed condition and shall be free of tension or stress upon completion of installation. The liner is not to be pulled tight or subjected to undue stress.. As a general rule, rolls shall be overlapped a minimum of 100mm (4 inches) in preparation for thermal fusion welding of the seam.

3.5.1 TEMPERATURE CONSIDERATIONS

The liner is generally deployed when the ambient temperature is above 0°C (32°F) or below 50°C (122°F) unless agreed upon and approved by the Project Engineer.

If the material will be installed at temperatures outside of this range, special installation considerations should be agreed upon in advance. A geosynthetic installer's cold weather-seaming plan should be written into the specifications and follow the GRI GM 9 (Cold Weather Seaming Specifications). If there is a concern that the job will be extended into cold weather. No cover soil shall be placed on the geomembrane when it is below 0 C (32 F).

3.5.2 LOADING OR BALLASTING

Temporary ballast (i.e. sandbags) can be put into place to hold the liner if the wind is a concern. However, care should be taken to be sure there are no sharp edges that may tear or puncture the liner.

Geomembrane panels which have been displaced by wind should be inspected and approved by the Project Engineer on site. If the geomembrane has been damaged by wind uplift, the damage should be repaired by patching those sections torn, ripped or punctured. Patching methods are described in section 4.8 below.

3.5.3 EQUIPMENT TRAFFIC

Materials or equipment shall not be dragged across the surface of the liner. Any portion of the liner damaged by equipment or methods during installation, shall be repaired by the installer. All parties walking or working on the liner shall wear shoes that will not damage the liner.

No vehicles, other than those approved by the installer and/or the engineer, are allowed directly on the geomembrane. Areas of excessively high traffic shall be protected with a temporary layer of geotextile, geonet composite or liner rub sheet. Low ground pressure vehicles such as small rubber-tired equipment with a ground pressure not exceeding 35 kpa (5psi) will be permitted. Only equipment required during installation and for testing should be allowed on the liner.

3.5.4 RELAXED INSTALLATION

Minimum wrinkles will be allowed to ensure the liner is installed in a "relaxed" condition. Excessive wrinkles which overlap themselves will not be allowed. No wrinkles will be cut until the liner has gone through its expansion and contraction cycle and the sheet material has been positioned and large wrinkles or waves have been walked out or reduced in size.

3.5.5 DEPLOYMENT SCHEDULE

Only those rolls or panels which can be seamed together in the same day should be deployed. The soil covering operation (if required) can begin as soon as the seams have been tested and approved. If left exposed, proper ballast such as sandbags shall be used to protect the deployed panels from movement due to wind.

3.6 SEALING AROUND PENETRATIONS

The HDPE or LLDPE geomembrane roll or panel shall be sealed to all concrete structures and other openings through the lining in accordance with details shown on the engineer-approved shop drawings. Factory and/or field fabricated pipe boots shall be used to seal all pipes penetrating the liner. All joints shall be tightly bonded and tested in accordance with current industry standards and specification.

3.7 FIELD WELDING METHODS

The HDPE and LLDPE geomembranes are field welded by thermal fusion welding for all production seams and extrusion welded for details and patches. All welding methods require that the seaming surfaces must be clean and dry. If the liner surface needs to be cleaned, use only dry clean rags. The welding operation requires a firm, smooth subsurface and any conditions that make it difficult to weld must be adjusted prior to welding.

Trial welds are to be conducted by the technicians prior to each welding period. All trial welds will be conducted under the same conditions as will be encountered during the actual field welding.

Weather conditions will affect the welding process. Welding is best performed when sheet temperature is between 10°C (50°F) and 40°C (105°F). If the temperature is higher than 40°C (105°F), welding may continue, however changes in the welding process may be necessary. If the temperature is lower than 10°C (50°F) extra care needs to be taken for cold weather installation. This may, although not always, involve building a shelter from the natural elements. Other methods, such as pre-heating the liner prior to welding, may be deemed necessary by the installer. Increased quality control measures will be necessary under cold weather circumstances. The weather conditions that the welding was performed in should be documented. All cold weather welding shall follow GRI GM9 (Cold Weather Seaming) guidelines.

3.7.1 THERMAL FUSION WELDING

Thermal Fusion welds are made using a hot wedge welder. The minimum seam width for hot wedge welding is a nominal 25 mm (1.0 inch) in two approximately 12 mm (0.5 inch) tracks separated by an air channel for dual track welding. The wedge is electrically heated and passes between two sheets of liner. As it melts, the surface pressure is applied, and the seam is formed. These machines have automated control of temperature and speed of travel. The temperature and travel rate settings used to construct a seam should be documented. Only dual track thermal fusion welding is used on the HDPE or LLDPE geomembrane seams to allow for non-destructive testing by pressurized air channel (ASTM D 5820)

3.7.2 TRIAL WELDS

Trial welds using representative liner material and thermal fusion welding apparatus are to be conducted by the welding technician prior to each welding period and/or at least once every 4 hours. All trial welds shall be conducted under the same conditions as will be encountered during actual field installation to demonstrate that seaming conditions and equipment are acceptable. Trial weld samples shall be a minimum of 3.0 ft in length by 1.0 ft width with the seam

centered. Seam specimens shall be 1.0 inch in width for field tensiometer testing in both peel and shear modes. Testing shall comply with project specifications for both number of specimens and pass/fail criterion.

3.8 PATCHES AND REPAIRS

Place a patch of the same material with a minimum of 150-mm (6 inches) overlap over the damaged area. The patch should have rounded corners. Patches shall be continuously Leister heat welded in place and flat over the damaged area with roller pressure applied to the two surfaces in order to achieve a thermal bond between the liner surfaces. The bonded area is normally 2.5-cm (1-inch) minimum and the edge of the patch is then extrusion welded.

Cap stripping is the method of bonding a separate strip of the parent material over the seamed edge. Cap stripping may be used to repair an extended length of seam. Caps shall extend a minimum of 150-mm (6 inches) beyond the limits of the nonconforming seam and all corners shall be rounded. The bonded area of the cap-strip perimeter should be a nominal 2.5-cm (1- inch) and extrusion welded. A cap-stripped section must be nondestructively tested as outlined in Section 4.9. This method can be achieved by using a hand-held heat gun and thermally welding the patch or cap-strip. Once welded in place, edges are extrusion welded.

Care should be taken to avoid "fish mouths" or wrinkles in field seams. When "fish mouths" do occur, slit the liner out far enough from the seam to dissipate the "fish mouth". Overlap the edges and then weld together and patch a large enough area so that the sheet lays flat once patched.

3.9 NON-DESTRUCTIVE SEAM TESTING (NDT)

Non-destructive seam testing is meant to verify the continuity of field seams. In this regard dual track air pressure NDT is used on all production seams of HDPE or LLDPE and in general accordance with ASTM D 5820. All detail extrusion welded patch areas, repairs and spot welding are tested by vacuum box in general accordance with ASTM D 5641. Generally, non-destructive testing is done as the seaming progresses. One hundred percent of all field seams are non-destructively tested in the field as are patches and appurtenances. Structure connection details may also be tested for continuity using the spark testing method (ASTM D 6365). Mark any areas in need of repair or patching with a permanent marking pen and a sandbag or other highly visual marking to make it easier to locate the repair.

Any seams found not to be bonded need to be repaired and re-tested. Patches and cap stripping must be non-destructively tested. All seams tested and found to be acceptable should be marked with a permanent marker to provide proof that the seam was tested. All NDT test results must be documented on appropriate QC forms.

3.9.1 NDT: AIR CHANNEL (ASTM D 5820), VACUUM BOX (ASTM D 5641) AND SPARK TESTING (ASTM D 6365)

In accordance with ASTM D 5820 procedures, the dual track thermal fusion seam used for production field seams is pressurized and held at a constant pressure of approximately 30 psi for up to 5 minutes. The actual pressure used and time duration will be dependent on the material type, stiffness and thickness and is commonly a specification requirement. This testing procedure provides NDT verification of seam continuity and will detect any discontinuities or open seam areas. This method is used to test long lengths of field seams for continuity.

In accordance with ASTM D 5641 procedures, a vacuum is applied by a special glass top box along all extrusion welded areas. Vacuum Box NDT is performed along all field seams, appurtenances, patches, and cap stripping. Any loose areas or pin holes will be detected by air bubbles in a soap solution at the point of the opening. The areas found to be defective should be marked for repair. When un-bonded areas are located, they can sometimes be repaired by supplying heat into the opening with a hand-held Leister hot air gun and applying pressure with a hand roller. If that is not satisfactory, repairs should be made by patching or cap-stripping the area. The patch also needs to be NDT tested to ensure integrity.

Spark testing NDT (ASTM D 6365) is sometimes used on attachment areas and corners that are difficult to access. To use this method, a conductive wire is first inserted into the field seam which is usually an extrusion weld. When a positive voltage is applied to the seam edge, suspect areas will spark indicating a void or open seam area that will require repair.

The testing of seams should be witnessed by a Representative of the Owner or the Owner's CQA Representative. The installer will be allowed to continue NDT testing if the Owner's Representative, Project Engineer or CQA Representative declines to witness the testing.

3.10 DESTRUCTIVE SEAM TESTING (ASTM D 6392, GRI GM 19)

Destructive seam testing shall be in accordance with the project specifications and taken at intervals as required. Samples are normally taken every 500 to 1000 linear feet per welder and are large enough to take five peel and five shear specimens from the installed geomembrane. The area is patched using a piece of the liner material with rounded corners and seamed according to Section 3.7. The frequency of sampling should be determined in advance by the project engineer and methods used shall be in accordance with the project specifications and in general accordance with ASTM D 6392. GRI GM 19 provides minimum seam strength requirements for thermal fusion bonded geomembrane seams.

In the absence of specified methods, each destructive sample shall, at a minimum, measure 30 cm (12 inches) wide by 90 cm (36 inches) long. The seam should be centered in the sample. One half of the sample should be given to the installer and the second half of the sample should be given to the owner. The owner may at their discretion and expense, promptly send this sample to a third party for immediate testing. The location of each sample taken must be noted on the record drawings.

An identifying number or letter is put on the sample with permanent marker. Mark all samples with their location, panel and seam number. Also record the date, time and name of technicians, ambient temperature and subgrade condition at the time the seam was made. Record the sample number on a Chain of Custody Form (See Section 3.11 below).

Prior to testing in the field, allow the specimens to cool and stabilize. Five peels and five shear specimens are taken from the sample. Four of the five specimens must pass for the sample to pass. The following procedure will apply whenever a sample fails a destructive test. The installer will either:

A. Reconstruct the seam between any two passed test locations, or

B. Trace the seam outward to intermediate points (at least 3.0 m (10 feet) from the location the failed test in each direction) and take a small sample for additional field tests at each location.

If this sample passes the field test, a full sample will be cut for verification, if the sample passes, the seam is then reconstructed between these two locations. If an intermediate sample fails, the process is repeated to establish the zone in which the seam should be reconstructed. All reconstructed seams must be bounded by two locations from which samples passing other destructive tests have been taken.

3.11 SAMPLE CUSTODY

Whenever a sample is taken, a Chain of Custody record should be made for that sample. If the sample is sent to a laboratory or another individual, this change in custody should be noted. A chain of custody record minimizes the possibility of losing a sample. Additionally, anomalous test results may be able to be traced and other testing problems recorded.

3.12 SOIL COVER PLACEMENT (IF REQUIRED)

If required in the lining system design, a minimum of a 30-cm (12-inch) thick clean earthen cover, free of foreign objects such as rocks, sticks, etc. should be used to cover the liner. The liner shall be covered as soon as possible after the liner

has been placed and the seams have been tested and approved. All equipment used in soil cover placement must be wide track low ground pressure (LGP) with < 5 psi under the tracks.

Earth moving equipment should remain on top of a minimum of 30-cm (12 inches) of cover material. Do not drive equipment on the liner itself. The only rubber tire vehicles allowed on the liner are lightweight all-terrain vehicles (ATV's) and testing equipment. The Project Engineer must determine the depth of cover based on the type of equipment that will be used. The soil thickness must be specified to ensure that the liner is not damaged by equipment during soil placement. The Project Engineer is responsible for specifying the type of cover material to be used.

Placement of the soil cover should proceed from a stable area next to the geomembrane and systematically work outward. The soil should not be pushed forward in a manner that could stress the liner. Placement or soil or other overburden materials directly onto the liner should be performed with the load close to the liner and inspected to make sure that it is clear of sharp objects. On side slopes, soil cover should be placed from the bottom of the slope and worked up slope until the soil is placed and compacted along the entire slope.

3.13 FINAL ACCEPTANCE

Once the geomembrane installation is complete, representatives of all parties involved shall perform a thorough inspection of the installation including all surfaces, seams and connections to structures or pipe penetrations. Any defects will be noted and repaired. Once complete, the installation shall be signed off as accepted by the project engineer or CQA representative. This is particularly important prior to any soil cover placement by the earth works contractor.

3.14 RECORD OR AS-CONSTRUCTED DRAWINGS

In addition to QC documentation, the Installation contractor shall provide a final as-constructed record drawing of the project which illustrates the panel layout, panel numbers, seam orientations, repairs and location of destructive cut-outs and structure/pipe connections as a minimum. The record drawing shall be submitted in accordance with project specification requirements.

APPENDIX A — RAVEN FABRICATION QC DOCUMENTATION FORMS

Appendix A - Factory Fabrication QA Form

APPENDIX B — RAVEN FIELD INSTALLATION QC FORMS

Appendix B – Daily Installation Report + Additional Pre-Weld Form
Appendix B – Destructive Test Report Form
Appendix B – Panel Placement Log Form
Appendix B – Repair Log Form
Appendix B – Seam Quality Control Form

Current Appendix A and B Forms located at https://ravenefd.com/installation/geo-liners-covers

APPENDIX C — RAVEN DURA♦SKRIM® SERIES PRODUCT SPECIFICATION SHEETS

HYDRALINE™ HD-Series HDPE (23' Smooth or Textured HDPE)

HYDRALINE™ LL-Series LLDPE (23' Smooth or Textured LLDPE)

Current Raven Product Specification Sheets located at www.ravenefd.com/products/product-data-sheets

SCAN THE QR CODES BELOW TO BE DIRECTED TO THE RAVEN WEBSITE LOCATION FOR ALL RESOURCES LISTED:

RAVEN QC FABRICATION AND FIELD INSTALLATION MANUALS

RAVEN QC FACTORY AND FIELD INSTALL DOCUMENTATION FORMS

RAVEN TECHNICAL INSTALLATION DETAIL DRAWINGS

RAVEN PRODUCT DATA SPECIFICATION SHEETS

Note: To the best of our knowledge, these are typical industry installation procedures and are intended as guidelines only. RAVEN INDUSTRIES MAKES NO WARRANTIES AS TO THE FITNESS FOR A SPECIFIC USE OR MERCHANTABILITY OF PRODUCTS OR GUIDELINES REFERRED TO, no guarantee of satisfactory results from reliance upon contained information or recommendations and we disclaim all liability for resulting loss or damage.

RAVEN ENGINEERED FILMS
Ph: +1 (605) 335-0174 • TF: +1 (800) 635-3456
efdsales@ravenind.com
www.ravenefd.com

010120 EFD1700