

Appendix C

Bingham Reservoir System Leak Detection and Repair Plan

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LEAK DETECTION AND REPAIR PROGRAM BINGHAM RESERVOIR SYSTEM

OVERVIEW

The operational premise of the Bingham Reservoir System under the Ground Water Discharge Permits is that if a leak in the liner is detected, Kennecott Utah Copper LLC (KUC) will locate and repair the leak using approved liner repair methods. Each facility within the Reservoir System has a specific leak detection program as described in Utah Ground Water Discharge Permits UGW350006.¹ If a leak is detected in any of the HDPE lined facilities and determined to require repair, KUC will repair it according to a schedule that balances the magnitude of the leak, the relative quality of the effluent, and the current operational status of the mine. This schedule will be mutually acceptable to KUC and to the State Division of Water Quality. KUC will inspect the liner system annually, including evaluation of sludge deposition, and will monitor the water levels in the leak detection sumps.

DOCUMENTATION

Documentation of the leak detection methods, investigation, and subsequent liner repairs are the responsibility of the KUC Superintendent of SAWS. A written and photographic record of site reconnaissance, pumping, and investigative procedures will be submitted in report form to the Director of KUC Environmental Affairs, who will in turn notify and provide the appropriate information to the regulatory agencies. This technical memorandum will contain a brief explanation of the problem, the cause of the problem and how it was detected, and an explanation of the repairs with appropriate Quality Assurance. A copy of this documentation will be kept with the facility file in case further repairs are needed.

If a leak is suspected or liner failure is noticed, the following action steps will be followed:

- If an increase in liquid in a leak detection sump or a visible liner failure is observed, the KUC Manager of Environmental Operational Support (or designate) will be notified.
- Prior to notification, it will be determined if sump water level readings are accurate or related to mechanical or equipment failure.

¹Because of the unique design of the Desilting Basin, the liner system within it requires specialized methods for leak detection. Refer to the Desilting Basin Monitoring Plan for leak detection procedures. Procedures for repairs to the HDPE liners are the same for the entire Reservoir System

- If a sump pump test is necessary, the SAWS Superintendent or his designate will document any sampling and sump pump testing. A sump pump test will determine if any further action is necessary. The procedure for pumping the leak collection system sumps will be performed in accordance with the approved method in the Water Quality Sampling Plan. The implementation of the sump pumping is the responsibility of the SAWS Superintendent who will consult the Environmental Operational Support. The sump pump test will commence within 72 hours after discovery of a leak.
 - The SAWS Superintendent or his designate will then conduct a field reconnaissance of the facility and begin documentation as required, using the attached field sheet or a similar transmittal. Once the facility in question has been visibly inspected, appropriate operational changes may need to be made if the leak is significant. These may include but are not limited to rerouting of water, pumping to lower water levels, or draining of the facility.
 - In the event of verification of the occurrence of a leak, an assessment will be made by the SAWS Superintendent or his designate to determine the extent of discharge, if any, to ground water. KUC will propose a schedule to the
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Executive Secretary of the Division of Water Quality to implement an appropriate corrective action program, if the leakage event is found to justify such action beyond that outlined in this procedure.

LINER INSPECTION

Once the area of the liner which contains the potential leak has been isolated, a visual inspection of the exposed liner in the bottom and sides of the reservoir, its perimeter, and all seams and penetrations will commence. The liner in the isolated area or cell will be inspected for the following characteristics: buckling, ballooning or trampolining, deformation and hollow spots, signs of weathering, hail damage or damage from animal activity, and vandalism. Particular attention will be paid to areas containing screen tracks and outlets. Because the surface layer of the 80mil primary liner in Zones 1 and 2 is white, any surface damage will appear black. The liners in the Desilting Basin and Tailwater reservoirs do not have a white outer surface.

Perimeter inspection will consist of close inspection of the following areas: anchor trenches, extrusion welds, joints, and areas near fencing, spillways, curbs and concrete aprons. Anchor trenches will be inspected for evidence of pulling and buckling, saturation, or movement of earth fill. All concrete will be evaluated for evidence of spalling, exfoliation, and freeze-thaw damage.

Heat-welded seams and joints between sheets will be inspected for integrity, signs of cracking, and shearing. This includes seams on rub sheets and HDPE steps. Washing or wiping may be required where a more thorough inspection of the seams or welds is necessary.

Any surfaces which exhibit signs of wear, damage, or defective areas in the HDPE liners, or perimeter areas, will be documented in detail on a facility drawing. The affected HDPE strip and dimensions of the problem should be noted precisely in order to make repairs easier.

Cleaning of the liner and lowering reservoir water levels may be necessary if the above inspections do not find the suspected leak. A plan to empty the reservoir incrementally will be developed and scheduled commensurate with operating conditions and weather. Cleaning of the exposed liner may involve removal of accumulated sediment and sludges. Programs for desludging and reservoir cleaning must be approved by the Utah Division of Water Quality. If all water has been drained and the leak still has not been identified, the liners in Zone 1 and 2 can be spark tested using the manufacturers specifications.

LINER REPAIR

Once the leak has been identified procedures for scheduling and documenting repairs should begin. The following action steps must be taken:

- Determine if repairs can be made using KUC personnel, notify appropriate personnel, and document any repairs that are made. This should include QA/QC. Forward a copy of this documentation to the KUC Environmental Operational Support.
 - Assess if earthwork beneath liner has been compromised in any way; if so, re-compaction and permeability testing may be necessary. Specifications for clay placement, compaction, and moisture content are contained in the facility permit.
 - Notify liner repair contractor of needed repairs and schedule work to be done.
 - A KUC employee will supervise all contract work to ensure that industry approved methods are used and to document all repairs.
 - All repairs to liner will be checked for Quality Assurance. See attached manufacturers specifications for HDPE liner Installation and Quality Assurance.
 - Document all Quality Assurance methods and test results.
 - Quality Assurance will consist of one or more of the following: Clay permeability/compaction testing, HDPE vacuum testing or air pressure testing, and field and laboratory destructive testing of seams and welds.
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Original installation of the HDPE liners in the Bingham Reservoir System were manufactured by Gundle Inc.

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Houston, TX 77073
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Areas that require extensive repairs (not effectively repairable by heat weld extrusion techniques) will be cut out and replaced by new sections of HDPE sheet, and welded in as recommended by the liner manufacturer.

Repairs to the Bingham Reservoir System are to be completed by a qualified contractor and follow applicable repair procedures as listed in this Appendix.

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LARGE BINGHAM RESERVOIR / SMALL RESERVOIR LINER REPAIR AND INSPECTION FORM

1. Facility which required repair? Zone 1, Zone2, DSB, Small Reservoir.
 2. Location of liner repair? Include drawing if necessary.
 3. When was problem first discovered/noticed and by whom?
 4. Probable Cause?
 5. Please describe how problem was repaired or corrected. Who was responsible for repairs, date repair was initiated and completed.
 6. Please describe QA/QC measures and provide results.
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Please attach any documentation: photos, field reports, lab reports, etc..

Signature of attending personnel

Date.

MANUFACTURERS SPECIFICATIONS FOR LINER QUALITY ASSURANCE

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GEOMEMBRANE AND BENTONITE BLANKET INSTALLATION

3.1 Crest Anchorage System

The anchor trench shall be excavated by the Earthwork Contractor (unless otherwise specified) to the lines and widths shown on the design drawings, prior to geomembrane or bentonite blanket placement. If the anchor trench is excavated in a clay liner susceptible to desiccation, no more than the amount of trench required for the geomembrane or bentonite blanket to be anchored in one day shall be excavated (unless otherwise specified) to minimize desiccation potential of the anchor trench clay soils. Slightly rounded corners shall be provided in the trench where the geomembrane and/or bentonite blanket adjoins the trench so as to avoid sharp bends in the geomembrane or bentonite blanket. No large rocks or clay lumps shall be allowed to underlie the geomembrane or bentonite blanket in the anchor trench. Backfilling of the anchor trench shall be conducted in accordance with Section 3.5.

3.2 Geosynthetic Placement

Immediately prior to installation of either the designed geomembrane liner or bentonite blanket, the surface shall be observed by GLCC and the owner or the owner's representative. The decision to repair cracks, if any, shall be made only by the Project Manager. The subgrade shall be walked by GLCC and the project Manager for joint approval. GLCC will sign acceptance of the surface condition if the subgrade. The integrity of the underlying soil is the responsibility of the owner/earth work contractor. (Please note Figure 5 for example of Pre-start Site Inspection Certificate of Acceptance.

Subgrade Preparation Recommendations

No liner shall be placed on surfaces not previously found acceptable by the GLCC project manager or his agent. No sharp stones or other hard objects that could penetrate the liner shall be present in the top 1 inch of the surfaces to be covered. Surfaces to be lined shall be smooth and free of all rocks, sharp stones, sticks, roots, sharp objects, or debris of any kind. The surface should provide a firm, unyielding foundation for the geosynthetic with no sudden, sharp or abrupt changes or break in grade.

3.2.1 Field Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field; i.e., a field panel is a roll or a portion of the roll is cut in the field.

At the time of installation, the GLCC Field Supervisor shall give each field panel an "identification code" (number or letter-number) consistent with the layout plan. (Panel layout is tentative and may be revised by Gundle site manager with the approval of the field engineer to suit field conditions at the time of installation. All such changes will be reflected on the As-Built Drawings.) This identification code shall be agreed upon by the Project Manager. This field panel identification code shall be as simple and logical as possible.

3.2.2 Field Panel Placement

3.2.2.1 Location

Field panels are installed at the location indicated in the layout plan, or as modified by the GLCC Field Supervisor based upon existing site conditions.

3.2.2.2 Installation Schedule

Field panels may be installed using any one of the following schedules:

All field panels are placed prior to field seaming (in order to protect the subgrade from erosion by rain or wind or bentonite blanket from rain); Field panels are placed one at a time, and each field panel is seamed immediately after its placement (in order to minimize the number of unseamed field panels); and

Any combination of the above.

GLCC shall record the identification code, location, and date of installation of each geomembrane field panel (set Figure 6, example of Daily Progress Report). Daily Progress Report to be submitted to Project Manager for forwarding to Engineer (owner) also on a daily basis.

3.2.2.3 Weather Conditions

Neither welding or bentonite blanket placement shall take place during any precipitation, in the presence of excessive moisture, or in the presence of excessive winds (unless wind barriers are provided). In addition, welding shall not take place in an area of ponded water.

3.2.2.4 Method of Placement

GLCC shall verify the following:

Any equipment used does not damage the geomembrane or bentonite blanket by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means; The prepared surface underlying the geomembrane or bentonite blanket has not deteriorated since previous acceptance and is still acceptable immediately prior to geosynthetic placement; Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris; All personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane; The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil; The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, or soil is recommended along edges of panels to minimize risk of wind flow under the panels); Direct contact with the geomembrane or bentonite blanket is minimized; i.e., the geosynthetic(s) are protected by geotextiles, extra geomembrane, or other suitable materials in areas where excessive traffic may be expected. Bentonite blanket installation is per engineered specifications. Bentonite blankets installed which have a geomembrane reinforcement may be installed two ways, bentonite side up or down. Bentonite Blanket overlap and bentonite side placement are to be per engineered specifications. GLCC shall inform the Project Manager if the above conditions are not fulfilled.

3.2.2.5 Damage

GLCC shall inspect each geosynthetic after placement and geomembrane prior to seaming for damage. GLCC shall advise the Project Manager which geosynthetic or portions of damaged geosynthetics should be repaired or accepted. Damaged geosynthetic or portions of damaged geosynthetics which have been rejected shall be marked and their removal from the work area recorded by GLCC. Repairs to geomembrane shall be made according to procedures described in Section 3.4. Bentonite Blankets are to be installed as dry as possible. Should rain damage a Bentonite Blanket, that Bentonite Blanket must be air dried prior to installation. Replacement decisions are to be made by the Project Manager.

3-3 Field Seaming

3.3.1 Seam Layout

Upon commencement of the installation, GLCC shall provide the Project Manager with a proposed panel layout drawing; i.e., a drawing of the facility to be lined based upon submitted engineering drawings. The proposed panel layout drawing is tentative and may be modified by GLCC Field Supervisor with Project Manager approval.

In general, seams should be oriented parallel to the line of maximum slope; i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 feet (1.5m) from the toe of the slope or areas of potential stress concentrations unless otherwise authorized. When full roll lengths will extend past the toe of slope, panel ends may be seamed provided the panel end is cut at an angle greater than 45 to minimize seam strengths.

A seam numbering system compatible with a panel numbering system shall be agreed upon at the Resolution and/or Pre-Construction Meeting.

3.3.1.1 Field joints shall be made by overlapping adjacent sheets a minimum of 3 inches for extrusion welding and 4 inches for hot wedge welding (unless approved by the engineer).

3.3.1.2. Polyethylene pipe sleeves shall be used for pipe sleeves penetrating through the lined area. When the pipe composition is polyethylene the sleeve should be extrusion welded directly to the pipe if space permits. For dissimilar materials, the sleeve should be fastened by mechanical means and sealant applied between the pipe and sleeve.

3.3.1.3. Seaming Equipment and Products

The approved process for field seaming are extrusion welding and fusion (hot wedge) welding. Proposed alternate processes shall be documented and submitted to the Owner or his representatives for his approval. The extrusion welding apparatus shall be equipped with gauges giving the temperature of the apparatus at the nozzle and extruder barrel.

The fusion welding apparatus must be an automated vehicular mounted device which produces a double seam with an enclosed space or solid seam with an enclosed space or solid seam in thin mil material as specified. The fusion welding apparatus shall be equipped with gauges giving the applicable temperatures.

GLCC shall verify that:

Equipment used for seaming is not likely to damage geomembrane;

The extrusion welder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;

The electric generator is placed on a smooth base such that no damage occurs to the geomembrane,

Buffing shall be completed no more than one (1) hour prior to extrusion welding (buffing is not necessary for hot wedge welding);

A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and

The geomembrane is protected from damage in heavily trafficked areas.

3.3.3 Seam Preparation

GLCC shall verify that:

Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;

Seams are aligned with the fewest possible number of wrinkles and “fishmouths”.

3.3.4 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows:

The high temperature limit for welding is the temperature at which the well-being of the crew becomes uncertain.

Unless authorized in writing by the Project Manager, no seaming shall be attempted at ambient temperatures below 5 degrees Fahrenheit.

The colder the weather, the slower the welding speeds possible for effective welding. Further detail for cold weather welding follows in this section.

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

GLCC shall verify that these weather conditions are fulfilled and will advise Project Manager if they are not. The Project Manager shall then decide if the installation shall be stopped or postponed.

Cold Weather Seaming of Polyethylene Liners

Cold weather welding restrictions exist because problems associated with hot air seaming techniques have been mistakenly applied to extrusion welds. The Gundle extrusion weld, however, has been successfully employed in cold weather in several dozen job sites. With the assistance of preheating the sheet, the Gundle weld has been applied in as low as -5 degrees Fahrenheit. Both the Gundle extrusion weld and hoe wedge weld are able to overcome cold weather welding restrictions because of their unique designs.

Gundle’s extrusion weld is not solely temperature dependent. It combines pressure, extrudate, and mixing actions in addition to temperature, to bond the liner together. The mixing action means that convective heat transfer takes place in addition to conductive heat transfer. Overall heat transfer is thus improved and sensitivity to ambient temperature is dramatically reduced.

The Gundle extrusion welder is capable of continuously monitoring and controlling the temperatures of the extrudate and the zone of contact for independence of environmental conditions. To control the molten bead temperature accurately and to ensure no fluctuation out of the predetermined range the machine has:

- a. An over capacity heater band on the extruder.
- b. An extra over capacity heater band on the nozzle.
- c. A separate proportional temperature controller for each heater band.
- c. The nozzle thermocouple positioned approximately 1/8 inch from the end of the nozzle which rides on sheet.

The Gundle hot wedge welder lifts the sheet slightly to minimize the effects of subcooling from a frozen subbase. In addition the hot wedge welder comes equipped with a hot air blower attached to the welder which automatically preheats the sheet in the path of the hot wedge. Temperature controls can be adjusted to guarantee fully integrated welding as demonstrated by pod testing.

Destructive testing results are included in Exhibit 8 from a cold weather installment where the welding temperatures were known not to exceed 10 degrees F. The failure rates compare quite favorably with summertime work and indicate that the cold weather conditions did not imply bad welds for the Gundle welding system.

But to guarantee quality welding in cold weather, the following procedures are recommended for Gundle welds:

1. The sheet should be preheated before welding any time ice crystals are present in the weld path.
- 2- When strong winds are present, a shield of some sort should be set in place to prevent large convection heat losses from the welding gun during seaming. (Tunnels over the seams were used for such a purpose at the Midland, Michigan project.)
2. Test welds should always be prepared and tested before seaming in order to gauge appropriate welding conditions. (Example: Welding machine temperatures should be set higher and welding rates slowed down.)

3.3.5 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period (start of day, midday, and anytime equipment is turned off and allowed to cool down) for each seaming apparatus used. Trial seams shall be made under the same conditions as actual seams (see Figure 6, example of Pre-Weld Qualification form).

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

Two adjoining specimens each 1 inch (25 mm) wide, shall be cut from the trial seam sample by the installer. The specimens shall be tested respectively in shear and peel using a field tensiometer, and they should not fail in the seam. If the additional specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful full trial welds are achieved.

3.3.6 General Seaming Procedure

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

The rolls of membrane shall be overlapped by a minimum of four (4) inches (100 mm) for fusion welding and three (3) inches (75 mm) for extrusion welding.

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

Seaming shall extend up the panels and well into the anchor trench.

All cross seams are to be extrusion welded where they intersect. The top flap of membrane is removed in the area to be extrusion welded and the weld area is ground parallel to the seam prior to welding.

For fusion welding, a movable protective layer of plastic may be required to be placed directly below the overlapped membranes being seamed. This is to prevent any moisture buildup between the sheets to be welded and/or to provide consistent rate of speed for the wedge welding device.

3.3.7 Nondestructive Seam Continuity Testing

3.3.7.1 Concept

GLCC shall nondestructively test field seams over their full length using a vacuum test unit, air pressure testing, or other approved method. (Vacuum testing is described in Section 3.3.7.2 and air pressure testing is described in Section 3.3.7.3). The purpose of nondestructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

3.3.7.2 Vacuum Testing

The equipment shall be comprised of the following:

A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a gauge to indicate chamber vacuum;

A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;

A rubber pressure/vacuum hose with fittings and connections;

A bucket and wide brush or spray assembly;

A soapy solution;

The following procedures shall be followed:

Energize the vacuum pump and reduce the tank pressure to approximately 5 psi (10 inches. of Hg.);

Wet a strip of geomembrane approximately 12 inches by 48 inches (0-3 m by 1.2m) with the soapy solution;

Place the box over wetted area;

Close the bleed valve and open the vacuum valve;

Ensure that a leak tight seal is created;

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

If no bubble appears after 10 to 15 seconds, close the vacuum valve and open the bleed valve, move the box over next adjoining area with a minimum 3 inches (75 mm) overlap, and repeat the process;

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

Vacuum tested seams are recorded on Daily Progress Reports (Figure 6).

3.3.7.3

PRESSURE TEST SPECIFICATIONS FOR DUAL TRACK HOT WEDGE WELDS

Test Pressure (After 5 Min-) PSI Max. Pressure

<u>Sheet Thickness</u>	<u>Min.</u>	<u>Max.</u>	<u>Drop Allowed</u>
30 mil	24	30	3 PSI
40 mil	24	30	3 PSI
60 mil	27	30	3 PSI
80 mil	27	30	3 PSI

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3.3.7.4 Air Pressure Testing (For Double Fusion Seam Only)

The equipment shall be comprised of the following:

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

a rubber hose with fittings and connections;

a sharp hollow needle, or other approved pressure feed device.

The following procedures shall be followed:

seal both ends of the seam to be tested;

insert needle or other approved pressure feed device into the tunnel created by the fusion weld;

energize the air pump to a pressure between 25 and 30 psi (160 and 200 kPa), close valve, and sustain pressure for approximately five minutes;

if loss of pressure exceeds above listed values, or does not stabilize, locate faulty area and repair in accordance with Section 3.4;

remove needles or other approved pressure feed device and seal,

pressure tested seams are recorded on Daily Progress Reports (Figure 6).

3.3.8 Destructive Testing

3.3.8.1 Concept

Destructive seam tests shall be performed at random selected locations. The purpose of these tests is to check that welds are fully integrated with each other and to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

3.3.8.2 Location and Frequency

The owner and/or owner's representative shall select locations where seam samples will be cut. These locations shall be established as follows:

A frequency shall be agreed upon by GLCC and the Project Manager at the Resolution and/or Pre-Construction Meeting. Unless otherwise specified, destructive samples should be pulled at intervals of 1 sample for every 500 linear feet of weld.

The seaming technician shall not be informed in advance of the locations where the seam samples will be taken.

3.3.8.3 Sampling Procedure

Samples shall be cut by GLCC as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. GLCC shall:

Cut samples;

Assign a number to each sample which is to be based upon seam and sample number and mark it accordingly (see Figure 7, example of sample sticker);

Record sample location on layout drawing; and

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 3.4. The continuity of the new seams in the repaired area shall be tested according to Section 3.3.7.

3.3.8.4 Size of Samples

At a given sampling location, two types of samples shall be taken by the Installer.

First, two samples for field testing should be taken. Each of these samples shall be 1 inch (0.25 mm) wide by 12 inches (0.3m) long with the seam centered parallel to the length. The distance between these two samples shall be 42 inches.

If both samples pass the field test described in Section 3.3.8.5, a sample shall be cut into three parts and distributed as follows:

One portion to the Installer (GLCC) for laboratory testing (GLS), 18 inches x 12 inches;

One portion for Geosynthetic Quality Assurance Laboratory testing if applicable, 12 inches x 12 inches (0.3 m x 0.3 m); and

One portion to the Owner for archive storage, 12 inches x 12 inches (0.3 m x 0.3 m).

Final determination of the sample sizes shall be made at the Pre-Construction Meeting.

3.3.8.5. Field Testing

The- two 1 inch (25 mm) wide strips, mentioned in Section 3.3.8.4 shall be tested in the field for peel and shear and shall not fail in the seam. If any field test sample fails to pass, then the procedures outlined in 3.3.8.7 shall be followed.

Hand tensiometer testing in the field is also carried out. The following procedure is followed: If the test passes, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 3.4.

3.3.8.6 Laboratory Testing

Destructive test samples shall be packaged and shipped via express mail to Gundle's laboratory.

GLS Laboratory shall provide verbal test results no more than 24 hours after they receive the samples. Written results will follow within one week. (See Figure 8, example of destructive seam test report form.)

Destructive Testing of Seams

Destructive testing of seams is very important because it provides the only direct evaluation of seam strength and bonding efficiency which indicates seam durability.

Destructive testing involves two techniques: 1) Shear testing, and 2) peel testing. Shear testing applies a tensile stress from the top sheet through the weld and into the bottom sheet. Peel testing, on the other hand, peels the top sheet back against the overlapped edge of the bottom sheet in order to observe how separation occurs. The peel test indicates whether or not the sheets are continuously and homogeneously connected through the seam.

Specification for HDPE Seam Strength
(Based on NSF 54 Standards)

<u>Type of Material</u>	<u>No. of Coupons</u>	<u>Minimum Values Required</u> (Pounds per Inch of Width)			
		<u>Peel</u>	<u>Extrusion</u>	<u>Peel Fusion</u>	<u>Shear Fusion</u>
30 Mil HDPE	2	1	35	49	63 63
40 Mil HDPE	2	1	48	67	86 86
60 Mil HDPE	2	1	70	98	126 126
80 Mil HDPE	2	1	95	133	171 171
100 Mil HDPE	2	1	115	168	216 216
40 Mil HDT 2	1	42	60	76	76
60 Mil HDT 2	1	63	88	113	113
80 Mil HDT 2	1	94	118	151	151
20 Mil VLDPE	2	1	17	17	20 20
30 Mil VLDPE	2	1	23	23	30 30
40 Mil VLDPE	2	1	35	40	40 40
60 Mil VLDPE	2	1	52	52	50 50
80 Mil VLDPE	2	1	70	70	60 60
100 Mil VLDPE	2	1	88	88	100
40 Mil VLT 2	1	35	30	40	40
60 Mil VLT 2	1	52	50	60	60

Gundle standard testing procedure is as follows:

If there is a failure in either peel or shear then five total coupons are tested. If more than one coupon fails, then the sample fails. This is a modified ASTM method. The ASTM methods that are used are D4437, D413 and D638 which all can apply.

Reasons for Pass/Fail Criteria

The FTB requirement is very important. With a fully integrated, continuous connection through the seam, no weld bead/sheet or sheet/sheet interface exists. Such an interface might be separated by absorbed chemicals, causing failure of the seam.

In addition to the FTB criterion a minimum stress level is specified. This is important in order to protect against legitimate tearing of a thin portion of polymer in the weld (as might occur if the weld is off center).

The minimum stress levels are necessarily lower than tensile yield strengths of the parent sheet because of the different configuration of the test specimens during destructive testing. Bending moments come into play along with straight tensile stresses especially as the sheets are bent back in peel. These bending moments depend on the shape of the welds which vary even within the same welding technique. The minimum stress values are based on the average performance values of passed weld specimens tested in the laboratory.

3.3.8.7 Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails a destructive test. GLCC has two options:

- 1) Reconstruct the seam between any two passed test locations,
- 2) Trace the welding path to an intermediate location (10 feet maximum from the point of the failed test in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the field test, then full laboratory samples are taken. If the laboratory samples pass the tests, the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

All acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken.

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

3.4 Defects and Repairs

3.4.1 Identification

All seams and non-seam areas of the geomembrane shall be examined by GLCC for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. Bentonite blankets shall be inspected for tears or areas of bentonite loss.

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

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

3.4.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 3.3.7 as appropriate. Each location which fails the non-destructive testing shall be marked by GLCC and repaired. Work shall not proceed with any materials which will cover locations which have been repaired until laboratory tests results with passing values are available.

3.4.3 Repair Procedures

3.4.3.1 Geomembrane Repair Procedures

Any portion of the geomembrane failing a destructive or nondestructive test shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager and GLCC. The procedures available include:

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

Buffing and re-welding - used to repair small sections of extruded seams;

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

Capping - used to repair large lengths of failed seams;

Topping - used to repair areas of inadequate seams which have an exposed edge;

In addition, the following provisions shall be satisfied:

Surfaces of geomembrane which are to be repaired shall be abraded no more than one hour prior to the repair;

All surfaces must be clean and dry at the time of the repair;

All seaming equipment used in repairing procedures must be approved;

The repair procedures, materials and techniques shall be approved in advance of the specific repair by the Project Manager and GLCC.

Patches or caps shall extend at least 6 in. beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches.

3.4.3.2 Geomembrane Verification of Repairs

Each major repair requiring a patch or cap shall be identified on the as-built drawing. Each repair shall be nondestructively tested using the methods described in Section 3.3.7 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and retested until a passing result is obtained.

3.4.3.3 Bentonite Blanket Repair Procedures

Patching used to repair holes and tears to be free of contamination by foreign matter. Patching to be done with a patch that has a 12-inch overlap around the damaged area. The patch is to be tucked into place with excess bentonite poured over the overlap.

3.5 Backfilling of Anchor Trench

The anchor trench if any shall be adequately drained to prevent ponding or otherwise softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled by the Earthwork Contractor or as outlined in the specifications and bid documents.

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

3.6 Lining System Acceptance

The geosynthetic lining shall be accepted when:

The installation is finished;

Verification of the adequacy of all seams and repairs including associated testing is complete;

3.7 Soils in Contact with the Geomembrane

Important points for quality assurance of soils in contact with geomembranes include:

A geotextile or other cushion approved by the designer may be installed between angular aggregate and the geomembrane.

Equipment used for placing soil shall not be driven directly on the geomembrane.

A minimum thickness of 1 foot (0.3 m) of soil is recommended between a light dozer (such as a CAT D-3 or wide track caterpillar D-6 or lighter) and the geomembrane.

In heavily trafficked areas such as access ramps, soil thickness should be at least 2 to 3 feet (0.6-0.9m).

Soil/Earth Cover on top of Geomembrane

Placement of soils, sand or other types of earth cover on top of the liner shall not be performed until all destructive and nondestructive testing has been performed and accepted.

Placement should be performed to minimize wrinkles. Equipment operators should be briefed on method of placement and affects to thermal expansion and contraction of the liner.

Material placed on top of the liner should be back-dumped on liner and, in order to avoid the formation of wrinkles, efforts should be made to load the soil so that it comes down on top of the liner rather than being pushed across the sheet. This is done by 1) using a front end loader to place soil ahead of spreading soil cover, and 2) spreading soil by building a mound at the edge of soil, then pushing soil up and over the mound causing it to come down on the liner.

If a wrinkle forms, every effort should be made to walk the wrinkle out.

Minor folding over of wrinkles is acceptable providing an even transition occurs at the tail of the wrinkle. If excessive stress points are created at the tail of the wrinkle, the wrinkle should be cut out and repaired per Section 3.4.

4.0 GEOSYNTHETIC INSTALLATION

4.1 Anchor Trench Systems

All anchor trench systems will be excavated by the earthwork contractor (unless otherwise specified) in accordance with the lines and widths as shown on the contract drawings, before geosynthetics placement.

If the anchor trench is excavated in clay susceptible to desiccation, no more than the amount of trench required for the geosynthetic to be anchored in one (1) day will be excavated (unless otherwise specified) to minimize desiccation potential of the anchor trench clay soils.

The corners of the anchor trench where geosynthetic enters the trench should be slightly rounded to avoid sharp bends in the geosynthetics. No large rocks or clay lumps will be allowed to underlie the geosynthetic in the anchor trench.

Backfilling of the anchor trench will be conducted according to Section 4.5.

4.2 Geosynthetic Placement

Immediately before installation of any geosynthetics, the subgrade surface will be inspected by Gundle Lining Construction Corp. (GLCC) and the owner or the owner's representative. The decision to repair cracks, if any, will be made by the owner's representative. The subgrade will be walked by GLCC and the project manager for joint approval. GLCC will sign acceptance of the surface condition of the subgrade. The integrity of the underlying soil is the responsibility of the owner/earthwork contractor. (See Exhibits 10.6 and 10.7 in Section 10.0 for example of Pre-start Site Inspection and Subgrade Surface Acceptance Forms.)

Subgrade Preparation Recommendations

No geosynthetic will be placed on surfaces not previously found acceptable by the GLCC Supervisor or his agent.

No sharp stones or other hard objects that could penetrate the liner will be present in the top one inch (1") (2.5 cm) of the surfaces to be covered.

Surfaces to be lined will be smooth and free of all rocks, sharp stones, sticks, roots, other sharp objects, or debris of any kind. The surface should provide a firm, unyielding foundation for the geosynthetic with no sudden, sharp or abrupt changes or break in grade.

4.2-A Geomembrane Placement

4.2.A.1 Installation Schedule

Field panels are placed only after the subgrade has been accepted by GLCC and the project manager. GLCC takes responsibility only for accepting the surface conditions of the subgrade.

Field panels are placed one at a time and each field panel will be seamed immediately after its placement.

4.2-A-2 Location

Field panels are located by the GLCC Field Supervisor in a manner consistent with the specifications and in a manner best suited to existing site conditions (i.e., a field panel is a roll or a portion of roll cut in the field).

4.2.A.3 Field Panel Identification

A field panel is the unit area of geomembrane that is to be seamed in the field.

At the time of installation, the GLCC Field Supervisor will give each field panel an “identification code” (alpha or alphanumeric). This identification code will be agreed upon by the project manager. This field panel identification code will be as simple and logical as possible.

GLCC will record the identification code, roll number, and date of installation of each geomembrane field panel on the Daily Progress Report (see Exhibit 10.8 in Section 10.0). Daily Progress Reports are to be submitted to project manager on a daily basis.

4.2.A.4 Weather Conditions

Neither welding nor placement of geomembrane will take place during any precipitation, in the presence of excessive moisture, blowing dust, or in the presence of high winds (unless wind barriers are provided). In addition, neither placement nor welding will take place in areas of standing water.

4.2.A.5 Method of Placement

GLCC will verify that:

- Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means;
- The prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately before geosynthetic placement;
- Construction equipment used to deploy geomembranes should not create excessive rutting in the subgrade;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- If the substrata is a geosynthetic material, deployment may be by hand, by use of small jack lifts on pneumatic tires having low ground contact pressure, or by use of all-terrain vehicles (ATVs) having low ground contact pressure;

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

-
- No personnel working on the geomembrane will smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane;
 - The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
 - Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, or soil is recommended along edges of panels to minimize risk of wind flow under the panels);
 - Direct contact with the geomembrane is minimized; i.e., the geosynthetics are protected by geotextiles, extra geomembrane, or other suitable materials in areas where excessive traffic may be expected;
 - In the case of high density conductive geomembrane, the electrically conductive layer should be placed conductive side down, and
 - GLCC will inform the project manager if the above conditions are not fulfilled.

4.2.A.6 Damage

GLCC will inspect each geomembrane panel for damage prior to seaming. GLCC will advise the project manager what panel or portions of panels should be repaired as required. Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by GLCC. Repairs to geomembrane will be made according to procedures described in Section 4.4.A.

4.2.B Geotextile and Geonet Placement

Geotextile and geonets will be handled in such a manner as to ensure they are not damaged in any way.

On slopes, geotextiles and geonets will be anchored in the anchor trench; then rolled down the slope in such a manner as to continually keep the material in tension.

In the presence of wind, the materials will be weighted with sandbags until final covers are installed.

Care will be taken to assure that any underlying layers are not damaged during placement of geotextiles and geonets.

Care will be taken to assure that stones, mud, and dirt are not entrapped in the geotextile and geonet during placement and seaming operations.

Cutting and trimming of product placed on top of the liner must be done with hooked blade knives.

4.2.C Geosynthetic Clay Liner (GCL) Placement

The geosynthetic clay liner must be installed in general accordance with the manufacturer's specifications and in such a way as to prevent any damage to the GCL.

One method of installing a GCL is to utilize a piece of equipment such as a front-end loader or forklift that is capable of lifting the GCL. A spreader bar is attached to the lifting equipment, and a core bar is installed through the GCL core. Straps or other types of attachments are looped over the core bar and the spreader bar. The equipment then lifts the GCL above the subgrade soils and while backing away from the initial starting point unrolls the GCL roll. This method can be used to install a membrane-backed GCL with the bentonite side up or side down.

For GCLs with a geomembrane backing, an alternate method for installing the GCL with the membrane facing against the soil is to attach a ten foot (10') long bar clamp to the end of the roll. The upper clamp has a chain attachment that can easily fit over a trailer hitch that is on a truck or other type of equipment. The GCL is then pulled across the subgrade soils. If the membrane is textured, then rub sheets should be used.

Folds in the GCL must be "stretched out" prior to installation of any overlying geosynthetics or soils. If these folds cannot be removed by realignment of the GCL, then these folds must be "cut" from the GCL and patched according to the manufacturer's specifications.

4.3 Geosynthetic Seaming and Joining

4.3.A Geomembrane Seaming

See Section 6 for more guidance.

4.3.A.1 Seam Layout

Seams will be made by overlapping adjacent sheets approximately three inches (3") (2.5 cm) for extrusion welding and approximately four inches (4") (10 cm) for hot wedge welding.

In general, seams should be oriented parallel to the line of maximum slope; i.e., oriented along and not across the slope. For corners and odd-shaped geometric locations, the number of seams should be minimized. Horizontal seams should be a minimum of five feet (5') from the toe of the slope, crest of berms, or areas of potential stress concentrations unless otherwise authorized. When full, a panel does not extend five feet (5') (1.5 cm) past the toe of slope. A cross seam may be welded provided the panel end is cut at an angle greater than forty-five degrees (45°).

A seam numbering system compatible with a panel numbering system will be agreed upon at the Pre-Construction Meeting.

4.3.A.2 Seaming Equipment and Products

The approved processes for field seaming are extrusion welding and hot wedge (fusion) welding. Proposed alternate processes will be documented and submitted to the owner or his representative for approval.

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

The fusion welding apparatus must be an automated device that produces a double seam with an enclosed space or solid seam on thin mil material as specified.

The fusion welding apparatus will be equipped with gauges giving the applicable temperatures and speed settings.

The fusion welding apparatus will also be equipped with gauges giving the nip force on the knurled rollers and the supplied line voltage.

GLCC will verify that

- Equipment used for seaming is not likely to damage geomembrane;
- The extrusion welder is purged before starting a seam until all heat-degraded extrudate has been removed from the barrel;
- The electric generator if utilized is placed on a smooth base such that no damage occurs to the geomembrane;
- Buffing the geomembrane to remove waxes and oxides will be completed no more than one hour before extrusion welding (buffing is not necessary for hot wedge welding); and
- An insulating plate or fabric is placed beneath the hot welding apparatus.

4.3.A.3 Seam Preparation

GLCC will verify that:

- Before seaming, the area is clean and free of moisture, dust, dirt, and foreign material of any kind;
- Seams are aligned with the fewest possible number of wrinkles and “fishmouths”.

4.3.A.4 Seaming In Various Weather Conditions

The high temperature limit for welding is based on two factors: (1) The well-being of, the crew. Black lining material will get very hot when exposed to sunlight. It is possible that the elevated sheet temperature in conjunction with immoderate ambient conditions could place the well-being of the crew at risk. (2) Material capability. The highest temperature at which the materials can be properly welded is dependent upon such things as ambient temperature, wind, subgrade conditions, exposure to sunlight, material type, and material thickness to name a few.

Thinner materials and low density products are the most difficult to seam at high liner temperatures. The problem typically is characterized by frequent burnouts (places in the

weld where the rollers lose traction and the machine stops moving causing the wedge to burn through the liner). The number of burnouts can often be reduced by increasing the speed and/or decreasing the wedge temperature until a quality weld with a minimum number of burnouts is attained. The sheet temperature may reach a point at which the supervisor determines there are an excessive number of burnouts at which time the supervisor will order welding to stop.

In some areas of extreme temperature conditions, the supervisor may determine it would be more advantageous to work at night under artificial light, or split the work day to utilize the cooler morning and late evening hours.

The lowest allowable temperature at which welding may be permitted is also dependent upon conditions such as ambient temperature, wind, subgrade conditions, exposure to sunlight, material type, and material thickness. Typically cold weather welding may proceed by reducing welding speeds and/or increasing wedge temperature. Preheating the sheet in advance of the welding apparatus may also be done by using a hot air blower. When fusion welding preheat can be accomplished by installing a heater mounted ahead of the hot wedge so that the hot air will be directed between the sheets in the overlap. If the welder mounted blower is to be used as a preheater, the welder control box can no longer be used as a power source for the blower. It is necessary to use a separate power cord.

Whenever temperatures become cold, increased attention should be given to pre-weld destructive samples (Section 4.3.A.5). In cold conditions; it is even more critical that these trial welds be performed under the same conditions that will be seen during actual seaming. Quite often a technician will dry the material with a hot air blower before making a trial weld. This may significantly increase the sheet temperature and skew the results of the test. Also, if welding takes place on a frozen subgrade, the trial seams must also be done on frozen subgrade.

The lowest temperature at which welding may take place is the lowest temperature at which consistent passing trial seams can be performed under actual seaming conditions. In order to obtain passing results, it may be necessary to preheat the sheet in advance of the welder and/or shield the welding apparatus and the seaming area from wind.

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

GLCC will verify that these adjustments for various weather conditions are fulfilled and will advise the project manager if they are not. The project manager will then decide if the installation will be stopped or postponed.

4.3.A.5 Trial Seams

Trial seams will be made on fragments of geomembrane liner to verify that seaming equipment and conditions are adequate. Such trial seams will be made at the beginning of each seaming period (start of day, midday, and anytime equipment is turned off and allowed to cool down) for each seaming apparatus used. Trial seams will be made under the same conditions as actual seaming process.

The trial seam sample will be approximately three feet long by one foot wide (3' x 1' wide (1.0 m x 0.3m) for extrusion and six feet long by one foot wide (6' x 1') (2.0 m x 0.3 m) for hot wedge welds with the seam centered lengthwise. Seam overlap will be nominally

three inches (3") (7.5 cm) for extrusion welds and four inches (4') (10 cm) for hot wedge welds.

Two adjoining specimens, each one inch (1") (2.5 cm) wide, will be cut from the trial seam sample by the installer. The specimens will be tested respectively in shear and peel using field tensiometer, and they should not fail in the seam. If a specimen fails, the entire operation will be repeated. If the additional specimen fails, the seaming apparatus and procedures will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved.

4.3.A.6 Seaming Procedure

Unless otherwise specified, the general seaming procedure used by GLCC will be as follows:

- The rolls of membrane will be overlapped by approximately four inches (4") (10 mm) for fusion welding and approximately three inches (3") (7.5 cm) for extrusion welding. Seam strength is not a function of the overlap. The overlap simply needs to be wide enough to weld and test property.
- "Fishmouths", or wrinkles at the seam overlaps, will be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut "fishmouths" or wrinkles will be seamed and any portion where the overlap is inadequate will be repaired in accordance with the repair procedures described in Section 4.4.A.
- Seaming will extend along panel edges into the anchor trench.
- For hot wedge welding on damp or muddy subgrade, a movable protective layer of plastic may be required to be placed directly below the overlapped membranes being seamed. This is to prevent any moisture buildup between the sheets to be welded and/or to provide a more stable base on which the wedge welding device can travel.

4.3.A.7 Non-destructive Seam Testing

GLCC will non-destructively test all field seams over their full length using a vacuum test unit, air pressure testing, or other approved methods where applicable. The purpose of non-destructive tests is to check the seams for leaks. It does not provide information on seam strength or quality of bonding. Non-destructive testing will be carried out as the seaming progresses, not at the completion of a job.

4.3.A.7.1 Vacuum Testing

The equipment will be comprised of the following:

- A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a gauge to indicate chamber vacuum;
- A steel vacuum tank and pump assembly equipped with a vacuum gauge and pipe connections;
- A rubber pressure/vacuum hose with fittings and connections;
- A bucket and wide brush, mop or spray assembly; and
- A soapy solution.

The following procedures will be followed:

- Energize the vacuum pump;
-

-
- Wet a strip of geomembrane approximately twelve inches by forty-eight inches (12" x 48") with the soapy solution;
 - Place the box over the wet area;
 - Close the bleed valve and open the vacuum valve;
 - Ensure that a leak tight seal is created;
 - For a period of approximately five (5) to ten (10) seconds, examine the geomembrane through the viewing window for the propagation of soap bubbles;
 - After ten (10) to fifteen (15) seconds, close the vacuum valve and open the bleed valve, move the box over the adjoining area with a minimum three inches (3") overlap, and repeat the process;
 - All areas where soap bubbles appear will be marked and repaired in accordance with Section 4.4; and
 - Vacuum tested seams are recorded on Daily Progress Reports (see Exhibit 10.8 in Section 10.0).

4.3.A.7.2 Air Pressure Testing (For Double Hot Wedge Seam Only)

The equipment will be comprised of the following:

- An air pump (manual or motor driven) equipment with pressure gauge capable of generating a pressure between 25 and 40 psi (173 and 276 kPa);
- A rubber hose with fittings and connections; and
- Hollow needle and clamp assembly as shown in Figure 6.3, Section 6, or other approved pressure feed device.

The following procedures will be followed:

- Seal one end of the seam to be tested;
- Insert needle or other approved pressure feed device into the tunnel created by the fusion weld;
- Energize the air pump to a pressure between 25 and 40 psi (173 and 276 kPa), close valve, and hold pressure for approximately five minutes;
- If loss of pressure exceeds the values listed below, or does not stabilize, locate faulty area and repair in accordance with Section 4.4.A.
- Release air pressure by puncturing seam at opposite end of where pressure is applied to assure there is no blockage in the air channel and verify that the full seam has been pressurized;
- Remove needle or other approved pressure feed device and seal; and
- Pressure tested seams are recorded on Daily Progress Reports (see Exhibit 10.8 in Section 10.0).

**PRESSURE TEST SPECIFICATIONS FOR DUAL TRACK HOT WEDGE WELDS
IN HDPE AND VLDPE**

Test Pressure (After 5 Min.) PSI (kPa)

<u>Pressure Sheet Thickness</u>	<u>Min.</u>	<u>Max.</u>	<u>Drop Allowed</u>
30 mil (.75 mm)	24(166)	40(276)	3 PSI (21 kPa)
40 mil (1.0 mm)	24(166)	40(276)	3 PSI (21 kPa)
60 mil (1.5 mm)	27 (186)	40(276)	3 PSI (21 kPa)
80 mil (2.0 mm)	27(186)	40(176)	3 PSI (21 kPa)
100 mil (2.5 mm) & thicker	30(207)	40(276)	3 PSI (21 kPa)

4.3.A.7.3 Spark Testing Conductive Liner

Background

Spark testing was originally developed to inspect coatings on steel pipe. In this application, a high electrical potential (voltage) of negative polarity (ground) is applied to the metal pipe. A wand or brush of opposite positive polarity is passed over the coating and any voids in the coating establish electrical continuity and allow a spark to pass between the metal pipe and the wand.

DRAFT

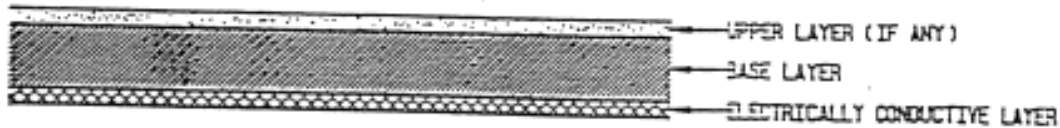
This same technology is now used to test synthetic liners for defects. Synthetic liners made of plastic materials such as high density polyethylene are nonconductors just as coatings on metal pipes. In order to spark test a synthetic liner, an electrically conductive material must be in "intimate contact" with the liner.

"Intimate contact" is critical for a valid test because air is also a good electrical insulator. Typically, 1,700 to 2,000 volts per millimeter is required to establish an electrical arc across a nonconductor. Therefore, to bridge a 1-inch air gap, a 35,000 to 50,000 volt potential would be required. To bridge a 4-inch air gap, 140,000 to 200,000 volts would be required.

If the conductive layer was the earth itself, wrinkles, bridged areas, or any condition separating the liner and the earth would invalidate the test.

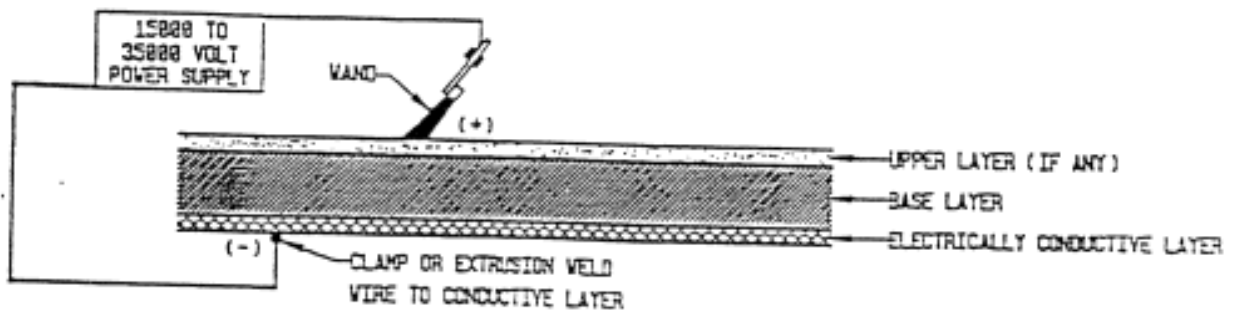
The Gundle Approach

Gundle has solved this problem by co-extruding a thin layer (minimum 2 mil) of liner material with elevated concentrations of high purity carbon black on one side of the liner. The special carbon black makes this layer electrically conductive and at the same time retains the performance characteristics of the base liner. Since the conductive layer is co-extruded, it is an integral part of the base liner and cannot be torn or damaged such that it fails to perform its basic duty. In cross-section the conductive liner is as shown below:

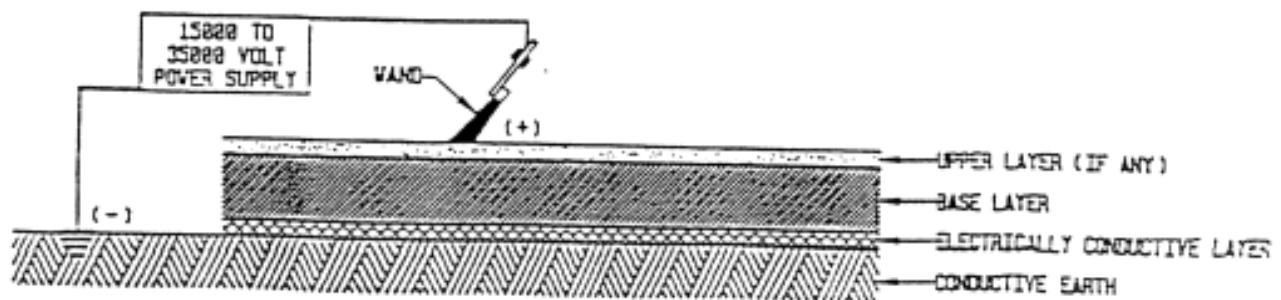


A high voltage potential (15,000 to 35,000 volts) source for spark testing can be connected to the liner in one of three ways.

1. Direct connection to the conductive layer:



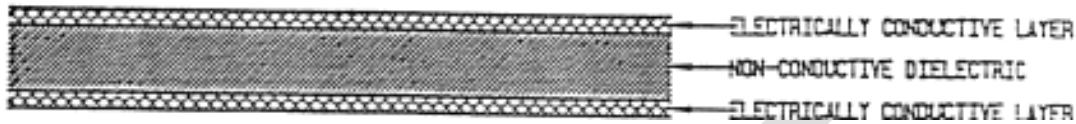
2. Through an Earth Ground:



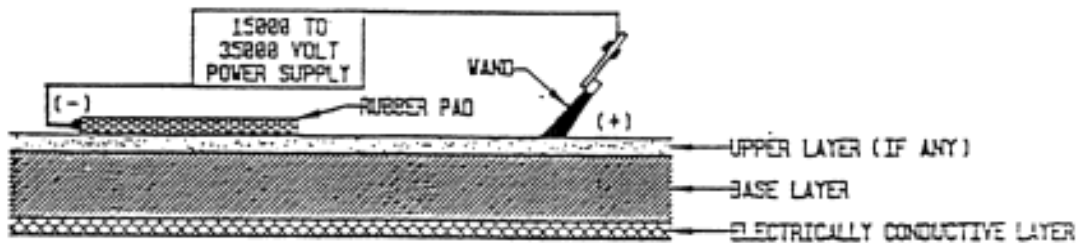
Both methods above require an electrical lead from the power supply to the wand, therefore, in a large lined area, thousands of feet of cable would be required which would in itself be cumbersome.

3. The Electrical Capacitance Effect: Gundle's Procedure with Co-extruded Conductive Layered Liner

It is possible to take advantage of the electrical property of capacitance and eliminate the long electrical lines. A capacitor is an electrical device in which two electrically conductive materials are separated by a dielectric (or non-conductive) material as shown below:



A capacitor will store an electrical charge in each conductive material when attached to power source. We take advantage of electrical capacitance by placing an electrically conductive rubber pad on top of the liner and inducing a potential in the conductive layer of the co-extruded conductive liner through electromagnetic induction. The rubber pad moves with the test unit.



Once the conductive liner layer has been energized by one of the methods above, the wand is passed over the upper surface of the liner. Any defect or pinhole which penetrates the liner to the conductive layer will allow a spark to pass through the liner to the wand. This spark is clearly visible and triggers an audible alarm on the testing unit. Gundle uses both hand held units and ATV trailer mounted units to spark test 100% of the area lined with conductive layered geomembrane under observation by the owner's representative, repairing all holes detected per Section 4.4.

4.3.A.8 Destructive Testing

4.3.A.8.1 Introduction

Destructive testing of seams is important because it provides direct evaluation of seam strength and banding efficiency which indicates seam durability.

Destructive testing involves two techniques: 1) shear testing, and 2) peel testing. Shear testing applies a tensile stress from the top sheet through the weld and into the bottom sheet. Peel testing, on the other hand, peels the top sheet back against the overlapped edge of the bottom sheet in order to observe how separation occurs. The peel test

indicates whether or not the sheets are continuously and homogeneously connected through the seam.

4.3.A.8.2 Location and Frequency

Destructive seam tests will be performed at randomly selected locations. The owner and/or owner's representative will select locations where destructive samples will be a cut.

A frequency will be agreed upon by GLCC and the project manager at the Resolution and/or Pre-Construction Meeting. Unless otherwise specified, destructive samples should be pulled at intervals of one (1) sample for every 500 linear feet of weld.

The seaming technician will not be informed in advance of the locations where the seam samples will be taken.

4.3.A.8.3 Sampling Procedure

Samples will be cut by GLCC as seaming progresses. When cutting samples above an existing geomembrane, hook blade knives should be used.

A number shall be assigned to each sample which is to be based upon seam and sample number and mark it accordingly (see Exhibit 10.9 in Section 10.0, example of sample sticker);

Destructive sample locations will be recorded on daily report and on the as-built drawing; and

All holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in accordance with repair procedures described in Section 4.4.

4.3.A.8.4 Size of Samples

At a given sampling location, two coupons for field testing should be taken. Each of the coupons will be one inch wide by twelve inches (1"x 12") (0.25 m x 0.3m) long with the seam centered parallel to the length. The distance between these two (2) coupons will be 42 inches (107 cm).

If both coupons pass the field test described in Section 4.4.A.8.5, a sample will be cut between the two coupons. This sample will be cut into three (3) parts and distributed as follows:

- One portion to the Installer (GLCC) for testing, 18 inches x 12 inches (.45 m x .3 m);
- One portion for geosynthetic quality assurance laboratory testing if applicable, 12 inches x 12 inches (4.8 cm x 4.8 cm); and
- One portion to the owner for archive storage, 12 inches x 12 inches (4.8 cm x 4.8 cm).

Final determination of the sample sizes will be made at the Pre-Construction Meeting.

4.3.A.8.5 Field Testing

Electric or hand tensiometer destructive testing is to be carried out in the field. Testing procedure is as follows:

- Two (2) one inch (1") (2.5 cm) wide strips will be tested in the field for peel and shear and will not fail in the seam. If seam strengths are being evaluated, samples should be cut with a die to provide proper geometry.
- If any field test sample fails to pass, then the procedures outlined in 4.3.A.8.7 will be followed.
- If the initial sample coupon test passes with a Film Tearing Bond (FTB) (see Figures 6.6 and 6.7 in Section 6.0), the sample qualifies for further testing to obtain quantitative results per Table 4. If it fails, the seam should be repaired in accordance with Section 4.4.

4.3.A.8.6 Gundle Laboratory Test Procedures

Gundle standard testing procedure is as follows:

- If there is a failure in either peel or shear, then five (5) total coupons are tested. If more than one coupon fails, then the sample fails. This is a modified ASTM method. The ASTM method used is D4437.
 - The Film Tear Bond (FTB) is very important (see Figures 6.6 and 6.7 in Section 6). With a fully integrated, continuous connection through the seam, no weld bead/sheet or sheet/sheet interface exists, and the specimen tears the sheet as it pulls apart (FTB). Such an interface might eventually be separated by absorbed chemicals, causing failure of the seam.
 - In addition to the FTB criterion, a minimum stress level is specified. This is important in order to protect against FTB tearing of a thin portion of polymer in the weld (as might occur if the weld is off center).
 - The minimum stress levels are necessarily lower than tensile yield strengths of the parent sheet because of the different configuration of the test specimens during destructive testing. Bending moments come into play along with tensile stresses, especially as the sheets are bent back in peel. These bending moments depend on the shape of the welds which vary even within the same welding technique. The minimum stress values are based on the averaged performance values of passed weld specimens tested in the laboratory.
-

Table 4

SPECIFICATION FOR SEAM STRENGTH
(Meets NSF 54 - 1993 Standards)

Type of Material	No. of Coupons		Minimum Values Required ppi (N/cm)			
	Peel	Shear	Peel Extrusion	Peel Fusion	Shear Extrusion	Shear Fusion
<u>HDPE</u>						
30 Mil (0.75 mm)	2	1	35 (51)	49 (65)	63 (110)	63 (110)
40 Mil (1.0 mm)	2	1	48 (84)	67 (117)	86 (151)	86 (151)
60 Mil (1.5 mm)	2	1	70 (123)	98 (172)	126 (221)	126 (221)
80 Mil (2.0 mm)	2	1	92 (161)	130 (228)	166 (291)	166 (291)
100 Mil (2.5 mm)	2	1	115 (201)	143 (250)	207 (362)	207 (362)
<u>HDT</u>						
40 Mil (1.0 mm)	2	1	42 (74)	60 (105)	76 (133)	76 (133)
60 Mil (1.5 mm)	2	1	63 (110)	88 (154)	113 (198)	113 (198)
80 Mil (2.0 mm)	2	1	84 (147)	118 (207)	151 (264)	151 (264)
100 Mil (2.5 mm)	2	1	105 (184)	143 (250)	189 (331)	189 (331)
<u>VLDPE</u>						
30 Mil (0.75 mm)	2	1	30 (53)	30 (53)	33 (58)	33 (58)
40 Mil (1.0 mm)	2	1	40 (70)	40 (70)	44 (77)	44 (77)
60 Mil (1.5 mm)	2	1	60 (105)	60 (105)	66 (116)	66 (116)
80 Mil (2.0 mm)	2	1	72 (125)	72 (125)	80 (140)	80 (140)
100 Mil (2.5 mm)	2	1	88 (154)	88 (154)	100 (173)	100 (173)
<u>VLT</u>						
40 Mil (1.0 mm)	2	1	40 (70)	40 (70)	44 (77)	44 (77)
60 Mil (1.5 mm)	2	1	60 (105)	60 (105)	66 (116)	66 (116)
<u>HD/ML/HD</u>						
30 Mil (.75 mm)	2	1	30 (53)	30 (53)	33 (58)	33 (58)
40 MIL (1.0 mm)	2	1	40 (70)	40 (70)	44 (77)	44 (77)
60 Mil (1.5 mm)	2	1	60 (105)	60 (105)	66 (116)	66 (116)
80 Mil (2.0 mm)	2	1	72 (125)	72 (125)	80 (140)	80 (140)
<u>HDT/ML/HDT</u>						
30 Mil (.75 mm)	2	1	30 (53)	30 (53)	33 (58)	33 (58)
40 MIL (1.0 mm)	2	1	40 (70)	40 (70)	44 (77)	44 (77)
60 Mil (1.5 mm)	2	1	60 (105)	60 (105)	66 (116)	66 (116)
80 Mil (2.0 mm)	2	1	72 (125)	72 (125)	80 (140)	80 (140)

4.3.A.8.7 Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test. GLCC has two options:

1. Reconstruct the seam between any two passed destructive test locations.
2. Trace the welding path to an intermediate location ten feet (10') (3 m) minimum from the point of the failed test in each direction and take a small sample coupon for an additional field test at each location. If these additional samples pass the field test, then full samples are taken. If these samples pass the tests, then the seam is

reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

All acceptable seams must be bounded by two (2) locations from which samples passing destructive tests have been taken.

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

4.3.B Geotextiles, Geonets and Fabri-Net Joining

4.3.B.1 Geotextiles

Geotextiles may be installed by overlapping, by thermally bonding on a spot or continuous basis, or by sewing as specifications dictate.

If sewing is required, the thread used will be a polymeric material with chemical resistance similar to the geotextile.

4.3.B.2 Geonets

Geonets may be butt joined or lapped if specified. Nylon/plastic cable ties will be applied to the net edge at five foot (5') (1.5 m) intervals along the edge.

End splices will be made as follows: On slopes, the ends will overlap two feet (2') (0.6 m) with uphill panels on top and two (2) rows of cable ties applied. In flat areas, the ends will overlap a minimum of two inches (2") (50 mm) and one row of three (3) cable ties applied.

4.3.B.3 Fabri-Net

Geocomposites can be overlapped with the net portion tied and the geotextile portion thermally bonded or seamed as required by the project specifications.

4.3.C Geosynthetic Clay Liner (GCL) Joining

Seaming of GCLs is achieved by simply overlapping the GCL panels. Care must be taken in order to determine if any loose bentonite should be spread between the overlap. When placing a GCL with a membrane backing with the bentonite side down, it is necessary to place tape along the seam in order to prevent intrusion of overlying cover soils into the overlap. Alternately, the geomembrane backing can be welded in accordance with the membrane and GCL manufacturer specifications.

4.4 Geosynthetic Repair Procedures

4.4.A Defects and Repairs of Geomembranes

4.4.A.1 Identification

All seams and non-seam areas of the geomembrane will be examined by GLCC, for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.

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

Defects, holes, blisters, undispersed raw materials, signs of contamination by foreign matter, unacceptable welds in geomembranes, and other unsatisfactory conditions will be identified. The repair/corrective action to repair the area will be recorded.

Work will not proceed with any materials which will cover these areas until they are repaired in accordance with Section 4.4.A.3.

4.4.A.2 Repair Procedures

Any portion of the geomembrane failing a destructive or non-destructive test will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the project manager and GLCC. The procedures available include:

- Patching - used to repair large holes, tears, and contamination by foreign matter;
- Buffing and re-welding - used to repair small sections of extruded seams;
- Spot welding or seaming - used to repair pinholes, or other minor localized flaws;
- Capping - used to repair large lengths of failed seams; and
- Topping - used to repair areas of inadequate seams which have an exposed edge;

In addition, the following provisions will be satisfied:

- Surfaces of the geomembrane which are to be repaired will be abraded no more than one hour prior to the repair;
 - All surfaces must be clean and dry at the time of the repair;
 - All seaming equipment used in repair procedures must be approved;
 - The repair procedures, materials, and techniques will be approved in advance of the specific repair by the project manager and GLCC; and
 - Patches or caps will extend at least six inches (6") (15 cm) beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least three inches (3") (8 cm).
-

4.4.A.3 Repair - Non-destructive Testing

Each repair will be non-destructively tested using the methods described in Section 4.4 as appropriate. Repairs which pass the non-destructive test will be taken as an indication of an adequate repair. Failed tests indicate that the repair will be redone and re-tested until a passing test result is obtained.

4.4.13 Geotextile, Geonets and Fabri-Net Repairs

Any holes, tears, or burn throughs from thermal seaming in geotextiles will be repaired by patching with the same geotextile. The patch will be a minimum of twelve inches (12") (30 cm) larger in all directions than the area to be repaired and will be spot bonded thermally.

Any holes or tears in geonets will be repaired by patching with the same geonet. The patch will be a minimum of twelve inches (12") (30 cm) larger in all directions than the area to be repaired. The patch will be tied in place using a minimum of four (4) nylon cable ties.

4.4.C Geosynthetic Clay Liner (GCL) Repair Procedures

GCLs will be inspected for cuts, tears, or areas of bentonite loss.

The area to be repaired (patched) must be free of contamination by foreign matter. Patches must have a twelve inch (12") (30 cm) overlap around the damaged area. For fabric-encased GCLs, the patch is to be tucked into place with excess bentonite poured over the overlap. Simple overlapping of the patch is sufficient for geomembrane backed GCLs. However, temporary attachment of patches is required to ensure that the patch is not dislodged by covering with a geomembrane or soil.

4.5 Backfilling of Anchor Trench

The anchor trench, if any, will be adequately drained by owner/earthwork contractor to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench will be backfilled by the earthwork contractor or as outlined in the specifications and bid documents.

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

4.6 Lining System Acceptance

The geosynthetic lining system will be accepted when:

- The installation of all materials are deployed and welded; and
 - Verification of the adequacy of all seams and repairs including associated testing is complete.
-

4.7 Soils in Contact with the Geosynthetics

Important points for quality assurance of soils in contact with geomembranes include:

- A geotextile or other cushion approved by the designer may be installed between angular aggregate and the geomembrane.
- Equipment used for placing soil will not be driven directly on the geomembrane.
- A minimum thickness of one foot (1') (0.3 m) of soil is recommended between a light dozer (such as a CAT D-3 or wide track caterpillar D-6 or lighter) and the geomembrane.
- In areas of heavy traffic such as access ramps, soil thickness should be at least two (2) to three (3) feet (0.6-0.9 m).

Soil /Earth Cover on Top of Geomembrane

Placement of soil (sand or other types of earth) cover on top of, the liner will not be performed until all destructive and non-destructive testing has been performed and accepted.

Placement should be performed to minimize wrinkles. Equipment operators should be briefed on method and timing of soil placement to deal with thermal expansion and contraction of the liner. Soil placement during cooler parts of the day minimizes wrinkle problems.

Material placed on top of the liner should be back-dumped on liner and, in order to avoid the formation of wrinkles, efforts should be made to load the soil so that it comes down on top of the liner rather than being pushed across the sheet. This is done by 1) using a front-end loader to place soil ahead of spreading soil cover, and 2) spreading soil by building a mound at the edge of soil, then pushing soil up and over the mound causing it to come down on the liner.

If a wrinkle forms, every effort should be made to walk the wrinkle out.

Minor folding over of wrinkles is acceptable providing an even transition occurs at the tail of the wrinkle. If excessive stress points are created at the tail of the wrinkle, the wrinkle should be cut out and repaired per Section 4.4.

When installing panels in an open trench, the trench will not have any protrusion from the trench walls which could damage the panels or inhibit installation.

5.4.B Installation Procedure

5.4.B.1 Preliminary Considerations

Gundle shall fabricate the barrier panels to the desired lengths in the factory or designated fabrication facility. Sheet panels, interlock sections, and bottom anchors will be assembled using either wedge or extrusion welding.

Additional materials for the manufacturing of closure panels and the repair of damaged sections will be available for field use.

The Gundle Supervisor will walk the installation path with the engineer or his representative prior to beginning any work. Starting and stopping points, utility locations, and overhead obstructions will be discussed and checked against the drawings.

5.4.13-2 Vibratory Installation Procedures

The installation must be designed by Geotechnics America, Inc. and Gundle Lining Construction Corp or any other system acceptable to the architect/engineer will be utilized for the installation of each panel.

The initial panel is to be installed with the male section of the panel interlock oriented in the direction of installation.

The interlock seal will be fed into the female section as each panel is installed. The seal will be monitored during installation to ensure that it is being fed into the lock at the same rate as the panel installation. If the progress of the seal comes to a halt during the installation and the seal cannot be restarted, then the panel being installed will be removed and the seal replaced. Installation can then continue as before. If during an insertion the plate comes to a complete halt prior to reaching the installation depth, then the plate will be withdrawn and a trench excavated along the path of installation to ascertain the nature and extent of the obstruction. If the obstruction is removed, the excavation will be back-filled and the installation continued. If the obstruction is not removed, the installation plan will be modified as approved by the architect/engineer.

5.4.C Destructive Testing of Panel Interlocks

5.4.C.1 Introduction

Destructive peel and shear tests will be performed on the membrane/interlock interface (see Section 4.3.A.8). The purpose of these tests is to check that welds are fully integrated with each other and to evaluate seam strength. Seam strength testing will be done as work progresses, not at the completion of all fabricated panels.

5.4.C.2 Frequency

Destructive samples will be taken at intervals of one sample for each side of the Gundwall panel (male and female) for every 1,000 linear feet (1,000') (300 m) (or less) of weld.

5.4.C.3 Sampling Procedure

Samples will be cut by Gundle Fabrication as the seaming progresses. Gundle Fabrication will:

Cut samples; and

Assign a number to each sample which is to be based upon panel number.

5.4.C.4 Sample Size and Testing

At a given sampling location, two (2) samples from each side (male and female) of the panel will be taken.

Both samples are destructively tested and will pass according to the values provided in Section 4.3.A.6. If any samples fail to pass, the panel will be refused.

Destructive test samples at Gundle's Fabrication Facility will be delivered to Gundle's Laboratory.

Gundle's Laboratory will provide verbal results no more than 24 hours after they receive the samples. Written results will follow within one week.

GUNDLOCK INSTALLATION GUIDE

Gundlock is a High Density Polyethylene (HDPE) extruded shape designed to provide a mechanical anchor attachment for Gundline is designed to be embedded in any face of new cast-in-place or precast concrete construction and can be fabricated to maneuver around shapes and corners.

Any thickness of Gundline HD can be welded to the Gundlock. If unexpectedly high tensile loads are experienced by the liner, the liner is designed to yield before the Gundlock yields or pulls out of the concrete. The Gundlock profile is detailed in Figure 1.

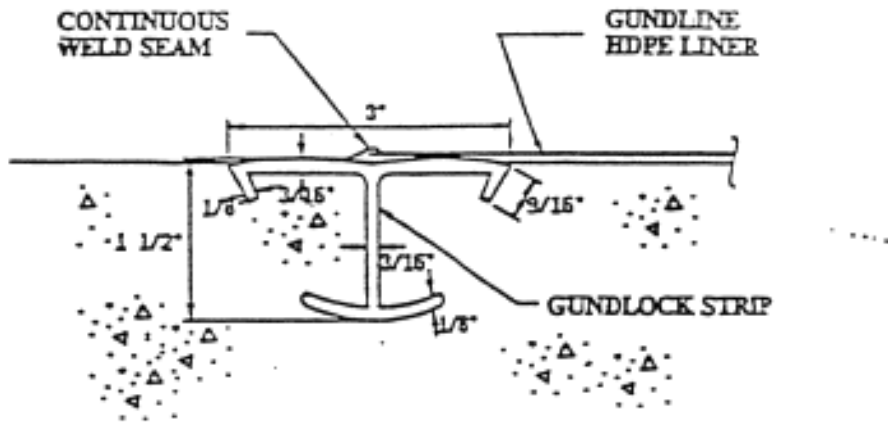


Figure 1

Attachment of Gundline HD to Gundlock is performed by grinding the Gundlock and Gundline HD and then extrusion Welding the Gundline HD to the Gundlock.

Gundlock should not be used as a waterstop for most installations although it may be utilized as such in special applications. (Please consult Gundle Lining Construction for further information.)

Proper installation techniques must be observed to insure a secure embedment of the Gundlock and a sound weld to the Gundline HD sheeting.

GUNDLOCK INSTALLATION

Gundlock must be cut and butt-welded together to fit corners and shapes. (Figures 2 and 3). This cutting and welding, if Performed correctly, will provide continuous support for the liner and secure a seal. Corners and "T" connections can be supplied prefabrication.

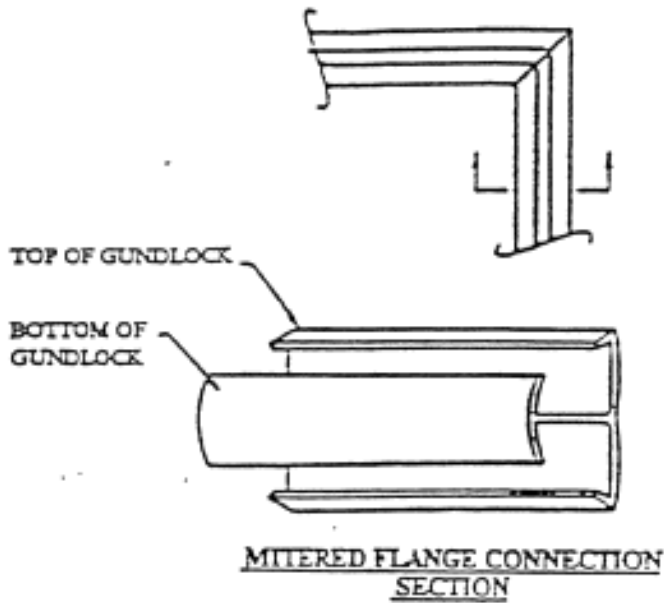


FIGURE 2

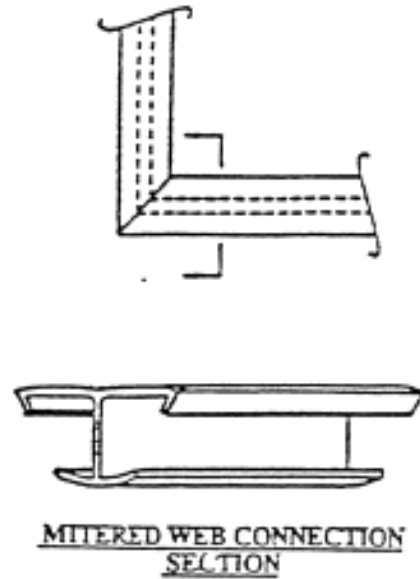


FIGURE 3

ATTACHMENT OF GUNDLOCK TO FORMS

Gundlock is attached to the inside of a concrete form with finishing nails prior to concrete placement (Figure 4). The size of the finishing nails must be no longer than 1". The nails must be driven flush with the back side of the Gundlock to allow for their easy removal when the forms are "wrecked". The Gundlock should be attached at sufficient points to insure a flush fitting with the form. Alternate methods of attachment are staples or shot-in anchors.

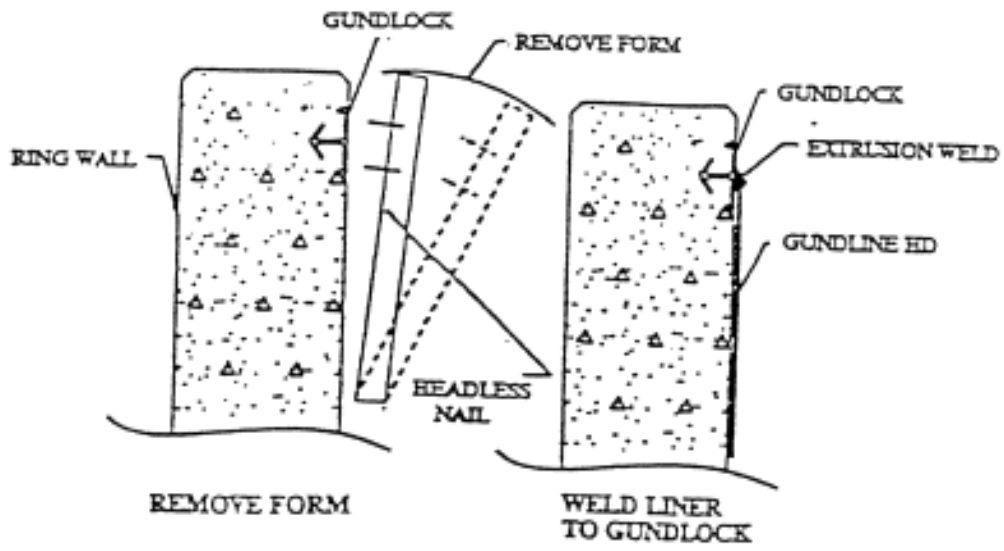


FIGURE 4

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