

LIITE 14

Laatusuunnitelma 17.4.2008

Kaitos Oy

TALVIVAARA KAIVOSHANKE

**KAITOS OY**  
**LAATUSUUNNITELMA**

**TIIVISTYSRAKENTEIDEN LAADUNVARMISTUS TYÖMAALLA**

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# KAITOS OY

## LAATUSUUNNITELMA

### TIIVISTYSRAKENTEIDEN LAADUNVARMISTUS TYÖMAALLA

**Tilaja** Talvivaara Projekti Oy  
Lahnasjärventie 73  
88120 TUHKAKYLÄ

**Kohde:** Talvivaaran Projekti Oy:n tiivistysrakenteet v. 2008, Sotkamo

**Kohteet ja tiivistysrakenteissa käytettävien materiaalien arvioidut määrät:**

KOHDE	Asennettava materiaali	määrä m <sup>2</sup>
Primary heap 1.vaiheen liuotuskasa	HDPE 2,0 mm	3*480 000
Primary heap 1.vaiheen liuotuskasa	bentoniittimatto	3 * 480 000
Waste rock foundation under secondary heap Sivukivialue	HDPE 1,5 mm	442 000
Solution ponds PLS Liuosaltaat	HDPE 1,5 mm + HDPE 2,0 mm + bentoniittimatto + salaojamatto	136 000
Solution ponds EM Liuosaltaat	Bentonite mat + HDPE 1,5 mm	69 000
Solution ponds IP Liuosaltaat	HDPE 1,5 mm + HDPE 2,0 mm + salaojamatto	110 000
Gypsum ponds Kipsisakka-allas	HDPE 1,5 mm	287 000
<b>TOTAL / AVG</b>		<b>2 484 000</b>

## **1 ASENNUSURAKOITSIJA**

KAITOS OY  
Karapellontie 8  
02610 ESPOO

Projektipäällikkö: Jukka Voutilainen, p. 050 – 588 0186  
Asennustyön työnjohtaja: Timo Immonen, p. 040 – 7358744

Arvioidut enimmäishenkilöstöresurssit:

Asentajat:

Asennusryhmiä 9 kpl

Asennusryhmä: 2 RAM + 3 RM + KKH+KUP

Laadunvalvontahenkilöstö: laadunvalvonta arvioitu 3+6 henkilöä

## **2 ASENNUSSUUNNITELMA**

### **2.1 Aloituspalaveri**

Aloituspalaveri pidetään ennen töiden aloitusta. Aloituspalaverissa käydään läpi yhdessä rakennuttajan, muiden urakoitsijoiden sekä mahdollisen ulkopuolisen laadunvalvojan kanssa tiivistyskalvon ja bentoniittimaton asennuksessa huomioitavia asioita mm. tiivistyskalvosuunnitelmat, urakkarajat, toteutusaikataulu, eri osapuolten tehtävät, tiivistyskalvon ja bentoniittimaton suojaus- ja ankkurointi-toimenpiteet, laadunvalvontatoimenpiteet, tiivistyskalvon ja bentoniittimaton varo- ja korjaustoimenpiteet. Mikäli suunnitelmia on täsmennettävä tai muutettava sovitaan täsmennyksistä ja muutoksista viimeistään tässä yhteydessä. Kokouksesta laaditaan muistio kaikkien osapuolten käytettäväksi.

### **2.2 Asennuspohjan tarkistus**

Tarkistetaan, että asennusalusta täyttää tiivistyskalvon tai bentoniittimaton alapuoliselle rakenteelle asetetut vaatimukset. Pinnan tulee olla kantava,

kuiva ja tasainen eikä siinä ole kiviä tai muita epäpuhtauksia, jotka saattavat aiheuttaa kalvolle tai bentoniittimatolle mekaanista räsitusta (esim. pistemäinen kuorma). Tiivistysrakenteiden alla ei saa olla irtokiviä eikä yli 10 mm teräviä särmiä. Pohjamaassa ei saa olla vettäkerääviä painanteita.

Primäärikasassa kalvon asennuspohjana on bentoniittimatto, jonka pinnan tulee olla rypytön sekä puhdas kivistä ja muusta irtoaineksesta ennen kalvon asennusta. Kalvon asentaminen voidaan tehdä bentoniittimaton päältä sellaisella levityskalustolla, ettei siitä aiheudu vahinkoa bentoniittimatolle tai muulle alapuoliselle rakenteelle.

## **2.3 Asennuspohjan tasaisuusvaatimukset**

### **2.3.1 Bentoniittimatto**

Tarkistetaan, että bentoniittimatto tukeutuu tasaisesti alustaansa, jolloin mattoon ei tule ylimääräisiä, liian suuria vetorasituksia. Pohjan taitteissa matto asennetaan taitteita vastaavasti.

Tasomaisilla pinnoilla voidaan sallia sellaiset epätasaisuudet joista ei aiheudu haittaa bentoniittimaton toiminnalle. Suurin sallittu epätasaisuus (kulman muutos) on 200 mm / 4 m. Epätasaisuus mitataan oikolaudalla, ja tasaisuusvaatimukset on täytyttävä sekä koverissa että kuperissa taitteissa kaikkiin suuntiin. Seisovaa vettä ei saa kuitenkaan esiintyä pinnoilla

Bentoniittimatto voidaan asentaa jäätyneen maan varaan, kunhan pohjamaan tiiveys- ja tasausvaatimus täyttyy.

### **2.3.2 Tiivistyskalvot**

Tarkistetaan, että kalvo tukeutuu tasaisesti alustaansa, jolloin kalvon päälle tuleva kuormitus ei aiheuta kalvoon ylimääräisiä, liian suuria vetorasituksia. Pohjan taitteissa kalvo asennetaan taitteita vastaavasti.

Tasomaisilla pinnoilla voidaan sallia sellaiset epätasaisuudet joista aiheutuva vetorasitus kalvolle on hyväksyttävällä tasolla. Suurin sallittu epätasaisuus (kulman muutos) on 200 mm / 4 m. Epätasaisuus mitataan oikolaudalla, ja tasaisuusvaatimukset on täytyttävä sekä koverissa että

kuperissa taitteissa kaikkiin suuntiin. Epätasaisuus ei saa kuitenkaan olla niin suuri, että pinnalle jää vettä keräävä painanne.

## **2.4 Levityssuunnitelma**

Levitystyöstä laaditaan levityssuunnitelma ennen töiden aloitusta. Suunnitelmassa tarkistetaan levityksen aloituspaikka sekä sovitaan työjärjestys. Levityssuunnitelmassa esitetään kalvojen ja bentoniittimaton levityssuunta, kalvosaumojen sijainti ja suunnitellut läpiviennit. Samoin tarkistetaan kalvojen painotus ja -ankkuroinnit.

## **2.5 Tiivistysrakenteiden saumaus**

### **2.5.1 Bentoniittimatto**

Mattokaistaleet liitetään toisiinsa limittämällä. Limityspituus on vähintään 150 mm. Jatkoslimityksen pituus (mattojen päissä) on vähintään 300 mm. Saumoissa, jotka eivät ole itsetiivistyviä käytetään granulaattimuotoista bentoniittia noin 0,4 kg/jm.

### **2.5.2 Tiivistyskalvot**

#### **2.5.2.1 Eri saumausmenetelmät**

Tiivistyskalvon kaikki saumat saumataan hitsaamalla tiiviiksi. Kalvokaistojen ja kalvojatkokosten väliset saumat tehdään painekoesaumoina ja hitsataan kuumakiila- tai kuumailma- ja kuumakiila -menetelmän yhdistelmällä. Putkien läpiviennit ja mahdolliset paikat yms. hitsataan käyttämällä ekstruusiohitsausta.

#### **2.5.2.2 Koesaumot**

Ennen varsinaista hitsaustyön aloitusta tehdään saumoista työnäyte kohteittain. Koesaumoista tehdään tarvittaessa painekoe, kuorintakoe ja vetokoe.

Koesaumot tehdään ennen varsinaisen hitsaustyön aloitusta ja asennusolosuhteiden kuten säätilan muuttuessa merkittävästi.

#### **2.5.2.3 Kuumakiilahitsaus**

Kuumakiilahitsauksessa käytetään pitkittäissaumoissa prosessiohjattua tulostavaa/tallentavaa kuumailmakiila- tai kuumakiilahitsauskoneetta. Ennen hitsauksen aloitusta asetusrivot asetetaan koneeseen koesauman

tulosten perusteella. Poikittaissaumoissa käytetään prosessiohjattua kuumailmakiila- tai kuumakiilahitsauskonetta.

Hitsauskoneita ohjataan ja hitsausnauman laatua arvioidaan koneen tulosteiden ja koetulosten perusteella.

#### **2.5.2.4 Ekstruusiohitsaus**

Ekstruusiohitsaukseen käytetään siihen tarkoitettuja hitsauslaitteita ja käytettävä materiaali on yhteensopivaa käytettävän kalvomateriaalin kanssa. Ennen hitsaamista tehdään pääkalvon karhennus ja muotoilu. Sauman tiiviys varmistetaan kipinäkokeella.

### **2.6 Tiivistyskalvorullien käsittely ja varastointi**

#### **2.6.1 Bentoniittimatto**

Bentoniittimatot toimitetaan työmaalle alkuperäisessä suojamuovissaan. Välittömästi ennen asennusta suojamuovi poistetaan vahingoittamatta bentoniittimattoa. Rullissa on rahdin purkamisen ja työmaalla siirtelyn helpottamiseksi kaksi kuormausliinaa. Bentoniittimattorullien nostelu ja siirto tehdään pääasiassa nostoliinoista tai erityisellä sisäputkella. Maton vetämistä maata pitkin tulee välttää

Rullat varastoidaan vaakasuoraan kuivalle ja tasaiselle maalle mielellään irti maasta esim. kuormalavojen tai puupölkkyjen päälle. Bentoniittimattojen osalta on erityisesti huolehdittava siitä, etteivät ne pääse kostumaan. Rullia saa varastoida enintään viisi päällekkäin.

#### **2.6.2 Tiivistyskalvot**

Tiivistyskalvorullien purkauksen ja työmaalla siirtelyn helpottamiseksi jokainen rullassa on kaksi kuormausliinaa. Työmaalla kalvorullia saa nostaa ilman erikoiskalustoa ainoastaan nostoliinoilla tai levityspalkilla. Tiivistyskalvorullat pyritään varastoimaan mahdollisimman lähelle työkohdetta ja mahdollisimman tasaiselle alustalle irti maasta esim. kuormalavojen tai puupölkkyjen päälle. Rullia saa varastoida enintään viisi päällekkäin.

Kalvoja tulee käsitellä ja varastoida siten, ettei niiden pintoja tai rullien päitä vahingoiteta.

## **2.7 Asennusolosuhteet**

### **2.7.1 Bentoniittimatto**

Bentoniittimatot on asennettava mahdollisuuksien mukaan sateettomana aikana. Tiivistyskalvot ja kalvon päälle tulevat suojarakenteet tulee asentaa bentoniittimattojen päälle mahdollisimman nopeasti.

### **2.7.2 Tiivistyskalvot**

Tiivistyskalvon asennuksessa tulee huomioida säätilan ja ympäristöolosuhteiden asettamat rajoitukset. Kalvon asennusta tulee välttää erityisen kovalla tuulella ja alhaisissa lämpötiloissa. Myöskään sellaisella sateella, jolloin on oletettavaa, että työn laatu merkittävästi heikkenee, ei kalvoa tule asentaa.

## **2.8 Tiivistyskalvojen painottaminen**

Tiivistyskalvon painottamiseen käytetään tiivistyskalvon yläpuoliseksi suojamateriaaliksi tarkoitettua materiaalia. Painotusmateriaali pyritään levittämään kalvon päälle mahdollisimman pian kalvon asennuksen jälkeen. Painotusmateriaalin ohjeellinen määrä on noin 4-5 kg/m<sup>2</sup>.

## **2.9 Tiivistyskalvojen ankkuroiminen**

Tiivistyskalvo ankkuroidaan altaissa käyttämällä ankkurointiojaa. Ankkurointi tehdään myöhemmin toteutettavan suunnitelman mukaisesti.

## **2.10 Vaurioiden korjaus**

### **2.10.1 Bentoniittimatto**

Mattoon syntyneet reiät paikataan mattokaistaleella, jonka limitys pitää olla väh. 300 mm. Saumoissa käytetään granulaattimuotoista bentoniittia runsaasti, noin 1,0 kg/jm.

Mattojen läpiviennit tehdään ulottamalla ylimääräinen mattokaistale väh. 300 mm limityksellä sekä käyttämällä saumoihin runsaasti (1,0 kg/jm) bentoniittijauhetta. Läpiviennin detaljipiirustukset hyväksytetään tilaajalla ennen töiden aloittamista

### **2.10.2 Tiivistyskalvo**

Mahdolliset tiivistyskalvon vauriot, viillot ja reiät korjataan riittävän isolla paikkalapulla (isot vauriokohdat yli min. 50 cm), joka saumataan ekstruusiohitsaamalla. Ennen hitsaamista on suoritettava tarvittavat toimenpiteet eli pohjakalvon karhennus ja reunan muotoilu. Sauman tiiviys varmistetaan kipinäkokeella.

## **3 MATERIAALIN LAADUNVARMISTUS**

### **3.1 Geomembraanit**

#### **3.1.1 Yleistä**

Työtä valvoo riippumaton valvoja, joka harkintansa mukaan tekee lisäkokeita työmaalla ja toimittaa alla esitetyn mukaisesti materiaalinäytteitä ulkopuolisen laboratorion tutkimuksiin.

#### **3.1.2 Laadunvarmistus tehtaalla**

Talvivaara Projekti Oy ostaa materiaalit suoraan tehtailta ja on toimitussopimuksissa edellyttänyt laadunvalvonnan suorittamisen.

Geomembraanien osalta tehtaan oma laadunvalvonta tehdään laatusuunnitelmassa esitetyn ja ko. tavarantoimittajan esittämän liitteiden mukaisesti, laatusuunnitelma liitteet 1 ja 2.

#### **3.1.3 Ulkopuolinen riippumaton laadunvarmistus**

Geomembraaneista otetaan näyte-erä jokaista toimitettua 500 000 m<sup>2</sup> määrä kohden. Näyte-erä koostuu edustavista näytekappaleista A ja B, jotka molemmat ovat vähintään A4 suuruisia paloja. Kumpikin näytepala otetaan eri rullasta. Näytteet pakataan ja mukaan liitetään tieto asennuspaikasta, rullan tunnistetiedot sekä näytteenottopäivämäärä.

Näytteistä toinen tutkitaan ulkopuolisessa tilaajan ja tavarantoimittajan hyväksymässä riippumattomassa laboratoriossa. Toinen näytekappale tutkitaan, mikäli ensimmäisessä tutkimuksessa havaitaan puutteita. Vaaditut arvot on esitetty, laatusuunnitelman liitteessä 2.

Näytteistä tutkitaan seuraavat ominaisuudet:

- Paksuus
- Tiheys

- Vetolujuudet
- Repimislujuus
- Puhkaisulujuus
- Hiilimustan määrä
- Hiilimustan hajonta
- OIT-arvo
- UV-kestävyys
- Oven Aging-testi

#### **3.1.4 Laadunvarmistus työmaalla**

Geomembraanien asennuksesta vastaa Kaitos Oy, joka tekee laadunvalvontasuunnitelmien mukaiset kokeet.

Tehtaan toimittamat materiaalikuormat otetaan vastaan ja tarkistetaan työmaalla materiaalien asennuksesta vastaavan Kaitos Oy:n toimesta. Rullakohtainen tarkastus tehdään kuormien purkamisen yhteydessä. Kuormien vastaanoton yhteydessä materiaalin kunto tarkastetaan silmämääräisesti. Kaikkien kalvorullien tyyppi, paksuus ja rullanumero tarkastetaan rullien mukana tulevista lähetystiedoista ja kirjataan ylös työmaa-asiakirjoihin ennen asennusta. Lisäksi työmaalla rullalle tehdään silmämääräinen tarkastus kun rulla levitetään auki asennusta varten. Asentajan tekemää silmämääräistä tarkistusta ei raportoida muutoin kuin jos havaitaan puutteita, jolloin niistä ilmoitetaan työmaan valvojalle. Rullien testiraportit käydään läpi ja poikkeamista raportoidaan välittömästi materiaalin toimittajille ja työmaan valvojalle.

#### **3.1.5 Tilaajan teettämä materiaalin laadunvarmistus**

Työtä valvoo riippumaton valvoja, joka varmistaa ja dokumentoi materiaalien valvonnan. Valvoja tekee harkintansa mukaan lisäkokeita työmaalla ja toimittaa harkintansa mukaiset sekä tässä laatusuunnitelmassa esitetyt materiaalinäytteet ulkopuolisen laboratorion tutkimuksiin. Tilaajan teettämien lisäkokeiden kustannuksista vastaa tilaaja.

## **3.2 Bentoniitimatto**

### **3.2.1 Laadunvarmistus tehtaalla**

Bentoniittimattojen osalta tehtaalla oma laadunvalvonta tehdään laatusuunnitelmassa esitetyn ja ko. tavarantoimittajan esittämän taulukon mukaisesti, taulukko 1. Vaaditut arvot ja tehtaalla omien testausten testitiheys on esitetty myös taulukossa 1.

Taulukko 1. Bentoniittimatolta edellytetyt ominaisuudet ja laadunvarmistus

OMINAISUUS	TESTI-MENETELMÄ	VAADITTAVA ARVO	TESTITIHEYS TEHDAS	TESTITIHEYS ULKO-PUOLINEN	HUOMAUTUS
Läpäisevä vesimäärä	ASTM D 5887-95	$< 2,50 \times 10^{-9} \text{ m}^3/\text{m}^2\text{s}$	75.000m <sup>2</sup>	500.000m <sup>2</sup>	150 kPa Puristus-, 15 kPa vesipaine
Paksuus paisutettuna	EN 964-1	6,0 mm	75.000m <sup>2</sup>	500.000m <sup>2</sup>	2 kPa Puristus-paine
Veden läpäisevyys		$< 1,10 \times 10^{-11} \text{ m/s}$	75.000m <sup>2</sup>	500.000m <sup>2</sup>	150 kPa Puristus-, 15 kPa vesipaine
Leveys, rullan koko	EN ISO 10320	5,00 m			työmaavalvonta
Bentoniitti massa/ m <sup>2</sup> ilman liima-ainetta w = 0 %	ASTM D 5993	Natrium bentoniitti keskiarvo $> 3500 \text{ g/m}^2$ minimi $> 3000 \text{ g/m}^2$	5.000m <sup>2</sup>	50.000m <sup>2</sup>	ulkopuolinen testaus = oma riipumaton laadunvalvoja
Paisumisindeksi	ASTM D 5890-95	$\geq 24 \text{ ml} / 2\text{g}$	5.000kg	50.000m <sup>2</sup>	ulkopuolinen testaus = oma riipumaton laadunvalvoja
Bentoniitin laatu	prEN 254056: 1999 annex A	Luonnon natriumbentoniitti Granuloitu Montmorilloniittipitoisuus $> 80 \%$	200.000kg	500.000m <sup>2</sup>	
Orgaaniset aineet bentoniitissa	Bentoniittiissa ei saa käyttää paisumista lisääviä tai vedenläpäisevyyttä pienentäviä orgaanisia lisäaineita, jos niiden pitkäaikaisominaisuuksia ei ole hyväksytty.		Valmistajan vakuutus		
Vetolujuus	EN ISO 10319	$> 7 \text{ kN/m}$	5.000m <sup>2</sup>	500.000m <sup>2</sup>	Kone- ja poikkisuunnassa
Muodonmuutos maksimi lujuus kohdalla	EN ISO 10319	$5 \% < \epsilon < 50 \%$	5.000m <sup>2</sup>	500.000m <sup>2</sup>	Kone- ja poikkisuunnassa
Repäisy lujuus / Peel test	EN ISO 10319	Keskiarvo $> 100 \text{ N} / 100\text{mm}$	5.000m <sup>2</sup>	500.000m <sup>2</sup>	Koekappaleen tukikankaat vedetään erilleen / auki
Staattinen puhkaisulujuus	EN ISO 12236	$\geq 1,5 \text{ kN}$	50.000m <sup>2</sup>	500.000m <sup>2</sup>	
Pintakankaiden massa	ASTM D 5261	Kuitukangas $\geq 200 \text{ g/m}^2$ Kudottu $\geq 100 \text{ g/m}^2$			Ominaisuus ei ole toiminnan kannalta olennainen. Kankaiden paino on mitattavissa vain valmiista tuotteesta. Testataan vain, jos muut ominaisuudet eivät täyty
Sauman rakenne ja toiminta	Valmistajan vakuutus	Muuta mattoa vastaava läpäisy			
Limitys merkinnät matossa		15,23 cm reunasta			työmaavalvonta

## **4 HITSAUSSAUMOJEN LAADUNVARMISTUS**

### **4.1 Koesaumat**

Ennen varsinaista hitsaustyön aloitusta tehdään koesauma eli ns. työnäyte, jonka mitatun puristuman perusteella tarkistetaan hitsausparametrien oikeellisuus. Paine- ja kuorintakoe tehdään tarvittaessa laitteen säätöjen varmistamiseksi. Koesauma tehdään tarvittaessa uudestaan olosuhteiden muuttuessa ja parametrit muutetaan asennusolosuhteita vastaaviksi.

### **4.2 Työsaumojen testausmenetelmät**

Kaikki saumat tarkastetaan silmämääräisesti sekä pitkittäissaumat tehtävin koestustestein; lujuus- ja tiiviyskokeet. Lisäksi kaikki kalvokaistaleet ja saumat numeroidaan. Tarvittaessa suoritetaan tarkistusmittauksia.

#### **4.2.1 Tiiviyskokeet**

Kaikkien saumojen tiiviys tarkistetaan aikaisintaan 0,5 h kuluttua hitsauksesta pääsääntöisesti GRI GM6 mukaisesti (liite 3). Poikittaissaumoille ei tehdä kokeita.

Tiivistyskalvosaumalle tehdään seuraavat tiiviyskokeet: painekoe tai kipinä- ja kuorintakoe saumausten menetelmän mukaan. Painekokeella testatuista saumojen koestuksista laaditaan pöytäkirja. Koetuloksia verrataan hitsauskoneen tulosteeseen.

Painekoe tehdään jokaiselle pituussuuntaiselle kaksoishitsausaumalle ja kipinä- ja kuorintakoe jokaiselle ekstruusiohitsausaumalle.

#### **4.2.2 Lujuuskokeet**

Tiivistyskalvojen pitkittäissaumoille tehdään seuraavat lujuuskokeet: veto- ja kuorintakoe. Saumojen koestuksista laaditaan pöytäkirja. Koetuloksia verrataan hitsauskoneen tulosteeseen.

Veto- ja kuorintakokeita tehdään pääsääntöisesti GRI GM19 mukaisesti (liite 4). Näytepalloja otetaan testejä varten kuitenkin vain saumojen päistä (esim. primäärirakan pohja; sauman pituus 400 m → näytepallo otetaan sauman molemmista päistä). Lujuuskokeiden vaaditut lujuusarvot ovat GRI GM19 mukaisesti.

Lujuusarvojen yksikkö on esitetty GRI GM19 tekstissä muodossa N/25 mm (koekappaleen leveysyksikkö). Vaadittu lujuusarvo on riipuvainen koekappaleen leveydestä. ”GRI GM19” -julkaisussa on esitetty lujuusarvot 25 mm leveälle koekappaleelle. Jos käytetään muun levyistä koekappaletta, vaadittu lujuusarvo muunnetaan vastaamaan ko. levyisen koekappaleen lujuusarvoa leveyksien suhteessa.

Vaadittu lujuusarvo= koekappaleen leveys [mm]/ 25 mm \* vaadittu lujuusarvo ( 25 mm koekappaleelle)

Alla olevaan taulukkoon on koottu esimerkin vuoksi yleisimmin käytettyjen koepalaleveyksien vaaditut lujuusarvot:

näytepalan leveys	Vaaditut lujuusarvot			
	vetokoe (shear) [N]		kuorintakoe (peel) [N]	
	HDPE 1,5 mm	HDPE 2,0 mm	HDPE 1,5 mm	HDPE 2,0 mm
15 mm	315	421	239	318
20 mm	420	561	318	424
25 mm	525	701	398	530

Työmaalla pitkittäissaumoista leikataan suurempi pala (=saumanäyte), josta leikataan ennen koestusta tarvittava määrä pienempiä ns. koestuspaloja. Testauksen jälkeen kaksi testaamaton koestuspala arkistoidaan saumatietoineen myöhempää käyttöä varten. Arkistoidut koestuspalat luovutetaan tilaajalle. Vain arkistoidut koestuspalat säilytetään myöhempää tarvetta varten. Yhdestä saumanäytteestä tehdään yksi vetokoe ja kaksi kuorintakoetta (yksi kummaltakin puolelta saumaa). Kuorintakokeet tehdään yhdellä koestuspalalla ja vetokoe toisella. Useampia koestuspaloja testataan vain, jos vaaditut lujuusarvot eivät täyty tai koe muuten epäonnistuu.

#### 4.2.3 Ulkopuolinen riippumaton laadunvarmistus

Urakoitsijan tekemien ja dokumentoitujen saumojen lujuus ja tivelyskokeiden lisäksi tehdään saumojen lujuuskokeita tilaajan ja tavaran toimittajan hyväksymässä riippumattomassa laboratorioissa. Näytepalojen koko sauman lujuustestausta varten on min. 150 x 300 mm (testisarja). Saumojen lujuuden määrityksiä tehdään ulkopuolisessa, riippumattomassa laboratorioissa kohteittain seuraavasti:

Kohde	Testi	Testisarjojen lkm
Pääliuoskasa	Veto- ja kuorintakokeet	6
Sekundäärikasan pohja	Veto- ja kuorintakokeet	3
Kipsisakka-allas	Veto- ja kuorintakokeet	3
Liuosaltaat	Veto- ja kuorintakokeet	2 / allas

Talvivaara Projekti Oy:n oma riippumaton laadunvalvoja ottaa näytepalat testejä varten tai toimittaa urakoitsijan ottamista näytepaloista testikappaleet laboratorioon.

Saumojen tiiviys testataan laatusuunnitelman mukaisesti paine- tai kipinäkokeella. Talvivaara Projekti Oy:n oma riippumaton laadunvalvoja osallistuu työn aikana saumojen tiiviyskokeiden valvontaan.

## 5 Salaojamaton asennus ja sauman laadunvarmistus

Salaojamatto (sydänosa) on tarkoitettu laitettavaksi puskusaumaan. Salaojamaton päällä oleva geotekstiili limitetään 100 mm matkalla (tehdas-asennettu limitys). Työn aikana varmistetaan, että matot ovat paikoillaan ennen kuin työnaikainen painotus tehdään (4-5 kg/m<sup>2</sup>).

Työnaikaisen painotuksen jälkeen, ennen varsinaisen salaojakerroksen rakentamista, salaojamattojen sauman tiiviys tarkistetaan ja se kirjataan päivittäin pidettäviin työmaapäiväkirjoihin. Tarkistus tehdään silmämääräisesti ja tarvittaessa mittaa apuna käyttäen. Jos sauman rako on yli 20 mm, mutta alle 50 mm, laitetaan saumaan ylimääräinen suodatinkangas kaistale N3 (leveys min. 200 mm). Jos sauman rako on yli 50 mm, laitetaan saumaan ylimääräinen salaojamattokaistale.

## 6 Laatuksoulutus asentajille

Geomembraanien toimittaja ja tiivistysrakenteiden konsultti ja urakoitsija Kaitos Oy järjestävät viikolla 17 (21.4.-25.4.) laatu- ja perehdyttämiskoulutuksen kaikille tiivistysrakenteista vastaaville henkilöille. Koulutus sisältää teoria osion sekä käytännön asennus ja laadunvalvonta osion.

## 7 RAPORTOINTI

Kaikki laatudokumentit ovat työmaalla tilaajan edustajan/ valvojan nähtävissä koko työn ajan.

### **7.1 TYÖMAAPÄIVÄKIRJA**

Työmaalla edellytetään täyttämään työmaapäiväkirjaa päivittäin, johon kirjataan tiedot tiivistyskalvon ja bentoniitimatton levitys- ja saumaustyön etenemisestä, työmaalla sovitut muutokset, sekä mahdolliset havaitut puutteet ja viat. Lisäksi päiväkirjaan merkitään mahdolliset työnkeskeytykset ja odotustunnit sekä asennustyöhön vaikuttavat muut seikat, kuten sääolosuhteet, jotka haittaavat asennusta. Kaitos Oy:n työnjohtaja sekä tilaajan edustaja tarkistaa ja allekirjoittaa päiväkirjat viikoittain ja ne liitetään laatuasiakirjoihin.

### **7.2 MATERIAALITODISTUKSET**

Tehtaan toimittamat materiaalitodistukset kootaan laatukansioon. Jokaisesta kalvorullasta otetaan tunnistuskoodit ylös ja merkitään levityspiirroksen.

### **7.3 SAUMOJEN TESTIRAPORTIT**

Tiivistyskalvon ja saumojen koestuspöytäkirjat tehdään päivittäin ja laatudokumentti aineisto kootaan viikottain seuraavan viikon aikana.

### **7.4 LEVITYSPIIRROS**

Levityspiirroksista käy ilmi kalvorullien tunnuskoodit, sijainti ja asennusjärjestys, sekä saumojen ja läpivientien tunnuskoodit ja sijainti.

## **8 ASIAKIRJOJEN DOKUMENTOINTI**

Kaikki kalvojen ja bentoniittimattojen asennukseen liittyvät asiapaperit (työmaapäiväkirjat, kalvon ja saumojen koestuspöytäkirjat yms. asiapaperit) liitetään yhteen laadunvalvontaraporttiin. Arkistoidut koestuspalat luovutetaan tilaajalle erikseen työn päätyttyä ja tilaajan niin vaatiessa yksittäisiä koestuspaloja voidaan toimittaa myös erikseen työn aikana kohtuulliseksi katsottava määrä. Laadunvalvontaraportteja tehdään kaksi yhtäpitävää kappaletta, yksi tilaajalle ja yksi kalvourakoitsijalle.

## **9 LIITTEET**

- Liite 1 GSE Geomembranes, Manufacturing Quality Assurance Manual
- Liite 2 GSE, HD – Product Data Sheets

Liite 3 GRI, Test method GM6  
Liite 4 GRI, Test method GM19

Perttu Juntunen  
Kaitos Oy

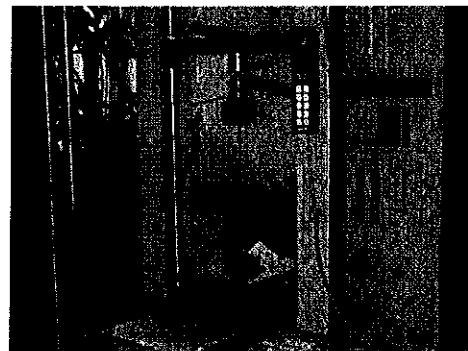
17.4.2008



GSE Lining Technology GmbH

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## Manufacturing Quality Assurance Manual GSE Geomembranes



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European Headquarters  
GSE Lining Technology GmbH  
Großmooring 4  
D-21079 Hamburg  
Tel. +49.40.76742-0; Fax. +49.40.76742-34  
e-mail: [europa@gseworld.com](mailto:europa@gseworld.com)  
[www.gseworld.com](http://www.gseworld.com)

# **GSE Lining Technology, GmbH**

## *GSE Geomembranes Manufacturing Quality Assurance Manual Foreword*

This manual contains proprietary information belonging to GSE Lining Technology, GmbH. This information is intended to provide a summary of standard quality procedures practiced by GSE's Manufacturing Quality Assurance Laboratories in Rechlin, Germany. These procedures apply to standard geomembrane materials only and do not explicitly address non-conforming materials.

This manual replaces in its entirety and supersedes all earlier versions issued by GSE Lining Technology, GmbH. We suggest you maintain contact with your GSE representative to confirm the validity of this version at future dates.

GSE Lining Technology, GmbH. reserves the right to change, modify, or discontinue the use of the policies and procedures described herein without notice or prior consent except as contractually obligated otherwise.

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**I. GSE LINING TECHNOLOGY QUALITY MANIFEST**

GSE Lining Technology GmbH is committed to providing the highest quality products and services to our customers. This requires a firm, total quality commitment from all individuals within our organization that we will only supply materials that meet or exceed the requirements and specifications of GSE and our customers.

GSE's commitment to quality starts with the highest quality raw materials. The quality of incoming raw materials is controlled at the supplier level with a complete vendor evaluation program in place.

**II. OVERVIEW OF GSE MANUFACTURING QUALITY ASSURANCE**

**A. Objective**

The objective of the GSE Quality Assurance program is to define implementation of basic manufacturing quality assurance (MQA) procedures necessary to insure consistent production of quality products supplied to the geosynthetic market.

**B. Scope**

In order to achieve GSE's stated purpose, a rigorous set of minimum standards and an effective test program to assure compliance has been established. These procedures and requirements are frequently reviewed and adjusted to assure compliance with current market demands and/or predetermined project specifications. These procedures assure that raw materials and process parameters are controlled to provide products complying with GSE's pre-defined minimum characteristics.

**III. MANUFACTURING QUALITY ASSURANCE ORGANIZATION**

This organization consists of the Manufacturing Quality Assurance Laboratories as well as the laboratories and manufacturing personnel. The combination of expertise and experience from these groups provides GSE with the proper tools to maintain the highest level of quality and customer service in the industry.

The Quality Assurance Department at GSE is charged by the managing directors to assure that only products meeting both GSE's and the customer's requirements are released for shipment. The Quality Assurance personnel are directly responsible for monitoring testing and providing feedback to the manufacturing department to ensure the production of the specified product quality. Each member of the Quality Assurance team must participate in detailed training that includes factory exposure.

**IV. STAFF AND SCHEDULING**

The Quality Assurance Laboratories are staffed whenever manufacturing is occurring; this is usually 24 hours per day in 3 shifts, from Monday to Sunday.

**V. PRODUCT IDENTIFICATION AND DOCUMENTATION**

**A. Roll Numbering**

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

**B. Approval Procedure**

Results for each tested roll of product is checked against both GSE and customer specifications for compliance. The Quality Assurance Laboratory approves those materials that meet both of these requirements for shipment.

**C. Non-Conformance**

Material that does not meet GSE minimum standards is given a roll number but is rejected and *not* placed into inventory. The material is identified as scrap and will not be utilized. Material that meets GSE minimum standards but does not meet a stricter customer specification is not allocated to that customer but is placed into inventory as GSE standard material.

**D. Documentation**

Individual Quality Assurance Certificates (RTDR: Roll Test Data Reports) are generated and supplied for each roll of geomembrane products to include all relevant quality assurance information about the material(s).

**VI. RECORDS RETENTION**

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

GSE's standards

MATERIAL	ITEM	YEARS
Raw materials	Resin Supplier Test Reports and Certifications	≥20
	GSE Resin Test Reports (in computer database)	≥20
	Resin Sample Retain (Archive)	≥5
Geomembrane	Roll Test Data Report (in computer database)	≥20
	Quality Control Certificates	≥10
	Sample Retain (approximately one square foot)	≥20

**VII. TESTING CAPABILITIES**

GSE maintains high capacity, state-of-the-art laboratory equipment suitable for performing the procedures listed in Appendices A-B. Calibration of equipment is updated according to ISO 9001. The appropriate certificates are maintained for review upon request by authorized parties.

**A. Routine Testing**

Through careful investigation, GSE has developed a strict and thorough Quality Assurance program. The testing program covers raw materials (see Appendix A) and finished goods (see Appendix B).

## VIII. MATERIAL QUALITY ASSURANCE

GSE Lining Technology GmbH, has established strict specifications for all raw materials and finished products. Test results must fall within the acceptable limits of GSE and customer specifications.

### A. Raw Material

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

All test data are entered into the computer database and checked for accuracy, consistency and compliance with GSE specifications. The material is not accepted unless all standard test requirements are met and the GSE test values meet the results on the suppliers' certificates of analysis within the normal limits of variation.

Copies of the supplier's certificate of analysis of raw material utilized in the production are available upon request. In addition, the GSE raw material test results are mentioned on the roll test data report.

### B. Geomembrane Products

GSE has implemented a strict and thorough Quality Assurance program for all geomembrane products. The geomembrane product line can be broken into two primary categories: smooth and textured. Tables containing GSE test frequencies for the smooth and textured GSE geomembrane products are in Appendix B.

#### 1. On-Line Manufacturing Quality Assurance

The Quality Assurance program for finished product begins during the manufacturing process. The manufacturing lines are equipped with state-of-the-art monitoring devices that provide feedback on the physical quality of the materials being produced. The geomembrane production lines are equipped with both a  $\beta$ -gage and spark-testing device.

##### a) $\beta$ -gage

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

##### b) Spark Testing

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

## **2. Smooth Geomembrane Materials**

Smooth geomembrane products available include high density and linear low density polyethylene materials with 2-3% carbon black.

### *a) Sampling*

Every roll of geomembrane is sampled for QA testing. A 30 cm by roll width sample is cut for Quality Assurance testing as each roll is completed. Test samples are taken from one of five predetermined positions across the width of the roll. The test sample positions are defined as a constantly repeating set of locations determined by the roll sequence. This enables the position from which any specimen was taken to be determined for future reference. Specimens for testing, both the machine direction and the transverse direction are cut from the selected test sample. A "retain" or archive sample approximately (30 x 30 cm) in size is taken, labeled and kept for future reference (see Section VI).

### *b) Evaluation of Results*

All data are entered into a computer database for calculation and comparison to GSE and customer-specific specifications. If materials do not meet GSE minimums and/or the customer specifications, the manufacturing personnel are immediately notified in order for the appropriate adjustments to be made. Only products meeting GSE minimums and customer specifications will be approved for shipment.

### *c) Reporting*

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

## **3. Textured Geomembranes**

### *a) GSE patented spraying technology*

The textured geomembrane is produced in a 2-step process. The process is a secondary texturing process in which molten polyethylene is sprayed onto one or both sides of a smooth geomembrane creating a textured surface. The smooth geomembrane used is tested according to standard GSE QA procedures prior to being textured. Once the material is textured, the roll will be checked on its spray weight.

### *b) Coextruded texturing technologies*

Textured geomembrane is produced utilizing a round die with coextrusion technology. The texture is produced in a process in which one or two of the outer layers of a three-layer extrusion are blended with nitrogen gas. Nitrogen bubbles form in the molten resin and escape upon exiting the die, creating a rough,

textured surface. Regular, White, green surfaced, and Conductive geomembranes are available with coextruded texturing.

**C. Third Party Conformance Sampling**

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

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

## APPENDIX A

<b>MINIMUM TESTING FREQUENCIES FOR POLYMERIC RAW MATERIALS <sup>(1)</sup></b>		
<b>Property</b>	<b>Test Method</b>	<b>Natural Raw Material</b>
Density	DIN EN ISO 1183-1/A / ASTM D 792	once per delivery truck: approx. 25 to
Melt Flow Index	DIN EN ISO 1133 / ASTM D 1238	once per delivery truck: approx. 25 to
Carbon Black Content*	ASTM D 1603, modified	once per delivery truck: approx. 25 to
Moisture Content	GSE Method	once per delivery truck: approx. 25 to

<b>MINIMUM PROPERTIES FOR POLYMERIC RAW MATERIALS <sup>(1)</sup></b>			
<b>Property</b>	<b>Test Method</b>	<b>HDPE</b>	<b>LLDPE</b>
Density [g/cm <sup>3</sup> ]	DIN EN ISO 1183-1/A / ASTM D 792	≥ 0.930	≤ 0.929
Melt Flow Index [g/10 min] 190 °C / 2.16 kg	DIN EN ISO 1133 / ASTM D 1238	≤ 1.0	≤ 1.0
Carbon Black Content* [%]	ASTM D 1603, modified	≥ 2	≥ 2
Moisture Content [%]	GSE Method	≤ 0.15	≤ 0.15

\* for precompounded raw materials only

(1) All procedures and values are subject to change without prior notification.

## APPENDIX B

<b>MINIMUM TESTING FREQUENCIES FOR STANDARD GSE GEOMEMBRANE PRODUCTS<sup>(1)</sup></b>		
<b>Property</b>	<b>Test Method</b>	<b>GSE Frequency</b>
Thickness	DIN EN ISO 2286-3 ASTM D 5199 ASTM D 5994 <sup>(2)</sup>	continuously
Density	DIN EN ISO 1183-1/A / ASTM D 792	every 10 <sup>th</sup> roll
Tensile Properties	DIN EN ISO 527-3 ASTM D 638 / D 6693	every roll
Tear Resistance	DIN ISO 34-1/B(a) / ASTM D 1004	every 10 <sup>th</sup> roll
Puncture Resistance	ASTM D 4833	every 10 <sup>th</sup> roll
Carbon Black Content	ASTM D 1603, modified	every 10 <sup>th</sup> roll
Carbon Black Dispersion	ASTM D 5596	every 10 <sup>th</sup> roll
Perforation / Height of Fall	DIN 16726	every production lot
Shrinkage	DIN 53377 ASTM D 1204	every 10 <sup>th</sup> roll
Spraying weight <sup>(2)</sup>	GSE-Method	every roll
Asperity height <sup>(2)</sup>	GRI – GM 12	every roll
Stress Crack Resistance (NCTL) <sup>(3)</sup>	ASTM D 5397, Appendix	every production lot
Oxidative Induction Time (OIT)	ASTM D 3895	every production lot

(1) All procedures and values are subject to change without prior notification.

(2) Specific test methods for textured geomembrane.

(3) NCTL is only determined on HDPE geomembranes.



**GSE HD - Product Data Sheet**  
(available from 0.3 – 3.0 mm)

Lite 2

GSE HD is a black, high quality, high density polyethylene (HDPE) geomembrane produced from specially formulated, virgin polyethylene resin. The polyethylene resin is designed specifically for flexible and durable geomembrane applications. GSE HD contains approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers. GSE HD has outstanding chemical resistance, mechanical properties, environmental stress crack resistance, dimensional stability and thermal aging characteristics. GSE HD has excellent resistance to UV radiation and is suitable for exposed applications.

Tested Property	Unit	Test Method	Values (*)
Thickness			
Nominal Value <sup>(a)</sup>	mm	ASTM D 5199	1.5
Minimum average Value	---		nominal - 5 %
Lowest individual Value	---		nominal - 10 %
Density	g/cm <sup>3</sup>	ASTM D 792	≥ 0.94
Tensile Properties (each Direction)		ASTM D 638 / D 6693; type IV	
Strength at Yield	N/mm	50 mm/min	24 (22)
Elongation at Yield	%	l <sub>0</sub> = 33 mm	16 (13)
Strength at Break	N/mm	200 mm/min	49 (40)
Elongation at Break	%	l <sub>0</sub> = 50 mm	800 (700)
Tear Resistance	N	ASTM D 1004	205 (187)
Puncture Resistance	N	ASTM D 4833	560 (480)
Carbon Black Content	%	ASTM D 1603	2.0 - 3.0
Carbon Black Dispersion	Category	ASTM D 5596	1 / 2 <sup>(b)</sup>
Dimensional Stability (each Direction)	%	ASTM D 1204 (120 °C/1h)	± 2
Melt Flow Index <sup>(c)</sup>	g/10 min	ASTM D 1238 (190 °C / 5.0 kg) (190 °C / 2.16 kg)	≤ 3.0 ≤ 1.0
Stress Crack Resistance (NCTL)	h	ASTM D 5397; Appendix	≥ 400
Reference Property	Unit	Test Method	Values (†)
Low Temperature Brittleness	°C	ASTM D 746	- 77
Oxidative Induction Time (OIT)	min	ASTM D 3895 (200°C; Pure O <sub>2</sub> ; 1 atm)	≥ 100
UV Resistance <sup>(d)</sup> HP-OIT retained after 1,600 hours <sup>(e)</sup>	%	GRI-GM 11 ASTM D 5885	≥ 50
Oven Ageing at 85°C HP-OIT retained after 90 days	%	ASTM D 5721 ASTM D 5885	≥ 80
Roll Width (approx.)	m	---	7.5
Surface	---	---	double-sided smooth

(\*): All values - unless otherwise noted - are nominal values. Values in brackets are minimum values within the 95% confidence interval.

(a): Tolerance ± 5% related to the actual average thickness.

(b): Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be category 1 or 2. No more than 1 view from category 3.

(c): Standard test conditions: 190 °C / 5.0 kg.

(d): Test-Conditions: 20 hours UV cycle at 75°C followed by 4 hours condensation at 60°C; total: 1,600 hours.

(e): UV Resistance is based on percent retained value regardless of the original High Pressure - OIT value.

GSE HD is produced at GSE Rechlin plant, Germany.

This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSE assumes no liability in connection with the use of this information. Please check with GSE for current, standard minimum quality assurance procedures. This information is subject to change without prior notice. Please contact GSE for updated information.



**European Headquarters**  
GSE Lining Technology GmbH  
Großmooring 4  
21079 Hamburg  
Germany  
Tel.: +49-40-76742-0  
Fax: +49-40-76742-34

**Corporate Headquarters**  
GSE Lining Technology, Inc.  
19103 Gundie Road  
Houston, Texas 77073  
USA  
Tel: +1-281-443-8564  
Fax: +1-281-875-6010

**Other Production facilities & Sales Offices**  
United Kingdom  
Spain  
Russia  
Turkey  
Thailand  
Egypt  
Chile  
Australia



e-mail: europe@gseworld.de

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## GSE HD - Product Data Sheet (available from 0.3 – 3.0 mm)

GSE HD is a black, high quality, high density polyethylene (HDPE) geomembrane produced from specially formulated, virgin polyethylene resin. The polyethylene resin is designed specifically for flexible and durable geomembrane applications. GSE HD contains approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers. GSE HD has outstanding chemical resistance, mechanical properties, environmental stress crack resistance, dimensional stability and thermal aging characteristics. GSE HD has excellent resistance to UV radiation and is suitable for exposed applications. These product specifications meet or exceed GRI-GM 13.

Tested Property	Unit	Test Method	Values (*)
Thickness (a)	mm	ASTM D 5199	2.0
Density	g/cm <sup>3</sup>	ASTM D 792	≥ 0.94
Tensile Properties (each Direction)		ASTM D 638 / D 6693; type IV	
Strength at Yield	N/mm	50 mm/min	32 (30)
Elongation at Yield	%	l <sub>0</sub> = 33 mm	16 (13)
Strength at Break	N/mm	200 mm/min	66 (53)
Elongation at Break	%	l <sub>0</sub> = 50 mm	800 (700)
Tear Resistance	N	ASTM D 1004	275 (250)
Puncture Resistance	N	ASTM D 4833	690 (640)
Carbon Black Content	%	ASTM D 1603	2.0 – 3.0
Carbon Black Dispersion	Category	ASTM D 5596	1 / 2 (b)
Dimensional Stability (each Direction)	%	ASTM D 1204 (120 °C/1h)	± 2
Melt Flow Index (c)	g/10 min	ASTM D 1238 (190 °C / 5.0 kg) (190 °C / 2.16 kg)	≤ 3.0 ≤ 1.0
Stress Crack Resistance (NCTL)	h	ASTM D 5397; Appendix	≥ 400
Reference Property	Unit	Test Method	Values (*)
Low Temperature Brittleness	°C	ASTM D 746	- 77
Oxidative Induction Time (OIT)	min	ASTM D 3895 (200 °C; Pure O <sub>2</sub> ; 1 atm)	≥ 100
UV Resistance (d) HP-OIT retained after 1,600 hours (e)	%	GRI-GM 11 ASTM D 5885	≥ 50
Oven Ageing at 85 °C HP-OIT retained after 90 days	%	ASTM D 5721 ASTM D 5885	≥ 80
Roll Width (approx.)	m	---	7.5
Surface	---	---	double-sided smooth

(\*): All values - unless otherwise noted - are nominal values. Values in brackets are minimum values within the 95% confidence interval.

(a): Tolerance ± 5% - Special thickness available upon request.

(b): Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be category 1 or 2. No more than 1 view from category 3.

(c): Standard test conditions: 190 °C / 5.0 kg.

(d): Test-Conditions: 20 hours UV cycle at 75 °C followed by 4 hours condensation at 60 °C; total: 1,600 hours.

(e): UV Resistance is based on percent retained value regardless of the original High Pressure - OIT value.

GSE HD is produced at GSE Rechlin plant, Germany.

*This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSE assumes no liability in connection with the use of this information. Please check with GSE for current, standard minimum quality assurance procedures. This information is subject to change without prior notice. Please contact GSE for updated information.*



**European Headquarters**  
GSE Lining Technology GmbH  
Großmooring 4  
21079 Hamburg  
Germany  
Tel.: +49-40-76742-0  
Fax: +49-40-76742-34

**Corporate Headquarters**  
GSE Lining Technology, Inc.  
19103 Gundle Road  
Houston, Texas 77073  
USA  
Tel: +1-281-443-8564  
Fax: +1-281-875-6010

**Other Production facilities & Sales Offices**  
United Kingdom  
Spain  
Russia  
Turkey  
Thailand  
Egypt  
Chile  
Australia



e-mail: europe@gseworld.de

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## Geomembranes

adopted - 1992  
last revised - 1994

### GRI Test Method GM6

Standard Practice for

#### "Pressurized Air Channel Test for Dual Seamed Geomembranes"

##### 1. Scope

- 1.1 The test is intended to provide a nondestructive evaluation of the integrity of geomembrane seams made in the form of two closely spaced tracks.
- 1.2 The dual seam itself can be made by a number of methods the most common being the *hot wedge* technique. Other possible methods are *hot air* and *ultrasonic* bonding techniques.
- 1.3 The presence of the unwelded channel between the two distinct seamed regions allows for inflation of the sealed channel with air to a predetermined pressure. Extremely long lengths of seam can be evaluated, e.g., lengths of 300 m (1000 ft.) have been successfully monitored.
- 1.4 The air pressure tightness of the pressurized air channel over time is noted and recorded.
- 1.5 If air pressure cannot be maintained within the prescribed limits and dwell time, a leak in the seam is indicated and corrective actions are required.
- 1.6 The test has applicability to all types of geomembranes made from thermoplastic polymers.

##### 2. Summary

- 2.1 This method utilizes a dual, or double, bonded seam where an air channel exists between the two seam tracks. Both ends of the air channel are sealed with a heat gun and then a hollow needle or probe with attached pressure gauge is inserted into the air space. Air pressure is applied and locked-off within the channel. The gauge is monitored for excessive loss of air pressure.
- 2.2 Air pressure is related to the thickness and stiffness of the various geomembrane types and varies from 70 to 205 kPa (10 to 35 lb/in<sup>2</sup>).
- 2.3 Monitoring, or dwell, time is related to the thickness and stiffness of the various geomembrane types and varies from 2 to 5 minutes.
- 2.4 Maximum allowable loss of air pressure is related to the thickness and stiffness of the various geomembrane types and varies from 14 to 35 kPa (2 to 5 lb/in<sup>2</sup>).

##### 3. Significance and Use

- 3.1 The increased use of geomembranes as barrier materials to restrict liquid or vapor movement, and the common use of dual track seams in joining these sheets, has created a need for a standard nondestructive test by which the quality of the seams can be assessed and compared to known competent seams.
- 3.2 This standard practice method recommends an air pressure test within the channel created between dual seamed tracks whereby the presence of unbonded sections or channels, voids, nonhomogenities, discontinuities, foreign objects, etc., in the seamed region can be identified.
- 3.3 This technique is intended for use on geomembrane sheet material formulated from the appropriate polymers and compounding ingredients to form a thermoplastic sheet material that meets all specified requirements for the end use of the product. The sheet material (reinforced or nonreinforced) shall be capable of being bonded or seamed by an appropriate method in which a minimum open space of 2.5 mm (0.1 in.) can be continuously maintained.

#### 4. Equipment

- 4.1 A hand-held heat device (i.e., a hot air gun) is necessary to seal the two ends of the air channel.
- 4.2 Wide mouth vice grips are sometimes necessary to further lock-off these sealed ends.
- 4.3 A sharp, hollow needle or hollow probe with a properly functioning pressure gage is necessary to insert air into the open channel and monitor its pressure.
- 4.4 An air pump, either manual or motor driven, capable of generating and sustaining up to 350 kPa (50 lb/in<sup>2</sup>) pressure is necessary. It is always to be placed on an adequate cushion so as not to damage the geomembrane. A flexible hose is used to connect the pump to the air pressure gage and insertion needle. This hose should have a quick connect on its end for disengagement after pressure is supplied to its desired value, i.e., the pump is not to be attached while the air pressure is being monitored.
- 4.5 Suitable cutting instruments must be available in the event that the liner material must be cut or trimmed.

#### 5. Procedure

- 5.1 After making the desired dual track seam (see Figure 1) and deciding upon the length of seam that is to be evaluated, seal off the two ends of the continuous air channel. This is done by heating both of the ends of the air channel with a hand-held hot air device until the geomembrane becomes pliable and the flow temperature is achieved.
- 5.2 As a back-up to the heat seal it is usually necessary to clamp both ends of the air channel with wide-mouth vice grip clamps (or other suitable means). The clamps can remain in place throughout the test or be removed as the installer sees fit.
- 5.3 Insert the air pressure needle into the air channel by penetrating the upper geomembrane. The needle is to be inserted at the shallowest possible angle and only until the upper sheet is penetrated. The lower sheet beneath the air channel must not be penetrated. Alternatively if using a probe, the entry point may be at the sealed end of the air channel. The pressure gage is connected directly to the end of the hollow needle or probe. If problems are encountered in obtaining a good seal around the needle or probe, heating with a hot air device may be helpful.
- 5.4 Connect an air pump to the pressure gage with a flexible hose via a quick connect and pressurize the air channel. The pressure schedule for various geomembranes is given in Table 1. Maintain these pressures with the air pump connected during a two-minute stabilization period.

Table 1(a) - Air Pressure Inflation Schedule for HDPE and Coextruded Polyethylene Geomembranes (both smooth and textured types)

Geomembrane Thickness		Minimum Pressure		Maximum Pressure	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )	(kPa)	(lb/in <sup>2</sup> )
1.0	40	165	24	205	30
1.5	60	185	27	205	30
2.0	80	205	30	205	35
2.5	100	205	30	205	35

Table 1(b) - Air Pressure Inflation Schedule for VLDPE and LLDPE (smooth and textured) and PVC, PP Geomembranes and other Nonreinforced Flexible Geomembranes-

Geomembrane Thickness		Minimum Pressure		Maximum Pressure	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )	(kPa)	(lb/in <sup>2</sup> )
0.5	20	70	10	140	20
0.75	30	105	15	170	25
1.0	40	140	20	200	30
1.25	50	170	25	240	35
1.5	60	170	25	240	35

Table 1(c) - Air Pressure Inflation Schedule for CSPE-R and PP-R Geomembranes (and other Scrim Reinforced Flexible Geomembranes)

Geomembrane Thickness		Minimum Pressure		Maximum Pressure	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )	(kPa)	(lb/in <sup>2</sup> )
0.90	36	140	20	200	30
1.15	45	170	25	240	35

5.5 Remove the flexible hose which connects the pressure gage to the air pump. Observe the air pressure gage for the desired dwell time. The test time varies from 2 to 5 minutes depending on the geomembrane type and thickness. Mark the time and pressure of the beginning and end of the test on the geomembrane with a clearly visible marker. The maximum allowable pressure drop should not exceed the values given in Table 2.

Table 2(a) - Maximum Pressure Drop Schedule for HDPE and Coextruded Polyethylene Geomembranes (both Smooth and Textured Types)

Geomembrane Thickness		Maximum Pressure Drop Over 5 Min.	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )
1.0	40	28	4.0
1.5	60	21	3.0
2.0	80	14	2.0
2.5	100	14	2.0

Table 2(b) - Maximum Pressure Drop Schedule for VLPDE and LLDPE (smooth and textured) and PVC, PP Geomembranes and other Nonreinforced Flexible Geomembranes

Geomembrane Thickness		Maximum Pressure Drop Over 2 Min.	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )
0.5	20	35	5.0
0.75	30	35	5.0
1.0	40	27	4.0
1.25	50	27	4.0
1.5	60	20	3.0

Table 2(c) - Maximum Pressure Drop Schedule for CSPE-R and PP-R Geomembranes (and other Scrim Reinforced Flexible Geomembranes)

Geomembrane Thickness		Maximum Pressure Drop Over 3 Min.	
(mm)	(mil)	(kPa)	(lb/in <sup>2</sup> )
0.90	36	27	4.0
1.15	45	20	3.0

5.6 If the pressure does not drop below the value listed in Table 2 after the required test period, remove the clamp and cut the air channel open at the end farthest away from the pressure gage. Air should rush out and the pressure gage should register an immediate drop in pressure, indicating that the entire length of the seam has been tested.

If this does not happen, the air channel is blocked. Walk the seam to look and feel for the location of the blockage. The channel should be inflated up to that point. Cut the air channel on the gage side of the blockage and verify the pressure loss. Then inflate the weld from the far side. If the pressure holds, cut the seam just prior to the blockage and verify the pressure drop. If the location of the blockage cannot be found, it may be necessary to cut the seam in the middle and treat both halves as separately seamed sections. Patch all cuts and seal small holes with the appropriate seaming method for the particular geomembrane being installed.

NOTE 1: If multiple blocked locations are suspected or if the seam is short, it may be easiest to cut the seam out and remake the weld.

5.7 For a pressure drop greater than the appropriate value listed in Table 2, check the end seals and where the needle enters into the air channel. Reseal these areas with a hand held hot air device if a leak is noticed and then repeat the entire test.

NOTE 2: Leaks around the end seals and air pressure insertion needle can usually be located by putting moisture around the suspected area and looking for bubbles to occur.

5.8 If the problem is not located, perform peel tests at the beginning and end of the seam to determine seam strength.

5.9 If the seam fails the destructive peel tests, the edge of the loose flap of the upper sheet (which extends beyond the outer track, recall Figure 1) is appropriately seamed to the bottom sheet. Thus the newly made seam becomes the primary seam. It is then vacuum box or air lance tested until satisfactory performance is observed.

5.10 If the seam passes the destructive peel tests, the leak is investigated with the flap in place. If the leak is found, it is repaired. If it cannot be found, cut away the flap shown in Figure 1. Then vacuum box or air lance test the outer track of the seam. If a leak is found, repair it. In both cases, repairs are made by the appropriate seaming method for the particular type of geomembrane being installed.

5.11 If no leak is found in the outer track and all other leak location possibilities have been eliminated, the leak is assumed to be in the inner track. Since this inner track is for the purpose of air channel testing only, it is redundant and can be ignored. The single good outer track is adequate and should be accepted as such.

NOTE 3: If the outer air track cannot be accepted as the primary (and only) seam, a cap strip over the entire seam, or the entire seam cut out and rewelded, are alternative possibilities.

## 6. Report

6.1 The report of a pressurized dual seam test is usually given in the form of a completed chart. It should include the following information:

- project identification and type of geomembrane
- date of test
- time of test
- ambient and sheet temperature at time of test (optional)
- location of test with respect to panel layout plan
- initial channel pressure
- duration of dwell time
- pressure drop during test
- outcome of test (pass/fail)
- if fail - remedial action is described in detail

6.2 A form as shown in Table 3 includes the above information and may be used for such reporting.

## 7. Precision and Bias

7.1 The precision of this test has not been established.

7.2 The threshold value for accepting seam quality is that value agreed upon by all parties overseeing the installation of the project and is thus the source of bias in this procedure.

Fig. 1 - General Configuration of a Dual Track Geomembrane Seam



**Geosynthetic Research Institute**

475 Kedron Avenue  
 Folsom, PA 19033-1208 USA  
 TEL (610) 522-8440  
 FAX (610) 522-8441



Revision 1: May 15, 2003  
 Revision 2: January 28, 2005  
 Revision schedule is on pg. 12

**GRI Test Method GM19\***  
 Standard Specification for  
**Seam Strength and Related Properties  
 of Thermally Bonded Polyolefin Geomembranes**

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

**1. Scope**

- 1.1 This specification addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).
- 1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.
  - Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.
- 1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

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\*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

Note 2: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

- 1.4 This specification also suggests the distance between destructive seam samples to be taken in the field, i.e., the sampling interval. However, project-specific conditions will always prevail in this regard.
- 1.5 This specification is only applicable to laboratory testing.
- 1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents

### 2.1 ASTM Standards

- D751 Standard Test Methods for Coated Fabrics
- D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

### 2.2 EPA Standards

- EPA 600/2.88/052 (NTIS PB-89-129670)  
Lining of Waste Containment and Other Containment Facilities

### 2.3 NSF Standards

- NSF International Standard, Flexible Membrane Liners, NSF 54-1993 (depreciated)

### 2.4 GRI Standards

- GM13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
- GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
- GM18 Test Properties, Testing Frequency and Recommended Warranty for Flexible Polypropylene (fPP and fPP-R) Geomembranes

## 3. Definition

- 3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

- 3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.
- 3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.
- 3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running an ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.
- 3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A deprecated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

#### **4. Significance and Use**

- 4.1 The various methods of field fabrication of seams in polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel. The specification also provides guidance as to what spacing intervals the samples should be taken at typical field installation projects.

#### **5. Sample and Specimen Preparation**

- 5.1 The spacing for taking field seam samples for destructive testing is to be 1 per 500 feet (1 per 150 m) of seam length, or as by directed by the construction quality assurance inspector. As the project continues and data is accumulated, however, this sampling interval should be varied according to the procedure set forth in GRI GM14. Following this procedure three different situations can result.

- 5.1.1 Good seaming with fewer rejected test results than the preset historic average can result in a sequential increase in the spacing interval, i.e., one per greater than 500 ft. (one per greater than 150 m).
- 5.1.2 Poor seaming with more rejected test results than the preset historic average can result in a sequential decrease in the spacing interval, i.e., one per less than 500 ft. (one per less than 150 m).
- 5.1.3 Average seaming with approximately the same test results as the preset historic average will result in the spacing interval remaining the same, i.e., one per 500 ft. (one per 150 m).

Note 3: The method of attributes referred to in GRI GM14 is only one of several statistical strategies that might be used to vary sampling frequency. The use of control charts should also be considered in this regard.

- 5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.
- 5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (as modified by NSF 54) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

## 6. Assessment of Seam Test Results

- 6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_0}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L<sub>0</sub> = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_0}(100) \quad (2)$$

where

S = separation (%)

A = average area of separation, or incursion (in<sup>2</sup> or mm<sup>2</sup>)

A<sub>0</sub> = original bonding area (in<sup>2</sup> or mm<sup>2</sup>)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Note 6: It should be recognized that ASTM D6392 recommends that peel separation be based on the linear measurement of incursion depth. This specification is based on incursion area which is felt to be more indicative of the behavior of peel separation.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2 and AD-WLD (unless strength is achieved)

6.2 LLDPE seams – For LLDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Table 2(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) and 2(b).

$$E = \frac{L}{L_0}(100) \quad (1)$$

where

E = elongation (%)  
L = extension at end of test (in. or mm)  
L<sub>o</sub> = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For LLDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) and 2(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) and 2(b). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation (%)  
A = average depth of separation, or incursion (in.<sup>2</sup> or mm<sup>2</sup>)  
A<sub>o</sub> = original bonding distance (in.<sup>2</sup> or mm<sup>2</sup>)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Note 6: It should be recognized that ASTM D6392 recommends that peel separation be based on the linear measurement of incursion depth. This specification is based on incursion area which is felt to be more indicative of the behavior of peel separation.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2, AD-WLD (unless strength is achieved)

6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in

Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b).

$$E = \frac{L}{L_0}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L<sub>0</sub> = original gauge length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as "not applicable" in Table 3(a) and 3(b).

For FPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_0}(100) \quad (2)$$

where

S = separation in (%)

A = average depth of separation, or incursion (in.<sup>2</sup> or mm<sup>2</sup>)

A<sub>0</sub> = original bonding distance (in.<sup>2</sup> or mm<sup>2</sup>)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Note 6: It should be recognized that ASTM D6392 recommends that peel separation be based on the linear measurement of incursion depth. This specification is based on incursion area which is felt to be more indicative of the behavior of peel separation.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2 and AD-WLD (unless strength is achieved)

## 7. Retest and Rejection

- 7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

## 8. Certification

- 8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

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

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
<b>Hot Wedge Seams<sup>(1)</sup></b>							
shear strength <sup>(2)</sup> , lb/in.	57	80	100	120	160	200	240
shear elongation at break <sup>(3)</sup> , %	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
<b>Extrusion Fillet Seams</b>							
shear strength <sup>(2)</sup> , lb/in.	57	80	100	120	160	200	240
shear elongation at break <sup>(3)</sup> , %	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , lb/in.	39	52	65	78	104	130	156
peel separation, %	25	25	25	25	25	25	25

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

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

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

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
<b>Hot Wedge Seams<sup>(1)</sup></b>							
shear strength <sup>(2)</sup> , N/25 mm.	250	350	438	525 <sup>15mm</sup> / <sub>315</sub>	701	876 <sup>526</sup>	1050
shear elongation at break <sup>(3)</sup> , %	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , N/25 mm	197	263	333	398 <sup>233</sup>	530	661 <sup>397</sup>	793
peel separation, %	25	25	25	25	25	25	25
<b>Extrusion Fillet Seams</b>							
shear strength <sup>(2)</sup> , N/25 mm	250	350	438	525	701	876	1050
shear elongation at break <sup>(3)</sup> , %	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , N/25 mm	170	225	285	340	455	570	680
peel separation, %	25	25	25	25	25	25	25

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

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
<b>Hot Wedge Seams<sup>(1)</sup></b>								
shear strength <sup>(2)</sup> , lb/in.	30	45	60	75	90	120	150	180
shear elongation <sup>(3)</sup> , %	50	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
<b>Extrusion Fillet Seams</b>								
shear strength <sup>(2)</sup> , lb/in.	30	45	60	75	90	120	150	180
shear elongation <sup>(3)</sup> , %	50	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

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

- Also for hot air and ultrasonic seaming methods
- Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5<sup>th</sup> specimen can be as low as 80% of the listed values
- Elongation measurements should be omitted for field testing

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

Geomembrane Nominal Thickness	0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
<b>Hot Wedge Seams<sup>(1)</sup></b>								
shear strength <sup>(2)</sup> , N/25 mm	131	197	263	328	394	525	657 <sup>15 mm</sup> / 395	788
shear elongation <sup>(3)</sup> , %	50	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , N/25 mm	109	166	219	276	328	438	547 <sup>328</sup>	657
peel separation, %	25	25	25	25	25	25	25	25
<b>Extrusion Fillet Seams</b>								
shear strength <sup>(2)</sup> , N/25 mm	131	197	263	328	394	525	657	788
shear elongation <sup>(3)</sup> , %	50	50	50	50	50	50	50	50
peel strength <sup>(2)</sup> , N/25 mm	95	150	190	250	290	385	500	595
peel separation, %	25	25	25	25	25	25	25	25

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Reinforced Flexible Polypropylene (fPP) Geomembranes (English Units)

Geomembrane Nominal Thickness	30 mil-NR	40 mil-NR	36 mil-R <sup>(4)</sup>	45 mil-R <sup>(4)</sup>
<b>Hot Wedge Seams<sup>(1)</sup></b>				
shear strength <sup>(2)</sup> , lb/in. (NR); lb (R)	25	30	200	200
shear elongation <sup>(3)</sup> , %	50	50	n/a	n/a
peel strength <sup>(2)</sup> , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a
<b>Extrusion Fillet Seams</b>				
shear strength <sup>(2)</sup> , lb/in. (NR); lb (R)	25	30	200	200
shear elongation <sup>(3)</sup> , %	50	50	n/a	n/a
peel strength <sup>(2)</sup> , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a

Notes for Tables 3(a) and 3(b):

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5<sup>th</sup> specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongations per D751 for laboratory tested specimens

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Reinforced Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.75 mm-NR	1.0 mm-NR	0.91 mm-R <sup>(4)</sup>	1.14 mm-R <sup>(4)</sup>
<b>Hot Wedge Seams<sup>(1)</sup></b>				
shear strength <sup>(2)</sup> , N/25 mm (NR); N (R)	110	130	890	890
shear elongation <sup>(3)</sup> , %	50	50	n/a	n/a
peel strength <sup>(2)</sup> , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a
<b>Extrusion Fillet Seams</b>				
shear strength <sup>(2)</sup> , N/25 mm (NR); N (R)	110	130	890	890
shear elongation <sup>(3)</sup> , %	50	50	n/a	n/a
peel strength <sup>(2)</sup> , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a

**Adoption and Revision Schedule**

**for**

**Seam Specification per GRI-GM19**

“Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes”

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

Material	Test	Seam Type	Current GM19	Proposed GM19	Difference
HDPE	Shear	Hot Wedge Extrusion	95% yield 95% yield	95% yield 95% yield	no change no change
	Peel	Hot Wedge Extrusion	62% yield 62% yield	72% yield 62% yield	16% increase no change
LLDPE	Shear	Hot Wedge Extrusion	1300 psi break 1300 psi break	1500 psi break 1500 psi break	15% increase 15% increase
	Peel	Hot Wedge Extrusion	1100 psi break 1100 psi break	1250 psi break 1100 psi break	14% increase no change

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.