Development of high temperature resistant geomembranes for oil sands secondary containments

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ABSTRACT
Development of oil sands and heavy oil resources has led to the widespread use of heated petroleum storage tanks. Underneath these tanks the soil temperatures rise quickly until the soil temperatures are nearly equal to the tank temperature. A secondary containment geomembrane placed underneath a heated tank will have to resist the effects of high temperatures for the service life of the geomembrane.

This paper will also outline the use of these high temperature resistant geomembrane materials on a recent oil sands project. The paper will discuss compatibility testing with the fluids to be contained and installation of the geomembranes.

RÉSUMÉ
Le développement de l'industrie des sables bitumineux et des pétroles lourds a entraîné la multiplication des réservoirs de stockage chaud. Sous ces réservoirs, la température du sol grimpe rapidement pour atteindre quasiment celle du liquide contenu dans le réservoir. La géomembrane de confinement secondaire installée sous le réservoir devra donc résister aux effets des températures élevées pendant toute sa vie utile.

Nous parlerons aussi de l'utilisation de ces géomembranes à haute résistance thermique en guise de matériaux de confinement secondaire sur un récent projet de sables bitumineux. Enfin, nous présenterons les essais de compatibilité effectués avec les fluides stockés dans les réservoirs et les techniques d'installation de ces géomembranes.

1 INTRODUCTION

The recent surge in development of oil sands and heavy oil has led the increase in the storage of hot petroleum products. These hot petroleum products are stored in tanks until needed by various refining processes. In some cases the petroleum products are too viscous to be easily handled at ambient temperatures and are heated so that they can be pumped and handled more easily. Our task was to find secondary containment liners that could be used with heated petroleum storage tanks.

2 HIGH TEMPERATURE ISSUES

There are two areas of difficulty with the secondary containment of heated petroleum products. The first problem is that plastic liner materials are adversely affected by chemicals at elevated temperatures and test data is often not available. The second problem is that subjecting polymeric materials to elevated temperatures can degrade the material prematurely.

2.1 Elevated Temperature Containment

The first issue is that of containment at elevated temperatures. Most chemical resistance charts are built using tests conducted at room temperature. In some rare instances there are specific chemicals that are tested at higher temperatures but these tests are usually in response to a specific industry requirement. In the metal plating industry some of the plating tanks operate at elevated temperatures. PVC tank liners were developed many years ago to address this specific industry and regularly contain low pH solutions at 90C. But containment of heated petroleum products is a much more difficult problem.

At their simplest level thermoplastic materials such as HDPE, and PVC are composed of tangled polymeric chains. As the temperature rises these chains relax and allow the chemical to penetrate deeper into the polymer. Since most thermoplastics are derivatives of petroleum in the first place they react strongly with heated petroleum. For example, a standard extraction test for polyethylene heats the polymer in hexane until it dissolves. When first confronted with the need to contain hot petroleum products with a thermoplastic there were a great many unanswered questions.

First of all when would the liner need to directly contain a hot petroleum product? A secondary containment liner runs underneath the tank in a tank farm and up the slopes of the containment berm. In the large tanks, that are typical of oil sands facilities, the tank sits on a constructed pad that is built on top of the liner. In the event of a major spill, any liquid would flow into the containment area where it would be recovered. A spill in the containment area is normally detected immediately and cleanup takes place within a few days. The normal evaluation of a secondary containment liner is to contain the liquid for 7 days with a change in liner properties of less than 15%. That change in properties can be either a weight loss/gain, or a change in another physical property such as tensile strength.

2.2 The Hot Under-tank Environment

The second major problem with heated tanks is the degradation of polymers under the effect of heat. The ground underneath these heated petroleum tanks will rise in temperature until an equilibrium point is reached. That equilibrium point is dependent on the diameter of the tank, the temperature of the tank, and the conductivity of the soil beneath the tank. Modeling of the flow of heat below heated tanks was done by Scott and Kosar . Their work showed that under an 80 m diameter tank operating at 175C the temperature at 3 m depth after one year would reach 142C. In a discussion with EBA Engineering about this issue they shared further models that showed that after 5 years of service the temperature at this same location would get very close to the operating temperature of the tank. Since liners are normally closer to the tank bottom than 3 m level we felt that our design criteria should be the service temperature of the heated tank for the life of the facility. There may be situations where the temperature under a tank is mitigated by any number of factors however the worst case would be that the temperature at the liner equals the tank temperature.

Degradation of plastics by heat is an oxidation reaction. The heat accelerates the oxidation of the polymeric chains which accelerates degradation. Any liner placed in the tank pad beneath a heated petroleum tank would need to resist oxidative degradation at, or near the operating temperature of the tank. The oxidation of polymers at elevated temperatures is a fairly well understood field and there are additive packages available to improve the oxidative performance of most polymers. One of the most useful areas of comparison was the field of wire and cable coating. Typically wire and cable is rated for service at 90C. We found that the tests used for wire and cable were applicable to the high service temperatures that a liner would be exposed to under a heated tank.

3 FIRST PROJECT EVALUATION

In 2001 an expansion of one of the major oil sands plants called for proposals for the selection, supply, and installation of tank containment liner systems. The request for proposals called for containment of Heavy Gas Oil, Light Gas Oil, and Naptha in tanks with operating temperatures up to 105C. The temperature in the ground below the tanks was estimated to be 79C. The design time frame was a minimum of 30 years. In later addendums the temperature was changed to a maximum upset temperature of 98.2C.

3.1 Initial Material Screening

Our initial contact with the geomembrane material manufacturers was mixed. The temperatures were too high for common geomembranes and only one manufacturer had actually tested these particular petroleum products at those kinds of temperatures before. One of our manufacturers had a liner material that had been tested in Naptha for 11 years; however they had not done any elevated temperature testing. Another manufacturer had a PVDF (PolyVinylidene Flouride) material available that had a continuous service rating of 177C. The manufacturer had also tested the PVDF in Naptha for 7 days at 110C so we knew this material would work for containment. Unfortunately PVDF is probably the most expensive geomembrane material available with installed costs exceeding $200/m2.

3.2 Test Setup

In order to answer the call for proposals we would have to screen materials to see if any would meet the containment requirements. Samples of Naptha, Light Gas Oil, and Heavy Gas Oil were obtained from the client. Handling these chemicals at 105C is not something that can be done in a regular testing lab. Fortunately Alberta Research Council in Edmonton has extensive research with oil sands products and worked with us to come up with a testing plan. The testing would be done using sealed containers (called bombs) that would be held in an oil bath. The chemical and liner samples would be placed in each bomb for 7 days and then removed for observation and physical testing. Due to time constraints the testing was shortened to 6 days.

Adding heat to these chemicals produced vapours that pressurized the bombs during the test. The bomb with Naptha reached a pressure of 386 kPa (56 psig), the Light Gas Oil reached a pressure of 110 kPa (16 psig), and the Heavy Gas Oil reached a pressure of 90 kPa (13 psig. This pressure would have had the effect of making the test more severe than chemical testing at atmospheric pressure.

Table 1. Identification of Trade Named Products

Tradename	Composition*	Designation
HAZGARD® 100	PVC alloy (U)	Green 0.75mm Alloy
HAZGARD® 500	UL Listed PVC alloy (S)	Red/Red** 0.94mm Alloy
HAZGARD® 1000	UL Listed Thermoplastic polyurethane (S)	Red/Black** 0.7 mm PUR
HAZGARD® 5000 HT	High Strength PVC alloy (S)	Red/Black** 0.75 mm Alloy
HT 2000	High Temp PVC alloy (U)	Blue 0.75 mm Alloy
Arctic Liner® NT	Cold Temp PVC alloy (U)	White 0.75 mm Alloy

* (U) unsupported or (S) fabric supported construction
**These colours will be abbreviated as R/R and R/B.

Table 2. Immersion Testing at 105C for 143 Hours

Material	Test Fluid	Thickness Change	Weight Change
R/B 0.7mm PUR	Naptha	+16%	+17%
	Light GO	+11%	+16%
	Heavy GO	+17%	+23%
Green 0.75mm Alloy	Naptha	-11%	-11%
	Light GO	+9%	-6%
	Heavy GO	+19%	+13%
R/B 0.75mm Alloy	Naptha	+21%	+17%
	Light GO	+21%	+16%
	Heavy GO	+52%	+23%
HDPE 80	Naptha	Dissolved	Dissolved
	Light GO	Dissolved	Dissolved
	Heavy GO	+8%	+117%
LLDPE 30	Naptha	Dissolved	Dissolved
	Light GO	Dissolved	Dissolved
	Heavy GO	+22%	+81%
PP 30	Naptha	Dissolved	Dissolved
	Light GO	+17%	+268%
	Heavy GO	+102%	+270%
Spray-on 1 Polyurea	Naptha	-53%	+103%
	Light GO	-46%	+85%
	Heavy GO	-46%	+92%
Spray-on 2 PUR	Naptha	+41%	+50%
	Light GO	+42%	+62%
	Heavy GO	+2%	+72%
OR PVC HT	Naptha	+13%*	+20%*
	Light GO	+17%*	+24%*
	Heavy GO	+23%*	+88%*

* Blistered

3.3 Test Discussion

R/B 0.7mm PUR is an ester-based thermoplastic polyurethane liner on a polyester fabric normally used for the containment of hydrocarbons. The R/B 0.7mm PUR remained flexible and visually did not appear to be adversely affected by the immersion in any of the three chemicals. R/B 0.7mm PUR experienced approximately 16% weight gain and a thickness increase of roughly 16% in the Naptha and Light Gas Oil. Weight change in the Heavy Gas Oil reached 23%. Repeated flexing of the R/B 0.7mm PUR samples following the immersion did not result in any cracking or tearing of the polyurethane coating.

Green 0.75mm Alloy is a specialized alloy of PVC. It lost about 11% weight and thickness in the Naptha. In the Gas Oils it swelled and gained weight. Weight and thickness change in the Light Gas Oil was 9 and 6% respectively. In Heavy Gas Oil the material swelled up to 19% with a weight gain of 13%.

R/B 0.75mm Alloy is an alloy of PVC and proprietary polymeric plasticizers. The material thickness increased by 21% in Naptha and Light Gas Oil with similar weight changes. Heavy Gas Oil was not suitable for the material as it swelled 52% in thickness and gained 72% in weight.

The HDPE/ LLDPE/ PP polyolefins were found to be completely unsuitable for this application. The High Density Polyethylene (HDPE 80) and Linear Low Density Polyethylene (LLDPE 30) materials were completely destroyed in both the Naptha and Light Gas Oil. They completely dissolved, with only a gummy liquid left over after six days. The combination of pressure and heat together were too much for either of these polyethylenes. The Polypropylene (PP 30) sample also dissolved during Naptha immersions and swelled over 250% in the other liquids.

Two commercially available spray–on materials were included in the immersion testing, a polyurea and a polyurethane. Both spray-on's were affected by the immersions, leaving them partially dissolved and softened to the point where they cracked and tore easily during handling. The polyurea (1) material experienced swelling near 50% in all three immersion tests and weight gains between 90 and 100%. The polyurethane (2) gained 0ver 40% in the Naptha and Light Gas Oil. The polyurethane gained over 50% in all three liquids including the Heavy Gas Oil where its 72% weight gain nullifies the minimal thickness change.

A competitor's Oil Resistant, High Temperature PVC 30 mil (OR PVC HT) was also tested. This material showed significant surface blistering in all three immersion chemicals. The weight gain for this material in Naptha and Light Gas Oil was about 20% with a thickness gain of 13 to 17%. Heavy Gas Oil weight gain was 88%. While the weight gains in Naptha and Light Gas Oil were similar to other materials. The blistering in all three fluids indicated incompatibility with the test chemicals at this temperature.

3.4 Conclusions from the first test

Weight loss/gain and thickness loss/gain were used to evaluate these specimens. The limited space in the bombs only permitted small specimens to be used which limited the options for physical testing.

In reviewing this initial test data we came to a number of conclusions. First, that the higher temperature and pressures of these tests were causing swelling and weight gains outside of the normally accepted 15% range. There were materials that were showing swelling and weight gain in the 15 to 20% range that appeared to be visually unaffected by the immersions. For a short term secondary containment application a swelling and weight change of under 20% was targeted. It was also apparent that the Heavy Gas Oil would be the most significant problem.

3.5 Outcome of the first proposal

Although we had completed our testing on the actual chemicals from the site we still were not able to clear the materials for the application. The main issue was that the manufacturers were hesitant to accept the high temperature application below the tanks. They saw our testing with the chemicals and were comfortable with the liners used in the main containment area; but, were uncomfortable with the environment under the tanks. Some initial thermal stability testing was completed by the manufacturers; however, the application was so new that none of them were willing to sign off without more testing.

The PVDF material was the only material we had available in time for our proposal that was backed by the manufacturer for these high temperatures under the tanks. We ended up proposing the PVDF material underneath the tanks which we would then mechanically connect to other materials in the main containment areas. We proposed lining the Naptha and Light Gas Oil areas with the Green 0.75mm Alloy material and the Heavy Gas Oil area with the R/B 0.7mm PUR.

Our option was not selected by the client. They accepted a lower cost bid from another vendor based on a manufacturer's warranty that was substantially longer than similar warranties on the market. Sadly, the manufacturer closed its doors a few years after the project was installed leaving the warranty unfunded.

4 EVALUATION OF HEAT STABILITY

Having lost the first major project requiring high temperature resistant materials we set out to complete our testing and to establish a selection of more reasonably priced materials before the next project was called.

The second problem that we had not completely solved was to deal with the degradation of the liner materials in the hot environment under the tank. In this situation we set our design assumption that the liner is going to be exposed to the same temperature as the operating temperature of the tank. Although there are many situations where the ground temperature may be lower than the tank temperature we decided to use the tank operating temperature as a conservative design approach for all heated tank secondary containment liners. Solving the problem of placing the liner under a heated tank required not only that we complete suitable testing but that we get our manufacturers to accept and warrant the application.

4.1 Heat Stability Test Methods

The use of plastics at elevated temperatures is most well developed in the field of wire and cable. PVC wire coatings rated for 90C service have been in place for decades. Thermal aging tests of wire insulation are normally done with oven aging tests. By testing at higher temperatures than expected service an estimate of thermal stability can be obtained. The standard test for thermal aging is ASTM D2633 Standard Test Methods for Thermoplastic Insulations and Jackets for Wire and Cable. Using an Air Oven test the plastic is exposed to a high temperature and then evaluated after exposure. The most common use of this test is a 7-day exposure at 175C. This exposure level is meant to evaluate PVC cable coatings that will see service at 90C. Another test that we used was ASTM D2115 Standard Practice for Oven Heat Stability of Poly(Vinyl Chloride) Compositions. In this test we measured weight loss over a 28-day period at 135C.

4.2 Testing Discussion

After this round of heat aging testing we began to see which materials would be suitable for under-tank applications. The Green 0.75mm Alloy and R/B 0.75mm Alloy materials were holding up well to the heat. The R/R 0.94mm Alloy and the Blue 0.75 mm Alloy were materials with promise that were added to the testing program. The Blue 0.75 mm Alloy was a new material that had been developed by another manufacturer specifically for high temperature containments. It was a special alloy of PVC with added heat stabilizers. The R/R 0.94mm Alloy was a fabric supported PVC alloy listed by ULC for above ground containment of fuels. The White 0.75 mm Alloy material and regular PVC liner materials were added for comparison.

Table 3. Heat Aging at 175C for 7 Days

Material	Tensile Retained MD	Tensile Retained TD	Elongation Retained MD	Elongation Retained TD
Green 0.75mm Alloy	94%	86%	103%	94%
R/R 0.94mm Alloy*	94%	102%	134%	115%
R/B 0.75mm Alloy *	100%	100%	137%	125%
White 0.75 mm Alloy	109%	100%	99%	82%
Blue 0.75 mm Alloy	101%	83%	114%	93%

* Tested the coatings only (normally coated fabrics)

Table 4. Heat Stability at 135C for 28 days

Material	7 day Weight	28 day weight
Green 0.75mm Alloy	-4.4%	-12.6%
R/R 0.94mm Alloy *	-6.1%	-16.8%
White 0.75 mm Alloy	-19.6%	-29.0%
Blue 0.75 mm Alloy	-3.2%	-18.6%
PVC	-25.7%	-37.3%

* Tested the coating only

4.3 Heat Aging and Stability Testing Conclusions

The heat stability tests showed that all of the materials proposed for under-tank heat stability did well. In Table 3 all materials except the Blue 0.75mm Alloy showed tensile strength retention within the 15% pass criteria. The Blue Alloy retained 17% of its tensile strength.

Retention of elongation was also within the 15% range except for one direction of the R/R 0.94mm Alloy and the R/B 0.75mm Alloy. Both of these materials are normally coated fabrics. In this testing a sample was prepared of the coating only without fabric support. We felt that the increase in elongation properties after exposure was not a significant problem. A major loss in elongation would have caused concern. The increase was felt to be the result of additional plasticization of the polymer due to the heat. During manufacture PVC products are heated to mix plasticizers with the resin. In some cases adding additional heat can continue that reaction.

A second series of heat stability tests were performed by one of the manufacturers. They tested the products that they manufacture and included the Blue 0.75 mm Alloy from another manufacturer. The results of these tests are shown in Table 4. The three materials that were being considered for high temperature applications all showed heat stability weight loss after 28 days of less than 20%. For comparison a regular PVC material lost over 37% after 28 days and the White 0.75 mm Alloy (intended for cold temperature applications) lost 29%.

Other manufacturers did additional testing of the heat stability of their materials which was not shared.

4.4 Resulting High Temp Warranties

Curiously there are no clear pass/fail criteria for this type of testing as this application is still very new. It is up to the individual manufacturers to accept or to decline the application of high temperature secondary containment lining. We felt that some of the materials had performed well but some manufacturers accepted the application and some did not. Each manufacturer had to determine if the application presented an acceptable risk and needed to prepare a warranty statement to support the application. Some of the materials that appeared to be promising were not backed by their manufacturers while others were.

Table 5. Manufacturer's Warranty Acceptance

Material	Service Temp	Warranty
Green 0.75mm Alloy		No high temp
R/R 0.94mm Alloy	65 C	Review by job
R/B 0.7mm PUR	65 C	Review by job
R/B 0.75mm Alloy	100 C	Std Warranty
Blue 0.75 mm Alloy	90 C	Std Warranty

5 SECOND PROJECT EVALUATION

Now that the testing of materials was completed and the manufacturers had accepted the application of hot petroleum storage we just needed to have a project. In the summer of 2005 we were invited to participate in the development of the liner specifications for a new oil sands facility being built north of Ft Mc Murray. We arranged for testing of the chemicals anticipated on the job with the liner materials available for high temperature applications. After reviewing previous tests we determined that two additional chemicals should be tested. These chemicals were diluted bitumen (sometimes called Dilbit) and diluent. These two chemicals would be the main items stored in hot tanks at this new site. Our previous test results were used for the evaluation of Naptha and Gas Oils.

5.1 Containment Testing

Representative samples of Diluted Bitumen and Diluent were obtained with the assistance of the client. Each liner/chemical combination was tested at 65 C, 85 C, and 100 C. All testing was done at the Alberta Research Council. The samples were loaded into pressure bombs and then placed in an oil bath to maintain temperature. In these sealed bombs the pressure increased with heat. The pressure inside the containers with diluted bitumen ranged from 55 kPa to 110 kPa (8 to 16 psig) while the pressure in the diluent container ranged from 76 kPa to 103 kPa (11 to 15 psig).

Table 6. Testing in Diluted Bitumen

		Diluted Bitumen		
		65 C	85 C	100 C
Green 0.75mm Alloy	Δ T Δ W	+1.8% -3.8%	+3.7% -6.8%	No Data
R/R 0.94mm Alloy	Δ T Δ W	+5.4% +8.5%	+11% +8.9%	+9.3%* +12%*
R/B 0.7mm PUR	Δ T Δ W	+3.4% +8.1%	+6.9% +12%	+5.2% +9.6%
R/B 0.75mm Alloy	Δ T Δ W	+13% +16%	+13% +22%	+21% +25%
Blue 0.75 mm Alloy	Δ T Δ W	+5.3% +13%	+3.4% +17%	+6.9%* +17%*
HDPE30	Δ T Δ W	0% +8.1%	+1.6% +9.9%	+4.6% +19%

* Blistering

Table 7. Testing in Diluent

		Diluent		
		65 C	85 C	100 C
Green 0.75mm Alloy	Δ T Δ W	-1.8% -15%	+3.8% -16%	0% -14%
R/R 0.94mm Alloy	Δ T Δ W	-5.4% -7.0%	-4.0%* -6.3%*	0% -6.0%
R/B 0.7mm PUR	Δ T Δ W	+3.4% +3.6%	+6.9% +3.6%	+8.6% +6.3%
R/B 0.75mm Alloy	Δ T Δ W	-5.9% -7.9%	-2.9% -8.0%	-5.9% -12%
Blue 0.75 mm Alloy	Δ T Δ W	0% -8.7%	+5.4% -9.6%	+3.5%* -9.3%*
HDPE30	Δ T Δ W	+1.5% +3.9%	0% 1.1%	Dissolve

* Blistering

5.2 Material Selection

There were 11 tanks in the facility that needed to be lined. The selection of material was done by first considering the tank temperature and contents, then reviewing the available materials, and then looking at material costs.

There were 6 tanks that contained Naptha, Distillate, or Naptha mixed with Distillate at temperatures between 40 and 50C. In all of our testing the R/B 0.7 mm PUR material had performed well with Distillates and Naptha. These two chemicals are considered flammable liquids and the R/B 0.7 mm PUR is ULC listed for the containment of flammable liquids and that listing gave the client additional confidence in the performance of the materials. The manufacturer of this material accepted the under tank temperatures of 50 to 60C and provided suitable warranties.

There was one Gas Oil tank that had an operating temperature of 65C. The testing results at 65C for the Blue 0.75 mm Alloy material were acceptable. This was one of the lower priced materials in this testing program and that figured into the selection.

The most difficult selection of liners was for a series of 4 tanks containing Diluted Bitumen and Gas Oil operating at temperatures of 85 to 100C. At these temperatures we were limited to the selection of either the R/B 0.75 mm Alloy or the Blue 0.75 mm Alloy. The other manufacturers would not offer their materials for the hot environment under the tank at these temperatures. After much discussion the R/B 0.75 mm Alloy was chosen for the under-tank liners. The selection was based on the test results but also on the backing of the manufacturer. In this case the manufacturer was able to provide a suitable warranty

As a cost saving measure the Blue 0.75 mm Alloy was used in the containment area of some of the hotter tanks. The ability to weld the R/B 0.75 mm Alloy to the Blue 0.75 mm Alloy was a factor in the selection of these two materials.

6 INSTALLATION

Installation of the secondary containment liners for large petroleum tanks takes place in two stages. In the first stage the liner is placed underneath the area where the tank will be located. Then the tank pad is built on top of that liner. Construction of the tank takes place on top of the pad. Berm construction doesn’t take place until the majority of the tank work is completed. This makes it easier for the tank construction crew to work since they do not have to work in an area where the containment is lined. This staged construction technique helps prevent damage to the liners.

6.1 Phase One Construction

Phase one construction started in the fall of 2006. The areas for the tank pads were cleared and compacted prior to our arrival on site. The ground under the pad was sloped to provide drainage of any leakage to the perimeter of the tank pad. Under each pad area we placed a square section of the liner material designated for that tank under-liner. These small sections of liner went in very quickly.

Table 8. Liner Material Selections

Tank	Contents	Temp	Under Tank	Berm Liner
1	Gas Oil	85 C	R/B 0.75mm Alloy	Blue 0.75 mm Alloy
2	Distillate	50 C	R/B 0.7mm PUR	R/B 0.7mm PUR
3	Naptha/Distillate	50 C	R/B 0.7mm PUR	R/B 0.7mm PUR
4	Naptha	40 C	R/B 0.7mm PUR	R/B 0.7mm PUR
5	Water	50 C	R/R 0.94mm Alloy	R/R 0.94mm Alloy
6	Oily water	80 C	R/B 0.75mm Alloy	Blue 0.75 mm Alloy
7	Oily water	80 C	R/B 0.75mm Alloy	Blue 0.75 mm Alloy
8	Gas Oil	65 C	Blue 0.75 mm Alloy	Blue 0.75 mm Alloy
9	Naptha	40 C	R/B 0.7mm PUR	R/B 0.7mm PUR
10	Distillate	50 C	R/B 0.7mm PUR	R/B 0.7mm PUR
11	Diluted Bitumen	100 C	R/B 0.75mm Alloy	R/B 0.75mm Alloy
14	Diluted Bitumen	100 C	R/B 0.75mm Alloy	R/B 0.75mm Alloy
15	Diluted Bitumen	100 C	R/B 0.75mm Alloy	R/B 0.75mm Alloy

Each under-tank liner had two leak detection chambers built into them with the liner sloped to these chambers. A pipe extended from each chamber to daylight so that leakage in the tank bottoms could be detected quickly.

After the installation of the pad liner the earthworks contractor built the tank pad and buried the edges of the liner with select fill materials. The pad was constructed with a designed slope to the perimeter of the tank. The top and sides of the tank pad were covered with geotextile for protection of the pad during tank construction.

Once the pads were built the tanks were built in place on top of the pads. The tanks were welded together from metal plates on site. By not building the berms in phase one there was access for cranes and other equipment to assist in the construction of the steel tanks.

6.2 Phase Two Construction

Phase two construction started in the summer of 2007 and was completed in the summer of 2008. We coordinated our construction with the earthworks contactor for the most efficient use of resources. As the earthworks contractor completed the berms we would line them immediately. Once a portion of the berms were lined and tested the earthworks contractor would backfill the liner immediately.

Once the tank pad liners were exhumed and inspected the lining of the main containment area began. The liner designated for the containment section was attached to the tank pad liner and extended up and over the earthen berms of the containment. This is the phase of the project where the most detail work was encountered. Pipe penetrations of the liner were constructed and sealed and in a number of cases pipe rack foundations were sealed in the tank containment area. In each tank farm containment area there were approximately 20 penetrations for pipe rack piling supports. In each containment area there were also two catch basins that were connected to piping used for rain water control.

Once each section of the liner was installed it was inspected and then signed over to the earthworks contractor for immediate covering. All of the liners in this installation were backfilled liners. Backfilling the liner provides protection from mechanical damage during tank farm operations and protects the liner from UV degradation and cold weather. Liner backfill also helps to protect the liner from the thermal effects of the contained liquid in the event of a spill. The backfill acts as a large thermal mass that would buffer the temperature of any hot liquid during a spill.

7 FINAL COMMENTS

The development of liners for high temperature tank containments is now developed to the point where most oil sands and heavy oil projects are possible. We recommend that testing be done prior to any unusual secondary containment project with chemicals and conditions matched as closely as possible to operating conditions.

In this case of a secondary containment of hot petroleum storage tanks performing tests on the materials to be contained was indispensable in geomembrane selection.

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