LAYFIELD GEOSYNTHETICS

TECHNICAL PAPER

Emerging Applications for Evaporation Control Covers

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ABSTRACT

In early 2013, we were contacted by a number of oil and gas producers interested in evaporation control covers for fresh water pits used for hydraulic fracturing. Large amounts of water are required for fracking, requiring geomembrane lined earthen pits used to store water. These large, open water pits are highly susceptible to evaporation, especially in more arid and windy climates. Operating losses as a result of high evaporation rates can cost producers hundreds of thousands of dollars over the relatively short lifecycle of a containment pit. This paper outlines the growing opportunities for evaporation control covers and the challenges to design and supply of an engineered, light weight evaporation cover system capable of withstanding the demanding installation challenges while meeting economic realities of producers. It also highlights our product development history and initiatives undertaken to meet the emerging market needs for lightweight evaporation control covers used today by various industries.

EVAPORATION COVERS – HISTORY & DEVELOPMENT

As a recognized supplier of floating cover systems, we have extensive experience supplying covers into various applications throughout North America and internationally. Historically, the main functions of our floating covers have been to protect the water from debris contamination, algae control, and to prevent evaporation in municipal potable water applications. These municipal applications normally incorporate an engineered floating cover design using more specialized heavy gauge geomembranes developed for longer term performance. These higher end floating cover systems are often not an economical solution for shorter term applications in other industry sectors. Dating back as early 2004, we recognized the need to develop lighter weight covers for evaporation control applications for other emerging markets. The main sectors supporting this were agricultural and horticultural markets driven by a growing population base and the need to protect what is increasingly being recognized as a scarce fresh water resource. This led to a spike in demand for floating covers designed for evaporation control. Life expectancy for many of these lighter weight cover applications can vary from 5 to 25 years. This created a number of challenges in the design of the cover and material selection.

To help address the emerging demand for more economical floating covers, our product development team began work in 2005 on the design of a new generation of light weight cover systems. In the summer of 2006, we prototyped our first light weight floating cover design in Clyde, Alberta, 45 miles (75 km) north of Edmonton, Alberta (Figures 1 and 2). The prototype cover design, included

prefabricating multiple panels from a flexible 30 mil (0.75 mm) linear low density polyethylene (LLDPE) unsupported geomembrane with a special undercover foam floatation design. The lightweight cover also incorporated a special reinforced leading edge which was used to pull the cover into place on top of an existing 60,000 ft^2 (5,600 m^2) irrigation pond. The cover system incorporated a simple, defined sump system using heavy chains as weights to help define the sump section and provide sufficient cover tensioning. The chosen LLDPE cover material was determined to provide sufficient mechanical properties, including tensile and tear strengths to support personnel on the cover for installation and maintenance purposes. This light weight cover system was then inspected on an annual basis over a 3 year period while being exposed to the harsh Alberta Canada weather conditions including heavy winds, snow, freeze thaw cycles, and summer heat. The cover stood up and performed very well over the 3 year test period, after which it was decommissioned. This prototype cover helped provide the design and performance criteria required to design thinner gauge flexible materials into larger scale floating covers for evaporation control applications.


Figure 1. Prototype design lightweight 30 mil (0.75mm) cover system with leading edge


Figure 2. Prototype 30 mil (0.75 mm) cover with field technicians on surface installing weighted sump

Based on the commercial development of this new light weight cover design, a number of small to mid-size evaporation covers were installed in the United States and Canada for agricultural, mining and recreational applications. In early 2007, we were contacted by a client in Adelaide, South Australia, who required a 250,000 ft^2 (23,200 m^2) light weight cover for a horticultural producer (Figures 3 and 4). For this project, we supplied a 30 mil (0.75 mm) white polyolefin flexible geomembrane material which was factory prefabricated into larger size panels and installed by an Australia based geomembrane supplier. These panels were then floated in on top of an existing filled water reservoir. The cover design incorporated extrusion welded surface floats as part of a defined sump design. The white material was chosen based on its ability to reflect UV light which helped to reduce the temperatures of the geomembrane resulting in less wrinkles in the cover material. Moving ahead to 2013, we were then contacted by a number of oil and gas producers interested in evaporation control covers for their fresh water pits used in conjunction with hydraulic fracturing operations.


Figure 3. Laydown area for fabrication of 30 mil (0.75 mm) panels in South Australia (Photo courtesy of Fabtech)


Figure 4. Installed 30 mil (0.75mm) defined sump floating cover in South Australia (Photo courtesy of Fabtech)

EVAPORATION CONTROL RATES

Evaporation is the process by which water changes from a liquid to a vapor. Evaporation is the primary pathway as water moves from the liquid state back into the water cycle as atmospheric water vapor. Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in the atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration (USGS). There are numerous identified factors that influence evaporation, including air temperature, wind speed, relative humidity, and the exposed water surface area. There are also various formulas and online tools to assist with calculating evaporation rates, including the Penman equation (Figure 5) commonly used by the design community.

$$E_{mass} = \frac{mR_n + \rho_a c_p (\delta e) g_a}{\lambda_v (m + \gamma)}$$

where:

- m = Slope of the saturation vapor pressure curve (Pa K^{-1})
- R_n = Net irradiance (W m^{-2})
- ρ_a = density of air (kg m^{-3})
- c_p = heat capacity of air (J kg^{-1} K^{-1})
- g_a = momentum surface aerodynamic conductance (m s^{-1})
- δe = vapor pressure deficit (Pa)
- λ_v = latent heat of vaporization (J kg^{-1})
- γ = psychrometric constant (Pa K^{-1})

Figure 5. Penman evaporation calculation equation

The loss of fresh water due to evaporation has become a major concern for governments and industry around the world. A 2009 report out of Australia stated that in excess of 8 million ML (2.1 trillion US gallons) is stored in farm ponds and tanks (called dams in Australia) and that there are more than 2 million of these farm ponds and tanks across Australia (accounting for 9% of stored water). Annual evaporation losses from these storage ponds and tanks are estimated at between 1.32GL and 2.88GL per year (349 million - 761 million US gal) (Schmidt 2009). Increasingly, Federal and Regional governments are reporting evaporation rates by State and County such as Table 1 which is the State of California San Joaquin District and Table 2 which is the State of Texas Water Development Board for a west Texas county. Table 1 and 2 show annual evaporation rates of 68 inches (173 cm) for the California example and 97 inches (246.8 cm) for the west Texas example.

State of California
The Resources Agency
Department of Water Resources
San Joaquin District

Summary of Agroclimatic Data
Wasco 7E /1
2010

MONTH	Air Temperature (*F)/4							Precip-itation (inches)	Wind Movement at 2 Meters (total miles)	Evaporation Class A Pan (inches)	Solar Radiation	
	Average Maximum	Average Minimum	Extremes								Average Langleys per day /2	Equivalent Evaporation (inches/month) /3
			Average	Maximum	Date	Minimum	Date					
January	55.1	39.7	47.4	73	12	34	9	2.14	2,088.3	1.62	156	3.25
February	60.5	43.4	52.0	71	18,26	36	23	1.40	1,201.9	1.32	241	4.54
March	66.0	42.2	54.0	79	20,28	33	11	1.39	2,290.0	5.60	423	8.82
April	68.0	43.4	55.7	83	26	34	6	1.17	1,826.7	5.31	533	10.76
May	76.7	49.3	63.0	101	13	40	6	0.24	2,396.9	7.67	679	14.16
June	87.6	58.0	72.8	102	28	49	19	0.00	2,453.4	11.80	745	15.04
July	97.3	64.1	80.7	112	10	58	4	0.00	1,697.6	10.12	694	14.48
August	92.2	60.6	76.4	105	25	50	29	0.00	1,867.4	10.58	670	13.98
September	89.3	58.5	73.9	100	28,29	52	10,14,15,22	0.00	1,336.8	6.03	549	11.08
October	78.9	54.9	66.9	96	1	41	26	0.43	1,537.2	4.20	350	7.30
November	66.8	41.0	53.9	92	5	28	26	0.91	1,914.2	2.94	254	5.13
December	59.4	43.3	51.3	71	5	32	31	6.49	1,482.7	1.17	158	3.30
Mar-Oct	82.0	53.9	67.9	97		45		3.23	15406.0	61.29	4,643	95.63
Jan-Dec	74.8	49.9	62.3	90		41		14.17	22093.1	68.33	5,452	111.85

1/ Station location: 7 miles east of Wasco at the junction of State Hwys. 99 & 46 - Famoso
2/ CIMIS Station #138
3/ 1,486 Langleys = 1 inch evaporation
4/ Equipment problems with hygrothermograph from 11/25 to 12/1, used CIMIS data

Latitude: 35 36' 13" N
Longitude: 119 12' 45" W

Prepared by N. Rambo 2-2-11

Table 1. State of California 2010 evaporation data for San Joaquin district

************ Quadrangle: 605 ******************
********** Data Units: Inches *****************
************ Monthly Evap ******************
************ Statistics ******************

n	Min	Max	Median	Mean	10%ile	90%ile
720	0.00	13.85	5.91	5.96	2.58	9.48

Month	n	Min	Max	Median	Mean	10%ile	90%ile
JAN	60	1.26	7.34	2.55	2.70	1.83	3.71
FEB	60	1.87	5.75	3.22	3.33	2.11	4.40
MAR	60	2.78	7.61	5.66	5.58	4.15	6.54
APR	60	3.98	10.23	7.26	7.19	5.30	8.71
MAY	60	4.09	10.44	7.47	7.50	5.79	9.63
JUN	60	5.73	12.32	8.86	8.97	7.21	10.69
JUL	60	5.11	13.73	9.44	9.28	6.91	11.47
AUG	60	5.00	13.85	8.26	8.38	6.46	10.26
SEP	60	4.21	9.66	6.25	6.53	4.99	8.45
OCT	60	0.68	7.84	5.19	5.20	3.88	6.76
NOV	60	1.88	7.18	3.92	3.86	2.74	4.80
DEC	60	0.00	6.83	2.80	2.95	1.82	4.16

************ Annual Evap ******************
************ Statistics ******************

n	Min	Max	Median	Mean	10%ile	90%ile
60	48.45	97.34	70.44	71.47	58.25	85.38

Table 2. Texas Water Development Board 2013 monthly evaporation data

OIL & GAS EVAPORATION COVERS

A growing application for evaporation control is for oil and gas upstream operations using the hydraulic fracturing process in hot dry regions of the Southern United States. Hydraulic fracturing, frequently called fracking, refers to the procedure of creating fractures in rocks and rock formations by injecting at high pressure a mixture of sand and high volumes of water to create cracks and fissures. These larger fissures allow more oil and gas to flow out of the formation and into the well bore, from where it can be extracted (Investopedia 2014). Significant volumes of water are required to be stored near the wellbore for these injection purposes. This water is normally contained in a lined frac water pond or structural tank referred to as frac tanks, frac ponds, or frac pits. It is a water-intensive practice. Typical projects use 1 to 3.5 million gallons (3.8 and 13.2 ML) of water for each well and 0.5 million pounds of sand. Large projects may require up to 5 million gallons (19 ML) of water (Congressional Research Service 2009).

To help meet productivity rates and cost targets, producers are increasingly looking at larger scale centralized water containment systems in certain shale plays in the US. These larger containment water storage facilities require geomembrane lined pits to contain frac water. These lined pits normally range in size from 100,000 ft2 (9,000 m2) to 500,000 ft2 (46,500 m2). In hotter, arid regions of Texas, Oklahoma, and New Mexico evaporation rates can often reach 70 - 90 inches (178 – 228 cm). Information from specific producers has confirmed evaporation rates on small to midsize pits being as high as 500 to 1,000 barrels of water per day. The other important operating input cost to the producer is the water source required for fracking. Typically, producers source either fresh or brine water from underground aquifers, or from surface water in rivers and lakes. Commonly, the water needs to be transported long distances by truck or pipeline to larger centralized water storage containment facilities or on site fracking operations. The cost of the water supply can fluctuate widely by location. Feedback from various producers has confirmed higher end water costs ranging from $0.50 to $1.00 per barrel. Based on evaporation rates of 1,000 barrels per day using a water cost of $1.00 per barrel a producer can lose hundreds of thousands of dollars per year in operating costs. Allowing the water to evaporate is also considered wasteful. By placing a properly designed and installed impermeable floating cover system over the water source evaporation can be virtually eliminated. This results in significantly reduced operating costs as well as demonstrates an important environmental sustainability strategy by the producer.

In many cases, these larger frac water storage pits for oil & gas have a life expectancy of between 3 to 5 years reinforcing the need for a cost effective cover design. These evaporation covers also need to be installed quickly as a result of the remote location of the facilities and difficult weather conditions. To meet these challenges, it is important that the covers are produced from light weight flexible materials that can be prefabricated. A fabricated geomembrane panel is shown in Figure 6. By prefabricating the panel, 70% to 100% of the required welding is done in the factory Table 2. Texas Water Development Board 2013 monthly evaporation data resulting in reduced construction time and costs. The prefabrication of cover panels is always done in the factory under controlled conditions. This provides better seam quality and overall seam integrity. In addition to the cover material being highly flexible allowing for prefabrication, the material requires sufficient tensile and tear properties to support personnel on the cover for installation and maintenance purposes. Based on the lighter gauge materials being used in the cover design, the material also required very good endurance properties including UV and anti-oxidant protection. To accomplish this we chose a fortified flexible polyolefin material for the cover material. A fortified geomembrane is defined as a product heavily treated with stabilizers providing enhanced heat, UV stability, and chemical resistance (Schiers 2009).

Figure 6. Example of a 4,000 lb. (1,800 kg) 30 mil (0.75 mm) 27,000 ft^2 (2,500 m^2) prefabricated geomembrane cover panel.

The material should also have proven resistance to high concentrations of brine as some fracking operations have tanks and ponds that contain water containing salts. To help verify this requirement for the producer in Texas, we provided a material that had undergone extensive accelerated hot brine fluid testing. Figure 9 below shows the results of our polyolefin alloy material tested in brine at 90°C (194°F) for 4,800 hours. The fortified material had a starting range of 2,500 minutes of high pressure oxidative induction time (HP OIT) as per ASTM D5885. At the completion of 4,800 hours of high temperature brine immersion testing, the fortified material maintained an HP OIT value of over 1,500 minutes. The normal specified levels of HP OIT for geomembrane materials is 400 minutes (GRI GM 17). In addition, proper design, installation techniques, safety and maintenance protocols needed to fully meet local requirements and closely follow the American Water Works Association California-Nevada Reservoir Floating Cover guidelines (AWWA CA-NV).

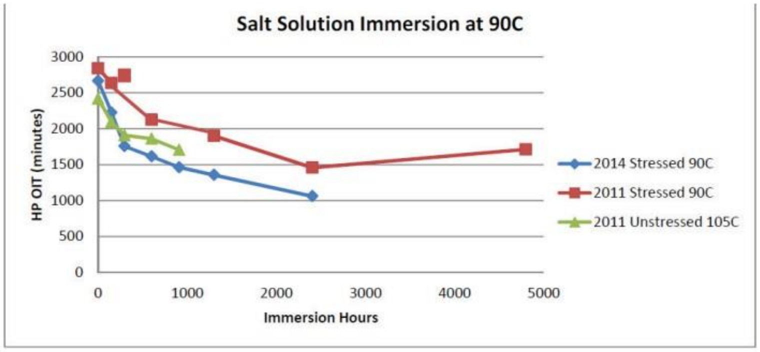

Figure 7. Accelerated hot brine fluid testing of fortified polyolefin material required for cover selection

CONCLUSION

Based on our early evaporation cover development trials and years of experience, we were able to understand and meet the challenging performance requirements for a number of evaporation covers for a number of oil & gas producers in Texas (Figures 8 and 9). This included providing a light weight prefabricated floating cover system designed to meet their relatively short term performance needs and tight budget requirements. We have since supplied numerous other cover systems to multiple oil & gas producers for both pit liners and open top frac tank cover applications. To date, all producers have been satisfied with the performance of the cover systems. The evaporation covers have allowed producers to both reduce operating costs as well as meet important corporate and community sustainability requirements. In addition to meeting the upstream needs of the oil and gas industry, we are increasingly supplying our designed light weight cover systems to meet other industry evaporation control applications.

Figure 8. Aerial view of completed 250,000 ft2 (23,200 m2) Frac water pond evaporation cover in TX.

Figure 9. Close up view of evaporation cover in TX.

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