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COMPOSITE LINER AND FLOATING COVER FOR NUCLEAR REACTOR EMERGENCY EFFLUENT BASINS

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Summary: Existing reactor effluent basins are being retrofitted with composite liners and floating covers.Such basins have a 15-year life and remain empty until an accident occurs. The retrofit must not interfere with ongoing operations and must provide for integrity testing.

Pursuant to a NATIONAL ACADEMY OF SCIENCE evaluation conducted at the Savannah River Site (SRS), existing reactor emergency effluent basins are being retrofitted with composite liners anf floating covers to minimize the environmrntal impact of the effluent. The basins were designed and installed in the 1960s to contain any cooling water generated during a reactor emergency. Such waters may be contaminated with Tritium and Iodine 131. Such radioactive contaminants must be contained wthin the basins.

The Functional Design Criteria (FDC) for the effluent basins requirers each basin to provide 50M gallons of storage capacity that would be continuously serviceable for a minimum of 15 years. Additionally, the FDC required that a floating cover be provided to contain the volatile Iodine 131 contamination. Such radiation has an effective life of only 30 days. Thus the post-accident design life of the cover is very small. Three additional FDC criteria contribute to the uniqueness of the project; first in the absence of an emergency, the basins would remain empty throughout the 15-year design life, secondly each basin had a 0.5M gallon steel tank located on the floor of the basin that would be left in place, and thirdly a leaching field for waste waters existed on a portion of the floor and had to remain serviceable during and after placement of the liner. Therefore the floating cover would be asked to spend its design life covering an empty basin and a steel tank.

Three reactors are currently part of the Tritium production facility at Savannah River Plant. Currently all three reactors are shutdown. The effluent basin project described in this paper is part of the K Reactor complex. The lining and cover work performed on this basin was performed as part of the restart of K Reactor. A plan view of the K Reactor effluent basin is shown on Figure 1. Having a total acreage of XX acres, the basin has a distinct horseshoe shape and a total containment volume of XX gallons. That portion of the basin floor containing the leaching field is shown on Figure 1 and comprised some XX acres. A profile view of this basin is shown on Figure 2. The 0.5M gallon storage tank has a diameter of XX feet and a height of XX feet. The effluent discharge pipe feeding this tank has a diameter of 48 inches and is elevated on timber columns.

BASIN LINER DESIGN

Selection of a liner profile was influenced by the desire to minimize liquid loss from the system and facility related limitations on the type of work that could be performed within the basin. A composite liner, e.g. a geomembrane over a compacted clay liner, was known to provide the most effective liner system. The leakage rate through a penetration in a synthetic liner can be expressed by (1)

where d is the effective diameter of the penetration, H is the head of water acting on the liner, and K is the permeability of the underlying soil liner. The on-site soils within the basin are silty sands having a permeability of approximately 1×10^{-4} cm/sec. While being a relatively good soil for a percolation field, this soil makes a poor soil component of a composite liner. Additionally the combination of the presence of the steel tank and supply pipeline, and the need to maintain containment volume, prevented placement of a compacted clay liner within the basin. Alternatives included using a bentonite amendment to reduce the permeability of the on-site soils or the use of a commercial bentonite board. The soil amendment option was both more expensive and would require greater construction time. The composite liner was therefore achieved using a 60-mil HDPE liner overlying a bentonite board.

The commercial bentonite board provides a permeability less than 1×10^{-12} cm/sec but with a thickness of only 0.25 to 0.75 inches when hydrated under load. The use of a bentonite board will thus substantially reduce the leakage of effluent water through a penetration in the synthetic liner. Two longterm performance aspects of a commercial bentonite board do, however, pose a potential problem in the effluent basin application.

The first potential bentonite board problem is caused by the significant shrinkage that occurs with a bentonite board product that has no normal load acting on it and has undergone cycles of wetting and drying. While a small normal load can be applied to the bentonite board in the bottom of the basins this is not possible on the sideslopes in these basins. In typical applications the basins would contain water during their design life and would provide a normal load acting on the bentonite board to prevent the shrinkage. In the effluent basins, the bentonite board will be subject to potential wet-dry cycles due to fluctuations in the ground water elevations. This creates the potential for significant long-term shrinkage of the bentonite boards that can result in significant gaps developing between the rolls. To eliminate this potential tests were performed by the installer (Gundle Liner) and a simple method of sewing the overlap seams of the bentonite board together.

The second potential bentonite board problem results from the significant reduction in shear strength that the bentonite experiences when it is allowed to hydrate under low normal pressures. Work by Shan(2) has shown that at low loads the shear strength of the bentonite board will reduce to a residual cohesion of 0.6 psi an a phi angle of 9 degrees. Thus the bentonite board placed on the 3Horizontal:1Vertical to 2Horizontal:1Vertical sideslopes will resist slope failure in cohesion. As with any cohesive material placed under a constant load application, a significant potential for creep movement downslope exists. The only source of water to the bentonite board during its pre-event service life comes from the groundwater beneath the facility. The capillary rise in the silty sands in less than 12 inches and the highest groundwater elevation was nearly 22 feet below the bottom of the basin. Thus it was determined that the bentonite board would have little potential for hydration.

COVER DESIGN

A worst case scenario of a potential reactor event indicated the potential for a slight concentration of Iodine 131 in the effluent basin. While the concentration of the Iodine was low, this radionuclide will readily diffuse into the surrounding air. Since Iodine 131 is a known carcenogen, it was decided that a floating cover was required to prevent its movement into the air. The Functional Requirements for the floating cover required in to remain draped into the empty basin for up to 15 years and to cover the 0.5M gallon steel tank located within the basin.

With the basin empty during it projected service life, the cover is exposed to slightly higher temperature cycles than it would experience over a water filled reservoir. The location of the facility is such that winter temperature extremes are minimal and the greatest thermal exposure is due to solar radiation. Recent studies at the Geosynthetic Research Institute have found that a white finish can reduce the surface temperature of the membrane by 40° (3) reason it was decided to specify a white finish on the geomembrane. To allow the white finish and to provide a service life of 15 years, the floating cover was constructed of a coextruded polyethylene geomembrane. In reality the cover consists of a perimeter membrane formed using a very low density polypropylene (VLDPE) and a more rigid high density polyethylene (HDPE) center. The HDPE section lays within the floor of the basin and the VLDPE section forms the sideslopes of the basin. The VLDPE is more flexible and allows formation of pleats that are required to take up the slack that develops as the basins fill with water.

Of particular concern to the survivability of the cover was its ability to rest upon the 0.5M gallon steel tank and not be damaged as it rose during the basin filling. The tank itself is XX fett in diameter and XX feet in height and has a 48-inch effluent inflow pipe feeding it. The tank is designed to contain the initial waste waters coming from a reactor incident. This water may have a higher concentration of contamination and it was felt that the tank provided an additional measure of security. Once the tank is full, and overflow valve releases the oncoming water into the basin itself. When the basin is filled, the tank is under water. Of significant impact was the facility requirement that the tank be inspected on a semi-annual basis. Thus access to the tank could not be limited even though the tank would be beneath the floating cover. To provide access and a better foundation for the cover, the tank was encased within a steel frame 'dome' that was covered with a geogrid. This 'dome' has a walkway that allows inspectors to walk down the embankement and inspect the tank, while being beneath the cover at all times.

During the service life of the facility, the cover will be subject to wind induced uplift forces. Normally the suction created between the cover and the underlying water resists such uplift forces and prevents damage to the cover. In this application the uplift resistance was developed by placing water over the cover at depths ranging fron 6-inches to 2-feet. This provides the resistance and yet does not require liquids beneath the cover. The water balance at the site is a +40 inches so maintenance of the water cover amounts to simply controlled removal of rainwater.

LONGTERM INTEGRITY VERIFICATION

In view of the nuclear support application of the effluent basins, a means of periodically verifying the integrity of major components within the basins was required. Verification systems range from simple visual inspection procedures to expensive redundant collection systems. The basic integrity verification strategy is shown on Table 1 and described in detail below.

Table 1 INTEGRITY VERIFICATION PROGRAM

Component	Location	Verification Procedure
LINER	Sidewalls	Air pressure testing of double wedge seams
	Bottom	Leak detection system under all of bottom with lysimeters to remove liquids
COVER	Sidewall	Visual inspection with vacuum box testing of potential flaws
	Bottom	Monitor rate of rainwater

	leakake into the primary sump
Dome	Use Smoke generator to visually find imperfections

Liner Verification---- The composite liner formed by the geomembrane and the bentonite board does not include a leak detection system that allows a simple evaluation of its integrity. Two distinct means are provided to verify integrity. The sideslopes provide the greatest thermal exposure to the underlying liner wich is not visible for inspection. The major concern on the longterm integrity of the liner on the sidewall was concern that the HDPE would fail fron stress cracking. Past experience with such failures indicates that such failures will always originate in the seams. During installation of the liner all sidewall seams were installed using a double wedge seam that allows verification of the seam using air testing. Continuity of this channel was ensured during installation. Annually this air test is repeated by performing the air test from the perimeter of the facility. Thus if the seam retain their integrity, then the panel integrity is assurrred.

The liner beneath the bottom of the basin can be verified only by measuring the amount of water leaking through the system. A leak detection layer was created beneath the composite liner by installing a geonet and second geomembrane beneath the composite liner. The amount of liquids entering the leak detection system is monitored using two lysimeters placed in sumps beneath this detection layer. A profile of this total bottom liner/leak detection system is shown on Figure 3.

Cover Verification---- The floating cover over the basin is available for visual inspection and limited testing. An annual visual inspection for gross damage is required as part of the integrity verification program.

That portion of the cover over the dome can be visually inspected from beneath the cover by simply looking for 'daylight' coming through penetrations. Additionally, a smoke generator such as used to identify leaks in sewer systems can be used to pin point small penetrations in the cover.

Over the bottom of the basin, the cover is beneath 6 to 24 inches of water. The integrity of this portion of the cover is verified by monitoring the rate of water flowing into the primary sump. A penetration of the cover in this area will allow excessive amounts of the overlying water to reach the primary sumps. If such a failure is detected, then a resistance survey will be performed to locate the penetration.

SUMMARY

This paper has focused on the difficulties in design of a water retention facility that must remain empty through much or all of its 15 year design life and still be able to provide emergency service. The cover in particular is required only during the first 30 days of post-event containment. This allows no time for repair of failures and such repair could not be performed without radiation exposure to the repair crew. Unfortunately, the exposure to an empty basin is greater than that of a filled basin. Novel longterm integrity testing was developed to ensure the serviceability of a system that could not otherwise be tested.

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REFERENCES