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INNOVATIVE GEOMEMBRANE LINER PENETRATION FOR LONG-TERM WASTE CONTAINMENT

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ABSTRACT

Proper management of waste containment systems requires the collection and removal of leachate that migrates from the waste. Two methods of removal, described in the paper, involve the use of either a side slope riser system or a pipe penetration through the geomembrane liner component of the containment system. Pipe penetrations are typically avoided because they are difficult to construct and can be a significant source of leakage from a containment system. The difficulties associated with pipe penetrations through geomembrane liners are described in this paper along with an innovative liner penetration developed to overcome these difficulties. Both design and construction issues associated with the geomembrane liner penetration are addressed.

INTRODUCTION

Most modern waste containment systems constructed in the United States incorporate a liner system consisting of hydraulic barrier and an overlying leachate collection system. Typical liner system profiles are shown in Figure 1. A geomembrane liner is incorporated into the hydraulic barrier because it can be installed as a continuous layer, and when properly designed and installed, with good construction quality control and construction quality assurance monitoring, can minimize the release of leachate that migrates from the waste, to the underlying subgrade (Bonaparte and Gross, 1990). Management of a containment system includes the regular removal of leachate which is usually done through a leachate collection system that consists of a free draining layer over the hydraulic barrier. This layer is sloped to drain to a collection corridor where either a pipe or a highly permeable aggregate drains the leachate to a low point or sump in the containment system. The leachate is then removed from the sump for proper treatment or disposal.

Early liner systems incorporated a pipe in the sump, which penetrated the hydraulic barrier, to drain the leachate. A typical penetration is shown in Figure 2. Since the pipe had to penetrate the geomembrane liner a good seal at the pipe penetration was critical for proper performance of the liner system. However, constructing a proper penetration is extremely difficult and was often the point where significant leakage through the liner system occurred. As a result side slope riser pipes replaced geomembrane liner penetrations, and a typical example is shown in Figure 3. A submersible pump is set at the base of the riser pipe to remove leachate to the top of the slope where it is allowed to flow by gravity, or more typically injected into a forcemain.

The design of a geomembrane liner penetration for a low-level radioactive waste containment facility with a 200- to 1000-year design life posed a considerable challenge to the author of this paper. Given the known problems with geomembrane liner penetrations, this feature was recognized as a critical design element. This paper presents an innovative geomembrane liner penetration that was developed for the project. Traditional geomembrane liner penetrations are reviewed. Next the geomembrane liner penetration developed by for the project is presented. The design is described along with experience gained during construction.

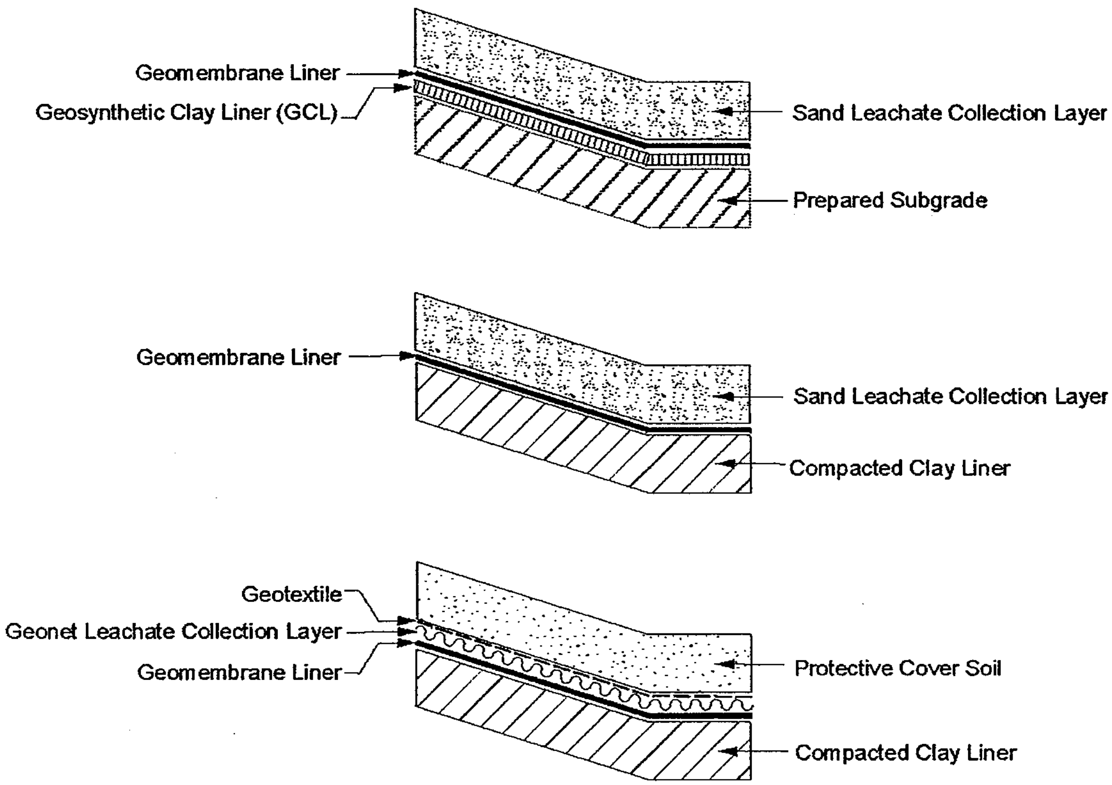


Figure 1. Typical liner system profiles.

TYPICAL GEOMEMBRANE LINER PENETRATION

USEPA Subtitle D regulations require that the leachate collection system component of a containment system be designed to maintain a hydraulic head on the underlying liner system of 12 in. (0.3 m) or less. To meet this requirement any pipe penetrating the liner system will need to be within 12 in. (0.3 m) of the liner system. Ideally, the pipe should be as close to the liner system as possible to minimize the permanent ponding of liquids in the sump. Placing the pipe close to the liner system increases the difficulty of constructing a penetration that will not leak. A typical geomembrane liner penetration detail used in waste containment facilities is shown in Figure 4. This mechanical penetration consists of: (1) the pipe, (2) the parent geomembrane material, (3) a pipe boot, consisting of an apron and a sleeve, fabricated from the same material as the parent geomembrane, (4) silicone sealant, (5) neoprene gaskets, (6) stainless steel band clamps, and (7) extrusion welds. The assemblage of these components involves fabricating a geomembrane pipe sleeve that fits snugly around the pipe. A geomembrane apron is then welded to the geomembrane pipe sleeve. The sleeve and apron are slid onto the pipe. The geomembrane pipe sleeve is extrusion welded to the pipe, and clamped to the pipe using silicone sealant, neoprene gaskets, and stainless steel band clamps. The geomembrane apron is extrusion welded to the parent geomembrane liner. The connection between a geomembrane liner and a pipe is often ineffective due to the limited space in which the work must be performed, problems associated with maintaining a tight fit between the geomembrane sleeve and the pipe, and difficulties associated with installing the silicone, neoprene gaskets, and stainless steel band clamps.

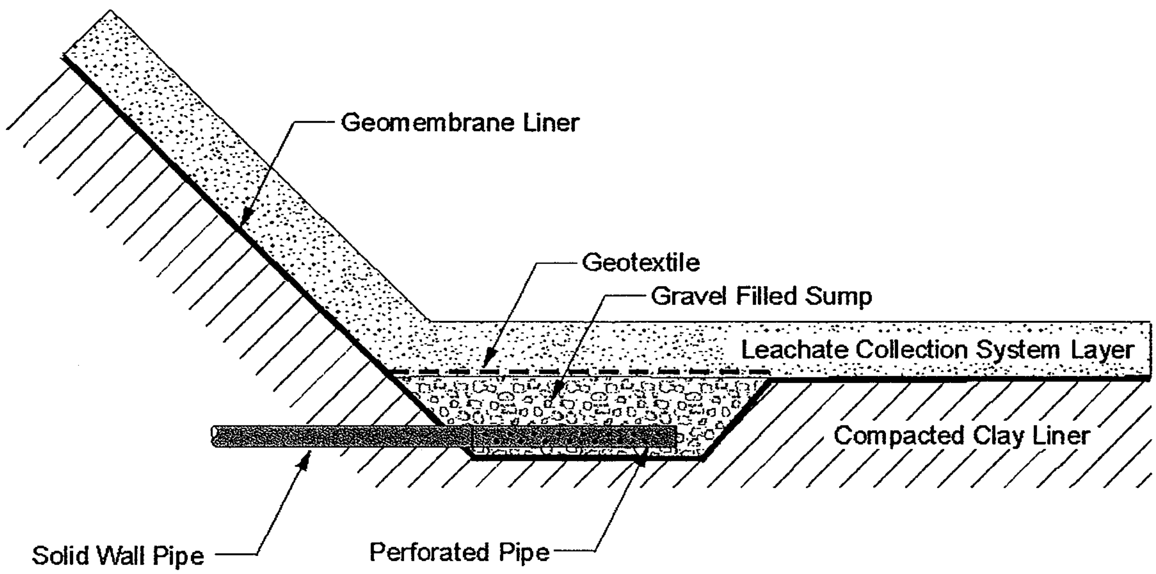


Figure 2. Typical geomembrane liner penetration.

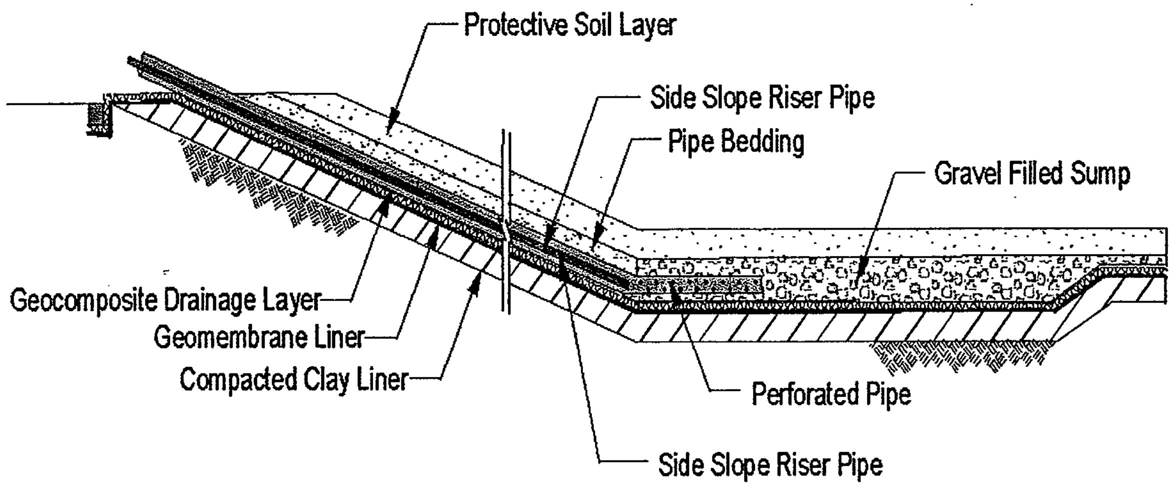


Figure 3. Typical side slope riser pipe.

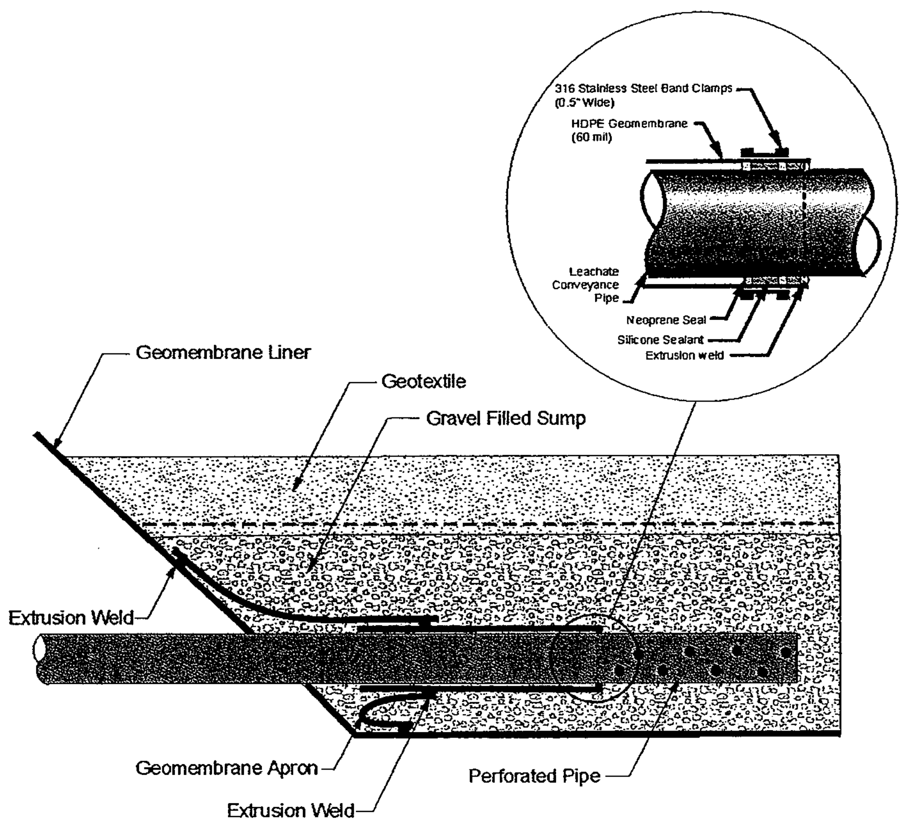


Figure 4. Detail of geomembrane liner penetration.

DESIGN OF INNOVATIVE LINER PENETRATION

A low-level radioactive waste containment facility was designed for a site near Cincinnati, Ohio. The facility has a design life of a minimum of 200 years and up to 1000 years. The containment system incorporates a double composite liner system and is shown in Figure 5. As noted previously most liner systems constructed today incorporate a side slope riser pipe. However, a functional requirement established for the low-level radioactive waste containment facility is that leachate be conveyed from the facility via gravity drainage. The intent of this requirement is to allow leachate to drain without the need to maintain a pumping system. Meeting this requirement was particularly important since the leachate conveyance system is required to be maintained for up to 200 years, and drainage by gravity eliminates the need to maintain pumps and controls used in a side slope riser system.

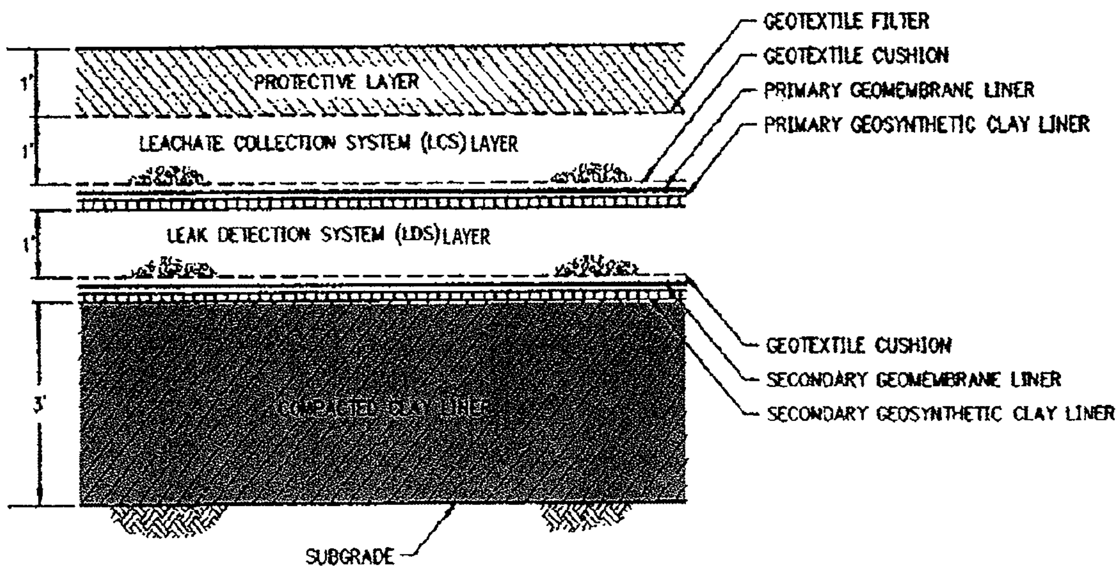
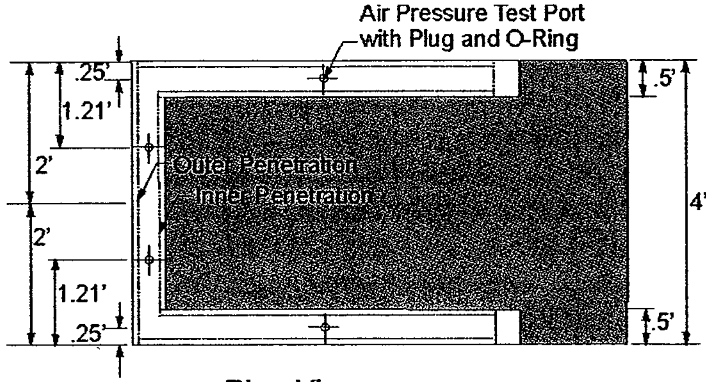


Figure 5. Double composite liner system.

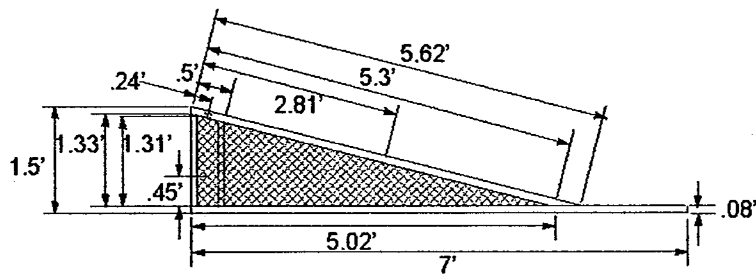
Conventional penetrations of pipes through geomembranes were reviewed as part of the design process. Attaching the geomembrane to the pipe was the critical design element for the geomembrane liner penetration. The decision was made to not rely on a mechanical connection (i.e., silicone, neoprene gasket, and stainless steel band clamps). This decision was based on the difficulties often encountered in achieving a good mechanical connection, and concerns the silicone, neoprene gasket, and stainless steel band clamps would not have sufficient durability to meet the required design life for the facility. Once this decision was made the design efforts focused on welding the geomembrane to the pipe. Welding was feasible since the design process had already established that the pipe and geomembrane liner would be manufactured from high-density polyethylene (HDPE) resin.

The feasibility of welding the geomembrane liner directly to the pipe was investigated. Difficulties occur with welding a geomembrane liner to a pipe because the geomembrane is planar and the pipe is cylindrical, and geomembrane welding equipment is designed to work with the geomembrane liner resting on a firm, flat substrate. However, HDPE pipe is routinely welded to HDPE flat stock (i.e., thick flat plates manufactured from HDPE resin), and a fabricator working under controlled conditions can make quality welds. Likewise, HDPE geomembrane can be welded to HDPE flat stock using conventional welding equipment. Therefore, the design focused on developing a section of the geomembrane liner that would be fabricated from HDPE flat stock at an off-site location under controlled conditions. This unit would then be installed in the field as part of the geomembrane liner installation.

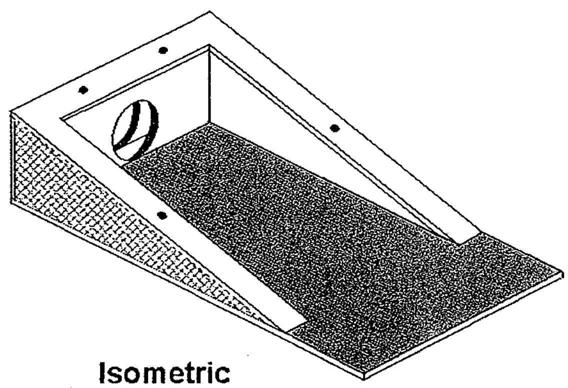
A detail of the geomembrane liner penetration unit (or "box") used on the project is shown in Figure 6. The geomembrane liner penetration box has a flat base, which can rest directly on a prepared surface. It also has a wide flat surface to which the geomembrane liner can be welded. This surface is inclined at the same angle as the side slope in which the box will be set. A photograph of the geomembrane liner penetration box in place prior to the installation of the geomembrane liner is shown in Figure 7. The unit has been installed with the HDPE flat stock surfaces flush with the ground surface. As previously noted, the liner system for this project is a double composite liner system, and a cross-section of the liner system at the penetration through the secondary composite liner is shown in Figure 8. At this cross-section a penetration through only the geomembrane liner component of the secondary composite liner is required. This penetration detail is applicable to the typical liner systems shown in Figure 1. Similar penetration details were developed for the pipes draining the leachate collection system shown in Figure 5. However in this case, a geomembrane penetration box was required for both the primary and secondary geomembrane liners.



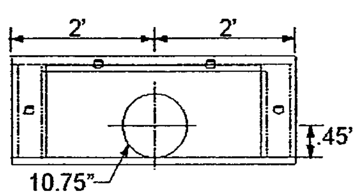
Plan View



Front Elevation



Isometric



Right Elevation

Figure 6. Detail of geomembrane liner penetration.

As shown in Figure 7 the geomembrane liner penetration box serves as part of the hydraulic barrier. Therefore, the welds used to connect the HPDE flat stock and HPDE pipe have to be continuous and possess adequate strength. Therefore, a sealed chamber is incorporated into the liner penetration box, which allows the welds to be pressure tested. Pressure testing of the welds was performed by the fabricator prior to delivery to the field, and by the contractor after the geomembrane liner penetration box was installed. Once the geomembrane liner penetration box was installed and pressure tested the chamber was filled with granular bentonite to provide a composite liner effect.

Figure 7. Example of a geomembrane liner penetration box after installation.

INSTALLATION OF INNOVATIVE LINER PENETRATION

As shown in Figures 7 and 8 the liner penetration through the secondary liner is set within the compacted clay component of the secondary liner. The liner penetration is also attached to a pipe that conveys leachate away from the containment facility. Therefore, the installation of the geomembrane liner penetration box had to be coordinated with the construction of the leachate conveyance pipe, general earthwork, and the compacted clay liner. The leachate conveyance pipe was installed as the general earthwork was performed. The compacted clay liner was installed once the general earthwork was completed. The end of the leachate conveyance pipe was protected during the placement of the compacted clay liner, and was left partially exposed. Once the compacted clay liner was placed the installation of the geosynthetic clay liner and geomembrane commenced. The geomembrane liner penetration box was installed in conjunction with these two geosynthetic components of the liner system. The sequence of the installation is presented in a series of photographs presented below.

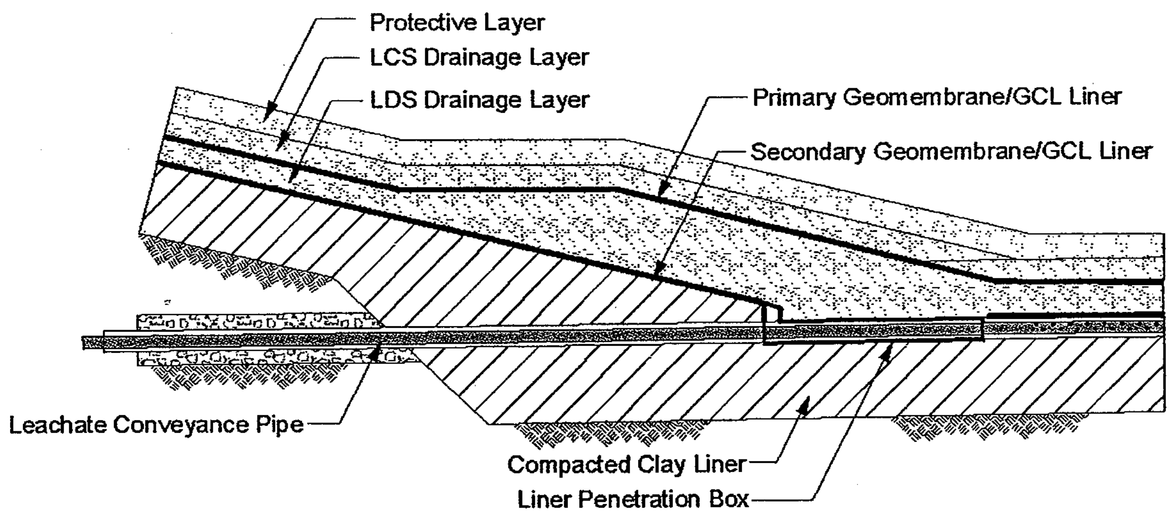


Figure 8. Cross-section of liner system incorporating a geomembrane liner penetration box.

Figure 9. The end of the pipe is exposed and the compacted clay liner is hand excavated. Excavation is performed in a controlled manner to ensure the surface of the geomembrane liner penetration box is aligned with the top of the compacted clay liner.

Figure 10. Once the excavation is complete the geomembrane liner penetration box is slid onto the base of the liner and the end of the pipe section attached to the box is prepared for joining to the leachate conveyance pipe.

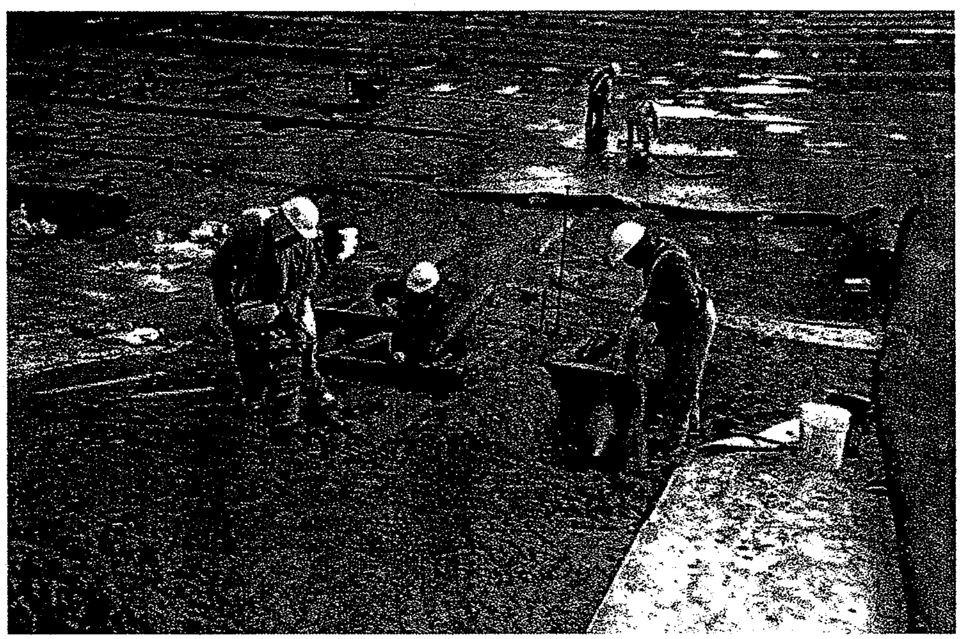


Figure 11. After joining of the pipe is complete, the compacted clay liner is placed over the leachate conveyance pipe using hand compaction equipment. At the same time the geomembrane liner penetration box is being prepared for pressure testing.

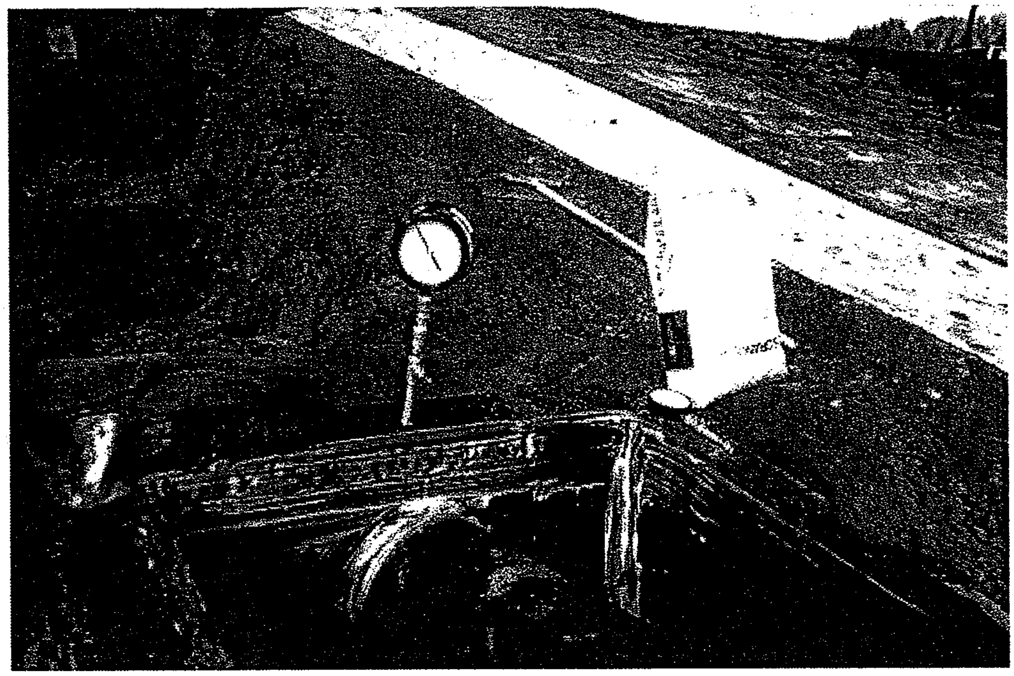


Figure 12. Air pressure was applied to the chamber in each geomembrane liner penetration box. The inside seams of each box were coated with a soapy solution to help detect any leaks.

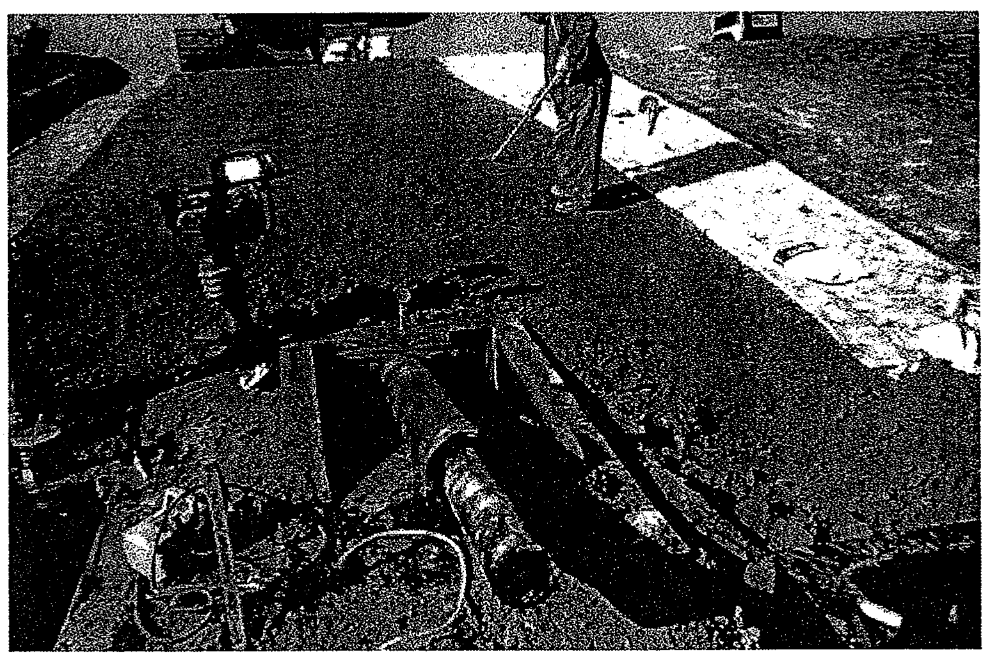


Figure 13. Once pressure testing is complete the surface of the compacted clay liner is prepared.

Figure 14. The chamber of the geomembrane liner penetration box is filled with granular bentonite.

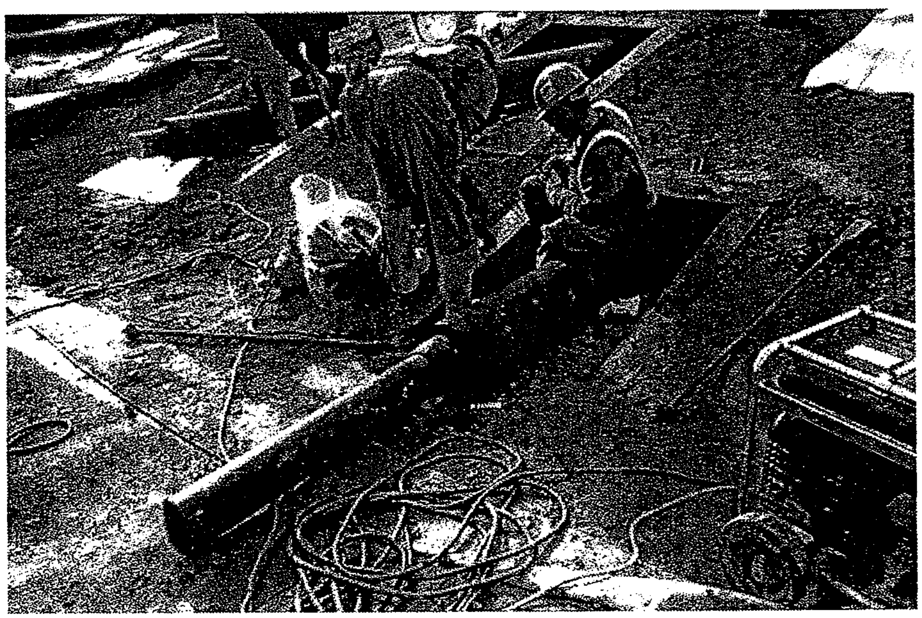


Figure 15. The ports used to fill the chamber of the geomembrane liner penetration box are sealed using an extrusion welder.

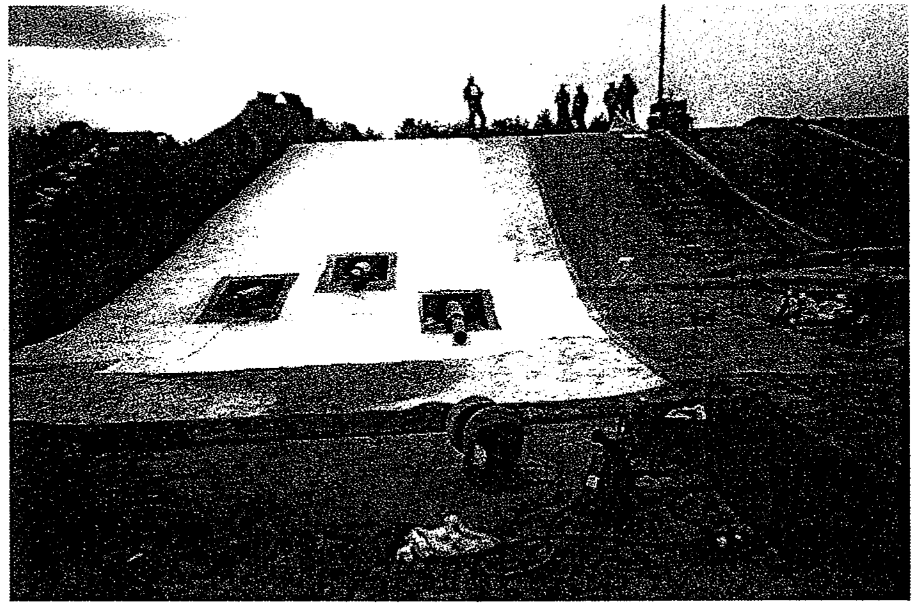


Figure 16. The geomembrane liner penetration boxes are installed and are ready to be welded to the geomembrane. The pipes at the left and center of the photograph drain the leachate collection system and will penetrate the primary geomembrane liner. The pipe at the right of the photograph drains the leak detection system and only penetrates the secondary geomembrane liner.

The installation of the geomembrane liner penetration boxes in the first cell of the containment facility identified two modifications that will be implemented during future cell construction. The geomembrane liner penetration boxes are heavy and awkward to handle. Therefore, the geomembrane liner penetration boxes fabricated for future cells will include lifting hooks. The hooks will facilitate loading and unloading of the boxes and their transportation into the cell. Some difficulty was encountered in aligning the edges of the geomembrane panel with the edge of the geomembrane liner penetration box. Therefore, a geomembrane skirt can be welded to the surface of the geomembrane liner penetration box. The geomembrane panels can then be weld to the skirt. The skirt can be trimmed to facilitate welding operations.

SUMMARY

The design of a low-level radioactive waste containment facility required that leachate be conveyed from the facility via gravity drainage, which required the leachate conveyance pipe to penetrate the liner system component of the containment system. Conventional pipe penetrations through geomembrane liners were reviewed as part of the design process. This review led to the conclusion that constructing a typical penetration is extremely difficult and is often the point where leakage through the liner system occurred. Therefore, attaching the geomembrane liner to the pipe was the critical design element for the penetration. The design focused on developing a section of the geomembrane liner that would be fabricated from HDPE flat stock at an off-site location

under controlled conditions. This geomembrane liner penetration box was installed in the field as part of the geomembrane liner installation. Installation of the geomembrane liner penetration box was successful and resulted in a quality connection of the geomembrane liner to the leachate conveyance pipe.

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REFERENCES

Bonaparte, R. and Gross, B.A. (1990), "Field Behavior of Double-Liner Systems", *Waste Containment Systems: Construction, Regulation, and Performance,* ASCE Geotechnical Special Publication No. 26, R. Bonaparte ed., New York, pp. 52-83