A HYBRID HIGH INTEGRITY CONTAINER FOR DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES

Steven B. McCoy
LN Technologies
Columbia, South Carolina 29201

Woodrow M. Poplin, Tim A. Jur
Engineering Design & Testing Corporation
Columbia, South Carolina 29202

ABSTRACT

High Integrity Containers (HIC's) are used to bury low-level radioactive waste in shallow land burial facilities. HIC's must be designed to meet a variety of shipping, handling and burial requirements and must contain the waste without loss of integrity for at least 300 years. This paper reviews the design requirements and describes a new "hybrid" HIC made of a stainless steel outer shell and an inner liner of polyethylene. The hybrid HIC utilizes to advantage the structural properties of the stainless steel and the corrosion resistance of the polyethylene.

INTRODUCTION

Over the last two years, LN Technologies (LN) has pursued a project to develop a high integrity container (HIC) which meets all the requirements of 10 CFR 61 and the burial site regulations, i.e. to stabilize low-level radioactive wastes for a period of 300 years (104). HIC's must be designed to withstand the effects of corrosion from both the soil and the contained wastes. They must also withstand the stresses associated with handling and soil overburden. Polyethylene has a low structural strength but excellent corrosion resistance. Stainless steels, on the other hand, have a high structural strength but are subject to corrosion from the contained waste. LN Technologies has combined the two materials in a hybrid design. The result is a HIC with high structural strength and excellent resistance to corrosion from contained wastes.

The hybrid HIC is fabricated with a 316L stainless steel shell and a polyethylene lining which is rotomolded into the container. The wall thickness is varied depending upon the burial overburden, currently 16.8 meters for the Hanford, Washington Site and 7.6 meters for the Barnwell, South Carolina facility. An entire family of containers, ranging from a 208 liter (55-gallon) drum size up to a full-size container approximately two meters in diameter by two meters in height, have been designed. The largest and the smallest of these containers are being tested in order to certify the entire family.

All of the hybrid HIC's use dished heads in order to withstand the burial overburden. Dished heads are used on both the top and bottom of the container since the stresses are essentially the same on both ends. The lid of the LN HIC is also dished and is secured to the container by a partial turn of the lid which engages the lock.

Prototypes of the hybrid HIC have been fabricated and are currently undergoing testing for certification in accordance with the requirements of 10 CFR 61 and the supporting USNRC Technical Position on Waste Form. Specific tests include biodegradation, compression, penetration, and drop tests (onto compacted soil and onto unyielding surface).

BACKGROUND

The HIC must be designed to be buried underground and to ensure containment of the waste for a period of 300 years. It must also be designed for the storage and handling expected prior to burial. From a designer's standpoint the shipping and handling criteria are relatively easy to meet. In addition, relatively inexpensive tests can be utilized to determine the suitability of the container to meet shipping and handling requirements. The regulations require several of these tests to verify the design. Of these, the most arduous for most container designs is the 7.6 meter (25 foot) drop test. This simulates a handling mishap and imposes severe restraints on the type of materials which can be used in a HIC. For example, it effectively rules out or severely limits the use of brittle materials.

The second major design criterion is the structural support of the soil overburden. The soil produces a downward load on the top of the container and in certain cases, soil loads are also imposed on the sides of the container as well. The HIC's are subject to burial as deep as 7.6 meters (25 feet) at Barnwell, South Carolina and 16.8 meters (55 feet) at Richland, Washington. Soil pressures at these depths can be significant. Although HIC's may be buried one on top of another, thereby effectively lowering soil pressures, the governing regulations address the worst case which is burial of single isolated containers. As part of the design certification, there is a required compression test which simulates to some extent the vertical load on the HIC's. This test does not address the lateral loads which are the more significant loads to be considered when designing the walls of the vessel to withstand the external pressure. The test is, therefore, not considered to be as rigorous as the actual burial conditions.

The third major design criterion is the long-term chemical and radioactive effects on the integrity of HIC materials. Corrosion concerns arise both from the exterior soil environment and from the chemical effects of the wastes inside the container. Maximum radiation levels are 1×10^8 rads total exposure. Since this level is quite well established, testing can be performed to allow fairly accurate prediction of material behavior due to radiation effects. Likewise, the chemical composition of the burial soils is fairly well established and the soil's effects on HIC materials can be reasonably predicted. The most difficult problem from the designer's viewpoint is the corrosiveness of the contents. Ideally the waste contents are primarily in a dry form. However, burial regulations do allow some liquids. The liquids will naturally tend to collect in the bottom of the container. Proper designs must take the corrosiveness of these free liquids into consideration. However, since the HIC's are waste containers, it is also desirable to place as few restrictions as possible on the allowable wastes, thereby alleviating much of the waste control and monitoring requirements.

In reviewing the various design requirements, it has been concluded that no single existing material provides an optimum solution to all HIC requirements. Considerable effort has, therefore, been expended to produce a HIC design which utilizes the properties of two well known materials to optimum advantage. In order to produce a HIC which can easily handle the soil pressures and remain relatively inert to the soil environment, 316L stainless steel is used for the outer shell of the HIC. The stainless steel shell has the advantage of being well suited to the storage, shipping and handling requirements of the HIC. Although stainless steel is an excellent choice for a structural shell, the waste contents potentially contain materials or chemicals which are relatively corrosive to stainless steel. This is especially true when considering a design life of 300 years. The HIC has, therefore, been designed with an inner liner of polyethylene. Polyethylene is a relatively inert material stable to 10^8 rads, which can safely contain a wide range of chemicals and, in the absence of stress, can be expected to do so for very long periods of time.

The final major design criterion is that the container must be relatively easy to fabricate and has to be competitive in cost. While this may be of secondary concern from a regulatory standpoint, it is of significant importance to the users. In this regard, the HIC is made using conventional techniques and familiar materials. The HIC is manufactured by first welding the pieces of the outer shell together in a manner typical of other stainless steel vessels of its size. Once the shell is completed, it is shipped to a rotomolding facility where the liner is molded inside the HIC. The shell is a cylindrical vessel with ASME Code heads on both ends. As such it is almost a perfect shape for the rotomolding process. In general rotomolding operations, stainless steel or a similar mold is used to fabricate various plastic shapes. Upon completion of the operation, the mold halves are separated and the completed plastic part removed. In rotomolding the LN HIC, the stainless steel shell acts as the mold. The shell is heated and the granulated plastic placed inside begins to melt. As the plastic melts, the mold is rotated about two axes allowing the plastic to coat the inside. The nature of the process ensures that all of the inside is coated with a smooth uniform layer of plastic of essentially the same thickness. After all of the plastic has melted and formed to the wall, the shell is cooled while it continues to rotate. This prevents the hot plastic from flowing to any one point. A seam-free plastic lining is thus formed inside the stainless steel shell. Since there is no way to remove the lining once it is formed, each shell is put through the operation separately. In this manner, a seamless plastic liner is created with only a single opening at the top where it is filled.

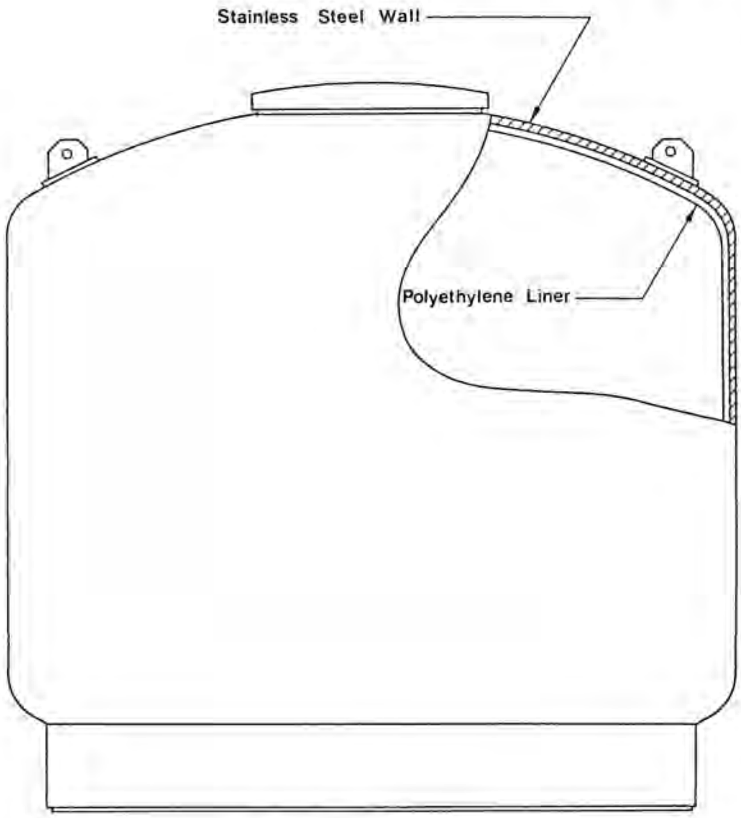

Fig. 1. LN Technologies High Integrity Container.

HYBRID DESIGN

The outer shell of the hybrid container is fabricated of stainless steel for a variety of reasons. Steel heads can be purchased as "off the shelf" type items. The remainder of the vessel is readily fabricated at almost any metalworking facility. Stainless steel also works well with the rotomolding technique since many of the industry's molds are normally made of this material.

Although almost any type of steel would satisfy the shipping, handling and structural requirements, the choice of steel was dictated by the burial soils. Considerable effort was expended to identify the optimum steel for the soil environment. In this regard, the National Bureau of Standards (NBS) has conducted extensive testing of various metals in a wide variety of soils (5,6). These long-term burial tests indicate that, in general, austenitic stainless steel performs best. 316 stainless steel resisted pitting in all of the soil in which it was tested. However, 316L was chosen for use in the HIC because it retains the desirable properties of 316 even in the welded condition thereby alleviating the normal concerns of additional corrosion at the weld seams. Using the NBS data, the maximum corrosion of the stainless steel shell is expected to be less than 0.3 cm during the 300 year life. Even if an isolated area of pitting occurs which breaches the outer shell of the container, the container would still retain its structural integrity and the polyethylene liner ensures full containment of the wastes.

The polyethylene liner is made of linear low density polyethylene. This type of resin was chosen because its melt temperature characteristics allow good coverage of the shell to an even depth and it offers excellent resistance to environment stress cracking.

Once the container is filled with waste, the polyethylene liner is pressed firmly against the stainless steel walls and bottom. Since expansion is restricted, stresses within the polyethylene are kept very low. Under low stress conditions, polyethylene is inert to most chemicals. Even the primary compounds which are detrimental to polyethylene, e.g. surfactants and various other organics, have little affect under the relatively stress free conditions of the hybrid HIC. An additional safety factor is incorporated with the use of the two materials. Although both polyethylene and 316L stainless steel are affected by only a few chemicals, those which affect one material do not affect the other. That is, even if a waste product harms the polyethylene liner it will be of a chemical form which does not react with stainless steel.

The general shape of the HIC is dictated primaily by two requirements, burial and rotomolding. As it turns out, the shape which is beneficial to one is also beneficial to the other. During burial, the HIC may be considered as an externally pressurized pressure vessel. Since the top head is required to be designed to prevent the collection of liquids, the top head is dished upward. This is also a good form to resist the vertical soil loads. In order to optimize the internal volume while still maintaining structural requirements, an ASME Code top head was chosen. Because the HIC may be subject to burial in relatively loose soils, the bottom of the HIC can be expected to experience similar loading conditions as the top. It is for this reason that the LN Technologies HIC also has an ASME Code bottom head.

The sidewall is designed to resist the lateral soil pressures which are imposed on a HIC buried under certain conditions. HIC's are normally buried in clusters. In these cases, lateral soil loads may be essentially nonexistent for HIC's which are surrounded by other containers. HIC's which are on the outside of the grouping, however, are exposed to significant soil pressures on the sidewalls. Under loose soil conditions, these pressures may be 50% of the overburden pressures at the same depth. Since the HIC is externally pressurized, buckling is the controlling design criterion of the sidewall. While vertical pressures have an effect on the sidewall design, it is the anticipated lateral pressures which have the predominate effect.

Regulations require that overburden loads be calculated on the basis of soil densities of 1926 kg/m (120 #/ft). Using this value, maximum soil pressures at Barnwell, South Carolina and Richland, Washington have been evaluated as follows.

Richland, Washington:

Maximum Depth - 16.8 m (55 feet)
Vertical Pressure - 316 kPa (45.8 PSI)
Horizontal Pressure - 158 kPa (22.9 PSI)

Barnwell, South Carolina:

Maximum Depth - 7.6 m (25 feet)
Vertical Pressure - 143 kPa (20.8 PSI)
Horizontal Pressure - 72 kPa (10.4 PSI)

The pressures given are for the bottom of the trench or the lowest portion of the HIC. Pressure reductions are taken into account based on the height of each individual size HIC. When containers are buried in groups, masonry arches may develop in the soil between containers. This produces an effective vertical pressure on a HIC which may under certain conditions be higher than the values given above. The LN Technologies design considers this effect as a 30% increase in the vertical overburden pressure exerted on the top and the bottom heads.

Another major part of the HIC design is the closure. The cover is attached to a short flue welded in the center of the top head. During the rotomolding process, the polyethylene lining is formed along the sides of the flue and overlaps the top edge. The cover is lined with polyethylene and, when in place, it forms a polyethylene-to-polyethylene seal around the edges of the flue. The cover is held in place by lugs on the outside of the flue which engage similar lugs on the cover. This allows the cover to be properly positioned and tightened by a partial turn which engages the lock. A tool is provided with the HIC to accomplish this procedure.

Low-level radioactive wastes are expected to produce various gases during the initial period after disposal. A vent has therefore been incorporated into the top of the HIC. The vent is a small plug-shaped device threaded into a hole which extends through the stainless steel shell and the polyethylene liner. In order to protect the integrity of the vent and prevent clogging by either the burial soil or the wastes on the inside, the vent has been positioned in the short neck area of the closure. This position ensures that the wastes will not cover the inside of the vent. When the container is buried, the sides of the cover prevent soil from obstructing the outside of the vent.

Four symmetrically placed lifting lugs are welded to the top head of the HIC. Since they are welded to the HIC, the lifting lugs are also made of 136L stainless steel.

Because the bottom head is dished, a support stand is provided to hold the HIC upright during shipping and handling. The stand consists of a short cylindrical "skirt" which is reinforced at the bottom edge. The skirt is bolted to tabs welded to the bottom of the HIC. These tabs prevent relative movement and also hold the skirt in place as the HIC is lifted with a crane. Since the skirt is only used during shipping and handling and is not welded to the HIC, it is made of carbon steel and can be expected to corrode shortly after burial.

TESTING

As of the date of this paper, the container materials and full-scale prototype containers will be undergoing testing as specified in the USNRC Technical Position (2) and the criteria issued by the states of South Carolina and Washington (3,4).

The container materials must undergo biodegration (fungi and bacterial), irradiation and thermal cycling without significant changes which will affect the integrity of the container. It is expected that neither the stainless steel nor the polyethylene will be affected by biodegradation or thermal cycling, and certainly the stainless steel, which is used in nuclear reactor construction, will be unaffected by the irradiation. The polyethylene will become less flexible as a result of the irradiation, i.e. elongation will decrease and the tensile strength will increase slightly, but the effectiveness of the polyethylene will not be degraded in performing its function of corrosion protection.

The full-scale prototype containers will undergo the required penetration, compression and drop testing. The penetration testing will be performed by dropping a 6 kilogram rod into the container from a distance of 1 meter and is not expected to affect the container. The compression test will be performed by imposing a uniaxial vertical load of five times the gross container weight onto the container.

Two different drop tests will be performed with the prototype containers, a 0.3 meter drop onto an unyielding surface and a 7.6 meter drop test onto compacted sand or clay. The containers will be loaded to the maximum gross weight with sand for the tests. In the 0.3 meter drop test, the container will be dropped onto a top corner to impact the lid and the top head, the configuration considered to be the most damaging to the container. In the 7.6 meter drop tests, a prototype container will be dropped onto five different portions of the container, i.e. top, top corner, side, bottom corner and bottom. The tests will be considered successful if there is no release of contents. In addition, the container vents will be inspected after each test to verify that the vent has not been damaged.

CONCLUSION

The hybrid high integrity container is composed of two materials, stainless steel and polyethylene, to provide structural strength and resistance to corrosion from the contents in disposing of low-level wastes. The new container is designed to withstand the stresses of handling, processing and transportation and to last for 300 years in the disposal environment. It is expected that testing will be completed and the topical report for the container submitted to the USNRC and the states of South Carolina and Washington by April 1987. The new containers should be in production and available for use by the summer of 1987.

REFERENCES

1. Code of Federal Regulations, Title 10, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

2. "Technical Position on Waste Form," Nuclear Regulatory Commission (May 1983).

3. "Guide for High Integrity Container Topical Report Applications," Revision 1, DHEC/BRH/073085, South Carolina Department of Health and Environment Control (July 1985).

4. "Criteria for High Integrity Containers," Washington State Radiation Control Program (August 1983).

5. Romanoff, M., "Underground Corrosion," Pb-168 350, National Bureau of Standards, Circular 579 (April 1957).

6. Gerhold, W.F., et al., "The Corrosion Behavior of Selected Stainless Steels in Soil Environment," NBSIR 81-2228, National Bureau of Standards (February 1963).