ROBUST SOLUTION TO DIFFICULT HYDROGEN ISSUES WHEN SHIPPING TRANSURANIC WASTE TO THE WASTE ISOLATION PILOT PLANT

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP) has been open, receiving, and disposing of transuranic (TRU) waste since March 26, 1999. The majority of the waste has a path forward for shipment to and disposal at the WIPP, but there are about two percent (2%) or approximately 3,020 cubic meters (m^3) of the volume of TRU waste (high wattage TRU waste) that is not shippable because of gas generation limits set by the U.S. Nuclear Regulatory Commission (NRC). This waste includes plutonium-238 waste, solidified organic waste, and other high plutonium-239 wastes.

Flammable gases are potentially generated during transport of TRU waste by the radiolysis of hydrogenous materials and therefore, the concentration at the end of the shipping period must be predicted. Two options are currently available to TRU waste sites for solving this problem: (1) gas generation testing on each drum, and (2) waste form modification by repackaging and/or treatment. Repackaging some of the high wattage waste may require up to 20:1 drum increase to meet the gas generation limits of less than five percent (5%) hydrogen in the inner most layer of confinement (the layer closest to the waste). (This is the limit set by the NRC.) These options increase waste handling and transportation risks and there are high costs and potential worker exposure associated with repackaging this high-wattage TRU waste.

The U.S. Department of Energy (DOE)'s Carlsbad Field Office (CBFO) is pursuing a twofold approach to develop a shipping path for these wastes. They are: regulatory change and technology development. For the regulatory change, a more detailed knowledge of the high wattage waste (e.g., void volumes, gas generation potential of specific chemical constituents) may allow refinement of the current assumptions in the gas generation model for Safety Analysis Reports for Packaging for Contact-Handled (CH) TRU waste. For technology development, one of the options being pursued is the use of a robust container, the ARROW-PAK™ System. (1) The ARROW-PAK™ is a macroencapsulation treatment technology, developed by Boh Environmental, LLC, New Orleans, Louisiana. This technology has been designed to withstand any unexpected hydrogen deflagration (i.e. no consequence) and other benefits such as criticality control.

INTRODUCTION

The WIPP has been open and disposing of TRU wastes for nearly four years. While the majority of the TRU waste has a path forward for shipment to and disposal at WIPP, there are about two 2%, or approximately 3,020 m^3 contact-handled TRU waste that are not currently shippable in the Transuranic Package Transporter Model 2 (TRUPACT-II). This waste is not shippable because it does not meet the gas generation limits imposed by the NRC of less than 5% hydrogen in the inner most layer of confinement. Currently, the only options available to the TRU wastes sites as a path forward are: (1) perform gas generation testing on each individual drum of waste, and (2) repackage and/or treat the waste. Both of these options require extra handling of the drums and, if repackaged, the opening and repackaging of these high wattage drums into as many as 20 progeny drums which poses potential worker exposure.

The newly designed ARROW-PAK™ offers a potential solution to concerns about hydrogen concentration buildup. The prototype was designed to withstand the explosive forces generated by a stoichiometric hydrogen-air deflagration, a worst-case scenario. In addition, to be acceptable for disposal at WIPP, the container must meet the testing requirements for the Department of Transportation (DOT) 7A Type A package.

DESCRIPTION OF ARROW-PAK™ TECHNOLOGY

The ARROW-PAK™ is a project that is funded by the Office of Environmental Science (EM-50) as an Accelerated Site Technology Deployment Program. This project included the design and fabrication of the ARROW-PAK™ as a robust payload container for high-wattage TRU waste.

The ARROW-PAK™ is a high-density polyethylene (HDPE) macroencapsulation treatment technology. The unit physically consists of a pipe-type central section fabricated from extra high molecular weight HDPE material that is closed by two end caps of identical material which are heat fused and joined to the central section. The fusion process thermally melts the HDPE semi-crystalline macro-molecular structures. Upon cooling, the polymer chains physically commingle, co-entangle and resolidify the semi-crystalline molecular structures to reunify into a homogeneous monolithic product. The unit's inherent material properties such toughness, ductility, strength, fusibility, chemical inertness, structural stability, and longevity, enable it to be land disposed to comply with 40 CFR 268.45 without risk of material degradation or leachability of hazardous constituents. (2) See Figure 1.

While the chief concern for transportation and emplacement is combustion or deflagration, these processes require both hydrogen and oxygen to occur. Since hydrogen is generated by the radiolysis process during the shipping period, removing most of the oxygen would achieve the same end. By removing oxygen to below the flammability threshold, the possibility of combustion is precluded, regardless of the amount of hydrogen generated. The ARROW-PAK™ has been designed by Boh Environmental, LLC, to withstand an unexpected hydrogen deflagration (i.e., no consequence).

Figure 1. The ARROW-PAK™

For the application for TRU waste, a high wattage drum is placed inside an ARROW-PAK™ and then sealed. A vacuum is applied, removing the air in the annular void space and throughout much of the drum, thus reducing the total quantity of oxygen to below the flammability threshold. After pumping down to high vacuum, the ARROW-PAK™ is back-filled with inert gas to atmospheric pressure. In this way, the oxygen concentration within the ARROW-PAK™, including any that might remain within the drum and enter the resulting inert atmosphere over time as a result of virtual leaks from unbroken bags within the drum, is maintained below the threshold required for hydrogen to combust, rendering the ARROW-PAK™ intrinsically safe.

TESTING OF THE ARROW-PAK™ (3)

Physical testing was performed on the ARROW-PAK™ at the New Mexico Institute of Mining Technology's Energetic Materials Research and Testing Center (EMRTC) at Socorro, New Mexico, in June 2002. The purpose of these tests were to evaluate performance of the ARROW-PAK™ to withstand vacuum, pressure, contain a stoichiometric deflagration explosion of a hydrogen/air mixture and to perform DOT Hazardous Materials Regulations HazMat Transportation 49CFR173.465 Type A Packaging Tests.

The first test was to demonstrate that the ARROW-PAK™ could achieve a vacuum of less than 3.5-psi absolute. At this pressure or below the oxygen concentration in the air within the ARROW-PAK™ is less than the lower flammability limit for combustion to occur. Next, a positive pressure of 150 pounds per square inch (psi) was applied in stages. This simulates the pressure the ARROW-PAK™ would experience from hydrogen gas

build-up generated by high-wattage TRU waste over an extended period of time. The third test was designed to determine whether the ARROW-PAK™ could withstand the total energy released during a hydrogen-air deflagration explosion.

Additional tests included DOT 7A Type A Packaging Tests for shipping containers, where an empty drum weighing 1,248 pounds was filled with inert contents and sealed in an ARROW-PAK™ for a total weight of 1804 pounds.

Vacuum and Backfilling Test
The ARROW-PAK™ fabricated for this test was subjected to a vacuum, left for an hour, then backfilled with nitrogen to atmospheric pressure of 15.4 psi absolute.

Pressure Test
The ARROW-PAK™ that was previously used for the vacuum and backfilling test was used for the pressure test. After backfilling, the ARROW-PAK™ to atmospheric pressure the pressurization was started. The pressure was increased in 25 psia increments at 30-minute intervals until the pressure of 164.7 psia was achieved. Leak checks were done at each interval. The ARROW-PAK™ was inspected and found to be undamaged from the tests. This completed the pressure test.

Deflagration Explosion Test
The ARROW-PAK™ used for the deflagration explosion test had a hydrogen diffuser installed into the center section to evenly disperse the hydrogen within the interior. Two additional pressure test ports were installed. One was used to install an electric match to ignite the hydrogen/air mixture and the other to install a dynamic pressure gauge to record the pressure during deflagration explosion.

For the test, hydrogen was injected into the ARROW-PAK™ until it reached 18.6 psia. The hydrogen was allowed to mix with the air in the ARROW-PAK™ for 30 minutes to stabilize.

A high-speed video camera was recording the sequence of events, and a microphone placed next to the ARROW-PAK™ recorded the sound of the deflagration explosion onto the videotape. The sound indicated a deflagration explosion occurred. Indications were that the oxygen and hydrogen had been converted from the gaseous state to the liquid state to form water, in turn reducing the internal pressure to below atmospheric.

The valves were kept closed for over an hour after the deflagration explosion to validate the integrity of the valves and seals.

A pressure test was then conducted to check for any breach of the ARROW-PAK™. This test was essentially the same as the pressure test conducted previously. Leak checks were performed after each 30-minute interval.

The ARROW-PAK™ was inspected and found to be undamaged from the tests. This completed the deflagration explosion test. The container was cut open after the

deflagration test and the clean interior indicated combustion with no heat damage. Also, there was no evidence of physical stress. See Figure 2.

Figure 2. ARROW-PAK™ after deflagration test

DOT CFR 49 §173.465 Type A Packaging Tests

A separate ARROW-PAK™ was fabricated with a drum inside for DOT Type A testing. The drum weighed 1,248 pounds, giving a gross weight of 1,804 pounds for the complete ARROW-PAK™.

- **Water Spray Test**
  In accordance with the DOT test procedures, the ARROW-PAK™ was subjected to a water spray test for an hour as required.

- **Free Drop Test**
  The ARROW-PAK™ was dropped from a height of four feet, four and one half inches (4' 4-1/2") onto a steel plate resting on a concrete slab. The ARROW-PAK™ article bounced and landed flat on its end with no significant damage being observed.

- **Stacking Test**
  The ARROW-PAK™ was subjected, for a period of at least 24 hours, to a compressive load equivalent of five times the mass of the actual package weight of 1804 pounds. No significant changes were observed.

- **Penetration Test**
  For the penetration test, a bar of 1.25 inches in diameter with a hemispherical end and a weight of 13.2 pounds was dropped from a height of four feet and directed to fall with its longitudinal axis vertical, onto the center of the weakest part of the

ARROW-PAK™, so that, if it penetrates far enough, it will hit the containment system. No significant damage was observed.

SUMARY OF TEST RESULTS

The first test was to demonstrate that the ARROW-PAK™ could achieve a vacuum of less than 3.5 psi absolute. At this pressure, the oxygen concentration in the air within the ARROW-PAK™ is less than the lower flammability limit for combustion to occur. A pressure of 0.5 psi absolute was achieved with no structural damage.

Next, a positive pressure of 150 psi absolute was applied. This simulated the pressure the ARROW-PAK™ would experience from hydrogen gas build-up generated by high-wattage TRU waste over an extended period of time. The ARROW-PAK™ successfully held the pressure.

The third test was designed to determine whether the ARROW-PAK™ could withstand the total energy released during a hydrogen-air deflagration explosion. The ARROW-PAK™ contained the deflagration explosion, and the subsequent pressure test verified that there was no breach of containment.

The ARROW-PAK™ also successfully passed the four required tests for DOT Type A Packaging Tests.

PATH FORWARD

The path forward is threefold. One, seek approval from the NRC to use this as an authorized payload container that can be shipped in the TRUPACT-II. Two, initiate the analyses for the WIPP Site Authorization Bases to see if the container is suitable for disposal at WIPP. Third, move forward to have the ARROW-PAK™ approved for disposal at the WIPP by the New Mexico Environment Department and U.S. Environmental Protection Agency.

In November 2002, a meeting was held with the NRC to discuss what would be required to make an application to the NRC in order to use the ARROW-PAK™ as a TRUPACT-II authorized payload container containing waste that potentially could have concentrations greater than 5% hydrogen in the inner most layer of confinement. From this meeting and these discussions, these conclusions were drawn:

1. The application may be a request for a modification to the Certificate of Compliance or may be a request for an exemption from 10CFR71.43.d.
2. The application will discuss the risk of repackaging and justification.
3. No credit will be taken for inerting the TRUPACT-II or the ARROW-PAK™.
4. The application will include a discussion on the ability of the ARROW-PAK™ to withstand impact stress from a 30-foot side drop in the TRUPACT-II.
5. The application will include discussion of the properties of the materials making up the ARROW-PAK™, shipping period calculations, design drawings and specifications, procedures for assembly, and authorized contents with dunnage.

The CBFO is moving forward to prepare the application, including any additional testing, to use the ARROW-PAK™ as a high wattage authorized payload container. This application will be submitted to the NRC. Current plans are to include this request with the Revision 20 modification application to the TRUPACT-II, scheduled for submittal in September 2003.

The WIPP Site Authorization Bases must include the emplacement of the ARROW-PAK™. WIPP site personnel will use the results of the testing, materials making up the payload container and other required data in order to determine if this payload container can safely be emplaced in the WIPP repository.

The U.S. Environmental Protection Agency must also accept the use of the ARROW-PAK™ for emplacement in WIPP. There is a limit of 20 million kilograms of cellulosics, plastic and rubber (CPR) that can be emplaced in WIPP without affecting the repository's performance. Since the ARROW-PAK™ is considered CPR, it must be taken into consideration during the Performance Assessment of the WIPP.

The New Mexico Environment Department must accept the use of the ARROW-PAK™ as a container that can be emplaced in WIPP and be within the bounds of the WIPP Hazardous Waste Facility Permit.

CONCLUSIONS

After evaluation of the data, the physical testing of three ARROW-PAK™ containers was successfully completed. The ARROW-PAK™ containers passed all of the tests they were subjected to with no visible or measurable damage. With the successful testing of the ARROW-PAK™, the CBFO is moving forward to obtaining all the approvals needed to use this new payload container as a robust solution to shipping and emplacing high wattage TRU waste to the WIPP for disposal.

REFERENCES

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