AN UP TO THE MINUTE STATUS OF TWO TRU WASTE TRANSPORTATION INITIATIVES TRUPACT-III AND ARROW-PAK^{TM}

J. L. Jackson, R. A. Johnson, S. A. Porter
Washington TRU Solutions LLC
4021 National Parks Highway, Carlsbad, NM 88220

R. T. Haelsig, P. W. Noss, R. J. Smith
Packaging Technology, Inc.
1102 Broadway Plaza, Suite 300, Tacoma, WA 98402

ABSTRACT

This paper presents the current status of two key U.S. Department of Energy (DOE) transuranic (TRU) waste transportation programs currently underway, the TRUPACT-III and the ARROW-PAK^{TM}.

Packaging Technology, Inc. (PacTec), is under contract to Washington TRU Solutions LLC (WTS) to develop and provide a U.S. Nuclear Regulatory Commission (NRC)-licensed TRUPACT-III transportation system to be used for the transport of oversized boxes of TRU waste now stored within the DOE complex. Without such a package, it would become necessary to repackage much of the waste for transport in the smaller TRUPACT-II.

WTS and PacTec are also jointly working with BOH Environmental, LLC (BOH) to deploy the ARROW-PAK^{TM} technology, which is owned by BOH. The ARROW-PAK^{TM} container is a robust, deflagration-proof payload container, which is to be used for shipment of high-wattage TRU waste within the TRUPACT-II. The ARROW-PAK^{TM} is also intended to serve as the burial container at the Waste Isolation Pilot Plant (WIPP).

Design, testing, and NRC certification status of both programs is summarized herein. As a reference point, several pre-submittal meetings with the NRC have taken place, and certification test activities for both projects were performed in August (ARROW-PAK^{TM}) and September (TRUPACT-III) of 2003. SAR submittals for both programs are anticipated in 2004.

INTRODUCTION

Several transportation packages currently exist which have been certified by the NRC as Type B packages for transportation of TRU waste to WIPP. Included are the TRUPACT-II and HalfPACT for contact-handled (CH)-TRU waste and the 72-B Cask and 10/160-B Cask for remote-handled (RH)-TRU waste. However, a significant subset of the current inventory of CH-TRU waste cannot be readily transported in these containers. Initiatives are currently underway to address two specific issues which, until resolved, will significantly limit the ability to complete DOE site clean-up in a timely and efficient manner.

First, nearly 25% (by volume) of the CH-TRU waste in the DOE complex is contained in oversized boxes that are too large to fit in one of the existing NRC-certified CH-TRU waste transportation packages. Repackaging into smaller containers, such as drums or standard waste boxes (SWBs), and transport within the TRUPACT-II is possible but would require very costly repackaging facilities and significantly increase operator exposure/risk. *As-low-as-reasonably-achievable* (ALARA) considerations therefore dictate development of a new transportation container for handling the oversized boxes. The solution selected for this subset of TRU waste is the TRUPACT-III, which is now under development by PacTec.

Deployment of the system in government fiscal year 2005 is planned in order to support current Savannah River Site (SRS) TRU waste shipping schedules.

A second problematic waste form, although much smaller in total quantity compared to the oversized box problem, is high-wattage waste, which has the potential for generating hydrogen in quantities that are greater than can be accommodated by the TRUPACT-II or HalfPACT packages as currently licensed. Significant limitations on the quantity of hydrogen allowed within the payload of these CH-TRU shipping packages (i.e., 5% by volume) dictate development of a new payload container for use within the TRUPACT-II as well as an alternative licensing approach.

One new container is the ARROW-PAK^{TM}, developed and owned by BOH. This plastic container is different than payload containers currently in use in that it is not vented. Rather, it is a robust container capable of withstanding significant pressures, including those due to a postulated worst-case deflagration, without rupture. Although operational practices are such to preclude a deflagration event (i.e., oxygen is removed from within the ARROW-PAK^{TM} subsequent to loading with waste), for NRC certification, an exemption is being pursued based on there being no consequence to the TRUPACT-II even if a deflagration were to occur within an ARROW-PAK^{TM} container.

The remainder of this paper provides a top level summary of the current status of the TRUPACT-III and ARROW-PAK^{TM} development efforts.

TRUPACT-III PROJECT

TRUPACT-III Purpose

The purpose of the TRUPACT-III is to allow for the transport of oversized boxes currently containing CH-TRU waste without the need for repackaging. Approximately 15,000 oversized boxes of CH-TRU waste reside throughout the DOE complex, which are nominally 1.22- × 1.22- × 2.13-m to 1.52- × 1.52- × 2.44-m in size. Actual dimensions can vary fairly significantly from these nominal values, but in virtually all cases, the boxes are too large for transport within the TRUPACT-II. The parallelepiped geometry of the boxes also dictates use of a rectangular cross section for the payload cavity, rather than the cylindrical cavity offered by the TRUPACT-II, to increase shipping efficiency. By adopting a rectangular cavity, legal width can be maintained during highway transportation. In anticipation of possible rail transport to WIPP in the future, the TRUPACT-III system is being developed for both highway and rail transport.

Waste forms to be transported in the TRUPACT-III are virtually identical to those currently authorized for transport in TRUPACT-II and HalfPACT. However, a key programmatic decision was made at the pre-proposal stage of the project to assume that the pending NRC rulemaking to eliminate double containment for shipments of greater than 20 curies of waste would be successful. As such, unlike the TRUPACT-II and HalfPACT, the TRUPACT-III is being developed as a single-containment system. Should the rulemaking fail, a contract option exists for PacTec to develop a second level of containment. In the event that a second level of containment becomes required, significant cost and schedule impacts will occur.

TRUPACT-III Description

The TRUPACT-III is a right parallelepiped very similar in external configuration to a standard 6.10-m ISO container. The design is very closely based on the TN-Gemini package, which is certified by the International Atomic Energy Agency (IAEA). The Gemini system, developed by Areva Cogema Logistics (ACL), has been fabricated in France (six production units exist) and is routinely used in Europe for the transport of TRU waste.

Figure 1 presents an exploded view of the TRUPACT-III. As can be seen, the package consists of a body, a closure lid, and a removable lid-end overpack. Butyl O-ring seals in a face seal configuration are used to form a single level of containment. Lid closure is achieved using 44, ASTM A320, Grade L43, fasteners torqued to 1,600 N-m each. The protective overpack is secured using 10, ASTM A320, Grade L43, bolts also torqued to 1,600 N-m each. The containment boundary and all primary structural members are fabricated from UNS S31803 stainless steel (SS), a high-strength duplex material. The containment boundary structure consists of an inner shell that is backed by a corrugated sheet of UNS S31803 SS and an outer structural shell. Completely surrounding the containment boundary structure is a unique combination of energy absorbing and insulating materials used for providing both structural and thermal protection. Redwood, balsa wood, and phenolic foam are enclosed between the containment boundary structure and an outer packaging skin, which is also fabricated from UNS S31803 SS. Embedded within the wood and foam components are UNS S31803 SS plates of varying thickness to mitigate the consequence of the hypothetical accident condition (HAC) puncture event (1-m drop on a 15-cm diameter puncture bar). In the immediate vicinity of the closure lid O-ring seal, calcium silicate insulation is employed along with a closure bolt protection plate structure to protect the closure area both structurally and thermally.

The overall external dimensions for the TRUPACT-III are 2.50-m wide, 2.65-m high, and 6.06-m long. The internal cavity provided by the TRUPACT-III for the payload is 1.84-m wide, 2.00-m high, and 4.51-m long. The maximum gross weight of the loaded TRUPACT-III is limited to 30,000 kg. The maximum allowed payload weight is 5,800 kg. At this size and weight, although legal width is maintained (≤2.59-m), most shipments will be overweight for highway transport. When deployed via rail, it is anticipated that three TRUPACT-IIIs would be placed on a single railcar.

Although the TRUPACT-III will be certified to transport the same drums and SWBs as transported within the TRUPACT-II, its primary focus will be on shipment of oversized boxes. To support such shipments, a set of three different sized standard large boxes (SLBs) is being developed. The smallest SLB, or SLB1, is sized to accommodate a 1.22- × 1.22- × 2.13-m box. An SLB2 is being sized to accommodate a 1.52- × 1.52- × 2.44-m box, and an SLB3 is sized to fill the entire cavity of the TRUPACT-III. Although it is possible to ship existing 1.22- × 1.22- × 2.13-m and 1.52- × 1.52- × 2.44-m boxes without a surrounding SLB, the age, integrity, and size diversity of the oversized boxes dictates that most of them will be overpacked in an SLB prior to being shipped to WIPP in the TRUPACT-III. As with other payload containers being shipped to WIPP, the SLBs are being developed as U.S. Department of Transportation (DOT) Type 7A containers. Program needs dictate that SLB designs are to be completed during the first half of 2004.

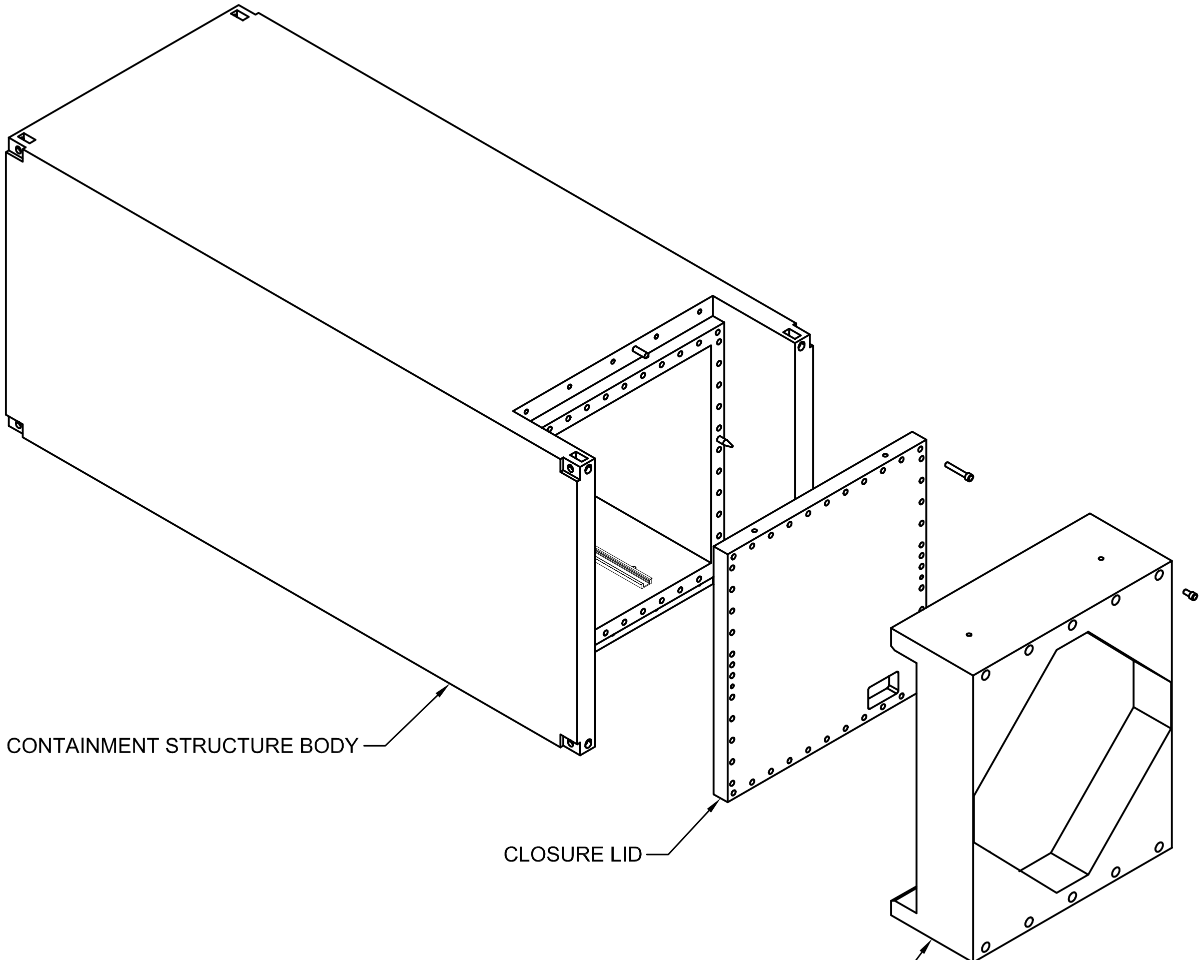

Fig. 1 TRUPACT-III exploded view

TRUPACT-III Testing

The TRUPACT-III design has been subjected to a significant set of structural (free drop and puncture) tests. In the mid-1990s, the nearly identical Gemini package was fabricated in half-scale and subjected to a series of 9-m free drops and 1-m puncture tests. During that testing, the original sidewall design of the Gemini failed during the puncture tests and was redesigned and successfully retested. IAEA certification of the Gemini was obtained based on successful testing, including, but not limited to, a demonstration of a leaktight containment boundary, coupled with supplementary analysis and analytically based reasoned arguments. The response to the HAC thermal (i.e., fire) event was established by analysis. Due to the significant similarity between the Gemini and the TRUPACT-III, drop testing results obtained from the original IAEA certification effort are also applicable to the TRUPACT-III design and serve as the starting point for certification in the United States.

Based on initial meetings with the NRC, a decision was made to resurrect and refurbish the original half-scale test article and perform additional testing in support of NRC certification. Notably, as a result of the original testing, the containment boundary structure was only very minimally damaged and could thus be quickly refurbished for additional testing. New tests were focused on maximizing damage to the closure lid end of the package. Tests with internal pressure and at cold temperatures were identified as being of interest. In addition, a 9-m free drop with the package longitudinal axis vertical and impact on the lid end of the package was identified as a potential worst case for the lid to body closure joint. Top-end edge and corner drops had previously been performed at ambient temperature conditions, and further testing of those conditions was judged to be unnecessary. Although a side drop along a longitudinal edge of the package had previously been performed, a drop onto a flat side of the package had not. From an analytical assessment of flat side impacts versus secondary impacts associated with shallow angle drops, it was concluded that a slapdown test should also be performed in support of licensing of the TRUPACT-III. Consequently, a 9-m free drop was performed with the package oriented for the drop such that a flat side of the package was at a 30º angle from horizontal (see Figure 2). Initial impact was at the base end of the package with a subsequent, or secondary, impact occurring on the closure lid end. Both the lid end vertical drop and the closure lid slapdown tests result in relatively high impact loadings, and both tests were performed with the test article chilled to -29 ºC or less. This was done since the impact absorbing materials are more sensitive to temperature than is the UNS S31803 SS. A such, impact load magnitudes increase faster with decreasing temperature than does the strength of the containment boundary.

Subsequent to the above cold temperature, pressurized, 9-m free drop tests, several puncture tests were also performed. Since puncture testing of the original Gemini design had been performed in several locations removed from the closure end of the package, the new TRUPACT-III tests focused on the closure end. Selected puncture tests directed at the location of the closure seals and/or attempting to open up thermal pathways for a subsequent HAC fire were performed to supplement the prior puncture tests. Since puncture panels in the sides and ends of the package are used as the primary means of mitigating the packages response to the puncture event and since those UNS S31803 SS panels are not highly sensitive to temperature, and remain ductile at low temperature, all puncture tests were performed at prevailing ambient temperatures.

Fig. 2 9-m free drop of the TRUPACT-III package – lid slapdown orientation

Overall, the testing of the TRUPACT-III was considered to be successful. Leakage rate testing of lid closure seals, vent port seals, and the entire containment boundary subsequent to all testing demonstrated that a leaktight condition existed for the half-scale model. However, acknowledging per ANSI N14.5 [1] that leakage rate tests do not scale, additional physical measurements of post-test geometries were also made. Measurements quantifying the relative movement of the seal flanges revealed very little permanent deformation at the location of the O-ring seal. Deformations that were observed were sufficiently small that they would not compromise the ability of the design to remain leaktight. This conclusion was supported by prior seal material testing performed during certification of the TRUPACT-II. That particular testing imposed a wide range of time, temperature, and compression states to the specific butyl compound used for the TRUPACT-II and planned for the TRUPACT-III. In addition, a full-sized production Gemini was fitted with butyl seals and the lid shimmed out from the body to demonstrate that a leaktight seal would be maintained even under reduced states of compression. The observed lack of significant deformation in the vicinity of the seal, coupled with the demonstrated leaktight performance capability of the closure seal material over a wide range of time, temperature, and compression states, provided the assurance necessary to establish that the TRUPACT-III design would remain leaktight under worst-case normal conditions of transport (NCT) and HAC conditions.

As with most test programs, a few surprises occurred during testing. Most notably, measured lid end and slapdown impact accelerations exceeded expected values by approximately 30%. In spite of this, observed deformations were minimal, and leaktight performance was not compromised. In addition, the depth of penetration of the puncture bar in a lid end puncture test was greater than expected. Although the observed damage was judged to be acceptable, design margin could not be readily judged. For this reason, a puncture panel similar to that used on other portions of the package was added within the lid end overpack.

TRUPACT-III Safety Analysis Report Status

With testing having been completed in September of 2003, the Safety Analysis Report (SAR) for the TRUPACT-III was expected to be submitted to the NRC in December of 2003. However, anticipated submittal to the NRC has been delayed. The delay is associated with fulfilling commitments made to the NRC during pre-submittal meetings that, in addition to the half-scale testing, finite element analyses of the governing HAC free drop conditions would also be provided with the initial application. The primary problem has been that although testing clearly demonstrated the adequacy of the design, analytical models have consistently underpredicted the structural capability of the design as evidenced by significant overpredictions of deformations compared to those observed. Part of the problem relates to the higher-than-anticipated measured impact accelerations discussed above. Until improved correlation between test and analysis is achieved or until it is demonstrated that results obtained using overly conservative analysis models still support a "leaktight" design condition, SAR submittal will likely continue to be delayed. In any event, SAR submittal is expected during the first quarter of 2004, and certification is still anticipated in time to support first use of the TRUPACT-III system at SRS in October of 2005. If the NRC rulemaking on double containment is unsuccessful, licensing will either be delayed while a separate inner vessel is developed for use within the TRUPACT-III, or the single containment version of the TRUPACT-III will continue in parallel with development of a double-contained TRUPACT-III.

ARROW-PAK™ PROJECT

ARROW-PAK™ Purpose

The ARROW-PAK™ is an engineered solution to solve the problem of packaging and transporting high-wattage TRU waste. Currently, up to 10% of the TRU waste inventory requires repackaging to satisfy current TRUPACT-II limits for high-wattage waste. The regulatory drivers that result in the need to repackage includes 10 CFR §71.43 [2] (no significant chemical or other reaction), NUREG-1609 [3], and NUREG/CR-6673 [4] (combustible gases may not exceed 5% by volume). The hydrogen concentration in a sealed container may increase to levels that could be flammable in a nominal oxygen atmosphere. If the hydrogen were to combust, the resultant pressure might breach the shipping container. Therefore, the existing solution to this problem is to open and repackage existing high-wattage drums into many additional drums, each with a small fraction of the alpha activity as the original. Repackaging is technically feasible, but results in increased dose to nuclear workers and an increased transport/handling cost, schedule, and risk due to the increase in the number of the high-wattage TRU shipments (5 to 10 times, by volume).

Given the above scenario, ALARA, cost, and schedule dictated a need for an alternate path forward. While the chief concern is combustion or deflagration, these processes require both hydrogen and oxygen to be present. Previous alternatives have investigated ways to sequester the hydrogen component. Since hydrogen is generating due to the radiolysis process, removing most of the oxygen would achieve the same end. By removing the readily available oxygen to below the flammability threshold, the possibility of combustion is greatly reduced, regardless of the amount of hydrogen generated.

One way to remove the oxygen from the shipping containers is by placing TRU drums inside of the BOH patented ARROW-PAK™ treatment units. The ARROW-PAK™ has been tested for vacuum, pressure, irradiation, and combustion, in addition to other physical tests. First, a high-wattage drum is placed inside an ARROW-PAK™. The ARROW-PAK™ is then heat sealed and a vacuum 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 backfilled 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. As a measure of redundancy, experimental tests were conducted in 2002 to demonstrate that the ARROW-PAK™ system is robust enough to withstand an internal deflagration of a stoichiometric mixture of hydrogen and oxygen. This section reports the certification testing and analyses that have taken place during 2003 to support a license amendment for the shipment of high-wattage waste in up to three ARROW-PAK™ units inside the TRUPACT-II package.

ARROW-PAK™ Description

The ARROW-PAK™ was originally designed and patented for two general functions: (1) as a U.S. Environmental Protection Agency (EPA)-acceptable treatment method for the macroencapsulation of radioactively contaminated lead and mixed low-level debris waste, and (2) as an improved form of waste packaging for treatment and both interim and final storage and/or disposal of drums of low-level radioactive waste. The ARROW-PAK™ technology meets the federal guidelines (40 CFR §268.45 [5]) for treatment and land disposal of mixed waste debris and radioactively contaminated lead. The macroencapsulation method places the debris in a thick, high-density polyethylene (HDPE) cylindrical vessel and seals it with a proprietary thermal fusion process to produce a leak-proof, strong, and durable monolithic unit that immobilizes the waste for at least 300 years. This technology has successfully treated mixed low-level waste at the DOE Hanford Reservation, Oak Ridge National Laboratory, and Envirocare of Utah. The ARROW-PAK™ is currently approved for the treatment of mixed waste by the states of Colorado, Tennessee, Washington, and Utah.

The ARROW-PAK™ physically consists of a pipe-type central cylindrical section fabricated from extra-high molecular weight polyethylene (EHMW HDPE) material that is closed by two end closure devices of identical material that 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 re-solidify the semi-crystalline molecular structures to reunify into a homogeneous monolithic product. The ARROW-PAK™ is designed to be transported vertically, three at a time, inside the TRUPACT-II shipping container. As a pressure vessel, its shape resembles a cylindrical propane tank approximately 1.83-m tall and 0.76-m in diameter. The wall thickness is a nominal 4.48 cm, and the torospherical end closures are approximately 7.62 cm thick. The wall section of the ARROW-PAK™ vessel is engineered to endure the time duration of applied stress, at a specified temperature, with an adequate design factor such that the strain of the vessel remains within tolerable limits without rupture of the vessel during its use. Table I provides the approximate dimensions of the ARROW-PAK™, designed for transporting high-wattage TRU waste in the TRUPACT-II.

Table I. Approximate Dimensions and Weight of ARROW-PAK™

Outside Diameter (cm)	**Inside Diameter (cm)**	**Side Wall Thickness (cm)**	**Outside Length (cm)**	**Inside Length (cm)**	**Empty Weight (kg)**
76.20	67.24	4.48	180.34	160.02	238

The ARROW-PAK™ material is strong, ductile, tough, and impact resistant across a wide range of temperatures from less than -57 ºC to +71 ºC. The performance of ARROW-PAK™ comes from the balance-of-properties built into the specifically qualified engineering pipe-grade, stress-rated, EHMW-HDPE. This HDPE polymer has been qualified through nearly 15 years of ARROW-PAK™ development and DOE field-testing, and is a highly strain tolerant, tough material, unlike lower strain metals and other polyethylene. ARROW-PAK™'s strength and dimensional properties are unaffected by gamma irradiation to a total dosage of over 7 kGy (dosage equivalent to the maximum expected for CH-TRU waste over a HDPE lifetime greater than 300 years).

ARROW-PAK™ has been tested for immersion in all chemicals likely to be associated with the Mixed Waste landfill (or leachate) to assure chemical resistance over at least a 100-year life span. The ARROW-PAK™ is inert and will not adversely react with any waste meeting the waste acceptance criteria for disposal at WIPP. In the case of radiolysis of the waste to generate hydrogen gas, the ARROW-PAK™ has been tested to demonstrate that a deflagration event would have no consequence in terms of health and safety.

ARROW-PAK™ Testing

Drop and pressure testing was conducted and reported in August 2003, to support a proposed exemption application for the transport of ARROW-PAK™ containers in the TRUPACT-II. The two primary tests were the regulatory HAC 9-m free drop test described in 10 CFR §71.73 [1], and a hydrostatic pressure validation (burst) test.

The drop tests were conducted at Westinghouse Engineered Products Department (WEPD) in Carlsbad, New Mexico. The burst test was conducted by Independent Pipe Products (IPP) in Grand Prairie, Texas. PacTec of Tacoma, Washington, provided test engineer and quality assurance (QA) direction and support for the testing. All fabrication and testing was performed under PacTec's NRC approved, 10 CFR 71, Subpart H, QA Program, in accordance with *Test Plan for the ARROW-PAK™*, TP-035 [6].

Fabrication of four ARROW-PAK™ test units was conducted by BOH in accordance with the PacTec QA Program. The test units were fabricated in accordance with *ARROW-PAK™ SAR Drawing* 163-005 [7]. All test units passed a soap bubble leak test following fabrication. Test units 1, 2, and 3 were used for the drop test, and test unit 4 was used for the hydrostatic validation test. Figure 3 presents three prototypic ARROW-PAK™ ready for testing.

An arrangement of three ARROW-PAK™s was assembled on a common pallet assembly and packaged in a TRUPACT- II inner containment vessel (ICV), see Figure 4. The TRUPACT-II outer containment assembly (OCA), with its energy absorbing polyurethane foam, was conservatively omitted from this test. Steel ribs were added to the bottom of the ICV to simulate the same loading distribution in a bottom end drop as would occur if the ICV were inside the OCA.

Drop Testing of Test Units 1, 2, and 3

The TRUPACT-II ICV and ARROW-PAK™ test units 1, 2, and 3 were prepared in accordance with test plan TP-035 [6]. Test units 1 and 2 were pre-loaded with concrete discs totaling 621 kg each, simulating a payload of compacted drums; test unit 3 was loaded with an empty 208-l drum. The test units were shrink-wrapped as a unit on a pallet and blocked into position such that ARROW-PAK™ test unit 3 was on the bottom of the horizontally positioned ICV, with the other two (heavier) test units on top, thus maximizing the forces on test unit 3. In addition, the saddle seal for ARROW-PAK™ test unit 3 was oriented 90º from the impact point, thus maximizing the stress at the saddle seal discontinuity. Marks were made on the ICV prior to attaching the lid, to ensure that the ARROW-PAK™ test unit 3 remained at the bottom while the ICV was welded and moved to the test location (a distance of a few hundred yards). Marks were also made on the tops of the test units to observe any rotation following the drops.

The ICV/ARROW-PAK™ test arrangement was subjected to two (horizontal and vertical bottom end) 9-m free drops onto a flat, essentially unyielding horizontal surface. The WEPD test pad is qualified as an unyielding surface as documented by *Engineering Specification for Drop Test Pad for Type A Performance Testing,* ES-A-001 [8]. At the conclusion of the two consecutive 9-m free fall drops, the ARROW-PAK™ test units were removed from the ICV for inspection and soap bubble leak testing.

Fig. 3 ARROW-PAK™ test units 1, 2, and 3 on the pallet assembly without shrink wrapping


Fig. 4. ARROW-PAK™ test units 1, 2, and 3 within the ICV in their side orientation.

Leak and Design Pressure Testing of Test Units 1, 2, and 3

Following the drop test, all fusion joints, penetrations, and saddle seals were soap bubble leak tested on each of the three test units. No visual indication of leaks was observed on any of the three test units. Following soap bubble leak testing, the most heavily loaded ARROW-PAK™ (test unit 3, as it took the highest load in the horizontal drop) was also pressure tested at its design pressure (690 kPa) for 10 minutes. No pressure drop or leakage was observed during a 10-minutes test at 731 kPa.

In addition to the 690 kPa design pressure test, an additional test at 1.45 MPa was performed for 10 minutes. A minor pressure drop was observed; after 10 minutes the final pressure was 1.38 MPa, a pressure drop largely be attributed to the elasticity of the material. No leakage was observed during the 10-minute test.

Following all drop, soap bubble, and design pressure testing, all three test units were destructively disassembled for inspection. All three ARROW-PAK™ test units were visually undamaged except for scuff marks from sliding across each other during handling and drop testing. The saddle seals were intact and operable. No "out of round" condition was observed.

Hydrostatic Validation Testing of ARROW-PAK™ Test Unit 4

A hydrostatic validation test (or "burst" test) was performed on a fourth undamaged ARROW-PAK™. This test unit was not part of the drop test sequence. The purpose of the hydrostatic test was to verify the maximum short-duration internal pressure capacity of the ARROW-PAK™ design as well as the rupture location.

The ARROW-PAK™ test unit 4 was prepared in accordance with the test plan TP-035. The test unit was horizontally positioned, filled with water and conditioned for one hour; the water and surface temperature was recorded at 25.5 ºC. Due to the volume capacity limitation of the accumulators in the pressurization system, four pressurization attempts were required to burst the test unit. Pressure was raised as high as 6.90 MPa, with burst finally occurring at 5.52 MPa during the pressure drop from 6.90 MPa. Approximately 68 seconds were required to force the rupture.

Rupture occurred as a longitudinal split in the center of the sidewall of the test unit pipe section. This was expected as the sidewall is the thinnest section and the point of maximum calculated deformation. No failure was observed in the test unit heads or transitions between the heads and the pipe wall.

ARROW-PAK™ Safety Analysis Report Status

The successful testing sequence reported above is further detailed and documented in *Test Report for the ARROW-PAK™*, TR-014 [9]. The test results will be used to support an exemption application for the shipment of high-wattage waste in up to three ARROW-PAK™ units in the TRUPACT-II package. Thermal and criticality analyses have been completed in support of the SAR revision. Structural analysis, operating procedures, and TRUCON code development are currently underway. It is expected that the submittal of the exemption application request to the NRC will occur before the end of fiscal year 2004.

CONCLUSIONS

The TRUPACT-III and ARROW-PAK™ programs currently underway support the overall DOE transportation program by providing a path forward for oversized and high-wattage CH-TRU waste. The completion of the certification of the TRUPACT-III will allow the DOE sites to transport oversized boxes without the need for repackaging or size reduction. NRC approval of an exemption for the use of the ARROW-PAK™ in the TRUPACT-II for high-wattage waste will provide a path forward for this waste.

REFERENCES

1 ANSI N14.5, *American National Standard for Radioactive Materials - Leakage Rate Tests on Packages for Shipment,* American National Standards Institute, Inc. (ANSI) (1997).

2 Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material*.

3 NUREG-1609, *Standard Review Plan for Transportation Packages for Radioactive Material*, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. (March 1999).

4 B.L. ANDERSON, M.K. SHEAFFER, AND L.E. FISCHER, *Hydrogen Generation in TRU Waste Transportation Packages*, NUREG/CR-6673, Lawrence Livermore National Laboratory (May 2000).

5 Title 40, Code of Federal Regulations, Part 268 (40 CFR 268), *Land Disposal Restrictions*.

6 *Test Plan for the ARROW-PAK*, TP-035, Rev. 1, Packaging Technology, Inc., Tacoma, WA (2003).

7 *ARROW-PAK SAR Drawing* 163-005, Rev. 0, Packaging Technology, Inc., Tacoma, WA (2003).

8 *Engineering Specification for Drop Test Pad for Type A Performance Testing,* ES-A-001, Rev. 0, Westinghouse Engineered Products Department, Carlsbad, NM (1998).

9 *Test Report for the ARROW-PAK™*, TR-014, Rev. 0, Packaging Technology, Inc., Tacoma, WA (2003).