Design and Testing of TRUPACT-II

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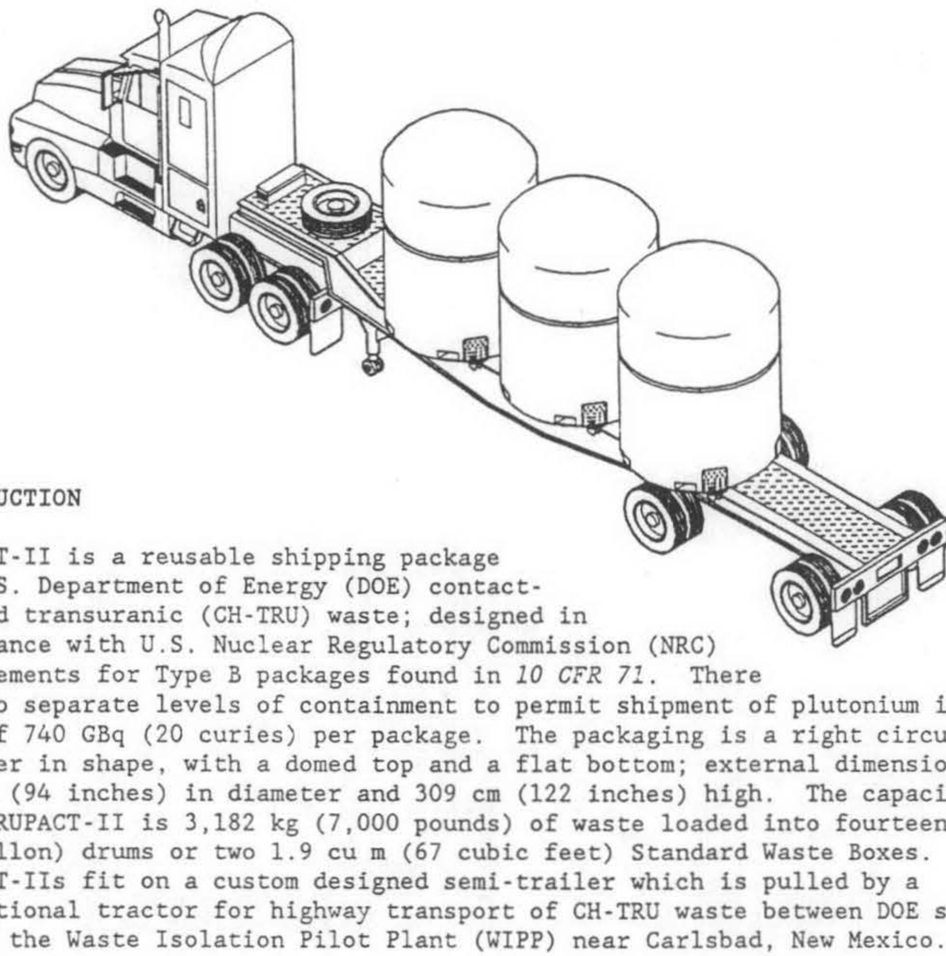


INTRODUCTION

TRUPACT-II is a reusable shipping package for U.S. Department of Energy (DOE) contact-handled transuranic (CH-TRU) waste; designed in accordance with U.S. Nuclear Regulatory Commission (NRC) requirements for Type B packages found in *10 CFR 71*. There are two separate levels of containment to permit shipment of plutonium in excess of 740 GBq (20 curies) per package. The packaging is a right circular cylinder in shape, with a domed top and a flat bottom; external dimensions are 240 cm (94 inches) in diameter and 309 cm (122 inches) high. The capacity of each TRUPACT-II is 3,182 kg (7,000 pounds) of waste loaded into fourteen 210-l (55-gallon) drums or two 1.9 cu m (67 cubic feet) Standard Waste Boxes. Three TRUPACT-IIs fit on a custom designed semi-trailer which is pulled by a conventional tractor for highway transport of CH-TRU waste between DOE sites and to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.

Nuclear Packaging, Inc. (NuPac), Federal Way, Washington designed and built TRUPACT-II for the DOE under a contract to Westinghouse Electric Corp., Waste Isolation Division (WID), Carlsbad, New Mexico. Full scale compliance testing was performed at Sandia National Laboratories (SNL), Albuquerque, New Mexico.

DESIGN CHALLENGE

Maximize Payload -- There are approximately 168,000 cu m (5,950,000 cubic feet) of waste which may ultimately be transported to WIPP in TRUPACT-II. This is expected to require more than 15,000 trips -- a total of 61,000,000 km (38,000,000 miles). Increasing the payload provides a safer, more economic, overall system by reducing the number of trips and total miles traveled. The decision to use a flexible stainless steel/foam design for impact and puncture protection as well as thermal insulation resulted in a dramatic payload increase compared to traditional "hard" cask designs.

Minimize Handling Time -- The large volume of waste dictated that the design would have to be "user friendly" to minimize the operator exposure to levels as low as reasonably achievable (ALARA). The selection of a rotating lock ring design, instead of a more conventional bolted closure, to attach the head to the body enables waste handlers to open a TRUPACT-II and load/unload the contents in less than 45 minutes.

Waste Characterization -- The variety of waste forms and uncertainties from "worst case scenarios" made payload descriptions a very difficult task. Physical, chemical and radiological characteristics of the waste were analyzed to determine the limits which will be imposed on the contents of the package. A new TRUPACT-II content code system (*TRUCON*) was developed. Shipping categories were defined for each waste type (e.g., solid organics, solid inorganics, etc.). These shipping categories include restrictions and requirements which determine how various payloads can be assembled.

DESIGN

Outer Containment -- The outer level of containment in TRUPACT-II is provided by a 4.8 - 6.4 mm (3/16 - 1/4 inch) thick stainless steel pressure vessel consisting of a cylindrical body, two ASME torispherical (flanged and dished) heads, and a set of closure rings which join together to form a double O-ring bore seal. This outer containment vessel (OCV) is surrounded by a layer of rigid closed-cell polyurethane foam approximately 25 cm (10 inches) thick and an external 6.4 - 9.6 mm (1/4 - 3/8 inch) thick stainless steel skin. Fork lift pockets are provided for handling. The cavity between the containment vessel and the outer skin is lined with a thin layer of ceramic fiber insulation prior to pouring the polyurethane foam (Figure 1). The foam is an excellent impact-energy absorber which also retards heat input during the hypothetical fire accident condition. The foam is flame-resistant and self-extinguishing; thus, minor tearing of the OCA exterior skin is acceptable. The stainless steel/ceramic fiber/foam sandwich construction of the outer containment assembly (OCA) forms a tough, puncture resistant and impact absorbing shell which cushions and insulates both containment vessels and their contents during normal and hypothetical accident conditions of transport.

Inner Containment -- Nested concentrically inside the OCV is a separate and removable stainless steel inner containment vessel (ICV). Like the OCV, the ICV consists of a cylindrical body, two flanged and dished heads and a set of closure rings with elastomer O-ring bore seals. The ICV usable interior volume is 184 cm (73 inches) in diameter and 192 cm (75 inches) high. Energy absorbing honeycomb spacers are located in the upper and lower heads to protect the heads from impact by the contents during the hypothetical accident free drop.

Thermal -- The thermal design rating of the package is 40 watts internal decay heat maximum. This relatively low internal heat load is dissipated entirely by passive heat transfer. Computer models were developed to predict maximum temperatures resulting from the regulatory assumptions and internal heat generated by the payload. The predicted average drum centerline temperature is 73 °C (163 °F) for normal conditions of transport with a 40 watt internal decay heat evenly distributed among 14 drums, plus the regulatory solar load.

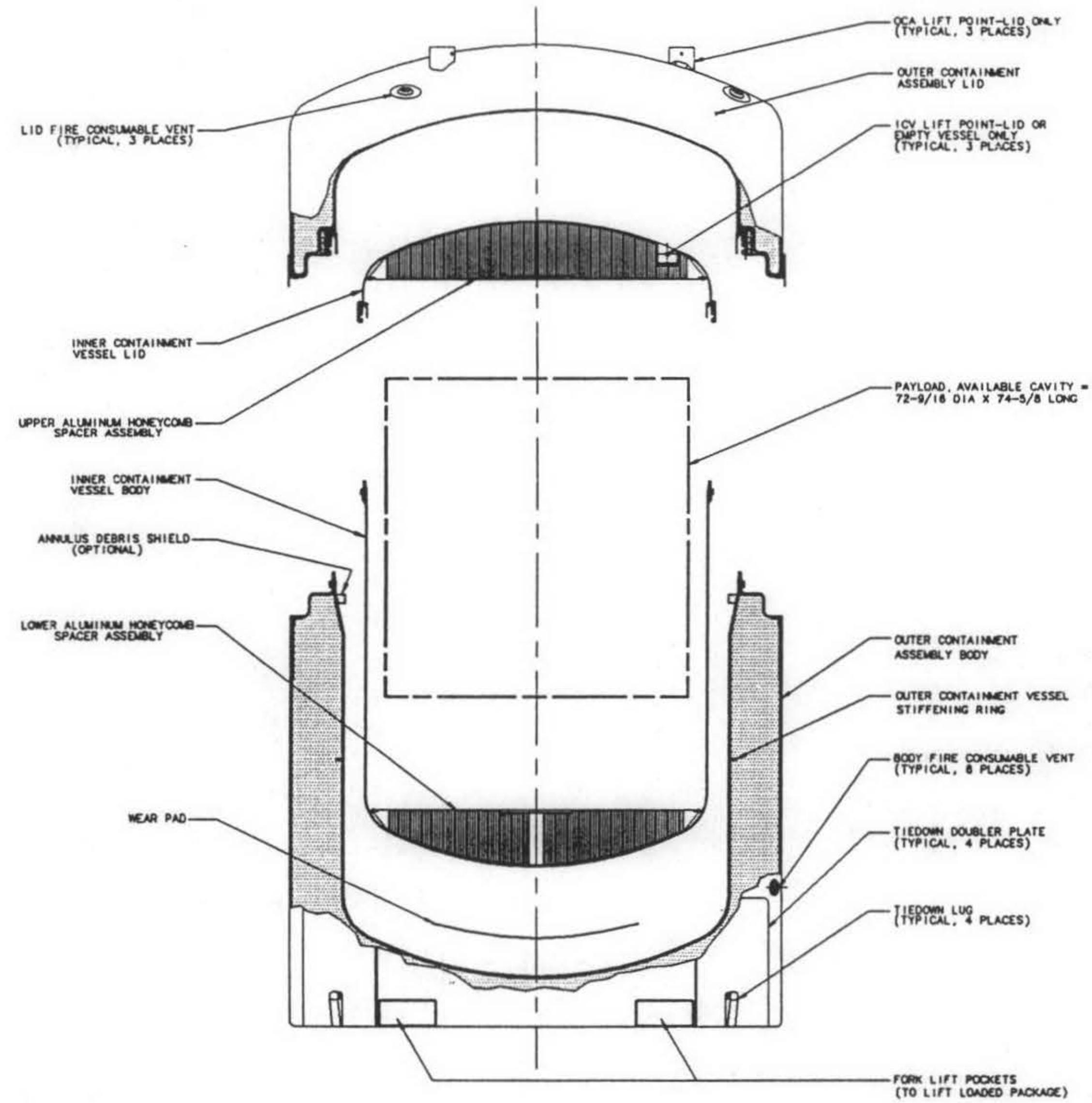


Figure 1

Closure -- A unique feature of the TRUPACT-II is the method of retaining the head to the body (Figure 2). The head and body have mating tongue and groove joints at the elastomer O-ring seal gland. The body has external lugs which align with internal lugs on the lock-ring. Rotating the lock-ring 10° locks/unlocks the head to/from the body. Both ICV and OCV use the same design; except the OCV uses a sheet metal actuator ring to reach the outside of the vessel.

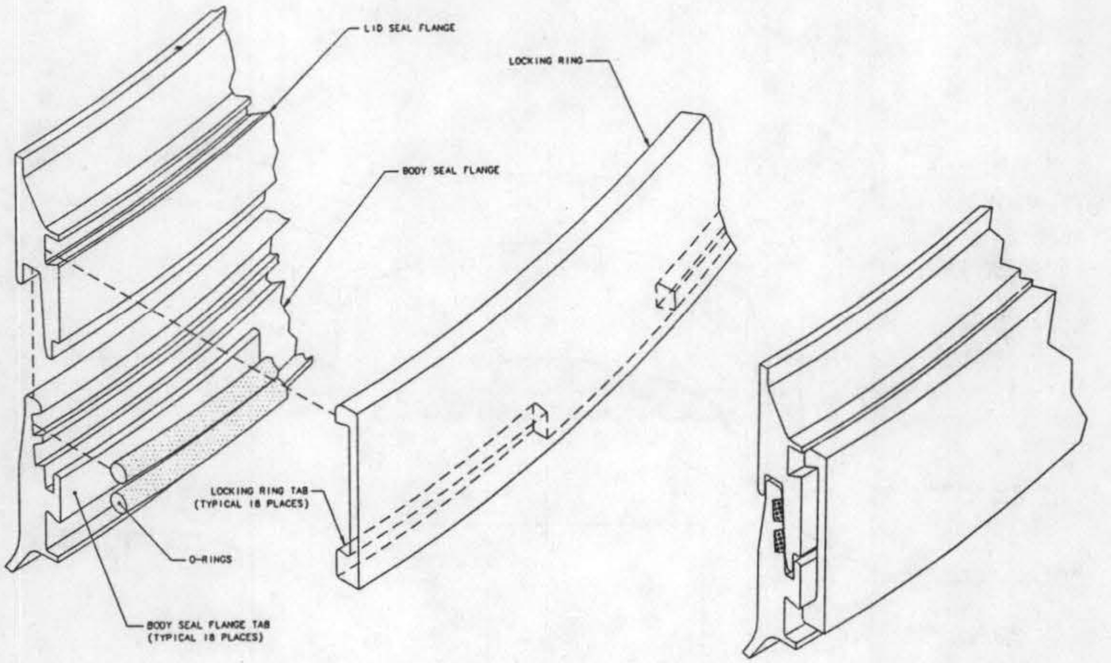


Figure 2

Pressure -- Both the OCV and the ICV are designed to withstand 345 kPs (50 psig) of internal pressure. Each is tested "leaktight" per *ANSI 14.5* (a leakage rate of 10E-7 scc/sec or less) for normal and hypothetical accident conditions of transport.

Shielding -- The TRUPACT-II contains no special shielding due to the low dose rates from the contents.

Criticality -- The TRUPACT-II does not require specific design features to provide neutron moderation and absorption for criticality control. Fissile materials in the payload are limited to an amount which ensures safely subcritical packages for normal and accident conditions.

Contents -- CH-TRU waste is characterized by having very small amounts of transuranic radioactivity contaminating a wide variety of materials. The waste typically consists of items like plastic, metal, glass, paper, salts, oxides, absorbents, filters, filter media, cloth, and cemented sludges. TRUPACT-II authorized methods for payload control (TRAMPAC) were developed and are included in the *Safety Analysis Report Report for the TRUPACT-II Shipping Package*. The DOE generator and storage sites will use the TRAMPAC to prepare payloads for shipment.

Controlled parameters include restrictions on physical and chemical form of the waste, chemical compatibility between constituents in the payload (and the package components), maximum pressure in the package during a 60 day transport period, potentially flammable gasses, layers of confinement, fissile material content, decay heat, weight, center of gravity, and dose rates for individual containers. Waste shipments can be shown to meet the TRAMPAC requirements by one of two ways: 1) show by analysis (without physically testing for each transportation parameter) that a particular waste container is safe for transport even under worst case conditions, 2) test individual payload containers under normal transport conditions to verify compliance.

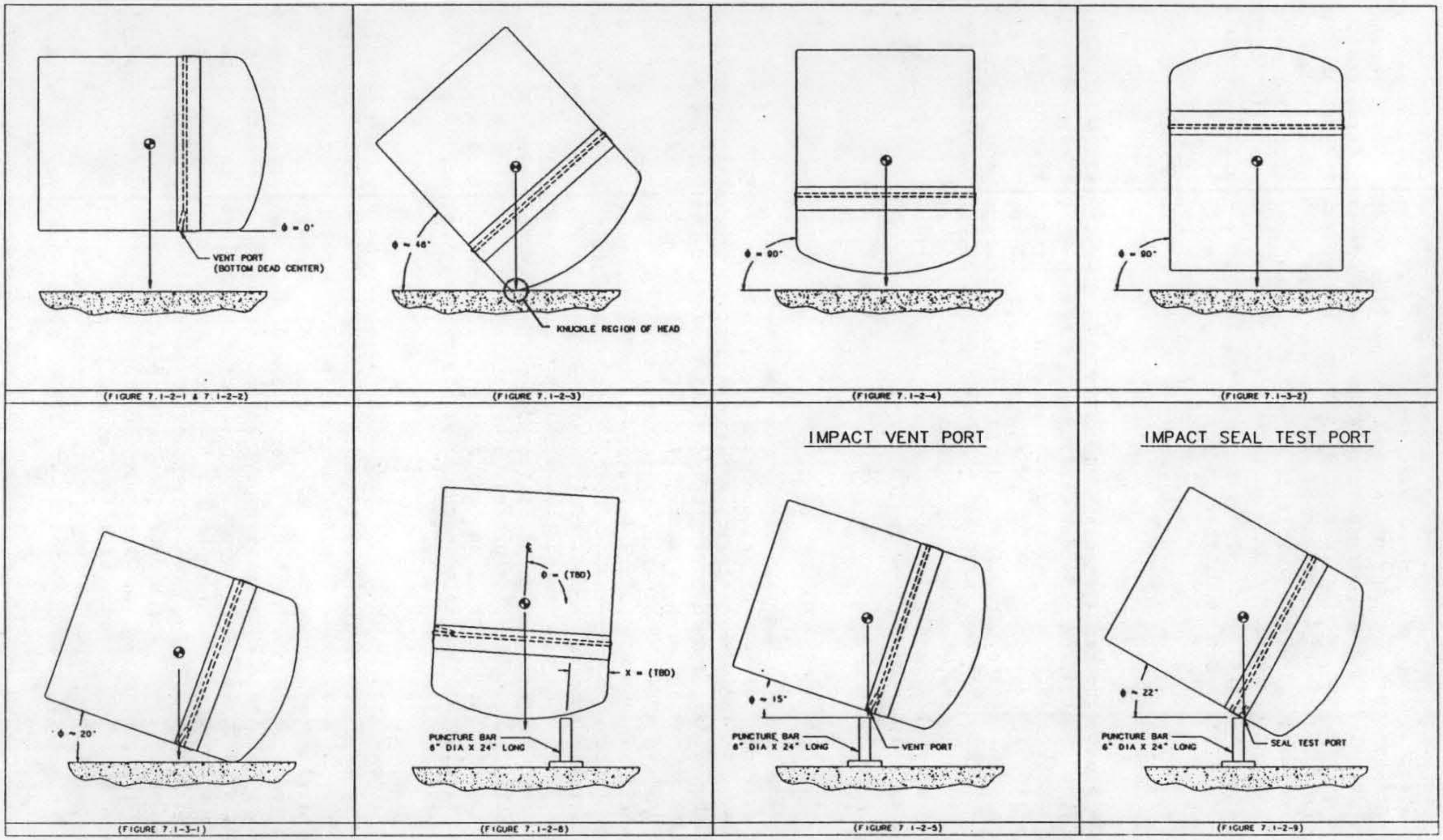
LICENSING APPROACH

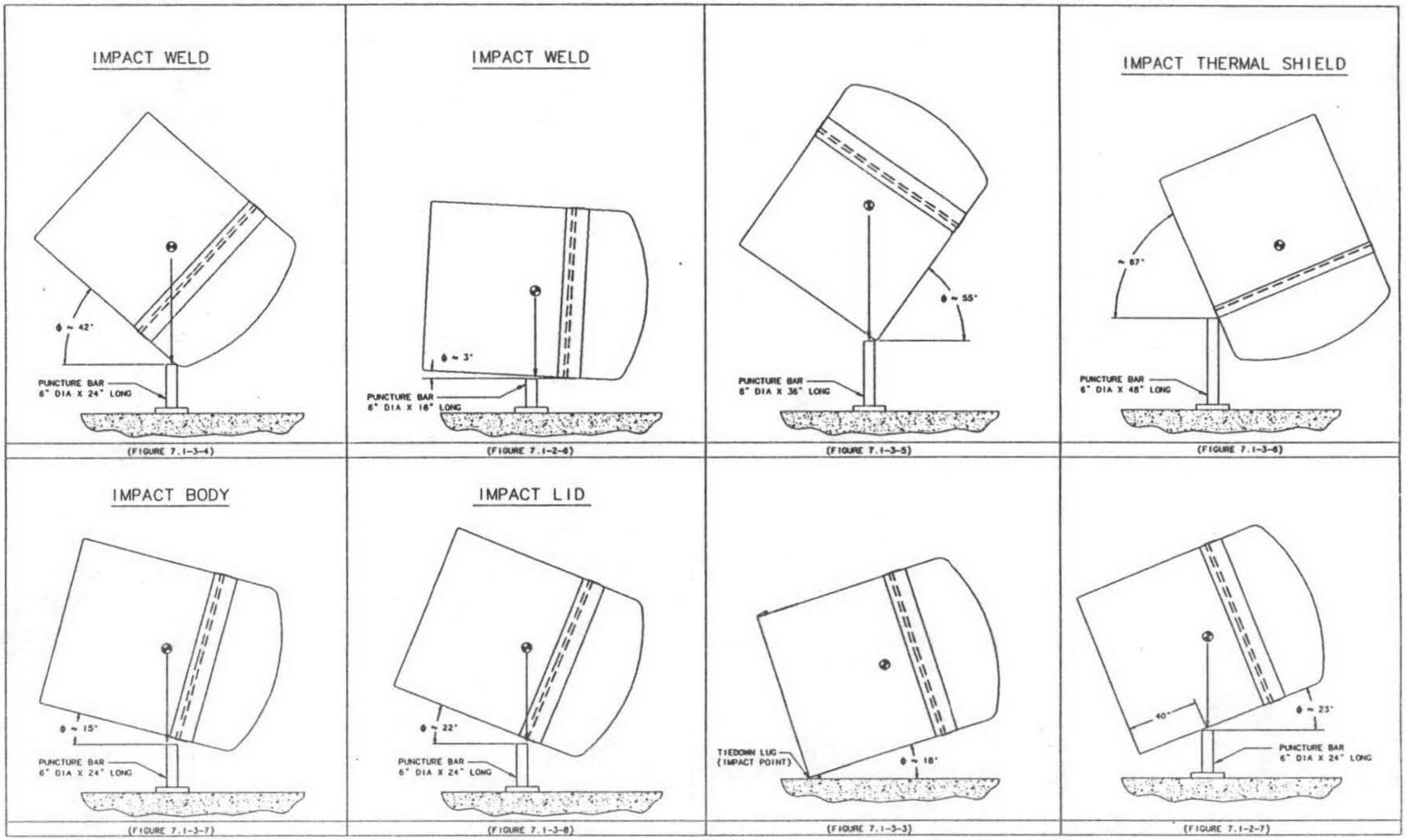
Compliance with the requirements of *10 CFR 71* was demonstrated by a combination of analyses and testing. Normal Conditions of Transport: 1) heat, 2) cold, 3) reduced external pressure, 4) increased external pressure, 5) vibration, 6) water spray, 7) free drop and 10) penetration were all analyzed. Hypothetical Accident Conditions of Transport: 1) free drop, 2) puncture and 3) thermal were tested; 5) immersion was analyzed. Analyses and tests were performed for initial hypothetical accident conditions between -29 °C (-20 °F) and +38 °C (100 °F). A Safety Analysis Report for the TRUPACT-II Shipping Package has been submitted to the NRC for review.

TESTING

Engineering Tests -- Numerous bench tests were conducted to verify the performance of a variety of components associated with the TRUPACT-II design. These tests included characterizing the strength and thermal properties of the polyurethane foam, and comparing the sealing capability of various O-ring materials at temperatures between -29 °C (-20 °F) and +204 °C (400 °F). Foam/stainless steel combinations were tested in 3/10 scale to develop the outer shell for optimum puncture resistance and minimum weight. Free drop and puncture tests were performed on both 1/2 and 3/4 scale models to confirm the puncture resistance of the OCA outer body and domed head. A full scale mock-up of the sealing area was destructively tested to demonstrate the effectiveness of the seal design during gross distortion of the head/body closure. A full scale TRUPACT-II engineering prototype was tested, prior to the start of full scale certification testing, to demonstrate the general worthiness of the design to withstand multiple sequences of the hypothetical accident conditions and a fully engulfing pool fire.

Certification Tests -- Three full scale TRUPACT-II packages, each loaded with 3,200 kg (7,000 pounds) of concrete in 14 drums, were tested at SNL. The tests were used to: 1) confirm the drop and puncture bar performance features, 2) demonstrate the O-ring seal performance at cold temperatures, 3) prove the effectiveness of the O-ring seals after drop and puncture tests, 4) demonstrate the ability of the ICV to survive payload impacts, and 5) demonstrate performance during a fully engulfing pool fire. The full scale tests consisted of free drops through a distance of 9 m (30 feet) followed by free drops of 1 m (40 inches) onto a 15.2 cm (6 inch) diameter puncture bar; sketches of drop orientations follow. After undergoing multiple free drops and puncture bar impacts, two of the packages were suspended over a pool containing approximately 30,000 l (8,000 gallons) of JP-4 (jet fuel) which burned for more than 30 minutes. The external skin temperature exceeded 800 °C (1,475 °F) during the fire. The maximum seal temperature was 127 °C (260 °F) -- well below allowable for the materials used.


ϕ = 0°
VENT PORT
(BOTTOM DEAD CENTER)
(FIGURE 7.1-2-1 & 7.1-2-2)
ϕ ~ 48°
KNUCKLE REGION OF HEAD
(FIGURE 7.1-2-3)
ϕ = 90°
(FIGURE 7.1-2-4)
ϕ = 90°
(FIGURE 7.1-3-2)
ϕ ~ 20°
(FIGURE 7.1-3-1)
ϕ = (TBD)
X = (TBD)
PUNCTURE BAR
6" DIA X 24" LONG
(FIGURE 7.1-2-8)
IMPACT VENT PORT
ϕ ~ 15°
PUNCTURE BAR
6" DIA X 24" LONG
VENT PORT
(FIGURE 7.1-2-5)
IMPACT SEAL TEST PORT
ϕ ~ 22°
PUNCTURE BAR
6" DIA X 24" LONG
SEAL TEST PORT
(FIGURE 7.1-2-9)



IMPACT WELD
ϕ ~ 42°
PUNCTURE BAR
6" DIA X 24" LONG
(FIGURE 7.1-3-4)
IMPACT WELD
ϕ ~ 3°
PUNCTURE BAR
6" DIA X 18" LONG
(FIGURE 7.1-2-6)
ϕ ~ 55°
PUNCTURE BAR
6" DIA X 36" LONG
(FIGURE 7.1-3-5)
IMPACT THERMAL SHIELD
~ 67°
PUNCTURE BAR
6" DIA X 48" LONG
(FIGURE 7.1-3-6)
IMPACT BODY
ϕ ~ 15°
PUNCTURE BAR
6" DIA X 24" LONG
(FIGURE 7.1-3-7)
IMPACT LID
ϕ ~ 22°
PUNCTURE BAR
6" DIA X 24" LONG
(FIGURE 7.1-3-8)
TIEDOWN LUG
(IMPACT POINT)
ϕ ~ 18°
(FIGURE 7.1-3-3)
40°
ϕ ~ 23°
PUNCTURE BAR
6" DIA X 24" LONG
(FIGURE 7.1-2-7)

Initial Conditions -- Hypothetical accident condition tests were conducted at ambient temperature on the first unit. The second and third units were chilled to -29 °C (-20 °F) prior to the first drop and again prior to the final leak test. The first and second units were preheated to 49 °C (120 °F) before the pool fire.

Results -- In order to demonstrate that there will be no release of contents during normal or hypothetical accident conditions of transport both ICV and OCV must remain leaktight; this is commonly referred to as "double containment". The test program was originally divided between two packages. On the first test unit both the ICV and OCV were leaktight. On the second test unit the OCV was leaktight but the ICV was not due to a test induced problem with debris interfering with the ICV containment boundary (upper) seal. A wiper O-ring was added to the ICV on a third test unit and its effectiveness was demonstrated by repeating the second test unit sequence, except for the pool fire. Both the OCV and the ICV were leak tested before and after each test sequence. At the conclusion of the tests, all containment boundaries were leaktight.

CONCLUSIONS

TRUPACT-II will provide a safe and efficient method for the transport of CH-TRU waste. The many technical and programmatic challenges were solved by personnel from DOE, WID, SNL and NuPac working together to find solutions whenever problems were identified. It was this team approach which made the design and testing of TRUPACT-II successful

REFERENCES

Packaging and Transportation of Radioactive Materials -- 10 CFR, Part 71; U.S. Nuclear Regulatory Commission, Rockville, MD (1983)

American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment -- ANSI N14.5; American National Standards Institute, New York, NY (1987)

TRUPACT-II Content Codes (TRUCON) -- DOE/WIPP 89-004; U.S. Department of Energy, Washington, DC (1989)

Safety Analysis Report for the TRUPACT-II Shipping Package -- NRC Docket No. 71-9218; Nuclear Packaging, Inc., Federal Way, WA (1989)