Nuclear Criticality Safety Evaluation for Remote-Handled Transuranic Waste Containers at the Waste Isolation Pilot Plant

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Nuclear Criticality Safety Evaluation for Remote-Handled Transuranic Waste Containers at the Waste Isolation Pilot Plant

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Executive Summary

This Nuclear Criticality Safety Evaluation (NCSE) of the Waste Isolation Pilot Plant (WIPP) facility remote-handled (RH) transuranic waste handling, storage, and disposal process provides a comprehensive analysis of waste forms, container types, and container storage, handling, and disposal configurations at the WIPP.

RH waste can be shipped to the WIPP from the U.S. Department of Energy generator sites in the 72-B or 10-160B shipping container. The 72-B container holds one 72-B canister. The 10-160B container holds two drum carriages with 5 drums of RH waste in each carriage. The container is designed to hold either 30- or 55-gallon drums. The waste containers are not removed from the containers until the containers are within the hot cell complex of the WIPP waste handling building.

The 72-B canister is transferred from the shipping container to the facility cask for subsequent transfer to the underground where the RH canister is disposed of in a borehole that was previously drilled into the walls of the disposal room. The drums from the 10-160B shipping container are transferred to the upper hot cell where they are then placed into a facility canister. The canister holds 3 drums. The loaded canister is then moved to the transfer cell in the lower portion of the hot cell complex where it, similar to the 72B canister, is then moved into the facility cask for subsequent transfer to the underground for disposal.

This NCSE considers the RH waste container handling process and permanent disposal of these waste containers. The evaluation considers the possible interactions between the different waste forms in the waste drums and canisters. The NCSE includes a double-contingency evaluation for credible upset scenarios and identifies the appropriate controls. The evaluation concludes that no credible criticality accident scenarios exist for the RH transuranic waste container storage, handling, and disposal process at the WIPP. Because the evaluation also demonstrates that a criticality at the WIPP is not credible, criticality alarm and detection systems are not required. The controls that ensure a criticality accident remain not credible at the WIPP are presented in Section 9.0.

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List of Acronyms

AEOF	average energy of fission
ANS	American Nuclear Standards
ANSI	American National Standards Institute
ASTM	American Society of Testing and Materials
C of C	Certificate of Compliance
CUR	cask unloading room
CH	contact handled
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FCLR	facility cask loading room
FCTC	facility cask transfer car
FEM	fissile equivalent mass
FGE	fissile gram equivalence
H/D	height to diameter
HDPE	high density polyethylene
HERE	Horizontal Emplacement and Retrieval Equipment
LEU	low enriched uranium
NaCl	sodium chloride
NCS	Nuclear Criticality Safety
NCSE	Nuclear Criticality Safety Evaluation
NRC	Nuclear Regulatory Commission
RCTC	road cask transfer car
RH	remote handled
RH-TRAMPAC	Remote Handled Transuranic Waste Authorized Methods for Payload Control
SAR	Safety Analysis Report
TRU	transuranic

USL	upper subcritical limit
WAC	Waste Acceptance Criteria
WHB	Waste Handling Building
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions
WDS	WIPP Waste Data System

1.0 Introduction

The Waste Isolation Pilot Plant (WIPP) facility serves as a final repository for transuranic (TRU) waste generated at various U.S. Department of Energy (DOE) sites. The majority of waste to be disposed of at the WIPP is TRU waste with plutonium as the primary TRU element. Two categories of waste, contact handled (CH) and remote handled (RH) are approved for disposal at the WIPP. Contact handled waste containers have surface radiation dose rates not exceeding 200 mrem/hr and are handled directly by human operators. Remote handled waste containers have surface radiation dose rates up to 1,000 rem/hr. This Nuclear Criticality Safety Evaluation (NCSE) establishes a nuclear criticality safety basis for the handling and disposal of RH waste containers at the WIPP facility.

Remote handled TRU waste will be shipped to the WIPP in Nuclear Regulatory Commission (NRC) certified Type B shipping packages (RH-TRU 72-B and 10-160B shipping containers). The 72-B shipping container encloses a single steel 72-B canister capable of holding loose, direct loaded waste or three waste drums. The 10-160B shipping container is designed to provide containment for shipment of RH TRU waste shipped in 30- or 55-gallon drums. The 10-160B shipping container can transport ten 30- or 55-gallon drums of RH TRU waste in two stacked-drum carriage units holding 5 drums each. The 72-B canister, 30-gallon and 55-gallon drums meet U.S. Department of Transportation (DOT)-Type A or equivalent requirements.

The fissile material and special reflector loading limits of the 72-B shipping container are defined in Section 6.0 of the *Safety Analysis Report for the RH-TRU 72-B Waste Shipping Package* (DOE-CBFO 2010a), Section 6.0. The ^{239}Pu fissile gram equivalence (FGE) limits for the direct-loaded 72-B canister used in this analysis are taken from the Safety Analysis Report (SAR). For drums of waste received in RH-72-B canisters or received in the 10-160B container and loaded into facility canisters, the Waste Acceptance Criteria (WAC) limits for CH waste in 55-gallon drums are evaluated in order to provide a consistent limit set between RH and CH waste at WIPP. The ^{239}Pu FGE factors are defined in Section 3.1.2 of the *Remote Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC)* (DOE-CBFO 2010b), which implements equivalence factors using *Nuclear Criticality Control of Special Actinide Elements* (American National Standards Institute [ANSI/ANS]-8.15) and *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* (ANSI/ANS-8.1). The fissile material is assumed to be 100% ^{239}Pu for this evaluation. Because ^{239}Pu has the smallest minimum critical mass of the nuclides available in significant quantity, modeling ^{239}Pu bounds any potential combination of fissile isotopes that may be loaded in accordance with the RH-TRU 72-B package SAR requirements (DOE-CBFO 2010a). The methodology for calculating the fissile equivalent mass (FEM) in the low enriched uranium (LEU) payload is also given in Section 3.1.2 of the RH-TRAMPAC, consistent with the references above and *Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors* (ANSI/ANS-8.12).

This NCSE provides a nuclear criticality safety basis for the receipt, process handling, conveyance to, and permanent disposal of the RH waste containers. Specifically, this NCSE addresses various bounding geometric configurations for the fissile mass and associated reflector matrix combinations within the RH waste containers and/or canisters in both the upper hot cell processing area of the Waste Handling Building (WHB) and the borehole complex in the underground repository disposal rooms and disposal panel access drifts. The RH waste package contents include non-compacted fissile mixtures with ≤ 1 wt% special reflector materials and with unlimited quantities of beryllium or graphite, and compacted waste streams with ≤ 1 wt% special reflector materials. A LEU payload is also allowed provided the maximum enrichment is ≤ 0.96 wt% ^{235}U FEM of distributed fissile isotopes in the non-fissile ^{238}U. The analysis considers full reflection by concrete, lead and salt to represent reflection conditions in the hot cell, during transport to the underground in a facility cask and emplaced in the salt borehole. Staging of drums in the upper hot cell processing area is evaluated using concrete reflection.

The evaluation also considers the possible interactions of RH-TRU waste with arrays of CH-TRU waste. The NCSE includes a double contingency evaluation for credible upset scenarios and identifies the appropriate controls. The evaluation concludes that no credible criticality accident scenarios exist for the RH-TRU waste container handling, processing, and disposal activities at the WIPP, and thus demonstrates that a criticality accident at the WIPP is not credible such that criticality alarm and detection systems are not required. The controls that ensure a criticality accident remain not credible at the WIPP are presented in Section 7.0.

2.0 Facility and Process Descriptions

2.1 WIPP Facility

The WIPP site, which is located in southeastern New Mexico 26 miles east of Carlsbad, serves as a final repository for TRU waste generated at other DOE sites and demonstrates the feasibility of safe disposal of radioactive wastes in deep underground salt formations. The site is owned by DOE and operated by Washington TRU Solutions (WTS). The WIPP facility is divided into three basic areas, namely: surface structures, shafts, and subsurface structures. The WIPP surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of TRU waste from the surface to the underground. The surface structures are located in an area within a perimeter security fence. The surface waste handling operations at the WIPP are conducted in the WHB, which is divided into the CH-TRU waste handling area, the RH-TRU waste handling area, and support areas. The only above-ground facility included in the scope of this analysis is the WHB. The remaining surface facilities are not used for processing RH or CH shipping containers or waste containers.

The RH portion of the WHB contains a series of rooms, referred to as the hot cell complex, with thick concrete walls, floors, ceilings, shield glass viewing windows, steel shield valves, steel shield doors, and a large concrete and steel shield door which segregates it from the remainder of the WHB. The hot cell complex walls are 36 to 54-in (~137 cm) thick and provide a shielded location for handling RH canisters or drums outside of a shielded shipping container or the

shielded facility cask. Within the hot cell complex is the cask unloading room (CUR), the lower hot cell, the upper hot cell, the crane maintenance room, and the transfer cell. The upper hot cell above the CUR will be used to place drums shipped in a 10-160B shipping container into facility canisters such that the facility canister can be handled in the same way as the 72-B canisters. The upper hot cell has 9 storage locations for canisters, but due to storage limits imposed by the WIPP Hazardous Waste Facility Permit, a maximum of 12 drums is allowed in the upper hot cell. A facility canister holds three 30- or 55-gallon drums. The upper hot cell provides temporary storage for unloaded drums; space for loading drums into facility canisters; and a station for the inspection of the physical integrity of the drums, the performance of a radiological contamination survey, and identification verification of each drum. The upper hot cell also includes space for overpacking a 72-B canister; however, there are no plans at this time for that operation. Figure 2-1 illustrates the RH surface facilities and the WHB complex.

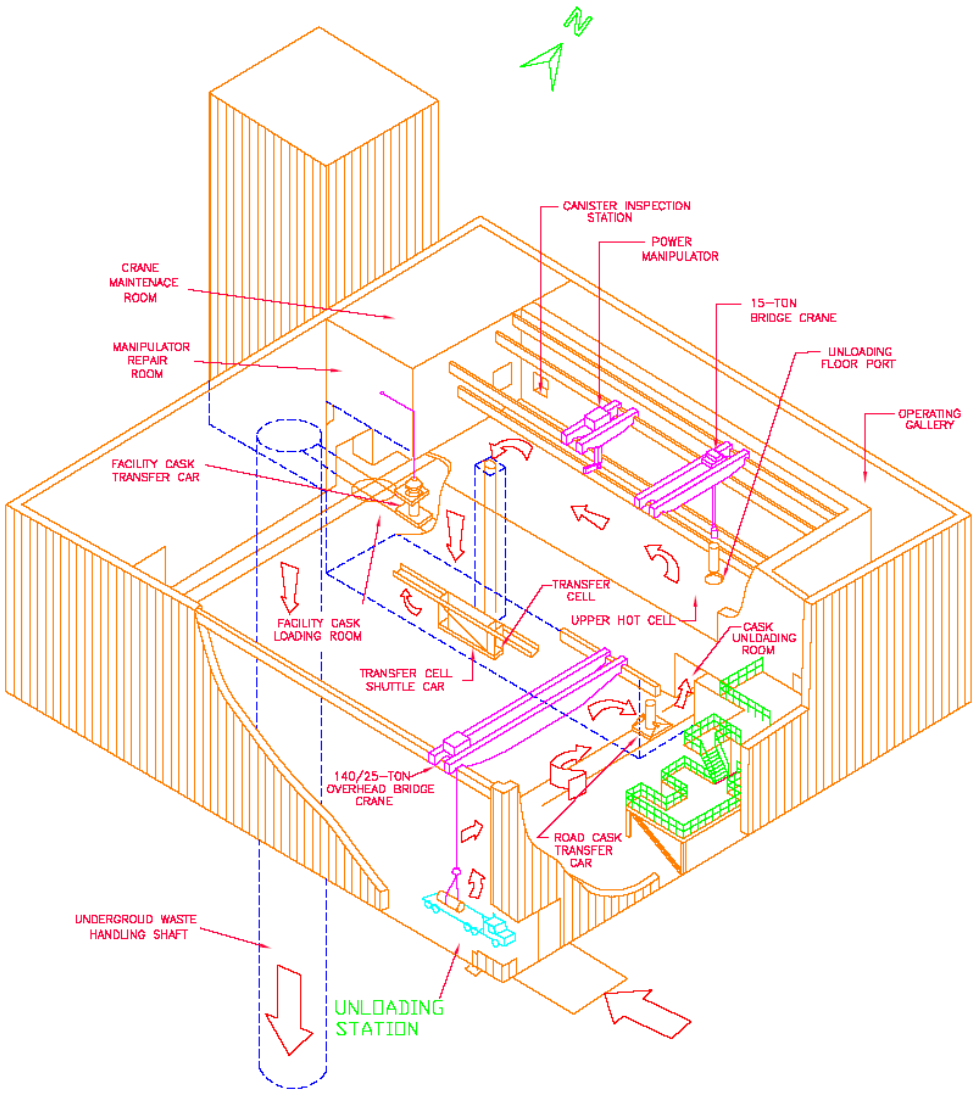


Figure 2-1, Pictorial View of the RH Surface Facilities

The vertical shafts extending from the surface to the underground storage area are the waste shaft, the salt handling shaft, the exhaust shaft, and the air intake shaft. Only the waste shaft is used for moving the waste from the surface to the underground. The waste shaft is located between the CH TRU and RH TRU areas in the WHB. It is nominally 19 ft (~5.8 m) in diameter and is serviced by a hoist utilizing a conveyance that is designed to accommodate a facility pallet of CH waste or the RH facility cask. The conveyance also has a man deck that is used for transport of personnel. TRU waste and personnel are not transported at the same time. The waste shaft conveyance is also used to transport other equipment to the underground, but not at the same time that waste or personnel are being transported. Figure 2-2 summarizes the general layout of the surface and underground structures and the shafts connecting them.

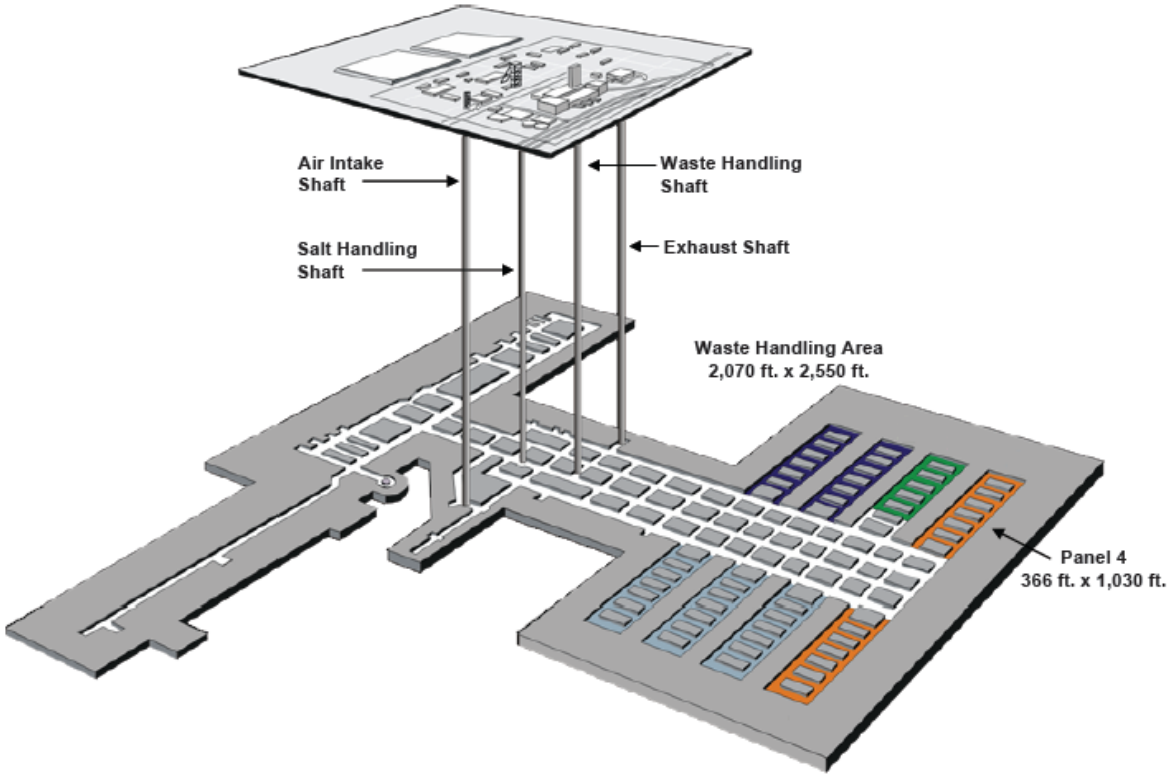


Figure 2-2, General Layout of Surface, Shaft and Underground Structure

The underground areas consist of the waste disposal area and the support area. The underground has four main entries (two entries for fresh air and two entries for return air). The layout of the shafts and entries and associated ventilation allows mining and disposal operations to proceed simultaneously. The first disposal panel is used to dispose waste while the next panel is being mined. Successive stages follow in a similar order.

A typical disposal panel consists of seven disposal rooms as shown in Figure 2-3. Each room is nominally 33 ft (~10 m) wide, 13 ft (~4 m) high, and 300 ft (~91.5 m) long. The disposal rooms are separated by pillars of salt 100 ft (~30.5 m) wide and 300 ft (~91.5 m) long. Panel entries at

the end of each of these disposal rooms are also 33 ft (~10 m) wide and 13 ft (~4 m) high and are used for waste disposal, except for the first 200 ft (~61 m) which is used for installation of the panel closure. The salt beds are 95% sodium chloride (NaCl) salt, with some interspersed clay.

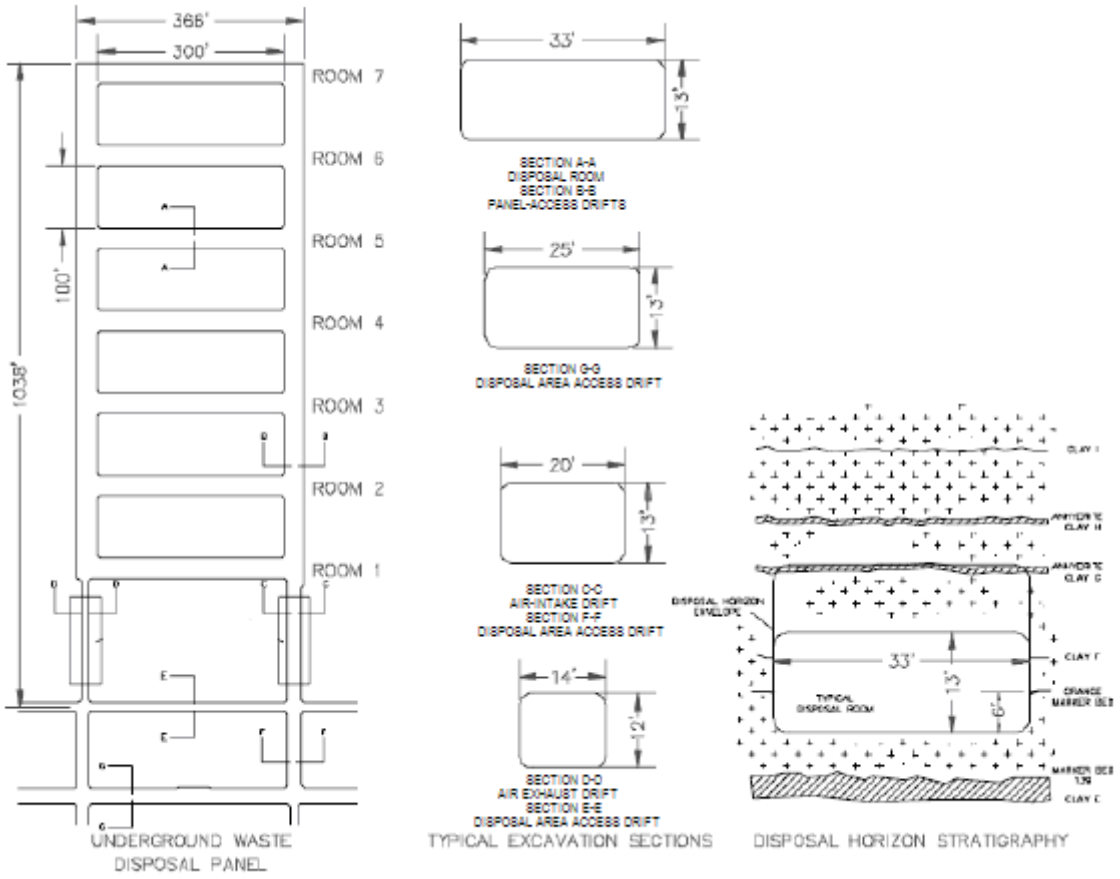


Figure 2-3, Typical Underground Repository Disposal Panel Layout

The RH canisters are placed in individual boreholes in the walls of the disposal rooms and access drifts. The boreholes are nominally spaced 8 ft center-to-center. CH waste container placement in rooms and access drifts will occur after placement of RH waste containers in those individual rooms and drifts. That is, a RH waste container cannot be placed in a given borehole once CH waste containers have been placed in front of the borehole locations. Figure 2-4 illustrates the RH and CH waste storage configuration in a typical panel of the underground repository complex.

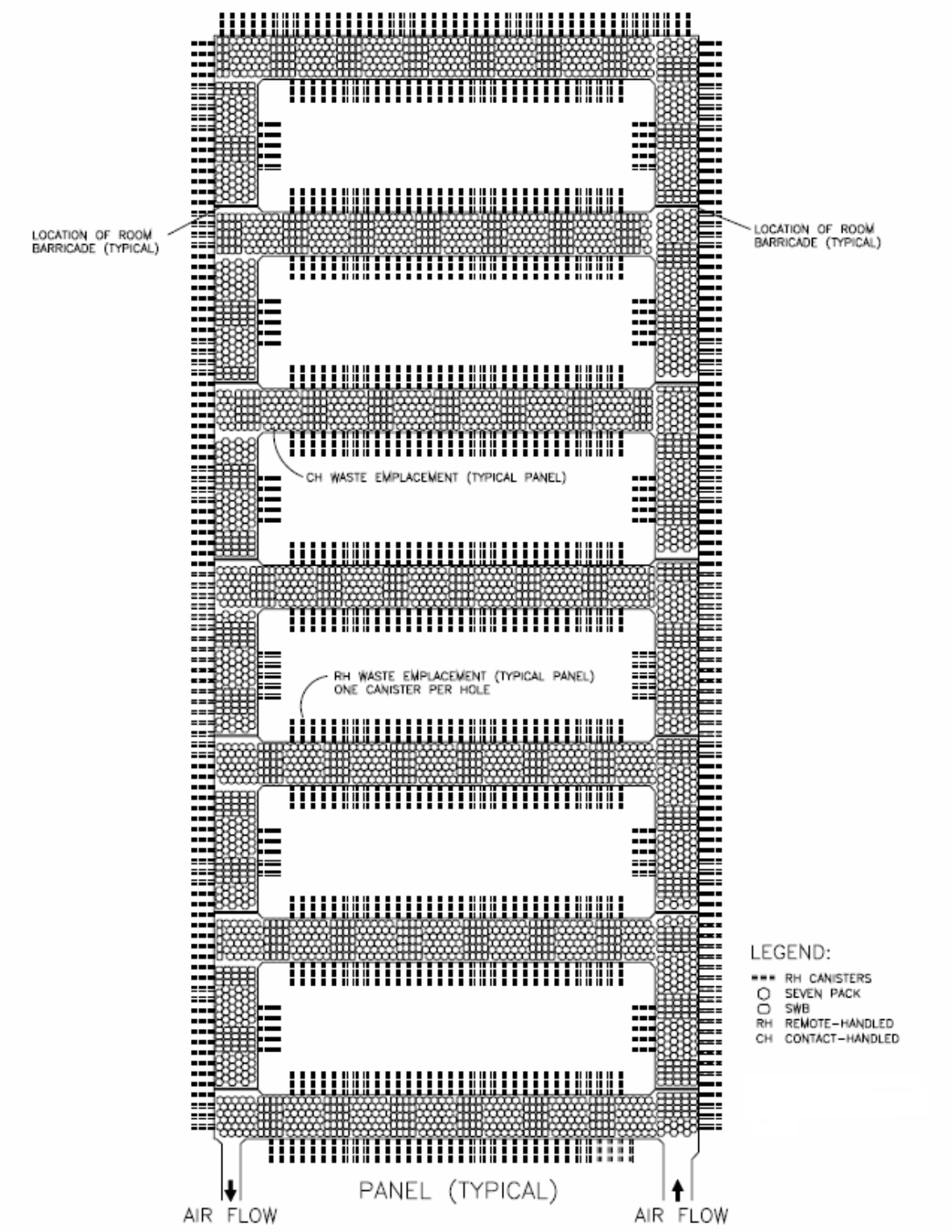


Figure 2-4, General Layout of RH and CH Waste Disposal in a Typical Panel of the Underground Repository

2.2 Description of Waste Containers

2.2.1 RH-TRU 72-B Shipping Container and Associated Waste Canister

The 72-B waste canister is a DOT Type A (or equivalent) container. It is a steel single-shell container with an outside diameter of 26 in. (66 cm), a wall thickness of 0.25 in. (0.64 cm), and an overall length of 120 in. (3.05 m) minimum to 121 in. (3.07 m) maximum. The canister has an inside diameter of 25.5 in. (64.77 cm) with an inside length of 108 in. (2.74 m). The 72-B canister has either a welded lid, nominally 0.375 in. (0.95 cm) thick, or a thicker removable lid. Both types of lids are equipped with a WIPP standard lift pintle. The canister is vented using filter vents. The 72-B canister holds up to three 30- or 55- gallon drums of radioactive waste or can be direct loaded with loose waste. The maximum gross weight of the canister is 8,000 lbs (3,628.7 kg). The empty weight is approximately 1,762 lb for the canister with a fixed lid and 1,100 lb for the canister with the removable lid as noted in Section 2.8 of the RH-TRAMPAC (DOE-CBFO 2010b). Figure 2-5 and Figure 2-6 summarize the pertinent features of the 72-B shipping container and associated payload canister. Figure 2-8 shows a photograph of a 72-B shipping canister on a transport arriving at the WIPP facility.

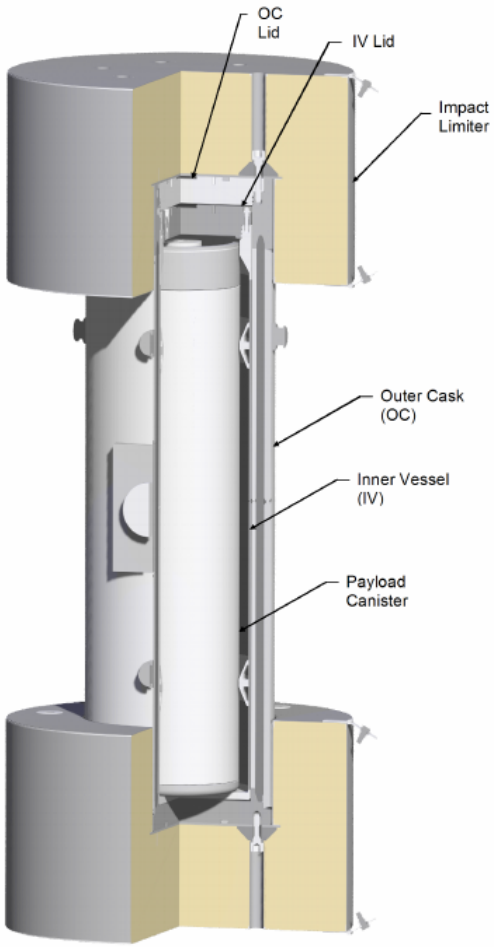


Figure 2-5, RH-TRU 72-B Shipping Container and Associated Payload Canister

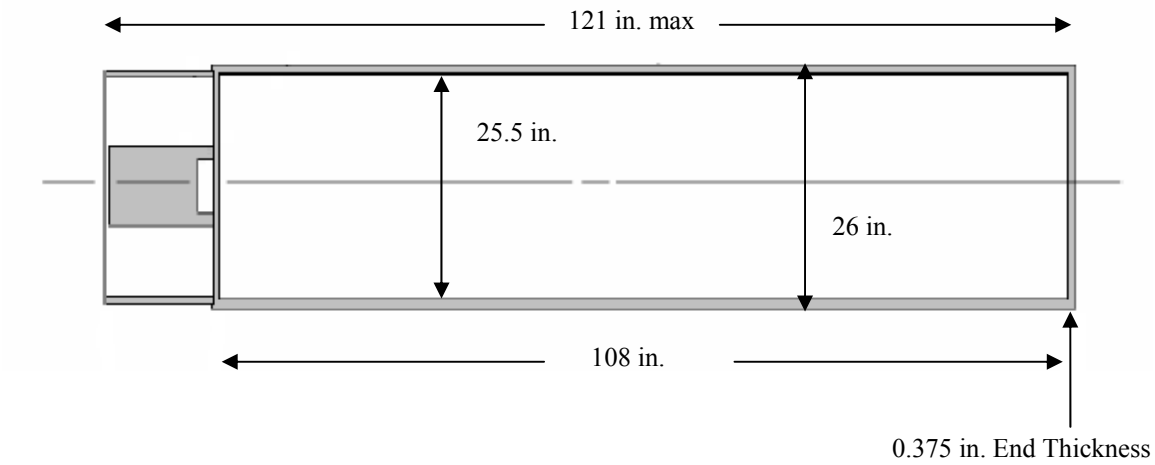


Figure 2-6, 72-B Canister Dimensions

2.2.2 CNS 10-160B Container

The CNS 10-160B container is designed to meet DOT Type B container requirements and consists of two carbon steel shells and a lead shield, welded to a carbon steel bottom plate. A 12-gauge stainless steel thermal shield surrounds the container outer shell, which is equipped with two steel-encased, rigid polyurethane foam impact limiters attached to the top and bottom of the container. The CNS 10-160B container is not vented. Payload capacity of each CNS 10-160B container is 14,500 lbs (6,577 kg). The payload consists of up to ten 30- or 55-gallon drums. The NRC Certificate of Compliance (C of C) for the 10-160B shipping container limits the load to 20 Pu Equivalent Ci content. If the total Ci content is Pu, the maximum loading limit for the container would be 318 FGE ^{239}Pu. No internal package limits are specified for fissile mass, beryllium, or graphite content in the 10-160B C of C.

The CNS 10-160B drum carriage is a steel device used to handle drums in the CNS 10-160B container. The drum carriages are stacked two high in the CNS 10-160B container during shipment. They are removed from the container using a below-the-hook lifting device termed a pentapod. The drum carriage is rated to lift up to five drums with a maximum weight of 1000 pounds each.

Figure 2-7 illustrates the general features of the CNS 10-160B shipping container. Figure 2-8 shows a photograph of the CNS 10-160B shipping container on a transport arriving at the WIPP facility.

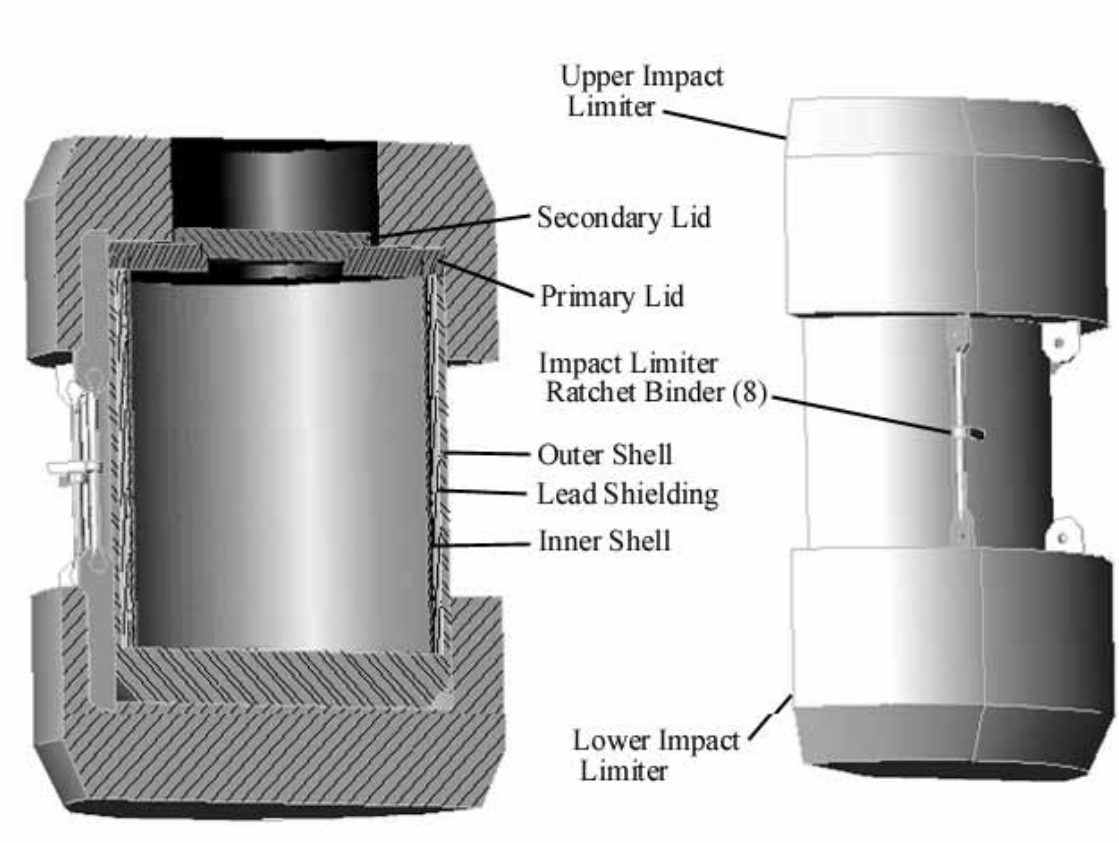


Figure 2-7, CNS 10-160B Shipping Container

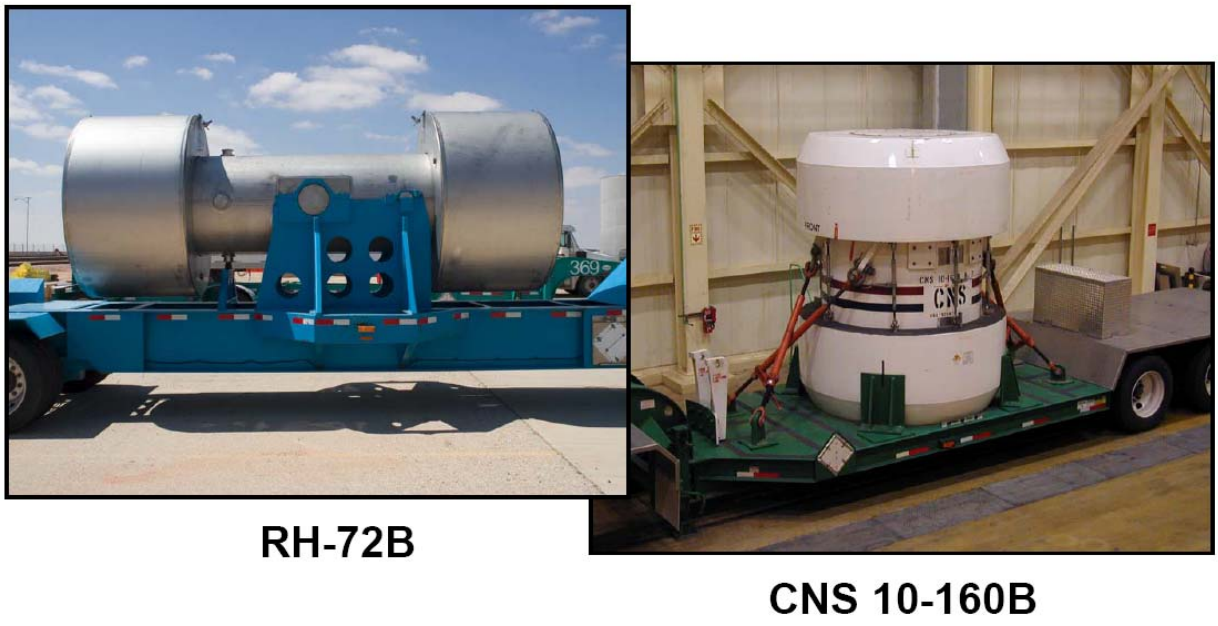


Figure 2-8, RH-TRU 72-B and CNS 10-160B Shipping Containers Arriving at WIPP

2.2.3 Facility Canister

The facility canister is a carbon steel single-shell container weighing approximately 981 lb (444.5 kg), with a nominal outside diameter of 28.5 in. (72.4 cm), a wall thickness of 0.25 in. (0.635 cm), and an overall length of nominally 120 in. (304.8 cm). It has an inside diameter of 28 in. (71.1 cm) with an inside length of 110 in. (279.4). The flat head with integral WIPP standard lift pintle is attached to the shell after the container is filled with waste. The canister can hold three 30- or 55-gallon drums of RH waste with a maximum (including canister) weight of 4,000 lb (1,814.4 kg). Drums received in the 10-160B are placed into the facility canister in the upper hot cell. Then the facility canister is handled in the same way as the 72-B canister. Figure 2-9 illustrates the nominal facility canister dimensions.

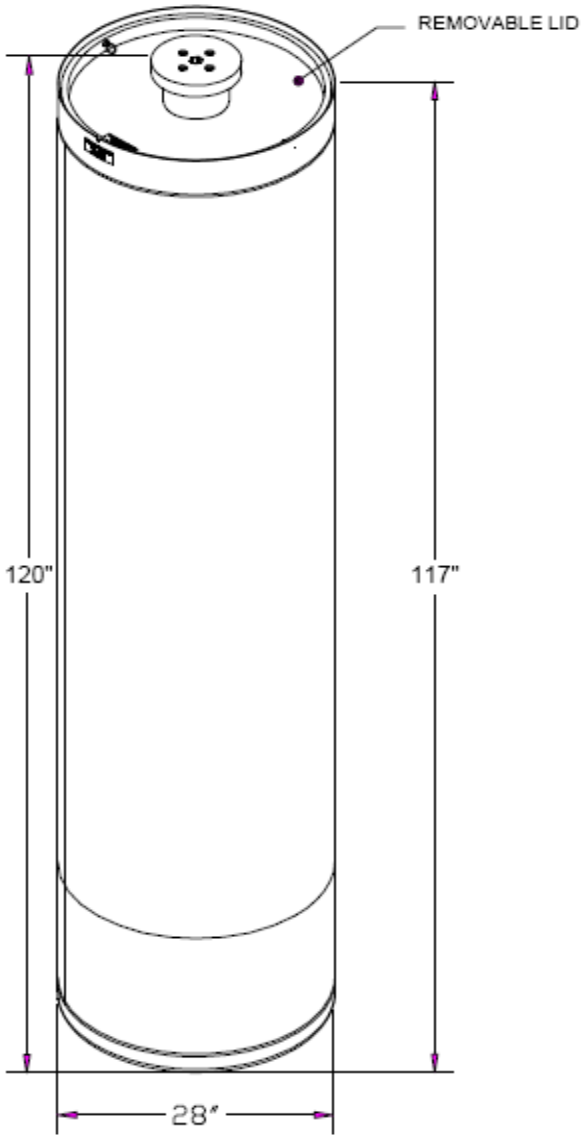


Figure 2-9, WIPP Facility Canister for the Disposal of RH Waste

2.2.4 30-Gallon and 55-Gallon Drums

RH waste in the 72-B and facility canisters can be packaged in three (3) individual 30-gallon or 55-gallon drums. The drums shipped in a 10-160B container must meet the requirements for DOT Type A containers. In this NCSE, the 30-gallon drum is used in the computational analysis because with the same FGE loading per drum type, a 30-gallon drum array bounds a 55-gallon drum array or a mixed 30- and 55-gallon drum array configuration due to the smaller 30-gallon drum diameter and hence tighter array packing. The 30-gallon drum is constructed of 304L stainless steel with an 18-gauge (0.0478 in. nominal) wall thickness. The drum has an inner diameter of 18 in. and an interior height of 28 in.

2.2.5 NS30 and NS15 Neutron Shielded Canisters

The NS30 and NS15 canisters are neutron shielded augmentations of the removable lid RH-TRU 72-B canister (see Section 2.2.1). The two configurations provide different levels of supplemental neutron shielding for 15- and 30-gallon inner containers (drums). As illustrated in Figure 2-9a, the NS30 neutron shielded canister incorporates the NS30 neutron shield insert which consists of HDPE top and bottom end caps (nominally 5 inches thick) with an integral open-cell urethane filter/gasket and a 24-inch outside diameter cylindrical pipe body (nominally 1.454 inches thick). The minimum thickness of HDPE neutron shielding provided by the body is 1.412 inches. The NS30 is designed to carry three approximately 30-gallon steel payload drums with internal lever-lock closures, with each drum and its contents limited to approximately 480 pounds. As illustrated in Figure 2-9b, the NS15 neutron shielded canister is essentially identical to the NS30 with appropriate modification to accommodate a thicker 24-inch outside diameter cylindrical HDPE insert (nominally 3.387 inches thick) with 3.288 inches minimum thickness. The NS15 canister has an approximate tare weight of 2,070 pounds and maximum gross weight of 3,100 pounds. It is designed to carry three approximately 15-gallon steel payload drums with internal lever-lock closures, with each drum and its contents limited to approximately 335 pounds (DOE-CBFO 2010c).

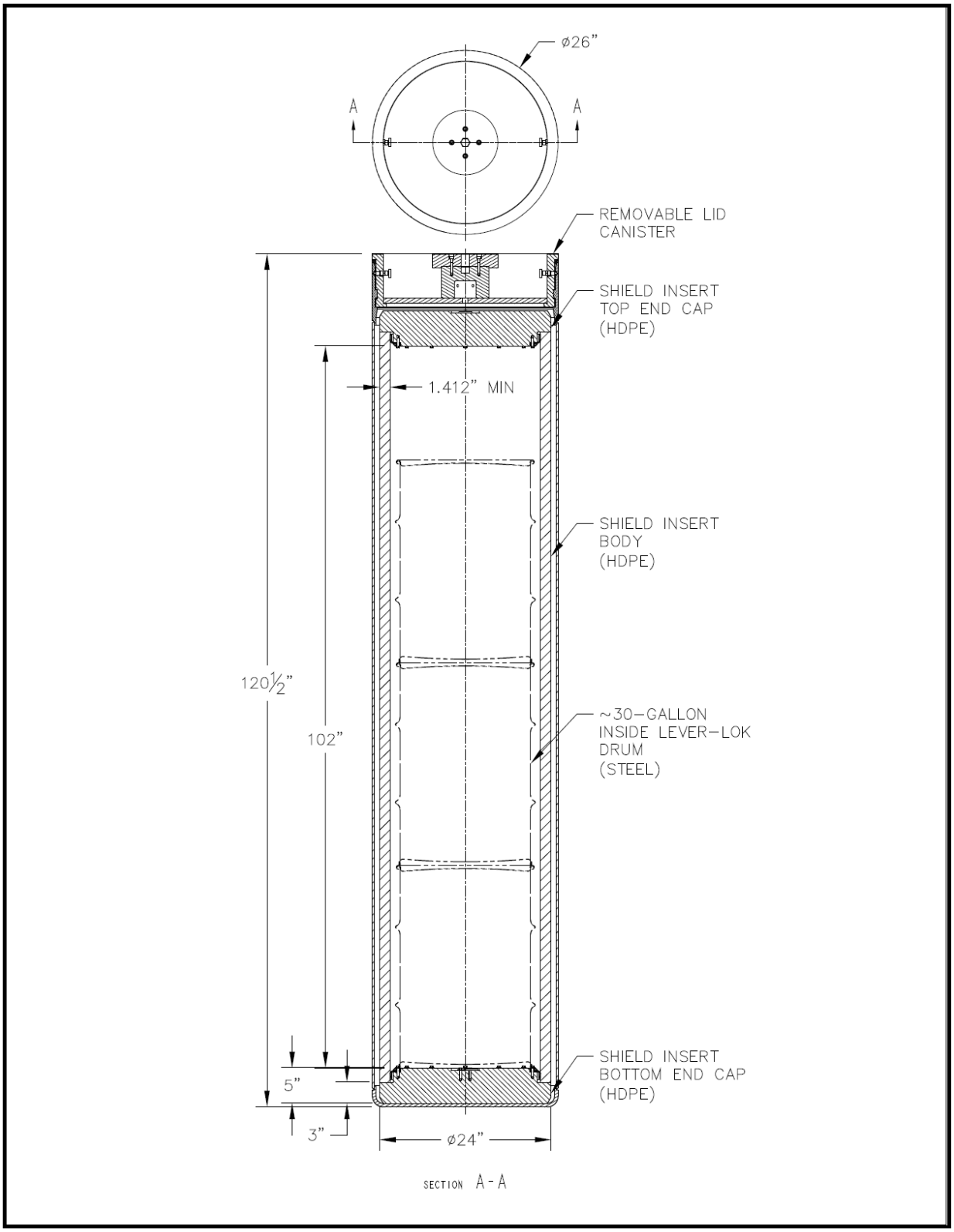


Figure 2-10, NS30 Neutron Shielded Canister

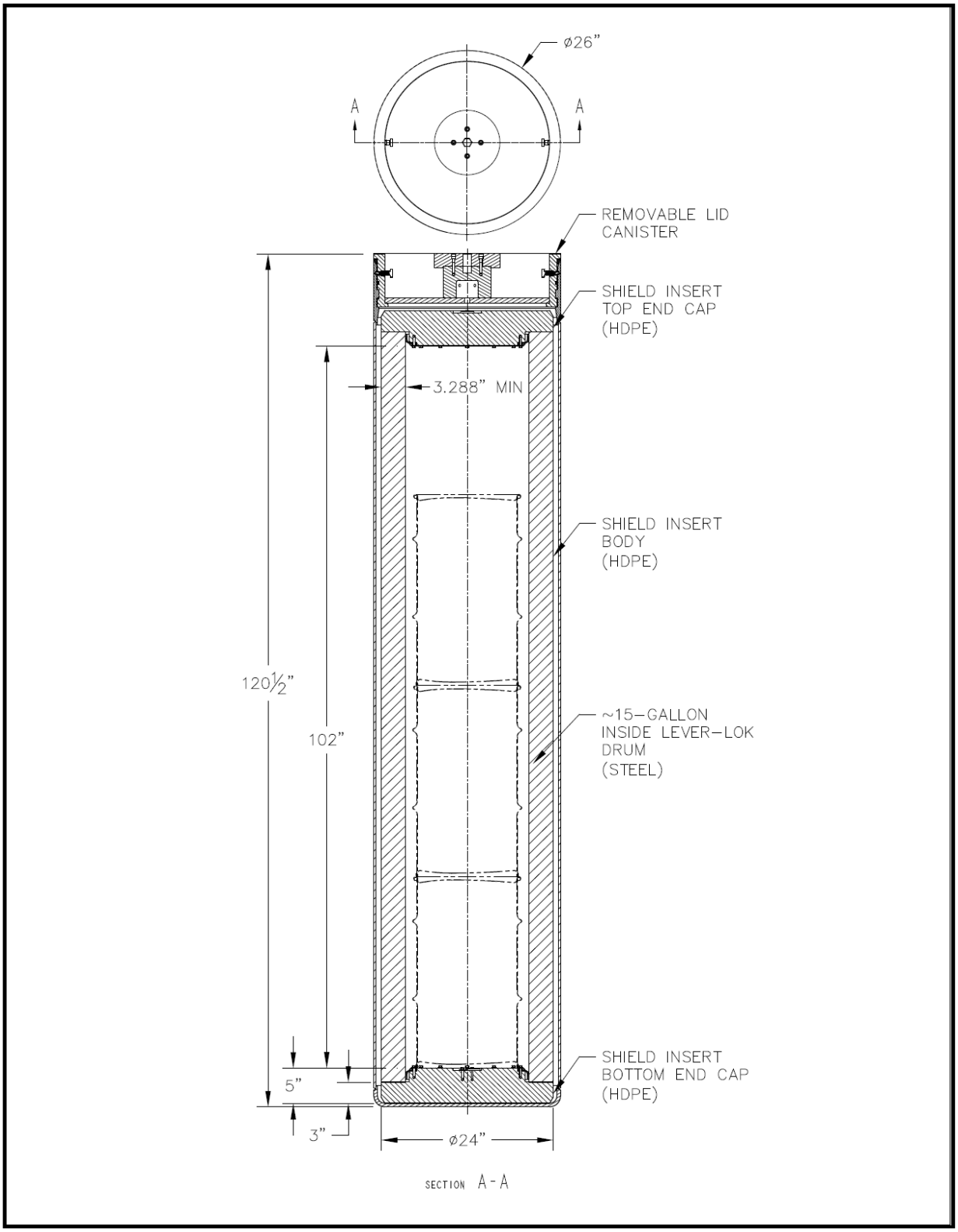


Figure 2-11, NS15 Neutron Shielded Canister

2.3 Waste Handling Equipment

2.3.1 Facility Cask

The facility cask is a massive cask with lead shielding, designed for holding an RH waste canister (either 72-B or a facility canister) from the time it is loaded into the cask in the WHB to the time it is emplaced in the borehole. Figure 2-12 shows a sketch of the facility cask and payload container. The facility cask wall consists of two concentric steel cylinders with the annulus between them filled with lead. The internal cylinder has a 30 in. diameter and a 0.50 in. wall thickness. The outer cylinder has an external diameter of 41.75 in. with a wall thickness of 0.625 in. The lead annulus is 4.75 in. thick. The ends of the casks are 8.61 in. thick steel shield valves that are motor operated for loading and unloading waste canisters. The robustness of the facility cask protects the waste canister from breaches. The facility cask is designed such that it maintains its shielding integrity when dropped from a height of 102 in.

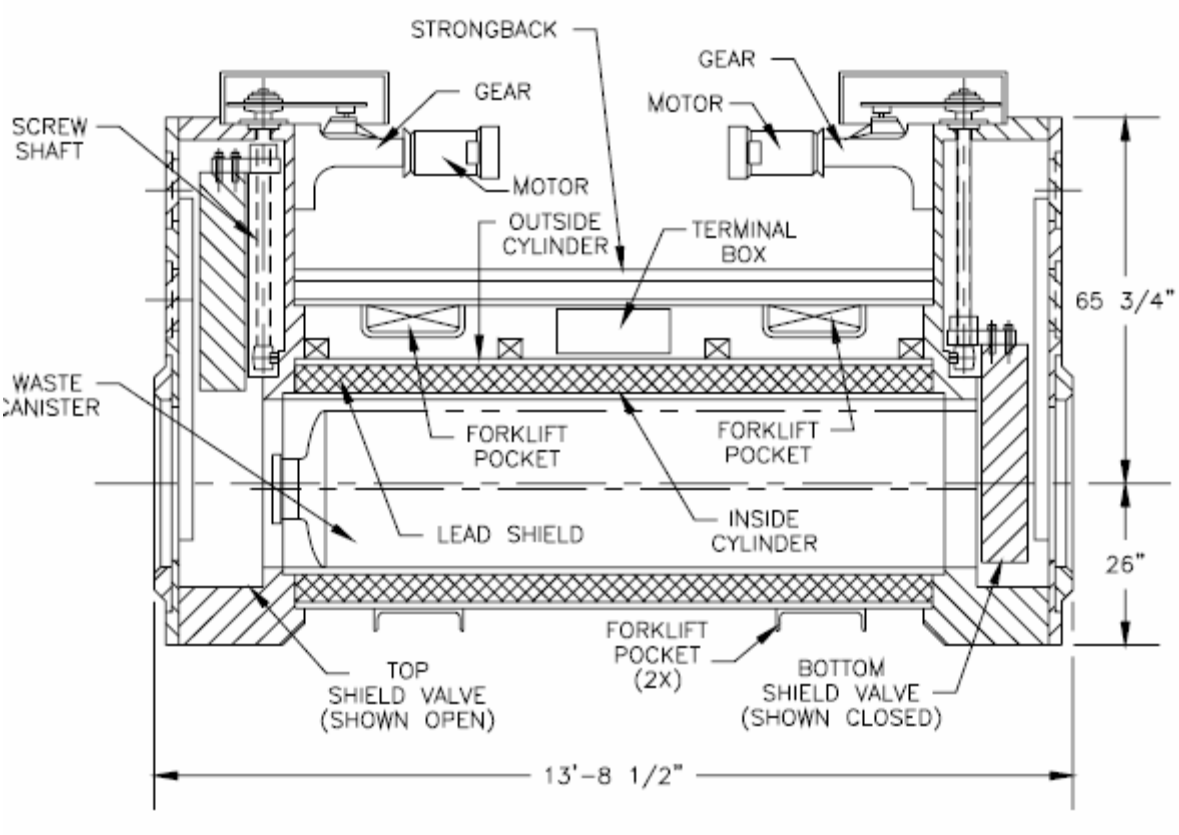


Figure 2-12, Facility Cask Used for Transporting RH Waste to Underground Repository

2.3.2 Light-Weight Facility Cask

The light-weight facility cask (LWFC) (Figure 2.5-31) is a double-end loading shielding container that is used to transport RH canisters containing the average expected RH TRU waste from the FCLR to the underground for emplacement. The LWFC is designed such that it provides radiation shielding for an RH waste canister and serves as secondary containment for RH waste canisters during their transportation through the WIPP facility and emplacement. The LWFC interfaces with the same existing facilities and control systems as the facility cask from separately located operational stations that are placed on the surface and the underground. The LWFC is dimensionally configured in a similar manner to the facility cask with two support trunnions located approximately mid-length at 180 degrees from each other. The trunnions are located to interface with trunnion support points on the FCTC. The LWFC has two similar electric motor operated gate-type shield valves, one at each end for loading and unloading RH waste canisters.

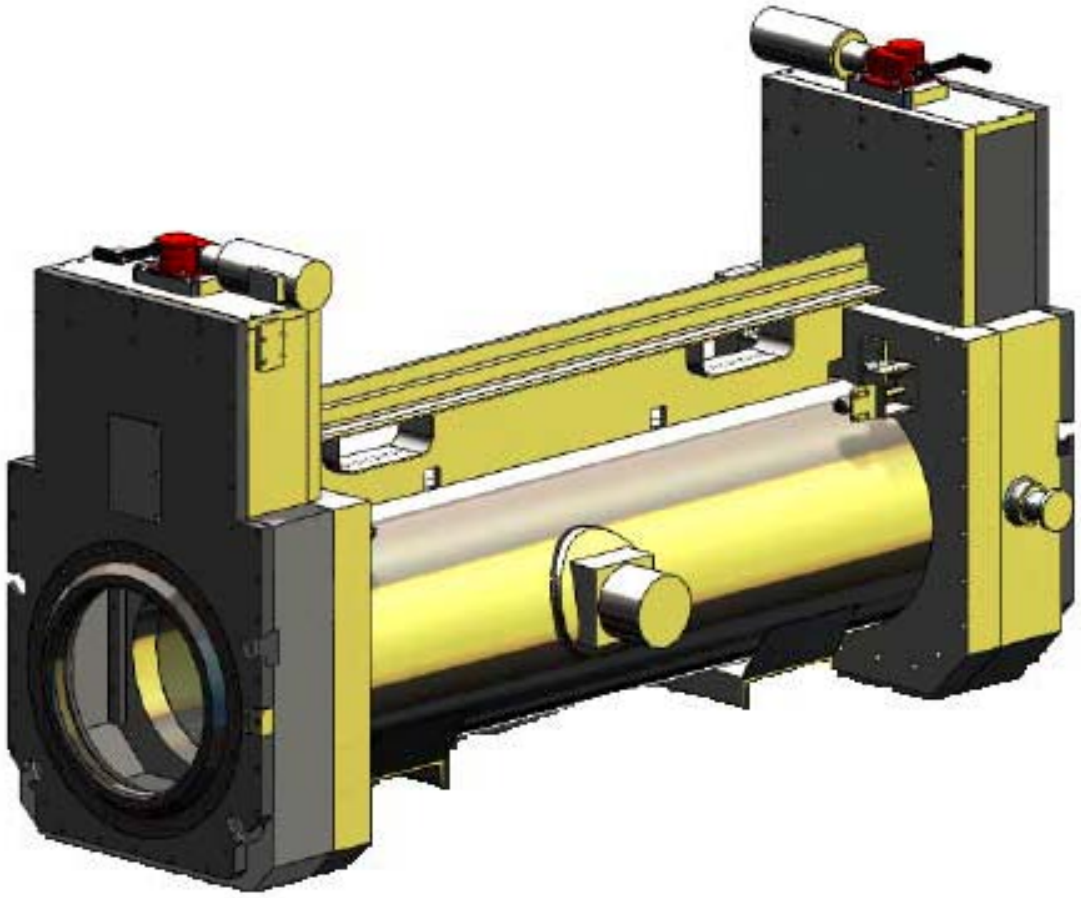


Figure 2-13, Light-Weight Facility Cask

2.3.3 Waste Hoist

The waste hoist system moves radioactive waste from the surface to the underground facilities. It also transports personnel, material, and equipment, although not at the same time as waste transport. The waste hoist system is installed in the waste hoist tower of the WHB and includes the hoist motor and drum, the head frame, the ropes and counter weight, and the conveyance. The waste hoist and structural support is designed to withstand a design basis earthquake.

2.3.4 Upper Hot Cell 15-Ton Crane

The remotely operated upper hot cell overhead 15-ton bridge crane has a 32 ft (9.75 m) span and can travel about 96 ft (29.3 m) in an east-west direction. It carries a trolley which can move 23 ft 10 in. (7.26 m) in the north-south direction. The trolley carries a hoist which supports a grapple rotating block and grapple. A hook can be attached to the grapple to handle loads, but typically the grapple is used with lift fixtures equipped with a standard pintle for lifting the upper hot cell shield plugs and loaded or empty 10-160B drum carriage units, and the 10-160B shipping container lid. The hoist has a lifting height of 64 ft (19.5 m). This crane is designed to stay on its rails, and to maintain control of its load in the event of a design basis earthquake or electrical failure.

2.3.5 Facility Cask Transfer Car

The facility cask transfer car (FCTC) is a device that runs on rails between the facility cask loading room (FCLR) and the waste shaft conveyance. This car takes the vertically mounted facility cask in the loading room, holds it during rotation to the horizontal position, and moves it onto the waste shaft conveyance. When the conveyance reaches the waste shaft station, the transfer car moves the cask out to the intersection of E-140 and S-400 where the underground RH waste handling 41-ton forklift can pick up the cask.

2.3.6 41-Ton Forklift

The 41-ton RH waste handling forklift is used to move the facility cask and the shielded, heavy portions of the horizontal emplacement retrieval equipment. The 41-ton forklift can also be used to move other large, heavy underground equipment from the waste hoist.

2.3.7 Horizontal Emplacement and Retrieval Equipment

The Horizontal Emplacement and Retrieval Equipment (HERE) device that mates with the facility cask provides a shielded path for transfer of an RH waste canister into a disposal borehole. The HERE includes the shield collar and alignment fixture, the leveling platform, the staging platform, and the transfer mechanism and the associated control equipment. The hydraulically actuated transfer mechanism is interlocked with the facility cask and tilt sensors such that a canister can be pushed into the disposal borehole. The shield collar, facility cask, and transfer mechanism provide the shielded path for transfer of the waste canister. Figure 2-13

illustrates the general features of the HERE and Figure 2-14 is a photograph of the HERE in the WIPP facility underground repository.

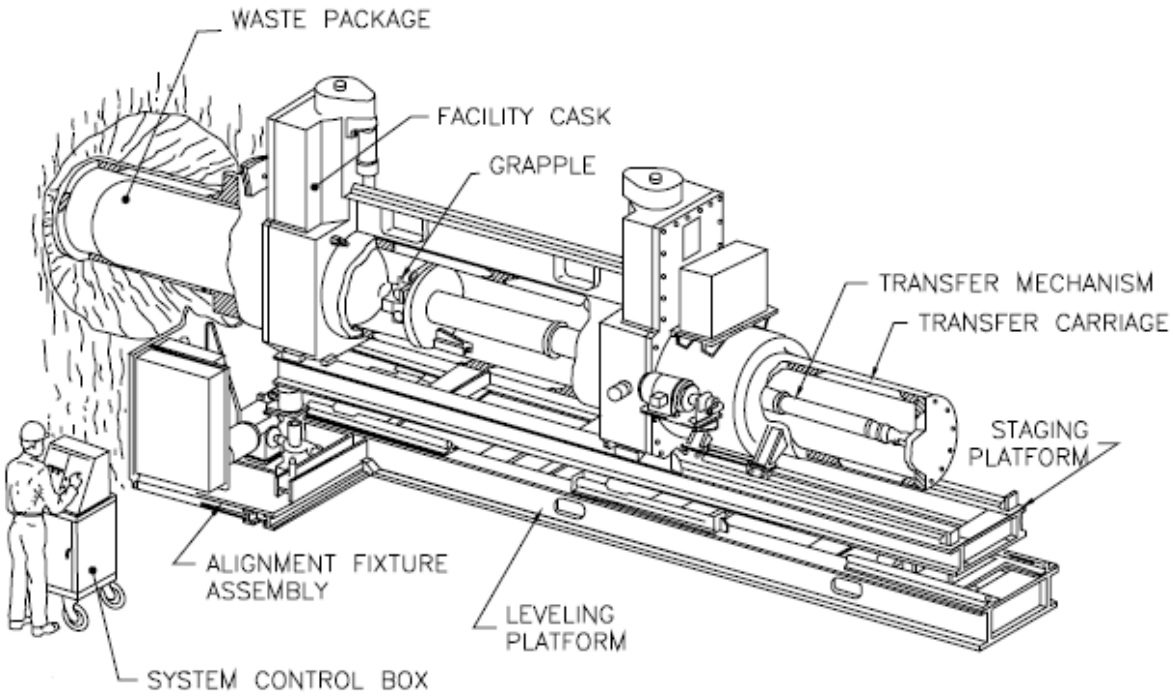


Figure 2-14, Horizontal Emplacement and Retrieval Equipment



Figure 2-15, Picture of WIPP HERE

2.3.8 Horizontal Emplacement Machine

The Horizontal Emplacement Machine (HEM) will be driven to an RH waste emplacement borehole using its hydraulically driven drive wheels and be readied for emplacement. To ready the HEM it will be connected to the HEM Control Panel and will be lifted off of its transport wheels and aligned with the borehole using its four integral leveling jacks. The RH waste cask with an RH waste canister is placed on the HEM cask carriage and is moved to contact the shield collar utilizing the cask carriage rails linear roller bearings and cask carriage hydraulic cylinder. After the cask is in place the shield valve with collar uses four rotating hydraulic locking clamps to lock the shield valve collar to the RH waste cask. The HEM waste transfer mechanism (WTM) is moved into contact with the RH waste cask rear shield valve utilizing the WTM carriage rails, linear roller bearings, and WTM hydraulic cylinder. Once in contact, the WTM is then locked in place by four rotating hydraulic locking clamps. The WTM uses a five stage hydraulic ram system enclosed in its housing to push the waste canister from the RH waste cask into the borehole or the shield plug from the shield plug carriage into the borehole. The shield plug carriage is then placed on the cask carriage of the HEM and the WTM is used to push the shield plug into the borehole.

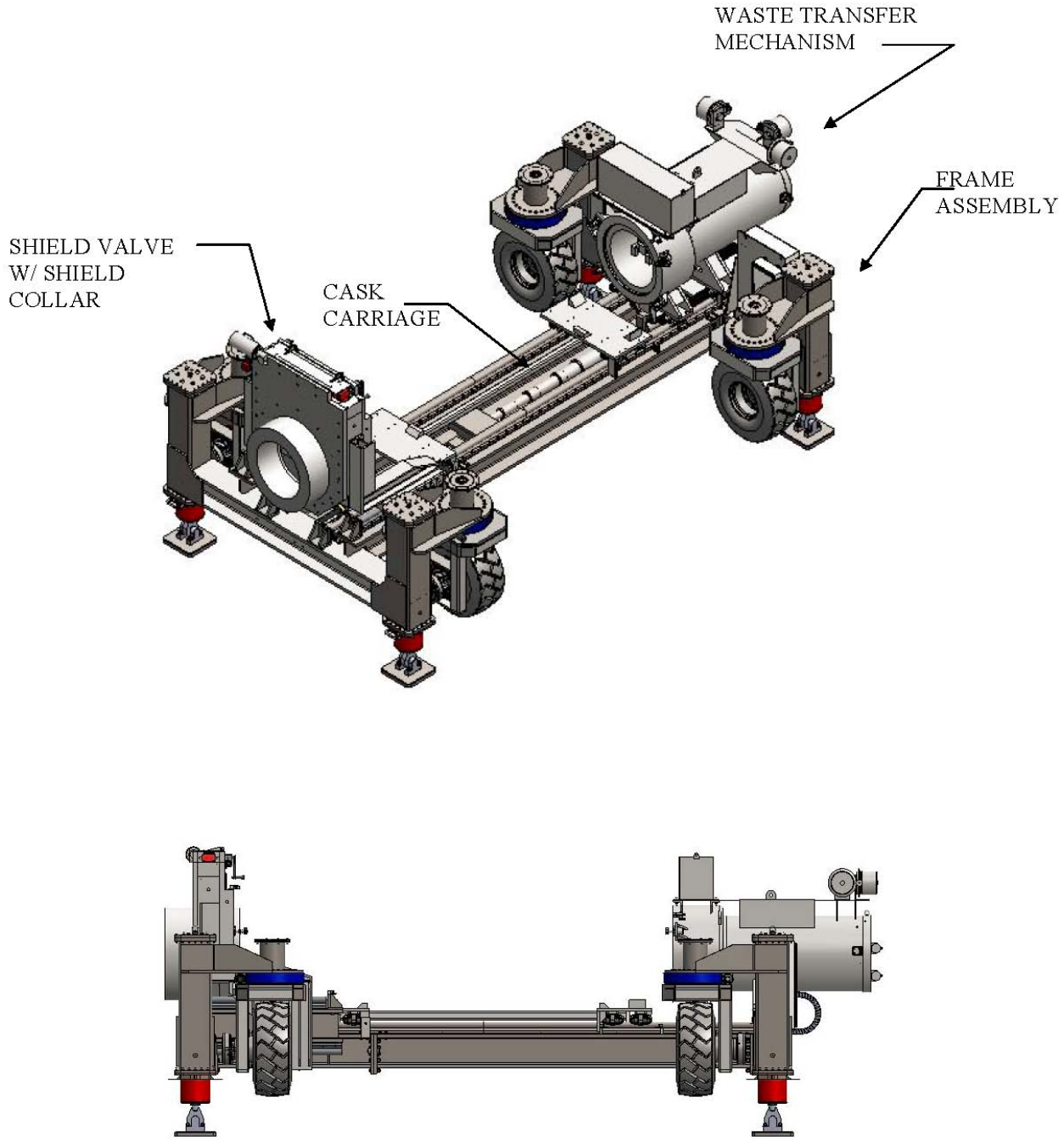


Figure 2-16, Horizontal Emplacement Machine

2.3.9 Shielded Insert

The shielded insert is specifically designed to be used in the transfer cell to hold and transport a loaded facility canister from the upper hot cell to the facility cask. The shielded insert is designed and constructed of carbon steel with external dimensions similar to the 72-B shipping container, but with a larger internal diameter so that it can accommodate the facility canister, which is slightly larger in diameter than the 72-B canister. The shielded insert is installed into and removed from the shuttle car similar to the 72-B shipping container.

2.4 Process Operations

The RH waste container handling process begins when the truck arrives at the WIPP gate with certified shipping packages. After the RH shipping container is surveyed for contamination and the shipping documentation confirmed, the loaded container trailer is move to the parking area near the RH entrance to the WHB. The loaded trailer is transferred into the WHB RH bay using a trailer jockey for the RH-TRU 72-B shipping container or the transport tractor for the 10-160B shipping container. Once inside the RH bay, the tractor or trailer jockey is detached and the RH bay doors are closed. Inside the RH bay, the impact limiter(s) are removed before the loaded shipping container is transferred to the road cask transfer car (RCTC). There are two rail mounted RCTCs, one for the 72-B shipping container and one for the 10-160B shipping container. One container is processed at a time since the container preparation station and CUR only accommodates one shipping container.

For the RH-TRU 72-B shipping container, the outer containment vessel lid of the container is removed and the inner containment vessel is vented. For the 10-160B shipping container, the container is vented and the lid bolts are removed. Either container is subsequently moved to the CUR.

2.4.1 RH-TRU 72-B Processing Flow in the WHB

In the CUR, the RH-TRU 72-B shipping container is lifted from its RCTC with the CUR crane and is lowered into the shuttle car basket in the transfer cell. In the transfer cell, the inner containment vessel lid of the 72-B road cask is removed using a robot, the identity of the waste canister is confirmed with cameras, and remote radiological surveys are performed, also using a robot.

The FCLR grapple hoist lifts the 72-B canister into the facility cask. The loaded facility cask is moved into the waste shaft conveyance, located at the waste shaft collar, for transfer to the disposal horizon. The waste is not removed from the 72-B canister at WIPP. The 72-B container is removed from the transfer cell and subsequently reloaded onto a trailer for return to a generator site.

2.4.2 10-160B Processing Flow to load Facility Canisters in the WHB

The 10-160B shipping container is moved to the CUR and the CUR shield door is closed. The 15-ton upper hot cell crane is used to remove the upper hot cell floor shield plugs and lift the 10-160B shipping container lid into the upper hot cell. Each of the two drum carriages is sequentially lifted into the upper hot cell. The cask lid is returned to the shipping container and the upper hot cell floor shield plugs are installed. The 10-160B shipping container can then be removed from the CUR and prepared for placement back on the transportation trailer.

In the upper hot cell, radiological surveys are performed on each drum and the identity of each drum is confirmed prior to loading into a facility canister. The upper hot cell is limited to 12 drums, either loose or within facility canisters, for reasons other than criticality safety. Starting with an empty upper hot cell configuration, 10 drums from a 10-160B road cask are unloaded and 9 of the drums reloaded into 3 facility canisters. The 3 facility canisters are removed from the hot cell leaving one drum stored in the hot cell. A second 10-160B road cask shipment is received and 3 additional facility canisters are loaded and removed leaving a total of 2 drums in the hot cell. A third 10-160B shipment is received and an additional 10 drums are unloaded into the upper hot cell for a total of 12 drums. The 12 drums are loaded into 4 facility canisters and the canisters removed leaving an empty hot cell.

For a facility canister to be processed from the upper hot cell, the transfer cell must be ready to receive it. The 72-B shipping container must be removed from the transfer cell and the shielded insert installed in the shuttle car. When the transfer cell is ready, the facility canister is lowered into the shielded insert. As with the 72-B canister, the FCLR grapple hoist lifts the facility canister into the facility cask. The loaded facility cask is moved into the waste shaft conveyance for transfer to the disposal horizon.

2.4.3 Disposal of the 72-B or Facility Canister in the Underground Repository

At the waste shaft station in the underground, the FCTC is moved from the conveyance to the intersection of S-400 and E-140 where the RH 41-ton waste handling forklift picks up the facility cask from the car, and moves it to the active RH disposal room. The forklift places the cask onto the HERE that has been aligned on a disposal borehole. The facility cask is pushed up against the shield collar with the transfer mechanism and is latched to the shield collar and the transfer mechanism. The rear shield valve is opened and the transfer mechanism extends through the cask and contacts the canister. The front shield valve is opened and the transfer mechanism extends and pushes the canister into the disposal borehole. The transfer mechanism is retracted and the front shield valve and rear shield valve are closed as the transfer mechanism retracts. The shield plug carriage and shield plug are placed onto the HERE behind the facility cask. The transfer mechanism extends to contact the shield plug. The rear shield valve on the facility cask opens and the transfer mechanism pushes the shield plug into the facility cask. The front shield valve opens and the transfer mechanism pushes the shield plug into the disposal borehole. Once the shield plug is in the borehole, the transfer mechanism is retracted, the shield plug carriage is

removed, the facility cask is removed and returned to the FCTC for transport to the surface, and the HERE is aligned on another borehole.

Either one or two canisters may be placed in a single borehole. If two canisters are placed, they will be axially aligned (that is, end-to-end). After the canister(s) are placed in the borehole, a shield plug is placed in the borehole following the last canister to reduce personnel exposure to radiation. A shield plug may also be placed between the canisters in the borehole to control dose rates while loading the second canister. Figure 2-15 and Figure 2-16 summarize RH-TRU operations for the 72-B and 10-160B waste containers respectively. Once the boreholes in the walls of a given room are filled with RH waste canisters, CH waste containers are placed in the associated room. Each panel is filled sequentially from Room 7 to Room 1. After each panel is filled, it is closed and inaccessible to personnel.

3.0 Requirements Documentation

The WIPP facility is subject to the requirements of DOE Order 420.1B, *Facility Safety*, Section 4.3, *Nuclear Criticality Safety* (DOE 2005). Compliance with the double contingency requirements of DOE Order 420.1B is demonstrated for RH waste containers in Section 7.0 of this analysis. This NCSE is written to meet the content requirements of DOE-STD-3007-2007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities* (DOE 2007).

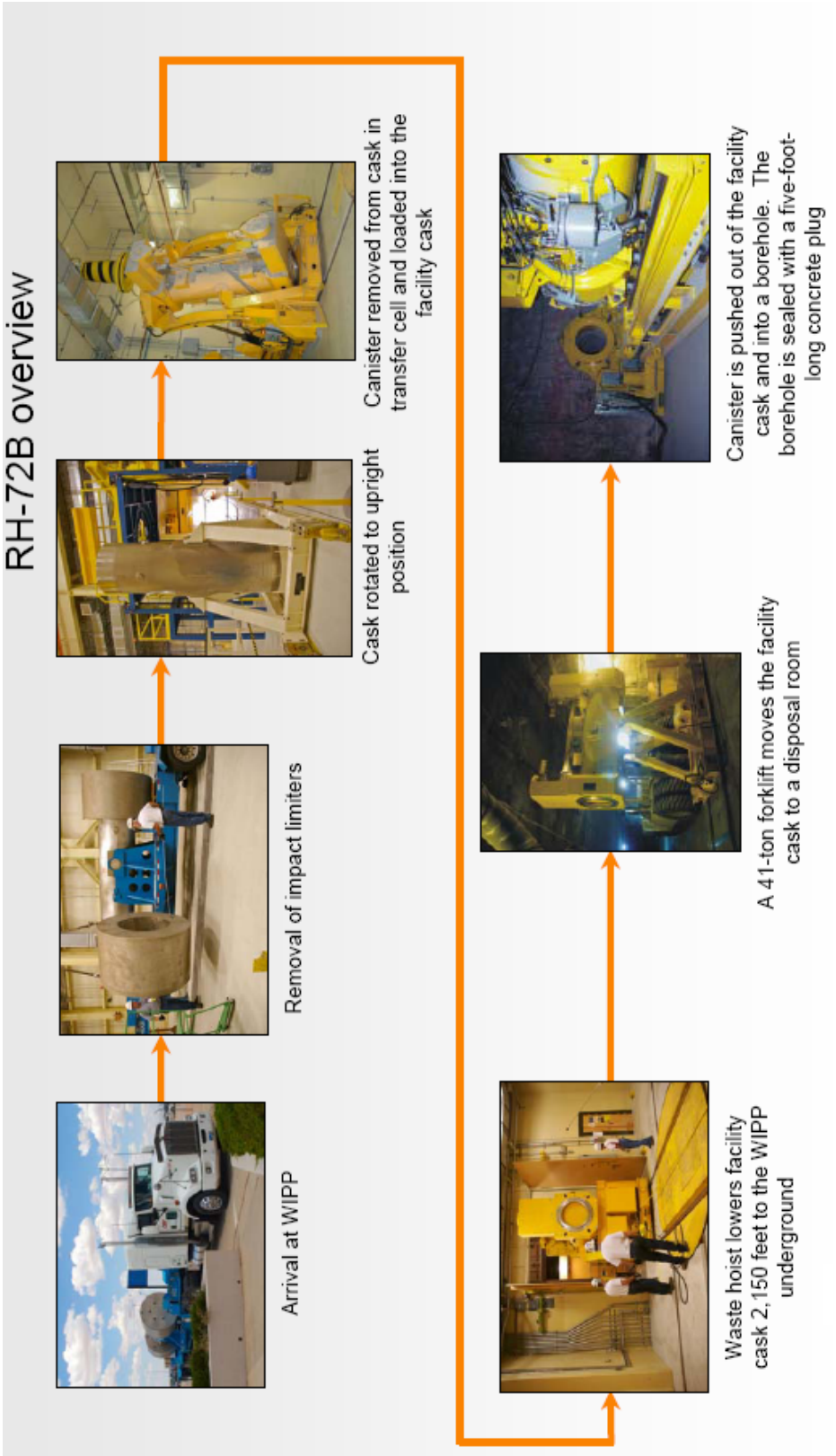


Figure 3-1, Pictorial Summary Depicting the Process Handling and Underground Disposal of the 72-B Canister

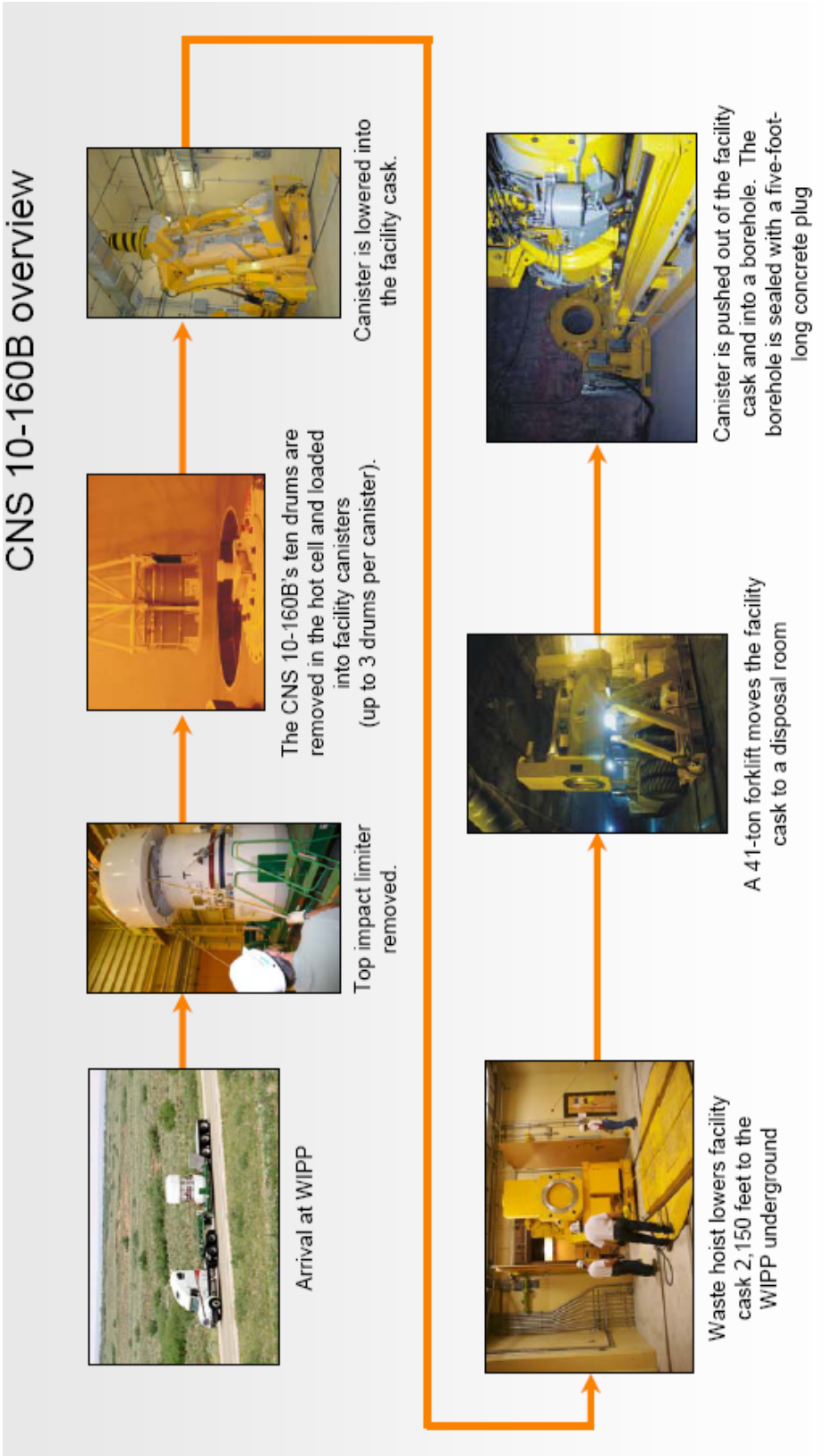


Figure 3-2, Pictorial Summary Depicting Process Handling of the 10-160B and Underground Disposal of the Facility Canister

4.0 Methodology

4.1 Evaluation Method

MCNP – A General Monte Carlo N-Particle Transport code, Version 5 (MCNP5) (LANL 2005) was used to perform the reactivity calculations for the various RH waste container handling operations and storage configurations. The baseline reactivity computations were performed with the precompiled PC version of MCNP5 supplied by the vendor (Los Alamos National Laboratory). The MCNP5 computer code was run under the allowed Microsoft platforms and validated (*Verification of MCNP5 on SAIC Computers* [Larson 2004]). The ENDF VI library was used for all computations with MCNP5.

Per *MCNP5 Bias Validation for the WIPP* (Hayes 2004), the upper subcritical limit (USL) for MCNP5 at the WIPP is 0.97. The USL was initially found to be 0.975 but the large presence of salt (NaCl) as a reflector was not considered to be adequately addressed in the benchmarks resulting in the addition of an administrative margin of 0.005. The basis for this offset value was that a USL of 0.975 gave a 5% probability that 1 in 10,000 critical systems would be modeled as having a reactivity of ≤0.975 and so to account for salt reflection, a 1 in 100,000 USL was chosen which equated to 0.97. This value is also applicable to systems containing Pu materials, water, stainless steel, concrete polyethylene, and beryllium, due to the presence of these materials in the benchmark systems as given in *Determination of Calculation Bias for Criticality Calculations at the WIPP using MCNP* (Rhoden 2003). As the benchmarks did not include systems with pure graphite, an additional margin of 0.01 is utilized for conservatism in the analysis based on engineering judgment as allowed by ANSI/ANS-8.1. This margin consists of 0.005 due to graphite reflection as done for NaCl and an additional 0.005 when graphite moderation is being utilized. When the moderating material is composed of hydrogenated compounds, then only the additional margin of 0.005 is warranted if graphite is being used as a reflector. Nonetheless, an additional margin of 0.01 is applied to calculations with graphite. Additionally, a 0.01 administrative margin is subtracted resulting in a USL of 0.96 for non-graphite systems and 0.95 for systems with graphite. The MCNP result at the k_{eff} +2σ level is compared to the USL and systems with a k_{eff} +2σ value below the USL are subcritical.

In addition, the bias analysis states that if the average energy of fission (AEOF) is greater than 2.5 eV, an additional 0.005 bias in k_{eff} should be utilized, which would further reduce the USL if the AEOF is not shown to be below 2.5 eV. Note that the AEOF values used were calculated based on the average neutron lethargy causing fission due to its basis from the KENO V.a runs taken from the Office of Environmental Compliance and Documentation benchmarks in CS-2002-002 (Rhoden 2003). This value was verified to be met based on the value of the "energy corresponding to the average neutron lethargy causing fission" in the MCNP output files, and no additional reduction in the USL is needed.

The LEU payload was not evaluated in the validation documents referenced above. A supplemental validation document (*MCNP5 Bias Validation For Lead And Low Enriched*

Uranium At The Waste Isolation Pilot Plant [Newell and Larson 2007]) was written which evaluated 82 LEU benchmarks. Eight of these benchmarks contained significant quantities of lead, which is also not well represented in the above referenced validation documents. The supplemental validation concluded that the USL of the LEU benchmarks is greater than that calculated for Pu benchmarks in CS-2004-002 and that the lead benchmarks result in a higher USL when included in the evaluated benchmark set compared to when they are removed. Thus, the 0.96 USL determined for plutonium systems is applicable to the LEU payload evaluated and also to lead as modeled in this NCSE to represent reflection from the facility cask.

5.0 Process Analysis

To accommodate the numerous RH waste processing and disposal configurations at the WIPP facility, a bounding analysis is performed to establish a nuclear criticality safety basis for the receipt, process handling, conveyance to, and permanent disposal of the RH waste packages. Specifically, three baseline configurations are addressed: (1) fully reflected single canisters, either direct loaded or containing drums of waste, to bound RH waste handling operations; (2) twelve (12) drum arrangements in the upper hot cell to bound 10-160B to facility canister re-packaging operations; and (3) borehole storage array configurations to bound underground repository emplacement and disposal operations. In addition, modifications to the baseline configurations were made to evaluate credible contingent conditions. For each geometric configuration, various RH waste package compositions and geometries within the canister are considered. To simplify the analyses, 30-gallon drums were used as the bounding RH waste drum, unless otherwise noted, because they are smaller than 55-gallon drums thus bringing the individual fissile masses closer together. The modeled dimensions of the drums are given in Table 5-1. Likewise, the 72-B canister was used as the representative RH canister; the 72-B and facility canisters are very similar geometrically but the smaller diameter of the 72-B canister brings the external reflector material closer to the fissile material. For the remainder of the NCSE, the term canister will be used to refer to both canister types as modeled with the 72-B canister dimensions as given in Figure 2-6. In the model, the difference in the inner and outer length, which is occupied by the pintle on the canister lid, was modeled as void. The surrounding reflector/shield materials include concrete, lead, and salt, depending on whether hot cell, conveyance in the facility cask, or underground disposal configuration.

Table 5-1, Modeled Drum Dimensions*

Container Type	ID (cm)	OD (cm)	Inside Height (cm)	Height (cm)	Wall Thickness (cm)	Active Volume (cm^3)
30-Gallon Drum	45.7200	45.9628	71.1200	71.3728	0.12141	116760
55-Gallon Drum	57.1500	57.3928	84.4550	84.6978	0.12141	216645

*MCNP drum models use inner dimensions plus the wall thickness

5.1 RH Waste Container Loading

The fissile mass loadings and special reflector (i.e., graphite, beryllium, etc.) loading limits of the RH-TRU 72-B shipping container are defined in Section 6.0 of the RH-TRU 72-B SAR (DOE-CBFO 2010a). The NRC C of C for the 10-160B shipping container limits the load to 20 Pu Equivalent Ci content. If the total Ci content is Pu, the maximum loading limit for the container would be 318 g ^{239}Pu. No internal package limits are specified by the NRC for fissile mass, beryllium, or graphite. Instead, the limits established for CH waste in 55-gallon drums at WIPP are evaluated for RH waste in both 30- and 55-gallon drums. The allowable contents in a direct loaded 72-B canister are taken from the RH-TRU 72-B SAR. The loadings as modeled in MCNP5 are described in the following subsections.

5.1.1 Non-Machine Compacted Waste Containing ≤ 1 wt% Special Reflector Materials

The 72-B canisters of non-compacted waste are currently limited to a maximum of 315 FGE of ^{239}Pu for the total payload if containerized per the RH-TRU 72-B SAR (DOE-CBFO 2010a) but are modeled in this NCSE at 325 FGE. Facility canisters hold up to 3 drums, each modeled at 200 FGE per drum, such that any drum of non-compacted waste received in the 10-160B container can be placed in any canister. Thus, the direct loaded, non-compacted waste canister model consists of a 325 g ^{239}Pu sphere and the containerized canister model contains 3 30-gallon drums with each drum containing 200 g ^{239}Pu. The fissile isotope modeled is 100% ^{239}Pu mixed with a polyethylene-water moderator, which is 25% by volume polyethylene and 75% by volume water. This moderating mixture has been shown to bound all moderators that could credibly moderate the TRU waste in a pure form, with the exception of beryllium, which is analyzed later in this NCSE, as documented in Section 6.2.1 of the RH-TRU 72-B SAR. Using the polyethylene-water moderating mixture is not intended to relieve the need to evaluate all new waste streams for criticality safety concerns, but is expected to preclude a future waste stream from having a more reactive moderating capability than those already analyzed for the WIPP.

In addition to the limits specified above, the RH-TRU 72-B SAR gives limits for direct loaded manually compacted waste (i.e., not machine compacted) with less than or equal to 1 wt% of special reflector materials that credit the presence of ^{240}Pu in the fissile mixture. Specifically, the RH waste is limited to 325 FGE with 5 g ^{240}Pu, 350 FGE with 15 g ^{240}Pu or 370 FGE with 25 g ^{240}Pu in the waste. The first loading is addressed by modeling 325 FGE with no ^{240}Pu in the base case, while the other two loadings were specifically analyzed.

A mixture of low density polyethylene and beryllium fills the remainder of the canister or 30-gallon drum reflecting the fissile mass. Containers accepted at the WIPP are limited to contain no more than 1 volume % liquids such that no water is modeled in the reflector region. The polyethylene density in the reflector is modeled 25% of theoretical as determined to bound the packing fraction of direct loaded (non-machine compacted) waste. The special reflector material is modeled as beryllium based on the evaluation in *Reactivity Effects of Moderator and Reflector Materials on a Finite Plutonium System* (Neeley et al. 2004) which found beryllium to

be the most reactive reflector material at infinite thickness for a polyethylene-water moderated ^{239}Pu system. The amount of beryllium modeled is based on 1 wt% of the maximum gross container loading limit. For the 72-B canister, 1 wt% of the maximum gross container loading limit equates to 32 kg. For the 55-gallon drum, the maximum gross container loading limit is 1,000 lbs or 455 kg, and 1 wt% of this value is rounded up to 5 kg Be per 55-gallon drum. A Be mass of 5 kg is also modeled in the 30-gallon drums, which is conservative as it exceeds 1% of the allowed weight limit. The beryllium is modeled as homogeneously mixed throughout the polyethylene reflector as the parametric study in Chapter 6 of the RH-TRU 72-B SAR (DOE-CBFO 2010a) found no statistical difference when the 1% beryllium was modeled in the reflector vs. in the moderator. Finally, the reflector material is allowed to fill the canister volume not occupied by the fissile mass for both direct loaded and containerized configurations. In this context, only the height of the drums within the RH canister is used to separate the fissile masses and the reflector fills the rest of the canister. This treatment ensures that the model is bounding of 55-gallon drums in the canister as the larger outer diameter would allow for a thicker reflector around the fissile mass.

5.1.2 Non-Machine Compacted Waste with > 1 wt% Special Reflector Materials

The RH-TRU 72-B SAR (DOE-CBFO 2010a) addresses the presence of large quantities of special reflector materials, materials that are better reflectors than water including beryllium and graphite, and provides two limits for containers with these materials in quantities > 1 wt% of the allowable weight contents of the canister. These limits are 100 FGE ^{239}Pu for unbound special reflector materials in the waste matrix (i.e., as a reflector of the fissile material) and 305 FGE ^{239}Pu when the fissile material is mechanically or chemically bound to the special reflector material, meaning the Pu is distributed throughout the special reflector material. A loading limit of 100 FGE per 55-gallon drum is also established for CH waste at WIPP. For RH waste, 100 FGE is evaluated for both 30- and 55-gallon drums in this NCSE. The FGE is mixed with a polyethylene-water moderator, which is 25% by volume polyethylene and 75% by volume water.

The study of reflector materials documented in Neeley et al. (2004) found beryllium to be the most reactive reflector material at infinite thickness for a polyethylene-water moderated ^{239}Pu system. Thus beryllium is modeled around the ^{239}Pu in waste containing high quantities of special reflector materials other than graphite (analyzed separately). The beryllium is either modeled at its full theoretical density of 1.85 g/cm^3, which is highly conservative as the beryllium would have to be specifically formed to fill the drum or canister around the fissile material, or at 70% density. The use of 100% dense beryllium or graphite, although bounding, is not possible in these waste drums per *Review of Special Reflectors in the TRU Waste Inventory* (Taggert and Moon 2004). Because the beryllium consists of molds, shapes, chunks, coarse particles and fines randomly filling the waste container instead of being specifically constructed to surround the fissile material and fill the container with no void, beryllium at 70% of theoretical density or 1.295 g/cm^3 is used given that the maximum theoretical density for randomly packed uniform spheres is 70% (“Recursive packing of dense particle mixtures” [Elliot et al. 2002] and “Is random packing of spheres well defined?” [Torquator et al. 2007]).

Following suit with the modeling practices employed for other reflector compositions, the beryllium reflector mass is not restricted, but allowed to fill the canister volume not occupied by the fissile mass for both direct loaded and containerized configurations, such that the beryllium is not restricted to the interior of the 30-gallon drum.

The contents model used for cases in which the Pu is mechanically or chemically bound to the special reflector material consists of a direct loaded 72-B canister in which 305 FGE ^{239}Pu is mixed with a moderating mixture which is 15% polyethylene/45% water/40% beryllium by volume. This moderating mixture represents the most reactive state per the RH-TRU 72-B SAR (DOE-CBFO 2010a) and as confirmed in this evaluation. The fissile mass is reflected by 25% dense polyethylene mixed with 32 kg beryllium.

5.1.3 Non-Machine Compacted Waste Containing ≥ 1 wt% Graphite and ≤ 1 wt% of other Special Reflector Materials

Although graphite is a special reflector material and thus addressed by the previous section, large quantities of graphite were analyzed separately to determine if a higher FGE limit than the SAR limit could be supported. The ^{239}Pu is mixed with a polyethylene-water moderator, which is 25% by volume polyethylene and 75% by volume water. In the baseline case, the graphite waste is modeled at full density (e.g., 2.3 g/cm^3). As discussed in the previous section for beryllium, additional cases are analyzed to establish the maximum mass loading in a more realistic case in which the graphite in the reflector is modeled at the maximum credible graphite density of 1.61 g/cm^3 or 70% of theoretical. Applying the 70% packing fraction to the graphite reflector bounds the actual configuration of random placement of waste in the containers. One wt% beryllium is also modeled in the graphite reflector region. One wt% beryllium equates to 32 kg per 72-B canister and 5 kg per drum based on 55-gallon drums, which is also conservatively applied to the 30-gallon drums. The beryllium is homogeneously distributed throughout the graphite reflector filling the container.

5.1.4 Machine Compacted Waste Containing ≤ 1 wt% of Special Reflector Materials

When the contents in the 72-B canister or waste drums are machine compacted, the contents, mainly polyethylene, approach their theoretical density, and consequently the fissile mass in the compacted waste model is moderated with 100% dense polyethylene. Neeley et al. (2004) concludes no material, that could credibly moderate a fissile sphere in a pure form, results in a higher reactivity than the 100% polyethylene moderated system. The RH-TRU 72-B SAR (DOE-CBFO 2010a) limits the fissile mass loading for the 72-B canister to 245 g FGE ^{239}Pu for this payload and the special reflector material content is limited to 1 wt%. The 30- and 55-gallon mass loading limit is set at 200 FGE ^{239}Pu per drum, for consistency with the WAC for CH waste.

The fissile mass is reflected by a 100% dense mixture of polyethylene with beryllium to represent the special reflector material. The beryllium content in the reflector mixture is

equivalent to 1 wt% of the rated weight capacity of the canister or drum, which is modeled as 32 kg in a canister and 5 kg in a 30- or 55-gallon drum.

5.1.5 Low Enriched Uranium

A separate payload limit is specified for 72-B canisters that contain LEU as the primary heavy metal component. The LEU contents must be distributed within the canister in such a manner that the maximum enrichment of the uranium does not exceed 0.96 wt% ^{235}U FEM in any location of the waste material and there are no variations in the fissile concentration that exceed 0.96 wt% ^{235}U FEM in any location. The LEU waste matrix is modeled as a fissile mass in which 0.96 wt% ^{235}U is mixed with a moderating material that is 25% polyethylene/74% water/1% beryllium by volume. Conversion factors for calculating the contribution of other fissile isotopes to the % ^{235}U FEM are given in the RH-TRAMPAC (DOE-CBFO 2010b). The moderator mixture represents the most reactive, non-compacted waste matrix per the RH-TRU 72-B SAR (DOE-CBFO 2010a). The only physical limit placed on the system is that the total mass of the uranium/moderator mixture in the canister does not exceed the contents weight limit of 6,900 pounds. A range of H/^{235}U ratios are evaluated to determine the optimum moderated configuration.

In order to ensure a conservative bound on the criticality analysis, the LEU fissile mixture is reflected by 100% dense beryllium. The use of an unlimited mass of special reflector is permitted in the RH-TRU 72-B SAR (DOE-CBFO 2010a), provided the weight limit for the canister is not exceeded, and reflection by beryllium represents the most reactive state.

5.2 RH Waste Container Model Geometry

This section describes the various MCNP5 geometric configurations used to model RH waste configurations in the WHB and underground. . As justified in Section 5.0, only the 72-B canister is modeled and is referred to simply as the “canister.”

5.2.1 Canister Models for Receipt, Storage, and Transport to Underground Repository

Models for the receipt, storage, and conveyance of RH canisters, exclusive of placing drums into a canister in the upper hot cell, consider containerized and direct-loaded canister configurations with and without waste drums, respectively, as described below.

5.2.1.1 Direct Loaded Canister Model for Above Ground Receipt, Processing, and Conveyance

The single fissile mass in the canister is modeled as a sphere. The canister is surrounded by close fitting, 2-meter thick concrete or lead to bound reflection from the WHB hot cell wall and the facility cask with a 4.75-in. lead wall, respectively. The lead reflector also bounds the reflector from the carbon steel shielded insert as lead is a better reflector than steel. To account for potential upset contingency conditions, some models will use a mirror boundary condition on the

lateral surfaces of the canister to simulate a planar array of canisters. In this configuration, only the upper and lower surfaces are reflected by the 2-meter thick concrete or lead. Figure 5-1 illustrates the single canister model used in the baseline analysis.

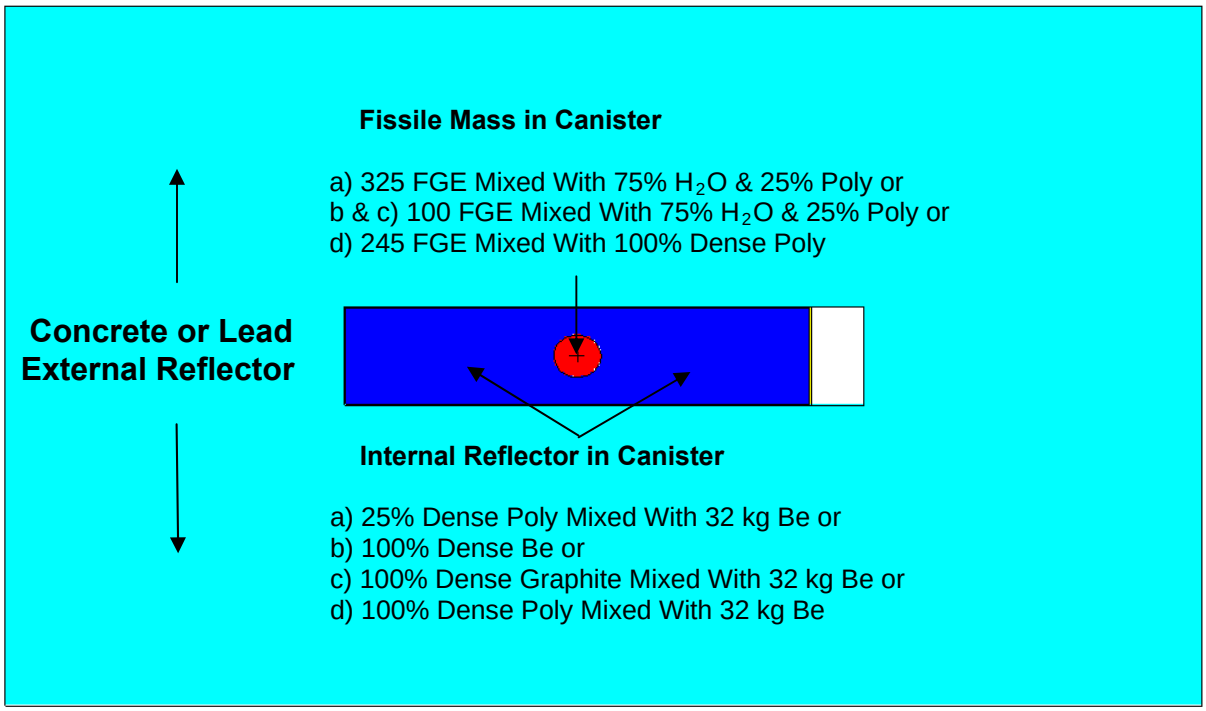


Figure 5-1, Model of Direct Loaded Canister

The computational model employed for the direct loaded 72-B canisters that possess LEU waste consists of a single cylindrical mass which radially fills the entire canister. The length of the cylindrical mass is adjusted such that the total mass of the fissile unit does not exceed 3,129 kg (6,900 lbs) at the optimal $H/^{235}U$ ratio. The remainder of the canister is filled with beryllium. The canister is surrounded by close fitting, 2-meter thick concrete or lead to bound reflection from the WHB hot cell walls and the facility cask, respectively. To account for potential upset contingency conditions, the ^{235}U enrichment is varied at constant mass until the USL is exceeded, thereby establishing an upper enrichment limit on the waste package. Figure 5-2 illustrates the model used for the LEU waste packages.

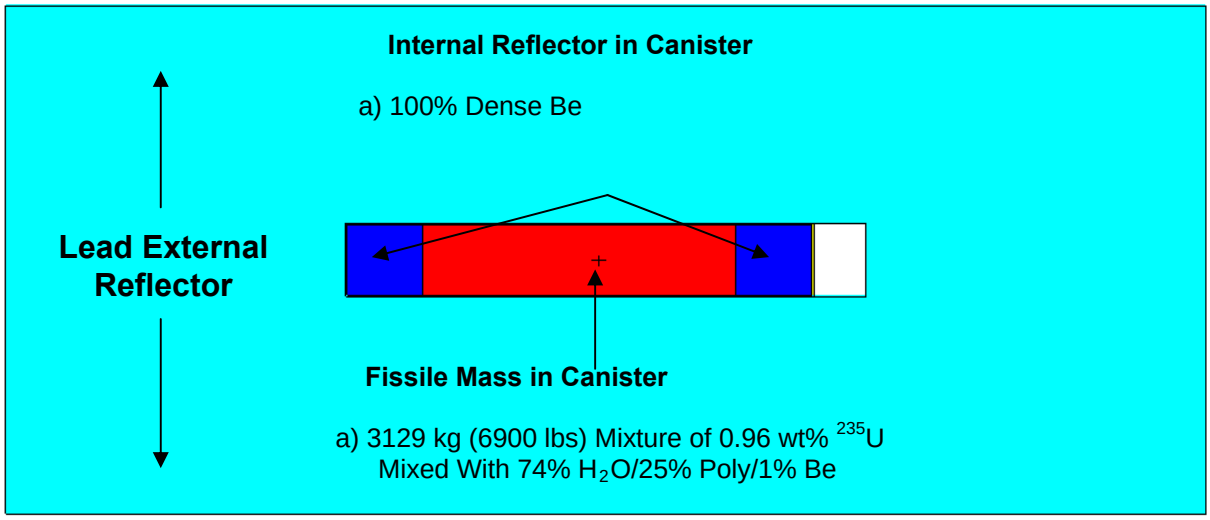


Figure 5-2, Model of Direct Loaded Canister Used in the LEU Waste Package Calculations

5.2.1.2 Canister Model Containing Three 30-Gallon Drums for Above Ground Receipt, Processing, and Conveyance

The three-drum canister model consists of three 30-gallon drums with the fissile masses within the drums positioned in various geometric locations. Two basic geometric configurations are considered, namely a conventional arrangement where the spherical fissile units are located in the center of each drum as shown in Figure 5-3, and a two drum arrangement in which the fissile masses in the drums are placed in close proximity to one another. In the latter model, the fissile masses contained in the top two adjacent drums are cylindrical pucks each with an aspect ratio of 0.5. The fissile mass in the middle drum is located at the top, while the fissile mass in the upper drum is located at the bottom. In this configuration, the fissile units form a cylinder with a height to diameter (H/D) ratio of one and a total mass of two times that allowed per container. When the combined cylindrical masses are fully reflected, their reactivity is very close to that of a sphere at optimum moderation for the same amount of fissile material. This configuration represents a conservative bound on the possible locations of the fissile material within the respective waste containers. The fissile mass in the drum by itself is modeled as a sphere. The canister is surrounded by close fitting, 2-meter thick concrete or lead to bound reflection from the WHB hot cell walls and the facility cask, respectively.

Two variations of the two-drum configuration are considered, namely one in which the two fissile masses are located on the central axis on the drum as shown in Figure 5-4, and one in which the fissile units are located adjacent to the inner wall of the drum as shown in Figure 5-5. As a general rule, no credit is taken for the 30-gallon drum wall steel, although the outer height is modeled to determine the spacing of the fissile units within the canister. Also, the entire canister

volume not occupied by the three fissile units is filled with the internal reflector material, thereby ignoring the drum radius. This configuration, although very conservative, bounds the larger diameter 55-gallon drums in the canister. For those two-drum configurations in which the 30-gallon drums contained machine compacted waste at 100% of theoretical density, a more realistic approach was required in which the drum was modeled explicitly, including structure of lid, bottom and sides (although at 50% of theoretical density), and placed in the canister without additional fill material around the drums. In addition, 1.0 in. of design spacing between the fissile masses in the two drums was credited in both the 30-gallon and 55-gallon drum model to account for the drum lid recess and outer lid ring structure. Both 30-gallon and 55-gallon drums were modeled as the larger radius of the 55-gallon drum allows for more reflector material within the canister. These configurations are shown in Figure 5-6 and Figure 5-7.

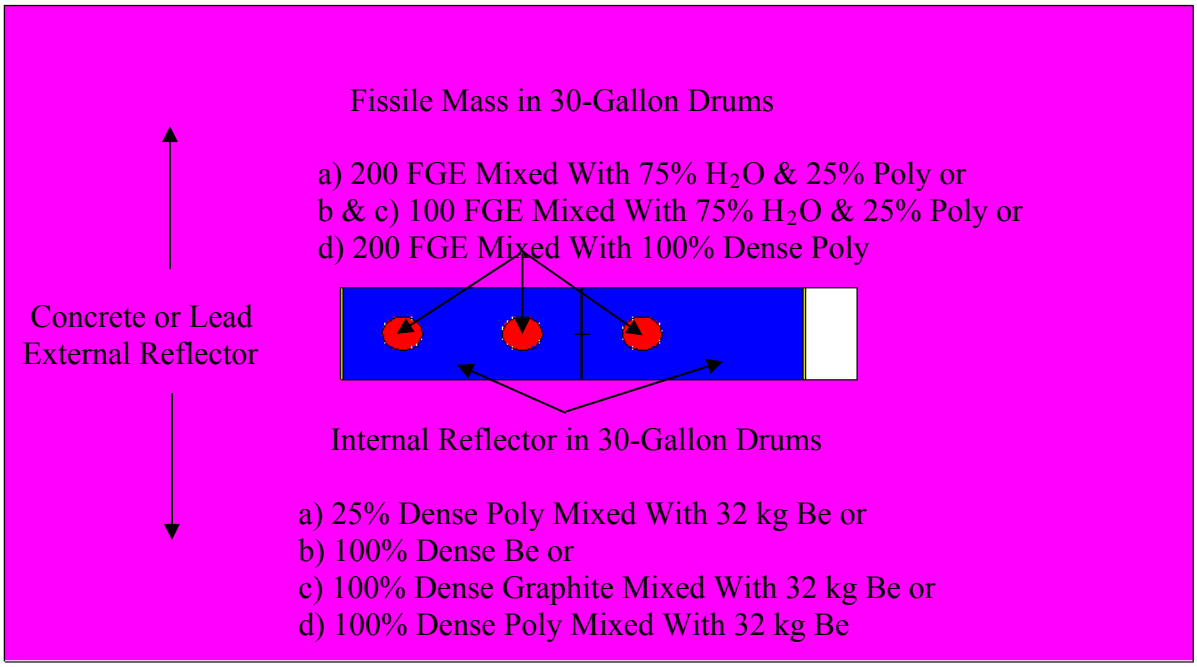


Figure 5-3, Model for Three 30-Gallon Drums in Canister

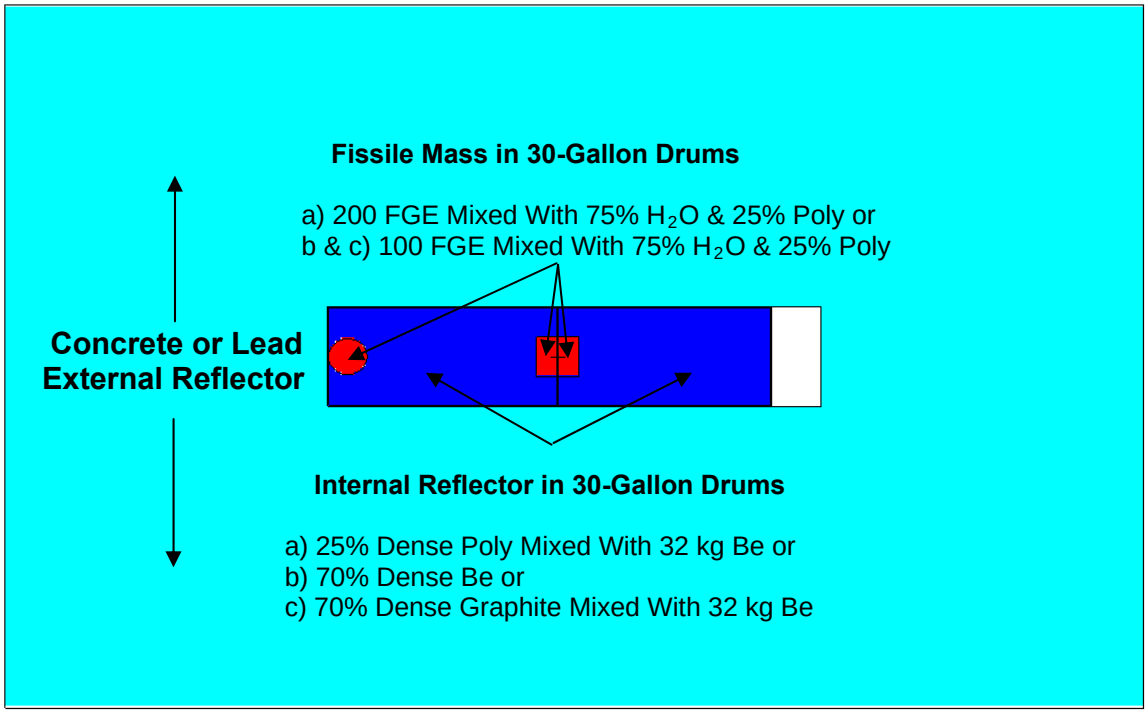


**Figure 5-4, Model for Three 30-Gallon Drums in Canister
Central Two-Drum Model)**

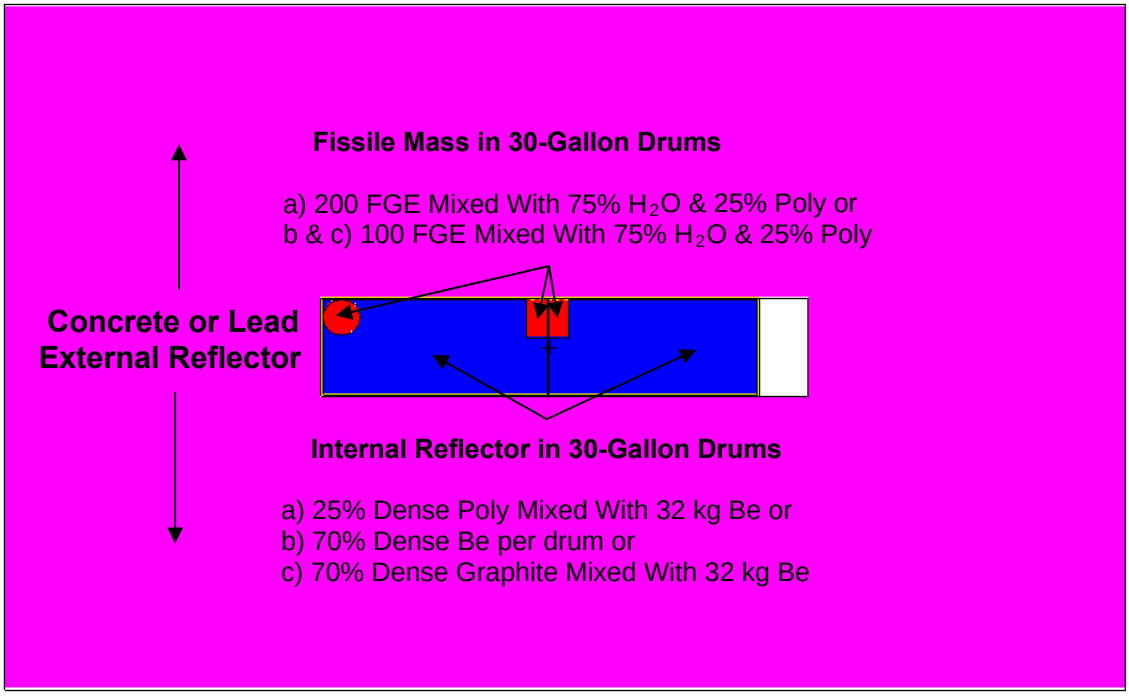


**Figure 5-5, Model for Three 30-Gallon Drums in Canister
(Edge Two-Drum Model)**

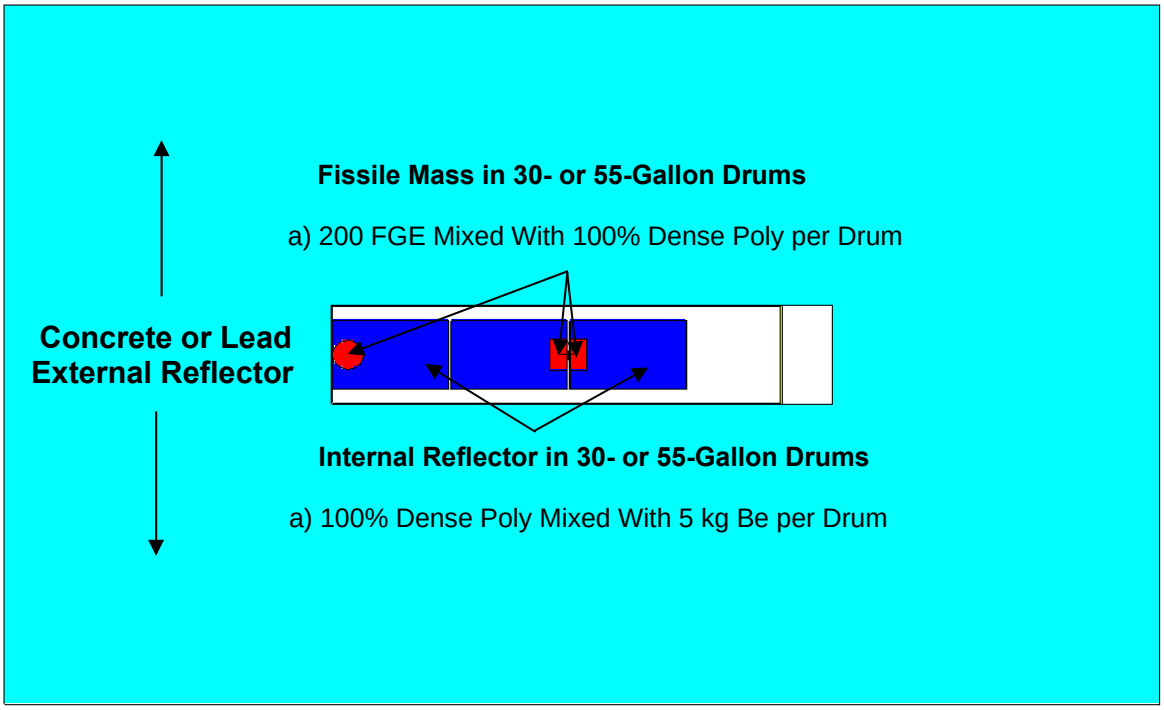


Figure 5-6, Model for Three Drums of Machine Compacted Waste in Canister (Explicit Central Model)

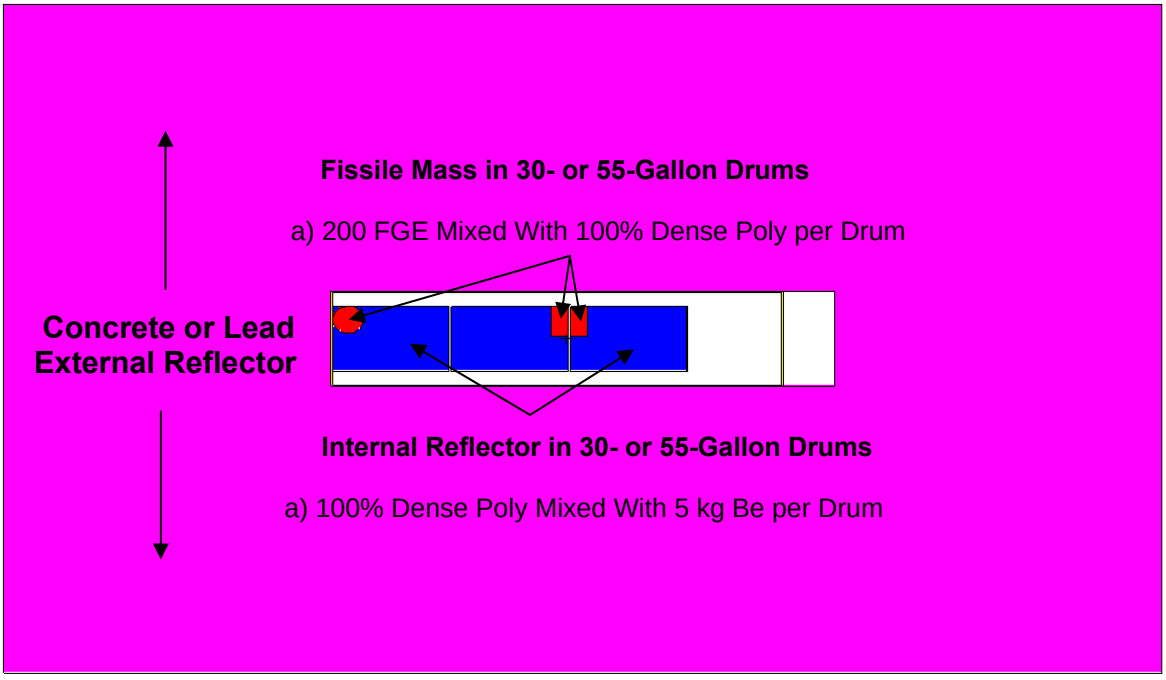


Figure 5-7, Model for Three Drums of Machine Compacted Waste in Canister (Explicit Edge Model)

5.2.1.3 Direct Loaded NS15 or NS30 Canister Model for Above Ground Receipt, Processing, and Conveyance

Except for the radial HDPE thickness, the NS15 and NS30 canisters are identical. Therefore, the canister with the thickest HDPE, the NS15, bounds both canisters. Thus a model of the NS15 is satisfactory to evaluate both canisters.

The NS15 model is based on the previous direct loaded canister model from Section 5.2.1.1 as shown in Figure 5-1. The direct loaded canister was selected as the base model for the NS15 because the RH-72B SAR specifies a 245 FGE/canister limit, not a per drum limit. Starting with the previous model, a zone of HDPE was added inside the canister as per Section 2.2.5 where the HDPE is an estimated maximum of 3.486 inches thick radially and 5 inches thick on each end (the maximum radial thickness was estimated as the difference between the minimum and nominal thicknesses added to the nominal thickness). The volume inside the HDPE cavity was conservatively filled (i.e., individual drums are ignored). Figure 5-7a illustrates the NS15 models with a centrally located FGE mass.

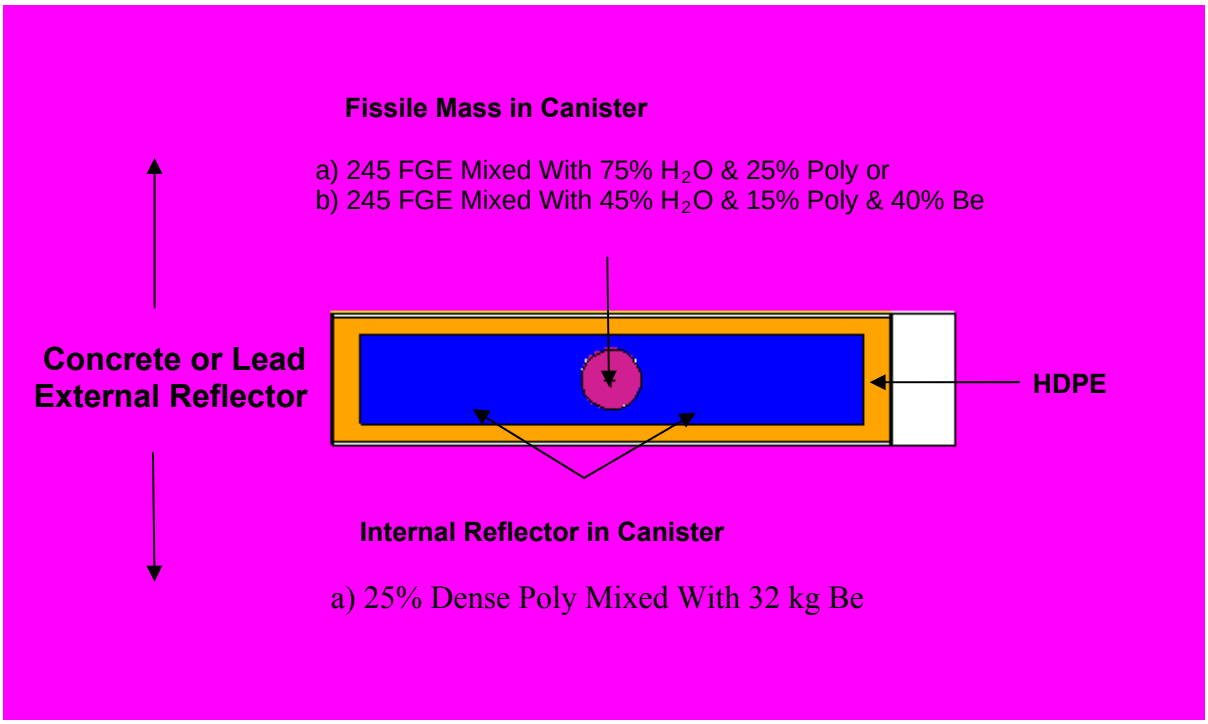


Figure 5-7a, Model for NS15 Neutron Shielded Canister

5.2.2 Twelve 30-Gallon Drum Upper Hot Cell Model

To simulate the most reactive condition that could exist in the upper hot cell during waste handling operations in which drums are removed from a 10-160B shipping container and placed in facility canisters, a closely-packed array of twelve 30-gallon drums was modeled. In essence, three rows of four drums each were placed in contact on a hexagonal pitch. In the standard

baseline configuration, the fissile spheres are centered axially in the drums as shown in Figure 5-8. A bounding configuration was also constructed by positioning the fissile masses in two selected drums toward each other as shown in Figure 5-9. The 12 drums are surrounded by close fitting concrete 2-meters thick. This reflector configuration is highly conservative as the hot cell is very large and a thick reflector could only be on up to 2 sides and below the drum array if the array was placed in the corner of the hot cell. Note that a 30-gallon drum array bounds a 55-gallon drum array or a mixed 30- and 55-gallon drum array due to the smaller 30-gallon drum diameter and hence the tighter packing in a 30-gallon drum array.

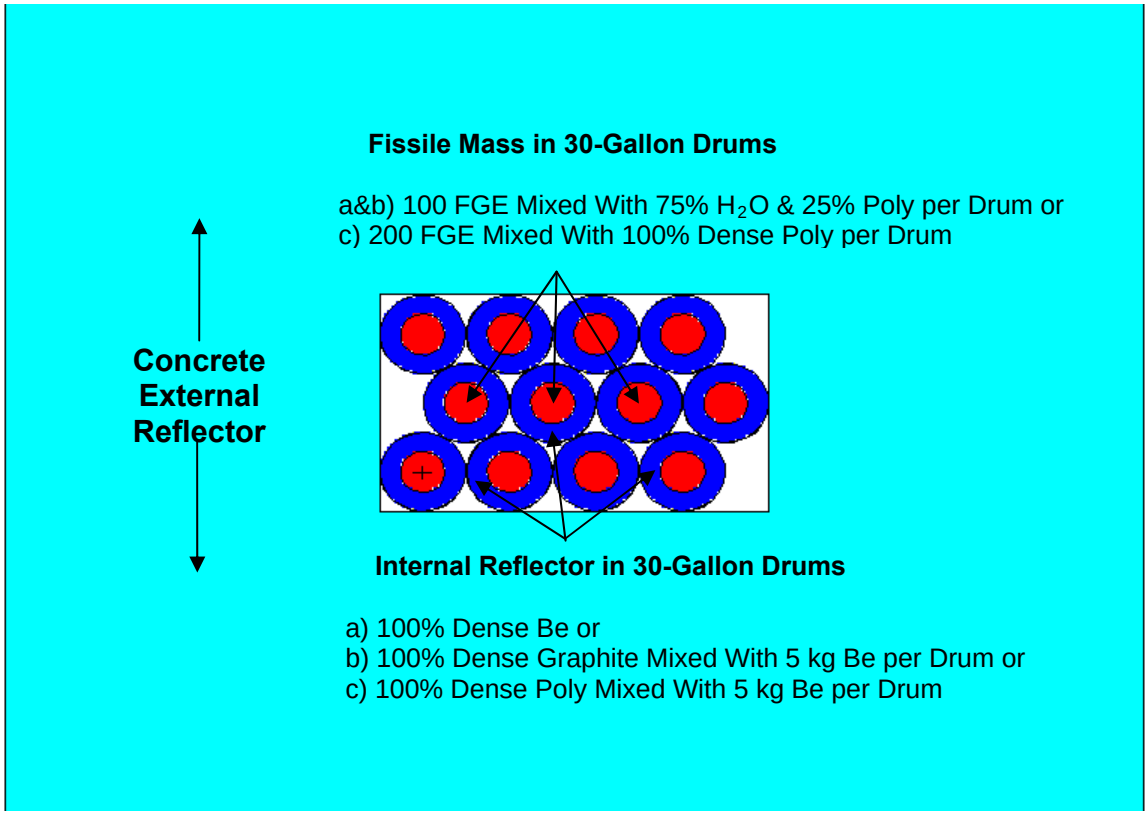


Figure 5-8, Model for Twelve 30-Gallon Drums in the WHB Upper Hot Cell

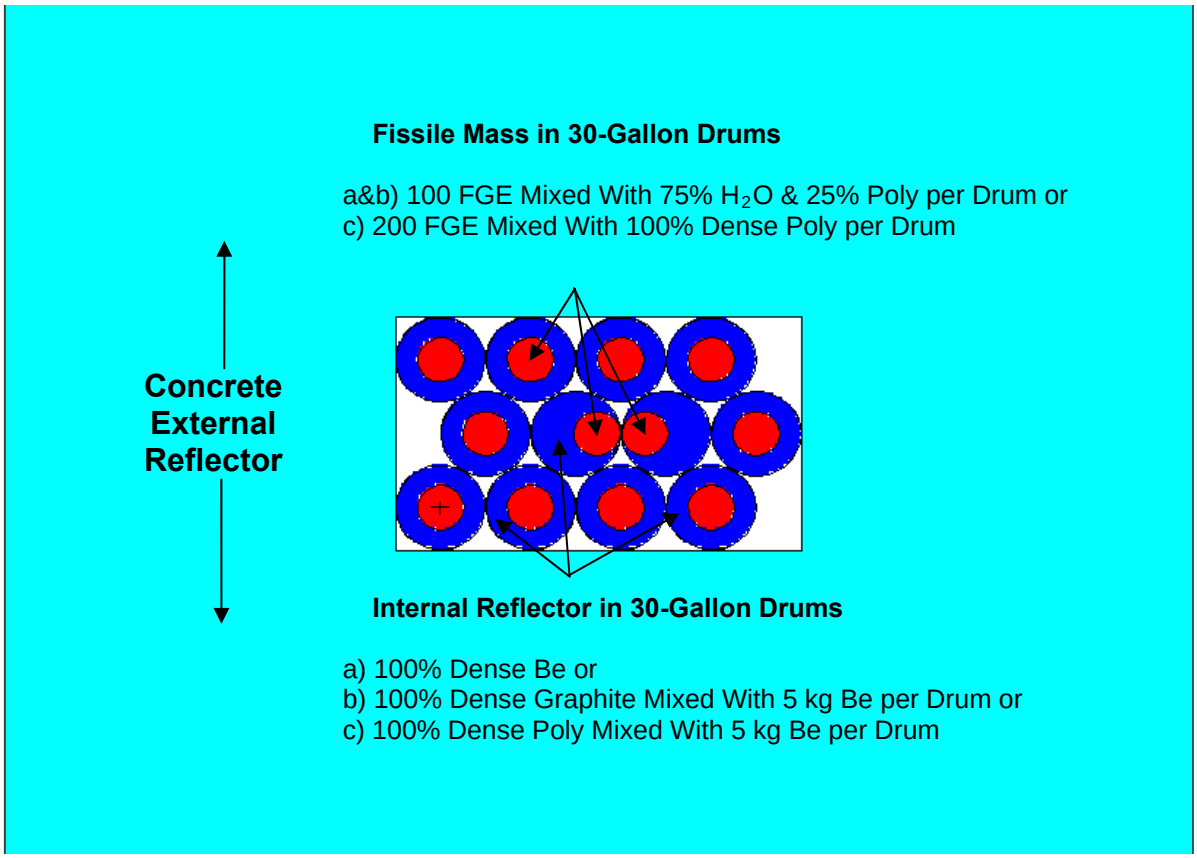


Figure 5-9, Model for Twelve 30-Gallon Drums in the WHB Upper Hot Cell (Close Proximity)

5.2.3 RH Waste Canister Borehole Array Models

Permanent disposal of RH waste canisters in the underground repository involves emplacing the 72-B or facility canisters in boreholes in the walls of the underground disposal rooms and disposal panel access drifts. Following disposal of the RH canisters in the wall of a given room or drift, the open space in the room or drift will be filled with CH waste containers. Borehole array models do not consider adjacent rooms and panels due to the large amount of salt between rooms and between panels (see Figure 2-4). Adjacent rooms have about 100 ft of salt between them, so that the back ends of the emplaced canisters in one room are always greater than 10 ft (over 300 cm) from the emplaced canisters in the next room. Adjacent panels have almost 200 ft of salt between them, so that the back ends of the canisters on the outside of one panel will be over 100 ft (over 30,000 cm) from those in the next panel. If boreholes are placed in both the disposal room walls and the panel access drift walls, the canisters may be within 10 ft of each other. The close proximity of canisters in rooms and connecting drifts requires that the bounding borehole array model be infinite in extent. More specifically, instead of modeling a specific room configuration, an infinitely long 2-deep array of the canisters is modeled.

The bounding model selected for this NCSE was a 2-deep array of 7-packs of RH canisters on a triangular pitch with a 2.5 ft center-to-center spacing between canisters. The 7-pack of canisters

is stacked horizontally in tandem to simulate two canisters per borehole. The shield plug is modeled as 5 ft thick concrete (greater than the 4 ft thick design) placed at the end of the second 7-pack to act as a radiation shield between the canisters in the boreholes and the personnel working outside the wall boreholes. The shield plug that is emplaced between canisters in a single borehole is conservatively ignored as it would isolate the canisters from one another. This model is very conservative compared to the nominal disposal configuration of one borehole every 8 ft but the use of the model does not drive any restrictions on the fissile loading.

The selected pitch represents the closest center-to-center distance that the canisters can be emplaced in the wall boreholes based on the borehole machine design constraints and mining practices. Typically, the RH canisters are placed on an 8-ft pitch with the salt in the wall acting to isolate each canister set from another. The use of a closely-packed array in the baseline analysis bounds potential misplacement of borehole location and also accounts for any movement or shifting in the salt which may result in a change in the initial borehole location.

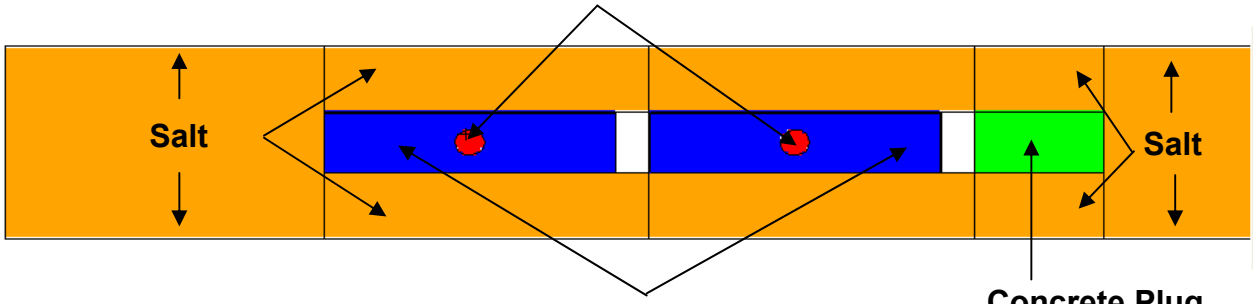
The number and location of the fissile masses within the canisters is contingent on whether the waste is direct loaded into the canister or is containerized in three 30-gallon drums. The baseline configuration assumes that the fissile mass is centered in the canister if direct loaded or centered in the individual drums if containerized as shown in Figure 5-10 and Figure 5-12, respectively. On average, this represents the most probable bounding configuration. The contents used in the underground storage array computations is consistent with that used in the above ground analysis since permanent disposal is the last step in the overall RH canister receipt and transport operation. Finally, a few highly improbable but limiting configurations are considered to simulate the possibility of fissile masses in adjacent canisters being placed in the closest proximity possible as shown in Figure 5-11.

The room or drift (i.e., the area adjacent to the boreholes) is initially empty but eventually filled with CH waste containers. As a result, a second configuration is considered where one end of the 2-deep canister array is reflected with 300 cm of salt and the other end is adjacent to a 7-pack of CH waste which is mirrored in all directions except the boundary facing the borehole. In this case, the composition of the infinite array of CH waste is selected to be a 7-pack of direct-loaded 55-gallon drums containing ≤ 1 wt% special reflector materials at the Nuclear Criticality Safety (NCS) limit of 650 FGE per 7-pack. The configuration of the 7-pack is the most reactive one found in *Two Container and Array Model Calculations for Non-Compacted Waste Containing <1wt% Beryllium* (Neeley 2007) in which one (1) of the drums contains 50 g ^{239}Pu, three (3) of the drums contain 200 g ^{239}Pu, and the other three (3) drums are non-fissile. All fissile bearing CH drums in the 7-pack contain ^{239}Pu mixed with a moderating mass that is 75% by volume water and 25% by volume polyethylene at an H/Pu ratio of 1,300. Five kilograms of beryllium is spread throughout the remainder of the drum volume. Likewise, the non-fissile bearing drums also contain 5 kg of beryllium. As shown in SAIC-1171-002, the absence of polyethylene in the reflector allows for maximum interaction between CH drums in the array. The MCNP5 model with CH waste is shown in Figure 5-13 and Figure 5-14 for direct loaded and containerized waste in the canisters, respectively.

Side View of Borehole

Fissile Mass in Canisters

a) 325 FGE Mixed With 75% H_2O & 25% Poly per Canister or
b & c) 100 FGE Mixed With 75% H_2O & 25% Poly per Canister or
d) 245 FGE Mixed With 100% Dense Poly per Canister



a) 25% Dense Poly Mixed With 32 kg Be or
b) 100% Dense Be or
c) 100% Dense Graphite Mixed With 32 kg Be or
d) 100% Dense Poly Mixed With 32 kg Be

End View of 7-Pack Array of Canisters in Boreholes

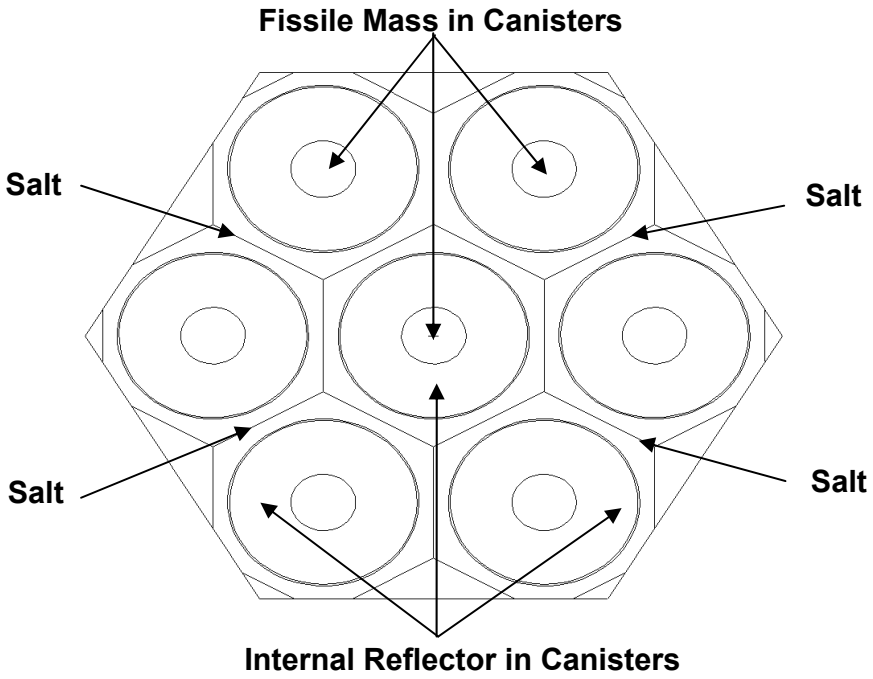
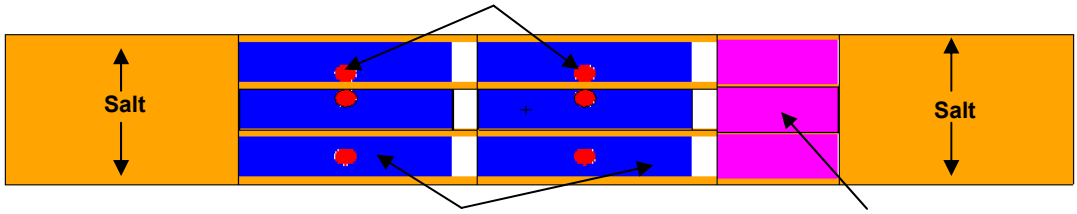


Figure 5-10, Model for Direct Loaded Canister in Underground Disposal Borehole Array

Side View of Borehole

Fissile Mass in Canisters

a) 325 FGE Mixed With 75% H_2O & 25% Poly per Canister or
b & c) 100 FGE Mixed With 75% H_2O & 25% Poly per Canister or
d) 245 FGE Mixed With 100% Dense Poly per Canister



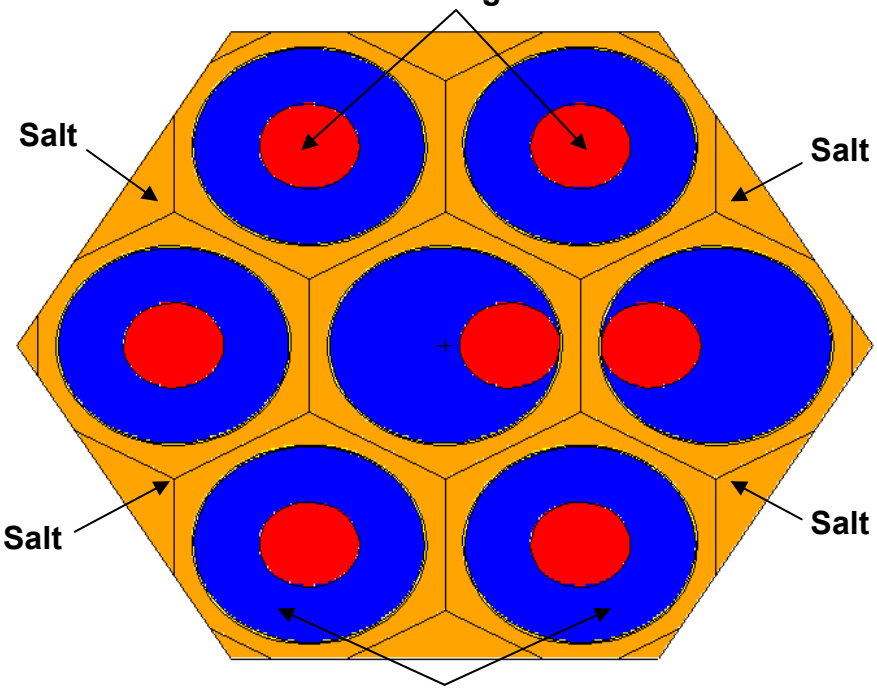
Internal Reflector in Canisters

Concrete Plug

a) 25% Dense Poly Mixed With 32 kg Be or
b) 100% Dense Be or
c) 100% Dense Graphite Mixed With 32 kg Be or
d) 100% Dense Poly Mixed With 32 kg Be

End View of 7-Pack Array of Canisters in Boreholes

Fissile Mass in 30-gallon Drums



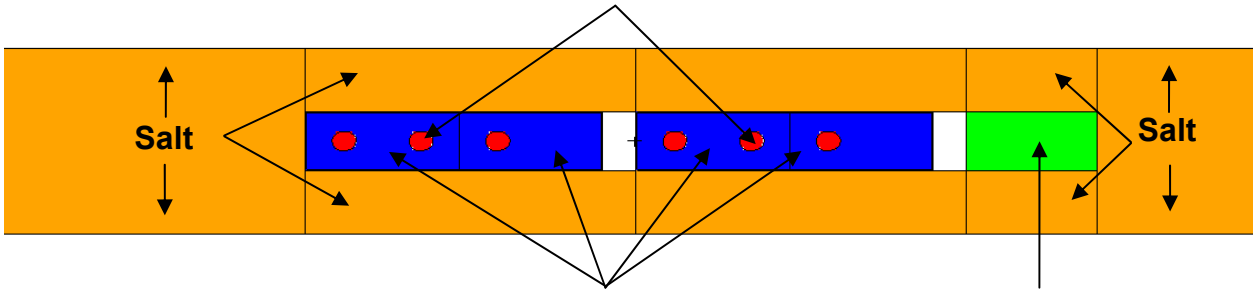
Internal Reflector in 30-gallon Drums

Figure 5-11, Model for Two Close Proximity Fissile Masses in Direct Loaded Canisters in Underground Disposal Borehole Array

Side View of Borehole

Fissile Mass in 30-Gallon Drums

a) 200 FGE Mixed With 75% H_2O & 25% Poly per Drum, or
b & c) 100 FGE Mixed With 75% H_2O & 25% Poly per Drum, or
d) 200 FGE Mixed With 100% Dense Poly per Drum



Internal Reflector in 30-Gallon Drums

Concrete Plug

- 25% Dense Poly Mixed With 32 kg Be or
- 100% Dense Be or
- 100% Dense Graphite Mixed With 32 kg Be or
- 100% Dense Poly Mixed With 32 kg Be

End View of 7-Pack Array of Canisters in Boreholes

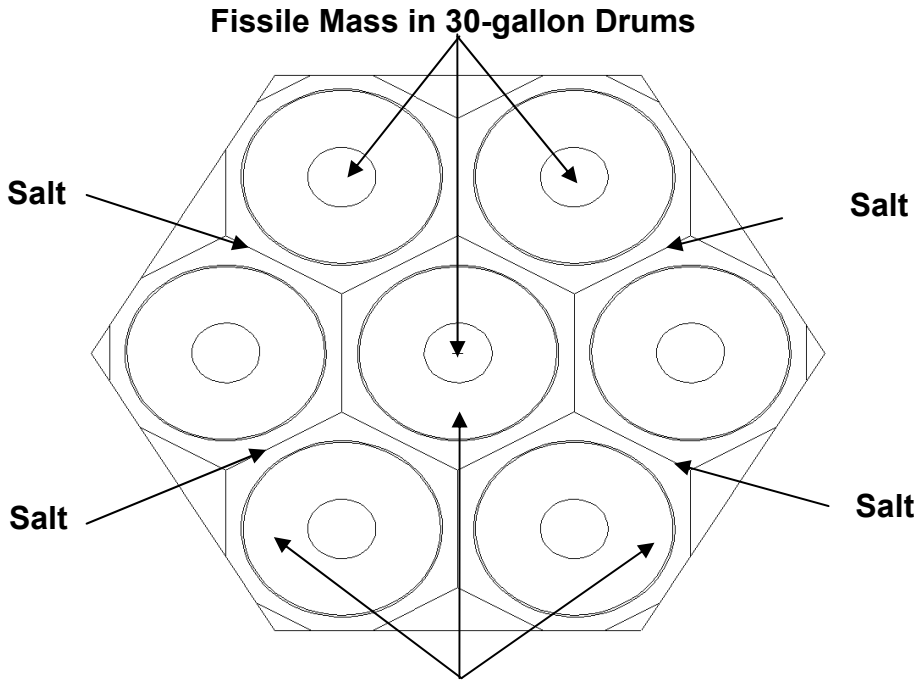


Figure 5-12, Model for Three 30-Gallon Drum Canister in Underground Disposal Borehole Array

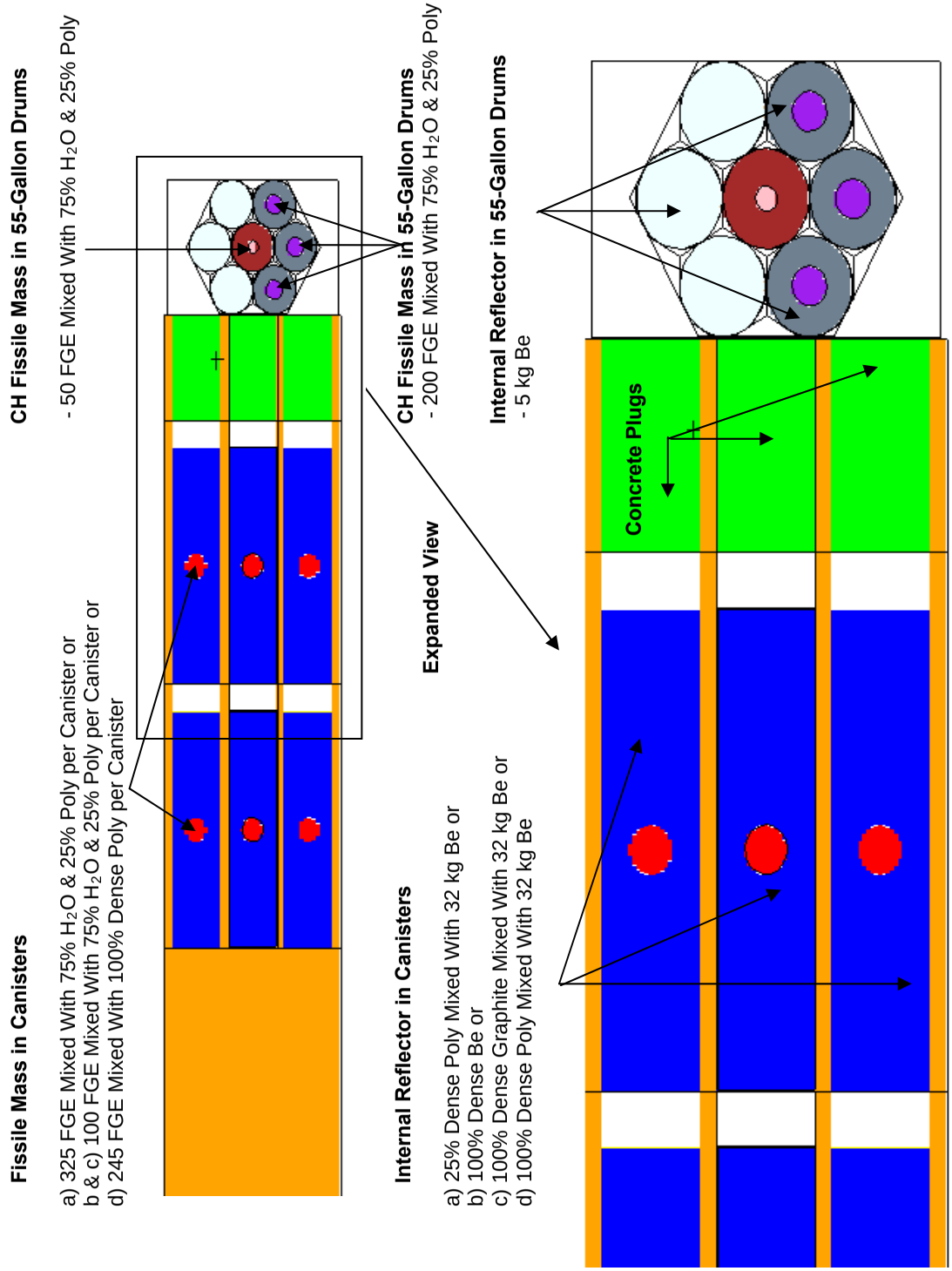


Figure 5-13, Model for Single Mass in Canister in Underground Disposal Borehole Array in the Presence of CH Waste

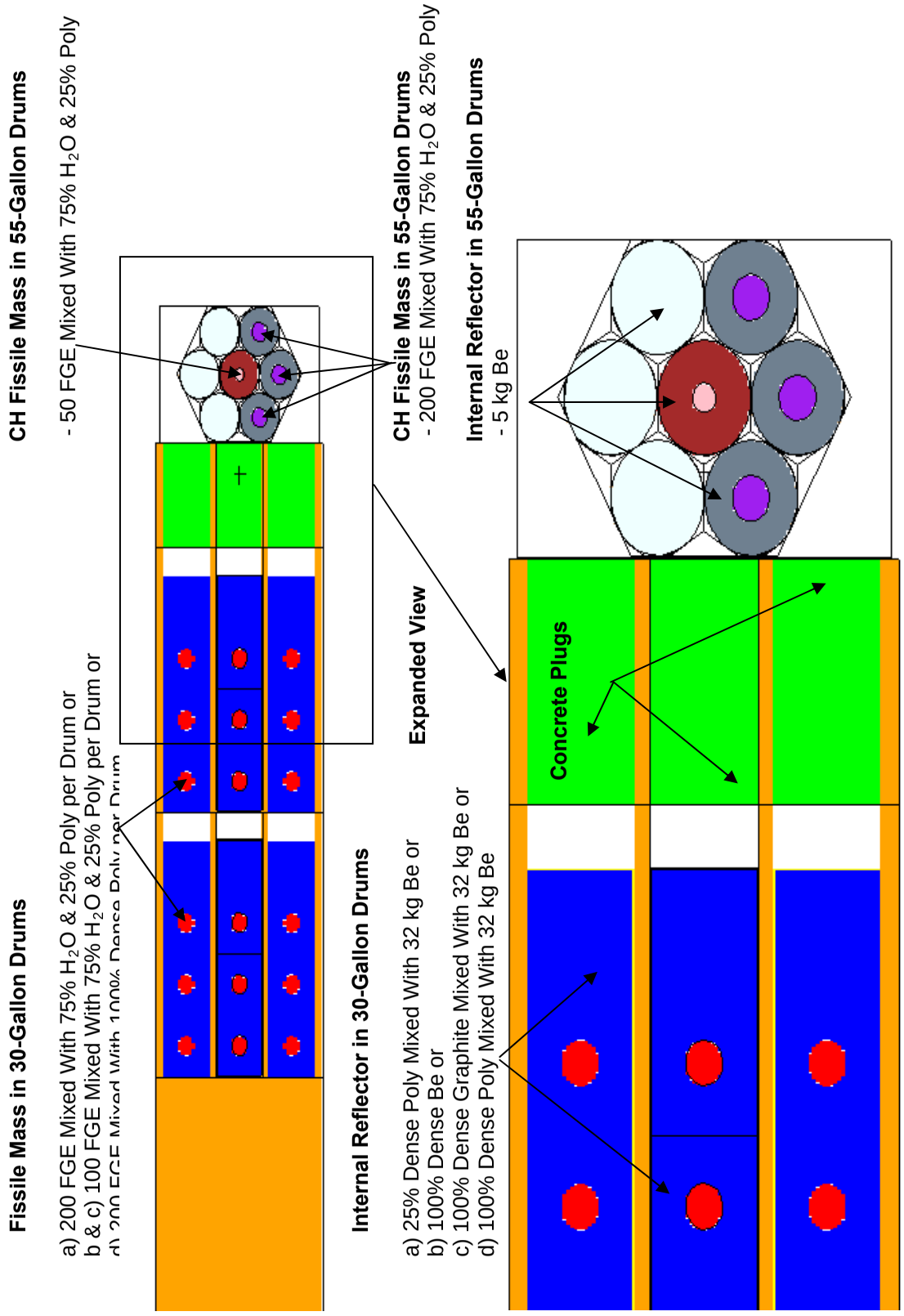


Figure 5-14, Model for Three 30-Gallon Drums in Canister in Underground Disposal Borehole Array in the Presence of CH Waste

5.3 Material Compositions

The material specifications used in the MCNP5 models are summarized in this section.

5.3.1 Fissile Waste Mixture

The majority of the fissile material to be disposed of at the WIPP is ^{239}Pu and is the only fissile component considered in the analysis, with the exception of the LEU payload which is modeled as ^{235}U. Other fissile isotopes are allowed at the WIPP on a ^{239}Pu FGE basis as defined in the RH-TRAMPAC (DOE-CBFO 2010b). The ^{239}Pu density used in determining source mixtures is 19.848 g/cm^3 (*Handbook of Chemistry and Physics* [CRC 1991-1992] and *Standard Composition Library* [Petrie et al. 2000]) for alpha phase Pu metal with a molecular weight of 239.05 (Petrie et al. 2000 and *Nuclides and Isotopes* [GE 1989]). The use of ^{239}Pu at 100% density bounds any potential combination of fissile nuclides that may be loaded in the waste stream.

The moderator component of the fissile mixture used in the criticality analyses is dependent on waste category. The moderating material in machine-compacted waste streams consists of pure polyethylene at its theoretical density of 0.923 g/cm^3 (Petrie et al. 2000). For all other non-compacted waste streams, the moderator was modeled as a mixture of polyethylene and water, which is 25% by volume polyethylene and 75% by volume water. Table 5-2 tabulates the fissile mass mixture compositions for ^{239}Pu with polyethylene and water moderation as a function of H/Pu ratio over the optimum range for the direct loaded and machine-compacted waste categories used in this NCSE. Table 5-3 gives similar values when ^{240}Pu is modeled with the ^{239}Pu and Table 5-4 tabulates the composition for waste mixtures containing ^{239}Pu bound to beryllium. The composition of the LEU fissile mixture is given in Table 5-5.

Table 5-2, Mixture Parameters for Various Waste Mixtures vs. H/Pu Ratio

H/Pu	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% ^{239}Pu	Wt.% H	Wt.% O	Wt.% C
325 g ^{239}Pu Mixed With 75% By Volume Water and 25% By Volume Polyethylene						
500	1.0320	11.1934	5.3608	11.3013	64.2472	19.0907
600	1.0232	11.8929	4.5076	11.4032	64.8264	19.2628
700	1.0170	12.5186	3.8887	11.4771	65.2466	19.3876
800	1.0123	13.0873	3.4193	11.5331	65.5653	19.4823
900	1.0087	13.6105	3.0509	11.5771	65.8153	19.5566
1000	1.0057	14.0962	2.7542	11.6125	66.0167	19.6165
1100	1.0033	14.5506	2.5101	11.6417	66.1824	19.6657
1200	1.0013	14.9783	2.3058	11.6661	66.3212	19.7070
1300	0.9997	15.3829	2.1322	11.6868	66.4390	19.7420
1400	0.9982	15.7672	1.9829	11.7046	66.5404	19.7721
1500	0.9970	16.1337	1.8532	11.7201	66.6284	19.7983

Table 5-2, Mixture Parameters for Various Waste Mixtures vs. H/Pu Ratio (continued)

H/Pu	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% ^{239}Pu	Wt.% H	Wt.% O	Wt.% C
200 g ^{239}Pu Mixed With 75% By Volume Water and 25% By Volume Polyethylene						
500	1.0320	9.52090	5.3608	11.3013	64.2472	19.0907
600	1.0232	10.1159	4.5076	11.4032	64.8264	19.2628
700	1.0170	10.6481	3.8887	11.4771	65.2466	19.3876
800	1.0123	11.1318	3.4193	11.5331	65.5653	19.4823
900	1.0087	11.5768	3.0509	11.5771	65.8153	19.5566
1000	1.0057	11.9900	2.7542	11.6125	66.0167	19.6165
1100	1.0033	12.3765	2.5101	11.6417	66.1824	19.6657
1200	1.0013	12.7403	2.3058	11.6661	66.3212	19.7070
1300	0.9997	13.0844	2.1322	11.6868	66.4390	19.7420
1400	0.9982	13.4113	1.9829	11.7046	66.5404	19.7721
1500	0.9970	13.7230	1.8532	11.7201	66.6284	19.7983
100 g ^{239}Pu Mixed With 75% By Volume Water and 25% By Volume Polyethylene						
500	1.0320	7.5567	5.3608	11.3013	64.2472	19.0907
600	1.0232	8.0290	4.5076	11.4032	64.8264	19.2628
700	1.0170	8.4514	3.8887	11.4771	65.2466	19.3876
800	1.0123	8.8353	3.4193	11.5331	65.5653	19.4823
900	1.0087	9.1885	3.0509	11.5771	65.8153	19.5566
1000	1.0057	9.5165	2.7542	11.6125	66.0167	19.6165
1100	1.0033	9.8232	2.5101	11.6417	66.1824	19.6657
1200	1.0013	10.1120	2.3058	11.6661	66.3212	19.7070
1300	0.9997	10.3851	2.1322	11.6868	66.4390	19.7420
1400	0.9982	10.6445	1.9829	11.7046	66.5404	19.7721
1500	0.9970	10.8919	1.8532	11.7201	66.6284	19.7983
245 g ^{239}Pu Mixed With 100% Dense Polyethylene						
500	0.9828	9.7675	6.3862	13.4628	0	80.1510
600	0.9729	10.3777	5.3791	13.6076	0	81.0133
700	0.9658	10.9235	4.6463	13.7130	0	81.6406
800	0.9604	11.4196	4.0893	13.7931	0	82.1176
900	0.9563	11.8760	3.6515	13.8561	0	82.4924
1000	0.9530	12.2998	3.2984	13.9069	0	82.7947
1100	0.9502	12.6962	3.0076	13.9487	0	83.0437
1200	0.9480	13.0693	2.7639	13.9837	0	83.2524

Table 5-2, Mixture Parameters for Various Waste Mixtures vs. H/Pu Ratio (continued)

H/Pu	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% ^{239}Pu	Wt.% H	Wt.% O	Wt.% C
1300	0.9461	13.4223	2.5567	14.0135	0	83.4298
1400	0.9444	13.7576	2.3784	14.0392	0	83.5824
1500	0.9430	14.0773	2.2234	14.0615	0	83.7152
200 g ^{239}Pu Mixed With 100% Dense Polyethylene						
500	0.9828	9.1286	6.3862	13.4628	0	80.1510
600	0.9729	9.6989	5.3791	13.6076	0	81.0133
700	0.9658	10.2090	4.6463	13.7130	0	81.6406
800	0.9604	10.6727	4.0893	13.7931	0	82.1176
900	0.9563	11.0992	3.6515	13.8561	0	82.4924
1000	0.9530	11.4953	3.2984	13.9069	0	82.7947
1100	0.9502	11.8658	3.0076	13.9487	0	83.0437
1200	0.9480	12.2145	2.7639	13.9837	0	83.2524
1300	0.9461	12.5443	2.5567	14.0135	0	83.4298
1400	0.9444	12.8577	2.3784	14.0392	0	83.5824
1500	0.9430	13.1565	2.2234	14.0615	0	83.7152

Table 5-3, Mixture Parameters for Waste Mixtures with ^{240}Pu vs. H/Pu Ratio

H/Pu	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% ^{239}Pu	Wt.% ^{240}Pu	Wt.% H	Wt.% O	Wt.% C
350 g ^{239}Pu/15 g ^{240}Pu Mixed With 75% By Volume Water and 25% By Volume Polyethylene							
500	1.0320	11.4731	5.2846	0.0766	11.3012	64.2470	19.0906
600	1.0233	12.1901	4.4435	0.0644	11.4031	64.8262	19.2627
700	1.0170	12.8314	3.8334	0.0556	11.4770	65.2464	19.3876
800	1.0123	13.4144	3.3706	0.0488	11.5331	65.5651	19.4823
900	1.0087	13.9506	3.0075	0.0436	11.5771	65.8152	19.5566
1000	1.0057	14.4485	2.7151	0.0393	11.6125	66.0166	19.6165
1100	1.0033	14.9143	2.4744	0.0359	11.6417	66.1823	19.6657
1200	1.0014	15.3526	2.2730	0.0329	11.6661	66.3211	19.7069
1300	0.9997	15.7673	2.1019	0.0305	11.6868	66.4389	19.7419
1400	0.9982	16.1612	1.9547	0.0283	11.7046	66.5403	19.7721
1500	0.9970	16.5368	1.8268	0.0265	11.7201	66.6284	19.7982

Table 5-3, Mixture Parameters for Waste Mixtures with ^{240}Pu vs. H/Pu Ratio (continued)

H/Pu	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% ^{239}Pu	Wt.% ^{240}Pu	Wt.% H	Wt.% O	Wt.% C
370 g ^{239}Pu/25 g ^{240}Pu Mixed With 75% By Volume Water and 25% By Volume Polyethylene							
500	1.0320	11.6872	5.1443	0.2174	11.3012	64.2466	19.0905
600	1.0233	12.4176	4.3256	0.1828	11.4031	64.8259	19.2626
700	1.0170	13.0709	3.7317	0.1577	11.4770	65.2461	19.3875
800	1.0123	13.6646	3.2812	0.1386	11.5331	65.5649	19.4822
900	1.0087	14.2109	2.9277	0.1237	11.5770	65.8150	19.5565
1000	1.0057	14.7181	2.6430	0.1117	11.6125	66.0164	19.6164
1100	1.0033	15.1925	2.4088	0.1018	11.6416	66.1822	19.6656
1200	1.0014	15.6391	2.2127	0.0935	11.6660	66.3209	19.7069
1300	0.9997	16.0615	2.0461	0.0865	11.6868	66.4388	19.7419
1400	0.9982	16.4628	1.9029	0.0804	11.7046	66.5401	19.7720
1500	0.9970	16.8454	1.7783	0.0751	11.7201	66.6282	19.7982

Table 5-4, Mixture Parameters for Waste Mixtures with ^{239}Pu bound with Beryllium vs. H/Pu Ratio

H/Pu Ratio	Mixture Density (g/cm^3)	Mixture Radius (cm)	Wt.% Pu	Wt.% H	Wt.% O	Wt.% C	Wt.% Be
305 FGE Mixed With 45% By Volume Water, 15% By Volume Polyethylene and 40% By Volume Be							
500	1.3586	12.9884	2.4459	5.1562	29.3130	8.7102	54.3747
600	1.3535	13.8009	2.0466	5.1773	29.4330	8.7458	54.5973
700	1.3498	14.5276	1.7594	5.1925	29.5193	8.7715	54.7574
800	1.3470	15.1881	1.5428	5.2040	29.5843	8.7908	54.8781
900	1.3449	15.7957	1.3738	5.2129	29.6351	8.8059	54.9723
1000	1.3432	16.3598	1.2381	5.2201	29.6759	8.8180	55.0479
1100	1.3417	16.8874	1.1268	5.2260	29.7093	8.8280	55.1099
1200	1.3406	17.3840	1.0339	5.2309	29.7373	8.8363	55.1617
1300	1.3396	17.8538	0.9551	5.2350	29.7609	8.8433	55.2056
1400	1.3387	18.3000	0.8875	5.2386	29.7812	8.8493	55.2433
1500	1.3380	18.7255	0.8288	5.2417	29.7989	8.8546	55.2760

Table 5-5, Mixture Parameters for LEU Fissile Waste Mixtures vs. ^{235}U Enrichment

^{235}U Enrichment	Mixture Density (g/cm^3)	Wt.% ^{235}U	Wt.% ^{238}U	Wt.% H	Wt.% O	Wt.% C	Wt.% Be
LEU Mixed With 75% By Volume Water, 25% By Volume Polyethylene and 1% by Volume Be at H/^{235}U Ratio of 500							
0.96	5.1470	0.8182	84.4082	1.7323	9.8103	2.9545	0.2767
1.10	4.7272	0.9177	82.5109	1.9431	11.0040	3.3140	0.3103
1.25	4.3623	1.0198	80.5650	2.1593	12.2284	3.6827	0.3448

5.3.2 Reflector Materials in the Waste Containers

The reflector materials modeled around the fissile mixtures were discussed in Section 5.1 for each waste loading. The reflector material internal to the canister was varied to maximize reactivity of the above ground RH waste container receipt, storage and conveyance models and the underground disposal array models. The reflector compositions modeled to meet this objective include: (1) 1 wt% beryllium (by maximum allowed container weight) mixed with and without 25% dense polyethylene; (2) 1 wt% beryllium mixed with graphite at 100% and 70% theoretical density or 2.3 and 1.61 g/cm^3 respectively; (3) unlimited beryllium at 100% and 70% of theoretical density or 1.85 and 1.295 g/cm^3 respectively; and (4) 1 wt% beryllium mixed with polyethylene at 100% of theoretical density or 0.923 g.cm^3. The theoretical densities are taken from Petrie et al. (2000). For waste types limited to $\leq$ 1 wt% special reflector materials, beryllium at 1 wt% of the maximum container contents loading is modeled spread through the reflector region.

5.3.3 Container Materials of Construction

All RH-TRU waste will be loaded directly into the payload canister or into 30- or 55-gallon drums which are then loaded into a canister. The 72-B payload canister can be made of either stainless steel or carbon steel (RH-TRAMPAC [DOE-CBFO 2010b]). The specifications for the drums in the canister require only that they be constructed of low carbon or stainless steel (304L). The drums may also be loaded into NS30 or NS15 neutron shielded canisters which are 72-B canisters augmented with HDPE (as per Section 2.2.5). The facility cask has a large amount of ASTM A36 steel in its structural components. Scoping studies found little difference in reactivity of the systems when varying the steel composition. Type 304L stainless steel was chosen for modeling all structural components of the canister and drums. Reflection during conveyance in the facility cask is modeled with 200 cm thick lead, which bounds any steel in the facility cask. Furthermore, because the WIPP repository is situated in a series of thick salt beds, the environment could cause a degradation of the structural components over long periods of time. If credit is taken for the nominal wall thickness (i.e., nominal wall density) in the analyses, the wall thickness becomes a controlled parameter. To avoid imposing controls on the thickness and nature of the drum walls, a reduced density of 50% of nominal is assumed in all criticality

safety calculations. The specification for the 304L stainless steel modeled is given in Table 5-6 and for the HDPE (ASTM D3350 cell classification of #345444C or better) in Table 5-7.

Table 5-6, Material Specification for 304L Stainless Steel Used in the MCNP5 Models

Element/Isotope	Wt%	Atom Fraction
Density 8.01 g/cm^3		
C	0.08	0.0036371
Mn	2.0	0.019879
P	0.045	0.00079333
S	0.03	0.00051087
Si	1.0	0.019443
Cr	20.0	0.21004
^{50}Cr	0.8357	0.0091366
^{52}Cr	16.74	0.17599
^{53}Cr	1.9345	0.019954
^{54}Cr	0.48964	0.0049569
Ni	12.0	0.11164
^{58}Ni	8.0641	0.076006
^{60}Ni	3.2127	0.029273
^{61}Ni	0.14202	0.0012727
^{62}Ni	0.45961	0.0040526
^{64}Ni	0.12155	0.0010383
Fe	64.845	0.63406
^{54}Fe	3.664	0.037092
^{56}Fe	59.591	0.58175
^{57}Fe	1.4016	0.013442
^{58}Fe	0.18836	0.0017754

Table 5-7, Material Composition for HDPE

Element	Atoms per Molecule
Density 0.94 g/cm^3	
H	2
C	1

5.3.4 External Reflector Compositions

To simulate the receipt, above ground interim storage, conveyance and permanent disposal in the underground repository, three different reflectors are used to bound the processing/storage/ disposal configurations, namely concrete, lead, and salt. Ordinary concrete at a density of 2.35 g/cm^3 is used to bound above ground processing and temporary storage as the hot cell walls are thick concrete. Likewise, lead is a significant material in the facility cask which is used in transporting the 72-B or facility canister from the WHB processing area to the underground repository for disposal emplacement. Lead has a density of 11.3437 g/cm^3 and consists of four naturally occurring isotopes, namely ^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb. ^{204}Pb, which represents 1.4 atom% of natural lead, and is not included in the ENDF-VI MCNP library. The abundance of the other three isotopes is normalized to account for the missing data. Finally, salt is used as a reflector in the underground array models. Salt is taken as NaCl with a density of 2.165 g/cm^3 with the atomic weights of sodium and chloride being 22.9898 and 35.4527, respectively. The compositions of the concrete, lead, and salt reflectors used are summarized in Table 5-8 through Table 5-10.

Table 5-8, Material Composition for Concrete

Element/Isotope	Wt%
Density 2.35 g/cm^3	
H	0.56
O	49.81
Na	1.71
Mg	0.26
Al	4.56
Si	31.51
S	0.13
K	1.92
Ca	8.29
^{54}Fe	0.070065
^{56}Fe	1.1395
^{57}Fe	0.026801
^{58}Fe	0.0036018

Table 5-9, Material Composition for Lead

Element/Isotope	Atom%	Atom% Normalized for lack of ^{204}Pb cross-section
Density 11.3437 g/cm^3		
^{206}Pb	24.1	24.444
^{207}Pb	22.1	22.414
^{208}Pb	52.4	53.144

Table 5-10, Material Composition for Salt

Element/Isotope	Wt%
Density 2.165 g/cm^3	
Na	39.3372
Cl	60.6628

5.4 Results of Above Ground Receipt, Processing, and Conveyance Calculations for Normal Conditions

The results of the MCNP5 calculations for normal conditions involving above ground handling and conveyance to the underground are discussed in this section. The results are tabulated in Appendix A and sample input files are given in Appendix B.

5.4.1 Results of Direct Loaded Canister Calculations

Nuclear criticality computations simulating the receipt, storage, and transport operations of RH waste direct loaded into a canister were performed with MCNP5 as described in Section 5.2.1. The results of the baseline calculations, which are consistent with the RH-TRU 72-B SAR (DOE-CBFO 2010a) loadings and assumptions, are tabulated in Table A-1 through Table A-4 of Appendix A. Figure 5-15 and Figure 5-16 illustrate graphically the reactivity variation of the various loadings as a function of H/Pu ratio for the two external reflectors modeled, lead and concrete, respectively. As indicated by the applicable tables and figures, all cases are well below the established USL with the highest $k_{eff} + 2\sigma$ value being less than 0.93.

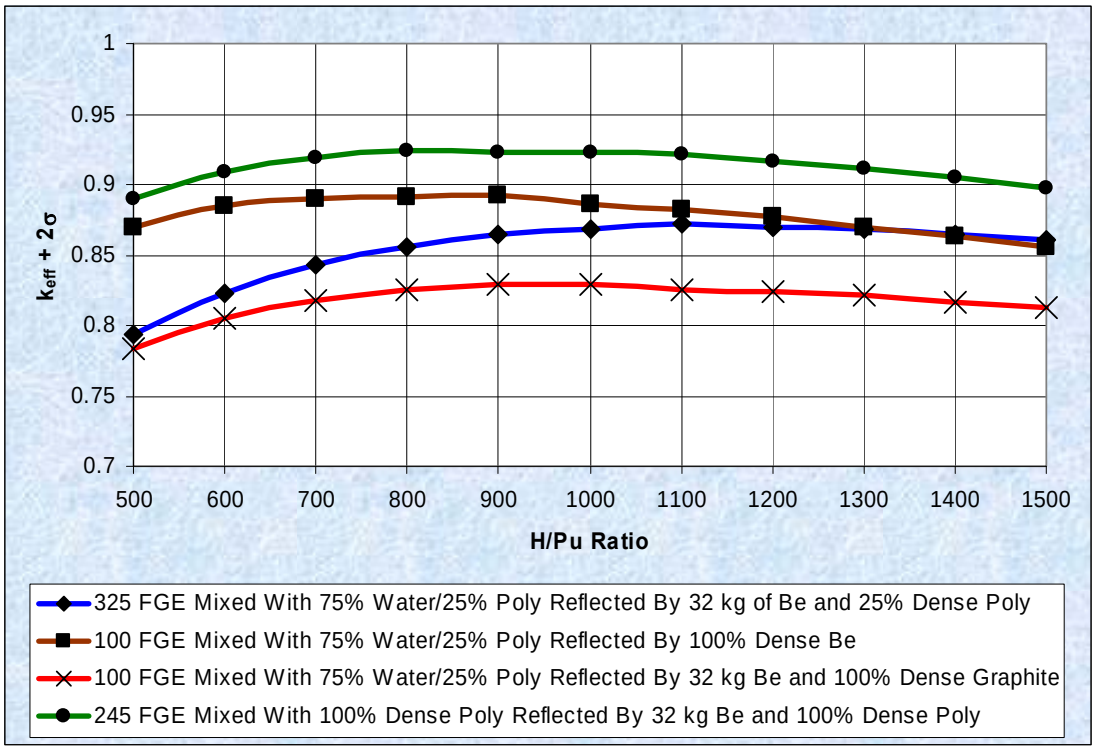


Figure 5-15, Single Direct Loaded Canister Reflected By 200 cm of Lead

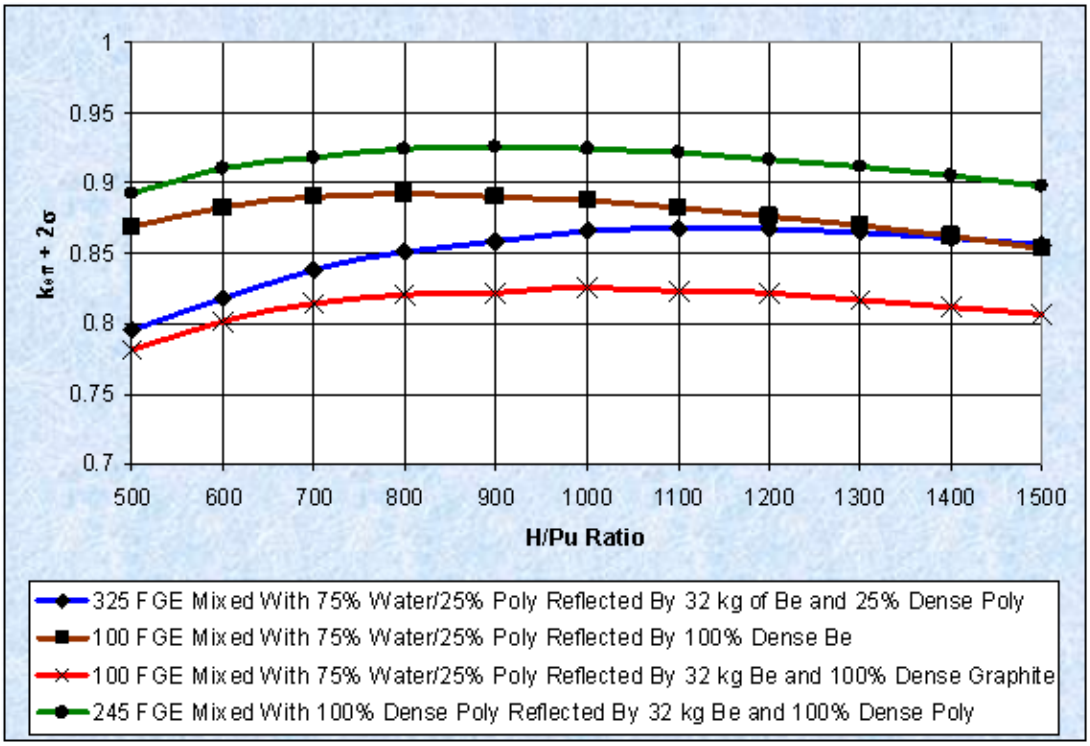


Figure 5-16, Single Direct Loaded Canister Reflected By 200 cm of Concrete

Criticality computations were also performed to address direct loaded waste packages that credit the ^{240}Pu content in the fissile mixture. Specifically, two fissile isotope mixtures were considered, namely 350 g ^{239}Pu with 15 g ^{240}Pu and with 370 g ^{239}Pu with 25 g ^{240}Pu. In both cases, the moderating mixture was 25% polyethylene/75% water by volume. The fissile masses were reflected by 32 kg of beryllium mixed with and without 25% dense polyethylene. The direct loaded canister was reflected by 2-meters of lead. The results of the calculation are summarized in Table A-5 through Table A-8 as well as Figure 5-17. As indicated by the tabulated and graphical data, all cases are well below the USL. As expected, the inclusion of the 25% dense polyethylene in the single canister model results in a higher reactivity than if it is excluded. (Because the previous calculations showed that lead and concrete reflection result in comparable k_{eff} values and the maximum k_{eff} value found with lead reflection is less than 0.88, these cases are not repeated with concrete reflection.)

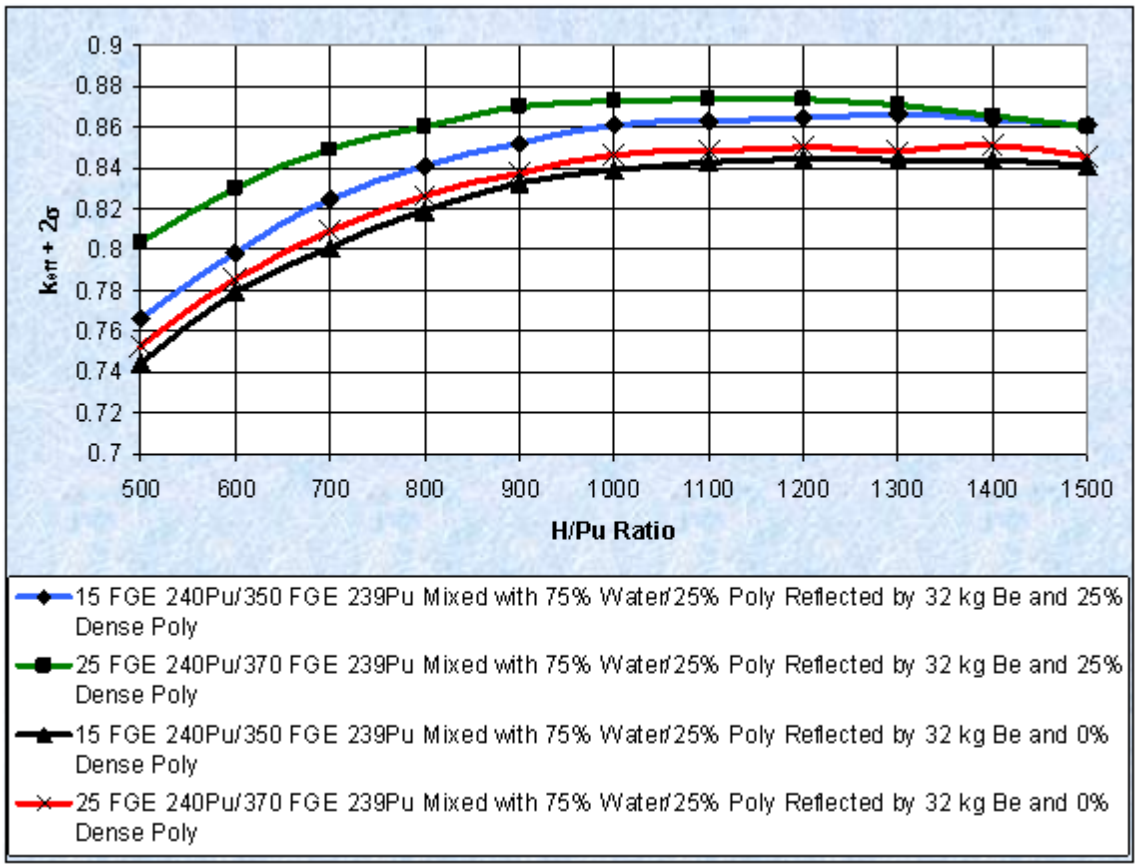


Figure 5-17, Single Direct Loaded Canister with a Fissile Mixture of ^{239}Pu and ^{240}Pu Reflected by 200 cm of Lead

Additionally, calculations involving waste packages in which the Pu is mechanically or chemically bound to the special reflector material were performed. A scoping study was performed to determine the most reactive moderating mixture as shown in Figure 5-18 and tabulated in Table A-9 through Table A-11. It was determined that a 15% polyethylene/45% water/40% beryllium by volume mixture was the most limiting moderator mixture, which is

consistent with that reported in the RH-TRU 72-B SAR (DOE-CBFO 2010a). Using this moderating mixture with 305 g ^{239}Pu to formulate the fissile mass, a series of computations were performed in which a direct loaded canister was reflected by 32 kg of beryllium both in the presence and absence of 25% dense polyethylene. The computational results, which are tabulated in Table A-12 through Table A-15 and displayed graphically in Figure 5-19, indicates that a direct loaded canister with 305 FGE ^{239}Pu mechanically or chemically bound to the special reflector material is well below the established USL of 0.96.

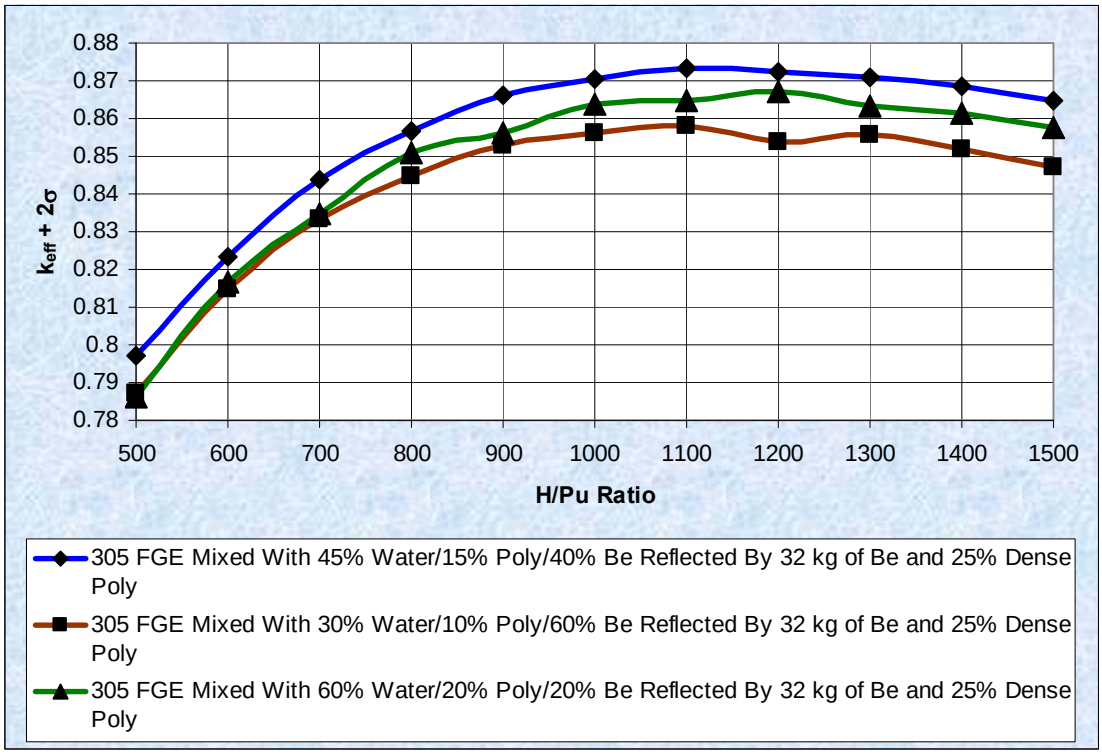


Figure 5-18, Study Results to Determine the Most Reactive Moderating Composition when Beryllium is Bound to the Fissile Mass

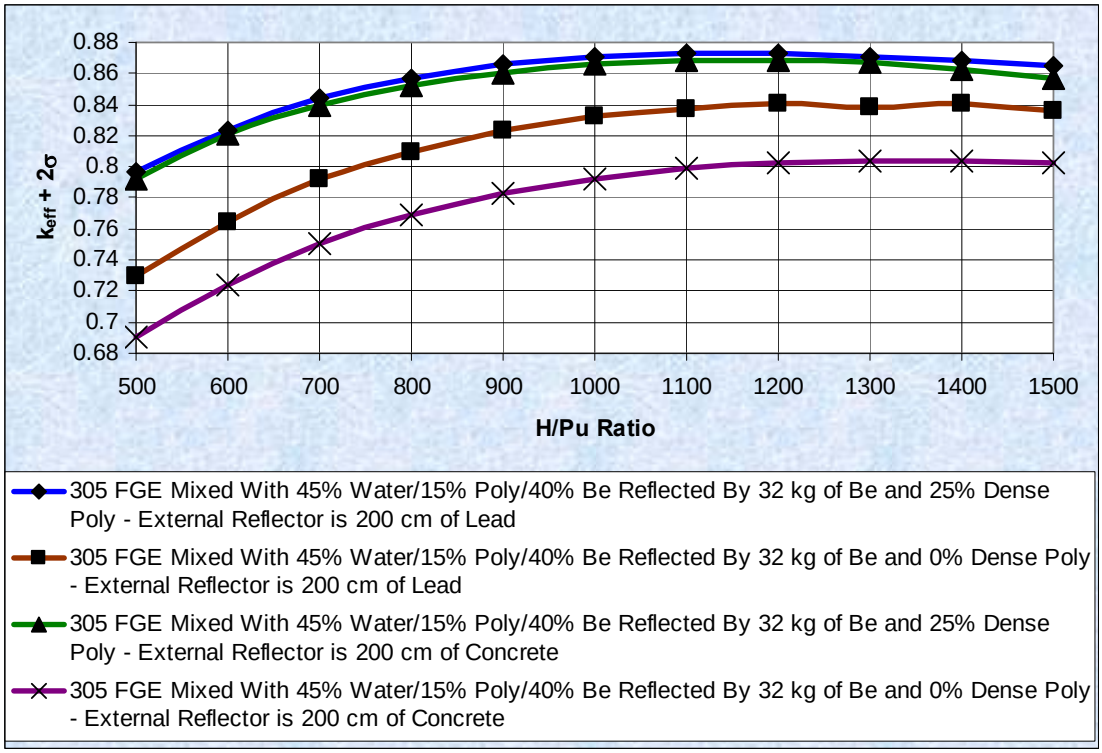


Figure 5-19, Single Direct Loaded Canister with Bound Beryllium

Finally to account for potential LEU waste streams, nuclear criticality computations were performed for direct loaded canisters that contain 0.96 wt% ^{235}U. Scoping parametric studies indicated that the most reactive moderating mixture was 25% polyethylene/74% water/1% beryllium by volume at an H/^{235}U ratio of 400. The results of the scoping study are summarized in Table A-16 and Figure 5-20. Using these mixture parameters at an H/^{235}U ratio of 400 in the geometric model described earlier in Section 5.2.1 in which the total fissile mixture mass was adjusted to 3,129 kg (6,900 lbs) and reflected with 100% dense beryllium yielded a system eigenvalue of 0.91276 which is again below the established USL.

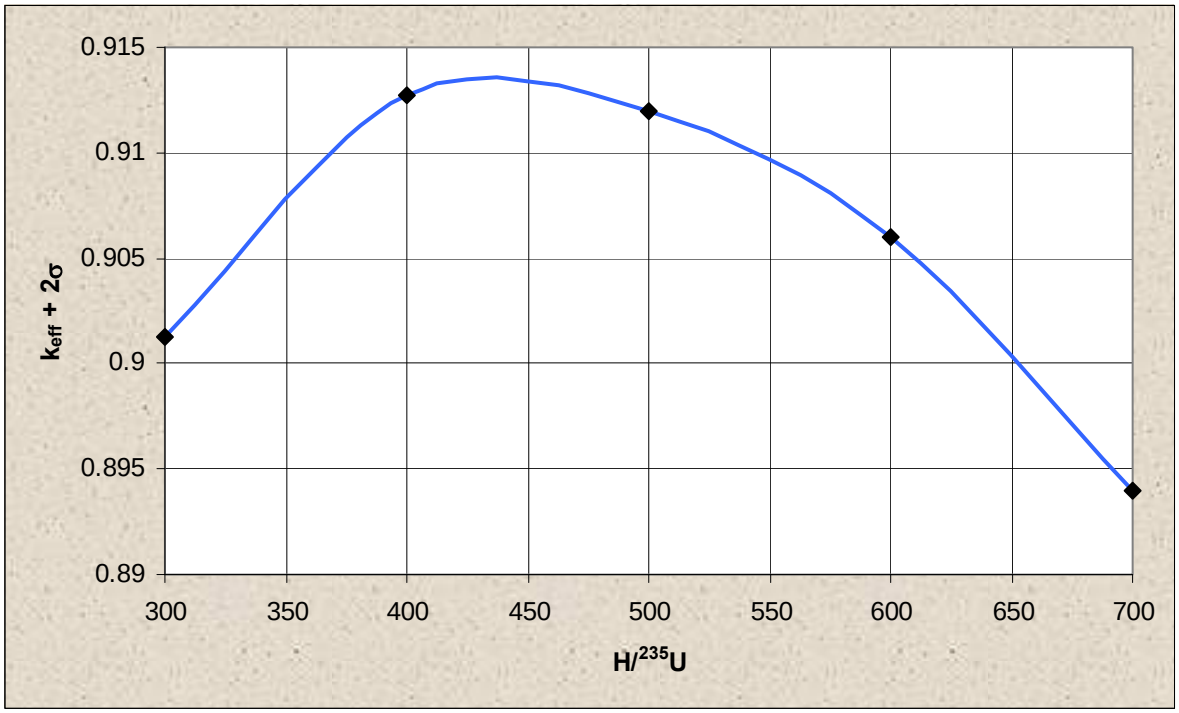


Figure 5-20, Reactivity of Single Direct Loaded Canister Containing LEU Waste Packages at 0.96% ^{235}U as a Function of H/U Ratios

5.4.2 Calculation Results for Canisters Containing Three 30-Gallon Drums

Nuclear calculations involving the receipt, waste handling operations, storage and disposal of containerized waste in RH canisters were performed with MCNP5 as described in Section 5.2.1. The results of the computational analyses are summarized numerically in: (1) Table A-17 through Table A-20 and graphically in Figure 5-21 and Figure 5-22 for the conventional centered fissile mass configuration shown in Figure 5-3; (2) Table A-21 through Table A-26 and Figure 5-23 through Figure 5-26 for the conservative central and edge two-drum arrangements shown in Figure 5-4 and Figure 5-5; and (3) Table A-27 through Table A-30 and Figure 5-27 through Figure 5-30 for the two-drum arrangements using the explicit central or edge two-drum models for 30-gallon and 55-gallon drums shown in Figures 5-6 and 5-7.

The results indicate that the reactivity state for all loadings and configurations are less than the established USL with the fissile material centrally located within each drum. In reality, the fissile material is expected to be spread throughout the drum and the creation of an optimally moderated, tight spherical fissile configuration is highly unlikely but modeled as a bounding configuration. Other conservatisms, as described in Section 5.2, include that the 1 wt% Be was conservatively modeled as 32 kg based on the canister net weight, which is greater than the maximum allowable drum loading of 5 kg Be and the dunnage fills the entire canister, not just the drums.

The results of the two-drum configuration, which is an even less likely configuration but does represent a worst-case normal condition, exceed the USL for loadings containing >1 wt% special reflector material, when modeled at 100% of theoretical density, or machine compacted waste. Thus, a more realistic approach was required for these loadings. For non-compacted waste packages with > 1 wt% special reflector materials, the special reflector packing fraction was reduced from theoretical density to 70% of theoretical density, as justified in Section 5.1.2. The reduction in reflector packing fraction has a large effect on reactivity and thus allows for adherence to established USL limits for drums containing 100 FGE per drum with >1% beryllium internal reflection, and a 20% increase in FGE (i.e., 120 g ^{239}Pu) for graphite reflected systems even in the most conservative two-drum model. Also, note that the lead reflector results in a higher k_{eff} value than concrete in the two-drum edge model as seen by comparing Figure 5-25 and Figure 5-26 and Figure 5-29 and Figure 5-30 whereas, in the other models, the difference is not statistically significant.

For machine-compacted waste packages, an explicit modeling approach was used in which the drums were modeled explicitly, including the drum lid structure plus 1.0-in. design spacing, and placed in the canister without additional fill around the drums. Two configurations, the explicit central and edge two-drum models shown in Figure 5-6 and Figure 5-7 were modeled. Both 30-gallon and 55-gallon drums were modeled as the larger radius of the 55-gallon drum allows for a thicker reflector within the canister. Using the explicit two-drum model, the canisters of drummed machine-compacted waste remain below the USL of 0.96.

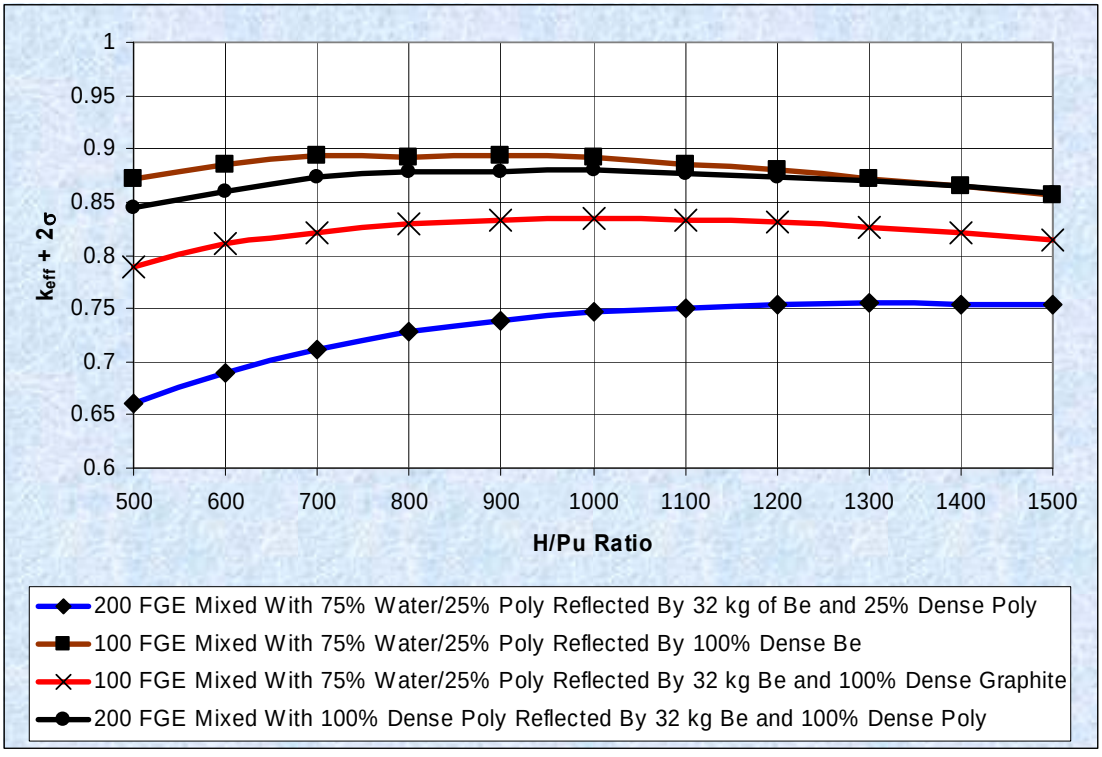


Figure 5-21, Three Drums in a Canister Reflected By 200 cm of Lead

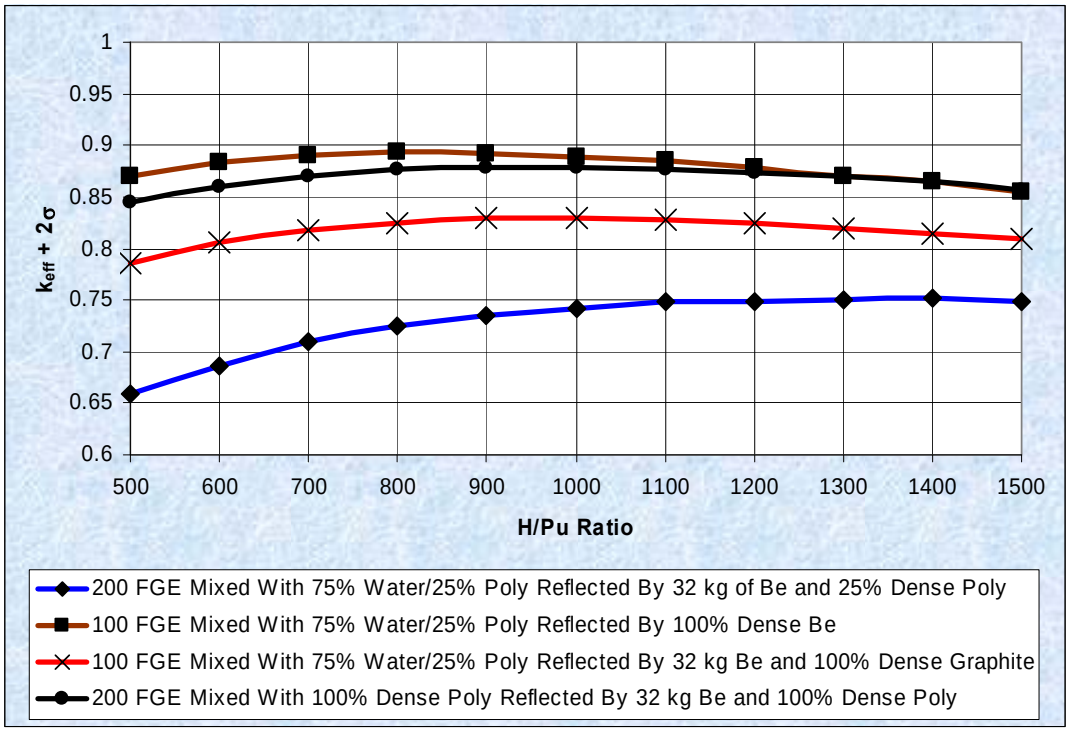


Figure 5-22, Three Drums in a Canister Reflected By 200 cm of Concrete

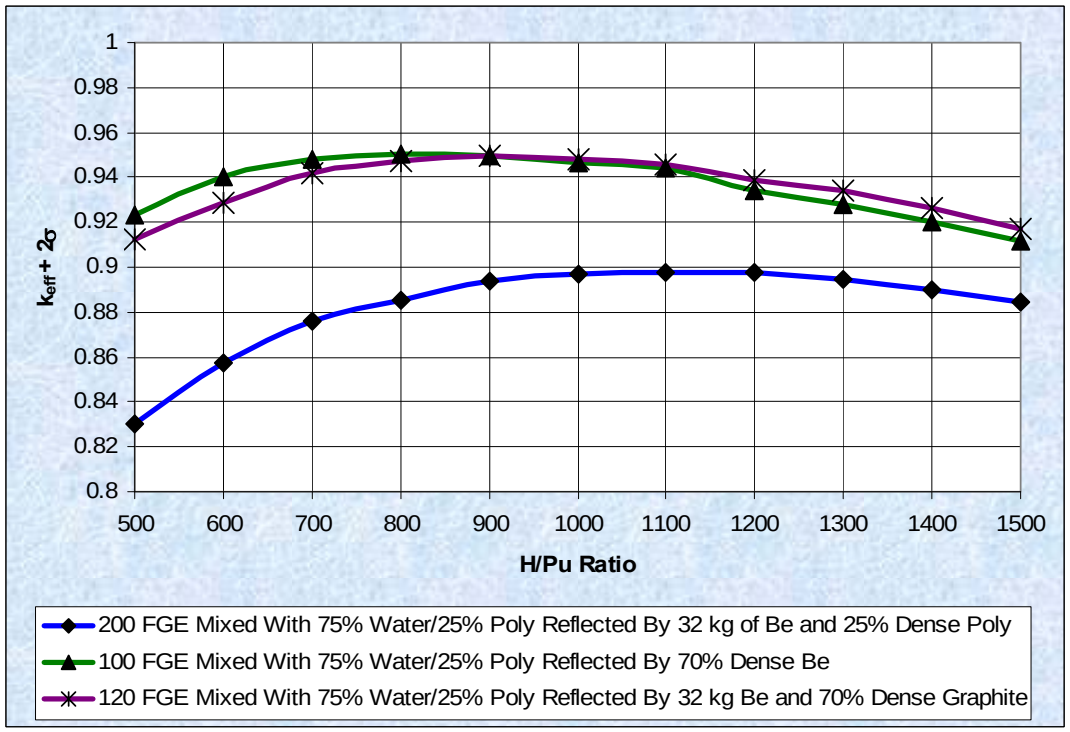


Figure 5-23, Three Drums in a Canister in a Central Two-Drum Configuration Reflected By 200 cm of Lead

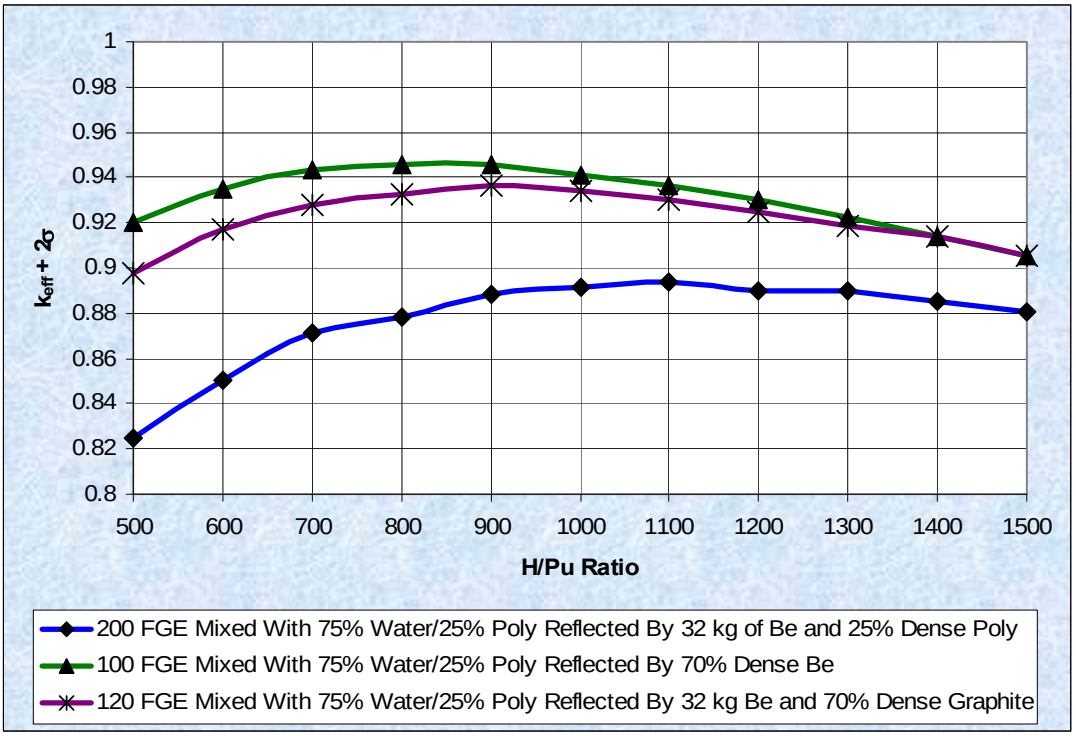


Figure 5-24, Three Drums in a Canister in a Central Two-Drum Configuration Reflected By 200 cm of Concrete

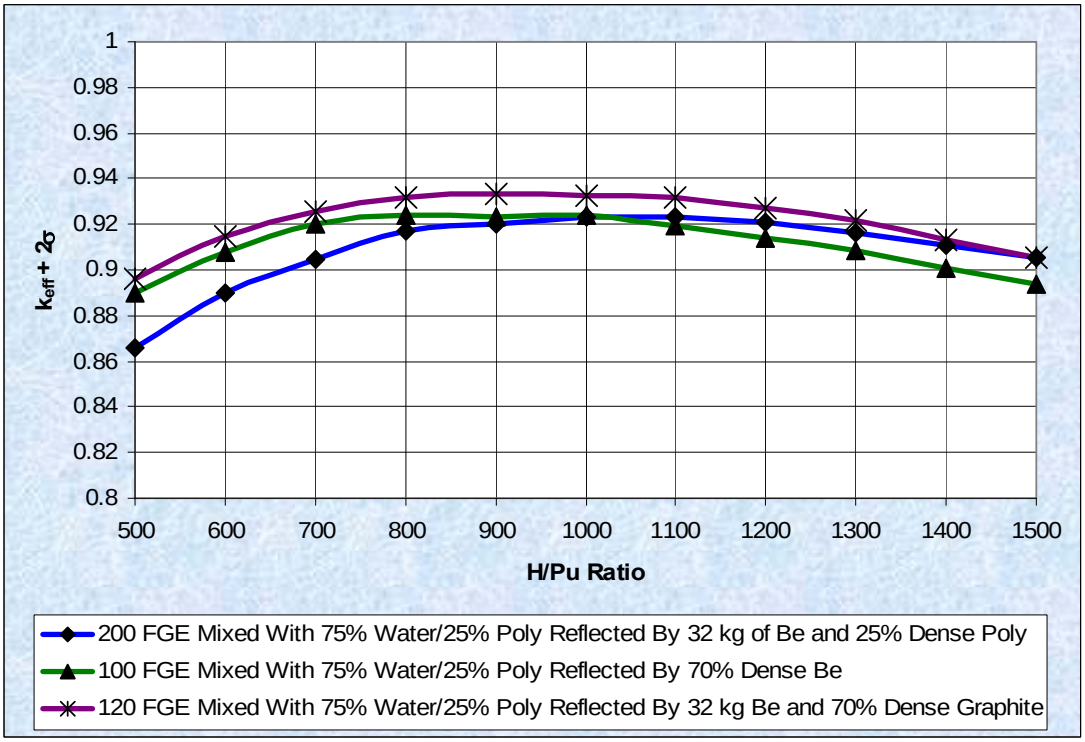


Figure 5-25, Three Drums in a Canister in an Edge Two-Drum Configuration Reflected By 200 cm of Lead

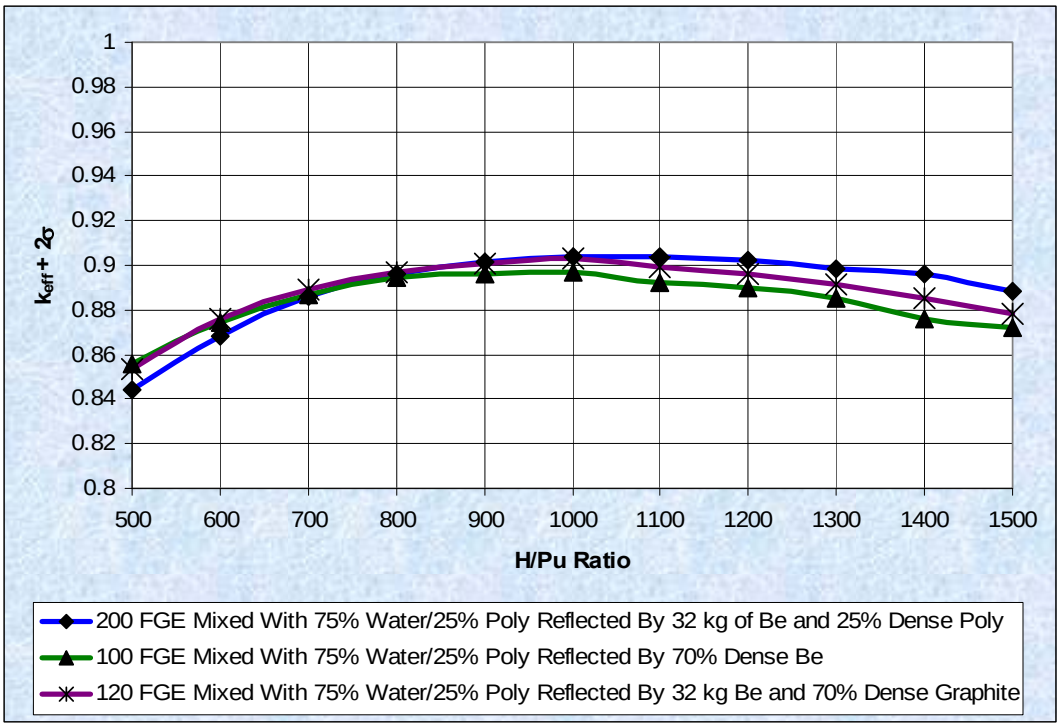


Figure 5-26, Three Drums in a Canister in an Edge Two-Drum Configuration Reflected By 200 cm of Concrete

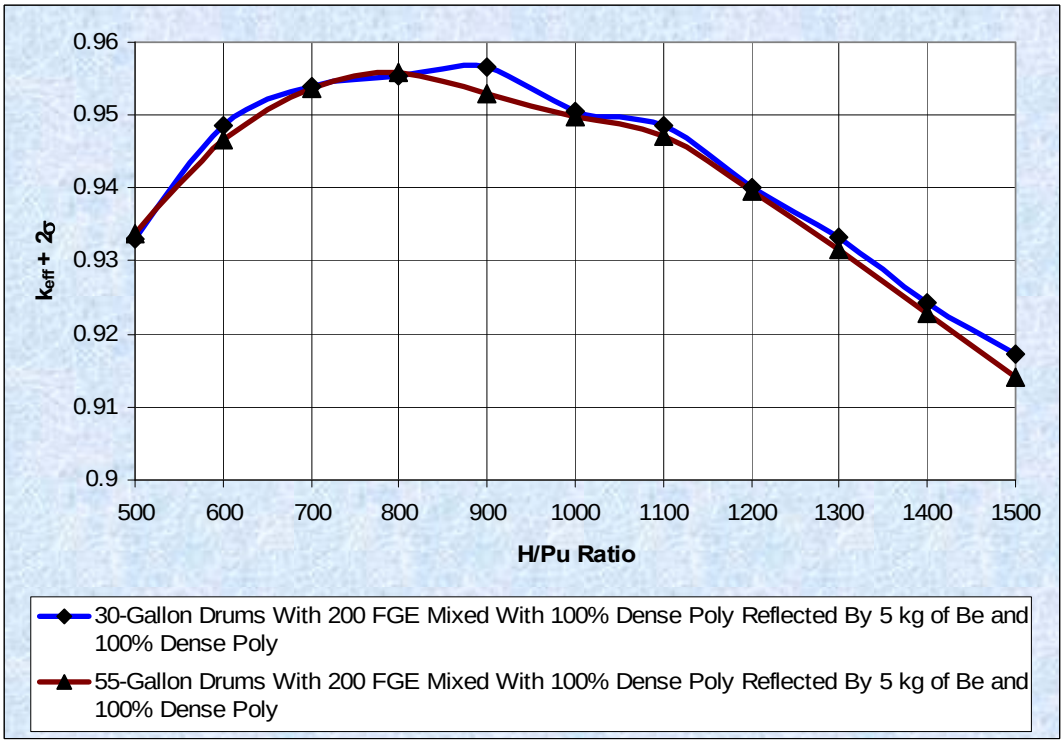


Figure 5-27, Three Explicit 30 or 55-Gallon Drums in a RH Waste Canister in a Central Two-Drum Configuration Reflected By 200 cm of Lead

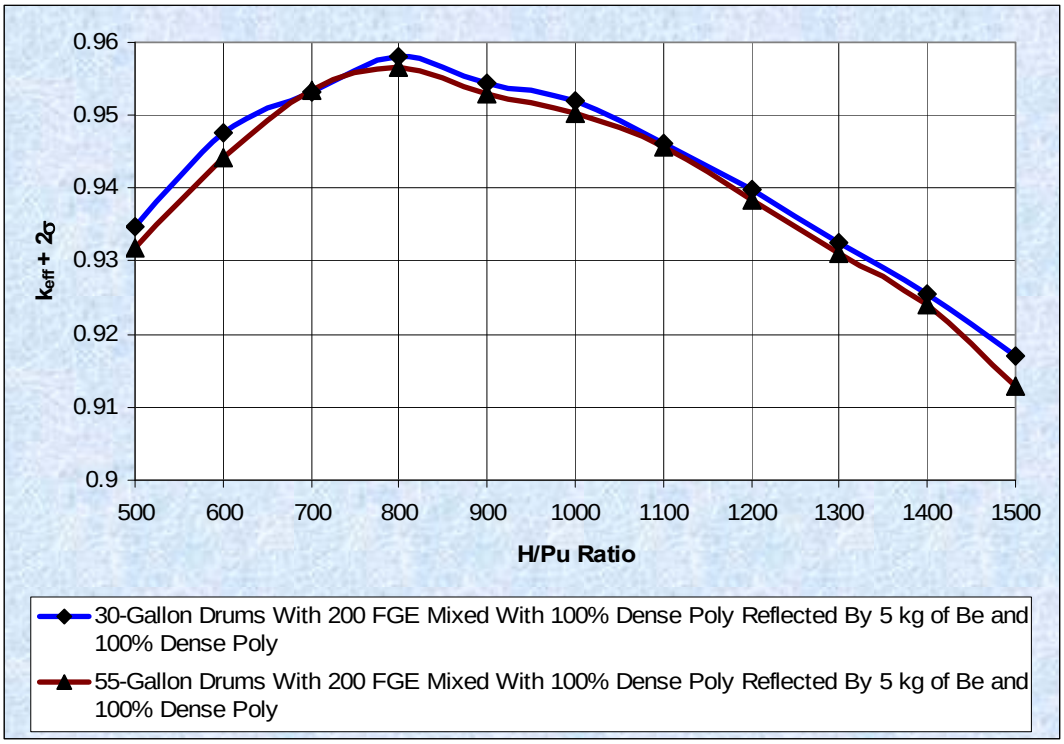


Figure 5-28, Three Explicit 30 or 55-Gallon Drums in a RH Waste Canister in a Central Two-Drum Configuration Reflected By 200 cm of Concrete

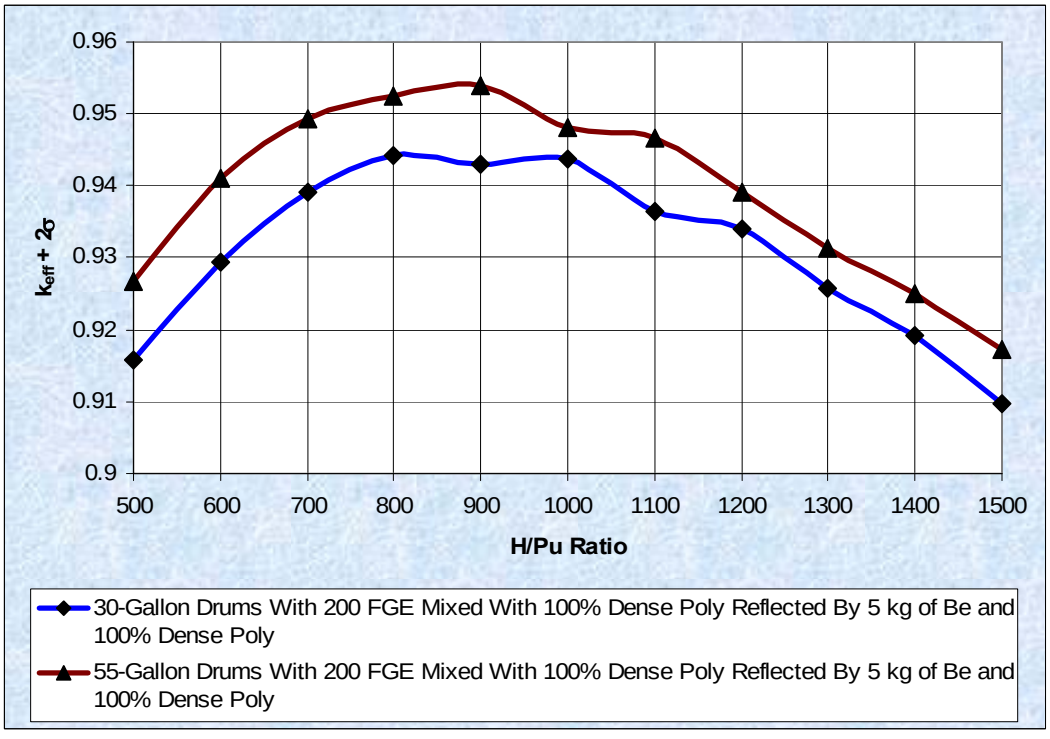


Figure 5-29, Three Explicit 30 or 55-Gallon Drums in a RH Waste Canister in an Edge Two-Drum Configuration Reflected By 200 cm of Lead

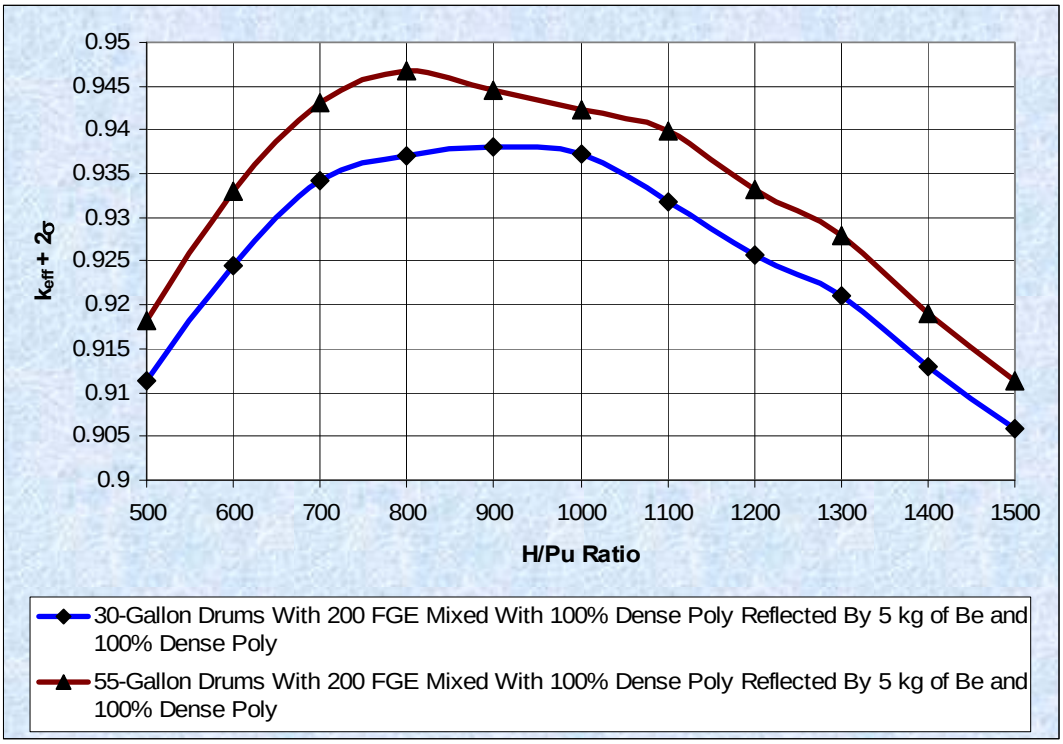


Figure 5-30, Three Explicit 30 or 55-Gallon Drums in a RH Waste Canister in an Edge Two-Drum Configuration Reflected By 200 cm of Concrete

It is instructive to note that if the inherent design spacing (1.0 in. between the material in the top of one drum and material in the bottom of the next drum) was removed from the machine-compacted two-drum model that the system would exceed the USL. In this case the maximum FGE loading must be lowered to 170 g ^{239}Pu. Figure 5-31 illustrates the system reactivity for the explicit two-drum model for a machine-compacted RH waste package with 170 g ^{239}Pu, no spacing between the fissile masses in the two drums, 100% dense steel in the drum wall and reflected externally by concrete. Degradation of the facility canister wall will be minimal as it has been fabricated for emplacement in the underground and minimal degradation of the steel will occur before emplacement. The canister wall is 0.25 in. thick compared to the drum wall of 18 gauge steel. Thus, modeling the drum wall as full density steel with the facility canister wall remaining at 50% dense is very conservative. Because the reactivity values are very comparable with concrete and lead reflection in the central two-drum model, lead reflection was not modeled. The results are tabulated in Table A-31.

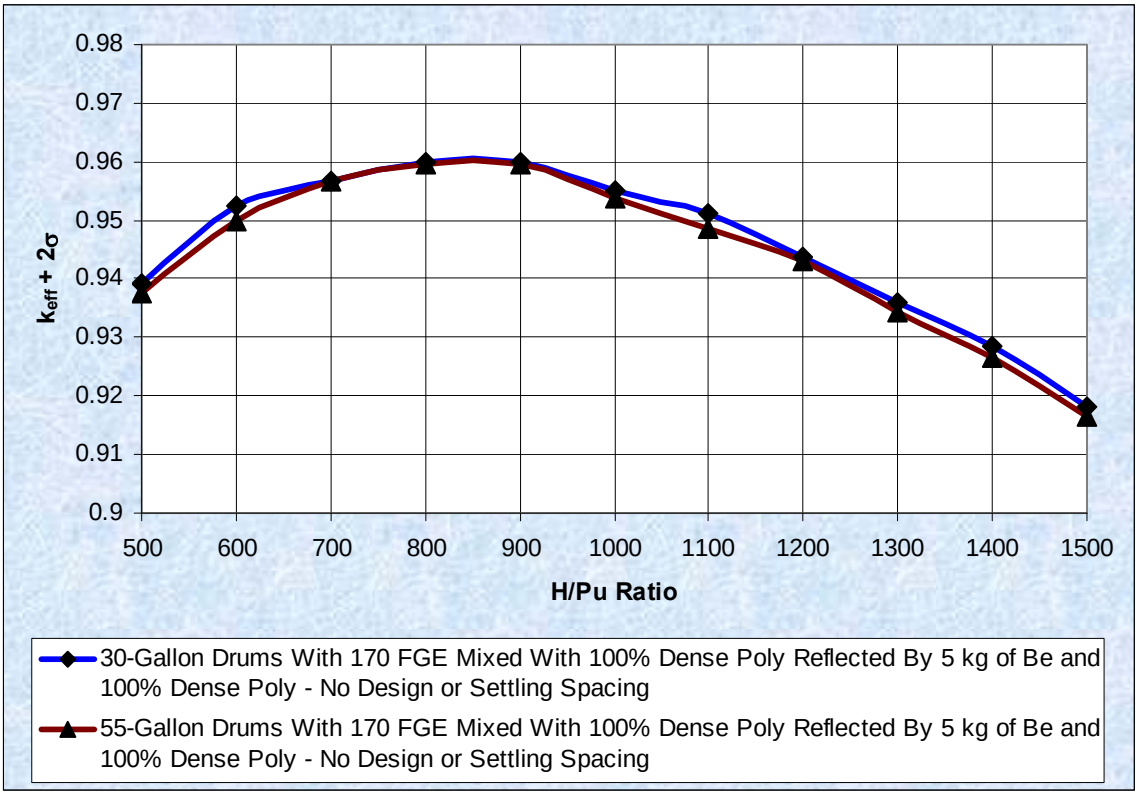


Figure 5-31, Three Explicit 30 or 55-Gallon Drums in a RH Waste Canister in a Central Two-Drum Configuration with no Design Spacing Reflected By 200 cm of Concrete

Finally, it is possible that the containerized RH waste within the canister may be packaged in lead-lined drums. To determine the bounding reactivity state for this configuration, a 3-in. lead liner inner-pack was inserted inside the 30-gallon drum explicit model for machine compacted waste. To ensure a conservative bound on the computational analyses, the 72-B canister FGE limit of 245 g ^{239}Pu was placed in one drum and moved adjacent to the lead liner. The other two drums were also lead lined, but contained no fissile mass, just internal reflector material. Due to the thick steel lid and bottom of the lead lined drum, the fissile masses in adjacent drums would have little interaction such that this model bounds the scenario with 200 FGE in each drum. Unlike the explicit model used for the two-drum calculations, this model assumes that all volume not occupied by the fissile mass and lead liners will be filled with a mixture of 32 kg beryllium and 100% polyethylene. As expected, the results of the calculation yielded an eigenvalue slightly higher than the direct loaded canister but still well below the USL of 0.96. Figure 5-32 and Table A-111 summarizes the result of this auxiliary calculation. This calculation verifies that canisters containing lead lined drums can be safely handled and stored at the WIPP.

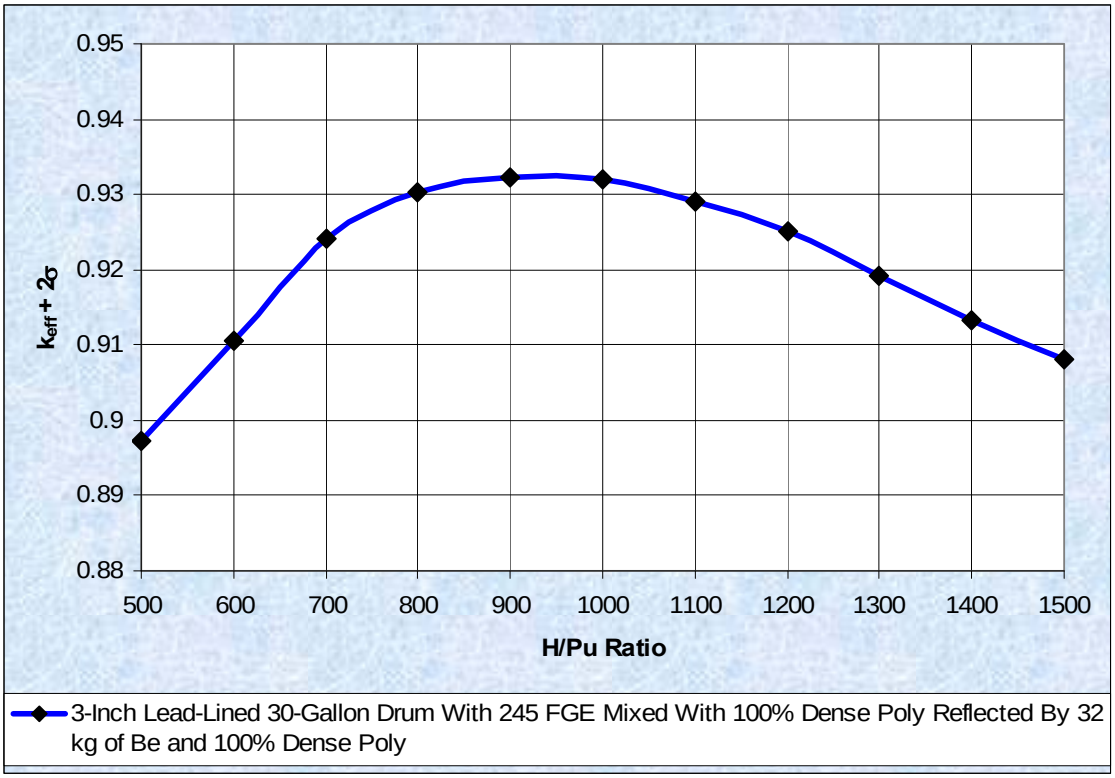


Figure 5-32, 3-Inch Lead-Lined 30-Gallon Drum Containing 245 FGE ^{239}Pu Mixed With 100% Dense Polyethylene and Reflected By 32 kg of Beryllium Mixed With 100% Dense Polyethylene

5.4.3 Computational Results for Twelve 30-Gallon Drum Upper Hot Cell

To simulate the bounding criticality states that could exist in the upper hot cell during waste handling operations and temporary storage, nuclear calculations involving a finite closely-pack triangular pitch array containing twelve 30-gallon drums were performed with MCNP5 as described in Section 5.2.2. Again, two mass limits were considered for drums reflected with significant quantities of graphite and ≤ 1% beryllium: (1) 100 FGE for a reflection mixture of 5 kg of beryllium mixed with 100% dense graphite and (2) 120 FGE for a reflection mixture of 5 kg of beryllium mixed with 70% dense graphite. The results of the baseline computational analyses are summarized in Figure 5-33 and Figure 5-34 and tabulated in Table A-31 through Table A-41 of Appendix A for the various loadings and geometric configurations considered in this analysis. As expected, the results indicated that the reactivity state for all loadings in the configuration modeled are less than the applicable USL with the bounding eigenvalue being the close proximity two-drum configuration yielding a $k_{eff} + 2\sigma$ of 0.9516 for the unlimited beryllium loading. All cases with unlimited graphite are below the lower USL of 0.95 for graphite systems.

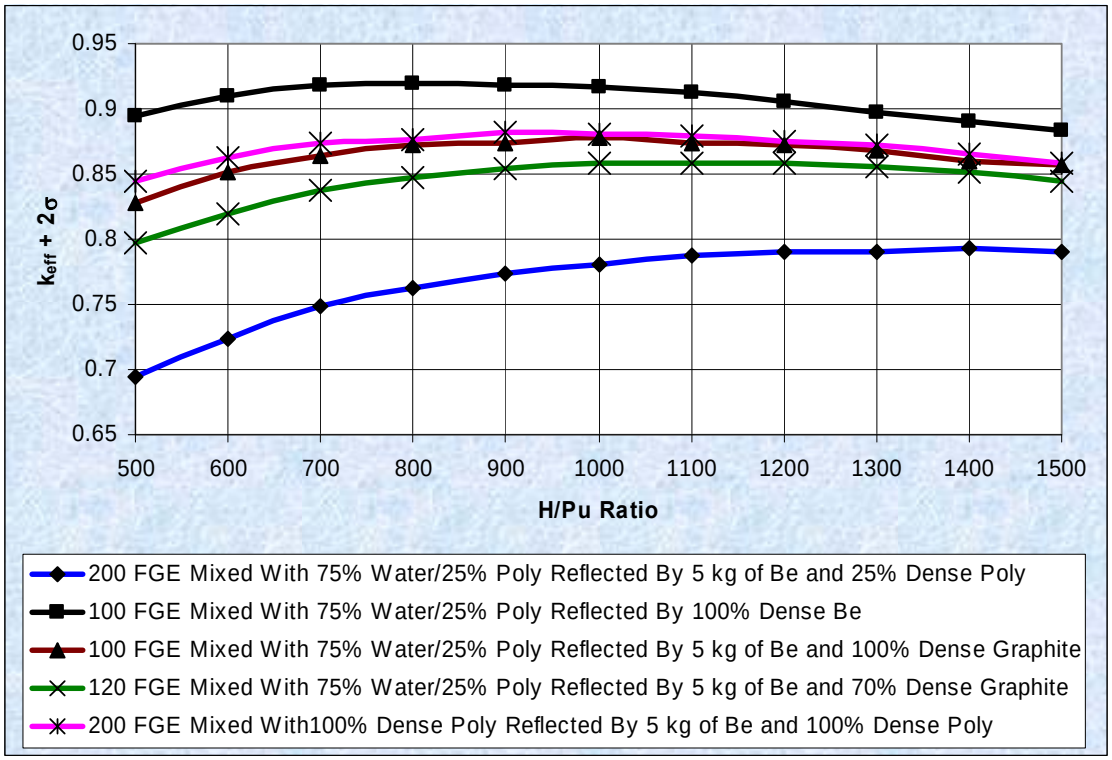


Figure 5-33, Twelve 30-Gallon Drums in Upper Hot Cell with Fissile Masses Centrally Located Reflected By 200 cm of Concrete

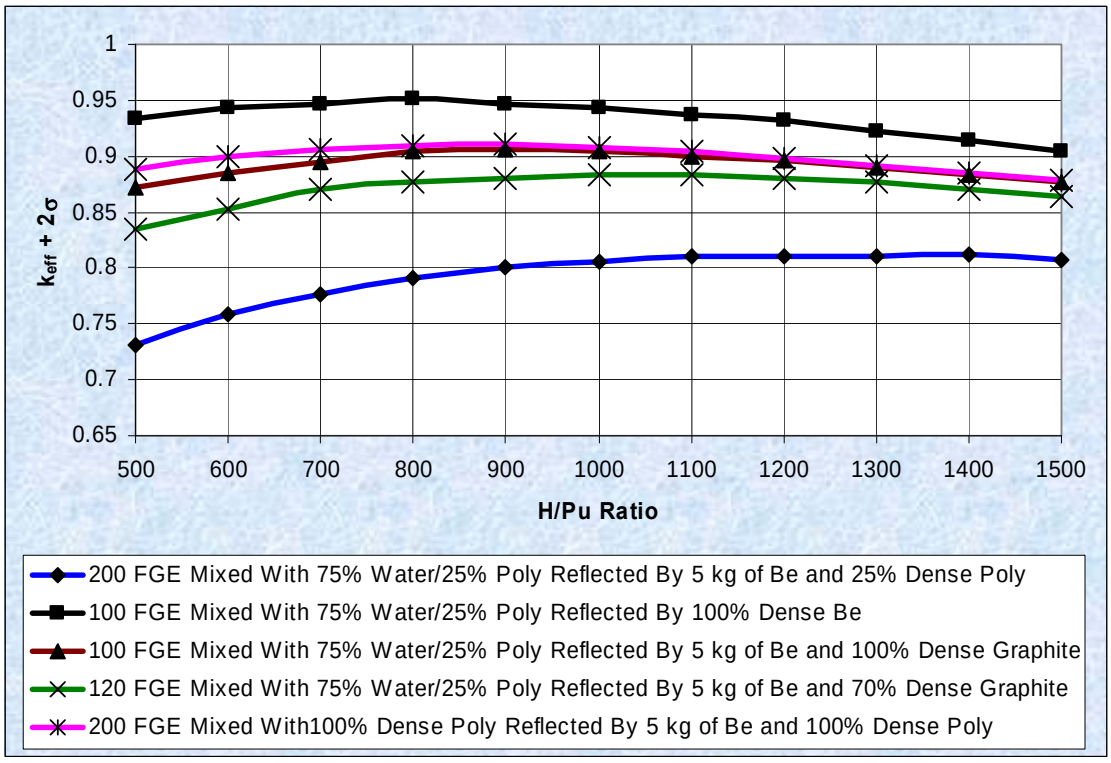


Figure 5-34, Twelve 30-Gallon Drums in Upper Hot Cell with Ten Fissile Masses Centrally Located and Two Fissile Masses in a Two-Drum Configuration Reflected By 200 cm of Concrete

5.4.4 Calculation Results for NS30 and NS15 Neutron Shielded Canisters

To simulate the bounding criticality states that could exist for NS30 and NS15 canisters, MCNP5 calculations were performed with the NS15 model described in Section 5.2.1.3. The results of the baseline computational analyses with a 245 FGE loading are summarized in Figure 5-35 (tabulated in Tables A-166 and A-167 of Appendix A) for the various loadings and geometric configurations considered in this analysis. The results indicate that the reactivity state for all loadings in the configurations modeled are less than the applicable USL.

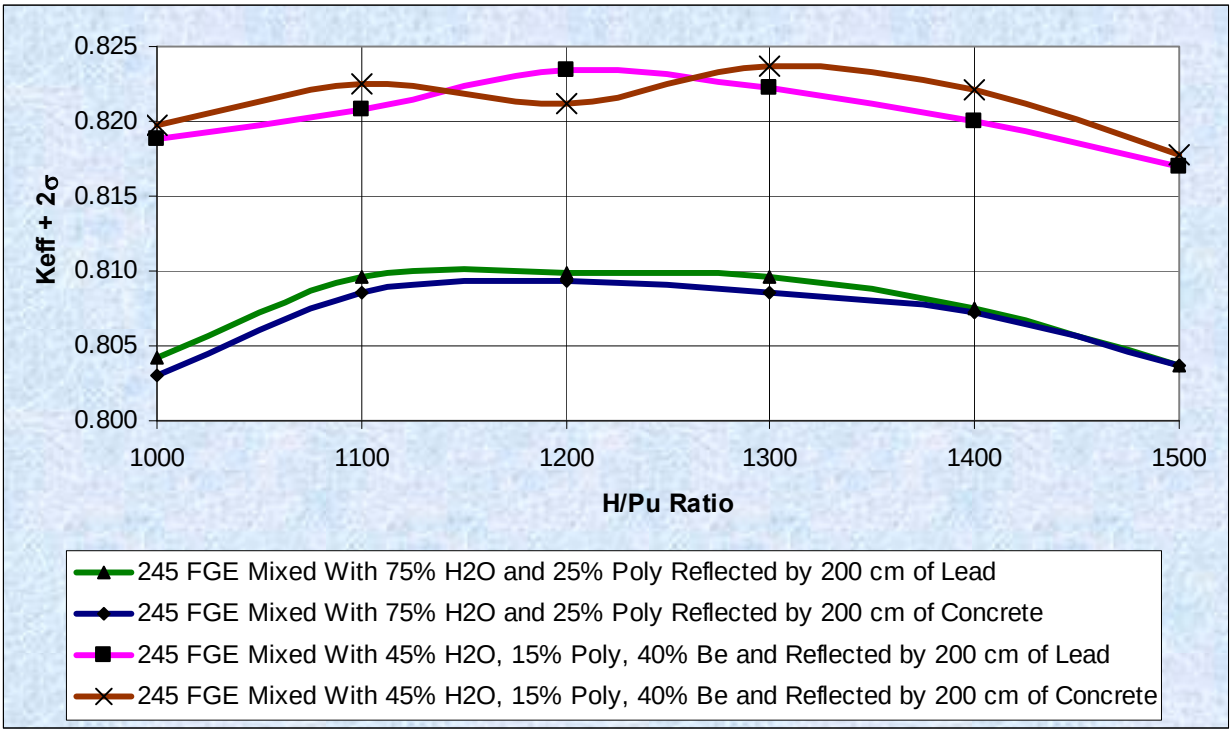


Figure 5-35, Single Direct Loaded NS15 Canister Reflected by Lead or Concrete

The limit for NS30 and NS15 neutron shielded canisters is based on the SAR evaluation that concluded non-shielded machine compacted waste in a 72B canister bounded the NS30 and NS15 canisters. While the additional HDPE has a slightly higher density than the machine compacted waste, the effect on the reactivity of the machine compacted case is negligible, particularly considering that the neutron shielded canisters also contain waste in drums which were conservatively not included in the model by allowing the waste to completely fill the canister. Therefore, the 245 FGE limit is also applicable for machine compacted waste in the NS15 and NS30 canisters.

Comparing the NS15 neutron shielded canister results to the 245 FGE machine compacted waste results in Section 5.4.1 (Figures 5-15 and 5-16) shows that the NS15 neutron shielded canister is bounded by the non-shielded machine compacted waste loading in the RH-72B. Table 5-11 summarizes the appropriate sections and peak results, and all cases are below the USL.

Table 5-11, Comparison of HDPE Neutron Shielded Cases

FGE	Neutron Shielded Cases			Non-Neutron Shielded Machine Compacted Cases	
	Waste Type	Figure/Table(s)	Peak $k_{eff} + 2\sigma$	Figures/Table	Peak $k_{eff} + 2\sigma$
245	Non-compacted	5-35 / A-166	0.80984	5-15, 16 / A-4	0.92483
	Bound to Be	5-35 / A-167	0.82370		

5.5 Underground Borehole Disposal Arrays

5.5.1 Borehole Array Results for Direct Loaded Canisters

A bounding nuclear criticality analysis was performed to determine the most reactive state for the long term disposal of direct loaded RH waste canisters in the underground repository using the models discussed in Section 5.2.3.

The computational analysis considered a variety of canister fissile loadings and internal reflector compositions. Additionally, both conventional configurations with the fissile mass centered in the canister and close proximity configurations with off-centered masses were evaluated. The computational results for direct loaded RH canister disposal array configurations in the absence and the presence of CH waste using the models shown in Figures 5-10 and 5-11, respectively are summarized in Figure 5-36 and Figure 5-37 with the details given in Table A-42 through Table A-51 of Appendix A. As indicated by the results, the maximum disposal array eigenvalue is 0.92484 for machine-compacted RH waste canisters and is less than the USL.

These calculations also show that the presence of adjacent CH waste in the rooms and drifts can be bounded by reflecting the canisters in the boreholes with salt as the results of the cases with and without CH waste in the two figures are statistically identical.

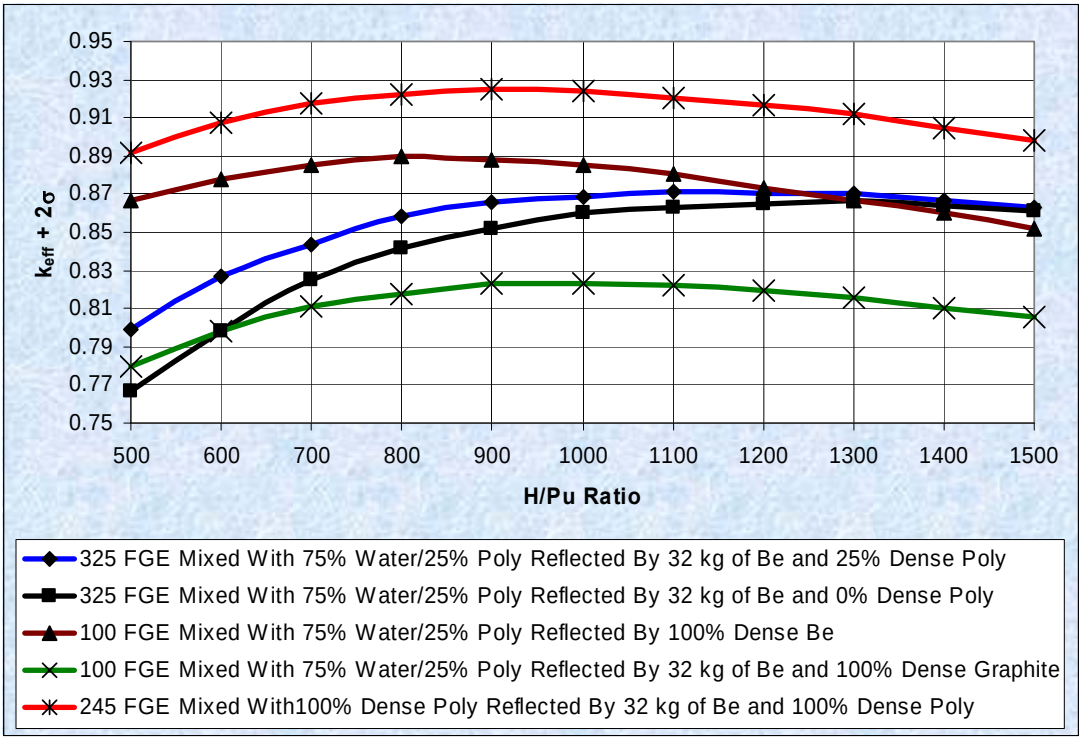


Figure 5-36, Borehole Array of Direct Loaded RH Waste Canisters with the Fissile Mass Centrally Located in the Absence of CH Waste

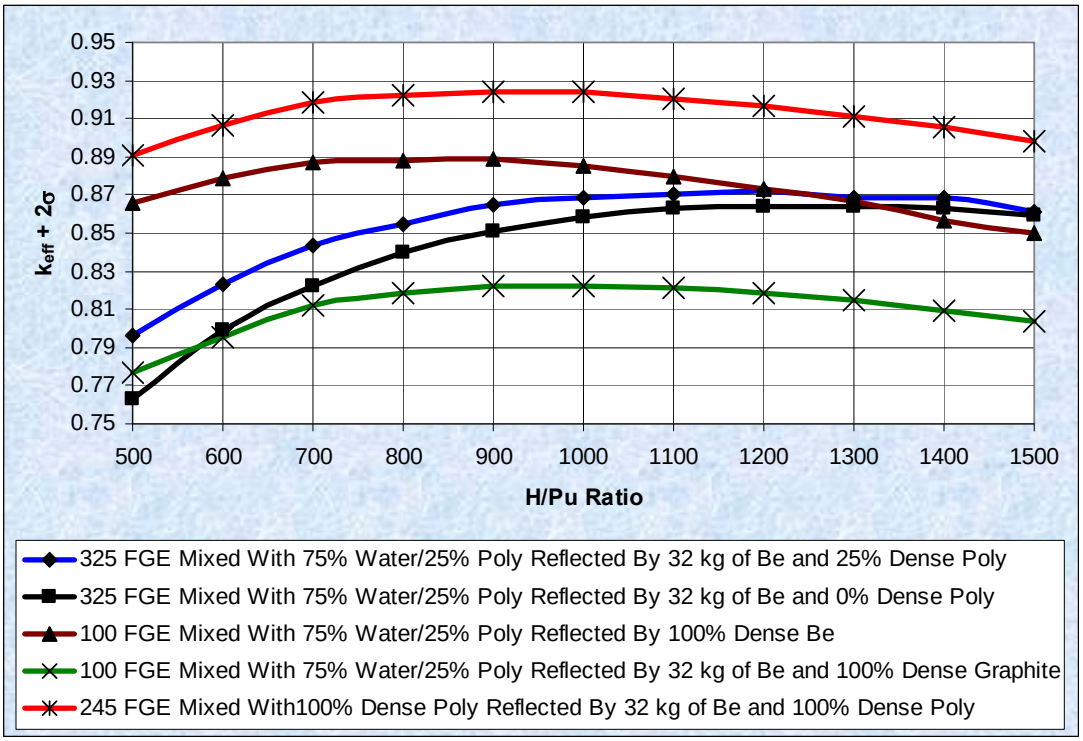


Figure 5-37, Borehole Array of Direct Loaded RH Waste Canisters with the Fissile Mass Centrally Located and in the Presence of CH Waste

Centering the fissile sphere in each canister in the array represents the average spacing between the fissile materials based on the random distribution of the fissile material in the waste. A worst-case scenario is also modeled in which the fissile masses in two canisters are located on the inside surface of the canister in close proximity as shown in Figure 5-11. The results of the computational analyses indicate that the intervening salt between the fissile masses in the borehole configuration is more than adequate to ensure that the reactivity of the system remains below the USL. Figure 5-38 and Table A-52 through Table A-55 summarize the results of the calculations.

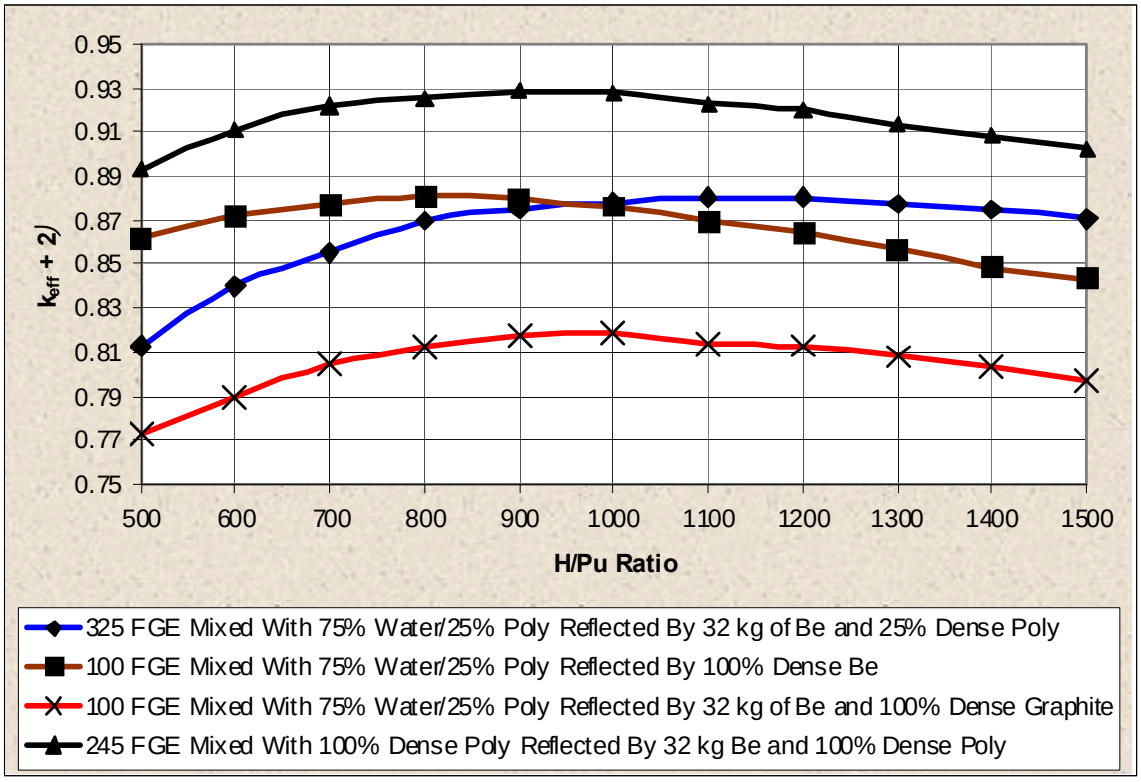


Figure 5-38, Close Proximity Fissile Masses in Direct Loaded Canisters in the Underground Disposal Borehole Array

Finally, additional studies were performed for the disposal of direct loaded canisters with manually-compacted waste which contains either: (1) ^{240}Pu in the fissile mixture; (2) 305 g ^{239}Pu which is mechanically or chemically bound to the special reflector; or (3) LEU material that contains 0.96 wt% ^{235}U. The various fissile mass and internal reflector compositions and geometric arrangements within the canisters are consistent with that discussed in the applicable parts of Sections 5.1 through 0. The canisters are placed in a borehole array with the same pitch and geometric configuration used previously. All array calculations are performed in the absence of CH waste as its presence was shown to have no statistical effect on the results. The computational results of the three waste loadings are summarized in Table A-56 through Table A-62 and Figure 5-39 through Figure 5-41. As indicated by both the tabular and graphical results, all system eigenvalues are compliant to the USL.

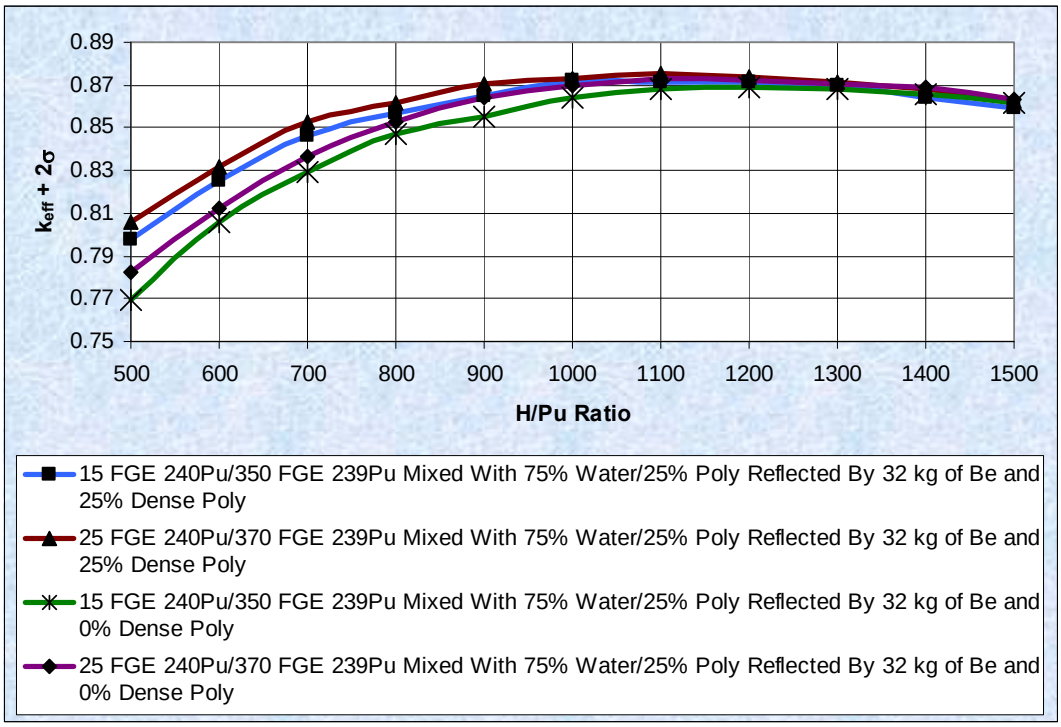


Figure 5-39, Borehole Array of Direct Loaded Canisters with a Fissile Mixture of ^{239}Pu and ^{240}Pu

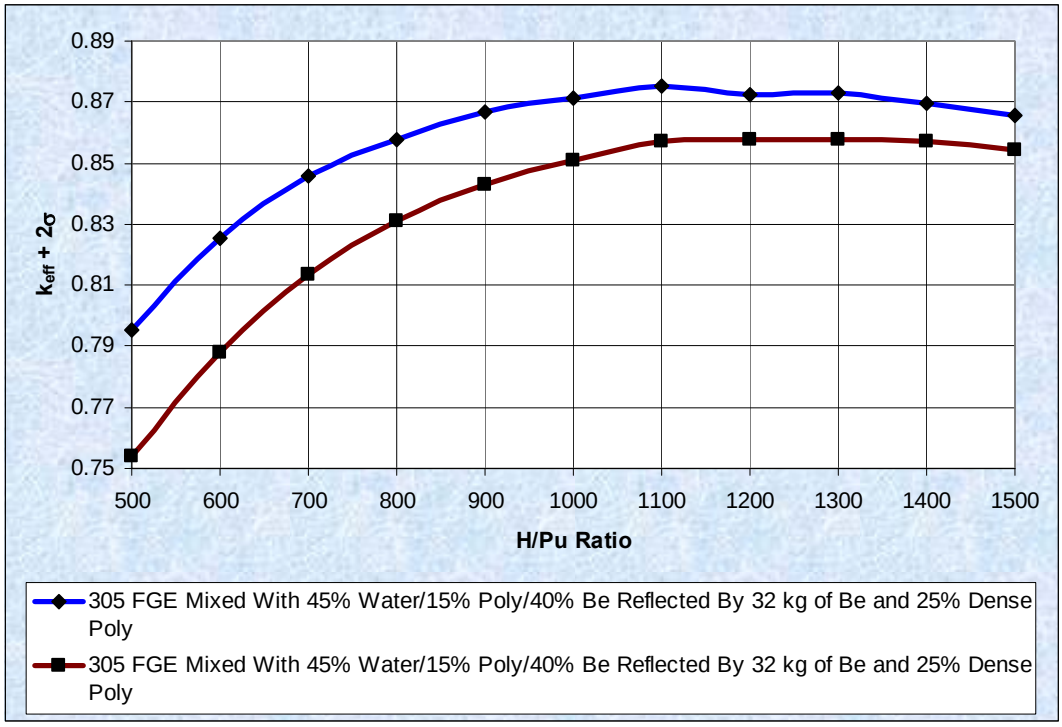


Figure 5-40, Borehole Array of Direct Loaded Canisters with 305 FGE Bound to Be

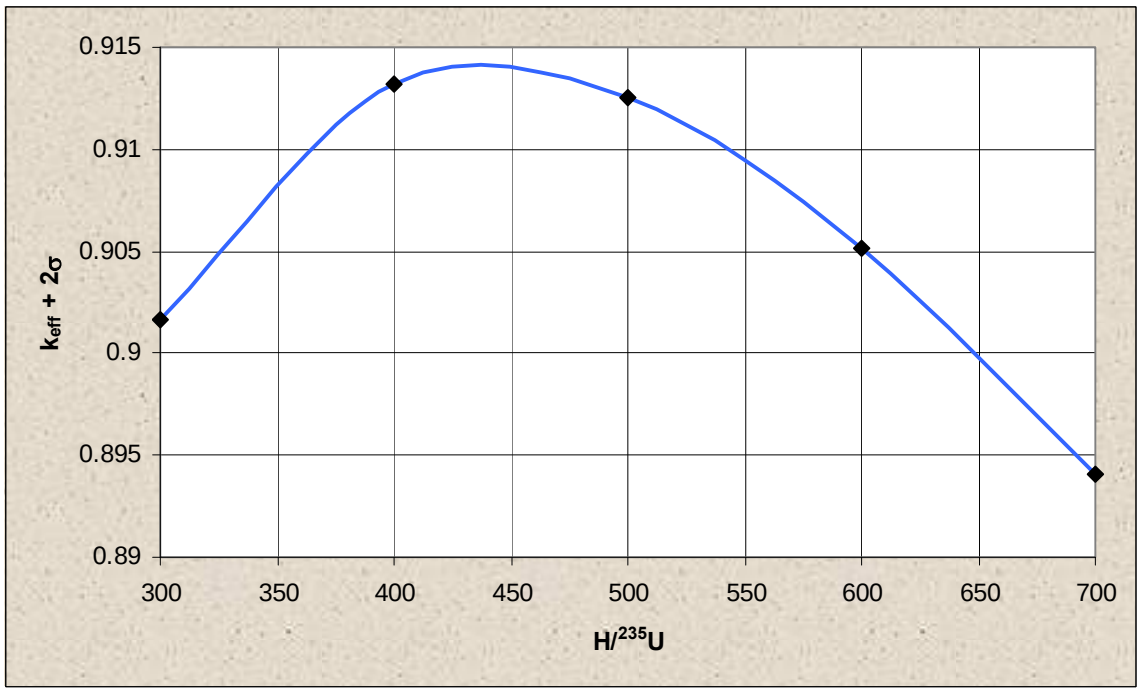


Figure 5-41, Reactivity of a Borehole Array of Direct Loaded Canister Containing LEU Waste Packages at 0.96% ^{235}U as a Function of H/U Ratio

5.5.2 Borehole Array Results for Canisters Containing Drums

The results for underground borehole disposal array calculations involving canisters of containerized RH waste containing various FGE loading and internal reflection compositions as shown in Figure 5-12 and Figure 5-14 are summarized in Table A-63 through Table A-74 and Figure 5-42 and Figure 5-43. As indicated by the data, the computational results show that the disposal configuration is well subcritical with a maximum $k_{eff} + 2\sigma$ value less than 0.9. Consistent with the conclusion in the previous section, an infinite salt reflector at the end of the borehole bounds the interaction with the disposed CH waste as no statistical difference in reactivity is found between the two models.

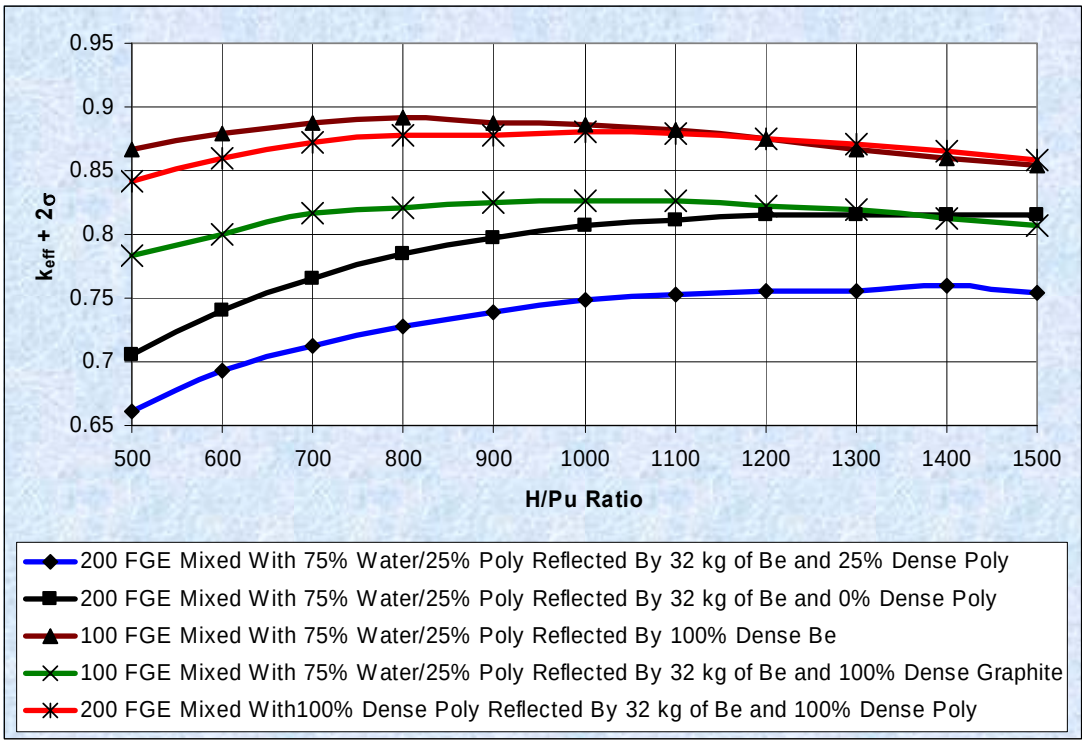


Figure 5-42, Borehole Array of RH Waste Canisters Containing Three Fissile Masses Centrally Located in the Absence of CH Waste

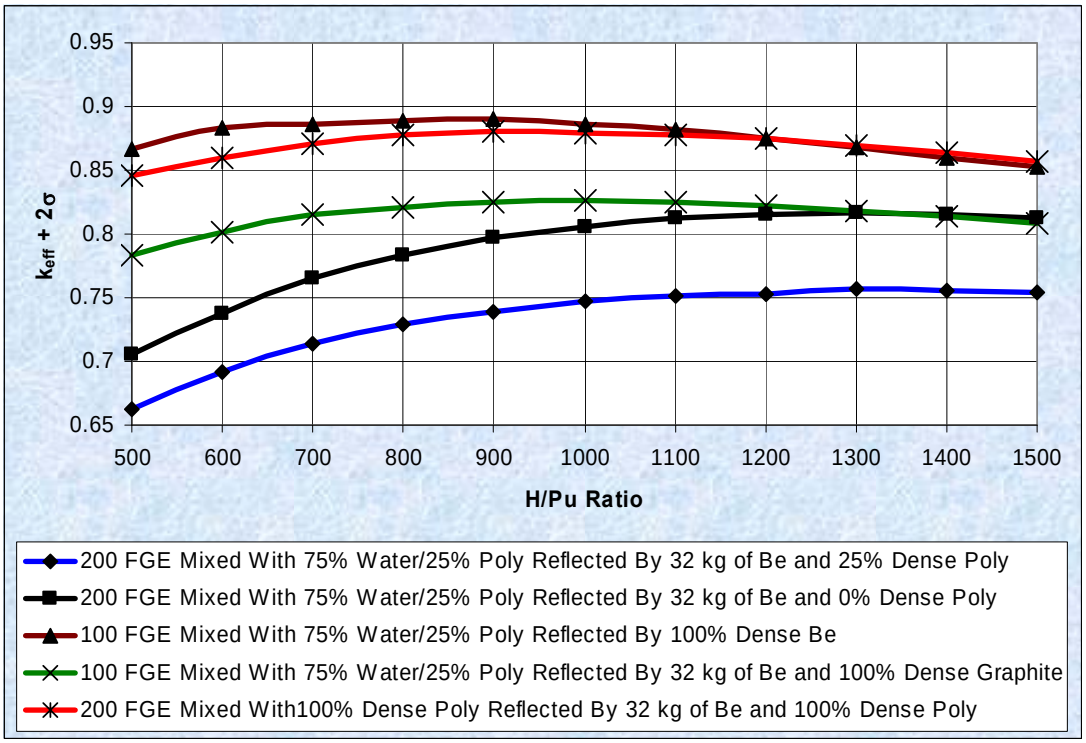


Figure 5-43, Borehole Array of RH Waste Canisters Containing Three Fissile Masses Centrally Located and in the Presence of CH Waste

6.0 Parameters

The following parameters are controlled for criticality safety at WIPP. The contingent events resulting from the loss of each controlled parameter are also given. The contingent events flow from the hazard evaluation tables given in Appendix C. These upset conditions are evaluated in detail in Section 7.0.

6.1 Mass

Fissile mass limits are required to maintain the system reactivity below the USL and thus mass is a controlled parameter. As a contingency condition, the fissile mass content within the RH waste canisters are increased to a minimum of 50% of the established mass limit. The mass over-batching condition is modeled for bounding configurations which encompass all above ground receipt, handling, and interim storage operations as well as conveyance to the underground repository, emplacement and permanent disposal of RH waste canisters containing both non-compacted and machine compacted RH waste packages. The loss of mass control contingency is evaluated in Section 7.1.1.

6.2 Geometry

The geometry of the fissile region within the RH packages is not controlled as the fissile mass is modeled as a sphere for the nominal configuration or a cylinder with an H/D ratio of 0.5 for selected two-drum configurations. Both of these geometric configurations minimize leakage and maximize the reactivity state of the system.

6.3 Moderation

Neutron moderation of the fissile region is optimized by varying the H/Pu ratio to determine the most reactive state. As a result moderation in the fissile region is not controlled.

With respect to the internal reflector region, canisters accepted at the WIPP are limited to a liquid content ≤ 1% by volume; consequently water is not modeled in the reflector region for the baseline analysis. To account for an upset condition in which either a potential handling and/or conveyance accident, or the corrosive environment during permanent disposal in the underground repository results in partial water seepage or fully flooded state in the canister, a water intrusion contingency is evaluated in Section 7.1.3.

Finally, because the canisters are handled one at a time and then placed into the borehole disposal array with salt between the canisters, interstitial moderation is not a concern. The hot cell complex does not contain sprinklers such that interstitial moderation between drums is also not a concern.

6.4 Interaction

The need for interaction control between RH waste canisters is contingent upon the operation being considered. Specifically, for above ground receipt and interim storage operations in the WHB, but not including upper hot cell repackaging tasks, a geometric configuration which bounds these operations is an infinite planar array of direct loaded RH waste packages whose fissile loading is set at the maximum allowable FGE. This contingency condition for above ground operations, excluding upper hot cell repackaging operations, is evaluated in Section 7.1.8. Since this contingency analysis assumes a 2-meter thick lead or concrete external reflection in the vertical planes, the ensuing reactivity state will bound conveyance to and permanent disposal operations in the underground repository.

During transfer of 30-gallon or 55-gallon drums from the 10-160B container to the RH facility canister in the upper hot cell, the nominal configuration considered in the baseline analysis assumed a planar array of twelve drums with a 2-meter thick concrete external reflection in all planes. To account for a loss of interaction control, a contingency state was postulated in which 12 extra drums were stacked on top of the 12 drum array and the top, bottom and lateral planes of the 2-tier high array were reflected with 2-meters of tight-fitting concrete to simulate maximum reflection from the hot cell. This contingency evaluation is performed in Section 7.1.5.

Interaction control between RH waste canisters in the underground repository is not required since the bounding model selected for this NCSE was a 2-deep array of 7-packs of RH canisters on a triangular pitch with a 2.5 ft center-to-center spacing between canisters. The selected pitch represents the closest center-to-center distance that the canisters can be emplaced in the wall boreholes based on the borehole machine design constraints and mining practices. The 7-pack of canisters is stacked horizontally in tandem to simulate two canisters per borehole. The shield plug that is emplaced between canisters in a single borehole is conservatively ignored as it would isolate the canisters from one another.

Interaction is also controlled by the RH waste container, which determines the distance between fissile masses if the waste is containerized. RH waste canisters approved for transportation to the WIPP in the RH-TRU 72-B container are evaluated in the RH-TRU 72-B SAR (DOE-CBFO 2010a). If the waste is containerized within the canister, 30- or 55-gallon drums have been approved for disposal at WIPP. The CNS 10-160B container, which has been designed to meet DOT Type B container requirements, also houses 30- or 55-gallon drums which are placed into facility canisters for disposal at WIPP.

6.5 Neutron Absorption

The only neutron absorber modeled is the steel in the RH canister walls, bottom and lid. If the waste is containerized within the canister, the steel structure of the inner drums is ignored in the nominal configuration. The wall, lid and bottom of the RH canister are modeled at full thickness but the steel density is modeled at 50% of its theoretical value. The 72-B and facility canisters are in good condition as they were fabricated for disposal at WIPP and have not been in an uncontrolled storage environment for decades like some waste drums. Thus modeling 50% of the steel content in the canister wall is conservative. The wall of any inner containers that may be placed in the canister was ignored. As a result, neutron absorption is controlled by the RH-TRU 72-B SAR requirement (DOE-CBFO 2010a). (No contingency event is analyzed as modeling only 50% of the steel wall in the normal condition.)

6.6 Reflection

6.6.1 Internal Container Reflection

Mass limits on special reflector materials, namely beryllium, within the RH canister are required to maintain system reactivity below the USL. Unless specifically evaluated, special reflector materials are limited to $\leq$ 1 wt% of the RH canister payload (32 kg). The RH canister mass limits were then set with this restriction on the beryllium content. A contingency state in which the beryllium contents in each canister was increased by a factor of 2 over the acceptable mass limit was evaluated in Section 7.1.2 to bound any probable over-batching condition that could occur at the WIPP.

A high beryllium content payload, in which the fissile mass is reflected by an unlimited amount of 100% dense beryllium, was also evaluated as a baseline loading configuration to determine

the mass limit on RH waste packages that contained > 1 wt% of the payload. Since this loading configuration represents a bounding state with respect to special reflector material in an RH waste package, a contingency analysis is not required for this loading configuration.

No restriction on internal container reflection occurs in the machine compacted waste payload as all analyses evaluated 100% dense polyethylene around the fissile material.

6.6.2 External Container Reflection

External reflection is modeled conservatively compared to actual conditions and thus is not a controlled parameter. Specifically, for above ground receipt, handling, repackaging and interim storage operations as well as conveyance to the underground repository, all external vertical and lateral boundaries were fully reflected by 2-meters of either lead or concrete. For emplacement and permanent disposal in the wall boreholes of the underground repository, 3-meters of salt is used as an external reflector for all non-mirrored boundaries of the disposal array configuration.

6.7 Volume

Volume is not credited in any of the analysis and thus is not controlled.

6.8 Enrichment

Enrichment is not controlled for RH canisters except those packaged under the LEU enrichment limit. For all other payloads, the fissile material is modeled as ^{239}Pu. ^{235}U and ^{233}U can be shipped under these limits using fissile gram equivalents (FGE) as defined in the RH-TRAMPAC (DOE-CBFO 2010b). The FGE value accounts for the differences in minimum critical mass between these isotopes.

For RH waste canisters containing LEU waste, the enrichment is restricted to 0.96 wt% ^{235}U. The mass limit compliant to this enrichment for the nominal baseline state is 3129 kg (~ 6900 lbs) of uranium, however enrichments up to 1.08 wt% ^{235}U are can be tolerated at this mass loading and still be compliant to the USL. To accommodate a potential over-batching event with LEU bearing RH waste packages, a contingency evaluation is performed in Section 7.1.2 in which the RH waste canister is completely filled with LEU at 0.96 wt% ^{235}U. Furthermore to determine the maximum enrichment which can be allowed and still remain at or below the safety limit, the contingency analysis in Section 7.1.2 provides for an increase in LEU enrichment at the over-batched mass loading.

6.9 Concentration

Concentration is not controlled. The optimum fissile concentration was modeled by varying the H/Pu ratio in the fissile region.

7.0 Contingency Analysis

The objective of this section is to document compliance with the double contingency principle for operations involving receipt, handling and storage/disposal of RH waste containers at the WIPP. To demonstrate the safe handling and storage/disposal of RH waste containers, credible abnormal scenarios were identified in the hazard evaluation in Appendix C and evaluated herein. Sample MCNP5 input files for this evaluation are given in Appendix B. The evaluation also goes beyond the double contingency principle to ensure that sufficient robust and independent barriers (see Section 9.0) are in place such that a criticality accident is deemed incredible and a criticality detection and alarm system is not required.

The credible accident scenarios further evaluated in this section are identified below:

- Excess fissile material loading in an RH waste container
- Excess special reflector material loading in an RH waste container
- Excess water/flooding in an RH waste container
- Loss of enrichment control in LEU payload
- Loss of interaction control in the upper hot cell
- Loss of interaction control between the RH waste canister in the borehole and the CH waste in the adjacent room
- Loss of confinement of fissile material
- Placement of facility cask next to CH waste
- Loss of interaction control during receipt, handling and interim storage of RH waste canisters

7.1.1 Excess Fissile Material Loading in RH Waste Container

This event postulates a criticality accident in a RH waste container as a result of fissile material over batching. WIPP does not open RH waste containers, but only loads waste drums from 10-160B shipping containers into facility canisters for final disposal. The drums remain sealed. The 72-B canister, whether containing direct loaded waste or three drums, will be disposed of without being repackaged. Therefore, there is no potential for adding fissile material to a drum or 72-B canister during operations at the WIPP. As a result, an over batching condition that may occur must originate at the generator site.

Waste generators package the containers using approved procedures that require compliance with the WIPP WAC limits and the limits specified in the SAR for the shipping container. Non-compliance with the WIPP WAC will also introduce unwanted criticality safety issues for the waste generator; thereby, generators are independently motivated to comply with the WIPP WAC requirements that are related to criticality safety. Waste is approved for shipment to WIPP through the WIPP Waste Data System (WDS) prior to being packaged for shipment. Personnel at

the generator site enter the specifics for each container as required by the WDS. The WDS contains queries that impose the WAC requirements for both the shipping container and the individual waste containers. Therefore, reliance is placed on the waste generators waste characterization program and criticality safety program to ensure that there are sufficient independent and unlikely-to-fail robust barriers against overbatching the shipping containers.

Although an overbatching event is highly improbable, overbatching contingency calculations were performed to determine the reactivity state of various waste package contents in a simulated overbatching condition during receipt, handling, conveyance, or permanent disposal of various RH waste packages. In the overbatched calculations, only the external lead reflector is considered as it results in either the higher reactivity or statistically equivalent reactivity compared to the external concrete reflector. Furthermore, for loadings with unlimited special reflector materials, a maximum achievable reflector density of 70% of theoretical density will be used as justified in Section 5.1.2.

7.1.1.1 Overloaded Drums in the Hot Cell Array

As discussed in Section 5.2.2, the hot cell drum array was modeled with each of the twelve drums containing either 200 FGE when special reflector materials are limited to ≤ 1 wt% of the contents or 100 FGE when the presence of special reflector materials are not restricted. The 10-160B container holds ten drums and the load is restricted to 20 Pu Equivalent Ci as discussed in Section 2.2.2. If the total Ci content is Pu, the maximum loading limit for the container would be 318 g ^{239}Pu in the 10 drums. Thus, hot cell models with each drum at the limit specified in this analysis contained 1,000 – 2,000 g ^{239}Pu in every 10 drums, which is more than a double batch of the container load. The results presented in Section 5.4.3 showed that all cases were below the USL. Thus, it is not credible for a criticality accident to occur due to overloaded drums in the hot cell.

7.1.1.2 Overloaded Direct Loaded Canister

Over batching contingency calculations, as summarized in Figure 7-1 and Table A-75 through Table A-81, for single, direct loaded canisters with infinite lead reflection demonstrate that canisters remain subcritical with the following loadings:

1. 470 FGE (~ 50% overbatch) for non-compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium);

2. 185 FGE (~ 85% overbatch) for non-compacted waste containing > 1 wt% beryllium at 70% density;

3. 425 FGE (~ 40% overbatch) for non-compacted waste with the fissile material mechanically or chemically bound with special reflector materials (i.e., beryllium);

4. 225 FGE (~ 88% overbatch) for non-compacted systems containing 70% dense graphite and ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium); and

5. 285 FGE (~ 16% overbatch) for 100% dense machine compacted waste containing <1 wt% special reflector material (i.e., up to 32 kg beryllium).

In three of the five cases, the overbatch loadings exceed the canister fissile limit by greater than or equal to 50%. Note that the over batching computation considered the maximum credible reflector density of 70% for beryllium and graphite to bound waste in a myriad of forms ranging from packed grains to chunks vs. a solid chunk perfectly formed to contain the fissile material while filling the entire canister with no voids.

As discussed above, in most cases the overbatch loadings exceed the canister fissile limit by greater than or equal to 50%. The two exceptions are the non-compacted waste with the fissile material mechanically or chemically bound with special reflector materials (i.e., beryllium), and the 100% dense machine compacted waste containing < 1 wt% special reflector material (i.e., up to 32 kg beryllium). With respect to the waste packages with mechanically or chemically bound beryllium, it stands to reason that the use of a spherical mass suspended in 25% dense polyethylene or less is a bounding configuration. More specifically, the more dense fissile mass will tend to settle and distribute the fissile loading axially. To simulate this effect, the geometry of the fissile mass can be modified to a cylindrical form with an H/D ratio ranging anywhere from one to three and possibly greater. A scoping analysis was performed to determine the maximum fissile loading compliant to the USL for H/D ratios varying from one to three. Figure 7-2 and Table A-82 summarize the results of the parametric study. As indicated by the graph, a slight change in geometry has a relatively significant effect on the allowable mass loading with overbatch values exceeding 2 times the FGE limit for an H/D ratio of 3.

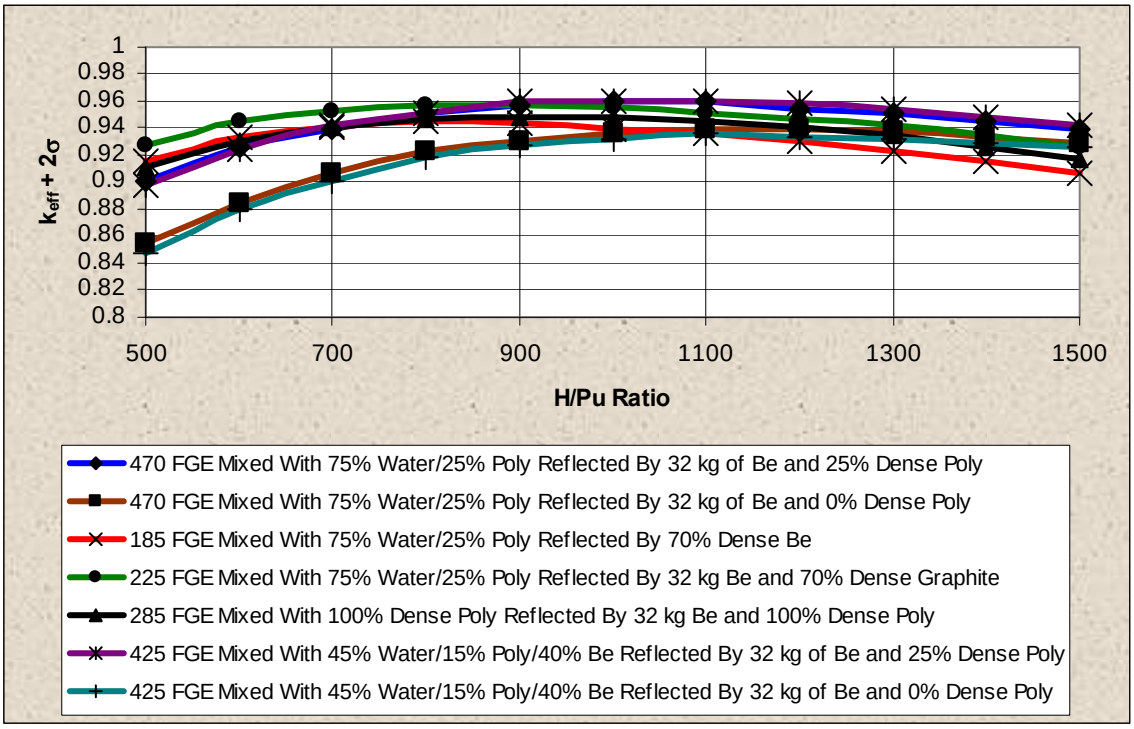


Figure 7-1, Overbatched Single Direct Loaded Canister Reflected By 200 cm of Lead

The more limiting waste package content with respect to the fissile mass over batching contingency was the 100% dense machine compacted waste containing < 1 wt% special reflector material. In modeling the over batching contingency for this waste package, no credit was taken for the actual state of the waste form itself, name that it is compressed into pucks and pucks loaded into the RH canister. If the waste form were modeled in a more realistic manner, the fissile mass would be segregated into discrete cylindrical pucks and loaded along the central axis of the canister. A cylindrical shape can be used for the fissile mass with a varying H/D ratio to evaluate the effect of a more realistic geometry of the reactivity of the system. Figure 7-3 and Table A-82 illustrates the effect of the fissile mass geometry on the system reactivity. It is noteworthy that an H/D ratio of 3 yield a 1.9 fold increase (i.e., close to 2 times the FGE limit) in fissile mass loading over the allowable FGE limit.

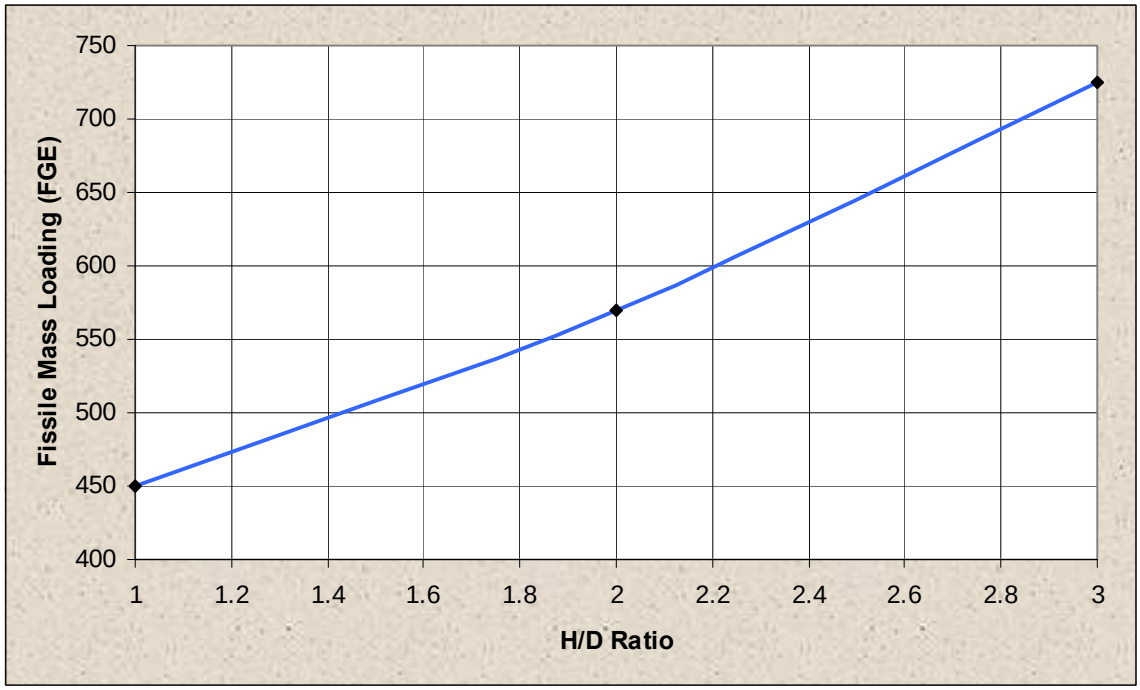


Figure 7-2, Single Direct Loaded Canister Fissile Mass Loading as a Function of H/D Ratio for Waste Packages With Mechanically or Chemically Bound Beryllium

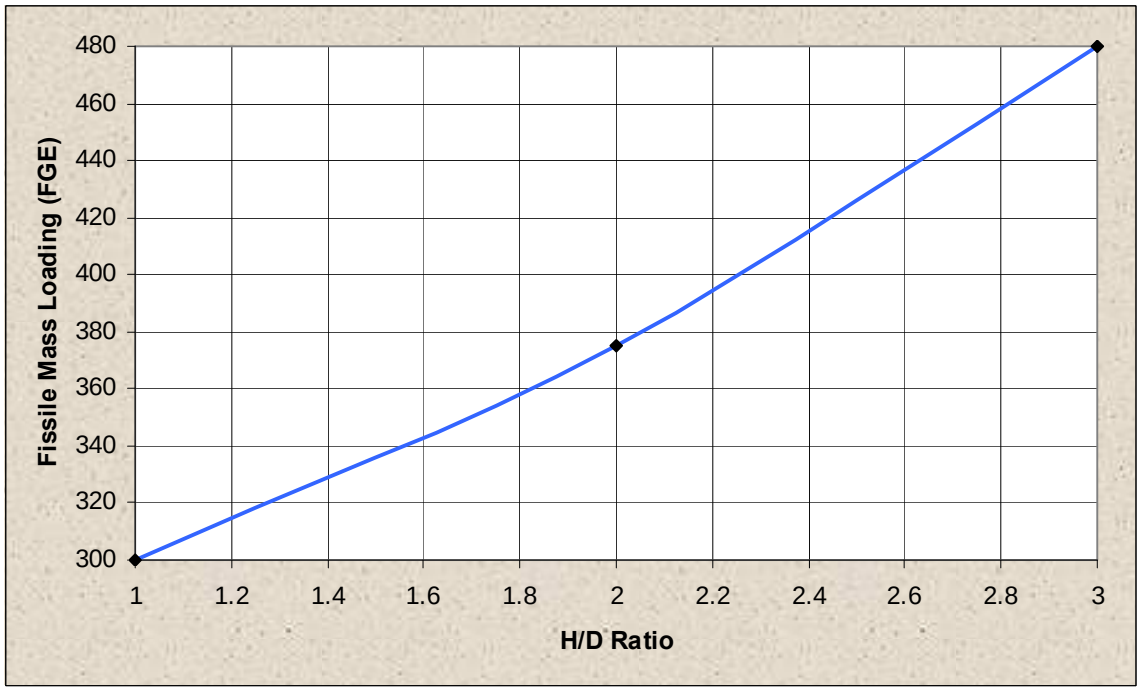


Figure 7-3, Single Direct Loaded Canister Fissile Mass Loading as a Function of H/D Ratio for Machine Compacted Waste Packages

7.1.1.3 Overloaded Canister of Containerized Waste

Over batched contingency computations were also performed for containerized waste during RH waste container receipt and interim storage in the WHB. In performing the over batched computations it was assumed that all fissile masses were centered in their respective drums thereby accounting for the expected random distribution of the fissile units within the drums. Furthermore the contingency computations did not take credit for the drum structure itself and allowed packing of loose waste around the drums in the canister, including beryllium up to 1 wt% of the canister weight limit of 32 kg instead of 5 kg per drum. Additionally, in evaluating overbatched states for non-compacted waste consisting of > 1 wt% beryllium or graphite, a 70% dense internal reflector was considered.

The results of the computational analysis, as summarized in Figure 7-4 and Table A-83 through Table A-87, yield the following FGE loadings which have a maximum $k_{eff} + 2\sigma$ value of ≤ 0.95 or ≤ 0.96 if the overbatch mass loading was < 50% over the FGE limit:

1. 380 FGE/drum (~ 90% overbatch) for non-compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium);

2. 180 FGE/drum (~ 80% overbatch) for non-compacted waste containing > 1 wt% beryllium at 70% density;

3. 215 FGE/drum (~ 79% overbatch) for non-compacted systems containing 70% dense graphite and ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium); and

4. 285 FGE/drum (~ 43% overbatch) for 100% dense machine compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium).

In all but one case, the overbatch loading exceeded 50% of the FGE. The use of a 50% margin (i.e., a factor of 1.5) over the FGE limit is desired since it ensures adequate margin to the limit for this contingency condition. The only waste package not compliant with this criterion was the 100% dense machine compacted waste containing ≤ 1 wt% special reflector material. To increase the mass loading for this waste package, one recalls that machine compacted waste is in the form of pucks and then containerized in 30-gallon drums. Thus by simply changing the geometry of the fissile mass from discrete spherical to cylindrical (pucks), the overbatch loading increases from 285 FGE/drum to 300 FGE/drum or 50% overbatch loading yielding a system eigenvalue of $k_{eff} + 2\sigma \leq 0.95778$.

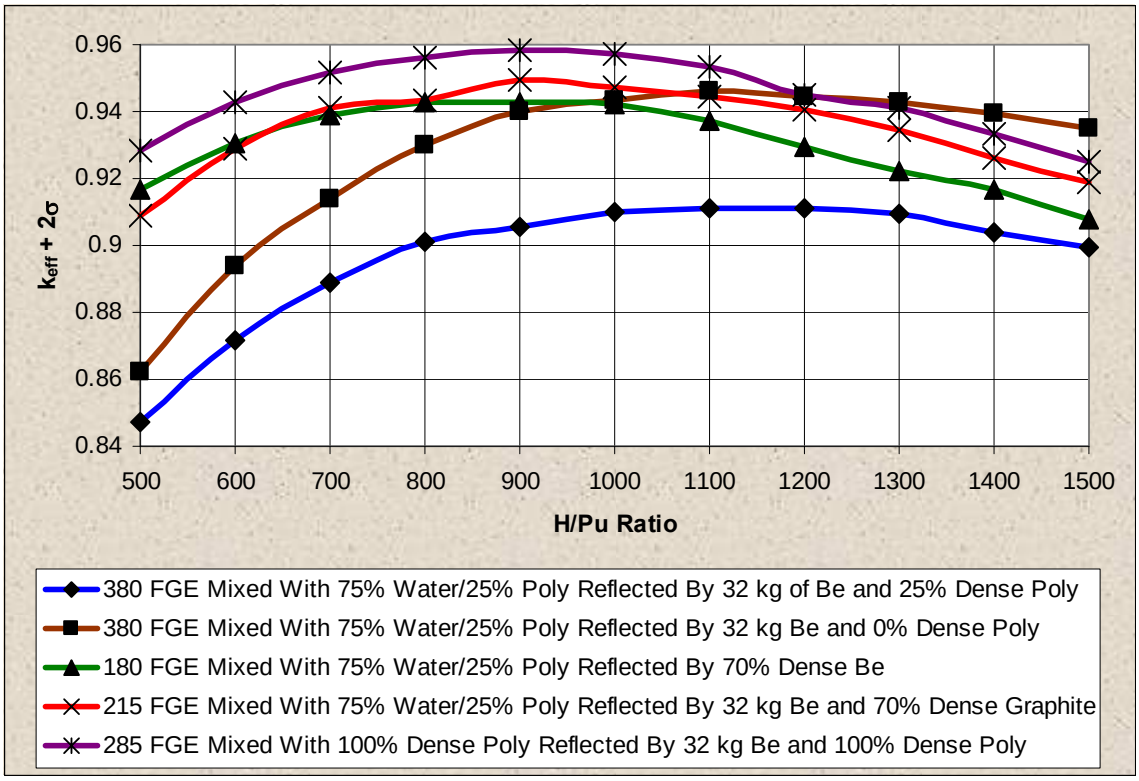


Figure 7-4, Three Overbatched Centrally Located Masses in a RH Waste Canister Reflected By 200 cm of Lead

7.1.1.4 Overloaded Direct Loaded Canister in Disposal Room Borehole

This analysis models the underground disposal room borehole configuration filled with overloaded canisters. The computation was performed using the assumptions that the fissile masses are centrally located within their respective canisters and that a maximum achievable special reflector density is 70% of theoretical density when such materials are present in more than trace quantities. Table A-88 through Table A-94 and Figure 7-5 summarize the overbatched reactivity state for both non-compacted and machine compacted waste with the canisters mirrored laterally to simulate an infinite array and bounded axially by 300 cm of salt. The results of the calculation indicate that the system eigenvalue for an array of direct loaded RH waste canisters can be demonstrated to be less than the USL with each canister loaded up to:

1. 460 FGE (~ 46% overbatch) FGE for non-compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium);

2. 190 FGE (~ 90% overbatch) for non-compacted waste containing > 1 wt% beryllium at 70% density;

3. 420 FGE (~ 38% overbatch) for non-compacted waste with the fissile material mechanically or chemically bound with special reflector materials (i.e., beryllium);

4. 225 FGE (~ 88% overbatch) for non-compacted systems containing 70% dense graphite and ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium); and

5. 285 FGE (~ 16% overbatch) for 100% dense machine compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium).

The over batch loadings are applicable both in the absence and presence of adjacent CH waste as the calculations in Sections 5.5.1 and 5.5.2 illustrate that the interaction with CH waste packages is bounded by the infinite salt reflector modeled at the end of the borehole.

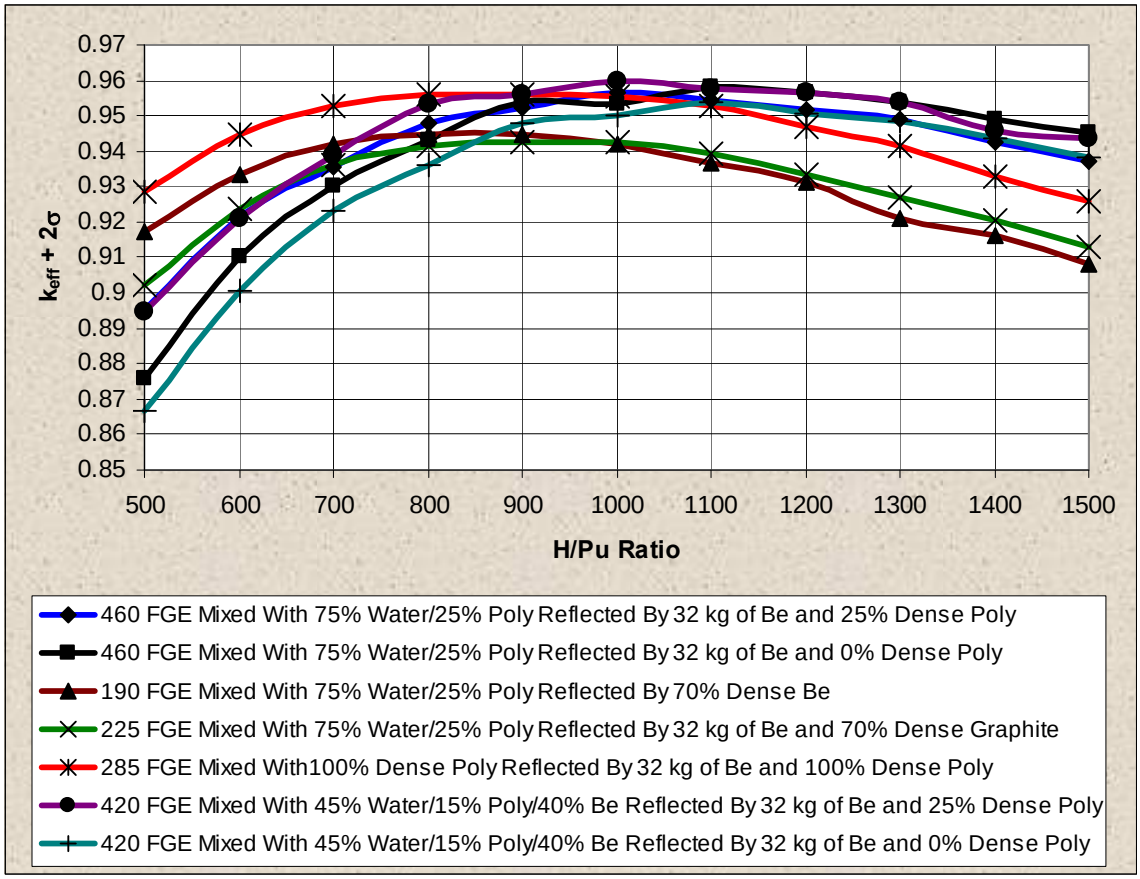


Figure 7-5, Overbatched Direct Loaded Canister Mirrored Laterally and Reflected Axially By 300 cm of Salt

Once again, it is desired to maximize the overbatch mass loading to ensure a large margin of safety. As discussed previously, a 50% over batch is an adequate margin. Three of the waste package over batch loadings were less than 50%, namely (1) the non-compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium); (2) the non-compacted waste with the fissile material mechanically or chemically bound with special reflector materials (i.e., beryllium); and (3) the 100% dense machine compacted waste containing < 1 wt% special reflector material (i.e., up to 32 kg beryllium). With respect to the non-compacted waste containing ≤ 1 wt% special reflector material, a slight geometry change from spherical to

cylindrical geometry with a H/D ratio of 1 yields an over batch of 500 FGE (~ 59% over-batch) which is compliant to the USL. This geometric change is justified by fact that the large mass density of the fissile unit will naturally settle along the axial length of the canister and evolve to a more distributed cylindrical shape as the canister is handled and placed into permanent storage.

The same reasoning can be applied to the non-compacted waste with the fissile material mechanically or chemically bound with special reflector materials in that the more dense fissile mass will tend to settle and distribute the fissile loading axially. This effect is simulated computationally by modifying the geometric form of the fissile mass from spherical to cylindrical and computing the maximum overbatch mass loading which is compliant to the USL for various H/D ratios. Figure 7-6 and Table A-95 summarize the results of the parametric study. As indicated by the data, a slight change in geometry has a relatively significant effect on the allowable mass loading with overbatch values exceeding 2.4 times the FGE limit at an H/D ratio of 3.

Finally, to demonstrate that overbatch mass loadings for waste packages containing 100% dense machine compacted waste with <1 wt% special reflector material can be increased substantially, the fissile mass can be modeled as discrete cylindrical pucks loaded along the central axis of the canister. For above ground handling of RH waste canisters, a cylindrical shape was used for the fissile mass and a parametric calculation was performed in which the H/D ratio was varied to evaluate the effect of a more realistic geometry on the reactivity of the system. Figure 7-7 and Table A-95 illustrate the effect of the fissile mass geometry on the system reactivity. Note that an H/D ratio of 3 results in a 1.9 fold increase (i.e., close to 2 times the FGE limit) in fissile mass loading over the allowable FGE limit.

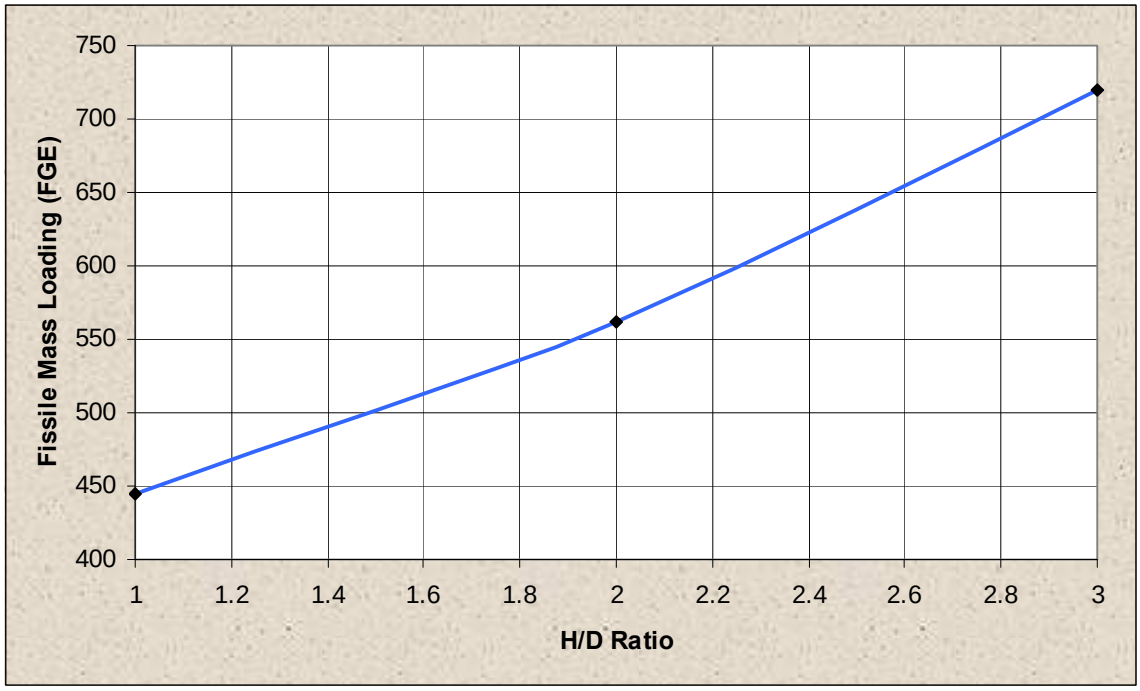


Figure 7-6, Direct Loaded Canister Fissile Mass Loading as a Function of H/D Ratio for Waste Packages With Mechanically or Chemically Bound Beryllium

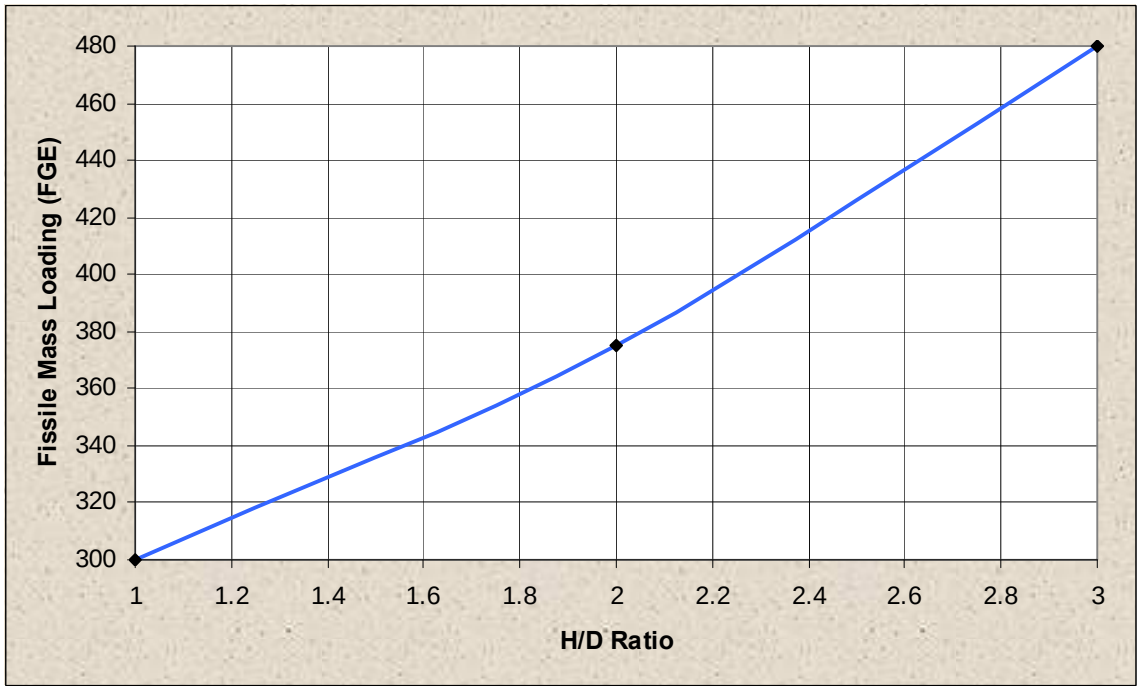


Figure 7-7, Direct Loaded Canister Fissile Mass Loading as a Function of H/D Ratio for Machine Compacted Waste Packages

7.1.1.5 Overloaded Canister of Containerized Waste in Disposal Room Borehole

Since WIPP does not open RH waste containers, there is no potential for adding fissile material to an RH container during operations at the WIPP. As a result, the accumulation of a critical configuration in the underground disposal room borehole array can only occur if waste exceeding the WAC fissile limits is sent to WIPP. It was demonstrated in Section 5.5 that if all the drums in a facility canister were loaded to their maximum allowable limits the system would remain below the USL. This is true even if the FGE limit for each drum was exceeded. Specifically, contingency calculations were performed for the underground disposal of containerized waste in the repository wall boreholes. Over batching contingency calculations for containerized RH waste packages assumed that all fissile masses were centered in their respective drums and the computations did not take credit for the drum structure itself while modeling loose waste around the drums in the canister up to the beryllium weight limit of 32 kg. Likewise, in evaluating overbatched states for non-compacted waste consisting of >1 wt% beryllium or graphite, a 70% dense internal reflection state was considered. Finally, the model used in the containerized over batch contingency analysis was identical to that used previously for disposal in the repository wall boreholes. A 2.5-ft center-to-center spacing between RH waste containers in a triangular pitch was assumed with the lateral surfaces mirrored to simulate a planar array configuration. The results of the computational analysis, as shown in Figure 7-8 and tabulated in Table A-96 through Table A-100, yield the following subcritical FGE loadings with a $k_{eff} + 2\sigma$ value below the USL of 0.96:

1. 320 FGE/drum (~ 60% overbatch) for non-compacted waste containing ≤1 wt% special reflector material (i.e., up to 32 kg beryllium);

2. 185 FGE/drum (~ 85% overbatch) for non-compacted waste containing > 1 wt% beryllium at 70% density;

3. 220 FGE/drum (~ 83% overbatch) for non-compacted systems containing 70% dense graphite and ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium); and

4. 285 FGE/drum (~ 43% over-batch) for 100% dense machine compacted waste containing ≤ 1 wt% special reflector material (i.e., up to 32 kg beryllium).

In all cases, each canister of 3 drums contains more than the 318 g ^{239}Pu allowed in the 10-160B container and an infinite planar array of canisters is modeled. The over batch loadings above are applicable both in the absence and presence of adjacent CH waste as the calculations in Section 5.5.2 illustrated that the interaction with CH waste packages is bounded by modeling an infinite salt reflector at the end of the borehole. Furthermore, as determined previously, most of the over batch loadings exceed 50% of their FGE limit. The only waste package whose over batch mass loading is less than 50% of its FGE limit is the 100% dense machine compacted waste containing ≤ 1 wt% special reflector material. However, by adjusting the containerized fissile mass from a spherical form to a cylindrical puck with an H/D ratio of one, the over batch loading mass can be

increased from 285 FGE/drum to 300 FGE/drum (or 50% over batch loading). The resulting system eigenvalue for the cylindrical configuration is $k_{eff} + 2\sigma \leq 0.95812$.

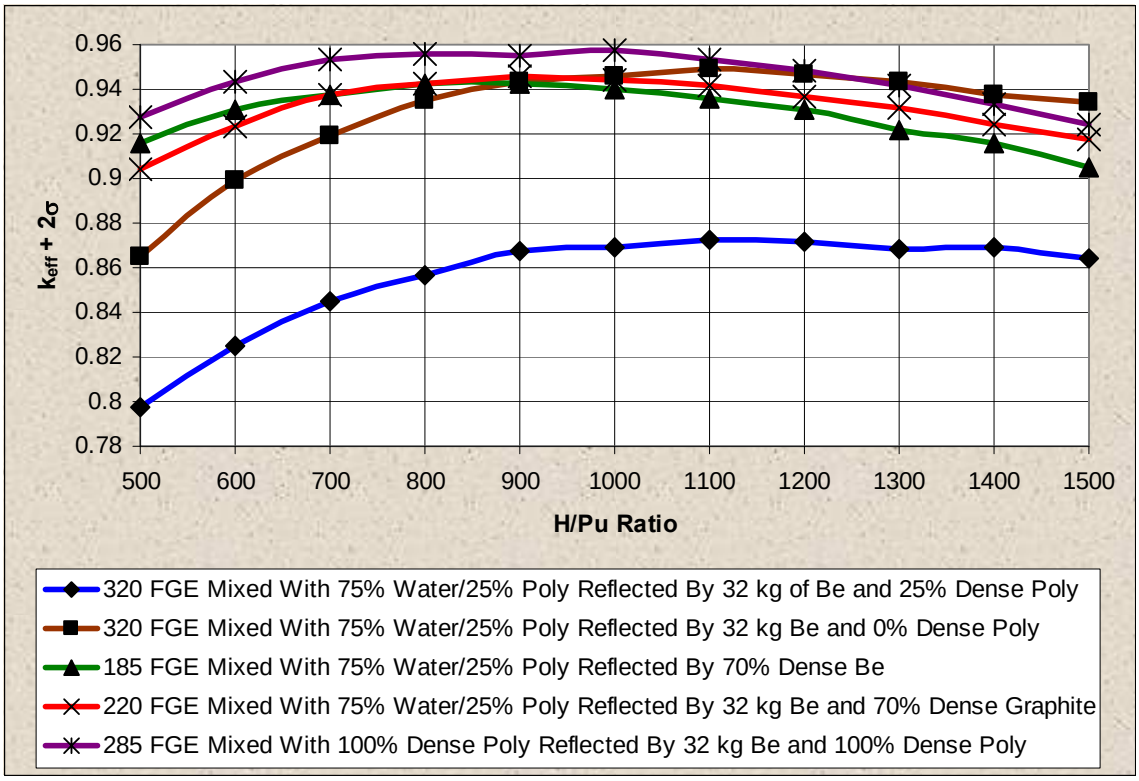


Figure 7-8, Three Overbatched Drums in RH Waste Canisters Mirrored Laterally and Reflected Axially By 300 cm of Salt

7.1.1.6 Overloaded Direct Loaded Canister Containing LEU

Contingency calculations for overbatched direct loaded 72-B canisters containing LEU waste streams enriched to 0.96 wt% ^{235}U were also performed. Both above ground receipt, handling and interim storage operations as well as conveyance to and permanent disposal into the underground boreholes were considered. Scoping parametric studies performed in Section 5.4.1 indicated that the most reactive moderating mixture was 25% polyethylene/74% water/1% beryllium by volume at an H/^{235}U ratio of 400. Using these mixture parameters in the geometric models described in Section 5.1.5, the total fissile mixture mass was adjusted to completely fill the canister thereby simulating an over batched condition as the mass limit of the container is exceeded. The computation yielded a system eigenvalue of 0.91617 and 0.91599 for the above ground and the underground repository models, respectively. These system reactivities were only slightly larger than LEU base case which contained 3,129 kg of uranium and was reflected by 100% dense beryllium indicating that the replacement of beryllium by LEU to accommodate the overloaded state has very little impact on the system eigenvalue and the safety margin.

7.1.1.7 Incorrect Waste Type Loaded into NS30 or NS15 Canister

Loading a neutron shielded canister with an incorrect waste type or loading was evaluated as a potential contingency. Three waste type loadings approved only for the non-shielded canister, 325 FGE for non-compacted waste, 305 FGE for special reflector material chemically or mechanically bound, and 100 FGE for waste with unlimited high Be content, were selected to represent the incorrect loadings. The results in Figures 7-9 and 7-10 (tabulated in Tables A-168 through A-170 of Appendix A) show that the NS15 canister remains below the USL under all three of these misloadings. As discussed previously, the NS15 canister contains a thicker polyethylene reflector such that these NS15 canister models bound incorrect loading in NS30 canisters.

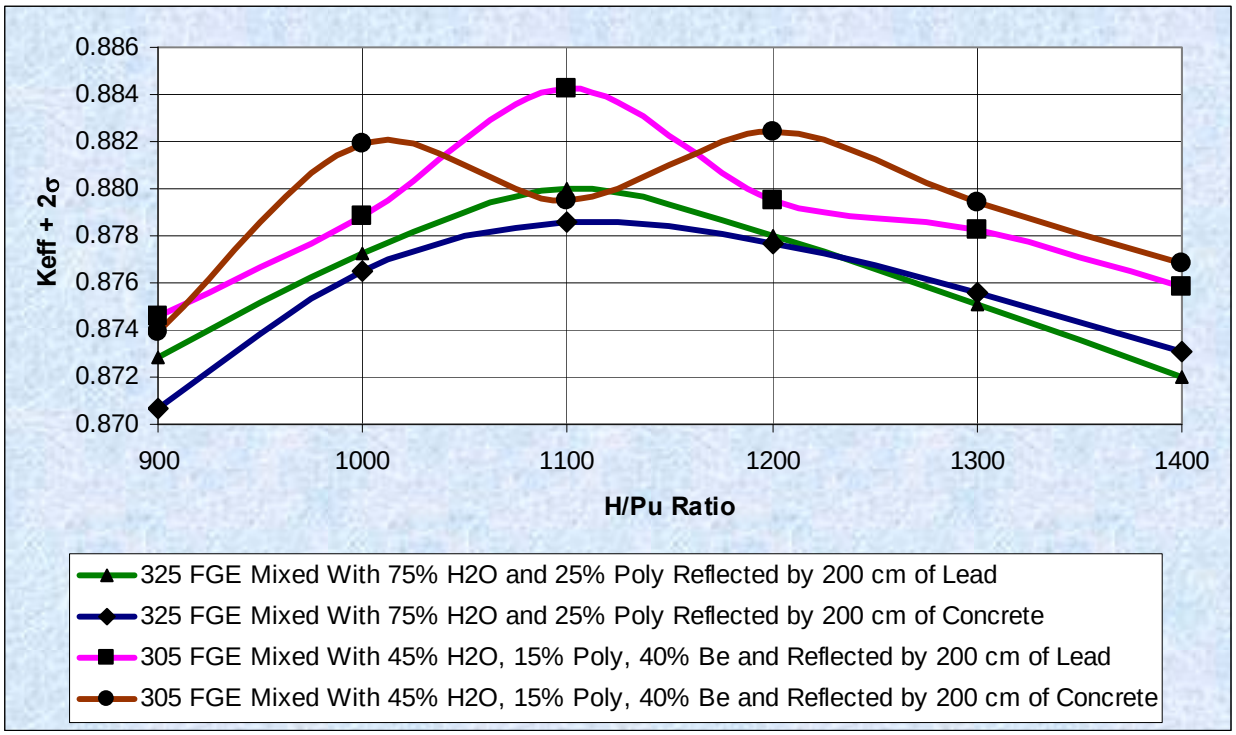


Figure 7-9, Misloaded NS15 RH Waste Canister with 25% Poly Reflection

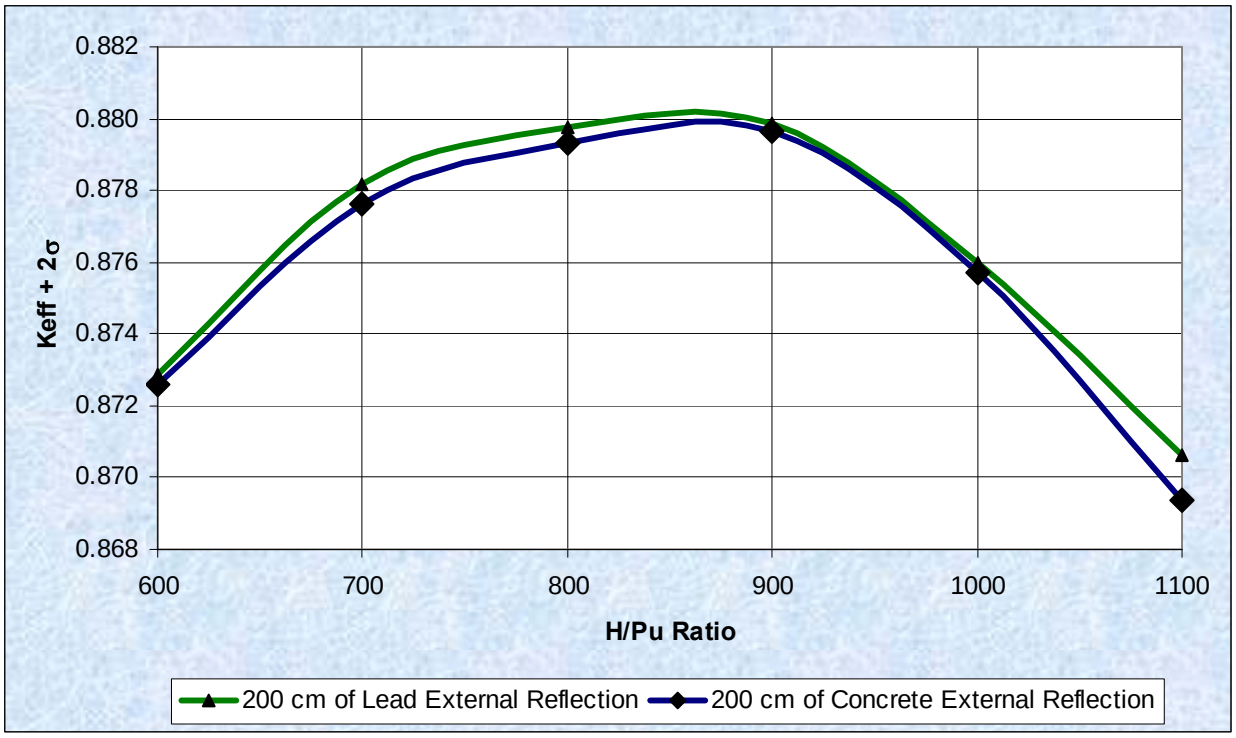


Figure 7-10, Misloaded NS15 RH Waste Canister with 100 FGE Mixed With 75% Water and 25% Dense Poly, Reflected by 100% Dense Be

7.1.1.8 Summary

As discussed earlier, the waste generator is required to control the canister FGE loading by the WIPP WAC and by the DOT and NRC package licensing requirements for both the RH-TRU 72-B and 10-160B shipping containers. Generator sites are periodically audited to verify compliance with the WAC limits. For these reasons, over batching the waste canisters is considered to be very unlikely. Additionally, to have an accidental criticality, the shipping requirements specified in the WIPP WAC would have to be violated repeatedly. The following points are made from a probabilistic viewpoint with respect to over batching:

- A misbatched RH container can be made by human error, mis-identification of containers, instrument miscalibration, or some other process upset. However, not all misbatched RH canisters will be above the NCS limit on fissile loading as fissile material is valuable and generally not considered waste unless only small quantities are present or the fissile material has been recovered to the extent practical. Containers below the NCS limits remain subcritical.
- The criticality models used in this NCSE are based on optimally moderated fissile materials in pure form at optimum shapes to minimize neutron loss. The reflector materials in the drums/canisters are also modeled at maximum credible densities to maximize reactivity. Even small deviations from these optimum conditions results in a significant reduction in reactivity.

- Every direct-loaded canister in the infinite borehole array can be overbatched and remain subcritical. The hot cell drum array remains subcritical even if the combined drum loading exceeds the 10-160B container limit per 10 drum load by more than a factor of two. For canisters loaded with waste drums, every canister contains more than the 10-160B container limit also.

Therefore, based on the above discussion, it is judged that a criticality accident in an RH container during receipt and conveyance at WIPP as a result of exceeding the fissile limit is not credible.

7.1.2 Excess Beryllium Loading in a RH Waste Container

This event postulates a criticality accident in an RH waste container as a result of beryllium over batching. Since WIPP does not open RH waste containers but only loads waste drums from 10-160B shipping containers into facility canisters for final disposal, there is no potential for adding beryllium to a canister during receipt, handling, conveyance, or permanent disposal operations. Consequently any possibility of exceeding the allowable beryllium content in a RH waste package must originate at the generator site. Although numerous safeguards are implemented at the generator sites to ensure adherence to the allowable beryllium mass loading limits in the various RH waste containers, a beryllium over batching contingency analysis was performed to quantify the reactivity effect of such an event and to ensure compliance to established limits at the WIPP facility.

7.1.2.1 Overloaded Direct Loaded Canister

To simulate a potential beryllium over batching condition during receipt, handling, interim storage and conveyance of a direct loaded canister, a double batch loading of 64 kg beryllium per canister was assumed in the most limiting external reflection state, namely full reflection in all directions by 200 cm of lead. The model used in the beryllium over batching computations was consistent with that employed in other criticality computations involving above ground handling operations with direct loaded canisters in that all fissile masses were centered in the canister, thereby accounting for the expected random distribution of the fissile material within the package. The results of the beryllium over batching calculations are summarized in Figure 7-11 and Table A-101 through Table A-104. Compared to the results for similar cases with 32 kg Be/canister shown in Figure 5-15, an increase in the canister beryllium content by a factor of 2 has only a minimal effect on the reactivity state of the system. The maximum system $k_{eff} + 2\sigma$ is 0.92651 and thus there is sufficient margin to the USL of 0.96. Therefore, it is concluded that a criticality accident due to a beryllium overloading condition in a direct loaded canister is not credible.

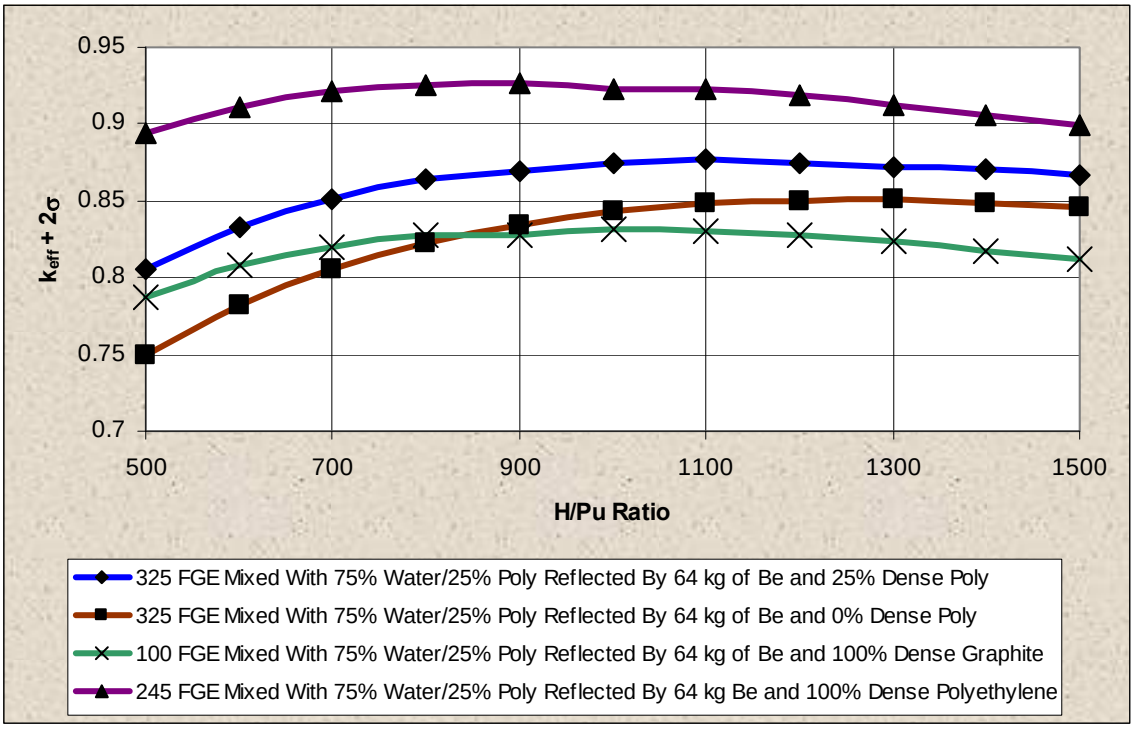


Figure 7-11, Beryllium Overbatch Contingency Results for a Single Direct Loaded Canister Reflected By 200 cm of Lead

7.1.2.2 Overloaded Canister of Containerized Waste

Beryllium over batching computations were also performed for containerized waste during RH waste container receipt and interim storage in the WHB as well as conveyance to the underground repository operations. In performing the contingency computations, the model used in the analysis was consistent with that employed in other above ground RH canister calculations containing containerized waste in that it was assumed: (1) that all fissile masses were centered in their respective drums, thereby accounting for the expected random distribution of the fissile units within the drums; (2) that no credit was given for the drum structure itself thereby allowing for packing of loose waste around the drums in the canister; and (3) that the RH waste canister was reflected on all sides by 200 cm of lead. Furthermore, the over batching contingency calculation assumed a beryllium loading of up to 2 wt% of the canister weight limit or 64 kg instead of 10 kg per drum.

The results of the computational analysis are summarized in Figure 7-12 and Table A-105 through Table A-108. As expected, only a slight increase in the reactivity from the nominal state (i.e., 32 kg of beryllium) shown in Figure 5-21 was observed. All results are less than 0.9 and thus there is sufficient margin to the established USL. As a result, a criticality accident due to a beryllium over batching error in a containerized 72-B canister is not credible.

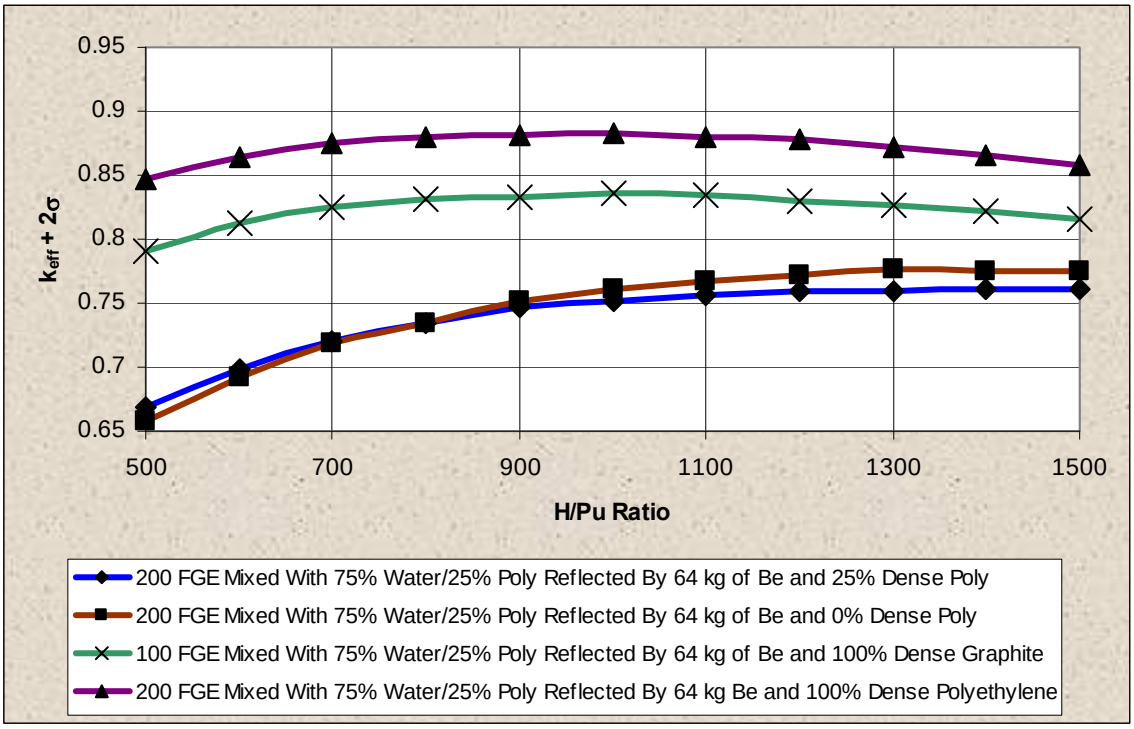


Figure 7-12, Three Drums in a RH Waste Canister Containing 64 kg of Beryllium Reflected By 200 cm of Lead

7.1.2.3 Overloaded Drums in the Hot Cell Array

As discussed in Section 5.2.2, the operations performed in the upper hot cell involve loading 30-gallon or 55-gallon drums from the 10-160B container to the RH facility canister. Since the drums remain sealed, no beryllium can be added to their content such that an over batch condition can only occur from a generator site error(s). Nevertheless, to simulate a potential beryllium overbatching event in the upper hot cell area, the beryllium content in each 30-gallon drum in the hot cell array was increased to 10 kg per drum which is approximately 2 wt% of the contents of each drum. The drum waste fissile contents, 12-drum geometric array arrangement, and external reflector configuration is consistent with that assumed in Section 5.2.2.

The results of the contingency calculation are presented graphically in Figure 7-13 below and tabulated in Table A-109 through Table A-112. Comparison of the results with the normal condition results in Figure 5-33 reveals that the excess beryllium has little effect on reactivity. The results of all cases were below 0.9 and thus well below the USL and it is not credible for a criticality accident to occur due to a beryllium overbatch condition in the hot cell.

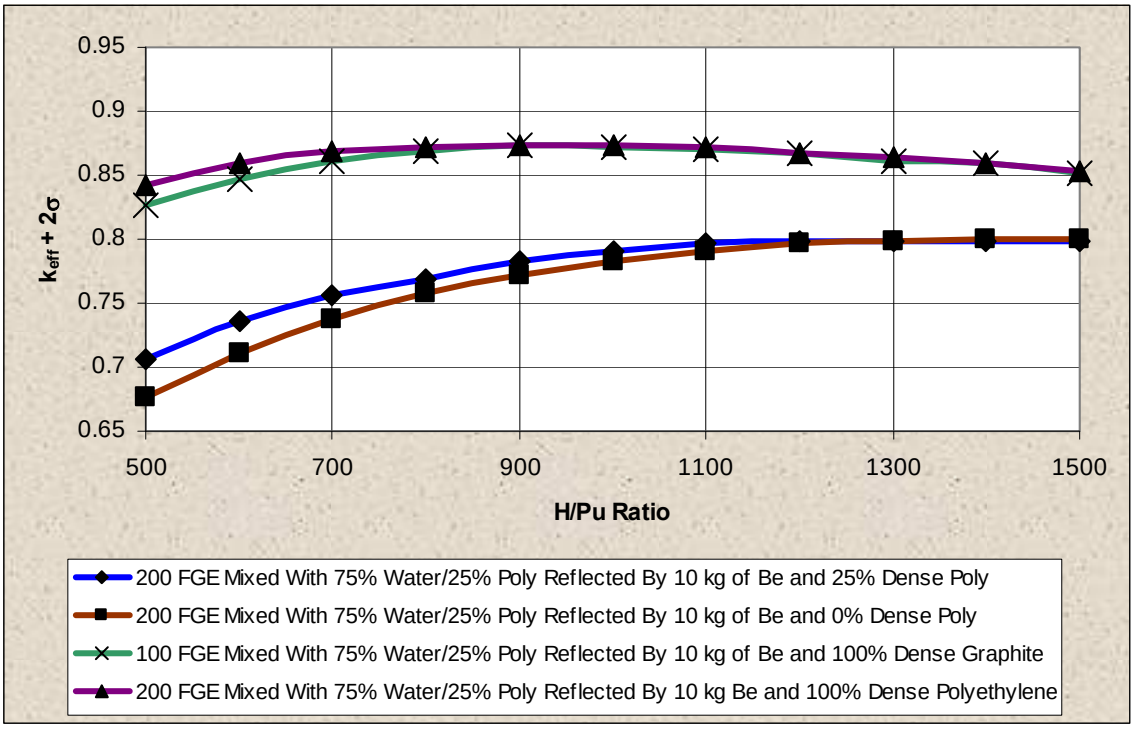


Figure 7-13, Beryllium Overbatching Contingency for a 12-Drum Array of 30-Gallon Drums in the Upper Hot Cell Area

7.1.2.4 Overloaded Direct Loaded Canister in Disposal Room Borehole

Following suit with the beryllium overbatching contingency analysis performed for direct loaded RH waste containers in above ground receipt, handling and conveyance operations, a computation was performed for the direct loaded canister in the underground disposal room borehole configuration with a double batched beryllium loading (i.e., 64 kg). The model used for the underground disposal of the canister in the boreholes was identical to that discussed in Section 5.2.3 with the exception of the increased beryllium loading per canister. Table A-113 through Table A-116 and Figure 7-14 summarize the results of the infinite canister array calculations reflected axially by 300 cm of salt for both non-compacted and machine compacted waste. The results of the calculation indicate that the system eigenvalue for direct loaded RH waste canisters is only slightly different from the nominal state with 32 kg of beryllium shown in Figure 5-36 and thus poses no credible threat for a criticality accident to occur due to a beryllium over batching condition in the underground disposal configuration for direct loaded RH waste packages.

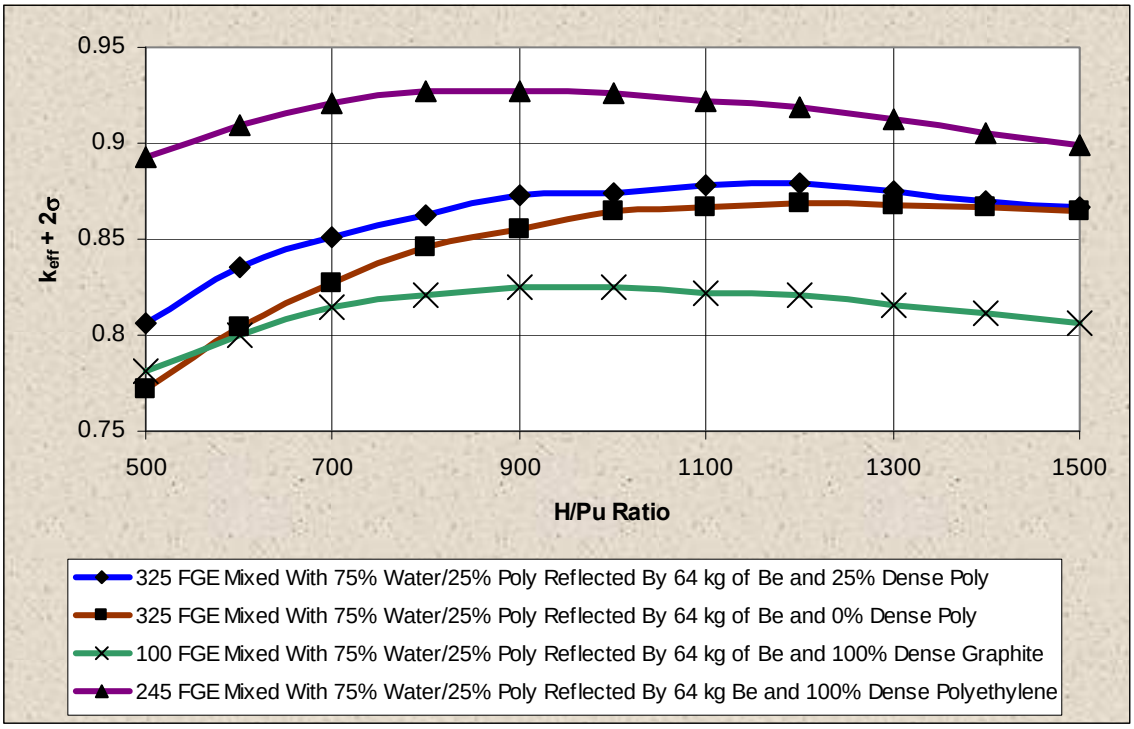


Figure 7-14, Beryllium Overbatch Event for a Single Direct Loaded Canister Mirrored Laterally and Reflected Axially By 300 cm of Salt

7.1.2.5 Overloaded Canister of Containerized Waste in Disposal Room Borehole

The final beryllium over batching contingency analyzed in this section involves the underground disposal of canisters of containerized RH waste canisters in the borehole array. The model used in the analysis was identical in nature to that described in Section 5.5.2 except for the increased loading of the beryllium to 64 kg/canister. The results of the computational analysis are illustrated in Figure 7-15 and tabulated in Table A-117 through Table A-120. The maximum $k_{eff} + 2\sigma$ for all cases considered was 0.88142 which corresponded to a machine-compacted waste package. Like all beryllium double batch contingencies evaluated, the maximum reactivity state was only slightly different from the nominal cases containing 32 kg of beryllium shown in Figure 5-42. Thus a criticality accident due to exceeding the allowed beryllium content by up to a factor of 2 is not credible.

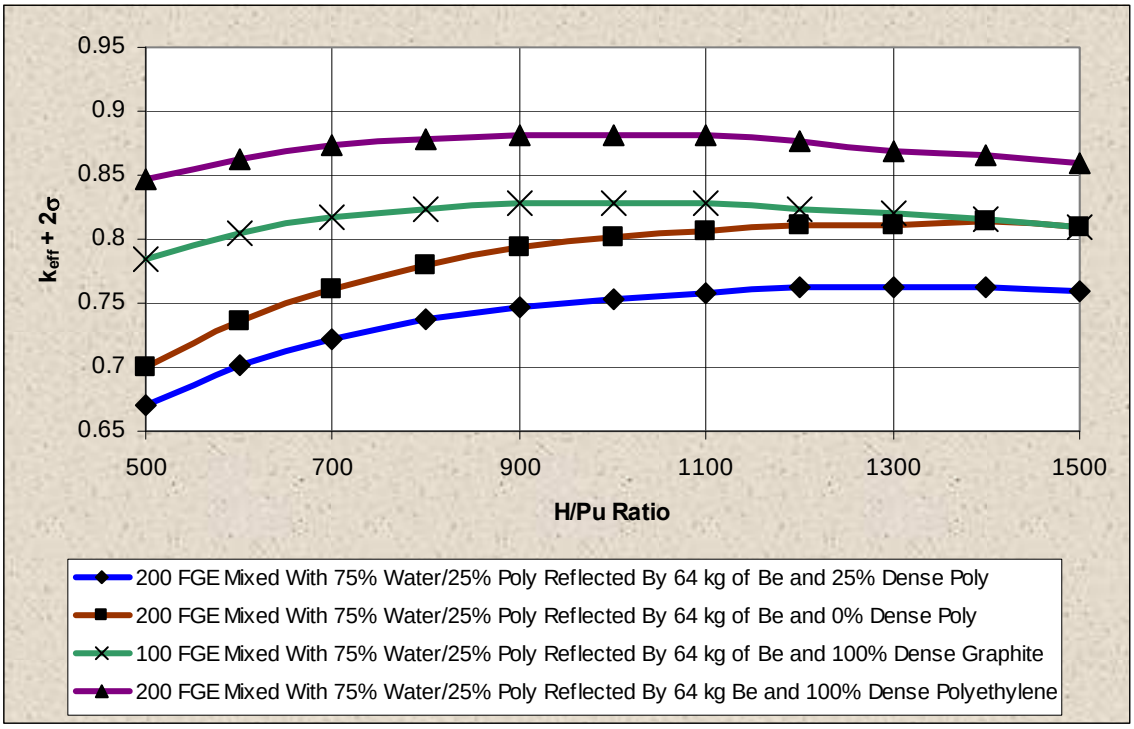


Figure 7-15, Three Beryllium Overbatched Drums in RH Waste Canisters Mirrored Laterally and Reflected Axially By 300 cm of Salt

7.1.3 Excess Water/Flooding in a RH Waste Container

This contingency condition simulates an abnormal state in which an RH waste container contains an excess of liquid in the dunnage as a result of either generator site error or water seepage into the container while being transported to or in process at WIPP. A water intrusion contingency analysis was performed in which it was assumed that various amounts of water mix with the internal polyethylene reflector. Only non-machine compacted canisters containing loose polyethylene dunnage mixed with beryllium were considered in the analysis since canisters with >1 wt% beryllium, 100% dense graphite mixed with beryllium, or machine compacted waste are less reactive if water is substituted for the special reflector material (Be, graphite, etc.) or the compaction is less than 100% with water filling the volume. The contingency calculation is parametric in nature in that it assumes that the beryllium is mixed with a polyethylene-water-void mixture whose percent by volume varies from dry to fully flooded. Specifically the following partially/fully flooded conditions are analyzed: (1) beryllium mixed with 25% by volume polyethylene and 18.75% by volume water; (2) beryllium mixed with 25% by volume polyethylene and 37.5% by volume water; (3) beryllium mixed with 25% by volume polyethylene and 56.25% by volume water; (4) beryllium mixed with 25% by volume polyethylene and 75% by volume water; (5) beryllium mixed with 15% by volume polyethylene and 85% by volume water; and (6) beryllium mixed with 5% by volume polyethylene and 95% by volume water. In all cases, the model used the simulate the potential water intrusion event is

as described in Section 5.2 with the internal canister or drum reflector material varied as stated above.

7.1.3.1 Partial and Full Flooding of a Direct Loaded Canister

The results of the flooding contingency calculation for direct loaded RH canisters with lead reflection to bound above ground and conveyance operations are summarized in Figure 7-16 and Figure 7-17 and Table A-121 through Table A-126. As indicated by the data, the system reactivity increases with the water content in the partial flooding state case with the fully flooded states being most reactive. In all cases, the system eigenvalue remained below the USL and therefore a criticality event result from a water intrusion contingency in a direct loaded canister is not credible.

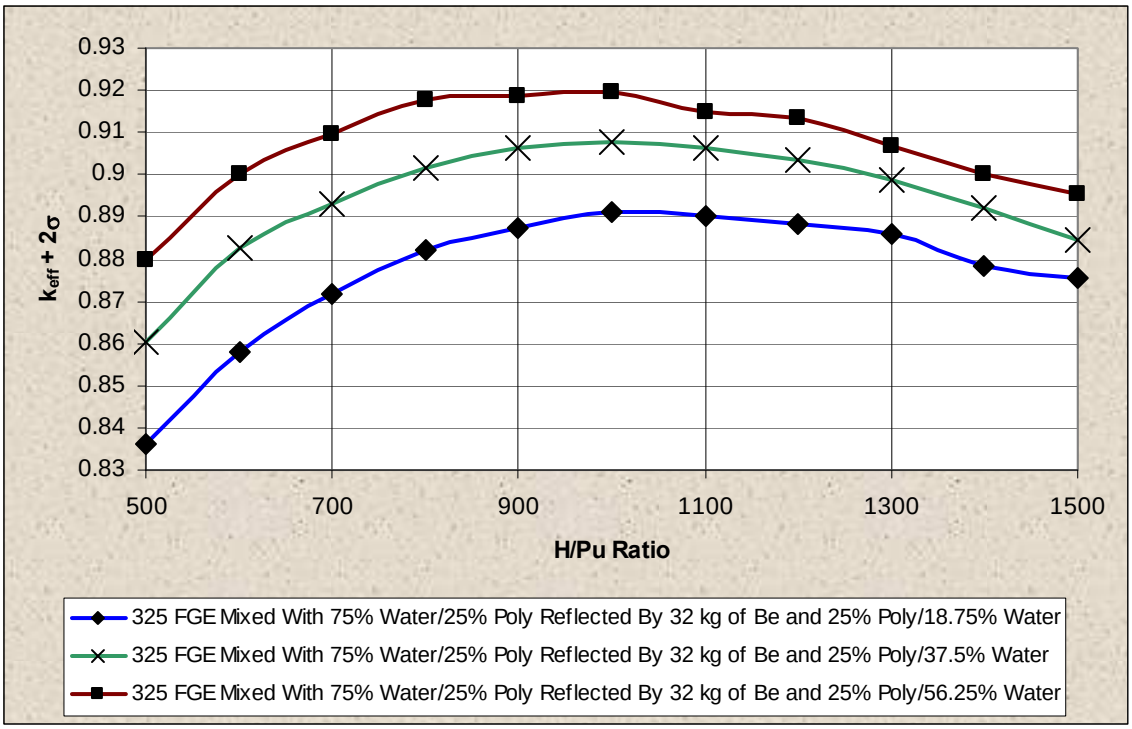


Figure 7-16, Partial Flooding Results for a Single Direct Loaded Canister Reflected By 200 cm of Lead

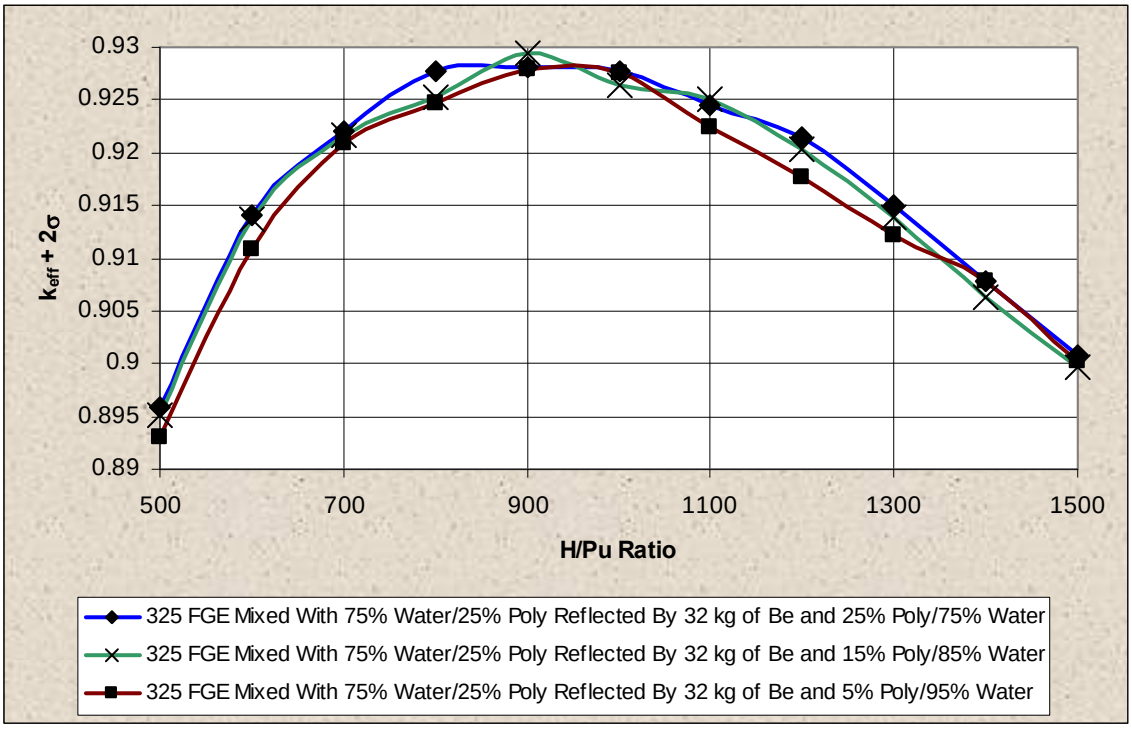


Figure 7-17, Full Flooding Results for a Single Direct Loaded Canister Reflected By 200 cm of Lead

7.1.3.2 Partial and Full Flooding of a Canister of Containerized Waste

Partial and full flooding contingencies were also performed for canisters of containerized waste with lead reflection. Figure 7-18 and Figure 7-19 as well as Table A-127 through Table A-132 summarize the computational results. The same trends in system reactivity with respect to water content seen in the direct loaded canister results are seen here. However, the overall system reactivity of the containerized waste canisters is lower than the direct loaded canisters as expected due to the smaller fissile units and the separation between them. In all cases, the system eigenvalue remained below the USL and therefore a criticality event resulting from a flooding contingency in canisters with containerized waste is not credible.

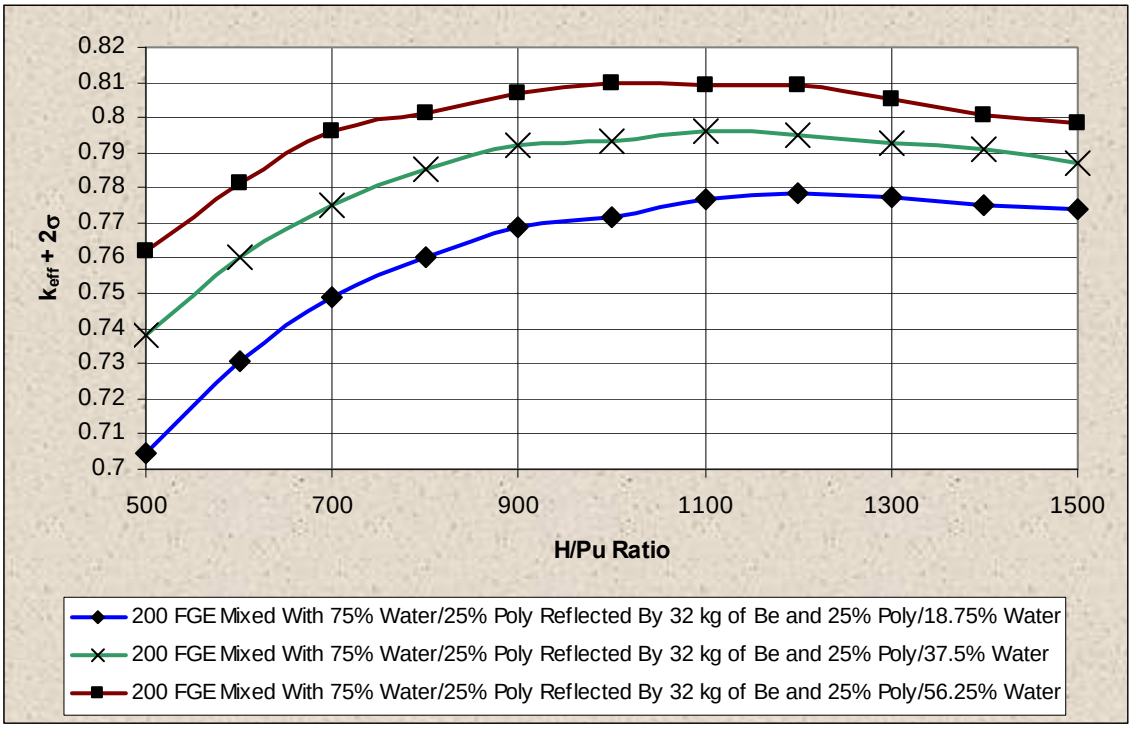


Figure 7-18, Partial Flooding Results Three Centrally Located Masses in a RH Waste Canister Containing 32 kg of Beryllium Reflected By 200 cm of Lead

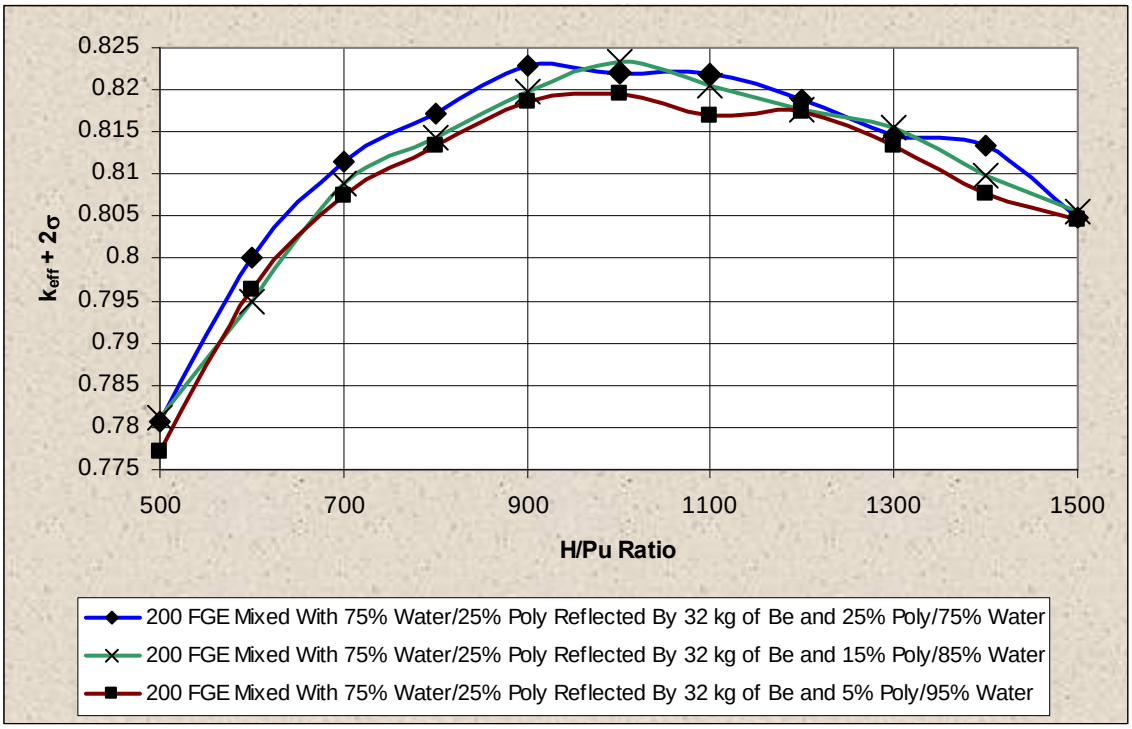


Figure 7-19, Full Flooding Results for Three Centrally Located Masses in a RH Waste Canister Containing 32 kg of Beryllium Reflected By 200 cm of Lead

7.1.3.3 Partial and Full Flooding of Drums in the Hot Cell Array

A water intrusion event in which it is postulated that a partial or full flooding contingency occurs in the upper hot cell during repackaging operations was simulated. Figure 7-20 and Figure 7-21 illustrate the computational results pictorially whereas Table A-133 through Table A-138 tabulate the associated numerical eigenvalues. System reactivity increases with water content in the partial flooding state and peaks for the fully flooded cases. The results indicate that all cases were well below the established USL (maximum reactivity below 0.83) and therefore a criticality event due to partial or full flooding condition in the upper hot cell is not credible.

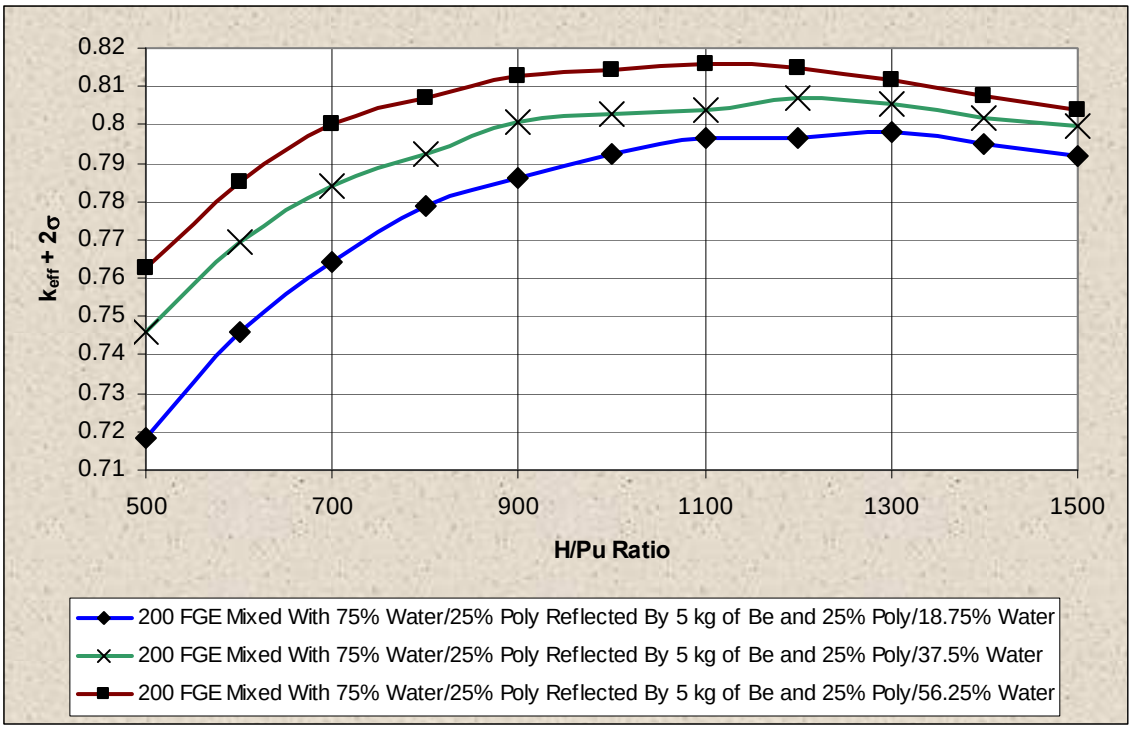


Figure 7-20, Partial Flooding Results for a 12-Drum Array of 30-Gallon Drums in the Upper Hot Cell Area

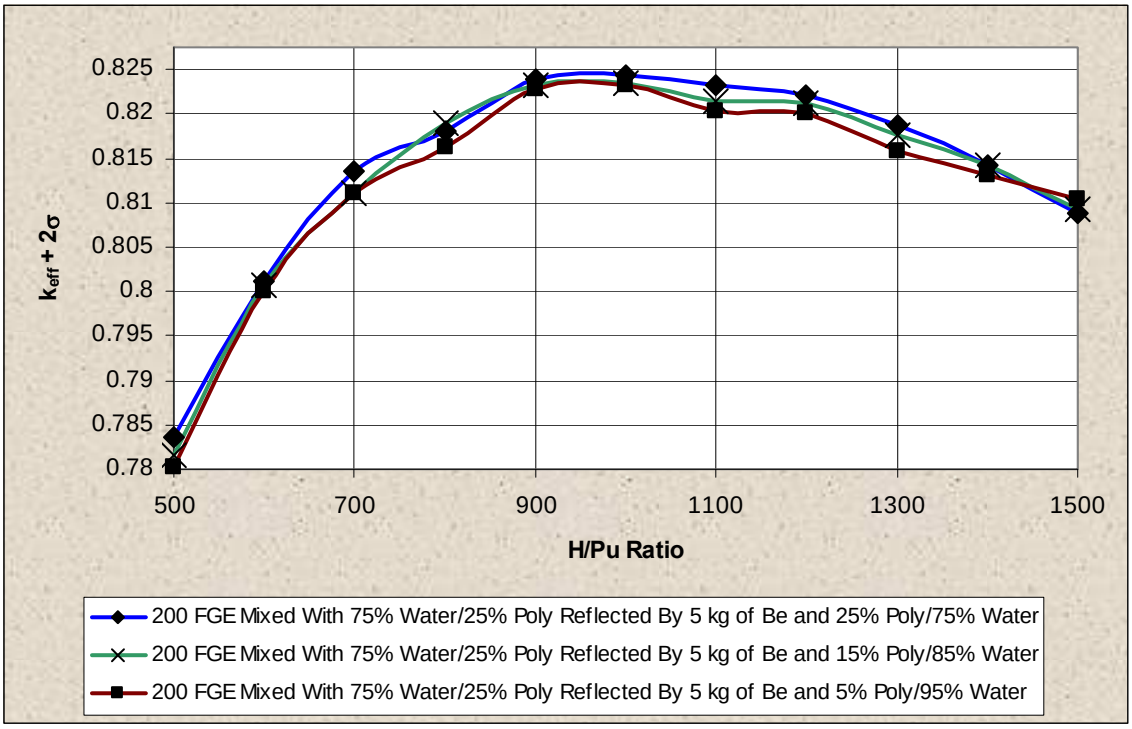


Figure 7-21, Full Flooding Results for a 12-Drum Array of 30-Gallon Drums in the Upper Hot Cell Area

7.1.3.4 Partial and Full Flooding of a Direct Loaded Canister in Disposal Room Borehole

The partial and/or full flooding of a direct loaded waste canister in the underground disposal room borehole configuration was also analyzed. Table A-139 through Table A-144 and Figure 7-22 and Figure 7-23 document the results of the parametric computation. As expected, the same trends as before are observed with the system reactivity increasing with water content. In all cases, the system eigenvalue remained below 0.93 and thus below the USL of 0.96; consequently a criticality event due to partial or full flooding condition of a direct loaded RH waste canister in the borehole arrays of the underground repository is not credible.

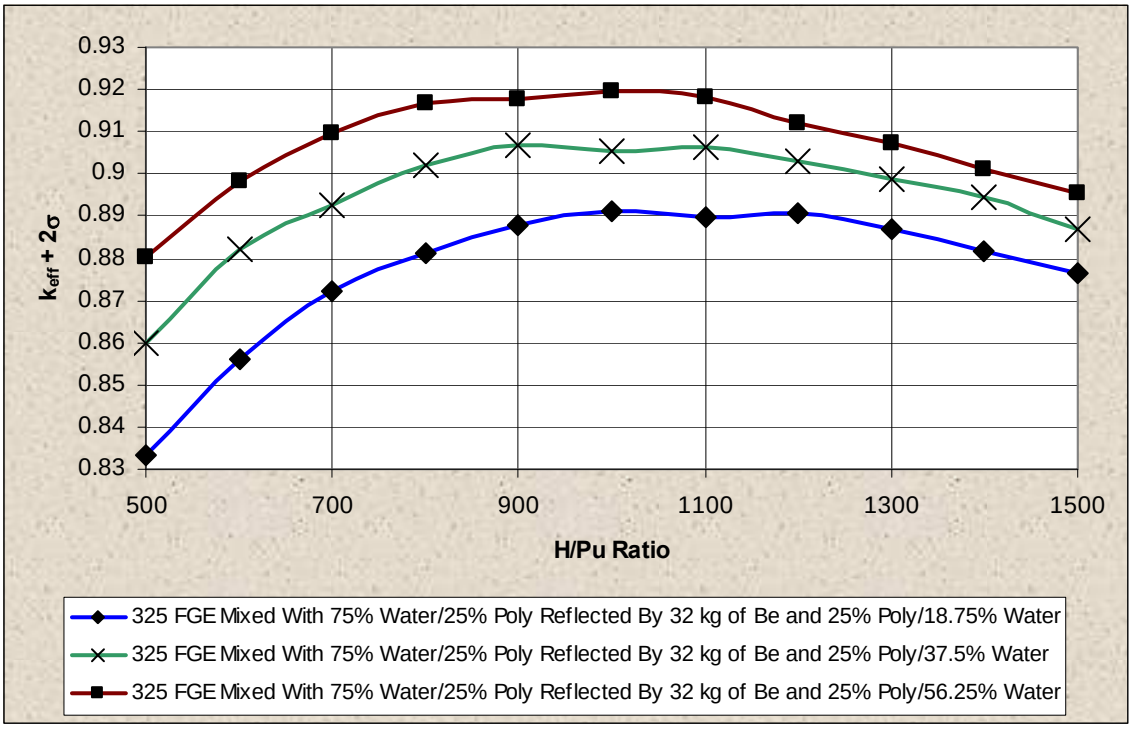


Figure 7-22, Partial Flooding Event for a Single Direct Loaded Canister Mirrored Laterally and Reflected Axially By 300 cm of Salt

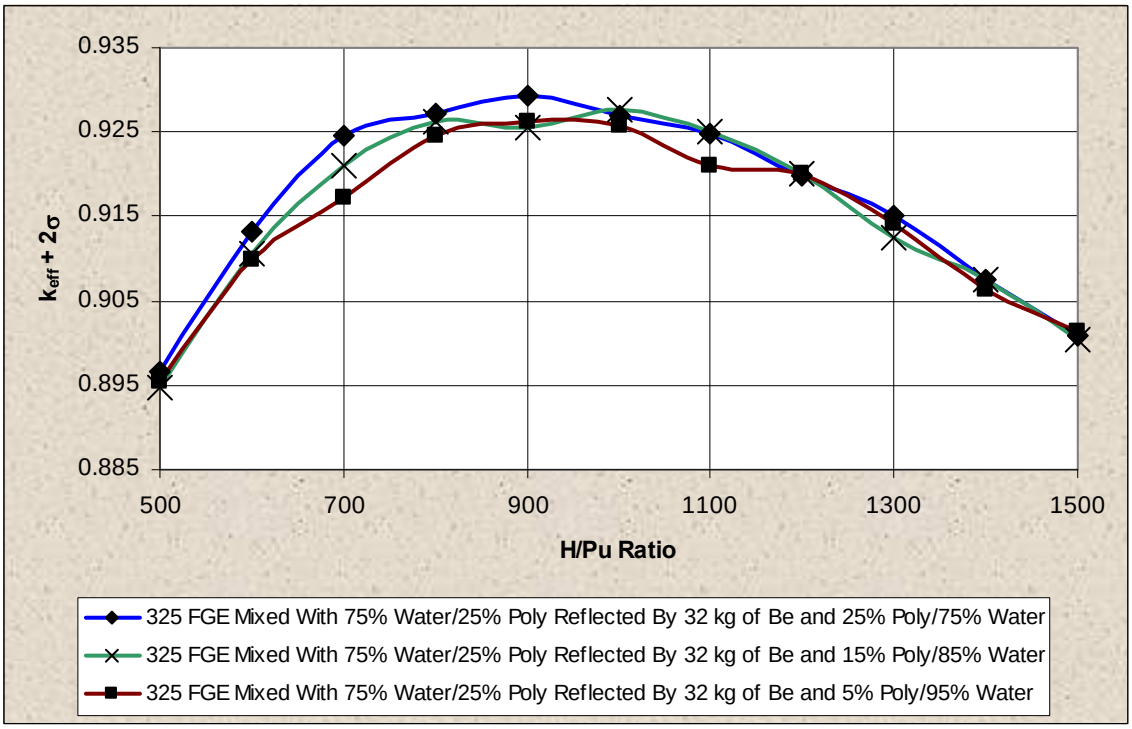


Figure 7-23, Full Flooding Event for a Single Direct Loaded Canister Mirrored Laterally and Reflected Axially By 300 cm of Salt

7.1.3.5 Partial and Full Flooding of a Canister of Containerized Waste in Disposal Room Borehole

The last water intrusion contingency analyzed in this section involves the underground disposal of canisters of containerized waste in boreholes. The results of the computational analysis follow the same behavior as that seen for the flooding contingency for other canister configurations. The results of the contingency analysis indicate that the maximum system eigenvalue was well 0.83 and thus well below the USL and that a criticality event due to partial or full flooding condition of canisters with containerized waste in the borehole arrays of the underground repository is not credible. Figure 7-24 and Figure 7-25 as well as Table A-145 through Table A-150 provide the pictorial and tabulated evidence of this conclusion.

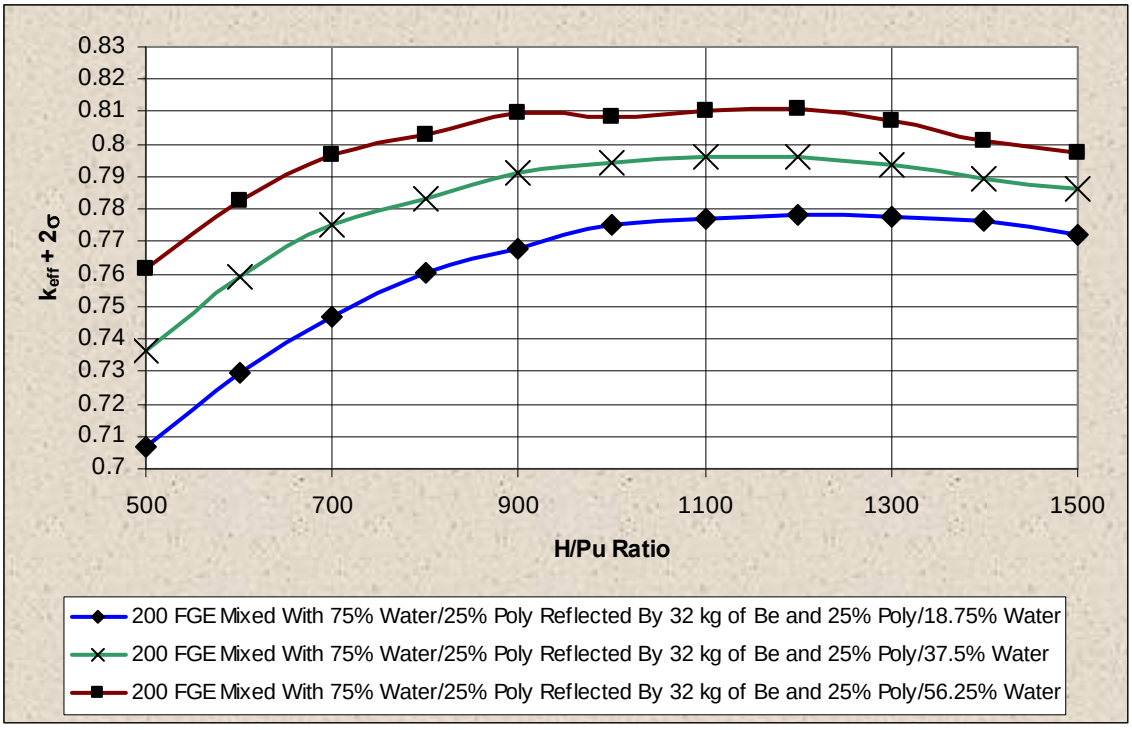


Figure 7-24, Partial Flooding Event for Three Drums in RH Waste Canisters Mirrored Laterally and Reflected Axially By 300 cm of Salt

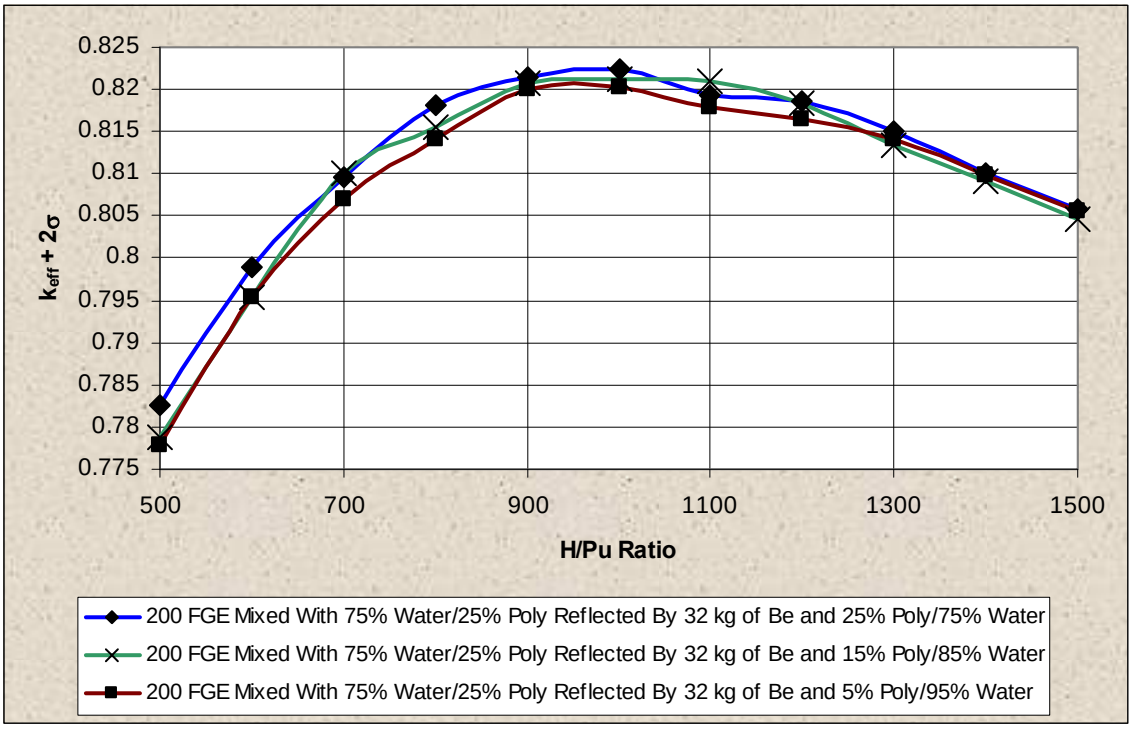


Figure 7-25, Full Flooding Event for Three Drums in RH Waste Canisters Mirrored Laterally and Reflected Axially By 300 cm of Salt

7.1.4 Loss of Enrichment Control in LEU Payload

Contingency calculations simulating a loss of enrichment control of direct loaded 72-B canisters containing LEU waste streams were also performed. Both above ground receipt, handling and interim storage operations as well as conveyance to and permanent disposal into the underground boreholes were considered. Scoping parametric studies indicated that the most reactive moderating mixture was 25% polyethylene/74% water/1% beryllium by volume at an $H/^{235}U$ ratio of 400 (see Section 5.4.1). Using these mixture parameters in the geometric models described in Section 5.1.5, the enrichment of the fissile isotope was adjusted and the highest ^{235}U enrichment that could be loaded in a canister and still be compliant to the USL was determined to be 1.1 wt%. The computational results are summarized in Figure 7-26 and Figure 7-27 as well as Table A-151 and Table A-152.

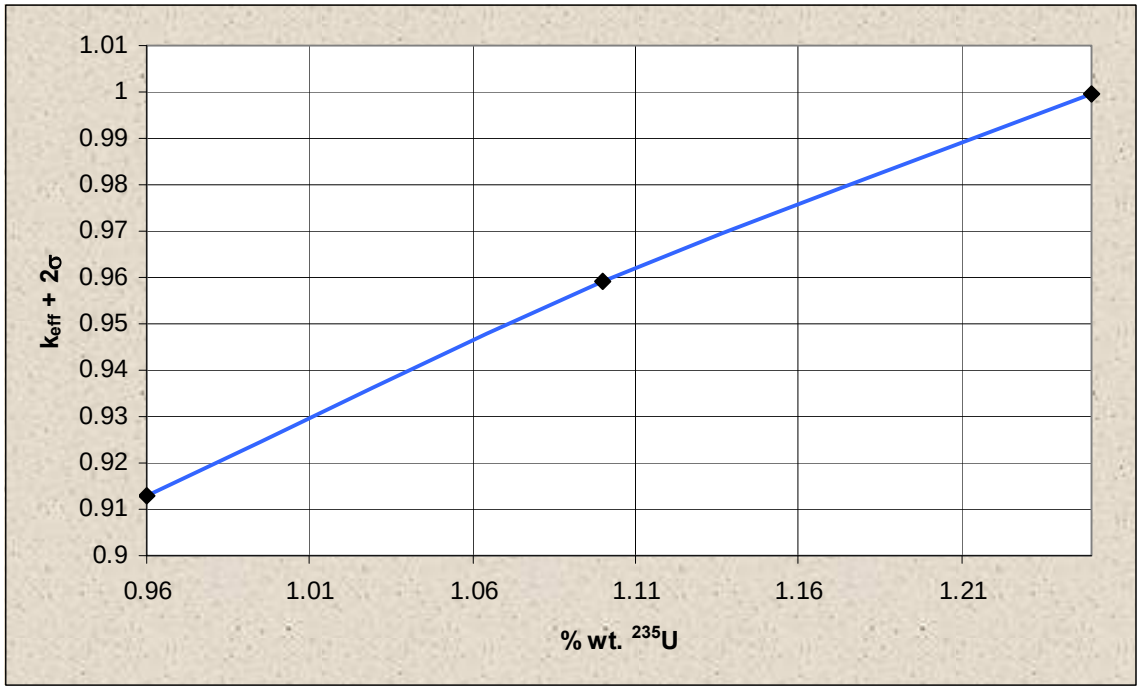


Figure 7-26, Reactivity of Single Direct Loaded Canister Containing LEU Waste Packages with Varying Uranium Enrichments

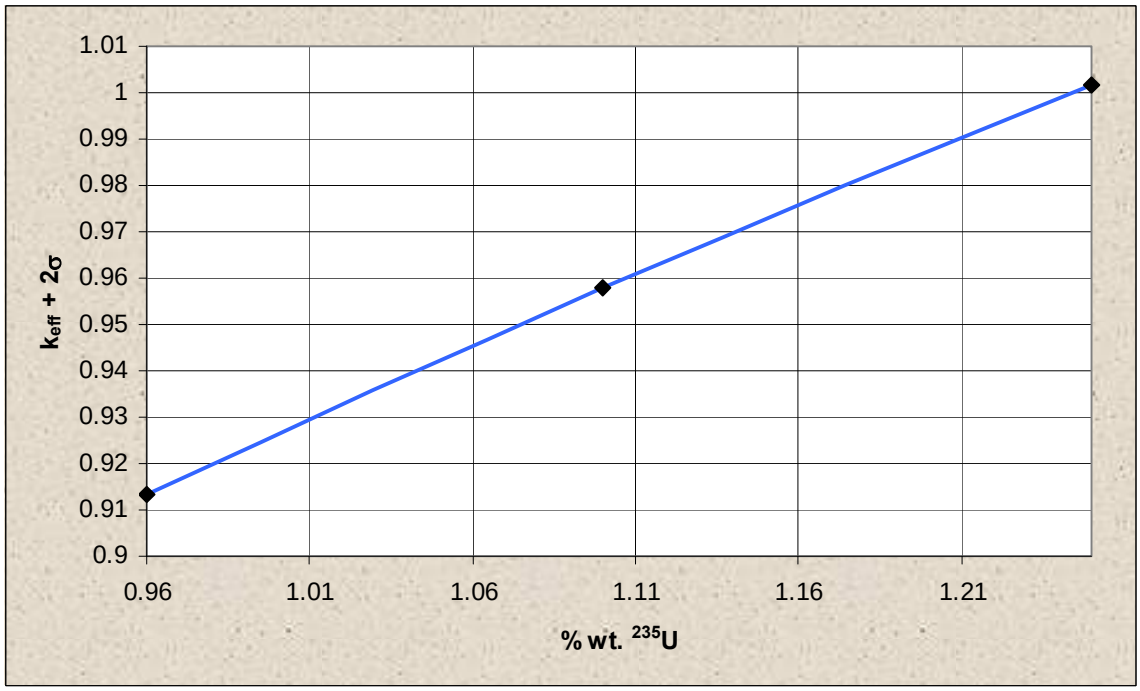


Figure 7-27, Reactivity of Borehole Array of Direct Loaded Canisters of LEU Waste with Varying Uranium Enrichments

7.1.5 Loss of Interaction Control in the Upper Hot Cell

Under normal conditions, the drums in the hot cell were modeled in a planar array of twelve drums as described in Section 5.2.2. This contingency considers a loss of multiple interaction controls in the upper hot cell by modeling 12 extra drums and considering them stacked on top of the 12 drums allowed in the hot cell. The top, bottom and sides of the 2-tier high array are reflected with 200 cm of tight-fitting concrete to simulate maximum reflection from the thick hot cell walls. Figure 7-28 summarizes the computational results of this bounding state with the details given in Table A-153 through Table A-158 in Appendix A. For all compositions considered, the system eigenvalue remains below 0.93 and thus below the USL. The results also show that removal of the polyethylene dunnage increases the interaction between the fissile masses in the drums. Additional scoping calculations showed that for the machine compacted and unlimited special reflector loadings, the reflector isolates one tier of the array from the next such that an infinite high stack of drums would remain subcritical. This is not true; however, for drums of non-compacted waste with ≤1 wt% of special reflector material and thus, the number of drums in the hot cell must be limited. Regardless, due to the conservatism in modeling multiple, concurrent upsets, it is judged that no condition exists during the canister loading operation in the upper hot cell facility such that that a group of 30-gallon or 55-gallon drums could credibly accumulate to form a critical configuration and a criticality in the upper hot cell is not credible. Note, that each drum in the hot cell containing the 200 FGE limit as modeled is highly unlikely in itself due to the fact that each 10-160B loading of 10 drums is limited to 20 Pu equivalent Ci content or 318 FGE ^{239}Pu to comply with the 10-160B Container SAR limits.

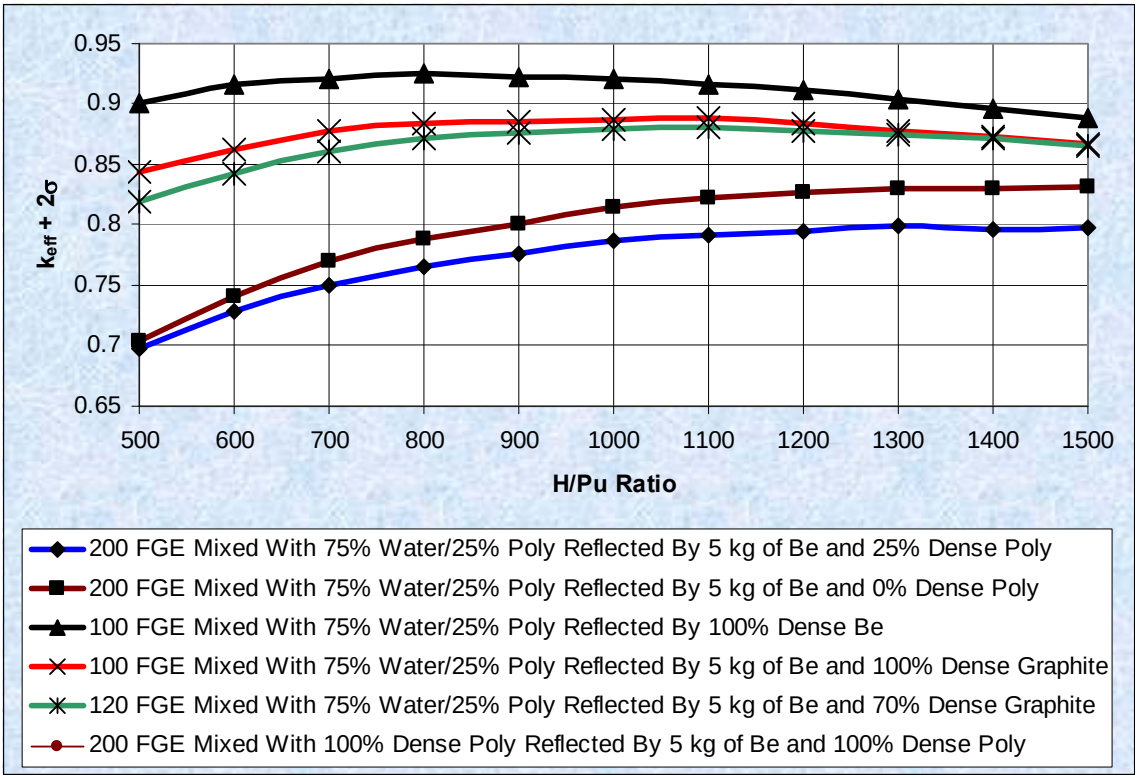


Figure 7-28, 2-Tier Stack of Twelve 30-Gallon Drums in Upper Hot Cell with Fissile Masses Centrally Located Reflected By 200 cm of Concrete

7.1.6 Loss of Interaction Control between the RH Waste Canister in the Borehole and the CH Waste Container in the Adjacent Room

This event postulates a loss of interaction control between the RH waste canisters in the borehole array and the CH waste containers in the adjacent room. Specifically, it is assumed that the shield plug is absent and the RH canisters are directly adjacent to 7-packs of 55-gallon drums of CH waste. Although very unlikely, this scenario simulates a bounding interaction case between RH and CH packages while in the disposal array configuration and also evaluates the need for the shield plug from a criticality safety standpoint. Furthermore to ensure a conservative bound on the analysis, the fissile masses in the RH waste packages are moved to the upper end of the RH canister next to the spindle. Figure 7-29 illustrates the geometric features of the model used in the calculation.

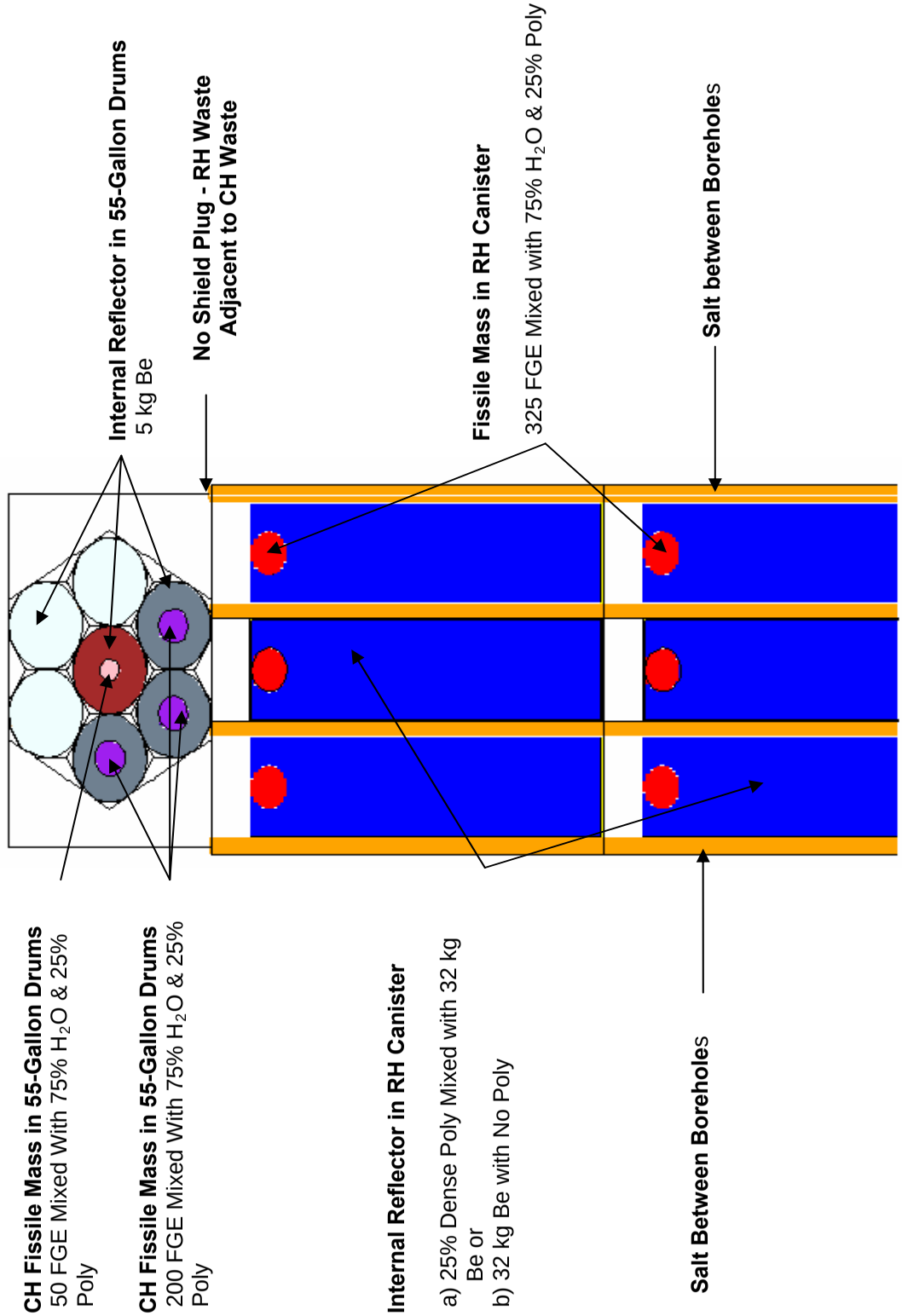


Figure 7-29, Model of Direct Loaded Canisters in Underground Disposal Borehole Array Adjacent to CH Waste without a Shield Plug

The results of the computational analysis are summarized in Figure 7-30 and Table A-159 and Table A-160 for an RH canister containing 325 FGE ^{239}Pu moderated by a 75% water and 25% polyethylene mixture and reflected internally by 32 kg of beryllium mixed with and without 25% dense polyethylene and for 245 FGE in machine compacted waste moderated and reflected with 100% dense polyethylene. All other RH waste package compositions are bounded by these cases per the results in Figure 5-36. As indicated by the graphs and tables, the system reactivity increases somewhat relative to the case when the shield plug is present (Figure 5-36) but all results are below the USL. Physically this is due primarily to: (1) the reflectivity of the shield plug; and (2) the fact that even though the waste packages are adjacent, the distance between the interacting fissile masses is large thereby resulting in significant neutron leakage from the system. As a result, no criticality safety requirements are placed on the shield plug design or use.

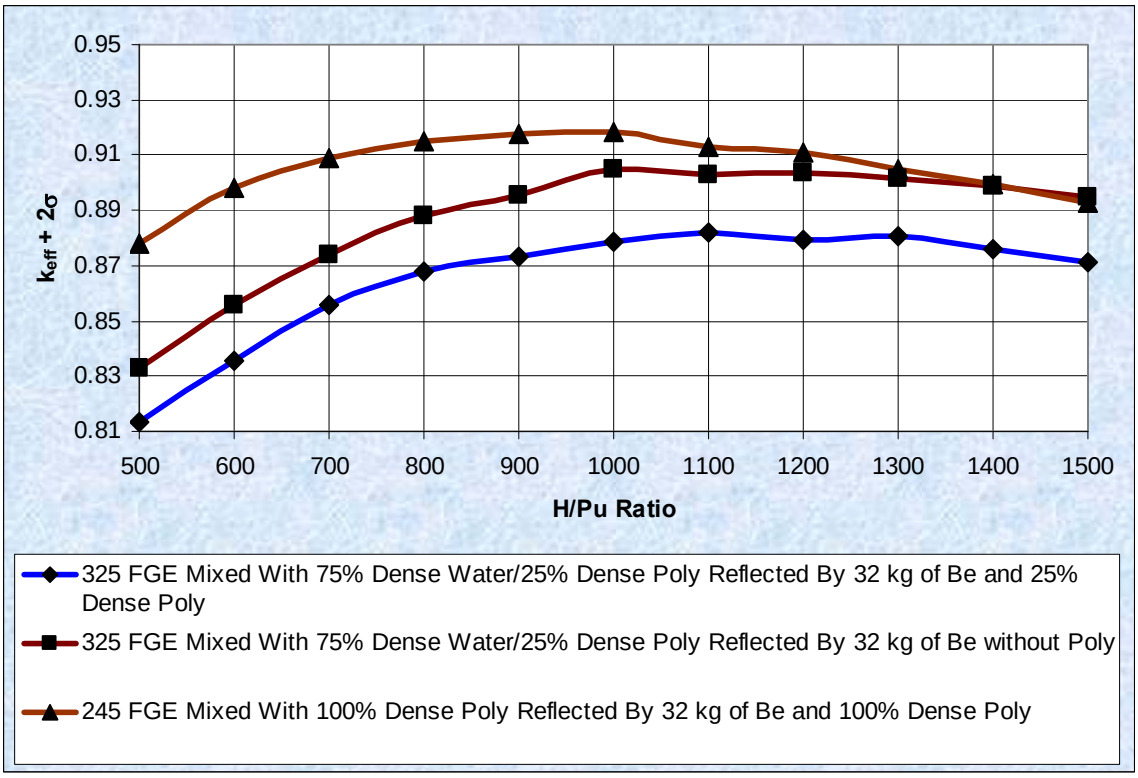


Figure 7-30, Borehole Array of RH Waste Canisters Adjacent to CH Waste Packages without Shield Plugs

7.1.7 Loss of Confinement of Fissile Material

The bounding RH event that results in a loss of confinement is the failure of the waste hoist such that the RH canister is breached when the facility cask falls down the waste shaft into the waste shaft sump. However, the failure of the waste hoist has been evaluated (DOE-CBFO 2009) to be beyond extremely unlikely due to the robust design of the waste hoist with redundant brakes and six ropes.

7.1.8 Placement of Facility Cask next to CH Waste

This event involves placement of the facility cask next to the CH waste. While this is contrary to the facility operating philosophy, it is a credible occurrence. Analysis in Section 7.1.5 shows that the resultant configuration in this event is subcritical. Additionally, a spill of fissile material from the canister inside the facility casks such that it interacts with the CH waste is not considered credible due to the robust nature of the canister, facility cask and the transportation and emplacement equipment, such as the HERE shown in Section 2.3.5. Therefore, this is not a criticality safety concern.

7.1.9 Loss of Interaction Control During Receipt, Handling and Interim Storage of RH Waste Canisters

This contingency simulates a loss of interaction control during receipt, handling and interim storage of RH waste canisters. To bound this upset condition, an infinite planar array of direct loaded RH canisters, each at the fissile loading limit, is modeled. The upper and lower vertical surfaces of the planar array are reflected by 200 cm of lead as the worst-case reflector material. The results of the computational analysis are summarized in Table A-161 through Table A-164 and Figure 7-31. As indicated in the figure, all compositions yield an eigenvalue below 0.93 which is less than the USL. Drums lined with 3 in. of lead were also evaluated in the canister; per the results in Table A-165, the lead increases the multiplication factor by 0.007 but all results remain below the USL. Thus, it is not credible for a criticality accident to occur due to a loss of interaction control during RH waste container receipt, handling and interim storage of the canisters. Also, because a planar array is subcritical with no spacing between canisters, no controls on spacing are required. Finally, since this contingency model includes a 2-meter thick lead external reflection in the vertical planes, the ensuing reactivity state will bound conveyance to and permanent disposal in the underground repository.

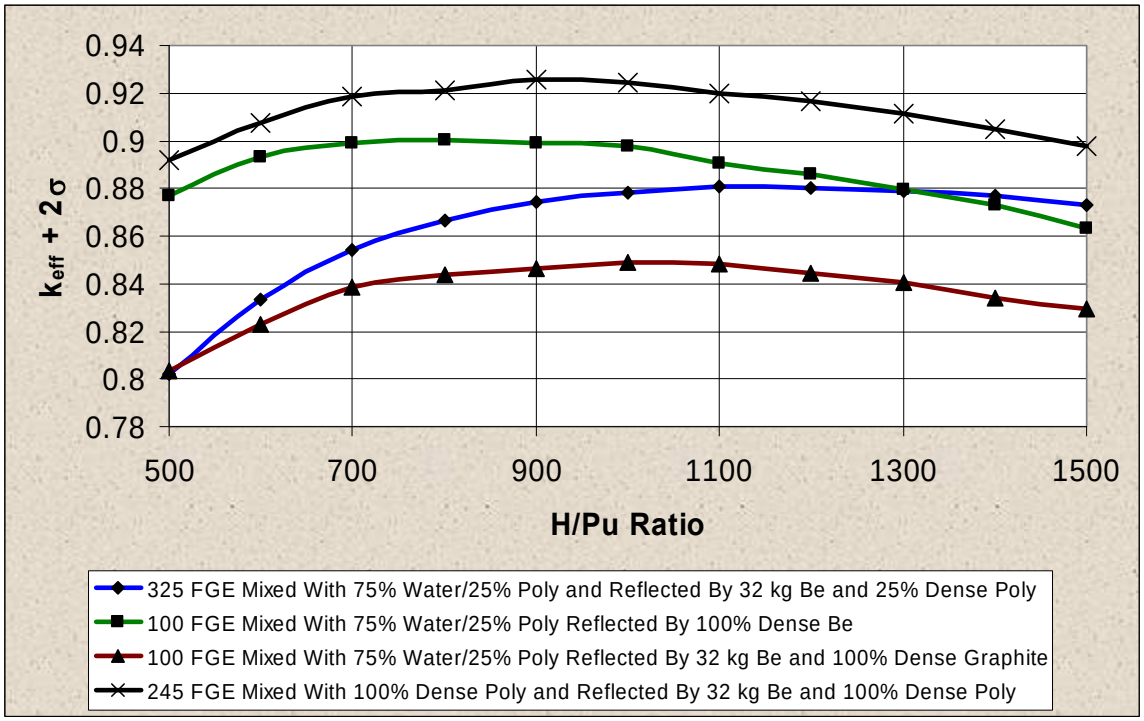


Figure 7-31, Infinite Planar Array of RH Waste Canisters Reflected Vertically By 200 cm of Lead

8.0 Beyond Design Basis Events

Flooding of the underground repository is beyond the design basis of the WIPP facility. For completeness; however, both partial and near full flooding of canisters containing RH waste packages during above ground receipt handling and transport operations as well as storage configurations in the underground repository were analyzed in Section 7.1.3. All water intrusion events evaluated were shown to not result in an increase in system reactivity above the USL and a criticality accident resulting from partial or near full flooding of an RH canister is not credible.

Section 7.1.1 evaluated credible fissile over batch scenarios. A bounding analyses was performed in Section 7.1.1 in which the fissile mass loading of all direct loaded and containerized RH canisters were over batched for both above ground receipt, handling and packaging operations as well as for permanent storage arrays in the underground repository. In most cases, the increase in fissile content exceeded the FGE mass limit by at least a factor of 1.5 (50% overbatch). Over batching by higher amounts was not considered credible, but is discussed here as a beyond design basis event. In general, the fissile material was modeled in an optimally moderated, compact configuration, which is highly conservative since the fissile material is more likely to be dispersed through the waste matrix. More specifically, the use of a spherical mass suspended in 25% dense polyethylene or less is a bounding configuration since the more dense fissile mass will tend to settle and distribute the fissile loading axially. The system multiplication factor decreases significantly as the fissile material is axially dispersed in the container as seen in the

study discussed in Section 7.1.1 in which the geometry of the fissile mass was modified to a cylindrical form and the H/D ratio was varied from one to three. In addition, in modeling the overbatch contingency state for 100% dense machine compacted waste, no credit was taken for the actual state of the waste form itself, namely that it is compressed into pucks and pucks loaded into the RH canister. If the waste form were modeled in a more realistic manner, the fissile mass would be segregated into discrete cylindrical pucks and loaded along the central axis of the canister. The more realistic geometry allows overbatch fissile contents to exceed 50% and in some cases exceed 2 to 3 times the FGE limit. Thus, further consideration of larger over batch events is not warranted.

The waste hoist failure is considered not credible based on the probabilistic analysis performed in the DSA. If the waste hoist failure occurred and the load was dropped, the contents could fall into the sump and become moderated. However, the size of the load is restricted to a single canister instead the robust facility cask with thick lead walls. For direct loaded canisters, a flooded canister with full reflection is shown to remain subcritical with the fissile mass modeled in a single compact geometry. For a canister of containerized waste, the fissile mass is modeled in three compact geometries, representing the 200 FGE allowed per drum, in the flooded, fully reflected state. The robust facility cask is expected to retain the fissile material within the drums if a waste hoist failure occurred. Regardless, the FGE limit for an entire load of drums from the 10-160B container is 318 $g^{239}Pu$, which is less than the 325 FGE analyzed in a direct loaded container. Overall, the risk of a criticality accident from a load drop from the waste hoist is low such that further analysis is not warranted.

9.0 Design Features and Administrative Limits & Requirements

A summary of the credited design features and administrative limits and requirements for criticality safety are provided in this section.

9.1 Design Features

Washington TRU Solutions maintains configuration control at the WIPP facility. Revision to significant design features requires an Unreviewed Safety Question Determination to verify that the change will remain within the authorization basis. For criticality safety, the following design features must be maintained, or receive the appropriate evaluation to ensure criticality safety.

For the purposes of this evaluation, the important feature of the design is the robustness of the facility canister and 72-B canister, including the shielded NS15 and NS30 canister models, such that they reduce fissile material releases due to loss of confinement and fire scenarios. The 72-B waste canister design is documented in the *RH-TRU 72-B Safety Analysis Report* (DOE-CBFO 2010a). The NS15 and NS30 canisters designs are documented in the *RH-TRU 72-B Payload Appendices* (DOE-CBFO 2010c). The design of the facility canister is documented on *RH-TRU RL Facility Canister Assembly* (Drawing 165-L-011-W1 [WTS 2007]).

9.2 Administrative Limits and Requirements

The controls listed below are required to be maintained to reach the conclusion that a criticality accident is not credible for WIPP RH waste container receipt, handling, and disposal operations.

1. RH waste shall be contained in a 72-B canister, as described in the RH-TRU 72-B SAR (DOE-CBFO 2010a), NS15 or NS30 canister, as described in *RH-TRU 72-B Payload Appendices* (DOE-CBFO 2010c), steel 30-gallon drums or steel 55-gallons drums. A maximum of 3 drums shall be loaded into a facility canister, as shown on Drawing 165-L-011-W1 (WTS 2007).

2. Waste is verified at the generator sites to meet the WIPP WAC which contains the limits in Table 9-1 prior to being accepted for shipment to WIPP. The boreholes shall not be placed closer than 30 in. (2.5-ft) center-to-center.

3. A maximum of 12 30-gallon and/or 55-gallon drums, loose or in canisters, shall be present in the upper hot cell. Note: Stacking of the drums is not restricted and spacing between drums or canisters is not required.

Table 9-1, Summary of Limits Imposed on RH Waste Containers

Waste Type[a]	Fissile Mass Limit[b]	Container Geometry Requirements	Non-Fissile Material Limits
72-B Canisters shall comply with the limits in one of the following rows: [c]			
Non-compacted	≤ 325 FGE per canister	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	≤ 350 FGE per canister with a minimum of 15 g ^{240}Pu	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	≤ 370 FGE per canister with a minimum of 25 g ^{240}Pu	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	≤ 100 FGE per canister	None	Unlimited Special Reflector Mass
Non-compacted	≤ 120 FGE per canister	None	Unlimited Graphite with Beryllium Mass ≤ 1 wt%
Non-compacted	≤ 305 FGE per canister	None	Unlimited Special Reflector Mass[d] provided it is mechanically or chemically bound to the fissile material
Machine Compacted	≤ 245 FGE per canister	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	Unlimited Uranium provided enrichment is ≤ 0.96 wt% FEM	None	Unlimited Special Reflector Mass[d]

Table 9-1, Summary of Limits Imposed on RH Waste Containers (continued)

Waste Type[a]	Fissile Mass Limit[b]	Container Geometry Requirements	Non-Fissile Material Limits
Individual 30- or 55-gallon drums shall comply with the limits in one of the following rows: A maximum of 3 drums meeting the following limits shall be loaded into a Facility Canister.			
Non-compacted	≤ 200 FGE per drum	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	≤ 100 FGE per drum	None	Unlimited Special Reflector Mass[d]
Non-compacted	≤ 120FGE per drum	None	Unlimited Graphite with Beryllium Mass ≤ 1 wt%
Machine Compacted (Compaction Density not limited)	≤ 200 FGE per drum	1.0-in design spacing between drum content and exterior top and bottom must be maintained	Special Reflector Mass[d] ≤ 1 wt%
Machine Compacted (Compaction Density not limited)	≤ 170 FGE per drum	None	Special Reflector Mass[d] ≤ 1 wt%
NS30 and NS15 Canisters shall comply with the limits in one of the following rows:			
Non-compacted	≤ 245 FGE per canister	None	Special Reflector Mass[d] ≤ 1 wt%
Non-compacted	≤ 245 FGE per canister	None	Unlimited Special Reflector Mass[d] provided it is mechanically or chemically bound to the fissile material
Machine Compacted	≤ 245 FGE per canister	None	Special Reflector Mass[d] ≤ 1 wt%

(a) The limit for polyethylene density for non-compacted waste is < 20% of the theoretical value and > 20% for machine compacted waste.

(b) Includes 2x measurement error.

(c) These limits are equivalent to or higher than those given in the RH-TRU 72-B SAR (DOE-CBFO 2010a). Waste may be direct loaded in the canister, or in drums, including lead-lined drums, provided these limits are met for the canister payload.

(d) Applies to beryllium and graphite.

10.0 Summary and Conclusions

This NCSE provides a nuclear criticality safety basis for the receipt, process handling, conveyance, and permanent disposal of the various RH waste compositions and packaging configurations that are possible at the WIPP facility. Specifically, the computational analysis encompassed a myriad of bounding geometric configurations for the fissile mass and associated reflector matrix combinations within the RH waste containers (30- or 55-gallon drums) and/or canisters in both the upper hot cell processing area of the WHB and the borehole complex in the underground repository disposal rooms and disposal panel access drifts. The RH waste package compositions evaluated included: (1) non-compacted waste containing ≤ 1 wt% special reflector

materials; (2) non-compacted waste containing large quantities of graphite with ≤ 1 wt% special reflector materials; (3) non-compacted waste containing unlimited quantities of special reflector materials; (4) machine compacted waste streams containing ≤ 1 wt% special reflector materials; and (5) non-compacted low enriched uranium with a maximum enrichment of 0.96 wt%. The analysis considered the various external reflection states that could be encountered at WIPP during receipt, canister loading operations in the upper hot cell area of the WHB complex, transport to the underground in a facility cask and emplacement in the salt borehole. The evaluation also considers the possible interactions of RH TRU waste with arrays of CH-TRU waste.

The double contingency analysis for credible upset scenarios considered overbatching events, spacing upsets, and abnormal fissile mass geometric configurations. The computational analysis results concluded that a criticality accident, due to activities involving receipt, handling, conveyance, emplacement, and permanent disposal of RH waste received in RH-TRU 72-B in either unshielded RH-72B or shielded NS15 or NS30 canisters or 10-160B shipping containers, is not credible provided the assumptions, design features, and limits and requirements of Section 8.0 are met. Furthermore, the following conservatisms exist in the models used to demonstrate this point:

- The fissile material inside the containers was conservatively modeled as optimally moderated spheres or as cylinders with an H/D ratio of unity when modeling two-drum configurations. In reality, the fissile material inside the containers is irregularly or randomly distributed as an integral part of the waste matrix. Because of the nature of the waste matrix, irregular/random distribution of fissile material within the waste matrix, and lack of any means inside the containers to accumulate the fissile material in one region and optimally moderate the fissile material, formation of a fissile material into a spherical configuration that is optimally moderated and reflected is judged unlikely. Calculations performed in *Nuclear Criticality Safety Evaluation for Remote Handled Waste at the waste Isolation Pilot Plant* (Eghbali and Harris 2006) demonstrate that when the fissile material is uniformly distributed throughout the containers, as opposed to an optimally moderated and reflected sphere, the system reactivity is reduced drastically.
- All containers/canisters in the models were loaded with the maximum amount of fissile material to determine the maximum reactivity state, when in reality most containers/ canisters will contain much less fissile material, due to the nature of waste operations.
- The calculations for non-compacted waste modeled the non-fissile waste in the RH waste canisters as 25% dense polyethylene when not considering special reflector material in excess of 1% of the allowable container weight. This is denser than typical waste packaging can accomplish without mechanical compacting.
- Calculations for non-compacted RH waste packages containing special reflector material >1% of the allowable container weight modeled the material at 70% or 100% of theoretical density. The maximum credible packing fraction of 70% to address potential

overbatch contingencies, and to increase the allowable FGE for the 10-160B drums that presently have no specified limit as to beryllium and/or graphite limit.

- All machine compacted waste forms were modeled at 100% of theoretical density, thereby bounding the reactivity state of these RH waste packages.
- Even though water ingress into the underground is not a credible event, all waste packages were shown to be subcritical with water ingress of varying density.

Because a criticality accident has been shown to be not credible due to the implementation of the design features and administrative limits and requirements, the requirements of ANS/ANSI-8.3 related to Nuclear Criticality Alarm System are not required for the operations involving receipt, handling, conveyance, emplacement, and permanent disposal of RH waste containers at the WIPP.

11.0 References

ANSI/ANS-8.1-1998. *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, Reaffirmed 2007, American National Standards Institute, Inc., Washington, D.C.

ANSI/ANS-8.12-1987. *Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors*, Reaffirmed 2002, American National Standards Institute, Inc., Washington, D.C.

ANSI/ANS-8.15-1981. *Nuclear Criticality Control of Special Actinide Elements*, Reaffirmed 2005, American National Standards Institute, Inc., Washington, D.C.

CRC, 1991-1992. *Handbook of Chemistry and Physics*, 72nd Edition, 1991-1992, CRC Press, Boca Raton, FL.

DOE, 2005. *Facility Safety*, DOE O 420.1B, Chapter III, "Nuclear Criticality Safety," December 22, 2005, U.S. Department of Energy, Washington, DC.

DOE, 2007. *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*, DOE-STD-3007-2007, February 2007, U.S. Department of Energy, Washington, DC.

DOE-CBFO, 2009. *Waste Isolation Pilot Plant Documented Safety Analysis*, DOE/WIPP-07-3372, Revision 1, February 2009, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, NM.

DOE-CBFO, 2010a. *Safety Analysis Report for the RH-TRU 72-B Waste Shipping Package*, Revision 5, February 2010, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, NM.

DOE-CBFO, 2010b. *Remote Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC)*, Revision 1, February 2010, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, NM.

DOE-CBFO. 2010c. *RH-TRU Payload Appendices*, Revision 1, February 2010, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, NM.

Eghbali, D.A. and R.D. Harris, 2006. *Nuclear Criticality Safety Evaluation for Remote Handled Waste at the Waste Isolation Pilot Plant*, WSMS-WIPP-00-0003, Revision 2, March 2006, Washington Safety Management Solutions, LLC, Aikin, SC.

Elliot J.A., A. Kelly, and A.H. Windle, 2002. "Recursive packing of dense particle mixtures," J. Mat. Sci. Lett. **21**:1249-1251; 2002.

GE, 1989. *Nuclides and Isotopes*, Chart of the Nuclides, 14th Edition, GE Nuclear, San Jose, CA.

Hayes, R., 2004. *MCNP5 Bias Validation for the WIPP*, CS-2004-002, Washington TRU Solutions LLC, Carlsbad, NM.

LANL, 2005. *MCNP — A General Monte Carlo N-Particle Transport Code*, Version 5, LA-UR-03-1987, October 3, 2005, Los Alamos National Laboratory, Los Alamos, NM.

Larson, S.L., 2004. *Verification of MCNP5 on SAIC Computers*, December 1, 2004, Memo to File, Science Applications International Corporation, Oak Ridge, TN.

Neeley, G.W., 2007. *Two Container and Array Model Calculations for Non-Compacted Waste Containing < 1wt% Beryllium*, SAIC-1171-002, Revision 2, October 15, 2007, Science Applications International Corporation, Oak Ridge, TN.

Neeley, G.W., D.L. Newell, S.L Larson, and R.J. Green, 2004. *Reactivity Effects of Moderator and Reflector Materials on a Finite Plutonium System*, SAIC-1322-001, Revision 1, May 2004, Science Applications International Corporation, Oak Ridge, TN.

Newell, D.L. and S.L. Larson, 2007. *MCNP5 Bias Validation For Lead And Low Enriched Uranium At The Waste Isolation Pilot Plant*, SAIC-WIPP-VAL-001, October 2007, Science Applications International Corporation, Oak Ridge, TN.

Petrie, L.M., P.B. Fox, and K, Lucius, 2000. *Standard Composition Library*, ORNL/NUREG/CSD-2/V3/R6, Volume 3, Section M8, March 2000, Oak Ridge National Laboratory, Oak Ridge, TN.

Rhoden, W.G., 2003. *Determination of Calculational Bias for Criticality Calculations at the WIPP using MCNP*, CS-2002-002, Revision 0, July 2003, Washington TRU Solutions LLC, Carlsbad, NM.

Taggert, D.P. and J.U. Moon, 2004. *Review of Special Reflectors in the TRU Waste Inventory*, LA-UR-04-0857, February 2004, Los Alamos National Laboratory, Los Alamos, NM.

Torquato, S., T.M. Truskett, and P.G. Debenedetti, 2007. "Is random packing of spheres well defined?" Phys. Rev. Lett. **84**:2064-2067; 2000.

WTS, 2007. *RH-TRU RL Facility Canister Assembly*, 165-L-011-W1, Revision D, June 2007, Washington TRU Solutions LLC, Carlsbad, NM.

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Appendix A

Tabulated MCNP5 Results

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Introduction

This attachment tabulates the results of the MCNP5 models discussed and referenced in Sections 5.4, 5.5, and 7.1.1 through 7.1.9 of this NCSE.

Single Direct Loaded Canister Results from Section 5.4.1

Table A-1, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.79151	0.00103	0.79357	1DCL010
600	Lead	0.82122	0.00101	0.82324	1DCL012
700	Lead	0.84057	0.00107	0.84271	1DCL014
800	Lead	0.85401	0.00099	0.85599	1DCL016
900	Lead	0.86277	0.00101	0.86479	1DCL018
1000	Lead	0.86597	0.00095	0.86787	1DCL020
1100	Lead	0.87010	0.00098	0.87206	1DCL022
1200	Lead	0.86774	0.00092	0.86958	1DCL024
1300	Lead	0.86599	0.00095	0.86789	1DCL026
1400	Lead	0.86323	0.00081	0.86485	1DCL028
1500	Lead	0.85910	0.00089	0.86088	1DCL030
500	Concrete	0.79292	0.00114	0.79520	1DCC010
600	Concrete	0.81623	0.00103	0.81829	1DCC012
700	Concrete	0.83615	0.00096	0.83807	1DCC014
800	Concrete	0.84913	0.00104	0.85121	1DCC016
900	Concrete	0.85601	0.00101	0.85803	1DCC018
1000	Concrete	0.86372	0.00100	0.86572	1DCC020
1100	Concrete	0.86524	0.00096	0.86716	1DCC022
1200	Concrete	0.86465	0.00095	0.86655	1DCC024
1300	Concrete	0.86287	0.00089	0.86465	1DCC026
1400	Concrete	0.85911	0.00101	0.86113	1DCC028
1500	Concrete	0.85460	0.00086	0.85632	1DCC030

Table A-2, Results for a Single Direct Loaded Canister with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.86765	0.00103	0.86971	1DCL050
600	Lead	0.88251	0.00100	0.88451	1DCL052
700	Lead	0.88764	0.00090	0.88944	1DCL054
800	Lead	0.88979	0.00090	0.89159	1DCL056
900	Lead	0.89052	0.00089	0.89230	1DCL058
1000	Lead	0.88425	0.00096	0.88617	1DCL060
1100	Lead	0.88085	0.00080	0.88245	1DCL062
1200	Lead	0.87559	0.00084	0.87727	1DCL064
1300	Lead	0.86802	0.00081	0.86964	1DCL066
1400	Lead	0.86187	0.00082	0.86351	1DCL068
1500	Lead	0.85422	0.00081	0.85584	1DCL070
500	Concrete	0.86662	0.00098	0.86858	1DCC050
600	Concrete	0.87987	0.00106	0.88199	1DCC052
700	Concrete	0.88791	0.00093	0.88977	1DCC054
800	Concrete	0.88999	0.00094	0.89187	1DCC056
900	Concrete	0.88814	0.00084	0.88982	1DCC058
1000	Concrete	0.88570	0.00094	0.88758	1DCC060
1100	Concrete	0.88027	0.00084	0.88195	1DCC062
1200	Concrete	0.87461	0.00093	0.87647	1DCC064
1300	Concrete	0.86763	0.00084	0.86931	1DCC066
1400	Concrete	0.85993	0.00080	0.86153	1DCC068
1500	Concrete	0.85129	0.00083	0.85295	1DCC070

Table A-3, Results for a Single Direct Loaded Canister with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78206	0.00097	0.78400	1DCL130
600	Lead	0.80263	0.00102	0.80467	1DCL132
700	Lead	0.81576	0.00093	0.81762	1DCL134
800	Lead	0.82335	0.00097	0.82529	1DCL136
900	Lead	0.82731	0.00092	0.82915	1DCL138
1000	Lead	0.82772	0.00091	0.82954	1DCL140
1100	Lead	0.82408	0.00093	0.82594	1DCL142
1200	Lead	0.82290	0.00079	0.82448	1DCL144
1300	Lead	0.81940	0.00082	0.82104	1DCL146
1400	Lead	0.81469	0.00082	0.81633	1DCL148
1500	Lead	0.81074	0.00079	0.81232	1DCL150
500	Concrete	0.77865	0.00104	0.78073	1DCC130
600	Concrete	0.79981	0.00104	0.80189	1DCC132
700	Concrete	0.81211	0.00099	0.81409	1DCC134
800	Concrete	0.81866	0.00098	0.82062	1DCC136
900	Concrete	0.81970	0.00088	0.82146	1DCC138
1000	Concrete	0.82320	0.00088	0.82496	1DCC140
1100	Concrete	0.82090	0.00082	0.82254	1DCC142
1200	Concrete	0.81935	0.00087	0.82109	1DCC144
1300	Concrete	0.81479	0.00088	0.81655	1DCC146
1400	Concrete	0.81029	0.00081	0.81191	1DCC148
1500	Concrete	0.80457	0.00084	0.80625	1DCC150

Table A-4, Results for a Single Direct Loaded Canister with 245 g ^{239}Pu Moderated by100% Dense Polyethylene and Reflected with 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.88808	0.00100	0.89008	1DCL210
600	Lead	0.90632	0.00100	0.90832	1DCL212
700	Lead	0.91737	0.00092	0.91921	1DCL214
800	Lead	0.92159	0.00094	0.92347	1DCL216
900	Lead	0.92118	0.00087	0.92292	1DCL218
1000	Lead	0.92159	0.00086	0.92331	1DCL220
1100	Lead	0.91968	0.0009	0.92148	1DCL222
1200	Lead	0.91407	0.00093	0.91593	1DCL224
1300	Lead	0.91018	0.00089	0.91196	1DCL226
1400	Lead	0.90339	0.0008	0.90499	1DCL228
1500	Lead	0.89592	0.00081	0.89754	1DCL230
500	Concrete	0.89083	0.00101	0.89285	1DCC210
600	Concrete	0.90750	0.00103	0.90956	1DCC212
700	Concrete	0.91613	0.00096	0.91805	1DCC214
800	Concrete	0.92148	0.00102	0.92352	1DCC216
900	Concrete	0.92299	0.00092	0.92483	1DCC218
1000	Concrete	0.92230	0.00093	0.92416	1DCC220
1100	Concrete	0.91970	0.00088	0.92146	1DCC222
1200	Concrete	0.91511	0.00082	0.91675	1DCC224
1300	Concrete	0.90907	0.00089	0.91085	1DCC226
1400	Concrete	0.90384	0.00086	0.90556	1DCC228
1500	Concrete	0.89633	0.00087	0.89807	1DCC230

Single Direct Loaded Canister Results with ^{240}Pu from Section 5.4.1

Table A-5, Results for a Single Direct Loaded Canister with 15 g ^{240}Pu/ 350 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.79427	0.00105	0.79637	1DCL650
600	Lead	0.82329	0.00098	0.82525	1DCL652
700	Lead	0.84226	0.00098	0.84422	1DCL654
800	Lead	0.85308	0.00095	0.85498	1DCL656
900	Lead	0.86167	0.00100	0.86367	1DCL658
1000	Lead	0.86641	0.00097	0.86835	1DCL660
1100	Lead	0.86819	0.00086	0.86991	1DCL662
1200	Lead	0.86745	0.00096	0.86937	1DCL664
1300	Lead	0.86471	0.00087	0.86645	1DCL666
1400	Lead	0.86268	0.00087	0.86442	1DCL668
1500	Lead	0.85790	0.00086	0.85962	1DCL670

Table A-6, Results for a Single Direct Loaded Canister with 25 g ^{240}Pu/ 370 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.80159	0.00106	0.80371	1DCL690
600	Lead	0.82818	0.00110	0.83038	1DCL692
700	Lead	0.84702	0.00100	0.84902	1DCL694
800	Lead	0.85761	0.00099	0.85959	1DCL696
900	Lead	0.86779	0.00103	0.86985	1DCL698
1000	Lead	0.87037	0.00104	0.87245	1DCL700
1100	Lead	0.87198	0.00094	0.87386	1DCL702
1200	Lead	0.87148	0.00091	0.87330	1DCL704
1300	Lead	0.86886	0.00089	0.87064	1DCL706
1400	Lead	0.86411	0.00084	0.86579	1DCL708
1500	Lead	0.85829	0.00084	0.85997	1DCL710

Table A-7, Results for a Single Direct Loaded Canister with 15 g ^{240}Pu/ 350 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.74232	0.00109	0.74450	1DCL770
600	Lead	0.77691	0.00111	0.77913	1DCL772
700	Lead	0.79927	0.00093	0.80113	1DCL774
800	Lead	0.81667	0.00105	0.81877	1DCL776
900	Lead	0.83066	0.00103	0.83272	1DCL778
1000	Lead	0.83699	0.00095	0.83889	1DCL780
1100	Lead	0.84099	0.00089	0.84277	1DCL782
1200	Lead	0.84249	0.00097	0.84443	1DCL784
1300	Lead	0.84197	0.00089	0.84375	1DCL786
1400	Lead	0.84154	0.00093	0.84340	1DCL788
1500	Lead	0.83960	0.00088	0.84136	1DCL790

Table A-8, Results for a Single Direct Loaded Canister with 25 g ^{240}Pu/ 370 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.75097	0.00108	0.75313	1DCL810
600	Lead	0.78347	0.00102	0.78551	1DCL812
700	Lead	0.80745	0.00099	0.80943	1DCL814
800	Lead	0.82452	0.00104	0.82660	1DCL816
900	Lead	0.83503	0.00095	0.83693	1DCL818
1000	Lead	0.84409	0.00096	0.84601	1DCL820
1100	Lead	0.84645	0.00089	0.84823	1DCL822
1200	Lead	0.84822	0.00091	0.85004	1DCL824
1300	Lead	0.84609	0.00088	0.84785	1DCL826
1400	Lead	0.84874	0.00094	0.85062	1DCL828
1500	Lead	0.84332	0.00089	0.84510	1DCL830

Single Direct Loaded Canister Results with Bound Special Reflector Materials from Section 5.4.1

Table A-9, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.79455	0.00119	0.79693	1DCL310
600	Lead	0.82112	0.00109	0.82330	1DCL312
700	Lead	0.84155	0.00109	0.84373	1DCL314
800	Lead	0.85478	0.00096	0.85670	1DCL316
900	Lead	0.86424	0.00102	0.86628	1DCL318
1000	Lead	0.86838	0.00104	0.87046	1DCL320
1100	Lead	0.87119	0.00096	0.87311	1DCL322
1200	Lead	0.87069	0.00093	0.87255	1DCL324
1300	Lead	0.86906	0.00092	0.87090	1DCL326
1400	Lead	0.86677	0.00089	0.86855	1DCL328
1500	Lead	0.86280	0.00092	0.86464	1DCL330

Table A-10, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 10% Polyethylene/ 30% Water/ 60% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78520	0.00104	0.78728	1DCL350
600	Lead	0.81269	0.00104	0.81477	1DCL352
700	Lead	0.83102	0.00108	0.83318	1DCL354
800	Lead	0.84270	0.00110	0.84490	1DCL356
900	Lead	0.85074	0.00104	0.85282	1DCL358
1000	Lead	0.85441	0.00098	0.85637	1DCL360
1100	Lead	0.85631	0.00096	0.85823	1DCL362
1200	Lead	0.85209	0.00092	0.85393	1DCL364
1300	Lead	0.85416	0.00086	0.85588	1DCL366
1400	Lead	0.85035	0.00088	0.85211	1DCL368
1500	Lead	0.84520	0.00090	0.84700	1DCL370

Table A-11, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 20% Polyethylene/ 60% Water/ 20% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78440	0.00100	0.78640	1DCL390
600	Lead	0.81423	0.00119	0.81661	1DCL392
700	Lead	0.83292	0.00102	0.83496	1DCL394
800	Lead	0.84896	0.00106	0.85108	1DCL396
900	Lead	0.85417	0.00099	0.85615	1DCL398
1000	Lead	0.86167	0.00096	0.86359	1DCL400
1100	Lead	0.86311	0.00093	0.86497	1DCL402
1200	Lead	0.86519	0.00096	0.86711	1DCL404
1300	Lead	0.86165	0.00093	0.86351	1DCL406
1400	Lead	0.85972	0.00088	0.86148	1DCL408
1500	Lead	0.85618	0.00083	0.85784	1DCL410

Table A-12, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.79455	0.00119	0.79693	1DCL310
600	Lead	0.82112	0.00109	0.82330	1DCL312
700	Lead	0.84155	0.00109	0.84373	1DCL314
800	Lead	0.85478	0.00096	0.85670	1DCL316
900	Lead	0.86424	0.00102	0.86628	1DCL318
1000	Lead	0.86838	0.00104	0.87046	1DCL320
1100	Lead	0.87119	0.00096	0.87311	1DCL322
1200	Lead	0.87069	0.00093	0.87255	1DCL324
1300	Lead	0.86906	0.00092	0.87090	1DCL326
1400	Lead	0.86677	0.00089	0.86855	1DCL328
1500	Lead	0.86280	0.00092	0.86464	1DCL330

Table A-13, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.72787	0.00104	0.72995	1DCL430
600	Lead	0.76276	0.00110	0.76496	1DCL432
700	Lead	0.79022	0.00100	0.79222	1DCL434
800	Lead	0.80728	0.00113	0.80954	1DCL436
900	Lead	0.82092	0.00099	0.82290	1DCL438
1000	Lead	0.83041	0.00098	0.83237	1DCL440
1100	Lead	0.83540	0.00097	0.83734	1DCL442
1200	Lead	0.83905	0.00089	0.84083	1DCL444
1300	Lead	0.83684	0.00099	0.83882	1DCL446
1400	Lead	0.83841	0.00086	0.84013	1DCL448
1500	Lead	0.83383	0.00084	0.83551	1DCL450

Table A-14, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.79026	0.00106	0.79238	1DCC310
600	Concrete	0.81862	0.00104	0.82070	1DCC312
700	Concrete	0.83712	0.00100	0.83912	1DCC314
800	Concrete	0.85074	0.00102	0.85278	1DCC316
900	Concrete	0.85802	0.00102	0.86006	1DCC318
1000	Concrete	0.86414	0.00111	0.86636	1DCC320
1100	Concrete	0.86676	0.00103	0.86882	1DCC322
1200	Concrete	0.86600	0.00095	0.86790	1DCC324
1300	Concrete	0.86507	0.00094	0.86695	1DCC326
1400	Concrete	0.86082	0.00088	0.86258	1DCC328
1500	Concrete	0.85551	0.00094	0.85739	1DCC330

Table A-15, Results for a Single Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.68856	0.0012	0.69096	1DCC350
600	Concrete	0.72235	0.00100	0.72435	1DCC352
700	Concrete	0.74817	0.00113	0.75043	1DCC354
800	Concrete	0.76763	0.00097	0.76957	1DCC356
900	Concrete	0.78086	0.00103	0.78292	1DCC358
1000	Concrete	0.79021	0.00106	0.79233	1DCC360
1100	Concrete	0.79658	0.00102	0.79862	1DCC362
1200	Concrete	0.80077	0.00094	0.80265	1DCC364
1300	Concrete	0.80239	0.00090	0.80419	1DCC366
1400	Concrete	0.80197	0.00091	0.80379	1DCC368
1500	Concrete	0.80066	0.00091	0.80248	1DCC370

LEU Single Direct Loaded Canister Results from Section 5.4.1

Table A-16, Results for a Single Direct Loaded Canister with LEU at 0.96% ^{235}U Moderated by a 25% Polyethylene/ 74% Water/ 1% Be Mixture at Various H/^{235}U Ratio and Reflected by 100% Dense Be

H/^{235}U	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
300	Lead	0.89990	0.00069	0.90128	1DUL300
400	Lead	0.91146	0.00065	0.91276	1DUL400
500	Lead	0.91063	0.00067	0.91197	1DUL500
600	Lead	0.90477	0.00064	0.90605	1DUL600
700	Lead	0.89275	0.00062	0.89399	1DUL700

Results for Conventional Configurations of Canisters of 30-gallon Drums from Section 5.4.2

Table A-17, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene + 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.65928	0.00109	0.66146	3DBL010
600	Lead	0.68810	0.00101	0.69012	3DBL012
700	Lead	0.70990	0.00094	0.71178	3DBL014
800	Lead	0.72602	0.00095	0.72792	3DBL016
900	Lead	0.73712	0.00100	0.73912	3DBL018
1000	Lead	0.74408	0.00103	0.74614	3DBL020
1100	Lead	0.74848	0.00097	0.75042	3DBL022
1200	Lead	0.75232	0.00092	0.75416	3DBL024
1300	Lead	0.75310	0.00090	0.75490	3DBL026
1400	Lead	0.75256	0.00087	0.75430	3DBL028
1500	Lead	0.75203	0.00087	0.75377	3DBL030
500	Concrete	0.65622	0.00107	0.65836	3DBC010
600	Concrete	0.68431	0.00097	0.68625	3DBC012
700	Concrete	0.70725	0.00102	0.70929	3DBC014
800	Concrete	0.72276	0.00096	0.72468	3DBC016
900	Concrete	0.73350	0.00097	0.73544	3DBC018
1000	Concrete	0.74021	0.00093	0.74207	3DBC020
1100	Concrete	0.74633	0.00096	0.74825	3DBC022
1200	Concrete	0.74688	0.00095	0.74878	3DBC024
1300	Concrete	0.74912	0.00092	0.75096	3DBC026
1400	Concrete	0.75029	0.00095	0.75219	3DBC028
1500	Concrete	0.74719	0.00096	0.74911	3DBC030

Table A-18, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.86928	0.00103	0.87134	3DBL050
600	Lead	0.88276	0.00099	0.88474	3DBL052
700	Lead	0.89130	0.00088	0.89306	3DBL054
800	Lead	0.89084	0.00095	0.89274	3DBL056
900	Lead	0.89262	0.00088	0.89438	3DBL058
1000	Lead	0.88936	0.00089	0.89114	3DBL060
1100	Lead	0.88345	0.00084	0.88513	3DBL062
1200	Lead	0.87758	0.00089	0.87936	3DBL064
1300	Lead	0.87015	0.00083	0.87181	3DBL066
1400	Lead	0.86370	0.00086	0.86542	3DBL068
1500	Lead	0.85527	0.00077	0.85681	3DBL070
500	Concrete	0.86798	0.00101	0.87000	3DBC050
600	Concrete	0.88222	0.00092	0.88406	3DBC052
700	Concrete	0.88823	0.00095	0.89013	3DBC054
800	Concrete	0.89242	0.00086	0.89414	3DBC056
900	Concrete	0.89119	0.00080	0.89279	3DBC058
1000	Concrete	0.88673	0.00091	0.88855	3DBC060
1100	Concrete	0.88382	0.00083	0.88548	3DBC062
1200	Concrete	0.87754	0.00087	0.87928	3DBC064
1300	Concrete	0.86867	0.00088	0.87043	3DBC066
1400	Concrete	0.86250	0.00088	0.86426	3DBC068
1500	Concrete	0.85365	0.00079	0.85523	3DBC070

Table A-19, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated By a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78763	0.00100	0.78963	3DBL130
600	Lead	0.80843	0.00098	0.81039	3DBL132
700	Lead	0.81931	0.00096	0.82123	3DBL134
800	Lead	0.82831	0.00095	0.83021	3DBL136
900	Lead	0.83013	0.00098	0.83209	3DBL138
1000	Lead	0.83203	0.00096	0.83395	3DBL140
1100	Lead	0.83132	0.00086	0.83304	3DBL142
1200	Lead	0.82959	0.00082	0.83123	3DBL144
1300	Lead	0.82415	0.00075	0.82565	3DBL146
1400	Lead	0.81906	0.00079	0.82064	3DBL148
1500	Lead	0.81270	0.00081	0.81432	3DBL150
500	Concrete	0.78305	0.00100	0.78505	3DBC130
600	Concrete	0.80365	0.00099	0.80563	3DBC132
700	Concrete	0.81565	0.00093	0.81751	3DBC134
800	Concrete	0.82220	0.00089	0.82398	3DBC136
900	Concrete	0.82718	0.00098	0.82914	3DBC138
1000	Concrete	0.82717	0.00088	0.82893	3DBC140
1100	Concrete	0.82701	0.00084	0.82869	3DBC142
1200	Concrete	0.82197	0.00088	0.82373	3DBC144
1300	Concrete	0.81816	0.00078	0.81972	3DBC146
1400	Concrete	0.81321	0.00080	0.81481	3DBC148
1500	Concrete	0.80725	0.00085	0.80895	3DBC150

Table A-20, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.84193	0.00111	0.84415	3DBL210
600	Lead	0.85789	0.00099	0.85987	3DBL212
700	Lead	0.87067	0.00107	0.87281	3DBL214
800	Lead	0.87584	0.00093	0.87770	3DBL216
900	Lead	0.87619	0.00098	0.87815	3DBL218
1000	Lead	0.87776	0.00100	0.87976	3DBL220
1100	Lead	0.87573	0.00088	0.87749	3DBL222
1200	Lead	0.87169	0.00089	0.87347	3DBL224
1300	Lead	0.86745	0.00091	0.86927	3DBL226
1400	Lead	0.86284	0.00084	0.86452	3DBL228
1500	Lead	0.85600	0.00088	0.85776	3DBL230
500	Concrete	0.84239	0.00103	0.84445	3DBC210
600	Concrete	0.85813	0.00100	0.86013	3DBC212
700	Concrete	0.86771	0.00092	0.86955	3DBC214
800	Concrete	0.87519	0.00108	0.87735	3DBC216
900	Concrete	0.87719	0.00097	0.87913	3DBC218
1000	Concrete	0.87681	0.00096	0.87873	3DBC220
1100	Concrete	0.87511	0.00086	0.87683	3DBC222
1200	Concrete	0.87168	0.00089	0.87346	3DBC224
1300	Concrete	0.86791	0.00091	0.86973	3DBC226
1400	Concrete	0.86258	0.00081	0.86420	3DBC228
1500	Concrete	0.85421	0.00080	0.85581	3DBC230

Results for Canisters of 30-gallon Drums in the Two-Drum Configuration (Conservative Model) from Section 5.4.3

Table A-21, Results for a Canister of 3 30-Gallon Drums in a Central Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated By a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.82769	0.00110	0.82989	3DCL010
600	Lead	0.85549	0.00110	0.85769	3DCL012
700	Lead	0.87414	0.00106	0.87626	3DCL014
800	Lead	0.88355	0.00102	0.88559	3DCL016
900	Lead	0.89204	0.00103	0.89410	3DCL018
1000	Lead	0.89489	0.00091	0.89671	3DCL020
1100	Lead	0.89544	0.00101	0.89746	3DCL022
1200	Lead	0.89590	0.00087	0.89764	3DCL024
1300	Lead	0.89267	0.00090	0.89447	3DCL026
1400	Lead	0.88841	0.00091	0.89023	3DCL028
1500	Lead	0.88272	0.00088	0.88448	3DCL030
500	Concrete	0.82294	0.00105	0.82504	3DCC010
600	Concrete	0.84802	0.00112	0.85026	3DCC012
700	Concrete	0.86891	0.00104	0.87099	3DCC014
800	Concrete	0.87606	0.00102	0.87810	3DCC016
900	Concrete	0.88628	0.00098	0.88824	3DCC018
1000	Concrete	0.88937	0.00096	0.89129	3DCC020
1100	Concrete	0.89168	0.00099	0.89366	3DCC022
1200	Concrete	0.88799	0.00094	0.88987	3DCC024
1300	Concrete	0.88786	0.00096	0.88978	3DCC026
1400	Concrete	0.88334	0.00095	0.88524	3DCC028
1500	Concrete	0.87887	0.00098	0.88083	3DCC030

Table A-22, Results for a Canister of 3 30-gallon Drums each in a Central Two-Drum Configuration Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.92124	0.00106	0.92336	3DCL090
600	Lead	0.93859	0.00103	0.94065	3DCL092
700	Lead	0.94570	0.00102	0.94774	3DCL094
800	Lead	0.94850	0.00099	0.95048	3DCL096
900	Lead	0.94738	0.00094	0.94926	3DCL098
1000	Lead	0.94439	0.00093	0.94625	3DCL100
1100	Lead	0.94192	0.00094	0.94380	3DCL102
1200	Lead	0.93266	0.00089	0.93444	3DCL104
1300	Lead	0.92636	0.00085	0.92806	3DCL106
1400	Lead	0.91842	0.00084	0.92010	3DCL108
1500	Lead	0.91042	0.00079	0.9120	3DCL110
500	Concrete	0.91819	0.00108	0.92035	3DCC090
600	Concrete	0.93302	0.00100	0.93502	3DCC092
700	Concrete	0.94132	0.00098	0.94328	3DCC094
800	Concrete	0.94392	0.00094	0.94580	3DCC096
900	Concrete	0.94430	0.00090	0.94610	3DCC098
1000	Concrete	0.93960	0.00093	0.94146	3DCC100
1100	Concrete	0.93474	0.00088	0.93650	3DCC102
1200	Concrete	0.92841	0.00090	0.93021	3DCC104
1300	Concrete	0.92085	0.00084	0.92253	3DCC106
1400	Concrete	0.91266	0.00079	0.91424	3DCC108
1500	Concrete	0.90375	0.00078	0.90531	3DCC110

Table A-23, Results for a Canister of 3 30-gallon Drums in a Central Two-Drum Configuration Each Containing 120 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.91018	0.00105	0.91228	3DCL170
600	Lead	0.92648	0.00100	0.92848	3DCL172
700	Lead	0.93995	0.00109	0.94213	3DCL174
800	Lead	0.94554	0.00096	0.94746	3DCL176
900	Lead	0.94793	0.00100	0.94993	3DCL178
1000	Lead	0.94626	0.00090	0.94806	3DCL180
1100	Lead	0.94420	0.00090	0.94600	3DCL182
1200	Lead	0.93713	0.00084	0.93881	3DCL184
1300	Lead	0.93275	0.00083	0.93441	3DCL186
1400	Lead	0.92479	0.00094	0.92667	3DCL188
1500	Lead	0.91560	0.00078	0.91716	3DCL190
500	Concrete	0.89540	0.00105	0.89750	3DCC170
600	Concrete	0.91478	0.00099	0.91676	3DCC172
700	Concrete	0.92572	0.00096	0.92764	3DCC174
800	Concrete	0.93075	0.00107	0.93289	3DCC176
900	Concrete	0.93409	0.00098	0.93605	3DCC178
1000	Concrete	0.93233	0.00093	0.93419	3DCC180
1100	Concrete	0.92829	0.00094	0.93017	3DCC182
1200	Concrete	0.92334	0.00080	0.92494	3DCC184
1300	Concrete	0.91704	0.00084	0.91872	3DCC186
1400	Concrete	0.91230	0.00083	0.91396	3DCC188
1500	Concrete	0.90353	0.00082	0.90517	3DCC190

Table A-24, Results for a Canister of 3 30-Gallon Drums in a Edge Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.86317	0.00119	0.86555	3DEL010
600	Lead	0.88784	0.00111	0.89006	3DEL012
700	Lead	0.90235	0.00108	0.90451	3DEL014
800	Lead	0.91493	0.00095	0.91683	3DEL016
900	Lead	0.91832	0.00103	0.92038	3DEL018
1000	Lead	0.92136	0.00099	0.92334	3DEL020
1100	Lead	0.92175	0.00094	0.92363	3DEL022
1200	Lead	0.91877	0.00089	0.92055	3DEL024
1300	Lead	0.91438	0.00091	0.91620	3DEL026
1400	Lead	0.90940	0.00088	0.91116	3DEL028
1500	Lead	0.90338	0.00086	0.9051	3DEL030
500	Concrete	0.84243	0.00103	0.84449	3DEC010
600	Concrete	0.86572	0.00112	0.86796	3DEC012
700	Concrete	0.88375	0.00111	0.88597	3DEC014
800	Concrete	0.89377	0.00115	0.89607	3DEC016
900	Concrete	0.89959	0.00100	0.90159	3DEC018
1000	Concrete	0.90213	0.00094	0.90401	3DEC020
1100	Concrete	0.90247	0.00089	0.90425	3DEC022
1200	Concrete	0.90059	0.00091	0.90241	3DEC024
1300	Concrete	0.89642	0.00093	0.89828	3DEC026
1400	Concrete	0.89444	0.00084	0.89612	3DEC028
1500	Concrete	0.88668	0.00086	0.88840	3DEC030

Table A-25, Results for a Canister of 3 30-gallon Drums each in an Edge Two-Drum Configuration Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.88743	0.00113	0.88969	3DEL090
600	Lead	0.90586	0.00104	0.90794	3DEL092
700	Lead	0.91783	0.00102	0.91987	3DEL094
800	Lead	0.92218	0.00103	0.92424	3DEL096
900	Lead	0.92165	0.00097	0.92359	3DEL098
1000	Lead	0.92209	0.00089	0.92387	3DEL100
1100	Lead	0.91797	0.00084	0.91965	3DEL102
1200	Lead	0.91230	0.00086	0.91402	3DEL104
1300	Lead	0.90666	0.00085	0.90836	3DEL106
1400	Lead	0.89904	0.00084	0.90072	3DEL108
1500	Lead	0.8922	0.00078	0.89376	3DEL110
500	Concrete	0.85403	0.00103	0.85609	3DEC090
600	Concrete	0.87264	0.00100	0.87464	3DEC092
700	Concrete	0.88444	0.00103	0.88650	3DEC094
800	Concrete	0.89211	0.00106	0.89423	3DEC096
900	Concrete	0.89457	0.00084	0.89625	3DEC098
1000	Concrete	0.89526	0.00089	0.89704	3DEC100
1100	Concrete	0.89000	0.00095	0.89190	3DEC102
1200	Concrete	0.88799	0.00087	0.88973	3DEC104
1300	Concrete	0.88330	0.00087	0.88504	3DEC106
1400	Concrete	0.87408	0.00084	0.87576	3DEC108
1500	Concrete	0.87007	0.00089	0.87185	3DEC110

Table A-26, Results for a Canister of 3 30-gallon Drums each in an Edge Two-Drum Configuration Each Containing 120 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89382	0.00096	0.89574	3DEL170
600	Lead	0.91238	0.00103	0.91444	3DEL172
700	Lead	0.92380	0.00091	0.92562	3DEL174
800	Lead	0.92977	0.00091	0.93159	3DEL176
900	Lead	0.93188	0.00092	0.93372	3DEL178
1000	Lead	0.93125	0.00083	0.93291	3DEL180
1100	Lead	0.92981	0.00091	0.93163	3DEL182
1200	Lead	0.92554	0.00089	0.92732	3DEL184
1300	Lead	0.92005	0.00081	0.92167	3DEL186
1400	Lead	0.91140	0.00085	0.91310	3DEL188
1500	Lead	0.90379	0.00084	0.90547	3DEL190
500	Concrete	0.85139	0.00098	0.85335	3DEC170
600	Concrete	0.87367	0.00110	0.87587	3DEC172
700	Concrete	0.88724	0.00103	0.88930	3DEC174
800	Concrete	0.89521	0.00094	0.89709	3DEC176
900	Concrete	0.89860	0.00098	0.90056	3DEC178
1000	Concrete	0.90144	0.00097	0.90338	3DEC180
1100	Concrete	0.89728	0.00091	0.89910	3DEC182
1200	Concrete	0.89395	0.00091	0.89577	3DEC184
1300	Concrete	0.88972	0.00083	0.89138	3DEC186
1400	Concrete	0.88338	0.00088	0.88514	3DEC188
1500	Concrete	0.87643	0.00083	0.87809	3DEC190

Results for Canisters of 30 and 55-gallon Drums in the Two-Drum Configuration (Explicit Model) from Section 5.4.2

Table A-27, Results for a Canister of 3 30 and 55-gallon Drums in a Central Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated By 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
30-gallon Drums					
500	Lead	0.93089	0.00105	0.93299	3DCLR10
600	Lead	0.94638	0.00106	0.9485	3DCLR12
700	Lead	0.95193	0.00095	0.95383	3DCLR14
800	Lead	0.95337	0.00098	0.95533	3DCLR16
900	Lead	0.95458	0.00097	0.95652	3DCLR18
1000	Lead	0.94873	0.00093	0.95059	3DCLR20
1100	Lead	0.94693	0.00086	0.94865	3DCLR22
1200	Lead	0.93828	0.00091	0.94010	3DCLR24
1300	Lead	0.93150	0.00084	0.93318	3DCLR26
1400	Lead	0.92250	0.00091	0.92432	3DCLR28
1500	Lead	0.91568	0.00082	0.91732	3DCLR30
55-gallon Drums					
500	Lead	0.93163	0.00106	0.93375	3DCLR50
600	Lead	0.94479	0.00094	0.94667	3DCLR52
700	Lead	0.95155	0.00108	0.95371	3DCLR54
800	Lead	0.95377	0.00100	0.95577	3DCLR56
900	Lead	0.95124	0.00087	0.95298	3DCLR58
1000	Lead	0.94798	0.00092	0.94982	3DCLR60
1100	Lead	0.94528	0.00090	0.94708	3DCLR62
1200	Lead	0.93785	0.00087	0.93959	3DCLR64
1300	Lead	0.92998	0.00086	0.93170	3DCLR66
1400	Lead	0.92124	0.00080	0.92284	3DCLR68
1500	Lead	0.91248	0.00076	0.91400	3DCLR70

Table A-28, Results for a Canister of 3 30 and 55-gallon Drums in a Central Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated By 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
30-gallon Drums					
500	Concrete	0.93301	0.00092	0.93485	3DCCR10
600	Concrete	0.94569	0.00096	0.94761	3DCCR12
700	Concrete	0.95108	0.00103	0.95314	3DCCR14
800	Concrete	0.95630	0.00091	0.95812	3DCCR16
900	Concrete	0.95270	0.00091	0.95452	3DCCR18
1000	Concrete	0.95010	0.00090	0.95190	3DCCR20
1100	Concrete	0.94432	0.00093	0.94618	3DCCR22
1200	Concrete	0.93800	0.00097	0.93994	3DCCR24
1300	Concrete	0.93109	0.00079	0.93267	3DCCR26
1400	Concrete	0.92379	0.00084	0.92547	3DCCR28
1500	Concrete	0.91525	0.00083	0.91691	3DCCR30
55-gallon Drums					
500	Concrete	0.92981	0.00104	0.93189	3DCCR50
600	Concrete	0.94241	0.00094	0.94429	3DCCR52
700	Concrete	0.95156	0.00098	0.95352	3DCCR54
800	Concrete	0.95486	0.00093	0.95672	3DCCR56
900	Concrete	0.95130	0.00087	0.95304	3DCCR58
1000	Concrete	0.94826	0.00100	0.95026	3DCCR60
1100	Concrete	0.94398	0.00085	0.94568	3DCCR62
1200	Concrete	0.93664	0.00086	0.93836	3DCCR64
1300	Concrete	0.92942	0.00086	0.93114	3DCCR66
1400	Concrete	0.92239	0.00089	0.92417	3DCCR68
1500	Concrete	0.91115	0.00084	0.91283	3DCCR70

Table A-29, Results for a Canister of 3 30 and 55-gallon Drums in an Edge Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated By 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
30-gallon Drums					
500	Lead	0.91356	0.00116	0.91588	3DELR10
600	Lead	0.92727	0.00110	0.92947	3DELR12
700	Lead	0.93709	0.00106	0.93921	3DELR14
800	Lead	0.94227	0.00093	0.94413	3DELR16
900	Lead	0.94103	0.00094	0.94291	3DELR18
1000	Lead	0.94204	0.00090	0.94384	3DELR20
1100	Lead	0.93439	0.00099	0.93637	3DELR22
1200	Lead	0.93217	0.00086	0.93389	3DELR24
1300	Lead	0.92386	0.00089	0.92564	3DELR26
1400	Lead	0.91738	0.00089	0.91916	3DELR28
1500	Lead	0.90802	0.00085	0.90972	3DELR30
55-gallon Drums					
500	Lead	0.92472	0.00101	0.92674	3DELR50
600	Lead	0.93901	0.00101	0.94103	3DELR52
700	Lead	0.94735	0.00102	0.94939	3DELR54
800	Lead	0.95055	0.00095	0.95245	3DELR56
900	Lead	0.95207	0.00097	0.95401	3DELR58
1000	Lead	0.94620	0.00095	0.94810	3DELR60
1100	Lead	0.94484	0.00084	0.94652	3DELR62
1200	Lead	0.93737	0.00089	0.93915	3DELR64
1300	Lead	0.92959	0.00087	0.93133	3DELR66
1400	Lead	0.92330	0.00087	0.92504	3DELR68
1500	Lead	0.91574	0.00077	0.91728	3DELR70

Table A-30, Results for a Canister of 3 30 and 55-gallon Drums in an Edge Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated By 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
30-gallon Drums					
500	Concrete	0.90903	0.00111	0.91125	3DECR10
600	Concrete	0.92258	0.00100	0.92458	3DECR12
700	Concrete	0.93219	0.00100	0.93419	3DECR14
800	Concrete	0.93508	0.00100	0.93708	3DECR16
900	Concrete	0.93590	0.00104	0.93798	3DECR18
1000	Concrete	0.93541	0.00093	0.93727	3DECR20
1100	Concrete	0.92991	0.00091	0.93173	3DECR22
1200	Concrete	0.92402	0.00085	0.92572	3DECR24
1300	Concrete	0.91921	0.00089	0.92099	3DECR26
1400	Concrete	0.91131	0.00087	0.91305	3DECR28
1500	Concrete	0.90412	0.00083	0.90578	3DECR30
55-gallon Drums					
500	Concrete	0.91607	0.00106	0.91819	3DECR50
600	Concrete	0.93095	0.00102	0.93299	3DECR52
700	Concrete	0.94093	0.00106	0.94305	3DECR54
800	Concrete	0.94480	0.00097	0.94674	3DECR56
900	Concrete	0.94271	0.00092	0.94455	3DECR58
1000	Concrete	0.94064	0.00088	0.94240	3DECR60
1100	Concrete	0.93791	0.00094	0.93979	3DECR62
1200	Concrete	0.93145	0.00088	0.93321	3DECR64
1300	Concrete	0.92617	0.00087	0.92791	3DECR66
1400	Concrete	0.91718	0.00088	0.91894	3DECR68
1500	Concrete	0.90960	0.00089	0.91138	3DECR70

Table A-31, Results for a Canister of 3 30 and 55-gallon Drums in a Central Two-Drum Configuration with no Design Spacing Each Containing 170 g ^{239}Pu Moderated By 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
30-gallon Drums					
500	Concrete	0.93712	0.00097	0.93906	3DCCR90
600	Concrete	0.95020	0.00107	0.95234	3DCCR92
700	Concrete	0.95475	0.00095	0.95665	3DCCR94
800	Concrete	0.95783	0.00111	0.96005	3DCCR96
900	Concrete	0.95808	0.00100	0.96008	3DCCR98
1000	Concrete	0.95312	0.00102	0.95516	3DCR100
1100	Concrete	0.94938	0.00087	0.95112	3DCR102
1200	Concrete	0.94173	0.00095	0.94363	3DCR104
1300	Concrete	0.93437	0.00082	0.93601	3DCR106
1400	Concrete	0.92661	0.00089	0.92839	3DCR108
1500	Concrete	0.91644	0.00084	0.91812	3DCR110
55-gallon Drums					
500	Concrete	0.93529	0.00111	0.93751	3DCR130
600	Concrete	0.94773	0.00101	0.94975	3DCR132
700	Concrete	0.95460	0.00106	0.95672	3DCR134
800	Concrete	0.95764	0.00105	0.95974	3DCR136
900	Concrete	0.95772	0.00098	0.95968	3DCR138
1000	Concrete	0.95183	0.00090	0.95363	3DCR140
1100	Concrete	0.94670	0.00099	0.94868	3DCR142
1200	Concrete	0.94109	0.00094	0.94297	3DCR144
1300	Concrete	0.93244	0.00089	0.93422	3DCR146
1400	Concrete	0.92484	0.00084	0.92652	3DCR148
1500	Concrete	0.91472	0.00082	0.91636	3DCR150

Results of Conventional Configurations of the Hot Cell Drum Model in Section 5.4.3

Table A-32, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.69278	0.00104	0.69486	12DC010
600	Concrete	0.72136	0.00096	0.72328	12DC012
700	Concrete	0.74638	0.00089	0.74816	12DC014
800	Concrete	0.76105	0.00091	0.76287	12DC016
900	Concrete	0.77199	0.00091	0.77381	12DC018
1000	Concrete	0.77885	0.00096	0.78077	12DC020
1100	Concrete	0.78503	0.00090	0.78683	12DC022
1200	Concrete	0.78916	0.00086	0.79088	12DC024
1300	Concrete	0.78860	0.00094	0.79048	12DC026
1400	Concrete	0.79108	0.00086	0.79280	12DC028
1500	Concrete	0.78799	0.00083	0.78965	12DC030

Table A-33, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.89265	0.00101	0.89467	12DC050
600	Concrete	0.90839	0.00100	0.91039	12DC052
700	Concrete	0.91637	0.00095	0.91827	12DC054
800	Concrete	0.91715	0.00095	0.91905	12DC056
900	Concrete	0.91619	0.00090	0.91799	12DC058
1000	Concrete	0.91479	0.00092	0.91663	12DC060
1100	Concrete	0.91028	0.00089	0.91206	12DC062
1200	Concrete	0.90386	0.00079	0.90544	12DC064
1300	Concrete	0.89556	0.00086	0.89728	12DC066
1400	Concrete	0.88812	0.00076	0.88964	12DC068
1500	Concrete	0.88184	0.00080	0.88344	12DC070

Table A-34, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.82621	0.00106	0.82833	12DC130
600	Concrete	0.84956	0.00099	0.85154	12DC132
700	Concrete	0.86149	0.00106	0.86361	12DC134
800	Concrete	0.86991	0.00096	0.87183	12DC136
900	Concrete	0.87162	0.00087	0.87336	12DC138
1000	Concrete	0.87546	0.00089	0.87724	12DC140
1100	Concrete	0.87134	0.00090	0.87314	12DC142
1200	Concrete	0.87086	0.00079	0.87244	12DC144
1300	Concrete	0.86654	0.00077	0.86808	12DC146
1400	Concrete	0.85865	0.00087	0.86039	12DC148
1500	Concrete	0.85527	0.00083	0.85693	12DC150

Table A-35, Results for 12 30-Gallon Drums Each Containing a Centrally Located 120 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.79501	0.00099	0.79699	12DC170
600	Concrete	0.81716	0.00098	0.81912	12DC172
700	Concrete	0.83508	0.00096	0.83700	12DC174
800	Concrete	0.84579	0.00105	0.84789	12DC176
900	Concrete	0.85262	0.00093	0.85448	12DC178
1000	Concrete	0.85643	0.00093	0.85829	12DC180
1100	Concrete	0.85650	0.00082	0.85814	12DC182
1200	Concrete	0.85652	0.00085	0.85822	12DC184
1300	Concrete	0.85450	0.00083	0.85616	12DC186
1400	Concrete	0.84994	0.00082	0.85158	12DC188
1500	Concrete	0.84325	0.00080	0.84485	12DC190

Table A-36, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.84216	0.00095	0.84406	12DC210
600	Concrete	0.86041	0.00098	0.86237	12DC212
700	Concrete	0.87197	0.00093	0.87383	12DC214
800	Concrete	0.87418	0.00092	0.87602	12DC216
900	Concrete	0.87985	0.00101	0.88187	12DC218
1000	Concrete	0.87928	0.00088	0.88104	12DC220
1100	Concrete	0.87676	0.00100	0.87876	12DC222
1200	Concrete	0.87339	0.00088	0.87515	12DC224
1300	Concrete	0.86993	0.00089	0.87171	12DC226
1400	Concrete	0.86404	0.00089	0.86582	12DC228
1500	Concrete	0.85655	0.00078	0.85811	12DC230

Results of Two-Drum Configurations of the Hot Cell Drum Model in Section 5.4.3

Table A-37, Results for 12 30-Gallon Drums in an Edge Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.72904	0.00101	0.73106	12D2010
600	Concrete	0.75677	0.00111	0.75899	12D2012
700	Concrete	0.77457	0.00097	0.77651	12D2014
800	Concrete	0.78834	0.00101	0.79036	12D2016
900	Concrete	0.79945	0.00098	0.80141	12D2018
1000	Concrete	0.80451	0.00091	0.80633	12D2020
1100	Concrete	0.80782	0.00091	0.80964	12D2022
1200	Concrete	0.80913	0.00083	0.81079	12D2024
1300	Concrete	0.80868	0.00089	0.81046	12D2026
1400	Concrete	0.80948	0.00090	0.81128	12D2028
1500	Concrete	0.80512	0.00080	0.80672	12D2030

Table A-38, Results for 12 30-Gallon Drums in an Edge Two-Drum Configuration Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.93074	0.00104	0.93282	12D2050
600	Concrete	0.94195	0.00107	0.94409	12D2052
700	Concrete	0.94466	0.00099	0.94664	12D2054
800	Concrete	0.94965	0.00098	0.95161	12D2056
900	Concrete	0.94476	0.00096	0.94668	12D2058
1000	Concrete	0.94150	0.00094	0.94338	12D2060
1100	Concrete	0.93587	0.00087	0.93761	12D2062
1200	Concrete	0.92998	0.00083	0.93164	12D2064
1300	Concrete	0.92008	0.00081	0.92170	12D2066
1400	Concrete	0.91268	0.00090	0.91448	12D2068
1500	Concrete	0.90259	0.00084	0.90427	12D2070

Table A-39, Results for 12 30-Gallon Drums in an Edge Two-Drum Configuration Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.86937	0.00108	0.87153	12D2130
600	Concrete	0.88267	0.00100	0.88467	12D2132
700	Concrete	0.89326	0.00098	0.89522	12D2134
800	Concrete	0.90233	0.00099	0.90431	12D2136
900	Concrete	0.90469	0.00092	0.90653	12D2138
1000	Concrete	0.90287	0.00092	0.90471	12D2140
1100	Concrete	0.89859	0.00087	0.90033	12D2142
1200	Concrete	0.89407	0.00087	0.89581	12D2144
1300	Concrete	0.88872	0.00086	0.89044	12D2146
1400	Concrete	0.88181	0.00086	0.88353	12D2148
1500	Concrete	0.87452	0.00080	0.87612	12D2150

Table A-40, Results for 12 30-Gallon Drums in an Edge Two-Drum Configuration Each Containing 120 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.83214	0.00098	0.8341	12D2170
600	Concrete	0.85080	0.00103	0.85286	12D2172
700	Concrete	0.86871	0.00095	0.87061	12D2174
800	Concrete	0.87541	0.00102	0.87745	12D2176
900	Concrete	0.87824	0.00094	0.88012	12D2178
1000	Concrete	0.88150	0.00088	0.88326	12D2180
1100	Concrete	0.88188	0.00087	0.88362	12D2182
1200	Concrete	0.87818	0.00088	0.87994	12D2184
1300	Concrete	0.87514	0.00086	0.87686	12D2186
1400	Concrete	0.86854	0.00079	0.87012	12D2188
1500	Concrete	0.86268	0.00079	0.86426	12D2190

Table A-41, Results for 12 30-Gallon Drums in an Edge Two-Drum Configuration Each Containing 200 g ^{239}Pu Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.88917	0.00053	0.89023	12D2210
600	Concrete	0.90145	0.00052	0.90249	12D2212
700	Concrete	0.91020	0.00051	0.91122	12D2214
800	Concrete	0.91226	0.00050	0.91326	12D2216
900	Concrete	0.91308	0.00047	0.91402	12D2218
1000	Concrete	0.91107	0.00048	0.91203	12D2220
1100	Concrete	0.90793	0.00044	0.90881	12D2222
1200	Concrete	0.90214	0.00045	0.90304	12D2224
1300	Concrete	0.89584	0.00044	0.89672	12D2226
1400	Concrete	0.88869	0.00043	0.88955	12D2228
1500	Concrete	0.88123	0.00042	0.88207	12D2230

Conventional Borehole Array Configurations of Direct Loaded Canisters in the Absence of Adjacent CH Waste from Section 5.5.1

Table A-42, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.79671	0.00107	0.79885	1DAC010
600	Salt	0.82504	0.00105	0.82714	1DAC012
700	Salt	0.84162	0.00098	0.84358	1DAC014
800	Salt	0.85636	0.00105	0.85846	1DAC016
900	Salt	0.86380	0.00103	0.86586	1DAC018
1000	Salt	0.86636	0.00094	0.86824	1DAC020
1100	Salt	0.86958	0.00100	0.87158	1DAC022
1200	Salt	0.86860	0.00090	0.87040	1DAC024
1300	Salt	0.86894	0.00090	0.87074	1DAC026
1400	Salt	0.86471	0.00090	0.86651	1DAC028
1500	Salt	0.86150	0.00086	0.86322	1DAC030

Table A-43, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.7646	0.00109	0.76678	1DAC050
600	Salt	0.79614	0.00101	0.79816	1DAC052
700	Salt	0.82268	0.00101	0.82470	1DAC054
800	Salt	0.83916	0.00103	0.84122	1DAC056
900	Salt	0.85005	0.00100	0.85205	1DAC058
1000	Salt	0.85873	0.00091	0.86055	1DAC060
1100	Salt	0.86099	0.00097	0.86293	1DAC062
1200	Salt	0.86283	0.00091	0.86465	1DAC064
1300	Salt	0.86505	0.00088	0.86681	1DAC066
1400	Salt	0.86225	0.00084	0.86393	1DAC068
1500	Salt	0.85929	0.00086	0.86101	1DAC070

Table A-44, Array Results for Direct Loaded Canisters of 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.86437	0.00108	0.86653	1DAC090
600	Salt	0.87617	0.00101	0.87819	1DAC092
700	Salt	0.88379	0.00092	0.88563	1DAC094
800	Salt	0.88754	0.00094	0.88942	1DAC096
900	Salt	0.88630	0.00090	0.88810	1DAC098
1000	Salt	0.88337	0.00089	0.88515	1DAC100
1100	Salt	0.87838	0.00090	0.88018	1DAC102
1200	Salt	0.87161	0.00089	0.87339	1DAC104
1300	Salt	0.86499	0.00086	0.86671	1DAC106
1400	Salt	0.85865	0.00078	0.86021	1DAC108
1500	Salt	0.85042	0.00078	0.85198	1DAC120

Table A-45, Array Results for Direct Loaded Canisters of 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77770	0.00106	0.77982	1DAC130
600	Salt	0.79625	0.00091	0.79807	1DAC132
700	Salt	0.80902	0.00095	0.81092	1DAC134
800	Salt	0.81585	0.00097	0.81779	1DAC136
900	Salt	0.82153	0.00097	0.82347	1DAC138
1000	Salt	0.82104	0.00090	0.82284	1DAC140
1100	Salt	0.82074	0.00089	0.82252	1DAC142
1200	Salt	0.81751	0.00095	0.81941	1DAC144
1300	Salt	0.81422	0.00090	0.81602	1DAC146
1400	Salt	0.80881	0.00086	0.81053	1DAC148
1500	Salt	0.80377	0.00078	0.80533	1DAC150

Table A-46, Array Results for Direct Loaded Canisters of 245 g ^{239}Pu Moderated by 100% Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.88933	0.00097	0.89127	1DAC170
600	Salt	0.90572	0.00101	0.90774	1DAC172
700	Salt	0.91583	0.00097	0.91777	1DAC174
800	Salt	0.92061	0.00092	0.92245	1DAC176
900	Salt	0.92304	0.00090	0.92484	1DAC178
1000	Salt	0.92250	0.00088	0.92426	1DAC180
1100	Salt	0.91812	0.00094	0.92000	1DAC182
1200	Salt	0.91453	0.00088	0.91629	1DAC184
1300	Salt	0.91024	0.00087	0.91198	1DAC186
1400	Salt	0.90250	0.00090	0.90430	1DAC188
1500	Salt	0.89667	0.00088	0.89843	1DAC190

Conventional Borehole Array Configurations of Direct Loaded Canisters in the Presence of Adjacent CH Waste from Section 5.5.1

Table A-47, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.79418	0.00105	0.79628	1DAC250
600	Salt/CH	0.82106	0.00103	0.82312	1DAC252
700	Salt/CH	0.84163	0.00108	0.84379	1DAC254
800	Salt/CH	0.85289	0.00104	0.85497	1DAC256
900	Salt/CH	0.86251	0.00100	0.86451	1DAC258
1000	Salt/CH	0.86708	0.00094	0.86896	1DAC260
1100	Salt/CH	0.86893	0.00095	0.87083	1DAC262
1200	Salt/CH	0.86994	0.00103	0.87200	1DAC264
1300	Salt/CH	0.86701	0.00087	0.86875	1DAC266
1400	Salt/CH	0.86692	0.00094	0.86880	1DAC268
1500	Salt/CH	0.85962	0.00088	0.86138	1DAC270

Table A-48, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.76095	0.00116	0.76327	1DAC290
600	Salt/CH	0.79706	0.00119	0.79944	1DAC292
700	Salt/CH	0.81984	0.00111	0.82206	1DAC294
800	Salt/CH	0.83765	0.00114	0.83993	1DAC296
900	Salt/CH	0.84905	0.00098	0.85101	1DAC298
1000	Salt/CH	0.85636	0.00102	0.85840	1DAC300
1100	Salt/CH	0.86133	0.00099	0.86331	1DAC302
1200	Salt/CH	0.86222	0.00090	0.86402	1DAC304
1300	Salt/CH	0.86231	0.00097	0.86425	1DAC306
1400	Salt/CH	0.86131	0.00085	0.86301	1DAC308
1500	Salt/CH	0.85744	0.00090	0.85924	1DAC310

Table A-49, Array Results for Direct Loaded Canisters of 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.86388	0.00102	0.86592	1DAC330
600	Salt/CH	0.87636	0.00104	0.87844	1DAC332
700	Salt/CH	0.88480	0.00094	0.88668	1DAC334
800	Salt/CH	0.88561	0.00096	0.88753	1DAC336
900	Salt/CH	0.88649	0.00099	0.88847	1DAC338
1000	Salt/CH	0.88318	0.00100	0.88518	1DAC340
1100	Salt/CH	0.87761	0.00099	0.87959	1DAC342
1200	Salt/CH	0.87159	0.00089	0.87337	1DAC344
1300	Salt/CH	0.86498	0.00087	0.86672	1DAC346
1400	Salt/CH	0.85517	0.00088	0.85693	1DAC348
1500	Salt/CH	0.84830	0.00088	0.85006	1DAC350

Table A-50, Array Results for Direct Loaded Canisters of 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.77517	0.00107	0.77731	1DAC370
600	Salt/CH	0.79343	0.00115	0.79573	1DAC372
700	Salt/CH	0.80961	0.00106	0.81173	1DAC374
800	Salt/CH	0.81637	0.00102	0.81841	1DAC376
900	Salt/CH	0.81986	0.00109	0.82204	1DAC378
1000	Salt/CH	0.82027	0.00102	0.82231	1DAC380
1100	Salt/CH	0.81983	0.00095	0.82173	1DAC382
1200	Salt/CH	0.81619	0.00095	0.81809	1DAC384
1300	Salt/CH	0.81276	0.00094	0.81464	1DAC386
1400	Salt/CH	0.80726	0.00093	0.80912	1DAC388
1500	Salt/CH	0.80205	0.00092	0.80389	1DAC390

Table A-51, Array Results for Direct Loaded Canisters of 245 g ^{239}Pu Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.88862	0.00102	0.89066	1DAC410
600	Salt/CH	0.90458	0.00099	0.90656	1DAC412
700	Salt/CH	0.91655	0.00100	0.91855	1DAC414
800	Salt/CH	0.91986	0.00101	0.92188	1DAC416
900	Salt/CH	0.92223	0.00094	0.92411	1DAC418
1000	Salt/CH	0.92250	0.00084	0.92418	1DAC420
1100	Salt/CH	0.91863	0.00092	0.92047	1DAC422
1200	Salt/CH	0.91480	0.00095	0.91670	1DAC424
1300	Salt/CH	0.90928	0.00088	0.91104	1DAC426
1400	Salt/CH	0.90382	0.00080	0.90542	1DAC428
1500	Salt/CH	0.89653	0.00084	0.89821	1DAC430

Borehole Array Configurations with Two Close Proximity Fissile Masses in Direct Loaded Canisters from Section 5.5.1

Table A-52, Array Results for Two Close Proximity Masses in Direct Loaded Canisters with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.81143	0.00099	0.81341	1AAC010
600	Salt	0.83829	0.00104	0.84037	1AAC012
700	Salt	0.85384	0.00103	0.85590	1AAC014
800	Salt	0.86754	0.00108	0.86970	1AAC016
900	Salt	0.87389	0.00111	0.87611	1AAC018
1000	Salt	0.87638	0.00095	0.87828	1AAC020
1100	Salt	0.87922	0.00093	0.88108	1AAC022
1200	Salt	0.87887	0.00086	0.88059	1AAC024
1300	Salt	0.87519	0.00092	0.87703	1AAC026
1400	Salt	0.87333	0.00085	0.87503	1AAC028
1500	Salt	0.86886	0.00092	0.87070	1AAC030

Table A-53, Array Results for Two Close Proximity Direct Loaded Canisters with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.86312	0.00052	0.86416	1AAC050
600	Salt	0.87758	0.00050	0.87858	1AAC052
700	Salt	0.88468	0.00050	0.88568	1AAC054
800	Salt	0.88636	0.00049	0.88734	1AAC056
900	Salt	0.88630	0.00047	0.88724	1AAC058
1000	Salt	0.88341	0.00050	0.88441	1AAC060
1100	Salt	0.87807	0.00044	0.87895	1AAC062
1200	Salt	0.87186	0.00044	0.87274	1AAC064
1300	Salt	0.86407	0.00043	0.86493	1AAC066
1400	Salt	0.85682	0.00040	0.85762	1AAC068
1500	Salt	0.84915	0.00042	0.84999	1AAC070

Table A-54, Array Results for Two Close Proximity Direct Loaded Canisters with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77451	0.00052	0.77555	1AAC090
600	Salt	0.79534	0.00052	0.79638	1AAC092
700	Salt	0.80772	0.00050	0.80872	1AAC094
800	Salt	0.81650	0.00048	0.81746	1AAC096
900	Salt	0.81998	0.00051	0.82100	1AAC098
1000	Salt	0.82010	0.00046	0.82102	1AAC100
1100	Salt	0.81880	0.00047	0.81974	1AAC102
1200	Salt	0.81620	0.00046	0.81712	1AAC104
1300	Salt	0.81161	0.00044	0.81249	1AAC106
1400	Salt	0.80760	0.00043	0.80846	1AAC108
1500	Salt	0.80170	0.00042	0.80254	1AAC110

Table A-55, Array Results for Two Close Proximity Direct Loaded Canisters with 245 g ^{239}Pu Moderated by 100% Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89112	0.00104	0.89320	1AAC170
600	Salt	0.90923	0.00099	0.91121	1AAC172
700	Salt	0.92004	0.00098	0.92200	1AAC174
800	Salt	0.92345	0.00095	0.92535	1AAC176
900	Salt	0.92700	0.00100	0.92900	1AAC178
1000	Salt	0.92643	0.00093	0.92829	1AAC180
1100	Salt	0.92131	0.00089	0.92309	1AAC182
1200	Salt	0.91835	0.00093	0.92021	1AAC184
1300	Salt	0.91225	0.00086	0.91397	1AAC186
1400	Salt	0.90668	0.00082	0.90832	1AAC188
1500	Salt	0.90086	0.00082	0.90250	1AAC190

Borehole Array Configurations with ^{240}Pu in Direct Loaded Canisters from Section 5.5.1

Table A-56, Array Results for a Direct Loaded Canister with 15 g ^{240}Pu/ 350 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.79560	0.00109	0.79778	1DAC650
600	Salt	0.82331	0.00102	0.82535	1ADC652
700	Salt	0.84464	0.00097	0.84658	1DAC654
800	Salt	0.85436	0.00108	0.85652	1DAC656
900	Salt	0.86336	0.00097	0.86530	1DAC658
1000	Salt	0.87007	0.00090	0.87187	1DAC660
1100	Salt	0.86933	0.00099	0.87131	1DAC662
1200	Salt	0.86970	0.00081	0.87132	1DAC664
1300	Salt	0.86810	0.00089	0.86988	1DAC666
1400	Salt	0.86244	0.00081	0.86406	1DAC668
1500	Salt	0.85777	0.00084	0.85945	1DAC670

Table A-57, Array Results for a Direct Loaded Canister with 25 g ^{240}Pu/ 370 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.80405	0.00098	0.80601	1DAC690
600	Salt	0.82992	0.00103	0.83198	1DAC692
700	Salt	0.85045	0.00099	0.85243	1DAC694
800	Salt	0.85970	0.00104	0.86178	1DAC696
900	Salt	0.86895	0.00098	0.87091	1DAC698
1000	Salt	0.87111	0.00095	0.87301	1DAC700
1100	Salt	0.87337	0.00093	0.87523	1DAC702
1200	Salt	0.87225	0.00098	0.87421	1DAC704
1300	Salt	0.86967	0.00090	0.87147	1DAC706
1400	Salt	0.86611	0.00096	0.86803	1DAC708
1500	Salt	0.86133	0.00078	0.86286	1DAC710

Table A-58, Results for a Single Direct Loaded Canister with 15 g ^{240}Pu/ 350 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.76750	0.00094	0.76938	1DAC770
600	Salt	0.80319	0.00119	0.80557	1DAC772
700	Salt	0.82766	0.00097	0.82960	1DAC774
800	Salt	0.84470	0.00103	0.84676	1DAC776
900	Salt	0.85346	0.00097	0.85540	1DAC778
1000	Salt	0.86176	0.00099	0.86374	1DAC780
1100	Salt	0.86665	0.00094	0.86853	1DAC782
1200	Salt	0.86756	0.00089	0.86934	1DAC784
1300	Salt	0.86656	0.00089	0.86834	1DAC786
1400	Salt	0.86385	0.00084	0.86553	1DAC788
1500	Salt	0.86024	0.00083	0.86190	1DAC790

Table A-59, Array Results for a Direct Loaded Canister with 25 g ^{240}Pu/ 370 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.78028	0.00111	0.78250	1DAC810
600	Salt	0.81049	0.00106	0.81261	1DAC812
700	Salt	0.83479	0.00093	0.83665	1DAC814
800	Salt	0.85077	0.00097	0.85271	1DAC816
900	Salt	0.86243	0.00096	0.86435	1DAC818
1000	Salt	0.86760	0.00102	0.86964	1DAC820
1100	Salt	0.87111	0.00089	0.87289	1DAC822
1200	Salt	0.87046	0.00087	0.87220	1DAC824
1300	Salt	0.86861	0.00084	0.87029	1DAC826
1400	Salt	0.86763	0.00084	0.86931	1DAC828
1500	Salt	0.86204	0.00077	0.86358	1DAC830

Borehole Array Configurations with Bound Special Reflector Materials in Direct Loaded Canisters from Section 5.5.1

Table A-60, Array Results for a Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.79295	0.00113	0.79521	1DAC310
600	Salt	0.82315	0.00104	0.82523	1DAC312
700	Salt	0.84374	0.00108	0.84590	1DAC314
800	Salt	0.85555	0.00104	0.85763	1DAC316
900	Salt	0.86495	0.00099	0.86693	1DAC318
1000	Salt	0.86941	0.00105	0.87151	1DAC320
1100	Salt	0.87346	0.00101	0.87548	1DAC322
1200	Salt	0.87092	0.00088	0.87268	1DAC324
1300	Salt	0.87107	0.00098	0.87303	1DAC326
1400	Salt	0.86807	0.00088	0.86983	1DAC328
1500	Salt	0.86386	0.00091	0.86568	1DAC330

Table A-61, Array Results for a Direct Loaded Canister with 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/40% Be Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.75215	0.00103	0.75421	1DAC350
600	Salt	0.78592	0.00111	0.78814	1DAC352
700	Salt	0.81160	0.00105	0.81370	1DAC354
800	Salt	0.82891	0.00112	0.83115	1DAC356
900	Salt	0.84102	0.00107	0.84316	1DAC358
1000	Salt	0.84891	0.00095	0.85081	1DAC360
1100	Salt	0.85512	0.00097	0.85706	1DAC362
1200	Salt	0.85591	0.00095	0.85781	1DAC364
1300	Salt	0.85587	0.00089	0.85765	1DAC366
1400	Salt	0.85519	0.00091	0.85701	1DAC368
1500	Salt	0.85229	0.00092	0.85413	1DAC370

Borehole Array Configurations with LEU Fissile Masses in Direct Loaded Canisters from Section 5.5.1

Table A-62, Results for a Borehole Array of Direct Loaded Canister with LEU at 0.96% ^{235}U Moderated by a 25% Polyethylene/ 74% Water/ 1% Be Mixture at Various H/^{235}U Ratio and Reflected by 100% Dense Be

H/^{235}U	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
300	Salt	0.90035	0.00067	0.90169	1DAU300
400	Salt	0.91182	0.00070	0.91322	1DAU400
500	Salt	0.91128	0.00061	0.91250	1DAU500
600	Salt	0.90400	0.00059	0.90518	1DAU600
700	Salt	0.89281	0.00062	0.89405	1DAU700

Conventional Borehole Array Configurations of Containerized Canisters in the Absence of Adjacent CH Waste from Section 5.5.2

Table A-63, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.65914	0.00107	0.66128	3DAC010
600	Salt	0.69080	0.00103	0.69286	3DAC012
700	Salt	0.71116	0.00093	0.71302	3DAC014
800	Salt	0.72571	0.00102	0.72775	3DAC016
900	Salt	0.73657	0.00103	0.73863	3DAC018
1000	Salt	0.74728	0.00093	0.74914	3DAC020
1100	Salt	0.75040	0.00100	0.75240	3DAC022
1200	Salt	0.75339	0.00088	0.75515	3DAC024
1300	Salt	0.75399	0.00089	0.75577	3DAC026
1400	Salt	0.75735	0.00090	0.75915	3DAC028
1500	Salt	0.75266	0.00087	0.75440	3DAC030

Table A-64, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.70350	0.00107	0.70564	3DAC050
600	Salt	0.73832	0.00099	0.74030	3DAC052
700	Salt	0.76329	0.00102	0.76533	3DAC054
800	Salt	0.78309	0.00098	0.78505	3DAC056
900	Salt	0.79496	0.00093	0.79682	3DAC058
1000	Salt	0.80526	0.00095	0.80716	3DAC060
1100	Salt	0.80937	0.00095	0.81127	3DAC062
1200	Salt	0.81409	0.00088	0.81585	3DAC064
1300	Salt	0.81400	0.00092	0.81584	3DAC066
1400	Salt	0.81407	0.00089	0.81585	3DAC068
1500	Salt	0.81384	0.00075	0.81534	3DAC070

Table A-65, Array Results for a Canister of 3 30-gallon Drums Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.86461	0.00101	0.86663	3DAC090
600	Salt	0.87758	0.00089	0.87936	3DAC092
700	Salt	0.88578	0.00095	0.88768	3DAC094
800	Salt	0.88919	0.00094	0.89107	3DAC096
900	Salt	0.88587	0.00093	0.88773	3DAC098
1000	Salt	0.88468	0.00094	0.88656	3DAC100
1100	Salt	0.88071	0.00087	0.88245	3DAC102
1200	Salt	0.87350	0.00089	0.87528	3DAC104
1300	Salt	0.86540	0.00081	0.86702	3DAC106
1400	Salt	0.85840	0.00086	0.86012	3DAC108
1500	Salt	0.85307	0.00084	0.85475	3DAC110

Table A-66, Array Results for a Canister of 3 30-gallon Drums Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.78098	0.00098	0.78294	3DAC130
600	Salt	0.79831	0.00099	0.80029	3DAC132
700	Salt	0.81462	0.00092	0.81646	3DAC134
800	Salt	0.81860	0.00097	0.82054	3DAC136
900	Salt	0.82278	0.00101	0.82480	3DAC138
1000	Salt	0.82492	0.00085	0.82662	3DAC140
1100	Salt	0.82523	0.00091	0.82705	3DAC142
1200	Salt	0.82013	0.00080	0.82173	3DAC144
1300	Salt	0.81716	0.00085	0.81886	3DAC146
1400	Salt	0.81021	0.00081	0.81183	3DAC148
1500	Salt	0.80531	0.00085	0.80701	3DAC150

Table A-67, Array Results for a Canister of 3 30-gallon Drums Each Containing 120 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.72376	0.00097	0.72570	3DAC450
600	Salt	0.75257	0.00108	0.75473	3DAC452
700	Salt	0.76745	0.00097	0.76939	3DAC454
800	Salt	0.77961	0.00101	0.78163	3DAC456
900	Salt	0.78577	0.00097	0.78771	3DAC458
1000	Salt	0.78963	0.00095	0.79153	3DAC460
1100	Salt	0.79217	0.00094	0.79405	3DAC462
1200	Salt	0.78933	0.00088	0.79109	3DAC464
1300	Salt	0.78957	0.00083	0.79123	3DAC466
1400	Salt	0.78610	0.00081	0.78772	3DAC468
1500	Salt	0.78038	0.00079	0.78196	3DAC470

Table A-68, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by 100% Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.83945	0.00104	0.84153	3DAC170
600	Salt	0.85824	0.00104	0.86032	3DAC172
700	Salt	0.86993	0.00089	0.87171	3DAC174
800	Salt	0.87557	0.00106	0.87769	3DAC176
900	Salt	0.87583	0.00091	0.87765	3DAC178
1000	Salt	0.87926	0.00092	0.88110	3DAC180
1100	Salt	0.87734	0.00083	0.87900	3DAC182
1200	Salt	0.87280	0.00084	0.87448	3DAC184
1300	Salt	0.86860	0.00094	0.87048	3DAC186
1400	Salt	0.86372	0.00077	0.86526	3DAC188
1500	Salt	0.85662	0.00080	0.85822	3DAC190

Conventional Borehole Array Configurations of Containerized Canisters in the Presence of Adjacent CH Waste from Section 5.5.2

Table A-69, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.66003	0.00096	0.66195	3DAC250
600	Salt/CH	0.69009	0.00095	0.69199	3DAC252
700	Salt/CH	0.71162	0.00102	0.71366	3DAC254
800	Salt/CH	0.72702	0.00097	0.72896	3DAC256
900	Salt/CH	0.73745	0.00099	0.73943	3DAC258
1000	Salt/CH	0.74511	0.00097	0.74705	3DAC260
1100	Salt/CH	0.75020	0.00093	0.75206	3DAC262
1200	Salt/CH	0.75110	0.00102	0.75314	3DAC264
1300	Salt/CH	0.75461	0.00097	0.75655	3DAC266
1400	Salt/CH	0.75374	0.00081	0.75536	3DAC268
1500	Salt/CH	0.75285	0.00086	0.75457	3DAC270

Table A-70, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.70373	0.00101	0.70575	3DAC290
600	Salt/CH	0.73598	0.00090	0.73778	3DAC292
700	Salt/CH	0.76375	0.00101	0.76577	3DAC294
800	Salt/CH	0.78153	0.00091	0.78335	3DAC296
900	Salt/CH	0.79477	0.00093	0.79663	3DAC298
1000	Salt/CH	0.80365	0.00093	0.80551	3DAC300
1100	Salt/CH	0.81017	0.00097	0.81211	3DAC302
1200	Salt/CH	0.81324	0.00088	0.81500	3DAC304
1300	Salt/CH	0.81437	0.00085	0.81607	3DAC306
1400	Salt/CH	0.81316	0.00089	0.81494	3DAC308
1500	Salt/CH	0.81126	0.00084	0.81294	3DAC310

Table A-71, Array Results for a Canister of 3 30-gallon Drums Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.86498	0.00097	0.86692	3DAC330
600	Salt/CH	0.88099	0.00102	0.88303	3DAC332
700	Salt/CH	0.88492	0.00093	0.88678	3DAC334
800	Salt/CH	0.88731	0.00103	0.88937	3DAC336
900	Salt/CH	0.88889	0.00099	0.89087	3DAC338
1000	Salt/CH	0.88436	0.00084	0.88604	3DAC340
1100	Salt/CH	0.88015	0.00088	0.88191	3DAC342
1200	Salt/CH	0.87319	0.00084	0.87487	3DAC344
1300	Salt/CH	0.86659	0.00080	0.86819	3DAC346
1400	Salt/CH	0.85826	0.00079	0.85984	3DAC348
1500	Salt/CH	0.85170	0.00083	0.85336	3DAC350

Table A-72, Array Results for a Canister of 3 30-gallon Drums Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.78161	0.00115	0.78391	3DAC370
600	Salt/CH	0.79947	0.00104	0.80155	3DAC372
700	Salt/CH	0.81304	0.00092	0.81488	3DAC374
800	Salt/CH	0.81938	0.00092	0.82122	3DAC376
900	Salt/CH	0.82304	0.00093	0.82490	3DAC378
1000	Salt/CH	0.82395	0.00088	0.82571	3DAC380
1100	Salt/CH	0.82356	0.00093	0.82542	3DAC382
1200	Salt/CH	0.82059	0.00080	0.82219	3DAC384
1300	Salt/CH	0.81686	0.00081	0.81848	3DAC386
1400	Salt/CH	0.81226	0.00080	0.81386	3DAC388
1500	Salt/CH	0.80633	0.00076	0.80785	3DAC390

Table A-73, Array Results for a Canister of 3 30-gallon Drums Each Containing 120 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.72284	0.00104	0.72492	3DAC490
600	Salt/CH	0.74917	0.00103	0.75123	3DAC492
700	Salt/CH	0.76803	0.00104	0.77011	3DAC494
800	Salt/CH	0.77959	0.00100	0.78159	3DAC496
900	Salt/CH	0.78378	0.00090	0.78558	3DAC498
1000	Salt/CH	0.78935	0.00099	0.79133	3DAC500
1100	Salt/CH	0.79154	0.00094	0.79342	3DAC502
1200	Salt/CH	0.78893	0.00092	0.79077	3DAC504
1300	Salt/CH	0.78745	0.00075	0.78895	3DAC506
1400	Salt/CH	0.78348	0.00088	0.78524	3DAC508
1500	Salt/CH	0.78088	0.00078	0.78244	3DAC510

Table A-74, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.84318	0.00109	0.84536	3DAC410
600	Salt/CH	0.85832	0.00101	0.86034	3DAC412
700	Salt/CH	0.86912	0.00101	0.87114	3DAC414
800	Salt/CH	0.87595	0.00095	0.87785	3DAC416
900	Salt/CH	0.87877	0.00097	0.88071	3DAC418
1000	Salt/CH	0.87713	0.00088	0.87889	3DAC420
1100	Salt/CH	0.87564	0.00088	0.87740	3DAC422
1200	Salt/CH	0.87318	0.00091	0.87500	3DAC424
1300	Salt/CH	0.86826	0.00083	0.86992	3DAC426
1400	Salt/CH	0.86170	0.00084	0.86338	3DAC428
1500	Salt/CH	0.85595	0.00084	0.85763	3DAC430

Over batched Single Direct Loaded Canister Results from Section 7.1.1

Table A-75, Results for an Over batched Single Direct Loaded Canister with 470 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89806	0.00111	0.90028	1DCO010
600	Lead	0.92333	0.00113	0.92559	1DCO012
700	Lead	0.93776	0.00107	0.93990	1DCO014
800	Lead	0.94889	0.00106	0.95101	1DCO016
900	Lead	0.95592	0.00092	0.95776	1DCO018
1000	Lead	0.95759	0.00090	0.95939	1DCO020
1100	Lead	0.95765	0.00099	0.95963	1DCO022
1200	Lead	0.95191	0.00092	0.95375	1DCO024
1300	Lead	0.94940	0.00096	0.95132	1DCO026
1400	Lead	0.94381	0.00082	0.94545	1DCO028
1500	Lead	0.93829	0.00083	0.93995	1DCO030

Table A-76, Results for an Over batched Single Direct Loaded Canister with 470 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.85237	0.00107	0.85451	1DCO050
600	Lead	0.88223	0.00101	0.88425	1DCO052
700	Lead	0.90502	0.00096	0.90694	1DCO054
800	Lead	0.92115	0.00094	0.92303	1DCO056
900	Lead	0.92801	0.00095	0.92991	1DCO058
1000	Lead	0.93408	0.00097	0.93602	1DCO060
1100	Lead	0.93759	0.00098	0.93955	1DCO062
1200	Lead	0.93672	0.00092	0.93856	1DCO064
1300	Lead	0.93547	0.00084	0.93715	1DCO066
1400	Lead	0.93183	0.00080	0.93343	1DCO068
1500	Lead	0.92763	0.00086	0.92935	1DCO070

Table A-77, Results for an Over batched Single Direct Loaded Canister with 185 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.91386	0.00098	0.91582	1DCO090
600	Lead	0.93185	0.0009	0.93365	1DCO092
700	Lead	0.93924	0.00092	0.94108	1DCO094
800	Lead	0.94275	0.00097	0.94469	1DCO096
900	Lead	0.94105	0.00097	0.94299	1DCO098
1000	Lead	0.93781	0.00094	0.93969	1DCO100
1100	Lead	0.93445	0.00086	0.93617	1DCO102
1200	Lead	0.92846	0.0008	0.93006	1DCO104
1300	Lead	0.9209	0.00088	0.92266	1DCO106
1400	Lead	0.91451	0.00086	0.91623	1DCO108
1500	Lead	0.90491	0.00084	0.90659	1DCO110

Table A-78, Results for an Over batched Single Direct Loaded Canister with 425 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89546	0.00110	0.89766	1DCO310
600	Lead	0.92203	0.00116	0.92435	1DCO312
700	Lead	0.93965	0.00105	0.94175	1DCO314
800	Lead	0.94932	0.00104	0.95140	1DCO316
900	Lead	0.95707	0.00111	0.95929	1DCO318
1000	Lead	0.95875	0.00056	0.95987	1DCO320
1100	Lead	0.95872	0.00057	0.95986	1DCO322
1200	Lead	0.95811	0.00054	0.95919	1DCO324
1300	Lead	0.95269	0.00090	0.95449	1DCO326
1400	Lead	0.94678	0.00087	0.94852	1DCO328
1500	Lead	0.93974	0.00097	0.94168	1DCO330

Table A-79, Results for an Over batched Single Direct Loaded Canister with 425 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.84553	0.00107	0.84767	1DCO350
600	Lead	0.87733	0.00114	0.87961	1DCO352
700	Lead	0.89836	0.00116	0.90068	1DCO354
800	Lead	0.91617	0.00116	0.91849	1DCO356
900	Lead	0.92573	0.00111	0.92795	1DCO358
1000	Lead	0.92941	0.00104	0.93149	1DCO360
1100	Lead	0.93460	0.00095	0.93650	1DCO362
1200	Lead	0.93158	0.00090	0.93338	1DCO364
1300	Lead	0.93067	0.00089	0.93245	1DCO366
1400	Lead	0.92696	0.00097	0.92890	1DCO368
1500	Lead	0.92374	0.00091	0.92556	1DCO370

Table A-80, Results for an Over batched Single Direct Loaded Canister with 225 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.90846	0.00109	0.91064	1DCO130
600	Lead	0.92893	0.00101	0.93095	1DCO132
700	Lead	0.93897	0.00104	0.94105	1DCO134
800	Lead	0.94497	0.00100	0.94697	1DCO136
900	Lead	0.94661	0.00106	0.94873	1DCO138
1000	Lead	0.94582	0.00095	0.94772	1DCO140
1100	Lead	0.94382	0.00091	0.94564	1DCO142
1200	Lead	0.93838	0.00085	0.94008	1DCO144
1300	Lead	0.93255	0.00086	0.93427	1DCO146
1400	Lead	0.92389	0.00078	0.92545	1DCO148
1500	Lead	0.91582	0.00090	0.91762	1DCO150

Table A-81, Results for an Over batched Single Direct Loaded Canister with 285 g ^{239}Pu Moderated by100% Dense Polyethylene and Reflected with 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.92568	0.00098	0.92764	1DCO170
600	Lead	0.94238	0.00113	0.94464	1DCO172
700	Lead	0.95120	0.00101	0.95322	1DCO174
800	Lead	0.95509	0.00103	0.95715	1DCO176
900	Lead	0.95493	0.00096	0.95685	1DCO178
1000	Lead	0.95352	0.00092	0.95536	1DCO180
1100	Lead	0.94959	0.00093	0.95145	1DCO182
1200	Lead	0.94477	0.00092	0.94661	1DCO184
1300	Lead	0.94012	0.00084	0.94180	1DCO186
1400	Lead	0.93245	0.00086	0.93417	1DCO188
1500	Lead	0.92373	0.00087	0.92547	1DCO190

Table A-82, Computational Results for a Single Direct Loaded Canister Reflected By 200 cm of Lead as a Function of H/D Ratio of the Fissile Material

H/D Ratio	FGE at Limit	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
Mechanically/Chemically Bound Be					
1	445	0.95558	0.00105	0.95768	1DCO450
2	570	0.95779	0.00091	0.95961	1DCO570
3	725	0.95677	0.00100	0.95877	1DCO725
Machine Compacted Waste					
1	300	0.95615	0.00087	0.95789	1DCO300
2	375	0.95661	0.00088	0.95837	1DCO375
3	480	0.95735	0.00093	0.95921	1DCO480

Over batched Configurations of Canisters of 30-gallon Drums from Section 7.1.1

Table A-83, Results for an Over batched Canister of 3 30-gallon Centrally Located Drums with 380 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.84509	0.00097	0.84703	3DBO010
600	Lead	0.86941	0.00100	0.87141	3DBO012
700	Lead	0.88671	0.00099	0.88869	3DBO014
800	Lead	0.89897	0.00094	0.90085	3DBO016
900	Lead	0.90356	0.00109	0.90574	3DBO018
1000	Lead	0.90830	0.00094	0.91018	3DBO020
1100	Lead	0.90942	0.00091	0.91124	3DBO022
1200	Lead	0.90950	0.00089	0.91128	3DBO024
1300	Lead	0.90773	0.00089	0.90951	3DBO026
1400	Lead	0.90242	0.00082	0.90406	3DBO028
1500	Lead	0.89786	0.00091	0.89968	3DBO030

Table A-84, Results for an Over batched Canister of 3 30-gallon Centrally Located Drums with 380 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 0% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.86029	0.00108	0.86245	3DBO050
600	Lead	0.89192	0.00104	0.89400	3DBO052
700	Lead	0.91175	0.00109	0.91393	3DBO054
800	Lead	0.92775	0.00104	0.92983	3DBO056
900	Lead	0.93818	0.00088	0.93994	3DBO058
1000	Lead	0.94147	0.00097	0.94341	3DBO060
1100	Lead	0.94441	0.00094	0.94629	3DBO062
1200	Lead	0.94280	0.00092	0.94464	3DBO064
1300	Lead	0.94085	0.00087	0.94259	3DBO066
1400	Lead	0.93757	0.00085	0.93927	3DBO068
1500	Lead	0.93343	0.00085	0.93513	3DBO070

Table A-85, Results for an Over batched Canister of 3 30-gallon Centrally Located Drums with 180 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.91461	0.00101	0.91663	3DBO090
600	Lead	0.92870	0.00100	0.93070	3DBO092
700	Lead	0.93711	0.00099	0.93909	3DBO094
800	Lead	0.94059	0.00098	0.94255	3DBO096
900	Lead	0.94105	0.00090	0.94285	3DBO098
1000	Lead	0.94038	0.00098	0.94234	3DBO100
1100	Lead	0.93541	0.00089	0.93719	3DBO102
1200	Lead	0.92798	0.00086	0.92970	3DBO104
1300	Lead	0.92079	0.00085	0.92249	3DBO106
1400	Lead	0.91524	0.00080	0.91684	3DBO108
1500	Lead	0.90603	0.00090	0.90783	3DBO110

Table A-86, Results for an Over batched Canister of 3 30-gallon Centrally Located Drums with 215 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.90662	0.00105	0.90872	3DBO130
600	Lead	0.92698	0.00100	0.92898	3DBO132
700	Lead	0.93933	0.00096	0.94125	3DBO134
800	Lead	0.94127	0.00105	0.94337	3DBO136
900	Lead	0.94755	0.00093	0.94941	3DBO138
1000	Lead	0.94523	0.00092	0.94707	3DBO140
1100	Lead	0.94275	0.00089	0.94453	3DBO142
1200	Lead	0.93880	0.00078	0.94036	3DBO144
1300	Lead	0.93275	0.00088	0.93451	3DBO146
1400	Lead	0.92436	0.00090	0.92616	3DBO148
1500	Lead	0.91710	0.00081	0.91872	3DBO150

Table A-87, Results for an Over batched Canister of 3 30-gallon Centrally Located Drums with 285 g ^{239}Pu Moderated by100% Dense Polyethylene and Reflected with 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.92638	0.00103	0.92844	3DBO170
600	Lead	0.94092	0.00097	0.94286	3DBO172
700	Lead	0.94969	0.00100	0.95169	3DBO174
800	Lead	0.95405	0.00094	0.95593	3DBO176
900	Lead	0.95743	0.00051	0.95845	3DBO178
1000	Lead	0.95519	0.00089	0.95697	3DBO180
1100	Lead	0.95135	0.00089	0.95313	3DBO182
1200	Lead	0.94332	0.00089	0.94510	3DBO184
1300	Lead	0.93966	0.00082	0.94130	3DBO186
1400	Lead	0.93125	0.00091	0.93307	3DBO188
1500	Lead	0.92351	0.00080	0.92511	3DBO190

Overbatched Borehole Array Configurations of Direct Loaded Canisters from Section 7.1.1

Table A-88, Overbatched Array Results for Direct Loaded Canisters of 460 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89304	0.00112	0.89528	010
600	Salt	0.91927	0.00110	0.92147	1DAO012
700	Salt	0.93371	0.00105	0.93581	1DAO014
800	Salt	0.94568	0.00100	0.94768	1DAO016
900	Salt	0.95024	0.00100	0.95224	1DAO018
1000	Salt	0.95440	0.00097	0.95634	1DAO020
1100	Salt	0.95261	0.00091	0.95443	1DAO022
1200	Salt	0.95004	0.00091	0.95186	1DAO024
1300	Salt	0.94732	0.00084	0.94900	1DAO026
1400	Salt	0.94093	0.00082	0.94257	1DAO028
1500	Salt	0.93554	0.00085	0.93724	1DAO030

Table A-89, Overbatched Array Results for Direct Loaded Canisters of 460 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.87382	0.00107	0.87596	1DAO050
600	Salt	0.90833	0.00100	0.91033	1DAO052
700	Salt	0.92806	0.00101	0.93008	1DAO054
800	Salt	0.94106	0.00093	0.94292	1DAO056
900	Salt	0.95144	0.00109	0.95362	1DAO058
1000	Salt	0.95164	0.00096	0.95356	1DAO060
1100	Salt	0.95716	0.00053	0.95822	1DAO062
1200	Salt	0.95486	0.00095	0.95676	1DAO064
1300	Salt	0.95185	0.00089	0.95363	1DAO066
1400	Salt	0.94709	0.00084	0.94877	1DAO068
1500	Salt	0.94357	0.00073	0.94503	1DAO070

Table A-90, Overbatched Array Results for Direct Loaded Canisters of 190 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.91554	0.00094	0.91742	1DAO090
600	Salt	0.93174	0.00096	0.93366	1DAO092
700	Salt	0.93989	0.00101	0.94191	1DAO094
800	Salt	0.94267	0.00102	0.94471	1DAO096
900	Salt	0.94266	0.00093	0.94452	1DAO098
1000	Salt	0.94002	0.00093	0.94188	1DAO100
1100	Salt	0.93479	0.00088	0.93655	1DAO102
1200	Salt	0.92927	0.00088	0.93103	1DAO104
1300	Salt	0.91962	0.00083	0.92128	1DAO106
1400	Salt	0.91426	0.00083	0.91592	1DAO108
1500	Salt	0.90653	0.00081	0.90815	1DAO110

Table A-91, Overbatched Array Results for Direct Loaded Canisters of 420 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89212	0.00116	0.89444	1DAO310
600	Salt	0.91875	0.00112	0.92099	1DAO312
700	Salt	0.93657	0.00103	0.93863	1DAO314
800	Salt	0.95144	0.00107	0.95358	1DAO316
900	Salt	0.95385	0.00121	0.95627	1DAO318
1000	Salt	0.95759	0.00099	0.95957	1DAO320
1100	Salt	0.95540	0.00098	0.95736	1DAO322
1200	Salt	0.95462	0.00102	0.95666	1DAO324
1300	Salt	0.95211	0.00097	0.95405	1DAO326
1400	Salt	0.94388	0.00097	0.94582	1DAO328
1500	Salt	0.94178	0.00093	0.94364	1DAO330

Table A-92, Overbatched Array Results for Direct Loaded Canisters of 420 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/40% Be Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.86477	0.00107	0.86691	1DAO350
600	Salt	0.89858	0.00106	0.90070	1DAO352
700	Salt	0.92076	0.00110	0.92296	1DAO354
800	Salt	0.93381	0.00102	0.93585	1DAO356
900	Salt	0.94576	0.00105	0.94786	1DAO358
1000	Salt	0.94765	0.00111	0.94987	1DAO360
1100	Salt	0.95219	0.00095	0.95409	1DAO362
1200	Salt	0.94902	0.00089	0.95080	1DAO364
1300	Salt	0.94649	0.00098	0.94845	1DAO366
1400	Salt	0.94167	0.00090	0.94347	1DAO368
1500	Salt	0.93627	0.00088	0.93803	1DAO370

Table A-93, Overbatched Array Results for Direct Loaded Canisters of 225 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.90006	0.00103	0.90212	1DAO130
600	Salt	0.92165	0.00099	0.92363	1DAO132
700	Salt	0.93438	0.00094	0.93626	1DAO134
800	Salt	0.93963	0.00103	0.94169	1DAO136
900	Salt	0.94089	0.00096	0.94281	1DAO138
1000	Salt	0.94062	0.00091	0.94244	1DAO140
1100	Salt	0.93743	0.00086	0.93915	1DAO142
1200	Salt	0.93169	0.00090	0.93349	1DAO144
1300	Salt	0.92507	0.0009	0.92687	1DAO146
1400	Salt	0.91901	0.00085	0.92071	1DAO148
1500	Salt	0.91103	0.00085	0.91273	1DAO150

Table A-94, Overbatched Array Results for Direct Loaded Canisters of 285 g ^{239}Pu Moderated by 100% Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.92670	0.00103	0.92876	1DAO170
600	Salt	0.94284	0.00103	0.94490	1DAO172
700	Salt	0.95056	0.00100	0.95256	1DAO174
800	Salt	0.95391	0.00093	0.95577	1DAO176
900	Salt	0.95395	0.00094	0.95583	1DAO178
1000	Salt	0.95365	0.00096	0.95557	1DAO180
1100	Salt	0.95108	0.00097	0.95302	1DAO182
1200	Salt	0.94535	0.00083	0.94701	1DAO184
1300	Salt	0.93966	0.00089	0.94144	1DAO186
1400	Salt	0.93129	0.00079	0.93287	1DAO188
1500	Salt	0.92416	0.00084	0.92584	1DAO190

Table A-95, Computational Results for a Single Direct Loaded Canister Mirrored Laterally and Reflected Axially By 300 cm of Salt as a Function of H/D Ratio of the Fissile Material

H/D Ratio	FGE at Limit	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
Mechanically/Chemically Bound Be					
1	445	0.95524	0.00097	0.95718	1DAO445
2	562	0.95635	0.00094	0.95823	1DAO562
3	720	0.95600	0.00107	0.95814	1DAO720
Machine Compacted Waste					
1	300	0.95589	0.00100	0.95789	1DAO300
2	375	0.95796	0.00096	0.95988	1DAO375
3	480	0.95716	0.00093	0.95902	1DAO480

Overbatched Borehole Array Configurations of Containerized Canisters from Section 7.1.1

Table A-96, Overbatched Array Results for a Canister of 3 30-gallon Drums Each Containing 320 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.79527	0.00105	0.79737	3DAO010
600	Salt	0.82269	0.00106	0.82481	3DAO012
700	Salt	0.84301	0.00109	0.84519	3DAO014
800	Salt	0.85450	0.00097	0.85644	3DAO016
900	Salt	0.86560	0.00103	0.86766	3DAO018
1000	Salt	0.86756	0.00099	0.86954	3DAO020
1100	Salt	0.87067	0.00097	0.87261	3DAO022
1200	Salt	0.87015	0.00094	0.87203	3DAO024
1300	Salt	0.86675	0.00087	0.86849	3DAO026
1400	Salt	0.86741	0.00090	0.86921	3DAO028
1500	Salt	0.86257	0.00088	0.86433	3DAO030

Table A-97, Overbatched Array Results for a Canister of 3 30-gallon Drums Each Containing 320 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 32 kg Be (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.86338	0.00099	0.86536	3DAO050
600	Salt	0.89691	0.00099	0.89889	3DAO052
700	Salt	0.91729	0.00099	0.91927	3DAO054
800	Salt	0.93328	0.00099	0.93526	3DAO056
900	Salt	0.94118	0.00098	0.94314	3DAO058
1000	Salt	0.94454	0.00083	0.94620	3DAO060
1100	Salt	0.94717	0.00083	0.94883	3DAO062
1200	Salt	0.94523	0.00084	0.94691	3DAO064
1300	Salt	0.94197	0.00079	0.94355	3DAO066
1400	Salt	0.93570	0.00079	0.93728	3DAO068
1500	Salt	0.93223	0.00078	0.93379	3DAO070

Table A-98, Overbatched Array Results for a Canister of 3 30-gallon Drums Each Containing 185 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.91379	0.00098	0.91575	3DAO090
600	Salt	0.92852	0.00098	0.93048	3DAO092
700	Salt	0.93524	0.00099	0.93722	3DAO094
800	Salt	0.94029	0.00098	0.94225	3DAO096
900	Salt	0.94071	0.00086	0.94243	3DAO098
1000	Salt	0.93837	0.00092	0.94021	3DAO100
1100	Salt	0.93384	0.00083	0.93550	3DAO102
1200	Salt	0.92874	0.00086	0.93046	3DAO104
1300	Salt	0.92013	0.00083	0.92179	3DAO106
1400	Salt	0.91370	0.00090	0.91550	3DAO108
1500	Salt	0.90306	0.00082	0.90470	3DAO110

Table A-99, Overbatched Array Results for a Canister of 3 30-gallon Drums Each Containing 220 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.90237	0.00110	0.90457	3DAO130
600	Salt	0.92167	0.00103	0.92373	3DAO132
700	Salt	0.93582	0.00101	0.93784	3DAO134
800	Salt	0.94074	0.00097	0.94268	3DAO136
900	Salt	0.94394	0.00104	0.94602	3DAO138
1000	Salt	0.94230	0.00098	0.94426	3DAO140
1100	Salt	0.93942	0.00095	0.94132	3DAO142
1200	Salt	0.93493	0.00086	0.93665	3DAO144
1300	Salt	0.93038	0.00082	0.93202	3DAO146
1400	Salt	0.92284	0.00084	0.92452	3DAO148
1500	Salt	0.91578	0.00009	0.91758	3DAO150

Table A-100, Overbatched Array Results for a Canister of 3 30-gallon Drums Each Containing 285 g ^{239}Pu Moderated by 100% Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.92586	0.00100	0.92786	3DAO170
600	Salt	0.94148	0.00089	0.94326	3DAO172
700	Salt	0.95112	0.00101	0.95314	3DAO174
800	Salt	0.95356	0.00097	0.95550	3DAO176
900	Salt	0.95327	0.00102	0.95531	3DAO178
1000	Salt	0.95541	0.00096	0.95733	3DAO180
1100	Salt	0.95198	0.00088	0.95374	3DAO182
1200	Salt	0.94612	0.00092	0.94796	3DAO184
1300	Salt	0.93968	0.00087	0.94142	3DAO186
1400	Salt	0.93203	0.00082	0.93367	3DAO188
1500	Salt	0.92236	0.00085	0.92406	3DAO190

Be Overbatch Contingency for a Single Direct Loaded Canister from Section 7.1.2

Table A-101, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 25% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.80338	0.00114	0.80566	1DCB010
600	Lead	0.83121	0.00099	0.83319	1DCB012
700	Lead	0.84967	0.00097	0.85161	1DCB014
800	Lead	0.86195	0.00090	0.86375	1DCB016
900	Lead	0.86717	0.00096	0.86909	1DCB018
1000	Lead	0.87266	0.00100	0.87466	1DCB020
1100	Lead	0.87498	0.00092	0.87682	1DCB022
1200	Lead	0.87216	0.00093	0.87402	1DCB024
1300	Lead	0.87064	0.00093	0.87250	1DCB026
1400	Lead	0.86882	0.00078	0.87038	1DCB028
1500	Lead	0.86439	0.00091	0.86621	1DCB030

Table A-102, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and No Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.74682	0.00104	0.7489	1DCB050
600	Lead	0.78000	0.00115	0.78230	1DCB052
700	Lead	0.80375	0.00105	0.80585	1DCB054
800	Lead	0.82108	0.00097	0.82302	1DCB056
900	Lead	0.83157	0.00107	0.83371	1DCB058
1000	Lead	0.84087	0.00101	0.84289	1DCB060
1100	Lead	0.84619	0.00097	0.84813	1DCB062
1200	Lead	0.84783	0.00086	0.84955	1DCB064
1300	Lead	0.84888	0.00088	0.85064	1DCB066
1400	Lead	0.84647	0.00082	0.84811	1DCB068
1500	Lead	0.84390	0.00085	0.84560	1DCB070

Table A-103, Results for a Single Direct Loaded Canister with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg Be and 100% Dense Graphite

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78553	0.00099	0.78751	1DCB130
600	Lead	0.80622	0.00092	0.80806	1DCB132
700	Lead	0.81783	0.00092	0.81967	1DCB134
800	Lead	0.82606	0.00095	0.82796	1DCB136
900	Lead	0.82557	0.00099	0.82755	1DCB138
1000	Lead	0.82948	0.00093	0.83134	1DCB140
1100	Lead	0.82879	0.00092	0.83063	1DCB142
1200	Lead	0.82536	0.00088	0.82712	1DCB144
1300	Lead	0.82157	0.00087	0.82331	1DCB146
1400	Lead	0.81571	0.00083	0.81737	1DCB148
1500	Lead	0.80991	0.00082	0.81155	1DCB150

Table A-104, Results for a Single Direct Loaded Canister with 245 g ^{239}Pu Moderated by 100% dense Polyethylene and Reflected by 64 kg Be and 100% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89191	0.00101	0.89393	1DCB170
600	Lead	0.90835	0.00104	0.91043	1DCB172
700	Lead	0.91938	0.00106	0.92150	1DCB174
800	Lead	0.92292	0.00093	0.92478	1DCB176
900	Lead	0.92451	0.00100	0.92651	1DCB178
1000	Lead	0.92120	0.00093	0.92306	1DCB180
1100	Lead	0.92043	0.00094	0.92231	1DCB182
1200	Lead	0.91732	0.00092	0.91916	1DCB184
1300	Lead	0.91089	0.00086	0.91261	1DCB186
1400	Lead	0.90468	0.00084	0.90636	1DCB188
1500	Lead	0.89750	0.00081	0.89912	1DCB190

Be Overbatch Contingency Results for a Canister Containing Three (3) 30-Gallon Drums from Section 7.1.2

Table A-105, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 25% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.66707	0.00110	0.66927	3DBB010
600	Lead	0.69665	0.00105	0.69875	3DBB012
700	Lead	0.71805	0.00094	0.71993	3DBB014
800	Lead	0.73235	0.00100	0.73435	3DBB016
900	Lead	0.74552	0.00097	0.74746	3DBB018
1000	Lead	0.74973	0.00100	0.75173	3DBB020
1100	Lead	0.75458	0.00096	0.75650	3DBB022
1200	Lead	0.75810	0.00090	0.75990	3DBB024
1300	Lead	0.75833	0.00080	0.75993	3DBB026
1400	Lead	0.75872	0.00086	0.76044	3DBB028
1500	Lead	0.75875	0.00089	0.76053	3DBB030

Table A-106, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and No Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.65528	0.00104	0.65736	3DBB050
600	Lead	0.69014	0.00099	0.69212	3DBB052
700	Lead	0.71608	0.00107	0.71822	3DBB054
800	Lead	0.73247	0.00100	0.73447	3DBB056
900	Lead	0.74912	0.00093	0.75098	3DBB058
1000	Lead	0.75994	0.00087	0.76168	3DBB060
1100	Lead	0.76583	0.00090	0.76763	3DBB062
1200	Lead	0.76953	0.00089	0.77131	3DBB064
1300	Lead	0.77409	0.00087	0.77583	3DBB066
1400	Lead	0.77294	0.00080	0.77454	3DBB068
1500	Lead	0.77359	0.00089	0.77537	3DBB070

Table A-107, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 100% Dense Graphite

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.78918	0.00096	0.79110	3DBB130
600	Lead	0.80965	0.00106	0.81177	3DBB132
700	Lead	0.82228	0.00101	0.82430	3DBB134
800	Lead	0.82999	0.00087	0.83173	3DBB136
900	Lead	0.83181	0.00088	0.83357	3DBB138
1000	Lead	0.83423	0.00090	0.83603	3DBB140
1100	Lead	0.83218	0.00083	0.83384	3DBB142
1200	Lead	0.82824	0.00087	0.82998	3DBB144
1300	Lead	0.82474	0.00085	0.82644	3DBB146
1400	Lead	0.82068	0.00084	0.82236	3DBB148
1500	Lead	0.81433	0.00082	0.81597	3DBB150

Table A-108, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 100% Dense Polyethylene and Reflected by 64 kg of Be and 100% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.84419	0.0010	0.84619	3DBB170
600	Lead	0.86237	0.00091	0.86419	3DBB172
700	Lead	0.87264	0.00098	0.87460	3DBB174
800	Lead	0.87864	0.00091	0.88046	3DBB176
900	Lead	0.87946	0.00097	0.88140	3DBB178
1000	Lead	0.88020	0.00099	0.88218	3DBB180
1100	Lead	0.87720	0.00087	0.87894	3DBB182
1200	Lead	0.87577	0.00085	0.87747	3DBB184
1300	Lead	0.87074	0.00092	0.87258	3DBB186
1400	Lead	0.86444	0.00085	0.86614	3DBB188
1500	Lead	0.85686	0.00082	0.85850	3DBB190

Be Overbatch Contingency Results for a Conventional Configuration of Twelve (12) 30-Gallon Drums in the Hot Cell from Section 7.1.2

Table A-109, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 10 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.70409	0.00113	0.70635	12DB010
600	Concrete	0.73441	0.00096	0.73633	12DB012
700	Concrete	0.75364	0.00104	0.75572	12DB014
800	Concrete	0.76720	0.00092	0.76904	12DB016
900	Concrete	0.78019	0.00101	0.78221	12DB018
1000	Concrete	0.78858	0.00087	0.79032	12DB020
1100	Concrete	0.79534	0.00092	0.79718	12DB022
1200	Concrete	0.79688	0.00083	0.79854	12DB024
1300	Concrete	0.79655	0.00088	0.79831	12DB026
1400	Concrete	0.79692	0.00088	0.79868	12DB028
1500	Concrete	0.79603	0.00086	0.79775	12DB030

Table A-110, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 10 kg Be/drum (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.67458	0.00097	0.67652	12DB050
600	Concrete	0.70955	0.00099	0.71153	12DB052
700	Concrete	0.73628	0.00100	0.73828	12DB054
800	Concrete	0.75597	0.00097	0.75791	12DB056
900	Concrete	0.77022	0.00096	0.77214	12DB058
1000	Concrete	0.78103	0.00084	0.78271	12DB060
1100	Concrete	0.78913	0.00087	0.79087	12DB062
1200	Concrete	0.79439	0.00091	0.79621	12DB064
1300	Concrete	0.79620	0.00084	0.79788	12DB066
1400	Concrete	0.79884	0.00082	0.80048	12DB068
1500	Concrete	0.79790	0.00082	0.79954	12DB070

Table A-111, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 10 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.82521	0.00097	0.82715	12DB130
600	Concrete	0.84547	0.00105	0.84757	12DB132
700	Concrete	0.85896	0.00093	0.86082	12DB134
800	Concrete	0.86696	0.00093	0.86882	12DB136
900	Concrete	0.87117	0.00087	0.87291	12DB138
1000	Concrete	0.87037	0.00085	0.87207	12DB140
1100	Concrete	0.86843	0.00082	0.87007	12DB142
1200	Concrete	0.86616	0.00086	0.86788	12DB144
1300	Concrete	0.85952	0.00084	0.8612	12DB146
1400	Concrete	0.85700	0.00085	0.85870	12DB148
1500	Concrete	0.84963	0.00081	0.85125	12DB150

Table A-112, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 10 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.83964	0.00101	0.84166	12DB170
600	Concrete	0.85655	0.00106	0.85867	12DB172
700	Concrete	0.86673	0.00095	0.86863	12DB174
800	Concrete	0.87017	0.00103	0.87223	12DB176
900	Concrete	0.87181	0.00090	0.87361	12DB178
1000	Concrete	0.87185	0.00092	0.87369	12DB180
1100	Concrete	0.87004	0.00094	0.87192	12DB182
1200	Concrete	0.86551	0.00083	0.86717	12DB184
1300	Concrete	0.86230	0.00084	0.86398	12DB186
1400	Concrete	0.85706	0.00088	0.85882	12DB188
1500	Concrete	0.85209	0.00077	0.85363	12DB190

Be Overbatch Contingency Results for a Borehole Array Configuration of Direct Loaded Canisters in the Absence of Adjacent CH Waste from Section 7.1.2

Table A-113, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 25% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.80374	0.00107	0.80588	1DAB010
600	Salt	0.83306	0.00107	0.83520	1DAB012
700	Salt	0.84908	0.00115	0.85138	1DAB014
800	Salt	0.86071	0.00102	0.86275	1DAB016
900	Salt	0.87125	0.00102	0.87329	1DAB018
1000	Salt	0.87167	0.00104	0.87375	1DAB020
1100	Salt	0.87585	0.00099	0.87783	1DAB022
1200	Salt	0.87684	0.00097	0.87878	1DAB024
1300	Salt	0.87286	0.00084	0.87454	1DAB026
1400	Salt	0.86808	0.00085	0.86978	1DAB028
1500	Salt	0.86504	0.00095	0.86694	1DAB030

Table A-114, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and No Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77014	0.0010	0.77214	1DAB050
600	Salt	0.80166	0.00106	0.80378	1DAB052
700	Salt	0.82486	0.00102	0.82690	1DAB054
800	Salt	0.84353	0.00109	0.84571	1DAB056
900	Salt	0.85331	0.00100	0.85531	1DAB058
1000	Salt	0.86309	0.00098	0.86505	1DAB060
1100	Salt	0.86445	0.00097	0.86639	1DAB062
1200	Salt	0.86656	0.00091	0.86838	1DAB064
1300	Salt	0.86610	0.00092	0.86794	1DAB066
1400	Salt	0.86539	0.00082	0.86703	1DAB068
1500	Salt	0.86297	0.00090	0.86477	1DAB070

Table A-115, Array Results for Direct Loaded Canisters of 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 100% Dense Graphite

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77894	0.00096	0.78086	1DAB130
600	Salt	0.79824	0.00104	0.80032	1DAB132
700	Salt	0.81323	0.00088	0.81499	1DAB134
800	Salt	0.81912	0.00089	0.82090	1DAB136
900	Salt	0.82290	0.00094	0.82478	1DAB138
1000	Salt	0.82333	0.00090	0.82513	1DAB140
1100	Salt	0.82052	0.00092	0.82236	1DAB142
1200	Salt	0.81948	0.00082	0.82112	1DAB144
1300	Salt	0.81350	0.00082	0.81514	1DAB146
1400	Salt	0.80987	0.00083	0.81153	1DAB148
1500	Salt	0.80409	0.00091	0.80591	1DAB150

Table A-116, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 100% Dense Polyethylene and Reflected by 64 kg of Be and 100% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89120	0.00096	0.89312	1DAB170
600	Salt	0.90714	0.00093	0.90900	1DAB172
700	Salt	0.91838	0.00103	0.92044	1DAB174
800	Salt	0.92477	0.00096	0.92669	1DAB176
900	Salt	0.92525	0.00090	0.92705	1DAB178
1000	Salt	0.92422	0.00090	0.92602	1DAB180
1100	Salt	0.92014	0.00085	0.92184	1DAB182
1200	Salt	0.91714	0.00086	0.91886	1DAB184
1300	Salt	0.91084	0.00083	0.91250	1DAB186
1400	Salt	0.90343	0.00084	0.90511	1DAB188
1500	Salt	0.89729	0.00084	0.89897	1DAB190

Be Overbatch Contingency Results for a Borehole Array Configuration of Canisters Containing Three (3) 30-Gallon Drums in the Absence of Adjacent CH Waste from Section 7.1.2

Table A-117, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 25% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.66898	0.00100	0.67098	3DAB010
600	Salt	0.69916	0.00104	0.70124	3DAB012
700	Salt	0.72018	0.00098	0.72214	3DAB014
800	Salt	0.73504	0.00103	0.73710	3DAB016
900	Salt	0.74493	0.00089	0.74671	3DAB018
1000	Salt	0.75177	0.00098	0.75373	3DAB020
1100	Salt	0.75655	0.00093	0.75841	3DAB022
1200	Salt	0.76051	0.00089	0.76229	3DAB024
1300	Salt	0.76042	0.00088	0.76218	3DAB026
1400	Salt	0.76018	0.00081	0.76180	3DAB028
1500	Salt	0.75789	0.00089	0.75967	3DAB030

Table A-118, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and No Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.69724	0.00111	0.69946	3DAB050
600	Salt	0.73324	0.00113	0.73550	3DAB052
700	Salt	0.75894	0.00099	0.76092	3DAB054
800	Salt	0.77786	0.00091	0.77968	3DAB056
900	Salt	0.79112	0.00093	0.79298	3DAB058
1000	Salt	0.80038	0.00085	0.80208	3DAB060
1100	Salt	0.80400	0.00088	0.80576	3DAB062
1200	Salt	0.80883	0.00085	0.81053	3DAB064
1300	Salt	0.80982	0.00084	0.81150	3DAB066
1400	Salt	0.81181	0.00086	0.81353	3DAB068
1500	Salt	0.80793	0.00076	0.80945	3DAB070

Table A-119, Array Results for a Canister of 3 30-gallon Drums Each Containing 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 64 kg of Be and 100% Dense Graphite

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.78227	0.00099	0.78425	3DAB130
600	Salt	0.80198	0.00099	0.80396	3DAB132
700	Salt	0.81525	0.00098	0.81721	3DAB134
800	Salt	0.82117	0.00086	0.82289	3DAB136
900	Salt	0.82558	0.00096	0.82750	3DAB138
1000	Salt	0.82658	0.00093	0.82844	3DAB140
1100	Salt	0.82557	0.00092	0.82741	3DAB142
1200	Salt	0.82200	0.00088	0.82376	3DAB144
1300	Salt	0.81923	0.00083	0.82089	3DAB146
1400	Salt	0.81395	0.00081	0.81557	3DAB148
1500	Salt	0.80770	0.00076	0.80922	3DAB150

Table A-120, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 100% Dense Polyethylene and Reflected by 64 kg of Be and 100% Dense Polyethylene

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.84469	0.00094	0.84657	3DAB170
600	Salt	0.86095	0.00099	0.86293	3DAB172
700	Salt	0.87079	0.00098	0.87275	3DAB174
800	Salt	0.87596	0.00095	0.87786	3DAB176
900	Salt	0.87966	0.00087	0.88140	3DAB178
1000	Salt	0.87968	0.00087	0.88142	3DAB180
1100	Salt	0.87867	0.00095	0.88057	3DAB182
1200	Salt	0.87537	0.00095	0.87727	3DAB184
1300	Salt	0.86773	0.00090	0.86953	3DAB186
1400	Salt	0.86397	0.00081	0.86559	3DAB188
1500	Salt	0.85731	0.00080	0.85891	3DAB190

Partial and Full Flooding Contingency for a Single Direct Loaded Canister from Section 7.1.3

Table A-121, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 18.75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.83386	0.00105	0.83596	1DCW310
600	Lead	0.85562	0.00111	0.85784	1DCW312
700	Lead	0.86947	0.00102	0.87151	1DCW314
800	Lead	0.88030	0.00100	0.88230	1DCW316
900	Lead	0.88554	0.00092	0.88738	1DCW318
1000	Lead	0.88903	0.00094	0.89091	1DCW320
1100	Lead	0.88827	0.00095	0.89017	1DCW322
1200	Lead	0.88665	0.00092	0.88849	1DCW324
1300	Lead	0.88398	0.00094	0.88586	1DCW326
1400	Lead	0.87657	0.00093	0.87843	1DCW328
1500	Lead	0.87380	0.00089	0.87558	1DCW330

Table A-122, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 37.5% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.85839	0.00103	0.86045	1DCW350
600	Lead	0.88055	0.00109	0.88273	1DCW352
700	Lead	0.89093	0.00103	0.89299	1DCW354
800	Lead	0.89979	0.00099	0.90177	1DCW356
900	Lead	0.90428	0.00095	0.90618	1DCW358
1000	Lead	0.90606	0.00094	0.90794	1DCW360
1100	Lead	0.90434	0.00091	0.90616	1DCW362
1200	Lead	0.90159	0.00093	0.90345	1DCW364
1300	Lead	0.89672	0.00091	0.89854	1DCW366
1400	Lead	0.89055	0.00081	0.89217	1DCW368
1500	Lead	0.88278	0.00086	0.88450	1DCW370

Table A-123, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 56.25% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.87778	0.00102	0.87982	1DCW390
600	Lead	0.89776	0.00108	0.89992	1DCW392
700	Lead	0.90747	0.00098	0.90943	1DCW394
800	Lead	0.91554	0.00102	0.91758	1DCW396
900	Lead	0.91657	0.00098	0.91853	1DCW398
1000	Lead	0.91769	0.00090	0.91949	1DCW400
1100	Lead	0.91292	0.00100	0.91492	1DCW402
1200	Lead	0.91144	0.00093	0.91330	1DCW404
1300	Lead	0.90509	0.00087	0.90683	1DCW406
1400	Lead	0.89820	0.00091	0.90002	1DCW408
1500	Lead	0.89388	0.00083	0.89554	1DCW410

Table A-124, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89390	0.00103	0.89596	1DCW010
600	Lead	0.91199	0.00101	0.91401	1DCW012
700	Lead	0.91995	0.00101	0.92197	1DCW014
800	Lead	0.92577	0.00095	0.92767	1DCW016
900	Lead	0.92638	0.00089	0.92816	1DCW018
1000	Lead	0.92589	0.00092	0.92773	1DCW020
1100	Lead	0.92252	0.00097	0.92446	1DCW022
1200	Lead	0.91967	0.00089	0.92145	1DCW024
1300	Lead	0.91326	0.00090	0.91506	1DCW026
1400	Lead	0.90615	0.00087	0.90789	1DCW028
1500	Lead	0.89926	0.00075	0.90076	1DCW030

Table A-125, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 15% by Volume Polyethylene, 85% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89298	0.00104	0.89506	1DCW090
600	Lead	0.91158	0.00106	0.9137	1DCW092
700	Lead	0.91954	0.00104	0.92162	1DCW094
800	Lead	0.92341	0.00096	0.92533	1DCW096
900	Lead	0.92741	0.00105	0.92951	1DCW098
1000	Lead	0.92473	0.00088	0.92649	1DCW100
1100	Lead	0.92334	0.00089	0.92512	1DCW102
1200	Lead	0.91861	0.00089	0.92039	1DCW104
1300	Lead	0.91218	0.00084	0.91386	1DCW106
1400	Lead	0.90457	0.00083	0.90623	1DCW108
1500	Lead	0.89788	0.00086	0.89960	1DCW110

Table A-126, Results for a Single Direct Loaded Canister with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 5% by Volume Polyethylene, 95% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.89066	0.00116	0.89298	1DCW170
600	Lead	0.90874	0.00101	0.91076	1DCW172
700	Lead	0.91908	0.00092	0.92092	1DCW174
800	Lead	0.92252	0.00106	0.92464	1DCW176
900	Lead	0.92612	0.00091	0.92794	1DCW178
1000	Lead	0.92563	0.00095	0.92753	1DCW180
1100	Lead	0.92062	0.00094	0.92250	1DCW182
1200	Lead	0.91593	0.00089	0.91771	1DCW184
1300	Lead	0.91052	0.00083	0.91218	1DCW186
1400	Lead	0.90612	0.00082	0.90776	1DCW188
1500	Lead	0.89865	0.00079	0.90023	1DCW190

Partial and Full Flooding Contingency for a Canister Containing Three (3) 30-Gallon Drums from Section 7.1.3

Table A-127, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 18.75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.70256	0.00101	0.70458	3DBW310
600	Lead	0.72842	0.00103	0.73048	3DBW312
700	Lead	0.74679	0.00096	0.74871	3DBW314
800	Lead	0.75844	0.00097	0.76038	3DBW316
900	Lead	0.76672	0.00093	0.76858	3DBW318
1000	Lead	0.77005	0.00089	0.77183	3DBW320
1100	Lead	0.77507	0.00094	0.77695	3DBW322
1200	Lead	0.77625	0.00101	0.77827	3DBW324
1300	Lead	0.77553	0.00084	0.77721	3DBW326
1400	Lead	0.77332	0.00077	0.77486	3DBW328
1500	Lead	0.77191	0.00093	0.77377	3DBW330

Table A-128, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 37.5% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.7364	0.00099	0.73838	3DBW350
600	Lead	0.75813	0.00103	0.76019	3DBW352
700	Lead	0.77279	0.00103	0.77485	3DBW354
800	Lead	0.78348	0.00097	0.78542	3DBW356
900	Lead	0.79012	0.00090	0.79192	3DBW358
1000	Lead	0.79174	0.00088	0.79350	3DBW360
1100	Lead	0.79449	0.00092	0.79633	3DBW362
1200	Lead	0.79341	0.00089	0.79519	3DBW364
1300	Lead	0.79089	0.00092	0.79273	3DBW366
1400	Lead	0.78933	0.00077	0.79087	3DBW368
1500	Lead	0.78515	0.00084	0.78683	3DBW370

Table A-129, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 56.25% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.75974	0.00111	0.76196	3DBW390
600	Lead	0.77936	0.00106	0.78148	3DBW392
700	Lead	0.79410	0.00101	0.79612	3DBW394
800	Lead	0.79914	0.00094	0.80102	3DBW396
900	Lead	0.80500	0.00092	0.80684	3DBW398
1000	Lead	0.80794	0.00097	0.80988	3DBW400
1100	Lead	0.80741	0.00092	0.80925	3DBW402
1200	Lead	0.80698	0.00099	0.80896	3DBW404
1300	Lead	0.80374	0.00084	0.80542	3DBW406
1400	Lead	0.79897	0.00083	0.80063	3DBW408
1500	Lead	0.79667	0.00083	0.79833	3DBW410

Table A-130, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.77851	0.00108	0.78067	3DBW010
600	Lead	0.79802	0.00104	0.80010	3DBW012
700	Lead	0.80945	0.00107	0.81159	3DBW014
800	Lead	0.81523	0.00101	0.81725	3DBW016
900	Lead	0.82091	0.00092	0.82275	3DBW018
1000	Lead	0.81997	0.00093	0.82183	3DBW020
1100	Lead	0.82015	0.00091	0.82197	3DBW022
1200	Lead	0.81695	0.00092	0.81879	3DBW024
1300	Lead	0.81275	0.00086	0.81447	3DBW026
1400	Lead	0.81175	0.00085	0.81345	3DBW028
1500	Lead	0.80322	0.00077	0.80476	3DBW030

Table A-131, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 15% by Volume Polyethylene, 85% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.77922	0.00102	0.78126	3DBW090
600	Lead	0.79299	0.00094	0.79487	3DBW092
700	Lead	0.80681	0.00103	0.80887	3DBW094
800	Lead	0.81238	0.00096	0.81430	3DBW096
900	Lead	0.81774	0.00097	0.81968	3DBW098
1000	Lead	0.82158	0.00090	0.82338	3DBW100
1100	Lead	0.81857	0.00091	0.82039	3DBW102
1200	Lead	0.81590	0.00086	0.81762	3DBW104
1300	Lead	0.81371	0.00085	0.81541	3DBW106
1400	Lead	0.80801	0.00086	0.80973	3DBW108
1500	Lead	0.80403	0.00079	0.80561	3DBW110

Table A-132, Results for a Canister of 3 30-gallon Drums each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 5% by Volume Polyethylene, 95% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.77479	0.00113	0.77705	3DBW170
600	Lead	0.79449	0.00089	0.79627	3DBW172
700	Lead	0.80554	0.00093	0.80740	3DBW174
800	Lead	0.81178	0.00084	0.81346	3DBW176
900	Lead	0.81673	0.00094	0.81861	3DBW178
1000	Lead	0.81763	0.00095	0.81953	3DBW180
1100	Lead	0.81518	0.00090	0.81698	3DBW182
1200	Lead	0.81560	0.00085	0.81730	3DBW184
1300	Lead	0.81171	0.00084	0.81339	3DBW186
1400	Lead	0.80605	0.00077	0.80759	3DBW188
1500	Lead	0.80284	0.00084	0.80452	3DBW190

Partial and Full Flooding Contingency Results for a Conventional Configuration of Twelve (12) 30-Gallon Drums in the Hot Cell from Section 7.1.3

Table A-133, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 18.75% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.71645	0.00098	0.71841	12DW310
600	Concrete	0.74371	0.00101	0.74573	12DW312
700	Concrete	0.76235	0.00099	0.76433	12DW314
800	Concrete	0.77682	0.00088	0.77858	12DW316
900	Concrete	0.78388	0.00104	0.78596	12DW318
1000	Concrete	0.79074	0.00090	0.79254	12DW320
1100	Concrete	0.79471	0.00088	0.79647	12DW322
1200	Concrete	0.79476	0.00087	0.79650	12DW324
1300	Concrete	0.79646	0.00091	0.79828	12DW326
1400	Concrete	0.79342	0.00089	0.79520	12DW328
1500	Concrete	0.79008	0.00084	0.79176	12DW330

Table A-134, Results for 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 37.5% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.74398	0.00107	0.74612	12DW350
600	Concrete	0.76764	0.00100	0.76964	12DW352
700	Concrete	0.78220	0.00099	0.78418	12DW354
800	Concrete	0.79066	0.00091	0.79248	12DW356
900	Concrete	0.79849	0.00101	0.80051	12DW358
1000	Concrete	0.80067	0.00101	0.80269	12DW360
1100	Concrete	0.80223	0.00086	0.80395	12DW362
1200	Concrete	0.80547	0.00086	0.80719	12DW364
1300	Concrete	0.80344	0.00093	0.80530	12DW366
1400	Concrete	0.80008	0.00094	0.80196	12DW368
1500	Concrete	0.79776	0.00084	0.79944	12DW370

Table A-135, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 56.25% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.76086	0.00100	0.76286	12DW390
600	Concrete	0.78275	0.00107	0.78489	12DW392
700	Concrete	0.79822	0.00089	0.80000	12DW394
800	Concrete	0.80504	0.00091	0.80686	12DW396
900	Concrete	0.81070	0.00097	0.81264	12DW398
1000	Concrete	0.81266	0.00089	0.81444	12DW400
1100	Concrete	0.81359	0.00099	0.81557	12DW402
1200	Concrete	0.81292	0.00085	0.81462	12DW404
1300	Concrete	0.81001	0.00088	0.81177	12DW406
1400	Concrete	0.80597	0.00084	0.80765	12DW408
1500	Concrete	0.80193	0.00085	0.80363	12DW410

Table A-136, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 75% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.78155	0.00108	0.78371	12DW010
600	Concrete	0.79927	0.00097	0.80121	12DW012
700	Concrete	0.81165	0.00095	0.81355	12DW014
800	Concrete	0.81602	0.00100	0.81802	12DW016
900	Concrete	0.82185	0.00097	0.82379	12DW018
1000	Concrete	0.82249	0.00092	0.82433	12DW020
1100	Concrete	0.82159	0.00084	0.82327	12DW022
1200	Concrete	0.82017	0.00094	0.82205	12DW024
1300	Concrete	0.81705	0.00085	0.81875	12DW026
1400	Concrete	0.81263	0.00079	0.81421	12DW028
1500	Concrete	0.80732	0.00080	0.80892	12DW030

Table A-137, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 15% by Volume Polyethylene, 85% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.77951	0.00107	0.78165	12DW090
600	Concrete	0.79863	0.00099	0.80061	12DW092
700	Concrete	0.80914	0.00101	0.81116	12DW094
800	Concrete	0.81698	0.00100	0.81898	12DW096
900	Concrete	0.82128	0.00092	0.82312	12DW098
1000	Concrete	0.82175	0.00085	0.82345	12DW100
1100	Concrete	0.81960	0.00090	0.82140	12DW102
1200	Concrete	0.81923	0.00094	0.82111	12DW104
1300	Concrete	0.81588	0.00089	0.81766	12DW106
1400	Concrete	0.81255	0.00082	0.81419	12DW108
1500	Concrete	0.80763	0.00082	0.80927	12DW110

Table A-138, Results for 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 5% by Volume Polyethylene, 95% by Volume Water, and 5 kg of Be per Drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.77843	0.00093	0.78029	12DW170
600	Concrete	0.79792	0.00102	0.79996	12DW172
700	Concrete	0.80906	0.00100	0.81106	12DW174
800	Concrete	0.81417	0.00101	0.81619	12DW176
900	Concrete	0.82090	0.00090	0.82270	12DW178
1000	Concrete	0.82150	0.00089	0.82328	12DW180
1100	Concrete	0.81852	0.00089	0.82030	12DW182
1200	Concrete	0.81827	0.00091	0.82009	12DW184
1300	Concrete	0.81400	0.00086	0.81572	12DW186
1400	Concrete	0.81147	0.00086	0.81319	12DW188
1500	Concrete	0.80885	0.00077	0.81039	12DW190

Partial and Full Flooding Contingency Results for a Borehole Array Configuration of Direct Loaded Canisters in the Absence of Adjacent CH Waste from Section 7.1.3

Table A-139, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 18.75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.83134	0.00106	0.83346	1DAW310
600	Salt	0.85419	0.00099	0.85617	1DAW312
700	Salt	0.87024	0.00099	0.87222	1DAW314
800	Salt	0.87932	0.00095	0.88122	1DAW316
900	Salt	0.88605	0.00096	0.88797	1DAW318
1000	Salt	0.88904	0.00105	0.89114	1DAW320
1100	Salt	0.88811	0.00090	0.88991	1DAW322
1200	Salt	0.88881	0.00084	0.89049	1DAW324
1300	Salt	0.88476	0.00095	0.88666	1DAW326
1400	Salt	0.88003	0.00090	0.88183	1DAW328
1500	Salt	0.87458	0.00088	0.87634	1DAW330

Table A-140, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 37.5% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.85767	0.00106	0.85979	1DAW350
600	Salt	0.88023	0.00098	0.88219	1DAW352
700	Salt	0.89061	0.00104	0.89269	1DAW354
800	Salt	0.89985	0.00110	0.90205	1DAW356
900	Salt	0.90502	0.00094	0.90690	1DAW358
1000	Salt	0.90330	0.00093	0.90516	1DAW360
1100	Salt	0.90412	0.00103	0.90618	1DAW362
1200	Salt	0.90103	0.00089	0.90281	1DAW364
1300	Salt	0.89699	0.00096	0.89891	1DAW366
1400	Salt	0.89250	0.00091	0.89432	1DAW368
1500	Salt	0.88503	0.00084	0.88671	1DAW370

Table A-141, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 56.25% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.87815	0.00105	0.88025	1DAW390
600	Salt	0.89635	0.00104	0.89843	1DAW392
700	Salt	0.90758	0.00109	0.90976	1DAW394
800	Salt	0.91467	0.00094	0.91655	1DAW396
900	Salt	0.91578	0.00095	0.91768	1DAW398
1000	Salt	0.91753	0.00097	0.91947	1DAW400
1100	Salt	0.91615	0.00101	0.91817	1DAW402
1200	Salt	0.91008	0.00084	0.91176	1DAW404
1300	Salt	0.90556	0.00085	0.90726	1DAW406
1400	Salt	0.89930	0.00089	0.90108	1DAW408
1500	Salt	0.89372	0.00084	0.89540	1DAW410

Table A-142, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89449	0.00106	0.89661	1DAW010
600	Salt	0.91115	0.00105	0.91325	1DAW012
700	Salt	0.92237	0.00106	0.92449	1DAW014
800	Salt	0.92510	0.00101	0.92712	1DAW016
900	Salt	0.92718	0.00101	0.92920	1DAW018
1000	Salt	0.92502	0.00101	0.92704	1DAW020
1100	Salt	0.92293	0.00090	0.92473	1DAW022
1200	Salt	0.91810	0.00090	0.91990	1DAW024
1300	Salt	0.91339	0.00089	0.91517	1DAW026
1400	Salt	0.90582	0.00087	0.90756	1DAW028
1500	Salt	0.89917	0.00082	0.90081	1DAW030

Table A-143, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 15% by Volume Polyethylene, 85% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89297	0.00093	0.89483	1DAW090
600	Salt	0.90870	0.00097	0.91064	1DAW092
700	Salt	0.91905	0.00096	0.92097	1DAW094
800	Salt	0.92429	0.00092	0.92613	1DAW096
900	Salt	0.92366	0.00090	0.92546	1DAW098
1000	Salt	0.92581	0.00097	0.92775	1DAW100
1100	Salt	0.92308	0.00093	0.92494	1DAW102
1200	Salt	0.91843	0.00087	0.92017	1DAW104
1300	Salt	0.91071	0.00084	0.91239	1DAW106
1400	Salt	0.90587	0.00080	0.90747	1DAW108
1500	Salt	0.89884	0.00073	0.90030	1DAW110

Table A-144, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 5% by Volume Polyethylene, 95% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.89346	0.00104	0.89554	1DAW170
600	Salt	0.90783	0.00098	0.90979	1DAW172
700	Salt	0.91538	0.00096	0.91730	1DAW174
800	Salt	0.92273	0.00093	0.92459	1DAW176
900	Salt	0.92428	0.00093	0.92614	1DAW178
1000	Salt	0.92383	0.00099	0.92581	1DAW180
1100	Salt	0.91922	0.00091	0.92104	1DAW182
1200	Salt	0.91824	0.00089	0.92002	1DAW184
1300	Salt	0.91240	0.00089	0.91418	1DAW186
1400	Salt	0.90468	0.00079	0.90626	1DAW188
1500	Salt	0.89983	0.00081	0.90145	1DAW190

Partial and Full Flooding Contingency Results for a Borehole Array Configuration of Canisters Containing Three (3) 30-Gallon Drums in the Absence of Adjacent CH Waste from Section 7.1.3

Table A-145, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 18.75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.70473	0.00100	0.70673	3DAW310
600	Salt	0.72744	0.00095	0.72934	3DAW312
700	Salt	0.74487	0.00098	0.74683	3DAW314
800	Salt	0.75862	0.00099	0.76060	3DAW316
900	Salt	0.76611	0.00094	0.76799	3DAW318
1000	Salt	0.77331	0.00095	0.77521	3DAW320
1100	Salt	0.77514	0.00091	0.77696	3DAW322
1200	Salt	0.77630	0.00091	0.77812	3DAW324
1300	Salt	0.77595	0.00089	0.77773	3DAW326
1400	Salt	0.77463	0.00098	0.77659	3DAW328
1500	Salt	0.77040	0.00081	0.77202	3DAW330

Table A-146, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 37.5% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.73415	0.00099	0.73613	3DAW350
600	Salt	0.75743	0.00098	0.75939	3DAW352
700	Salt	0.77356	0.00091	0.77538	3DAW354
800	Salt	0.78150	0.00094	0.78338	3DAW356
900	Salt	0.78937	0.00098	0.79133	3DAW358
1000	Salt	0.79220	0.00094	0.79408	3DAW360
1100	Salt	0.79405	0.00089	0.79583	3DAW362
1200	Salt	0.79449	0.00089	0.79627	3DAW364
1300	Salt	0.79206	0.00086	0.79378	3DAW366
1400	Salt	0.78775	0.00090	0.78955	3DAW368
1500	Salt	0.78457	0.00088	0.78633	3DAW370

Table A-147, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 56.75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.75974	0.00091	0.76156	3DAW390
600	Salt	0.78078	0.00104	0.78286	3DAW392
700	Salt	0.79460	0.00103	0.79666	3DAW394
800	Salt	0.80111	0.00093	0.80297	3DAW396
900	Salt	0.80752	0.00095	0.80942	3DAW398
1000	Salt	0.80621	0.00097	0.80815	3DAW400
1100	Salt	0.80830	0.00095	0.81020	3DAW402
1200	Salt	0.80908	0.00094	0.81096	3DAW404
1300	Salt	0.80519	0.00090	0.80699	3DAW406
1400	Salt	0.79914	0.00088	0.80000	3DAW408
1500	Salt	0.79558	0.00084	0.79726	3DAW410

Table A-148, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 25% by Volume Polyethylene, 75% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.78066	0.00093	0.78252	3DAW010
600	Salt	0.79685	0.00100	0.79885	3DAW012
700	Salt	0.80766	0.00097	0.80960	3DAW014
800	Salt	0.81635	0.00092	0.81819	3DAW016
900	Salt	0.81974	0.00087	0.82148	3DAW018
1000	Salt	0.82060	0.00090	0.82240	3DAW020
1100	Salt	0.81747	0.00087	0.81921	3DAW022
1200	Salt	0.81678	0.00086	0.81850	3DAW024
1300	Salt	0.81313	0.00090	0.81493	3DAW026
1400	Salt	0.80834	0.00089	0.81012	3DAW028
1500	Salt	0.80403	0.00085	0.80573	3DAW030

Table A-149, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 15% by Volume Polyethylene, 85% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77708	0.00091	0.77890	3DAW090
600	Salt	0.79351	0.00088	0.79527	3DAW092
700	Salt	0.80811	0.00095	0.81001	3DAW094
800	Salt	0.81356	0.00094	0.81544	3DAW096
900	Salt	0.81879	0.00092	0.82063	3DAW098
1000	Salt	0.81927	0.00093	0.82113	3DAW100
1100	Salt	0.81917	0.00088	0.82093	3DAW102
1200	Salt	0.81674	0.00083	0.81840	3DAW104
1300	Salt	0.81173	0.00080	0.81333	3DAW106
1400	Salt	0.80751	0.00084	0.80919	3DAW108
1500	Salt	0.80299	0.00084	0.80467	3DAW110

Table A-150, Array Results for a Canister of 3 30-gallon Drums Each Containing 200 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by a Mixture of 5% by Volume Polyethylene, 95% by Volume Water, and 32 kg of Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt	0.77577	0.00101	0.77779	3DAW170
600	Salt	0.79315	0.00107	0.79529	3DAW172
700	Salt	0.80486	0.00106	0.80698	3DAW174
800	Salt	0.81234	0.00092	0.81418	3DAW176
900	Salt	0.81800	0.00099	0.81998	3DAW178
1000	Salt	0.81829	0.00094	0.82017	3DAW180
1100	Salt	0.81621	0.00089	0.81799	3DAW182
1200	Salt	0.81477	0.00088	0.81653	3DAW184
1300	Salt	0.81238	0.00081	0.81400	3DAW186
1400	Salt	0.80812	0.00083	0.80978	3DAW188
1500	Salt	0.80393	0.00085	0.80563	3DAW190

LEU Single Direct Loaded Canister Results from Section 7.1.4

Table A-151, Results for a Single Direct Loaded Canister with LEU at Various Enrichments Moderated by a 25% Polyethylene/ 74% Water/ 1% Be Mixture at H/^{235}U Ratio of 400

Enrichment	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
0.96 wt%	Lead	0.91146	0.00065	0.91276	1DUL096
1.10 wt%	Lead	0.95787	0.00064	0.95915	1DUL110
1.25 wt%	Lead	0.99834	0.00072	0.99978	1DUL125

Table A-152, Array Results for a Direct Loaded Canister with LEU at Various Enrichments Moderated by a 25% Polyethylene/ 74% Water/ 1% Be Mixture at H/^{235}U Ratio of 400

Enrichment	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
0.96 wt%	Salt	0.91182	0.00070	0.91322	1DAU096
1.10 wt%	Salt	0.95648	0.00068	0.95784	1DAU110
1.25 wt%	Salt	1.00012	0.00072	1.00156	1DAU125

Loss of Interaction Control for the 30-Gallon Drums in the Upper Hot Cell from Section 7.1.5

Table A-153, Results for a 2 Tier Stack of 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.69599	0.00098	0.69795	12DI010
600	Concrete	0.72612	0.00104	0.7282	12DI012
700	Concrete	0.74791	0.00113	0.75017	12DI014
800	Concrete	0.76359	0.00094	0.76547	12DI016
900	Concrete	0.77417	0.00091	0.77599	12DI018
1000	Concrete	0.78507	0.00092	0.78691	12DI020
1100	Concrete	0.79005	0.00098	0.79201	12DI022
1200	Concrete	0.79296	0.00092	0.7948	12DI024
1300	Concrete	0.79717	0.00087	0.79891	12DI026
1400	Concrete	0.79469	0.00081	0.79631	12DI028
1500	Concrete	0.79610	0.00082	0.79774	12DI030

Table A-154, Results for a 2 Tier Stack of 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.89897	0.00099	0.90095	12DI050
600	Concrete	0.91358	0.00097	0.91552	12DI052
700	Concrete	0.91884	0.00092	0.92068	12DI054
800	Concrete	0.92322	0.00085	0.92492	12DI056
900	Concrete	0.91987	0.00087	0.92161	12DI058
1000	Concrete	0.91879	0.00089	0.92057	12DI060
1100	Concrete	0.91513	0.00087	0.91687	12DI062
1200	Concrete	0.90977	0.00089	0.91155	12DI064
1300	Concrete	0.90144	0.00086	0.90316	12DI066
1400	Concrete	0.89455	0.00078	0.89611	12DI068
1500	Concrete	0.88630	0.00079	0.88788	12DI070

Table A-155, Results for a 2 Tier Stack of 12 30-Gallon Drums Each Containing a Centrally Located 100 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.84115	0.00099	0.84313	12DI130
600	Concrete	0.86018	0.00094	0.86206	12DI132
700	Concrete	0.87543	0.00100	0.87743	12DI134
800	Concrete	0.88164	0.00088	0.8834	12DI136
900	Concrete	0.88309	0.00096	0.88501	12DI138
1000	Concrete	0.88599	0.00085	0.88769	12DI140
1100	Concrete	0.88663	0.00086	0.88835	12DI142
1200	Concrete	0.88156	0.00085	0.88326	12DI144
1300	Concrete	0.87536	0.00079	0.87694	12DI146
1400	Concrete	0.87105	0.00084	0.87273	12DI148
1500	Concrete	0.86546	0.00080	0.86706	12DI150

Table A-156, Results for a 2 Tier Stack of 12 30-Gallon Drums Each Containing a Centrally Located 120 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 70% Dense Graphite with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.81635	0.00106	0.81847	12DI170
600	Concrete	0.83962	0.00098	0.84158	12DI172
700	Concrete	0.85875	0.00092	0.86059	12DI174
800	Concrete	0.86966	0.00092	0.87150	12DI176
900	Concrete	0.87497	0.00089	0.87675	12DI178
1000	Concrete	0.87764	0.00098	0.87960	12DI180
1100	Concrete	0.87973	0.00083	0.88139	12DI182
1200	Concrete	0.87610	0.00079	0.87768	12DI184
1300	Concrete	0.87274	0.00082	0.87438	12DI186
1400	Concrete	0.86917	0.00082	0.87081	12DI188
1500	Concrete	0.86359	0.00081	0.86521	12DI190

Table A-157, Results for a 2 Tier Stack of 12 30-Gallon Drums Each Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 5 kg Be/drum

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.84243	0.00102	0.84447	12DI210
600	Concrete	0.85845	0.00103	0.86051	12DI212
700	Concrete	0.86920	0.00102	0.87124	12DI214
800	Concrete	0.87668	0.00099	0.87866	12DI216
900	Concrete	0.87939	0.00094	0.88127	12DI218
1000	Concrete	0.87936	0.00097	0.88130	12DI220
1100	Concrete	0.87887	0.00092	0.88071	12DI222
1200	Concrete	0.87441	0.00092	0.87625	12DI224
1300	Concrete	0.86996	0.00085	0.87166	12DI226
1400	Concrete	0.86482	0.00086	0.86654	12DI228
1500	Concrete	0.85810	0.00084	0.85978	12DI230

Table A-158, Results for a 2-Tier Stack of 12 30-Gallon Drums Containing a Centrally Located 200 g ^{239}Pu Mass Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 5 kg of Be/drum (No Polyethylene)

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
800	Concrete	0.78686	0.00097	0.78880	12DI256
900	Concrete	0.79969	0.00090	0.80149	12DI258
1000	Concrete	0.81364	0.00085	0.81534	12DI260
1100	Concrete	0.82015	0.00088	0.82191	12DI262
1200	Concrete	0.82558	0.00088	0.82734	12DI264
1300	Concrete	0.82837	0.00080	0.82997	12DI266
1400	Concrete	0.82759	0.00088	0.82935	12DI268
1500	Concrete	0.82924	0.00083	0.83090	12DI270
1600	Concrete	0.82669	0.00082	0.82833	12DI272
1700	Concrete	0.82447	0.00079	0.82605	12DI274
1800	Concrete	0.82174	0.00083	0.82340	12DI276

Results of RH Waste in the Borehole Array next to CH Waste in the Adjacent Room without a Shield Plug from Section 7.1.6

Table A-159, Array Results for Direct Loaded Canisters of 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by Polyethylene with 32 kg Be Adjacent to CH Waste Without a Shield Plug

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
25% Dense Polyethylene in Reflector					
500	Salt/CH	0.81107	0.00100	0.81307	1DAV010
600	Salt/CH	0.83336	0.00095	0.83526	1DAV012
700	Salt/CH	0.85396	0.00098	0.85592	1DAV014
800	Salt/CH	0.86559	0.00100	0.86759	1DAV016
900	Salt/CH	0.87124	0.00096	0.87316	1DAV018
1000	Salt/CH	0.87715	0.00092	0.87899	1DAV020
1100	Salt/CH	0.88036	0.00096	0.88228	1DAV022
1200	Salt/CH	0.87713	0.00099	0.87911	1DAV024
1300	Salt/CH	0.87861	0.00087	0.88035	1DAV026
1400	Salt/CH	0.87446	0.00088	0.87622	1DAV028
1500	Salt/CH	0.86961	0.00086	0.87133	1DAV030
No Polyethylene in Reflector					
500	Salt/CH	0.83056	0.00100	0.83256	1DAV050
600	Salt/CH	0.85410	0.00091	0.85592	1DAV052
700	Salt/CH	0.87180	0.00104	0.87388	1DAV054
800	Salt/CH	0.88637	0.00097	0.88831	1DAV056
900	Salt/CH	0.89361	0.00085	0.89531	1DAV058
1000	Salt/CH	0.90306	0.00093	0.90492	1DAV060
1100	Salt/CH	0.90123	0.00085	0.90293	1DAV062
1200	Salt/CH	0.90174	0.00086	0.90346	1DAV064
1300	Salt/CH	0.89996	0.00083	0.90162	1DAV066
1400	Salt/CH	0.89682	0.00089	0.89860	1DAV068
1500	Salt/CH	0.89317	0.00083	0.89483	1DAV070

Table A-160, Array Results for Direct Loaded Canisters of 245 g ^{239}Pu Moderated by 100% Dense Polyethylene and Reflected by 100% Dense Polyethylene with 32 kg Be Adjacent to CH Waste Without a Shield Plug

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Salt/CH	0.87602	0.00109	0.87820	1DAV110
600	Salt/CH	0.89597	0.00099	0.89795	1DAV112
700	Salt/CH	0.90710	0.00100	0.90910	1DAV114
800	Salt/CH	0.91320	0.00094	0.91508	1DAV116
900	Salt/CH	0.91557	0.00097	0.91751	1DAV118
1000	Salt/CH	0.91645	0.00086	0.91817	1DAV120
1100	Salt/CH	0.91124	0.00103	0.91330	1DAV122
1200	Salt/CH	0.90918	0.00093	0.91104	1DAV124
1300	Salt/CH	0.90317	0.00091	0.90499	1DAV126
1400	Salt/CH	0.89795	0.00085	0.89965	1DAV128
1500	Salt/CH	0.89103	0.00085	0.89273	1DAV130

Loss of Interaction Control During Receipt and Interim Storage of RH Waste in the WHB from Section 7.1.9

Table A-161, Results for an Infinite Planar Array of Single Direct Loaded Canisters with 325 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.80034	0.00100	0.80234	1ACL010
600	Lead	0.83146	0.00099	0.83344	1ACL012
700	Lead	0.85239	0.00102	0.85443	1ACL014
800	Lead	0.86469	0.00097	0.86663	1ACL016
900	Lead	0.87215	0.00092	0.87399	1ACL018
1000	Lead	0.87624	0.00099	0.87822	1ACL020
1100	Lead	0.87871	0.00089	0.88049	1ACL022
1200	Lead	0.87831	0.00099	0.88029	1ACL024
1300	Lead	0.87685	0.00087	0.87859	1ACL026
1400	Lead	0.8753	0.00087	0.87704	1ACL028
1500	Lead	0.87153	0.00084	0.87321	1ACL030

Table A-162, Results for an Infinite Planar Array of Single Direct Loaded Canisters with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.87495	0.00096	0.87687	1ACL050
600	Lead	0.89139	0.00100	0.89339	1ACL052
700	Lead	0.89718	0.00096	0.89910	1ACL054
800	Lead	0.89840	0.00092	0.90024	1ACL056
900	Lead	0.89724	0.00087	0.89898	1ACL058
1000	Lead	0.89622	0.00085	0.89792	1ACL060
1100	Lead	0.88880	0.00085	0.89050	1ACL062
1200	Lead	0.88409	0.00088	0.88585	1ACL064
1300	Lead	0.87774	0.00086	0.87946	1ACL066
1400	Lead	0.87118	0.00086	0.87290	1ACL068
1500	Lead	0.86145	0.00077	0.86299	1ACL070

Table A-163, Results for an Infinite Array of Direct Loaded Canisters with 100 g ^{239}Pu Moderated by a 25% Polyethylene/ 75% Water Mixture and Reflected by 100% Dense Graphite with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.80174	0.00094	0.80362	1ACL130
600	Lead	0.82090	0.00101	0.82292	1ACL132
700	Lead	0.83654	0.00099	0.83852	1ACL134
800	Lead	0.84200	0.00094	0.84388	1ACL136
900	Lead	0.84478	0.00091	0.84660	1ACL138
1000	Lead	0.84744	0.00088	0.84920	1ACL140
1100	Lead	0.84655	0.00093	0.84841	1ACL142
1200	Lead	0.84240	0.00090	0.84420	1ACL144
1300	Lead	0.83902	0.00079	0.84060	1ACL146
1400	Lead	0.83255	0.00084	0.83423	1ACL148
1500	Lead	0.82796	0.00083	0.82962	1ACL150

Table A-164, Results for an Infinite Array of Single Direct Loaded Canisters with 245 g ^{239}Pu Moderated by100% Dense Polyethylene and Reflected with 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Lead	0.88998	0.00106	0.89210	1ACL210
600	Lead	0.90587	0.00097	0.90781	1ACL212
700	Lead	0.91623	0.00104	0.91831	1ACL214
800	Lead	0.91945	0.00087	0.92119	1ACL216
900	Lead	0.92345	0.00096	0.92537	1ACL218
1000	Lead	0.92271	0.00094	0.92459	1ACL220
1100	Lead	0.91825	0.00093	0.92011	1ACL222
1200	Lead	0.91509	0.00092	0.91693	1ACL224
1300	Lead	0.90987	0.00089	0.91165	1ACL226
1400	Lead	0.90342	0.00086	0.90514	1ACL228
1500	Lead	0.89575	0.00086	0.89747	1ACL230

Table A-165, Results for a 3-Inch Lead Lined 30-Gallon Drum Containing 245 g ^{239}Pu Moderated by100% Dense Polyethylene and Reflected with 100% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
500	Concrete	0.89508	0.00103	0.89714	3DLLR10
600	Concrete	0.90855	0.00101	0.91057	3DLLR12
700	Concrete	0.92225	0.00097	0.92419	3DLLR14
800	Concrete	0.92819	0.00099	0.93017	3DLLR16
900	Concrete	0.93044	0.00094	0.93232	3DLLR18
1000	Concrete	0.93015	0.00094	0.93203	3DLLR20
1100	Concrete	0.92711	0.00091	0.92893	3DLLR22
1200	Concrete	0.92349	0.00085	0.92519	3DLLR24
1300	Concrete	0.91741	0.00091	0.91923	3DLLR26
1400	Concrete	0.91158	0.00085	0.91328	3DLLR28
1500	Concrete	0.90647	0.00077	0.90801	3DLLR30

Single Direct Loaded NS15 Canister Results from Section 5.4.1

Table A-166, Results for an NS15 Single Direct Loaded Canister with a Central Located FGE 245 g ^{239}Pu Moderated by a 25% Polyethylene and 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
1000	Lead	0.80231	0.00093	0.80417	25ncl10
1100	Lead	0.80826	0.00069	0.80964	25ncl11
1200	Lead	0.80796	0.00094	0.80984	25ncl12
1300	Lead	0.80777	0.00094	0.80965	25ncl13
1400	Lead	0.80580	0.00087	0.80754	25ncl14
1500	Lead	0.80182	0.00090	0.80362	25ncl15
1000	Concrete	0.80107	0.00096	0.80299	25ncc10
1100	Concrete	0.80664	0.00094	0.80852	25ncc11
1200	Concrete	0.80742	0.00097	0.80936	25ncc12
1300	Concrete	0.80675	0.00093	0.80861	25ncc13
1400	Concrete	0.80538	0.00094	0.80726	25ncc14
1500	Concrete	0.80194	0.00088	0.80370	25ncc15

Table A-167, Results for an NS15 Single Direct Loaded Canister with a Central Located FGE 245 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
1000	Lead	0.81788	0.00094	0.81976	25scl10
1100	Lead	0.82032	0.00106	0.82244	25scl11
1200	Lead	0.81922	0.00095	0.82112	25scl12
1300	Lead	0.82162	0.00104	0.82370	25scl13
1400	Lead	0.82029	0.00088	0.82205	25scl15
1500	Lead	0.81592	0.00090	0.81772	25scl14
1000	Concrete	0.81688	0.00095	0.81878	25scc10
1100	Concrete	0.81887	0.00098	0.82083	25scc11
1200	Concrete	0.82147	0.00096	0.82339	25scc12
1300	Concrete	0.82022	0.00099	0.82220	25scc13
1400	Concrete	0.81821	0.00089	0.81999	25scc14
1500	Concrete	0.81514	0.00092	0.81698	25scc15

Incorrect Waste Type Loaded into NS30 or NS15 Canister from Section 7.1.9

Table A-168, Results for an NS15 Single Direct Loaded Canister with a Central Located FGE 325 g ^{239}Pu Moderated by a 25% Polyethylene and 75% Water Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
900	Lead	0.87084	0.00098	0.87280	35ncl09
1000	Lead	0.87541	0.00092	0.87725	35ncl10
1100	Lead	0.87789	0.00104	0.87997	35ncl11
1200	Lead	0.87609	0.00094	0.87797	35ncl12
1300	Lead	0.87331	0.00088	0.87507	35ncl13
1400	Lead	0.87025	0.00089	0.87203	35ncl14
900	Concrete	0.86872	0.00098	0.87068	35ncc09
1000	Concrete	0.87439	0.00104	0.87647	35ncc10
1100	Concrete	0.87682	0.00087	0.87856	35ncc11
1200	Concrete	0.87610	0.00077	0.87764	35ncc12
1300	Concrete	0.87378	0.00091	0.87560	35ncc13
1400	Concrete	0.87144	0.00084	0.87312	35ncc14

Table A-169, Results for an NS15 Single Direct Loaded Canister with a Central Located FGE 305 g ^{239}Pu Moderated by a 15% Polyethylene/ 45% Water/ 40% Be Mixture and Reflected by 25% Dense Polyethylene with 32 kg Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
900	Lead	0.87259	0.00098	0.87455	35scl09
1000	Lead	0.87701	0.00091	0.87883	35scl10
1100	Lead	0.88234	0.00096	0.88426	35scl11
1200	Lead	0.87760	0.00094	0.87948	35scl12
1300	Lead	0.87641	0.00093	0.87827	35scl13
1400	Lead	0.87415	0.00086	0.87587	35scl14
900	Concrete	0.87191	0.00101	0.87393	35scc09
1000	Concrete	0.87995	0.00098	0.88191	35scc10
1100	Concrete	0.87744	0.00103	0.87950	35scc11
1200	Concrete	0.88055	0.00095	0.88245	35scc12
1300	Concrete	0.87747	0.00099	0.87945	35scc13
1400	Concrete	0.87505	0.00089	0.87683	35scc14

Table A-170, Results for an NS15 Single Direct Loaded Canister with a Centrally Located FGE 100 g ^{239}Pu Moderated by a 25% Polyethylene and 75% Water Mixture and Reflected by 100% Dense Be

H/Pu	Reflector	k_{eff}	σ	$k_{eff} + 2\sigma$	Filename
600	Lead	0.87072	0.00106	0.87284	15bcl06
700	Lead	0.87638	0.00089	0.87816	15bcl07
800	Lead	0.87774	0.00100	0.87974	15bcl08
900	Lead	0.87800	0.00094	0.87988	15bcl09
1000	Lead	0.87402	0.00098	0.87598	15bcl10
1100	Lead	0.86875	0.00094	0.87063	15bcl11
600	Concrete	0.87048	0.00105	0.87258	15bcc06
700	Concrete	0.87559	0.00103	0.87765	15bcc07
800	Concrete	0.87743	0.00095	0.87933	15bcc08
900	Concrete	0.87792	0.00086	0.87964	15bcc09
1000	Concrete	0.87399	0.00086	0.87571	15bcc10
1100	Concrete	0.86769	0.00084	0.86937	15bcc11

Appendix B

Sample MCNP5 Input Files for Appendix A

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B1.0 Sample Input Files

B1.1 Single Direct Loaded Canister with high Graphite and Lead Reflection (case 1DCL140)

```
C CCCC
```

```
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP         $
C                               CS-2003-003 REV0).                              $
C                                                                               $
C                                                                               $
M3     6000.60C      3.6371E-03                                                 $
      14000.60C      1.9442E-02                                                 $
      15031.60C      7.9333E-04                                                 $
      16032.60C      5.1087E-04                                                 $
      24050.60C      9.1366E-03                                                 $
      24052.60C      1.7599E-01                                                 $
      24053.60C      1.9954E-02                                                 $
      24054.60C      4.9569E-03                                                 $
      25055.60C      1.9879E-02                                                 $
      26054.60C      3.7092E-02                                                 $
      26056.60C      5.8175E-01                                                 $
      26057.60C      1.3442E-02                                                 $
      26058.60C      1.7754E-03                                                 $
      28058.60C      7.6006E-02                                                 $
      28060.60C      2.9273E-02                                                 $
      28061.60C      1.2727E-03                                                 $
      28062.60C      4.0525E-03                                                 $
      28064.60C      1.0383E-03                                                 $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH       $
C                               ADDENDUM TO WSMS-WIPP-00-003 REV2 AND           $
C                               WTS/WIPP CS-2003-003 REV0).                     $
C                                                                               $
M4     6000.60C      1.1921E-02                                                 $
      15031.60C      7.1117E-04                                                 $
      16032.60C      8.5868E-04                                                 $
      25055.60C      1.2029E-02                                                 $
      26054.60C      5.6447E-02                                                 $
      26056.60C      8.8530E-01                                                 $
      26057.60C      2.0456E-02                                                 $
      26058.60C      2.7017E-03                                                 $
      29063.60C      1.1989E-03                                                 $
      29065.60C      5.3435E-04                                                 $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                 $
      82207.60c      0.22100000                                                 $
      82208.60c      0.52400000                                                 $
C                                                                               $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO       $
C                       WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).   $
C                                                                               $
M6     1001.60C     -0.0056                                                    $
       8016.60C     -0.4981                                                    $
      11023.60C     -0.0171                                                    $
      12000.60C     -0.0026                                                    $
      13027.60C     -0.0457                                                    $
      14000.60C     -0.3151                                                    $
      16032.60C     -0.0013                                                    $
      19000.60C     -0.0192                                                    $
      20000.60C     -0.0829                                                    $
      26054.60C     -7.0065E-04                                                $
      26056.60C     -1.1395E-02                                                $
      26057.60C     -2.6801E-04                                                $
      26058.60C     -3.6018E-05                                                $
MT6   LWTR.01T                                                                  $
C                                                                               $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                         $
C                                                                               $
PRINT 40                                                                        $
C                                                                               $
C     PRINT TO MCTAL FILE                                                       $
C                                                                               $
PRDMP 2j 1                                                                      $
```

B1.2 Single Direct Loaded Canister containing 3 Drums of Compacted Waste with Lead Reflection (case 3DBL220)

```
C CCCC
```

```
C  BE-POLY REFLECTOR.                                                    $
C                                                                        $
M2     4009.60C     -0.038490                                           $
       6000.60C     -0.823234                                           $
       1001.60C     -0.138277                                           $
MT2   POLY.01T   BE.01T                                                  $
C                                                                        $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP  $
C                               CS-2003-003 REV0).                       $
C                                                                        $
C                                                                        $
M3     6000.60C      3.6371E-03                                          $
      14000.60C      1.9442E-02                                          $
      15031.60C      7.9333E-04                                          $
      16032.60C      5.1087E-04                                          $
      24050.60C      9.1366E-03                                          $
      24052.60C      1.7599E-01                                          $
      24053.60C      1.9954E-02                                          $
      24054.60C      4.9569E-03                                          $
      25055.60C      1.9879E-02                                          $
      26054.60C      3.7092E-02                                          $
      26056.60C      5.8175E-01                                          $
      26057.60C      1.3442E-02                                          $
      26058.60C      1.7754E-03                                          $
      28058.60C      7.6006E-02                                          $
      28060.60C      2.9273E-02                                          $
      28061.60C      1.2727E-03                                          $
      28062.60C      4.0525E-03                                          $
      28064.60C      1.0383E-03                                          $
C                                                                        $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH $
C                              ADDENDUM TO WSMS-WIPP-00-003 REV2 AND     $
C                              WTS/WIPP CS-2003-003 REV0).               $
C                                                                        $
M4     6000.60C      1.1921E-02                                          $
      15031.60C      7.1117E-04                                          $
      16032.60C      8.5868E-04                                          $
      25055.60C      1.2029E-02                                          $
      26054.60C      5.6447E-02                                          $
      26056.60C      8.8530E-01                                          $
      26057.60C      2.0456E-02                                          $
      26058.60C      2.7017E-03                                          $
      29063.60C      1.1989E-03                                          $
      29065.60C      5.3435E-04                                          $
C                                                                        $
C  LEAD REFLECTOR.                                                       $
C                                                                        $
M5    82206.60c      0.24100000                                          $
      82207.60c      0.22100000                                          $
      82208.60c      0.52400000                                          $
C                                                                        $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0). $
C                                                                        $
M6     1001.60C     -0.0056                                             $
       8016.60C     -0.4981                                             $
      11023.60C     -0.0171                                             $
      12000.60C     -0.0026                                             $
      13027.60C     -0.0457                                             $
      14000.60C     -0.3151                                             $
      16032.60C     -0.0013                                             $
      19000.60C     -0.0192                                             $
      20000.60C     -0.0829                                             $
      26054.60C     -7.0065E-04                                         $
      26056.60C     -1.1395E-02                                         $
      26057.60C     -2.6801E-04                                         $
      26058.60C     -3.6018E-05                                         $
MT6   LWTR.01T                                                           $
C                                                                        $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                  $
C                                                                        $
```

```
PRINT 40                                                                $
C                                                                       $
C     PRINT TO MCTAL FILE                                               $
C                                                                       $
PRDMP 2j 1                                                              $
```

B1.3 Two Drum Configuration in Canister with high Beryllium and Concrete Reflection (case 3DCC098)

```
C CCCC
```

```
KSRC  10 0 0  134 0 0  152 0 0                                                  $
C                                                                               $
C  MATERIAL CARDS                                                              $
C                                                                               $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 100 GRAMS OF PU.                 $
C                                                                               $
M1    94239.60C     -0.030509                                                   $
       1001.60C     -0.115771                                                   $
       8016.60C     -0.658153                                                   $
       6000.60C     -0.195566                                                   $
MT1   LWTR.01T   POLY.01T                                                       $
C                                                                               $
C  BE REFLECTOR.                                                                $
C                                                                               $
M2     4009.60C     -1.000000                                                   $
MT2   BE.01T                                                                    $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP         $
C                               CS-2003-003 REV0).                              $
C                                                                               $
C                                                                               $
M3     6000.60C      3.6371E-03                                                 $
      14000.60C      1.9442E-02                                                 $
      15031.60C      7.9333E-04                                                 $
      16032.60C      5.1087E-04                                                 $
      24050.60C      9.1366E-03                                                 $
      24052.60C      1.7599E-01                                                 $
      24053.60C      1.9954E-02                                                 $
      24054.60C      4.9569E-03                                                 $
      25055.60C      1.9879E-02                                                 $
      26054.60C      3.7092E-02                                                 $
      26056.60C      5.8175E-01                                                 $
      26057.60C      1.3442E-02                                                 $
      26058.60C      1.7754E-03                                                 $
      28058.60C      7.6006E-02                                                 $
      28060.60C      2.9273E-02                                                 $
      28061.60C      1.2727E-03                                                 $
      28062.60C      4.0525E-03                                                 $
      28064.60C      1.0383E-03                                                 $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH       $
C                               ADDENDUM TO WSMS-WIPP-00-003 REV2 AND           $
C                               WTS/WIPP CS-2003-003 REV0).                     $
C                                                                               $
M4     6000.60C      1.1921E-02                                                 $
      15031.60C      7.1117E-04                                                 $
      16032.60C      8.5868E-04                                                 $
      25055.60C      1.2029E-02                                                 $
      26054.60C      5.6447E-02                                                 $
      26056.60C      8.8530E-01                                                 $
      26057.60C      2.0456E-02                                                 $
      26058.60C      2.7017E-03                                                 $
      29063.60C      1.1989E-03                                                 $
      29065.60C      5.3435E-04                                                 $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                 $
      82207.60c      0.22100000                                                 $
      82208.60c      0.52400000                                                 $
C                                                                               $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO       $
C                       WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).   $
C                                                                               $
M6     1001.60C     -0.0056                                                    $
       8016.60C     -0.4981                                                    $
      11023.60C     -0.0171                                                    $
      12000.60C     -0.0026                                                    $
      13027.60C     -0.0457                                                    $
      14000.60C     -0.3151                                                    $
      16032.60C     -0.0013                                                    $
```

```
      19000.60C     -0.0192                                                 $
      20000.60C     -0.0829                                                 $
      26054.60C     -7.0065E-04                                             $
      26056.60C     -1.1395E-02                                             $
      26057.60C     -2.6801E-04                                             $
      26058.60C     -3.6018E-05                                             $
MT6   LWTR.01T                                                              $
C                                                                           $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                     $
C                                                                           $
PRINT 40                                                                    $
C                                                                           $
C     PRINT TO MCTAL FILE                                                   $
C                                                                           $
PRDMP 2j 1                                                                  $
```

B1.4 30-gallon Drum Explicit Model with Machine Compacted Waste and Concrete Reflection (case 3DCCR20)

```
C CCCC
```

```
14    PX    276.2250                                                    $
15    PX    307.3400                                                    $
20    PX      1.0739                                                    $
21    PX    143.0711                                                    $
22    PX    143.3139                                                    $
C                                                                       $
C     SURFACE CARDS FOR THE CONCRETE REFLECTOR                          $
C                                                                       $
30    CX    233.020                                                     $
32    PX   -200.000                                                     $
34    PX    507.340                                                     $
                                                                        $
C                                                                       $
C  DATA CARDS.                                                          $
C                                                                       $
MODE N                                                                  $
C                                                                       $
C  SOURCE CARDS.                                                        $
C                                                                       $
KCODE 3000 1.0 10 250                                                   $
KSRC  10 0 0  134 0 0  152 0 0                                          $
C                                                                       $
C  MATERIAL CARDS                                                       $
C                                                                       $
C  PU-POLY FOR THE FISSILE MASS CONTAINING 200 GRAMS OF PU.             $
C                                                                       $
M1    94239.60C     -0.032984                                           $
       1001.60C     -0.139069                                           $
       6000.60C     -0.827947                                           $
MT1   POLY.01T                                                          $
C                                                                       $
C  BE-POLY REFLECTOR.                                                   $
C                                                                       $
M2     4009.60C     -0.047892                                          $
       6000.60C     -0.815184                                          $
       1001.60C     -0.136925                                          $
MT2   POLY.01T   BE.01T                                                 $
C                                                                       $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP $
C                               CS-2003-003 REV0).                      $
C                                                                       $
C                                                                       $
M3     6000.60C      3.6371E-03                                         $
      14000.60C      1.9442E-02                                         $
      15031.60C      7.9333E-04                                         $
      16032.60C      5.1087E-04                                         $
      24050.60C      9.1366E-03                                         $
      24052.60C      1.7599E-01                                         $
      24053.60C      1.9954E-02                                         $
      24054.60C      4.9569E-03                                         $
      25055.60C      1.9879E-02                                         $
      26054.60C      3.7092E-02                                         $
      26056.60C      5.8175E-01                                         $
      26057.60C      1.3442E-02                                         $
      26058.60C      1.7754E-03                                         $
      28058.60C      7.6006E-02                                         $
      28060.60C      2.9273E-02                                         $
      28061.60C      1.2727E-03                                         $
      28062.60C      4.0525E-03                                         $
      28064.60C      1.0383E-03                                         $
C                                                                       $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH $
C                              ADDENDUM TO WSMS-WIPP-00-003 REV2 AND    $
C                              WTS/WIPP CS-2003-003 REV0).              $
C                                                                       $
M4     6000.60C      1.1921E-02                                         $
      15031.60C      7.1117E-04                                         $
      16032.60C      8.5868E-04                                         $
      25055.60C      1.2029E-02                                         $
      26054.60C      5.6447E-02                                         $
      26056.60C      8.8530E-01                                         $
```

```
      26057.60C      2.0456E-02                                                $
      26058.60C      2.7017E-03                                                $
      29063.60C      1.1989E-03                                                $
      29065.60C      5.3435E-04                                                $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                $
      82207.60c      0.22100000                                                $
      82208.60c      0.52400000                                                $
C                                                                               $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO       $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).    $
C                                                                               $
M6     1001.60C     -0.0056                                                    $
       8016.60C     -0.4981                                                    $
      11023.60C     -0.0171                                                    $
      12000.60C     -0.0026                                                    $
      13027.60C     -0.0457                                                    $
      14000.60C     -0.3151                                                    $
      16032.60C     -0.0013                                                    $
      19000.60C     -0.0192                                                    $
      20000.60C     -0.0829                                                    $
      26054.60C     -7.0065E-04                                                $
      26056.60C     -1.1395E-02                                                $
      26057.60C     -2.6801E-04                                                $
      26058.60C     -3.6018E-05                                                $
MT6   LWTR.01T                                                                  $
C                                                                               $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                         $
C                                                                               $
PRINT 40                                                                        $
C                                                                               $
C     PRINT TO MCTAL FILE                                                       $
C                                                                               $
PRDMP 2j 1                                                                      $
```

B1.5 Borehole Array Configuration with Direct Loaded Canisters (case 1DAC022)

```
C CCCC
```

```
C     CELL CARDS FOR THE SHIELD PLUG.                                          $
C                                                                              $
20    6    -2.35000  -16                                U=2    IMP:N=1        $
21    3    -4.01000  -17 16                             U=2    IMP:N=1        $
22    7    -2.16500   17                                U=2    IMP:N=1        $
C                                                                              $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK OF RH-72B CANISTERS.           $
C                                                                              $
31    7    -2.165     -41 40 -42 45 -43 44 -47 46 LAT=2 U=3    IMP:N=1        $
                       FILL=-3:3 -3:3 0:1                                      $
                       3 16R                                                   $
                           1 1   3 3 3 3                                       $
                          1 1 1  3 3 3 3                                       $
                           1 1   3 16R                                         $
                       3 16R                                                   $
                           1 1   3 3 3 3                                       $
                          1 1 1  3 3 3 3                                       $
                           1 1   3 16R                                         $
32    7    -2.165     -51 50 -52 55 -53 54 -57 56 FILL=3       IMP:N=1        $
C                                                                              $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK OF SHIELD PLUGS.               $
C                                                                              $
41    7    -2.165     -41 40 -42 45 -43 44 -67 66 LAT=2 U=4    IMP:N=1        $
                       FILL=-3:3 -3:3 0:0                                      $
                       4 16R                                                   $
                           2 2   4 4 4 4                                       $
                          2 2 2  4 4 4 4                                       $
                           2 2   4 16R                                         $
42    7    -2.165     -51 50 -52 55 -53 54 -77 76 FILL=4       IMP:N=1        $
C                                                                              $
C     CELL CARDS FOR THE SALT REFLECTION LAYERS.                               $
C                                                                              $
51    7    -2.165     (83:-56) -51 50 -52 55 -53 54 80 -82     IMP:N=1        $
C                                                                              $
C     CELL CARDS FOR THE REST OF THE UNIVERSE.                                 $
C                                                                              $
60    0               -80:82:51:-50:52:-55:53:-54              IMP:N=0        $
                                                                               $
C                                                                              $
C     SURFACE CARDS FOR THE RH72B CANISTER SURFACES                            $
C                                                                              $
1     SZ    138.1125    14.5506                                                $
4     CZ     32.3850                                                         $
6     CZ     33.0200                                                         $
8     PZ      0.0000                                                         $
10    PZ      0.9525                                                         $
12    PZ    275.2725                                                         $
14    PZ    276.2250                                                         $
15    PZ    307.3400                                                         $
C                                                                              $
C     SURFACE CARDS FOR THE SHIELD PLUG.                                       $
C
16 RCC 0 0 614.6800 0 0  156.2100  36.8300                                     $
17 RCC 0 0 614.6800 0 0  157.4800  37.4650                                     $
C                                                                              $
C     SURFACE CARDS FOR THE HEXAGONAL 7-PACK STACK OF RH-72B CANISTERS.        $
C                                                                              $
40 PX -38.1000                                                                 $
41 PX  38.1000                                                                 $
42 P   1    1.7321    0    76.2000                                             $
43 P  -1    1.7321    0    76.2000                                             $
44 P  -1    1.7321    0   -76.2000                                             $
45 P   1    1.7321    0   -76.2000                                             $
46 PZ  0.0                                                                     $
47 PZ  307.3400                                                                $
C                                                                              $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK OF RH-72B CANISTERS.    $
C                                                                              $
*50 PY -104.1000                                                               $
*51 PY  104.1000                                                               $
*52 P   1.7321   1    0   208.2000                                             $
```

```
*53 P   1.7321  -1    0   208.2000                                          $
*54 P   1.7321  -1    0  -208.2000                                          $
*55 P   1.7321   1    0  -208.2000                                          $
56 PZ   0.0                                                                $
57 PZ   614.6800                                                           $
C                                                                          $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK OF SHIELD PLUGS.           $
C                                                                          $
66 PZ  614.6800                                                            $
67 PZ  772.1600                                                            $
C                                                                          $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK OF SHIELD PLUGS.    $
C                                                                          $
76 PZ   614.6800                                                           $
77 PZ   772.1600                                                           $
C                                                                          $
C     SURFACE CARDS FOR THE SALT REFLECTION LAYERS.                        $
C                                                                          $
80 PZ -300.0000                                                            $
82 PZ 1072.1600                                                            $
83 PZ  772.1600                                                            $
                                                                           $
C                                                                          $
C  DATA CARDS.                                                             $
C                                                                          $
MODE N                                                                     $
C                                                                          $
C  SOURCE CARDS.                                                           $
C                                                                          $
KCODE 3000 1.0 10 250                                                      $
KSRC  0 0 138                                                              $
C                                                                          $
C  MATERIAL CARDS                                                          $
C                                                                          $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 200 GRAMS OF PU.            $
C                                                                          $
M1    94239.60C     -0.025101                                              $
       1001.60C     -0.116417                                              $
       8016.60C     -0.661824                                              $
       6000.60C     -0.196657                                              $
MT1   LWTR.01T   POLY.01T                                                  $
C                                                                          $
C  BE-POLY REFLECTOR.                                                      $
C                                                                          $
M2     4009.60C     -0.136990                                              $
       6000.60C     -0.738899                                              $
       1001.60C     -0.124111                                              $
MT2   POLY.01T   BE.01T                                                    $
C                                                                          $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP    $
C                               CS-2003-003 REV0).                         $
C                                                                          $
C                                                                          $
M3     6000.60C      3.6371E-03                                            $
      14000.60C      1.9442E-02                                            $
      15031.60C      7.9333E-04                                            $
      16032.60C      5.1087E-04                                            $
      24050.60C      9.1366E-03                                            $
      24052.60C      1.7599E-01                                            $
      24053.60C      1.9954E-02                                            $
      24054.60C      4.9569E-03                                            $
      25055.60C      1.9879E-02                                            $
      26054.60C      3.7092E-02                                            $
      26056.60C      5.8175E-01                                            $
      26057.60C      1.3442E-02                                            $
      26058.60C      1.7754E-03                                            $
      28058.60C      7.6006E-02                                            $
      28060.60C      2.9273E-02                                            $
      28061.60C      1.2727E-03                                            $
      28062.60C      4.0525E-03                                            $
      28064.60C      1.0383E-03                                            $
```

```
C                                                                              $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH      $
C                               ADDENDUM TO WSMS-WIPP-00-003 REV2 AND          $
C                               WTS/WIPP CS-2003-003 REV0).                    $
C                                                                              $
M4     6000.60C      1.1921E-02                                                $
      15031.60C      7.1117E-04                                                $
      16032.60C      8.5868E-04                                                $
      25055.60C      1.2029E-02                                                $
      26054.60C      5.6447E-02                                                $
      26056.60C      8.8530E-01                                                $
      26057.60C      2.0456E-02                                                $
      26058.60C      2.7017E-03                                                $
      29063.60C      1.1989E-03                                                $
      29065.60C      5.3435E-04                                                $
C                                                                              $
C  LEAD REFLECTOR.                                                             $
C                                                                              $
M5    82206.60c      0.24100000                                                $
      82207.60c      0.22100000                                                $
      82208.60c      0.52400000                                                $
C                                                                              $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO      $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).   $
C                                                                              $
M6     1001.60C     -0.0056                                                    $
       8016.60C     -0.4981                                                    $
      11023.60C     -0.0171                                                    $
      12000.60C     -0.0026                                                    $
      13027.60C     -0.0457                                                    $
      14000.60C     -0.3151                                                    $
      16032.60C     -0.0013                                                    $
      19000.60C     -0.0192                                                    $
      20000.60C     -0.0829                                                    $
      26054.60C     -7.0065E-04                                                $
      26056.60C     -1.1395E-02                                                $
      26057.60C     -2.6801E-04                                                $
      26058.60C     -3.6018E-05                                                $
MT6   LWTR.01T                                                                 $
C                                                                              $
C  SALT REFLECTOR.                                                             $
C                                                                              $
M7    11023.60C           0.5                                                  $
      17000.60C           0.5                                                  $
C                                                                              $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                        $
C                                                                              $
PRINT 40                                                                       $
C                                                                              $
C     PRINT TO MCTAL FILE                                                      $
C                                                                              $
PRDMP 2j 1                                                                     $
```

B1.6 Borehole Array Configurations of Containerized Canisters of Direct Loaded Waste in the Presence of Adjacent CH Waste (case 3DAC300)

```
C CCCC
```

```
C     5-FOOT CONCRETE SHIELD PLUG AT THE END IS USED TO SIMULATE A STORAGE ARRAY$
C     WHICH CONTAINS TWO CANISTERS PER BOREHOLE WITH ASSOCIATED SHIELD PLUG.    $
C     ONE END OF THE TWO 7-PACK GROUP IS REFLECTED WITH 300 CM OF SALT TO       $
C     SIMULATE INFINITE REFLECTION OF THE BOREHOLE BACKWALL WHEREAS THE OTHER   $
C     END IS REFLECTED BY A 7-PACK OF CH WASTE. ALL OTHER PLANES (BOUNDARIES)   $
C     ARE MIRRORED TO SIMULATE AN INFINITE NUMBER OF CLOSE PROXIMITY BOREHOLES  $
C     CONTAINING RH-72B CANISTERS. THIS ARRANGEMENT BOUNDS ANY UNDERGROUND RH   $
C     WASTE STORAGE CONFIGURATION IN WHICH ADJACENT CH WASTE IS PRESENT.        $$
C                                                                               $
C CCCC
```

```
C     CELL CARDS FOR THE BE-POLY CH DRUMS.                                    $
C                                                                             $
69   12    -0.02308  -92 -100  98                        U=7    IMP:N=1       $
70    LIKE 63 BUT U=7                                          IMP:N=1       $
71    LIKE 64 BUT U=7                                          IMP:N=1       $
C                                                                             $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK CONTAINING CH WASTE.          $
C                                                                             $
72    0              -111 110 -112 115 -113 114 -117 116                      $
                                                LAT=2 U=8    IMP:N=1       $
                      FILL=-3:3 -3:3 0:0                                      $
                      8 16R                                                   $
                         6 7   8 8 8 8                                        $
                        6 5 7  8 8 8 8                                       $
                         6 7   8 16R                                         $
73    0              -151 150 -152 155 -153 154 -117 116                      $
                                                FILL=8    IMP:N=1       $
74    0               (151:-150:152:-155:153:-154:117:-116)                   $
                      -161 160 -162 165 -163 164 85 -84        IMP:N=1       $
C                                                                             $
C     CELL CARDS FOR THE REST OF THE UNIVERSE.                                $
C                                                                             $
80    0  (-80:51:-50:52:-55:53:-54:82) #73 #74                 IMP:N=0       $
                                                                              $
C                                                                             $
C     SURFACE CARDS FOR ALL DRUM AND RH72B CANISTER SURFACES                  $
C                                                                             $
1   1 SPH     0.0000 0.0000  36.6339 11.9900                                  $
2   1 SPH     0.0000 0.0000 107.9967 11.9900                                  $
3   1 SPH     0.0000 0.0000 179.3596 11.9900                                  $
4   1  CZ     32.3850                                                         $
6   1  CZ     33.0200                                                         $
8   1  PZ      0.0000                                                         $
10  1  PZ      0.9525                                                         $
12  1  PZ    275.2725                                                         $
14  1  PZ    276.2250                                                         $
15  1  PZ    307.3400                                                         $
20  1  PZ      1.0739                                                         $
21  1  PZ    143.0711                                                         $
22  1  PZ    143.3139                                                         $
C                                                                             $
C     SURFACE CARDS FOR THE SHIELD PLUG.                                      $
C                                                                             $
16  1  RCC 0 0 614.6800 0 0  156.2100  36.8300                                 $
17  1  RCC 0 0 614.6800 0 0  157.4800  37.4650                                 $
C                                                                             $
C     SURFACE CARDS FOR THE HEXAGONAL 7-PACK STACK OF RH-72B CANISTERS.       $
C                                                                             $
40  1 PX -38.1000                                                             $
41  1 PX  38.1000                                                             $
42  1 P   1    1.7321    0    76.2000                                         $
43  1 P  -1    1.7321    0    76.2000                                         $
44  1 P  -1    1.7321    0   -76.2000                                         $
45  1 P   1    1.7321    0   -76.2000                                         $
46  1 PZ  0.0                                                                 $
47  1 PZ  307.3400                                                            $
C                                                                             $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK OF RH-72B CANISTERS.   $
C                                                                             $
*50 1 PY -104.1000                                                            $
*51 1 PY  104.1000                                                            $
*52 1 P   1.7321   1    0   208.2000                                          $
*53 1 P   1.7321  -1    0   208.2000                                          $
*54 1 P   1.7321  -1    0  -208.2000                                          $
*55 1 P   1.7321   1    0  -208.2000                                          $
56  1 PZ   0.0                                                                $
57  1 PZ   614.6800                                                           $
C                                                                             $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK OF SHIELD PLUGS.              $
C                                                                             $
66  1 PZ  614.6800                                                            $
```

```
67  1 PZ  772.1600                                                          $
C                                                                           $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK AND SHIELD PLUGS.    $
C                                                                           $
76  1 PZ  614.6800                                                         $
77  1 PZ  772.1600                                                         $
C                                                                           $
C     SURFACE CARDS FOR THE SALT REFLECTION LAYERS.                         $
C                                                                           $
80  1 PZ -300.0000                                                         $
82  1 PZ  772.1600                                                         $
83  1 PZ  772.1600                                                         $
C                                                                           $
C     SURFACE CARDS FOR ALL CH WASTE DRUM SURFACES                          $
C                                                                           $
92  2 CZ  28.575                                                           $
94  2 CZ  28.696                                                           $
96  2 PZ  0.0                                                              $
98  2 PZ  0.121                                                            $
100 2 PZ  84.576                                                           $
102 2 PZ  84.697                                                           $
C                                                                           $
C     CELL CARDS FOR THE 50 AND 200 FGE CH DRUMS.                           $
C                                                                           $
104 2 RCC 0 0  35.1479 0 0  14.4012   7.2006                                $
124 2 RCC 0 0  30.9182 0 0  22.8605  11.4303                                $
C                                                                           $
C     SURFACE CARDS FOR THE HEXAGONAL 7-PACK OF CH WASTE DRUMS.             $
C                                                                           $
110 2 PX -28.75                                                            $
111 2 PX  28.75                                                            $
112 2 P   1    1.7321    0    57.5                                         $
113 2 P  -1    1.7321    0    57.5                                         $
114 2 P  -1    1.7321    0   -57.5                                         $
115 2 P   1    1.7321    0   -57.5                                         $
116 2 PZ  0.0                                                              $
117 2 PZ  84.697                                                           $
C                                                                           $
C     SURFACE CARDS FOR THE 7-PACK STACK CH INFINITE ARRAY.                 $
C                                                                           $
150 2 PY -78.5                                                             $
151 2 PY  78.5                                                             $
152 2 P   1.7321   1    0   157                                           $
153 2 P   1.7321  -1    0   157                                           $
154 2 P   1.7321  -1    0  -157                                           $
155 2 P   1.7321   1    0  -157                                           $
C                                                                           $
C     SURFACE CARDS FOR THE RH-CH INFINITE ARRAY SYSTEM.                    $
C                                                                           $
*160 1 PY -100.0000                                                        $
*161 1 PY  100.0000                                                        $
*162 1 P   1.7321   1    0   200.0000                                     $
*163 1 P   1.7321  -1    0   200.0000                                     $
*164 1 P   1.7321  -1    0  -200.0000                                     $
*165 1 P   1.7321   1    0  -200.0000                                     $
*84  1 PZ  930.7600                                                        $
85  1 PZ  772.5600                                                         $
                                                                           $
C                                                                           $
C  DATA CARDS.                                                             $
C                                                                           $
MODE N                                                                     $
C                                                                           $
C  SOURCE CARDS.                                                           $
C                                                                           $
*TR1 0 0 0 0 90 90 90 -90 0 90 0 -90                                       $
 TR2 0 852.16 -42.3485                                                     $
KCODE 3000 1.0 10 250                                                      $
KSRC  0 37 0 0 107 0 0 179 0                                               $
     -58 853 0                                                             $
     -30 905 0                                                             $
```

```
     -30 805 0                                                                  $
C                                                                               $
C  MATERIAL CARDS                                                              $
C                                                                               $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 200 GRAMS OF PU.                 $
C                                                                               $
M1    94239.60C     -0.027542                                                   $
       1001.60C     -0.116125                                                   $
       8016.60C     -0.660167                                                   $
       6000.60C     -0.196165                                                   $
MT1   LWTR.01T   POLY.01T                                                       $
C                                                                               $
C  BEY REFLECTOR.                                                               $
C                                                                               $
M2     4009.60C     -1.000000                                                   $
MT2   BE.01T                                                                    $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP         $
C                               CS-2003-003 REV0).                              $
C                                                                               $
C                                                                               $
M3     6000.60C      3.6371E-03                                                 $
      14000.60C      1.9442E-02                                                 $
      15031.60C      7.9333E-04                                                 $
      16032.60C      5.1087E-04                                                 $
      24050.60C      9.1366E-03                                                 $
      24052.60C      1.7599E-01                                                 $
      24053.60C      1.9954E-02                                                 $
      24054.60C      4.9569E-03                                                 $
      25055.60C      1.9879E-02                                                 $
      26054.60C      3.7092E-02                                                 $
      26056.60C      5.8175E-01                                                 $
      26057.60C      1.3442E-02                                                 $
      26058.60C      1.7754E-03                                                 $
      28058.60C      7.6006E-02                                                 $
      28060.60C      2.9273E-02                                                 $
      28061.60C      1.2727E-03                                                 $
      28062.60C      4.0525E-03                                                 $
      28064.60C      1.0383E-03                                                 $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH       $
C                               ADDENDUM TO WSMS-WIPP-00-003 REV2 AND           $
C                               WTS/WIPP CS-2003-003 REV0).                     $
C                                                                               $
M4     6000.60C      1.1921E-02                                                 $
      15031.60C      7.1117E-04                                                 $
      16032.60C      8.5868E-04                                                 $
      25055.60C      1.2029E-02                                                 $
      26054.60C      5.6447E-02                                                 $
      26056.60C      8.8530E-01                                                 $
      26057.60C      2.0456E-02                                                 $
      26058.60C      2.7017E-03                                                 $
      29063.60C      1.1989E-03                                                 $
      29065.60C      5.3435E-04                                                 $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                 $
      82207.60c      0.22100000                                                 $
      82208.60c      0.52400000                                                 $
C                                                                               $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO       $
C                       WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).   $
C                                                                               $
M6     1001.60C     -0.0056                                                    $
       8016.60C     -0.4981                                                    $
      11023.60C     -0.0171                                                    $
      12000.60C     -0.0026                                                    $
      13027.60C     -0.0457                                                    $
      14000.60C     -0.3151                                                    $
      16032.60C     -0.0013                                                    $
```

```
      19000.60C     -0.0192                                                  $
      20000.60C     -0.0829                                                  $
      26054.60C     -7.0065E-04                                              $
      26056.60C     -1.1395E-02                                              $
      26057.60C     -2.6801E-04                                              $
      26058.60C     -3.6018E-05                                              $
MT6   LWTR.01T                                                               $
C                                                                            $
C  SALT REFLECTOR.                                                           $
C                                                                            $
M7    11023.60C           0.5                                              $
      17000.60C           0.5                                              $
C                                                                            $
C                                                                            $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 50 GRAMS OF PU.               $
C                                                                            $
M8    94239.60C     -0.021322                                              $
       1001.60C     -0.116868                                              $
       8016.60C     -0.664390                                              $
       6000.60C     -0.197420                                              $
MT8   LWTR.01T   POLY.01T                                                    $
C                                                                            $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 200 GRAMS OF PU.              $
C                                                                            $
M9    94239.60C     -0.021322                                              $
       1001.60C     -0.116868                                              $
       8016.60C     -0.664390                                              $
       6000.60C     -0.197420                                              $
MT9   LWTR.01T   POLY.01T                                                    $
C                                                                            $
C  BE-POLY REFLECTOR AROUND THE FISSILE MASS CONTAINING 50 GRAMS PU.         $
C                                                                            $
M10    4009.60C     -1.000000                                               $
MT0   BE.01T                                                                 $
C                                                                            $
C  BE-POLY REFLECTOR AROUND THE FISSILE MASS CONTAINING 200 GRAMS PU.        $
C                                                                            $
M11    4009.60C     -1.000000                                               $
MT11  BE.01T                                                                 $
C                                                                            $
C  BE-POLY REFLECTOR IN THE NON-FISSILE MASS DRUMS.                          $
C                                                                            $
M12    4009.60C     -1.000000                                               $
MT12  BE.01T                                                                 $
C                                                                            $
C  55-GALLON DRUM STEEL WALLS.                                               $
C                                                                            $
M13    6000.60C     -0.001500                                               $
      25055.60C     -0.006000                                              $
      15031.60C     -0.000350                                              $
      16000.60C     -0.000400                                              $
      26054.60C     -0.058513                                              $
      26056.60C     -0.909630                                              $
      26057.60C     -0.020827                                              $
      26058.60C     -0.0027769                                             $
C                                                                            $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                      $
C                                                                            $
PRINT 40                                                                     $
C                                                                            $
C     PRINT TO MCTAL FILE                                                    $
C                                                                            $
PRDMP 2j 1                                                                   $
```

B1.7 Overbatch Borehole Array Configurations of Direct Loaded Waste that is Chemically/Mechanically Bound the Pu at 720 FGE and an H/D Ratio of 3 (case 1DAO720)

```
C CCCC
```

```
60    0              -80:82:51:-50:52:-55:53:-54             IMP:N=0          $
                                                                                $
C                                                                               $
C     SURFACE CARDS FOR THE RH72B CANISTER SURFACES                             $
C                                                                               $
1     RCC    0 0  98.5298 0 0   79.1654 13.1942                                 $
4     CZ     32.3850                                                           $
6     CZ     33.0200                                                           $
8     PZ      0.0000                                                           $
10    PZ      0.9525                                                           $
12    PZ    275.2725                                                           $
14    PZ    276.2250                                                           $
15    PZ    307.3400                                                           $
C                                                                               $
C     SURFACE CARDS FOR THE SHIELD PLUG.                                        $
C                                                                               $
16 RCC 0 0 614.6800 0 0  156.2100  36.8300                                      $
17 RCC 0 0 614.6800 0 0  157.4800  37.4650                                      $
C                                                                               $
C     SURFACE CARDS FOR THE HEXAGONAL 7-PACK STACK OF RH-72B CANISTERS.         $
C                                                                               $
40 PX -38.1000                                                                  $
41 PX  38.1000                                                                  $
42 P   1    1.7321    0    76.2000                                             $
43 P  -1    1.7321    0    76.2000                                             $
44 P  -1    1.7321    0   -76.2000                                             $
45 P   1    1.7321    0   -76.2000                                             $
46 PZ  0.0                                                                      $
47 PZ  307.3400                                                                 $
C                                                                               $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK OF RH-72B CANISTERS.     $
C                                                                               $
*50 PY -104.1000                                                                $
*51 PY  104.1000                                                                $
*52 P   1.7321   1    0   208.2000                                              $
*53 P   1.7321  -1    0   208.2000                                              $
*54 P   1.7321  -1    0  -208.2000                                              $
*55 P   1.7321   1    0  -208.2000                                              $
56 PZ   0.0                                                                     $
57 PZ   614.6800                                                                $
C                                                                               $
C     CELL CARDS FOR THE HEXAGONAL 7-PACK STACK OF SHIELD PLUGS.                $
C                                                                               $
66 PZ  614.6800                                                                 $
67 PZ  772.1600                                                                 $
C                                                                               $
C     SURFACE CARDS FOR INFINITE ARRAY OF 7-PACK STACK OF SHIELD PLUGS.         $
C                                                                               $
76 PZ   614.6800                                                                $
77 PZ   772.1600                                                                $
C                                                                               $
C     SURFACE CARDS FOR THE SALT REFLECTION LAYERS.                             $
C                                                                               $
80 PZ -300.0000                                                                 $
82 PZ 1072.1600                                                                 $
83 PZ  772.1600                                                                 $
                                                                                $
C                                                                               $
C  DATA CARDS.                                                                  $
C                                                                               $
MODE N                                                                          $
C                                                                               $
C  SOURCE CARDS.                                                                $
C                                                                               $
KCODE 3000 1.0 10 250                                                           $
KSRC  0 0 138                                                                   $
C                                                                               $
C  MATERIAL CARDS                                                               $
C                                                                               $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 720 GRAMS OF PU.                 $
C                                                                               $
```

```
M1    94239.60C     -0.012381                                                 $
       1001.60C     -0.052201                                                 $
       8016.60C     -0.296759                                                 $
       6000.60C     -0.088180                                                 $
       4009.60C     -0.550479                                                 $
MT1   LWTR.01T   POLY.01T    BE.01T                                           $
C                                                                             $
C  BE-POLY REFLECTOR.                                                         $
C                                                                             $
M2     4009.60C     -0.141230                                                 $
       6000.60C     -0.735268                                                 $
       1001.60C     -0.123502                                                 $
MT2   POLY.01T   BE.01T                                                       $
C                                                                             $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP       $
C                               CS-2003-003 REV0).                            $
C                                                                             $
C                                                                             $
M3     6000.60C      3.6371E-03                                               $
      14000.60C      1.9442E-02                                               $
      15031.60C      7.9333E-04                                               $
      16032.60C      5.1087E-04                                               $
      24050.60C      9.1366E-03                                               $
      24052.60C      1.7599E-01                                               $
      24053.60C      1.9954E-02                                               $
      24054.60C      4.9569E-03                                               $
      25055.60C      1.9879E-02                                               $
      26054.60C      3.7092E-02                                               $
      26056.60C      5.8175E-01                                               $
      26057.60C      1.3442E-02                                               $
      26058.60C      1.7754E-03                                               $
      28058.60C      7.6006E-02                                               $
      28060.60C      2.9273E-02                                               $
      28061.60C      1.2727E-03                                               $
      28062.60C      4.0525E-03                                               $
      28064.60C      1.0383E-03                                               $
C                                                                             $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH     $
C                              ADDENDUM TO WSMS-WIPP-00-003 REV2 AND          $
C                              WTS/WIPP CS-2003-003 REV0).                    $
C                                                                             $
M4     6000.60C      1.1921E-02                                               $
      15031.60C      7.1117E-04                                               $
      16032.60C      8.5868E-04                                               $
      25055.60C      1.2029E-02                                               $
      26054.60C      5.6447E-02                                               $
      26056.60C      8.8530E-01                                               $
      26057.60C      2.0456E-02                                               $
      26058.60C      2.7017E-03                                               $
      29063.60C      1.1989E-03                                               $
      29065.60C      5.3435E-04                                               $
C                                                                             $
C  LEAD REFLECTOR.                                                            $
C                                                                             $
M5    82206.60c      0.24100000                                               $
      82207.60c      0.22100000                                               $
      82208.60c      0.52400000                                               $
C                                                                             $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO     $
C                       WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0). $
C                                                                             $
M6     1001.60C     -0.0056                                                  $
       8016.60C     -0.4981                                                  $
      11023.60C     -0.0171                                                  $
      12000.60C     -0.0026                                                  $
      13027.60C     -0.0457                                                  $
      14000.60C     -0.3151                                                  $
      16032.60C     -0.0013                                                  $
      19000.60C     -0.0192                                                  $
      20000.60C     -0.0829                                                  $
      26054.60C     -7.0065E-04                                              $
```

```
      26056.60C     -1.1395E-02                                              $
      26057.60C     -2.6801E-04                                              $
      26058.60C     -3.6018E-05                                              $
MT6   LWTR.01T                                                               $
C                                                                            $
C  SALT REFLECTOR.                                                           $
C                                                                            $
M7    11023.60C           0.5                                              $
      17000.60C           0.5                                              $
C                                                                            $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                      $
C                                                                            $
PRINT 40                                                                     $
C                                                                            $
C     PRINT TO MCTAL FILE                                                    $
C                                                                            $
PRDMP 2j 1                                                                   $
```

B1.8 30-gallon Drums in Hot Cell with Partial Water Flooding (37.5% by Volume) (case 3DBW362)

```
C CCCC
```

```
                                                                                $
C                                                                               $
C  DATA CARDS.                                                                  $
C                                                                               $
MODE N                                                                          $
C                                                                               $
C  SOURCE CARDS.                                                                $
C                                                                               $
KCODE 3000 1.0 10 250                                                           $
KSRC  36 0 0 107 0 0 179 0 0                                                    $
C                                                                               $
C  MATERIAL CARDS                                                               $
C                                                                               $
C  PU-H2O-POLY FOR THE FISSILE MASS CONTAINING 200 GRAMS OF PU.                 $
C                                                                               $
M1    94239.60C     -0.025101                                                   $
       1001.60C     -0.116417                                                   $
       8016.60C     -0.661824                                                   $
       6000.60C     -0.196657                                                   $
MT1   LWTR.01T   POLY.01T                                                       $
C                                                                               $
C  BE-POLY REFLECTOR.                                                           $
C                                                                               $
M2     4009.60C     -0.057847                                                   $
       6000.60C     -0.307626                                                   $
       1001.60C     -0.116890                                                   $
       8016.60C     -0.517637                                                   $
MT2   LWTR.01T   POLY.01T   BE.01T                                               $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP         $
C                               CS-2003-003 REV0).                              $
C                                                                               $
C                                                                               $
M3     6000.60C      3.6371E-03                                                 $
      14000.60C      1.9442E-02                                                 $
      15031.60C      7.9333E-04                                                 $
      16032.60C      5.1087E-04                                                 $
      24050.60C      9.1366E-03                                                 $
      24052.60C      1.7599E-01                                                 $
      24053.60C      1.9954E-02                                                 $
      24054.60C      4.9569E-03                                                 $
      25055.60C      1.9879E-02                                                 $
      26054.60C      3.7092E-02                                                 $
      26056.60C      5.8175E-01                                                 $
      26057.60C      1.3442E-02                                                 $
      26058.60C      1.7754E-03                                                 $
      28058.60C      7.6006E-02                                                 $
      28060.60C      2.9273E-02                                                 $
      28061.60C      1.2727E-03                                                 $
      28062.60C      4.0525E-03                                                 $
      28064.60C      1.0383E-03                                                 $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH       $
C                              ADDENDUM TO WSMS-WIPP-00-003 REV2 AND            $
C                              WTS/WIPP CS-2003-003 REV0).                      $
C                                                                               $
M4     6000.60C      1.1921E-02                                                 $
      15031.60C      7.1117E-04                                                 $
      16032.60C      8.5868E-04                                                 $
      25055.60C      1.2029E-02                                                 $
      26054.60C      5.6447E-02                                                 $
      26056.60C      8.8530E-01                                                 $
      26057.60C      2.0456E-02                                                 $
      26058.60C      2.7017E-03                                                 $
      29063.60C      1.1989E-03                                                 $
      29065.60C      5.3435E-04                                                 $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                 $
      82207.60c      0.22100000                                                 $
```

```
      82208.60c      0.52400000                                                $
C                                                                             $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO     $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).  $
C                                                                             $
M6     1001.60C     -0.0056                                                   $
       8016.60C     -0.4981                                                   $
      11023.60C     -0.0171                                                   $
      12000.60C     -0.0026                                                   $
      13027.60C     -0.0457                                                   $
      14000.60C     -0.3151                                                   $
      16032.60C     -0.0013                                                   $
      19000.60C     -0.0192                                                   $
      20000.60C     -0.0829                                                   $
      26054.60C     -7.0065E-04                                               $
      26056.60C     -1.1395E-02                                               $
      26057.60C     -2.6801E-04                                               $
      26058.60C     -3.6018E-05                                               $
MT6   LWTR.01T                                                                $
C                                                                             $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                       $
C                                                                             $
PRINT 40                                                                      $
C                                                                             $
C     PRINT TO MCTAL FILE                                                     $
C                                                                             $
PRDMP 2j 1                                                                    $
```

B1.9 Single Canister of LEU Waste at 1.1 wt% ^{235}U (case 1DUL110)

```
C CCCC
```

```
                                                                                $
C                                                                               $
C  DATA CARDS.                                                                  $
C                                                                               $
MODE N                                                                          $
C                                                                               $
C  SOURCE CARDS.                                                                $
C                                                                               $
KCODE 3000 1.0 10 250                                                           $
KSRC  138 0 0                                                                   $
C                                                                               $
C  MATERIAL CARDS                                                               $
C                                                                               $
C  U-H2O-POLY FOR THE FISSILE MASS CONTAINING 2700.5 KG OF U.                   $
C                                                                               $
M1    92235.60C     -0.009492                                                   $
      92238.60C     -0.853393                                                   $
       4009.60C     -0.002568                                                   $
       1001.60C     -0.016077                                                   $
       8016.60C     -0.091050                                                   $
       6000.60C     -0.027420                                                   $
MT1   LWTR.01T   POLY.01T                                                       $
C                                                                               $
C  BE REFLECTOR.                                                                $
C                                                                               $
M2     4009.60C     -1.000000                                                   $
MT2   BE.01T                                                                    $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP         $
C                               CS-2003-003 REV0).                              $
C                                                                               $
C                                                                               $
M3     6000.60C      3.6371E-03                                                 $
      14000.60C      1.9442E-02                                                 $
      15031.60C      7.9333E-04                                                 $
      16032.60C      5.1087E-04                                                 $
      24050.60C      9.1366E-03                                                 $
      24052.60C      1.7599E-01                                                 $
      24053.60C      1.9954E-02                                                 $
      24054.60C      4.9569E-03                                                 $
      25055.60C      1.9879E-02                                                 $
      26054.60C      3.7092E-02                                                 $
      26056.60C      5.8175E-01                                                 $
      26057.60C      1.3442E-02                                                 $
      26058.60C      1.7754E-03                                                 $
      28058.60C      7.6006E-02                                                 $
      28060.60C      2.9273E-02                                                 $
      28061.60C      1.2727E-03                                                 $
      28062.60C      4.0525E-03                                                 $
      28064.60C      1.0383E-03                                                 $
C                                                                               $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH       $
C                               ADDENDUM TO WSMS-WIPP-00-003 REV2 AND           $
C                               WTS/WIPP CS-2003-003 REV0).                     $
C                                                                               $
M4     6000.60C      1.1921E-02                                                 $
      15031.60C      7.1117E-04                                                 $
      16032.60C      8.5868E-04                                                 $
      25055.60C      1.2029E-02                                                 $
      26054.60C      5.6447E-02                                                 $
      26056.60C      8.8530E-01                                                 $
      26057.60C      2.0456E-02                                                 $
      26058.60C      2.7017E-03                                                 $
      29063.60C      1.1989E-03                                                 $
      29065.60C      5.3435E-04                                                 $
C                                                                               $
C  LEAD REFLECTOR.                                                              $
C                                                                               $
M5    82206.60c      0.24100000                                                 $
      82207.60c      0.22100000                                                 $
      82208.60c      0.52400000                                                 $
```

```
C                                                                       $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO       $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).    $
C                                                                       $
M6     1001.60C     -0.0056                                             $
       8016.60C     -0.4981                                             $
      11023.60C     -0.0171                                             $
      12000.60C     -0.0026                                             $
      13027.60C     -0.0457                                             $
      14000.60C     -0.3151                                             $
      16032.60C     -0.0013                                             $
      19000.60C     -0.0192                                             $
      20000.60C     -0.0829                                             $
      26054.60C     -7.0065E-04                                         $
      26056.60C     -1.1395E-02                                         $
      26057.60C     -2.6801E-04                                         $
      26058.60C     -3.6018E-05                                         $
MT6   LWTR.01T                                                          $
C                                                                       $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                 $
C                                                                       $
PRINT 40                                                                $
C                                                                       $
C     PRINT TO MCTAL FILE                                               $
C                                                                       $
PRDMP 2j 1                                                              $
```

B1.10 NS15 Neutron Shielded Canister (case 25ncc12)

```
NS-15 canister, single 245 fge, H/PU=1200, 75%h2o/25%poly mod, 25% poly refl
C     NS-15 CANISTER (RH-72B MODIFIED WITH HIGH DENSITY POLYETHYLENE            $
C     SHIELDING, 3.288 INCHES RADIALLY AND 5 INCHES ON EACH END)                $
C     CONTAINING ONE (1) SPHERICAL CENTRALLY LOCATED FGE WHICH IS 245 GRAMS     $
C     OF PU MIXED WITH 75% BY VOLUME H2O AND 25% BY VOLUME POLYETHYLENE AND     $
C     REFLECTED BY 32 KGS OF BERYLLIUM MIXED WITH 25% DENSE POLYETHYLENE.       $
C     THE RH-72B CANISTER IS REFLECTED BY 200 CM (2-METERS) OF CONCRETE TO      $
C     SIMULATE MAXIMUM SHIELDING OR REFLECTION.                                 $
C                                                                             $
C CCCC
```

```
C     SURFACE CARDS FOR THE HDPE SHIELD                                    $
C                                                                          $
40    CX     30.4800       $ SHIELD OR                                     $
41    CX     21.6256       $ SHIELD IR, t = 3.486 in.                      $
42    PX      0.9525                                                       $
43  1 PX    262.5725                                                       $
                                                                           $
C                                                                          $
C  DATA CARDS.                                                             $
C                                                                          $
MODE N                                                                     $
TR1 -12.7 0 0                                                              $
C                                                                          $
C  SOURCE CARDS.                                                           $
C                                                                          $
KCODE 3000 1.0 10 250                                                      $
KSRC  125 0 0                                                              $
C                                                                          $
C  MATERIAL CARDS                                                          $
C                                                                          $
C  PU-POLY FOR THE FISSILE MASS CONTAINING PU.                             $
C                                                                          $
M1    94239.60C     -0.023058                                              $
       1001.60C     -0.116661                                              $
       8016.60C     -0.663212                                              $
       6000.60C     -0.197070                                              $
MT1   LWTR.01T   POLY.01T                                                  $
C                                                                          $
C  BE-POLY REFLECTOR.                                                      $
C                                                                          $
M2     4009.60C     -0.291044                                              $
       6000.60C     -0.607000                                              $
       1001.60C     -0.101957                                              $
MT2   POLY.01T   BE.01T                                                    $
C                                                                          $
C  RH-72B CANISTER STEEL WALLS (ASTM 304 STEEL CONSISTENT WITH WTS/WIPP    $
C                               CS-2003-003 REV0).                         $
C                                                                          $
C                                                                          $
M3     6000.60C      3.6371E-03                                            $
      14000.60C      1.9442E-02                                            $
      15031.60C      7.9333E-04                                            $
      16032.60C      5.1087E-04                                            $
      24050.60C      9.1366E-03                                            $
      24052.60C      1.7599E-01                                            $
      24053.60C      1.9954E-02                                            $
      24054.60C      4.9569E-03                                            $
      25055.60C      1.9879E-02                                            $
      26054.60C      3.7092E-02                                            $
      26056.60C      5.8175E-01                                            $
      26057.60C      1.3442E-02                                            $
      26058.60C      1.7754E-03                                            $
      28058.60C      7.6006E-02                                            $
      28060.60C      2.9273E-02                                            $
      28061.60C      1.2727E-03                                            $
      28062.60C      4.0525E-03                                            $
      28064.60C      1.0383E-03                                            $
C                                                                          $
C  RH-72B CANISTER STEEL WALLS (ASTM A36 LOW CARBON STEEL CONSISTENT WITH  $
C                              ADDENDUM TO WSMS-WIPP-00-003 REV2 AND       $
C                              WTS/WIPP CS-2003-003 REV0).                 $
C                                                                          $
M4     6000.60C      1.1921E-02                                            $
      15031.60C      7.1117E-04                                            $
      16032.60C      8.5868E-04                                            $
      25055.60C      1.2029E-02                                            $
      26054.60C      5.6447E-02                                            $
      26056.60C      8.8530E-01                                            $
      26057.60C      2.0456E-02                                            $
      26058.60C      2.7017E-03                                            $
      29063.60C      1.1989E-03                                            $
```

```
      29065.60C      5.3435E-04                                                $
C                                                                              $
C  LEAD REFLECTOR.                                                            $
C                                                                              $
M5    82206.60c      0.24100000                                                $
      82207.60c      0.22100000                                                $
      82208.60c      0.52400000                                                $
C                                                                              $
C  CONCRETE REFLECTOR (CONCRETE SPECIFICATION CONSISTENT WITH ADDENDUM TO      $
C                      WSMS-WIPP-00-003 REV2 AND WTS/WIPP CS-2003-003 REV0).   $
C                                                                              $
M6     1001.60C     -0.0056                                                   $
       8016.60C     -0.4981                                                   $
      11023.60C     -0.0171                                                   $
      12000.60C     -0.0026                                                   $
      13027.60C     -0.0457                                                   $
      14000.60C     -0.3151                                                   $
      16032.60C     -0.0013                                                   $
      19000.60C     -0.0192                                                   $
      20000.60C     -0.0829                                                   $
      26054.60C     -7.0065E-04                                               $
      26056.60C     -1.1395E-02                                               $
      26057.60C     -2.6801E-04                                               $
      26058.60C     -3.6018E-05                                               $
MT6   LWTR.01T                                                                 $
C                                                                              $
C  HDPE SHIELD.                                                               $
C                                                                              $
M7     6000.60C  1   1001.60C  2                                               $
MT7   POLY.01T                                                                 $
C                                                                              $
C     PRINT TABLE 40 FOR MASS FRACTIONS                                        $
C                                                                              $
PRINT 40                                                                       $
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Appendix C

Hazard Evaluation Tables

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Introduction

The following hazard evaluation tables include potential causes for loss of controlled parameters described in section 6.0 of this NCSE. The contingent events flow from the hazard evaluation tables and the associated upset conditions are evaluated in Section 7.0.

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Table C-1, Waste Handling Building Hazard Evaluation by Control Parameter

Waste Handling Building	**Waste remains in shipping container until inside the hot cell complex in Waste Handling Building (WHB). Loaded shipping container is stored in parking area on over the road transportation trailer; loaded shipping container is stored in remote-handled (RH) bay on over the road transportation trailer until moved using the 140/25 ton crane to road cask transfer car. 72-B container moved directly to transfer cell. Drums from 10-160B container are placed into a facility canister which is lowered from the upper hot cell to transfer cell. Waste canister transferred from transfer cell to facility cask. Facility cask transferred to waste shaft conveyance.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Mass	Generator site error result in excess mass	Fissile mass and beryllium are over batched beyond the Waste Acceptance Criteria (WAC) requirements in the contingency analysis. Normal condition and contingency analysis models an optimized fissile mass in terms of moderation and geometry, which is very conservative compared to expected waste configuration. Use of expected configuration would result in higher subcritical mass.	Fissile mass limits established for transportation in 72-B canisters and drums within a 10-160B shipping container. Fissile mass and beryllium limits established for RH waste canisters and drums in Waste Isolation Pilot Plant (WIPP) WAC.	Fissile limits must not be exceeded including 2 times the measurement uncertainty.
Geometry	Collision, fires, collision followed by fire, or dropped drum baskets causes change in geometry	While geometry could be modified from a fire or other breach of a waste container (such as crane or grapple failure) only one waste canister is involved in the cask unloading room (CUR), transfer cell, facility cask loading room (FCLR), or during transport to the waste shaft conveyance. 10-160B contents limited to 20 Pu Equivalent Ci or 318 FGE, which is less than analyzed in a single, optimally moderated, fully reflected fissile mass in the canister.	Waste container design, facility cask, shipping container in the RH bay and outside area, grapple design, upper hot cell crane design, CUR crane design, facility canister design, fire suppression system in RH bay, limited material in RH bay available to burn, vehicle control program to prevent non waste handling vehicles in the RH bay during waste handling.	Fissile material conservatively modeled as either spheres centralized to the container or cylinders conservatively placed in two adjacent drums in the canister such that the fissile material from the two drums is separated only by the thickness of the drum lid/bottom (steel ignored).

Table C-1, Waste Handling Building Hazard Evaluation by Control Parameter

Waste Handling Building	**Waste remains in shipping container until inside the hot cell complex in Waste Handling Building (WHB). Loaded shipping container is stored in parking area on over the road transportation trailer; loaded shipping container is stored in remote-handled (RH) bay on over the road transportation trailer until moved using the 140/25 ton crane to road cask transfer car. 72-B container moved directly to transfer cell. Drums from 10-160B container are placed into a facility canister which is lowered from the upper hot cell to transfer cell. Waste canister transferred from transfer cell to facility cask. Facility cask transferred to waste shaft conveyance.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Moderation	Excess moderation provided by plastic, graphite, beryllium, or water	Analysis modeled fissile mass in compact geometry at optimum moderation level by polyethylene/water mixture with no liquid restriction. Be and graphite moderation shown to decrease reactivity. Polyethylene density up to 100 volume % assumed in analysis depending on compaction state.	WIPP WAC imposes fissile and beryllium mass limits. WIPP WAC restricts residual liquid content of waste to less than 1% by volume. No sprinklers in hot cell complex; shipping container lids are in place in RH bay and canister is in facility cask in FCLR.	The compaction density is not controlled as polyethylene at theoretical density was modeled for machine compacted waste.
Interaction	Waste container compaction resulting from collision in the parking area or RH portion of the WHB (RH bay, conveyance car loading room, conveyance loading room) OR more than 12 drums loaded into upper hot cell	Infinite planar array of canisters was modeled and shown to be subcritical such that spacing between canisters is not required for criticality safety. Analysis modeled 24 drums, stacked 2 high, with close fitting, concrete reflection in upper hot cell.	Shipping containers, transfer cell and facility cask only hold one canister; no more than two filled drum carriages in the upper hot cell or CUR. Canister wells in upper hot cell provide separation of canisters from other drums. Vehicle control program to prevent non waste handling vehicles in the RH bay during waste handling.	

Table C-1, Waste Handling Building Hazard Evaluation by Control Parameter

Waste Handling Building	**Waste remains in shipping container until inside the hot cell complex in Waste Handling Building (WHB). Loaded shipping container is stored in parking area on over the road transportation trailer; loaded shipping container is stored in remote-handled (RH) bay on over the road transportation trailer until moved using the 140/25 ton crane to road cask transfer car. 72-B container moved directly to transfer cell. Drums from 10-160B container are placed into a facility canister which is lowered from the upper hot cell to transfer cell. Waste canister transferred from transfer cell to facility cask. Facility cask transferred to waste shaft conveyance.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Neutron Absorption	Degraded container has rusted steel wall	Analysis models 50 steel density to account for degraded containers.	WAC requires that drums are of good integrity. RH-TRAMPAC also requires that drums are of good integrity prior to shipment to WIPP.	
Reflection – Internal to Container	Excess reflection provided by excess beryllium, polyethylene, lead, etc. in container	Beryllium mass over batched beyond the WAC requirements in the contingency analysis. Compacted waste modeled polyethylene at theoretical density to maximize internal reflection. Water filling containers of non-compacted waste also evaluated and system shown to remain subcritical.	WIPP WAC and shipping container Safety Analysis Reports (SARs) impose fissile and special reflector mass limits.	The compaction density is not controlled as polyethylene at theoretical density was modeled for machine compacted waste.
Reflection – External to Container	Excess reflection provided by concrete or lead around the container	Analysis models infinite thick (2 m) lead to simulate the 4.75” lead wall of the facility cask and close fitting, infinite thick, concrete reflection on all sides of the drums in the hot cell.	Upper hot cell is large such that there is no tight fitting concrete reflector on all sides of the drums. No lead available in appreciable thicknesses other than the wall of the facility cask.	

Table C-1, Waste Handling Building Hazard Evaluation by Control Parameter

Waste Handling Building	**Waste remains in shipping container until inside the hot cell complex in Waste Handling Building (WHB). Loaded shipping container is stored in parking area on over the road transportation trailer; loaded shipping container is stored in remote-handled (RH) bay on over the road transportation trailer until moved using the 140/25 ton crane to road cask transfer car. 72-B container moved directly to transfer cell. Drums from 10-160B container are placed into a facility canister which is lowered from the upper hot cell to transfer cell. Waste canister transferred from transfer cell to facility cask. Facility cask transferred to waste shaft conveyance.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Enrichment	Enrichment limit for low enriched uranium (LEU) payload exceeded by generator site	Contingency analysis evaluates small increase in LEU enrichment which accounts for variations in the enrichment within the canister.	The WAC imposes the enrichment limit for the LEU payload. The RH-transuranic (TRU) 72-B SAR also imposes this enrichment limit for shipments to the WIPP. The fissile limits expressed in fissile gram equivalent (FGE). The FGE value account for the differences in minimum critical mass between these isotopes.	
Volume	Not controlled	Analysis conservatively models fissile masses as spheres of unrestricted volume with the remainder of the waste container filled with Be, water/poly mixtures or poly only.	Volume is limited by the size of the approved waste containers.	All containers approved to be shipped to WIPP in the RH-TRU 72-B and CNS 10-160B shipping containers are evaluated.
Concentration	Not controlled	The fissile concentration was unrestricted and optimized by varying the H/Pu ratio in the fissile region.		

Table C-2, Underground Hazard Evaluation by Control Parameter

Underground	**Waste transported onto conveyance; conveyance moved from waste shaft collar to the waste shaft station; waste moved from waste shaft station to active disposal room using 41 ton forklift; waste placed in a RH disposal borehole using HERE.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Mass	Generator site error result in excess mass	Fissile mass and beryllium are over batched beyond the WAC requirements in the contingency analysis. Normal condition and contingency analysis models an optimized fissile mass in terms of moderation and geometry, which is very conservative compared to expected waste configuration. Use of expected configuration would result in higher subcritical mass.	Fissile mass limits established for transportation in 72-B canisters and drums within a 10-160B shipping container. Fissile mass and beryllium limits established for RH waste canisters and drums in WIPP WAC.	Limits must not be exceeded including 2 time the measurement uncertainty
Geometry	Collision, fires, collision followed by fire, or dropped drum baskets causes change in geometry	While geometry could be modified from a fire or other breach of a waste container (such as waste hoist failure), only one RH waste canister is involved during transport to the underground and to the active disposal room.	Facility cask, waste hoist brake and rope redundancy, shipping container in the RH bay and outside area	Fissile material conservatively modeled as either spheres centralized to the container or cylinders conservatively placed in two adjacent drums in the canister such that the fissile material from the two drums is separated only by the thickness of the drum lid/bottom (steel ignored).
Moderation	Excess moderation provided by plastic, graphite, beryllium, or water OR Water- in waste as a result of hoist failure such that the facility cask falls into the waste shaft sump	Analysis modeled fissile mass in compact geometry at optimum moderation level by polyethylene/water mixture with no liquid restriction. Be and graphite moderation shown to decrease reactivity. Polyethylene density up to 100 volume % assumed in analysis depending on compaction state.	WAC restricts residual liquid content of waste to less than 1% by volume. Waste hoist design with seismic structure, redundant brakes, and redundant ropes to prevent submerging.	The compaction density is not controlled as polyethylene at theoretical density was modeled for machine compacted waste.

Table C-2, Underground Hazard Evaluation by Control Parameter

Underground	**Waste transported onto conveyance; conveyance moved from waste shaft collar to the waste shaft station; waste moved from waste shaft station to active disposal room using 41 ton forklift; waste placed in a RH disposal borehole using HERE.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Interaction	Waste container compaction resulting from waste hoist failure, collision in the underground; roof fall during transport or after disposal	Infinite planar array of canisters was modeled and shown to be subcritical such that spacing between canisters is not required for criticality safety.	Facility cask protects RH waste container during transport and emplacement from roof fall and collisions. RH waste handling typically precedes contact-handled (CH) waste handling such that the CH waste face is not at risk Also RH waste handling equipment is typically placed such that the Horizontal Emplacement and Retrieval Equipment (HERE) is between a CH waste face and the approaching RH forklift. Shield plug and salt isolate disposed RH canisters from each other and from CH waste.	
Neutron Absorption	Degraded container has rusted steel wall	Analysis models 50 steel density to account for degraded containers.	WAC requires that drums are of good integrity. Remote Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC) also requires that drums are of good integrity prior to shipment to WIPP.	

Table C-2, Underground Hazard Evaluation by Control Parameter

Underground	**Waste transported onto conveyance; conveyance moved from waste shaft collar to the waste shaft station; waste moved from waste shaft station to active disposal room using 41 ton forklift; waste placed in a RH disposal borehole using HERE.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Reflection – Internal to Container	Excess reflection provided by excess beryllium, polyethylene, lead, etc. in container OR Water- in waste as a result of hoist failure such that the facility cask falls into the waste shaft sump	Beryllium mass over batched beyond the WAC requirements in the contingency analysis. Compacted waste modeled polyethylene at theoretical density to maximize internal reflection. Water filling containers of non-compacted waste also evaluated and system shown to remain subcritical.	WIPP WAC and shipping container SARs impose fissile and special reflector mass limits.	The compaction density is not controlled as polyethylene at theoretical density was modeled for machine compacted waste.
Reflection – External to Container	Excess reflection provided by concrete or lead around the container	Analysis models infinite thick (2 m) lead to simulate the 4.75" lead wall of the facility cask and reflection from the HERE structure. Tight fitting, thick salt reflection modeled in borehole analyses.	No lead available in appreciable thicknesses other than the wall of the facility cask.	
Enrichment	Enrichment limit for LEU payload exceeded by generator site	Contingency analysis evaluates small increase in LEU enrichment which accounts for variations in the enrichment within the canister.	The WAC imposes the enrichment limit for the LEU payload. The RH-TRU 72-B SAR also imposes this enrichment limit for shipments to the WIPP. WAC imposes other fissile limits expressed in FGE. The FGE value account for the differences in minimum critical mass between these isotopes.	

Table C-2, Underground Hazard Evaluation by Control Parameter

Underground	**Waste transported onto conveyance; conveyance moved from waste shaft collar to the waste shaft station; waste moved from waste shaft station to active disposal room using 41 ton forklift; waste placed in a RH disposal borehole using HERE.**			
Parameter	**Causes**	**Consequences/Analysis Limits**	**Barriers**	**Notes**
Volume	Not controlled	Analysis conservatively models fissile masses as spheres of unrestricted volume with the remainder of the waste container filled with Be, water/poly mixtures or poly only.	Volume is limited by the size of the approved waste containers.	All containers approved to be shipped to WIPP in the RH-TRU 72-B and CNS 10-160B shipping containers are evaluated.
Concentration	Not controlled	The fissile concentration was unrestricted and optimized by varying the H/Pu ratio in the fissile region.		