Washington State Department of Health
Environmental Health Programs
Division of Radiation Protection

TECHNICAL EVALUATION REPORT

Related to the report covering the Evaluation of Potential Dose Pathways From Disposal of Portland General Electric's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility Richland, Washington, prepared by Chase Environmental Group, Inc.

Prepared by: Waste Management Section

September 1998

ABSTRACT

This Technical Evaluation Report (TER) has been prepared by the Waste Management Section of the Washington State Department of Health for the review of the report prepared by Chase Environmental Group, Inc. on behalf of US Ecology, Inc. and Portland General Electric, entitled "Evaluation of Potential Dose Pathways From Disposal of Portland General Electric's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility Richland, Washington." The reactor vessel is proposed for intact disposal at the low-level radioactive waste disposal site in compliance with WAC 246-249, WAC 246-250 and US Ecology's Radioactive Materials License #WN-I019-1. The staff concludes that the Portland General Electric reactor vessel with its highly activated internals in place (but without the fuel) meets the stability and performance requirements of the above documents and may be disposed of at the US Ecology Richland low-level radioactive waste disposal site as Class C waste.

Table of Contents

1.0 BACKGROUND

1.1 Regulations

By Federal Register Notice dated December 27, 1982 (47 FR 57446), the United States Nuclear Regulatory Commission (NRC) amended its regulations to provide specific requirements for licensing of facilities for the land disposal of low-level radioactive waste. The majority of the federal regulations were codified in Part 61 of Title 10 of the Code of Federal Regulations (10 CFR 61). Since the state of Washington had already established itself as an Agreement State, compatible state regulations were subsequently adopted and codified in Washington Administrative Code (WAC) Chapters 246-249 and 246-250.

The effective date for the implementation of sections of the state WAC requiring generators to meet the waste classification and waste form requirements was December 11, 1986. As set forth in the regulations, generators must classify their waste as Class A, B, or C. Further, Class B and Class C waste must meet structural stability requirements that are established under WAC 246-249 and US Ecology's Radioactive Material License WN-I019-1. As noted in WAC 246-249, structural stability could be provided by, among other means, the waste itself (as with large activated steel components). To the extent practicable, Class B and C waste forms or containers should, according to Section 61.7 of Part 61, maintain structural stability for 300 years. In May 1983, the NRC provided additional guidance by means of a Technical Position on Waste Form[1] that describes test procedures and criteria that can be used to demonstrate the required long-term, 300-year, structural stability. Additional guidance was provided in January 1995 in the form of another Technical Position on Concentration Averaging and Encapsulation (Ref 5). This new position expands on, further defines, and replaces that guidance which was provided in Section C.3 of the original 1983 Technical Position. Other sections of the original 1983 position remain in effect (except some minor changes noted in a footnote of the new position).

1.2 Performance Evaluation Report Submittals

US Ecology Inc., in a letter to G. Robertson dated March 12, 1996, requested the department's concurrence on the waste classification of the reactor vessel with the internals left in place.[2] The submittal included the total source term, but did not include the expected radionuclide inventory in each internal component of the vessel.

In a letter to US Ecology, Inc. dated April 2, 1996, the department requested additional information (RAI #1) as a result of reviewing the March 12, 1996 submittal.[3]

---

[1] U.S. NRC Technical Position on Waste Form, Rev. 0, May 1983.

[2] US Ecology, Inc. letter to Mr. Gary Robertson, Head, Waste Management Section, WDOH, from A. Palmer, Chief Radiological Control and Safety Officer, dated March 12, 1996

[3] State of Washington, Department of Health letter to A. Palmer, Chief Radiological Control & Safety Officer, US Ecology, Inc., from M. Elsen, dated April 2, 1996.

US Ecology Inc., responded to the RAI #1 in a letter dated April 17, 1996[4], in which additional material was provided and concerns addressed.

On June 10, 1996, the department conditionally approved the classification of Portland General Electric (PGE) Trojan Reactor Vessel (TRV) as Class C waste.[5] This decision was based upon US Ecology's replies and treating the vessel and internals as one component, which allowed waste classification to be performed in accordance with the Branch Technical Position (BTP) on Concentration Averaging and Encapsulation, Section 3.3 (Ref 5).

In a letter to the NRC from Stephen Quennoz, Trojan Site Executive, dated June 18, 1997[6], PGE responded to a request for additional information from the NRC. In this submittal, PGE characterizes the various "sub-components" of the internals of the reactor vessel. In Attachment II, PGE states that the reactor vessel and core internals are considered to be one component containing neutron activated metals incorporating radioactivity in its design, thus allowing concentration averaging over the displaced volume of the material in accordance with the BTP Section 3.3 (Ref 5).

The NRC, in a letter to the department[7] dated January 30, 1998, restated PGE's findings that some of the TRV internals, if treated individually, are Greater-Than-Class C (GTCC), and that averaging the reactor internals (i.e., core baffle plates, the core former plates, and the lower core plate) with the reactor vessel would not comply with the blending ratio protocols in Section 3.3 of the BTP. The NRC staff would consider alternative approaches to waste nuclide averaging (per Section 3.9 of the BTP) if it can be shown that the wastes will meet the performance objectives of 10 CFR 61 (and WAC 246-250). The evaluation should include a comprehensive and defensible pathway analysis that includes all relevant pathways. NRC specifically requested that an intruder-construction and intruder resident-farmer scenario carried out for 10,000 years be analyzed.

The state of Washington Department of Health (WDOH), through letter[8] dated March 2, 1998, requested additional analyses be submitted, including a detailed pathway analysis and dose model representing a time period up to 10,000 years after vessel disposal at the LLRW facility, to justify the package meets the performance objectives of WAC 246-250-170 through 200 (i.e., 10 CFR Part 61). Scenarios developed for 10 CFR 61 (i.e., intruder-construction and intruder resident-farmer) were specifically requested, as well as detailed corrosion analysis.

---

[4] US Ecology, Inc. letter to Mr. Mike Elsen, Radiation Health Physicist, WDOH, from A. Palmer, Chief Radiological Control and Safety Officer, dated April 17, 1996.
[5] State of Washington, Department of Health letter to Mr. Art Palmer, Chief Radiological & Safety Officer, US Ecology, Inc. from Mr. Mike Elsen, dated June 10, 1996.
[6] Portland General Electric Company letter to U.S. Nuclear Regulatory Commission from Stephen M. Quennoz, Trojan Site Executive, dated June 18, 1997.
[7] U.S. Nuclear Regulatory Commission letter to Mr. John Erickson, Director, Division of Radiation Protection, WDOH, from Mr. Richard L. Bangart, Director, Office of State Programs, dated January 30, 1998.
[8] State of Washington, Department of Health letter to Mr. Charles Coleman, CRS&SO, US Ecology, Inc., from Mr. Gary Robertson, dated March 2, 1998.

PGE has submitted a Safety Analysis Report[9] to the Nuclear Regulatory Commission (NRC) to license this package under 10 CFR 71.

Previous to formal document submittal, representatives from PGE and their contractors met with officials from the NRC and the state of Washington in separate meetings to determine prominent concerns. State of Washington meeting attendees represented the following disciplines: mechanical engineering, civil engineering, hydrogeology, geology, and health physics.

By letter dated June 1, 1998, US Ecology requested consideration by the state of Washington to dispose of the reactor vessel from Portland General Electric (PGE) with the highly activated internal components in place as Class C waste. The state of Washington has, in turn, performed a review of the submittal to determine whether it reasonably demonstrates compliance with the four performance objectives in WAC 246-250-170 through 200.

During WDOH's review of the aforementioned project, PGE submitted, concurrent with the letter dated June 1, 1998, two copies of the requested evaluation.

During the review process, staff developed several comments. A request for additional information (RAI #2)[10] dated August 7, 1998 was sent to Portland General Electric.

Portland General Electric's responses to WDOH's RAI #2 were submitted in a US Ecology letter dated August 31, 1998[11]. After a subsequent review of these responses by WDOH, staff determined that WDOH questions had been adequately addressed.

1.3 Reactor Vessel Description

The Trojan reactor vessel is a right cylindrical carbon steel vessel, 42 feet 6 inches tall and 17 feet 1 inch in diameter, that will weigh approximately 950 tons. The physical size and composition of the reactor vessel is 5- to 8-inch thick carbon steel vessel walls and stainless steel internals. It is proposed that the void spaces be filled with Low Density Cellular Concrete (LDCC) prior to disposal. The TRV will be a completely sealed package. All penetration through the vessel walls (e.g., inlet/outlet nozzles, control rod drive mechanisms ports, instrument tubes) are proposed to be welded closed (i.e., ½" welds) with metal plates varying in thickness from 5/8" to 2". Additional metal plates will be welded to the outside of the TRV to act as shielding to lower the dose rate to US DOT levels per 49 CFR 173.441. A description of the TRV, detailing relevant materials and dimension specifics, is provided in Appendix A to Attachment B of the submittal.

[9] Portland General Electric, "Trojan Reactor Vessel Package Safety Analysis Report", March 31, 1997.
[10] Letter from G. Robertson, WDOH to Mr. Charles Coleman, CRC&SO, US Ecology, Inc. dated August 7, 1998.
[11] Letter from B. Bede, Vice President, US Ecology to G. Robertson, Head, Waste Management Section, WDOH dated August 31, 1998.

2.0 SUMMARY OF PERFORMANCE EVALUATION REPORT

The performance evaluation report is intended to demonstrate with reasonable assurance that the disposal of the PGE TRV meets all the applicable requirements and criteria of (a) WAC 246-250 and (b) US Ecology's Radioactive Materials License #WN-I019-1.

Dose models were developed and pathway analyses were performed for a group of hypothetical radiation release scenarios involving vessel disposal. Agricultural, intruder-well construction, and intruder-residential scenarios were presented. Exposure pathways included ingestion, inhalation, and direct exposure. Transport mechanisms reviewed included groundwater, surface water, biotic intrusion, wind, and seismic.

The agricultural scenario assumes a family resides adjacent to the LLRW facility and consumes crops, milk, and groundwater potentially impacted by site operations. The intruder-construction and intruder-residential scenarios assume that intruders were exposed after they uncovered waste. These hypothetical exposure scenarios are conservative, considering the fact that the US Ecology LLRW Facility is located within the 200 Area Plateau on the U.S. Department of Energy Hanford Reservation. This area has been designated by the United States Department of Energy as a controlled area for long-term waste management and disposal activities. Additionally, the TRV will be disposed at a depth exceeding five meters, which is postulated to preclude future contact with intruders.

As acknowledged in the report, a critical area associated with demonstrating acceptable performance assessment was the selection of appropriate hydrogeologic parameters. In order to reduce the potential number of candidate nuclides, isotopes were sorted by amount (i.e., activity) and half-life. Long-lived isotopes or radionuclides with significant quantities were analyzed. Significant parameters included elemental solubility, soil absorption (i.e., K_d's), soil permeability, and infiltration rate.

Corrosion is also analyzed in the report. The effect of corrosion was a time shift retardation in the peak dose from C-14 and/or Tc-99. If the radionuclides inside the TRV are immediately available for leaching, the peak dose is not higher, but simply occurs sooner. The TRV was originally designed to operate as a key component of a pressurized water reactor (PWR) plant. As such, internal pressures approximating 2500 psia were experienced by the TRV during normal plant operations. In order to contain this high pressure, the vessel walls were designed to ASME Boiler Code standards, Subsection NE. This design feature limits the effect of corrosion.

Additionally, an assessment was prepared in accordance with the methodologies utilized in the 10 CFR 61 Environmental Impact Statement (EIS). This assessment demonstrates that the exposures received, using highly conservative intruder exposure scenarios, are less than the 500 mrem per year general whole body dose limitation selected by the NRC for these scenarios. Details of this assessment are provided in Attachment A of the submittal.

The advantages of leaving the vessel intact for disposal, versus removing and sectioning the internals prior to disposal, are also discussed. Occupational and radiological safety parameters during handling the TRV as a single shipment and as approximately 45 shipments are reviewed and evaluated. Collective worker dose is drastically reduced with the TRV intact. The risk of an accident or mishap occurring, during the unloading process, is increased if the TRV internals are sectioned for disposal.

3.0 SUMMARY OF REGULATORY EVALUATION

3.1 Major Areas of Review

The objectives of this technical evaluation of the performance assessment are to confirm that the intact disposal of PGE's TRV meets the performance objective requirement of WAC 246-250. The NRC's Technical Position on Waste Form (as revised) provides guidance on how to classify waste (e.g., different types and forms of LLRW that may be combined and contained in single packages received at the disposal sites) in accordance with US Ecology's Radioactive Materials License #WN-I019-1. The NRC's regulatory position is stated in Section 3, "Volumes and Masses for Determination of Concentration," of BTP "Technical Position on Concentration Averaging and Encapsulation." However, during the development of the 1995 BTP revision, it was recognized that all unique disposals could not be addressed. The TRV is a unique waste form that was not addressed in the basic discussion in Section 3. In such special cases, an "Alternative Provisions" section (Section 3.9 of the BTP) was included to define other classification averaging positions that may be judged acceptable. The key portion of Section 3.9 is:

> "Alternatives to the determination of radionuclide concentrations for waste classification purposes, other than those defined in this technical position, may be considered acceptable. For example, the physical form of certain discrete wastes (e.g., activated metals) may be such that intruder exposure scenarios, other than those used to establish the values in Tables 1 and 2 of 10 CFR 61.55, may be appropriate. A case in point could be the disposal of a large intact activated component filled with a structurally stable medium (e.g., cement), or enclosed in a massive robust container capable of meeting structural stability requirements. A request that demonstrates, with reasonable assurance, that the performance objectives in Subpart C of 10 CFR Part 61 (WAC 246-250) are met, may be used to justify that the waste is acceptable for near-surface disposal. Alternatives would require the approval of, or otherwise be authorized by, the NRC or Agreement State regulatory agency."

The major areas of review that are derived from the above paragraph and addressed in this TER are the four performance objectives in WAC 246-250-170 through 200:

1. Long-term protection of the public health and safety (and the environment);
2. Protection of an inadvertent intruder;
3. Protection of workers and the public during operation of a LLRW disposal facility; and
4. Long-term stability of the disposal site after closure.

Elements within these four areas include: corrosion, structural analyses, gas generation and internal pressurization, radiation and ultra-violet stability, and expected climatic effects over the 10,000 year analysis period. PGE's quality assurance and inspection program is also evaluated.

These and other applicable items are evaluated in the following sections. In some cases the area of concern has received recent and extensive review in another WDOH document.[12] Where there has been no significant change in the state of knowledge as a result of this submittal, it is so stated and reference is made to the earlier review for more detailed information. The contents of the earlier review are not restated in the present review.

While the pathway analysis ensures that the performance criteria of WAC 246-250 have been met, WDOH additionally verified that the TRV, if treated as one component under Section 3.3 of the BTP, would be acceptable for disposal at the US Ecology disposal facility. Verification was performed by reviewing the sum-of-fractions calculations performed by PGE. The final sum-of-fractions yielded 32.8% of the Class C limit for Table 1 (long-lived) radionuclides and 30.3% of the Class C limit for Table 2 radionuclides. Since (1) the internals of the TRV would require disassembly by a cutting torch, and (2) the voids within the vessel are to be filled with LDCC, the TRV can be viewed as one large, massive component.

3.2 Long-Term Protection of the Public Health and Safety (and the Environment)

3.2.1 Background

The long-term protection of the public and environment is stated as a dose limit to the whole body, the thyroid, and any other organ. The original regulatory limits were 25 mrem/year, 75 mrem/year, and 25 mrem/year, respectively.[13] These dose limits were based upon ICRP 2 methodology (e.g., critical organ concept). Since the original

[12] State of Washington, Department of Health, Division of Radiation Protection, "Technical Evaluation Report for the 1996 US Ecology Site Stabilization and Closure Plan for the Low-Level Radioactive Waste Disposal Facility, Richland, Washington", pending publication, expected in October 1998.
[13] WAC 246-250-170.

statement of the performance objective, the NRC and the state of Washington have adopted new regulations[14] based upon ICRP 26/30 dose methodology. Under this scheme, dose is related to the risk of dying from cancer. Instead of having dose limits, organs of the body are assigned weighting factors in proportion to their radiation sensitivity to causing death or genetic mutations. As a result of the new regulations, organ limits are no longer required. Regulatory compliance is shown by maintaining the whole body dose below 25 mrem in one year, and as low as reasonably achievable (ALARA).[15]

3.2.2 Summary of Elements Relating to Long-Term Protection

The concentrations of radionuclides projected to be released to the general environment from disposal of the TRV, result in annual doses substantially below the regulatory limit of 25 mrem to the whole body (Ref 6, Section 5). The projected doses were calculated utilizing conservative assumptions and are projected to be a fraction of that allowed, for the reasons discussed below:

- Disposal site characteristics and closure cap design reduce moisture infiltration and thus the contact of water with waste; minimizing the potential migration of radionuclides via the groundwater pathway.

- TRV burial depth minimizes the potential for exposure from radionuclides transported via dispersion, air transport of gaseous products, intrusion of plants and animals; or from uncovered waste.

- Waste packaging and waste form will contain the activity in a stable matrix for tens of thousands of years into the future, allowing the short-lived gamma-emanating radionuclides to decay to background levels. The SAIC study (Ref 6, Attachment B) demonstrates that the metals corrode very slowly in the dry disposal environment. Additionally, the waste form "activated metal" is one of the most leach-resistant waste forms normally sent to LLRW disposal facilities.

- Location of the LLRW facility on the Hanford Reservation within the 200 Area Plateau. The US Department of Energy has sited a waste site (e.g., Environmental Restoration Disposal Facility) within this same area. While co-locating disposal facilities does not preclude the public from establishing a presence on or around the facility, long-term government oversight of the area is a virtual reality.

A key element in the long-term protection of the public and environment is the stability derived from the TRV itself. The TRV was designed to handle an internal pressure of 2500 psia. In order to achieve this design goal, it was constructed as a thick right cylindrical vessel using high strength steels. These same metal properties enhance

[14] WAC Title 246 sections adopted December 21, 1994.

[15] Letter from Paul Lohaus, Deputy Director, Office of State Programs, U.S. NRC to Mr. Jay D. Ringenberg, LLRW Program Manager, Department of Environmental Quality, State of Nebraska, dated June 30, 1998 validating the use of the ICRP 26/30 methodology. NUREG-1573 (DRAFT) also uses this technique to determine compliance in long-term performance assessments.

its use as a disposal package. Specifically, the thickness of the vessel walls provides an excellent deterrent to leaching radionuclides. The disposal of the TRV in an arid environment serves to reduce the corrosion of the TRV walls, thus reducing an already low radionuclide migration. Under extreme hypothetical conditions, less than 10% of the TRV internals are oxidized during the timeframe needed for all isotopes, including Tc-99, C-14, Ni-59, and Nb-94, to decay to less than 1 mCi. Thus, the transport of radionuclides from the TRV to the environment is controlled by the corrosion rate and not by the solubility of the constituent. In essence, the TRV effectively retards the release of soluble materials for a substantial time period.

Radionuclide release is further retarded by the low-density cellular concrete (LDCC) used to fill the voids within the TRV. By encapsulating the stainless steel internals, the alkalinity of the LDCC causes the formation of a passive oxide film on steel, which prevents corrosion (e.g., acid attack due to carbonic acid from water and CO_2) on the steel surface under most conditions. This protective film can be damaged or destroyed by chloride ions, which penetrate concrete to a considerable depth, depending on the concrete permeability and the local environment. A concrete thickness of at least 5 cm is recommended when corrosive agents are present. While the chloride concentration in the soils at the disposal site ranges from <1 to ≈6 mg/l, the concentration is not expected to approach the levels seen near saltwater (e.g., high levels of chlorides) seawalls and where chloride-based de-icers are used. The recommended thicknesses in these cases are 7.5 cm (3 inches) and 10 cm (4 inches), respectively. Historically, concrete durability ranges from decades to thousands of years, with failures due to poor material qualities and/or inadequate procedural controls (e.g., mixing). As such, with high quality ingredients and proper construction, the LDCC is expected to last from several hundred to a few thousand years (e.g., 500-2000 years).[16] Even though the LDCC is several centimeters thick (TRV sides: 40 cm (16 inches); TRV top/bottom: 285 – ≈550 cm (9.5-18 feet)), the performance assessment takes no credit for the concrete to limit the access of oxygen, carbon dioxide, and water to the stainless steel internals. Also, filling the internal voids with LDCC effectively precludes serious attempts at salvaging the stainless steel internals. The shear amount of LDCC and the resultant thickness surrounding the intact internals would make it prohibitively expensive to retrieve potentially valuable resources (e.g., stainless steel).

In order to place added perspective to this evaluation, the technical evaluation report being written in support of US Ecology's Closure Plan includes the activity from all shipments received to-date and projected until proposed site closure in 2056, but also the source term from the PGE decommissioning (including the intact TRV) and an estimated source term from WNP-2 decommissioning. The dose assessment performed in the comprehensive evaluation, using very conservative modeling parameters and a

[16] MacKenzie, D. R., et al. "Preliminary Assessment of the Performance of Concrete as a Structural Material for Alternative Low-Level Radioactive Waste Disposal Technologies," NUREG/CR-4714, BNL-NUREG-52016, Brookhaven National Laboratory, Upton, New York, December, 1986.

10,000-year timeframe, concludes that the site is in compliance with WAC 246-250 and 10 CFR 61.[17]

3.3 Protection of an Inadvertent Intruder

An inadvertent intruder is a person who might occupy the disposal site after closure and engage in normal activities, such as agriculture, dwelling construction, or other pursuits in which an individual might be unknowingly exposed to radiation from the waste.[18]

A well construction and residential intruder scenarios were analyzed. In the well construction scenario, an inadvertent intruder attempts to drill a well shortly after institutional controls have expired (e.g., about 2163). Assuming the driller is able to pierce the 2" thick nozzle cover plates, radioactive material is exhumed from the vessel in the well cuttings. The driller realizes that he has penetrated something abnormal and stops when reaching the TRV centerline. In contrast, the inadvertent intruder in the residential scenario builds a house with a basement directly above the TRV after controls have expired. The excavation for the basement is assumed to remove about 10 feet of the cover over the TRV causing an increase in direct radiation levels.

As presented in Sections 4.2 and 4.3 (and in Attachment A) of Reference 6, the projected exposures for the intruder scenarios evaluated were below the 500 mrem/yr. guidance value utilized by 10 CFR Part 61 to set waste concentration limits between waste classes, and to demonstrate that the waste is acceptable for near surface land disposal. The intruder scenarios considered were very conservative with respect to the assumptions made in evaluating the projected doses. The conservative assumptions for the postulated inadvertent intruder scenarios are:

- After 500 years, the TRV is assumed to have decomposed to the point that it was indistinguishable from dirt. This is very conservative, based upon the arid disposal environment and the massive design of the TRV. Protection for the inadvertent intruder is derived from enhanced waste forms and packages reducing potential exposures from the inhalation and ingestion pathways.

- The cover over the TRV is eroded at least 6.5 feet to a depth that would allow a basement to be excavated down to the buried waste. The overburden and cover erosion depth that is required to gain access to the TRV would be approximately 24 feet. This degree of erosion is not credible and would require large-scale erosion of major landforms for potential exposure of the TRV.

---

[17] State of Washington, Department of Health, Division of Radiation Protection, "Technical Evaluation Report for the 1996 US Ecology Site Stabilization and Closure Plan for the Low-Level Radioactive Waste Disposal Facility, Richland, Washington", pending publication, expected in October 1998.
[18] WAC 246-250-010(13)

- Inadvertent intrusion that would allow construction of a house or well could be possible if perpetual control of the LLRW facility and the 200 Area plateau by the state or federal government is no longer effective.

3.4 Protection of Workers and Public During Operation of a LLRW Disposal Facility

As discussed in Section 6.0 of Reference 6, the projected exposure to workers is minimized by disposing of the vessel without removing the internals. It would be difficult to remove selected "higher activity" internals (i.e., lower core barrel) individually without removing or sectioning others.

Once removed or sectioned, those individual pieces which are acceptable for LLRW disposal would have to be shipped in liners and casks to the disposal facility. Thus, segmenting the internals will increase the number of shipments and thus exposure to LLRW facility personnel, just from the number of shipments alone. Additionally, unloading high-activity casks is a far more demanding task due to the extreme radiation levels involved and the severe consequences that would result from a mishap during the unloading process. Previous experience unloading packages (e.g., disposable liners) containing activated reactor core components reveals a higher person-rem (population) dose initially that decreases as expertise is gained. Since the last high activity cask shipment occurred in 1992, onsite expertise will need to be re-acquired due to a change in site personnel. Additionally, post-disposal cask handling requires special procedures and equipment (i.e., decontamination tent) to prevent the spread of contamination to personnel and the surrounding environment. In the four shipments received at the disposal site in 1991 and 1992, one individual was internally contaminated and the site was contaminated with very small wind blown particles (e.g., "fleas") twice.[19]

Since the TRV with internals in-place would be limited to the dose rates in the U.S. DOT and NRC regulations (e.g., 2 mSv/hr (200 mrem/hr) on contact) and essentially handled remotely with cranes (at PGE's site) and large hydraulic movers, it is consistent with the ALARA principle to dispose of the vessel intact. Prior to shipment, radiation surveys of the TRV will be performed to ensure that the external dose rates satisfy U.S. DOT and NRC regulations. Additional shielding will be added as necessary. The LDCC, injected into the TRV to fill the void spaces and provide shielding, will also prevent the movement of contaminants within the TRV, thereby preventing radiation level changes during transport. In PGE's Safety Analysis Report[20], the surface dose rate was estimated at 0.95 mSv/hr (95 mrem/hr), and about 0.06 mSv/hr (6 mrem/hr) at 2 meters.

As a result of the remoteness of US Ecology's LLRW facility on the Hanford Reservation, the potential for exposure to the general public due to releases from the TRV is extremely small. In order to preclude damaging the TRV, it is proposed to backfill that

---

[19] Memos from E. Fordham, WDOH Resident Inspector, to G. Robertson, Head, Waste Management Section, WDOH, dated June 21, 1991 and November 5, 1992.

[20] Portland General Electric Company, "Trojan Reactor Vessel Package Safety Analysis Report," dated August 13, 1998, Section 5.

portion of the trench immediately after placement, thus further limiting the potential for exposure. Additionally, leaving the vessel intact reduces the risk of accidents by minimizing the number of waste shipments to the LLRW facility.

From an occupational safety standpoint, the TRV weight poses a safety concern when working nearby, especially under the vessel. Sectioning the internals will not add to worker safety. The estimated weight of the TRV with the internals in place is approximately 2,040,000 lbs (1020 tons). As a result of sectioning the internal pieces, only about 218,000 lbs. (109 tons) (10.7%) would be removed from the TRV prior to its disposal. Subsequently, about 44 additional shipments are required to transport the LLRW to the disposal facility. Off-loading these additional shipments requires using the site crane to lift disposable packages into the air from shipping casks to engineered barriers within a disposal trench. An intact TRV will be placed in the trench without the use of the site crane. Sectioning the internals causes (1) an increased risk from falling objects (e.g., crane moving the disposal package in the air from truck to trench) and (2) more time in the trench for the workers (e.g., removing the concrete lid and sealing the barrier after package is inserted). The two events increase the risk of an occupational accident.

3.5 Long-Term Stability of the Disposal Site After Closure.

The reactor vessel, if disposed intact, will require one package for disposal. The shielded TRV, with wall thickness from 5.5 to 10.7 inches, has been shown by the SAIC analysis (Reference 6, Attachment B) to provide stability for over 10,000 years. This time frame far exceeds the 300 years assumed under the 10 CFR 61 EIS to meet the waste form stability requirements. Even if the vessel were to corrode, the voids within the vessel are to be filled with low-density concrete that will provide structural stability for the overall package.

3.5.1 Brittle Fracture

In addition to the structural stability provided by the vessel, the grout, and metal internal parts, the TRV was analyzed for brittle fracture. Brittle fracture is the sudden catastrophic failure of a specimen with little or no plastic deformation. A prominent example was the sudden fracture of the keels of World War II Liberty ships at pier side. The effect of fast neutron irradiation on the mechanical properties of metals, such as used in the TRV, is documented in industry literature. As a result of neutron bombardment, the TRV will show an increase in hardness and tensile properties, and a decrease in ductility and toughness. These changes make the TRV more susceptible to brittle fracture. To address any concerns, PGE performed a brittle fracture analysis in the Safety Analysis Report.[21] In the analysis, the TRV was reviewed under hypothetical transportation conditions with the temperature as low as -20°F with a minimal margin of safety. Since winter temperatures at the site can be as low as -26°F for several days to

[21] Portland General Electric Company, "Trojan Reactor Vessel Package Safety Analysis Report," dated August 13, 1998, Appendix 2-12.

weeks, further analysis was requested in RAI #2. In response, PGE analyzed the TRV with the temperature at -30°F and held only by two support cradles (e.g., simulated open trench condition in winter). In this condition, the highest stresses are co-located with the most embrittled materials (e.g., at the core barrel centerline). Under these conditions, the existing stresses were found to be less than the reduced allowable stress by a significant margin of safety (e.g., factor of safety = 2.7).

3.5.2 Gas Generation and Internal Pressurization

Gas generation and internal pressurization is recognized in the NRC's Technical Position.[22] The radionuclides commonly considered to exist in gaseous form in disposed waste are H-3, C-14, and Rn-222. In addition to radioactive gases, radiolysis of resins and chemical changes in the waste stream itself can cause gas generation.

Tritium will decay to insignificant levels before the vessel is compromised. The TRV corrosion evaluation completed by Science Application International Corporation (SAIC) conservatively estimated that the package would not be breached for a period in excess of 1,450 years. A conservative set of assumptions was made which involved far more aggressive corrosion conditions than are expected at the burial site at burial depth. The 5/8" thick vessel penetration closure plates were conservatively estimated to be breached after 1,450 years for the water immersion case, and after 2,910 years for the galvanic coupling case study. The SAIC study is included as Attachment B of Ref 6. These two estimated time periods represent greater than ten "half-lives" for tritium.

Additionally, there are no organic compounds in the vessel internals to decay the carbon to methane gas. Thus, C-14 as a radioactive gas will not be generated.

Since radon precursor radionuclides (i.e., U-238) are present in the TRV inventory in very small quantities (e.g., mCi's), Rn-222 is not a concern.

Finally, the TRV waste form is predominantly irradiated metal with loose metal oxides fixed in place with LDCC[23]. With the lack of resins and other materials that undergo chemical changes, the TRV is not expected to generate any gas.

For these reasons, gaseous compounds containing radionuclides would not be present in significant quantities to cause internal pressurization of the TRV that could potential breach the vessel.

3.5.3 Long-Term Climate Effects

In an effort to determine if future climatic changes will cause a detrimental impact to the TRV (e.g., accelerate the corrosion rate), the Hanford Reservation climate during

[22] US NRC Technical Position on Waste Form, Rev. 0, May 1983

[23] Evaluation of Potential Dose Pathways From Disposal of PGE's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility", Chase Environmental Group, May 22, 1998.

the next 10,000 years was estimated by reviewing literature published in support of the Basalt Waste Isolation Project (BWIP). No conclusive evidence was found in literature sources that indicated a wetter or drier environment was more likely in the future. In the absence of significant counteracting atmospheric effects, insufficient information exists to predict future precipitation patterns. However, it seems unlikely according to some scientists that the mean precipitation has varied over a factor of two from its present value (e.g., about 16 cm/year (~6.3 inches/year) since the last glacial maximum. Thus, mean precipitation has ranged from 8 to 32 cm (3.1 – 12.6 inches) per year. These values serve as bounding estimates for future predictions.[24]

3.5.4 Radiation and Ultra-Violet Stability

The NRC Technical Position[25] requires that HIC designs consider the radiation (including ultra-violet) stability of the proposed container materials, as well as the radiation degradation effects of the wastes. The TRV was designed for at least a 35-year operating life (with a possible extension to 40 years). The major source of damage to the TRV materials is the neutron flux of an operating reactor. Gamma irradiation, while detrimental to resins when present, does not affect the metal components of the TRV. The brittle fracture analysis documented above demonstrates the TRV's ability to withstand irradiation damage. In the disposal environment, further irradiation damage is not expected, as the TRV will not contain detectable levels of neutron-emitting materials (e.g., fuel).

With regard to the potential effect of ultra-violet (UV) radiation on the TRV, this is only of concern for nonmetallic materials (e.g., polymeric materials). Since the TRV does not contain this type of material and will be buried underground, there is no concern about the effects of UV radiation on the TRV.

3.6 Quality Assurance and Inspection

Regulations require that all waste be processed and classified in accordance with quality assurance program.[26] The quality assurance requirements are covered in PGE's NRC-approved 10 CFR 50 Appendix B quality assurance program (PGE-8010). PGE-8010, "Trojan Nuclear Plant Nuclear Quality Assurance Program," was approved by the NRC for application to transportation packages in December, 1994.[27] A WDOH review of PGE's QA program for waste processing and classification in 1994 found no deficiencies and did not recommend any changes. A detailed testing and inspection program is presented in Section 8 of PGE's TRV Package Safety Analysis Report.[28] Regarding TRV waste form acceptability at the disposal facility, the important features are the leak checks, de-watering, and LDCC injection.

[24] US Department of Energy, "Site Characterization Report for the Basalt Waste Isolation Project," DOE/RL 82-3 Volume II, prepared by Rockwell Hanford Operations, November 1982.
[25] U.S. NRC Technical Position on Waste Form, Rev. 0, May 1983
[26] WAC 246-249-090
[27] Letter from the NRC, "Quality Assurance Program Approval for Radioactive Material Packages, No. 0327, Revision No. 7," dated December 22, 1994.
[28] Portland General Electric Company, "Trojan Reactor Vessel Package Safety Analysis Report," dated August 13, 1998.

The waste classification is based upon activation analysis performed utilizing ANISN and ORIGEN2 computer codes. The results from these codes were normalized to plant specific data obtained from TRV specimens retrieved in 1990. In addition, a shielding analysis was performed and compared to actual in-plant radiation surveys taken in April 1996. The predicted radiation levels were found to be higher than actual levels. A multiplicative normalization factor of 0.78 was used in correcting predicted values to actual radiation survey results. The normalization factor is conservative, since it uses the absolute maximum measured dose rate and neglects the dose contributed from the activated stainless steel insulation and concrete biological shield wall, and the effects of backscatter from the shield wall.[29] The normalized source terms were decay-corrected to November 1997, to conservatively establish a source term.

4.0 REGULATORY POSITION

WDOH staff have completed the review of the performance evaluation report that is intended to serve as the reference document that describes the potential impacts from disposal of the intact TRV at US Ecology's Low-Level Radioactive Waste Disposal Facility near Richland, Washington. In the evaluation, WDOH focussed on (1) the pathway analysis dealing with long-term protection of the public and environment, and (2) the various factors affecting the rate of corrosion that the TRV may experience. Based upon this evaluation of the information provided in (a) the performance evaluation report, (b) written responses by Chase Environmental Group, Inc.,[30] and (c) meetings and telephone discussions with PGE and CEG representatives, WDOH staff concludes that there is reasonable assurance that, considering the proposed method of package sealing and trench placement (e.g., immediate backfill), the TRV meets the performance requirements of WAC 246-250 and is consistent with the NRC's Staff Technical Position on Waste Form (as amended).

WDOH approval of the intact disposal of the TRV is predicated on the following:

1. Final approval by WDOH's responsible officials, following public comment period.
2. The TRV is backfilled within 30 working days of placement within Trench 12.
3. The density of the backfilled area (exclusive of the TRV) is 90% of site soil in-situ density before excavation of Trench 12.
4. The TRV is placed such that neither the inlet nor outlet nozzles are in a vertical position (e.g., desire to keep closure plates in the off vertical position).

[29] Portland General Electric Company, "Trojan Reactor Vessel Package Safety Analysis Report," dated August 13, 1998, Section 5.

[30] "Responses to State of Washington's Comments of August 7, 1998 on Disposal of Portland General Electric's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility Richland, Washington", Chase Environmental Group, Inc. & AquAeTer, Inc., August 27, 1998.

5.0 **REFERENCES**

1. 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste, U. S. Government Printing Office, January 1, 1983
2. State of Washington Administrative Code Chapter 246 – 249
3. State of Washington Administrative Code Chapter 246 – 250
4. Technical Position on Waste Form, Revision 0, U. S. Nuclear Regulatory Commission, May 1983.
5. Technical Position on Concentration Averaging and Encapsulation, Revision in Part to Waste Classification, U.S. Nuclear Regulatory Commission, January 17, 1995.
6. "Evaluation of Potential Dose Pathways From Disposal of Portland General Electric's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility Richland, Washington," Chase Environmental Group, Inc. & AquAeTer, Inc., Louisville, Kentucky, May 22, 1998.
7. US Ecology's Radioactive Materials License #WN-I019-1 issued by the state of Washington, Department of Health, Division of Radiation, Waste Management Section, Olympia, WA.
8. Portland General Electric, "Trojan Reactor Vessel Package Safety Analysis Report", Revision 2 dated August 13, 1998.
9. State of Washington, Department of Health letter to Mr. Charles Coleman, CRC&SO, US Ecology, Inc., from Mr. Gary Robertson, March 2, 1998.
10. Internal report to Gary Robertson, Head, Waste Management Section, WDOH, from Earl Fordham, entitled "Contamination on and incident to the IF-300 from Niagara Mohawk Power Corporation during March to June, 1991," dated June 21, 1991.
11. Internal report to Gary Robertson, Head, Waste Management Section, WDOH, from Earl Fordham, entitled "Personnel and LLRW site contamination incident to an IF-300 shipment on August 20, 1992," dated November 5, 1992
12. MacKenzie, D. R., Kiskind, B., Bowerman, B. S., Piciulo, P. L., "Preliminary Assessment of the Performance of Concrete as a Structural Material for Alternative Low-Level Radioactive Waste Disposal Technologies," NUREG/CR-4714, BNL-NUREG-52016, Brookhaven National Laboratory, Upton, New York, December, 1986.
13. U.S. Department of Energy, "Site Characterization Report for the Basalt Waste Isolation Project," DOE/RL 82-3 Volume II, prepared by Rockwell Hanford Operations, November 1982.
14. "Response to State of Washington's Comments of August 7, 1998 on Disposal of Portland General Electric's Trojan Reactor Vessel at US Ecology's Low-Level Radioactive Waste Disposal Facility Richland, Washington," Chase Environmental Group, Inc. & AquAeTer, Inc., Louisville, Kentucky, August 27, 1998.