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PUREX Roof Collapse Accident Analysis

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ACRONYMS/ABBREVIATIONS

ARF	airborne release fraction
Ci	Curie
DOE	U.S. Department of Energy
DR	damage ratio
ICRP	International Commission on Radiological Protection
MAR	material at risk
Pu	Plutonium
PUREX	Plutonium Uranium Extraction
RC	risk class
REDOX	Reduction Oxide
RF	respirable fraction
RL	U.S. Department of Energy, Richland, Operations Office
USQ	Unreviewed Safety Question
X/Q′	atmospheric dispersion coefficients

1.0 INTRODUCTION

This safety addendum has been prepared to support planned roof upgrade activities at the Plutonium Uranium Reduction Extraction (PUREX) facility (202-A Building). The roof upgrade involves placement of a new roof over the existing roof, supported by the facility structure.

1.1 PURPOSE

This safety addendum was developed to support the one time activity for placement of a new roof over the existing roof. It identifies the potential hazards and appropriate controls associated with the proposed roof installation. Approval of this safety addendum by the U.S. Department of Energy (DOE) will authorize the use of a crane to complete the installation of this roof. Administrative controls identified within this safety addendum are applicable to the installation of the new roof. The approved safety addendum will be used, as applicable, for the next update of the safety analysis document (HNF-SD-CP-ISB-004, *Plutonium Uranium Extraction (PUREX) End State Basis for Interim Operation for Surveillance and Maintenance*).

The new roof will be a steel structure that is enclosed with metal panels (Appendix A, *Figures*). An engineering evaluation (HNF-11732, *PUREX and B Plant Canyon Roof Investigation*), documents compliance with existing design standards. The shape will be a sloped shed, built over and enclosing the existing roof. The roof is designed to provide minimal maintenance and, most importantly, a slope that will drain run-off from the canyon structure. Installation of the new roof will close some of the outstanding actions identified with completion of the facility deactivation.

1.2 DESCRIPTION OF PROPOSED ACTIVITY

The planned work, presented in outline form, provides an overview of the proposed activities. This outline is not the level of detail that will be provided in fieldwork documentation, but is rather a summary level discussion that was used to clarify this safety addendum.

General construction requirements include:

- Implementation of Hanford site procedures that implement Occupational Safety and Health Administration requirements

- Performance of radiological aspects of the roof work in accordance with the site radiological control program and the requirements of 10 CFR 835, *Occupational Radiation Protection*

- Installation in accordance with approved drawings and procurement documents.

The major subtasks in the roof upgrade project are:

1. Material and Personnel Mobilization
2. Fall Protection Installation
3. Framing Installation
4. Wall Panel Installation
5. Purlin Installation
6. Roof Panel Installation.

A brief summary of the key activities for each of these subtasks is presented in the following sections.

1.2.1 Material and Personnel Mobilization

Mobilization activities consist of staging the roofing components, construction trailer, crane, forklifts, self-propelled elevating work platform, diesel generator, and various tools at the construction site. The construction trailer will include an electrical feed from the diesel generator. This same generator will also feed electrical spider boxes on the roof that supply power to tools being used in the fabrication of the replacement roof. A Port-O-Let will be staged at the site, near the trailer. A forklift and a self/manually propelled elevating work platform will be staged to assist the re-roofing work activities.

Tractor-trailers will deliver bundles of roofing components to the site. A forklift will be used to off-load the bundles from the trailers and for staging bundles around the building. Some of the roofing component bundles may be required to be broken down into smaller bundles.

A separate Unreviewed Safety Question (USQ) determination was completed for this work (FN-2002-32, *Staging of Equipment for PUREX Roofing Job*). These activities were authorized based on the results of that USQ determination.

1.2.2 Fall Protection Installation

Fall protection equipment/components will be the first equipment installed on the roof. The fall protection equipment consists of fall protection stanchions, Hilti bolts, portable stanchions, and a warning line. The fall protection equipment will be transported to the roof with a self-propelled elevating work platform. The stanchions and line will be installed first, and located at least 1.8 m (6 ft) from the edges of the roof, to act as warning indicators to personnel. Once the equipment has been installed, the existing roofing material will be cut and the fall protection stanchions will be installed using Hilti bolts. The fall protection systems consist of stanchions placed 12.2 m (40 ft) apart along the centerline of the roof. The Hilti bolt anchor holes will be drilled and then the bolts will be installed. Once the stanchions are secured in place, the roofing material that was removed will be replaced over the base plate at each location.

Fall protection installation activities were authorized based on the results of the separate USQ determination (FN-2002-32).

1.2.3 Framing Installation

The framing components will be lifted to the roof from the ground using a crane. The base plates will be the first of the components to be installed. These components will be installed in the same manor as the fall protection stanchions, by removing the existing roofing materials and using Hilti bolts.

1.2.4 Wall Panel Installation

Once all the base plates have been installed, the north and south end walls will be installed on the roof. The roof design calls for the high side of the roof to be installed on the north side of the building. The rise in height (approximately 1.8 m [6 ft]) will be achieved using wall panels. The wall panels are shop fabricated into variable length sections, up to 3.1 m (10 ft) in length. These sections will be loaded from the trailer directly to the roof (starting at the east end of the facility) using a crane (Appendix A). The walls will be anchored to the existing roof approximately 10 cm (4 in.) from the edge, using Hilti bolts.

1.2.5 Purlin Installation

In the roof area where the end wall sections have been installed, the vertical legs, upper clips, and bracing installation may begin. Typically, after 5 to 6 rows of vertical legs, upper clips, and bracing have been installed, a purlin (10 cm [4 in.] wide, 9.1 m [30 ft] long) bundle (20 purlins to a bundle weighing approximately 1,134 kg [2,500 lbs]) will be staged on the roof between two of the finished rows (Appendix A). The purlins will be clamped in place one at a time until all of the purlins in that section of the roof are in place. As this is being performed, the installation of the vertical legs, upper clips, and bracing continues. Typically, after another 5 to 6 rows have been completed, the installation process of the purlins will be repeated and the overlap of the two mating purlins will be secured with fasteners.

1.2.6 Roofing Panel Installation

Typically, when about a third of the roof has had the frame and purlins installed, the roofing panel (46 cm [18 in.] wide, approximately 18.3 m [60 ft] long) bundles (weighing less than 680.4 kg [1,500 lbs]) will be transported to that portion of the roof using a crane and staged perpendicular and on top of the purlins. The roofing panels will be secured to the frame using clips and then connected to each other by overlapping the panels and mechanically rolling the edges. Then installation of the frame components, purlins, and roofing panels will proceed concurrently until the activities are completed.

2.0 HAZARD AND ACCIDENT ANALYSIS

The hazard and accident analysis is based on the hazard analysis document, (HNF-SD-CP-ISB-004 and SD-HS-SAR-001, *PUREX Plant Final Safety Analysis Report).*

2.1 HAZARD ANALYSIS METHODOLOGY

Using the information provided above, a hazard analysis was performed June 11, 2002 on the PUREX roof repair activities. The hazard analysis team included:

Singh Bath	FH Project Lead
John Bell	RCP Industrial and Fire Protection Safety
Mark Deichman	FFS Industrial Safety
Edwin Dodd	200 ASF Nuclear Safety/Lead Analyst
Dee Ekstrom	Radiological Control
Robert Fox	200 ASF Operations
Steve Giamberardini	200 ASF Chief Engineer
Edward Gonsalves	200 ASF Design Authority
Khris Judy	RSM Project Lead
Darrell Riffe	RCP ESQ Director
Rich Stephenson	200 ASF Field Work Supervisor
Wendy Sudikutus	FH Project Subcontracting

The hazard analysis was conducted using a "What if/Checklist" methodology. The checklist used was developed from the American Institute of Chemical Engineers (AIChE), *Guidelines for Hazard Evaluation Procedures.*

To assist in the identification of hazards associated with the planned activities, a hazard baseline checklist was completed by the team prior to completion of the "What if/Checklist" analysis on the work plan.

2.2 HAZARD EVALUATION

In performing the hazard analysis (Appendix B, *Hazard Analysis*), the review team considered each of the major subtasks associated with the planned activities and determined the potential hazards associated with these activities. The hazards identified in Appendix B were further evaluated to identify events requiring more detailed analysis. The results of the evaluation are documented in Table 1, *Hazard Evaluation.*

Table 1. Hazard Evaluation. (2 pages)

ID	Potential Event/ Location	Hazard Type	Event and Possible Causes	Event Ranking		Preventive and Mitigative Features		Risk Class	Comments
				F*	C*	Engineered	Administrative		
1.	Fire Adjacent to Facility	Radioactive material, flammable/ combustible materials	Flammable or combustible liquid spilled within area and ignited. Burning pool fire potentially involves radioactive contamination exterior to the facility, resulting in release to the environment. Possible cause: Breach of fuel tank from vehicle due to impact and subsequent ignition, by ignition source.	A	L	Concrete structure	Vehicle access/ operation controls. Fire Protection Program requirements (e.g., staging of fire extinguishers, separation of generator from building, etc.)	III	Due to the passive concrete structure of the facility, the fire will not propagate to the inside of the facility. Therefore, no radiological release is anticipated. No further evaluation is required.
2.	Fire/ Facility Roof	Radioactive material, flammable/ combustible materials, hazardous materials	Combustibles are ignited and resulting local fire potentially suspends radioactive material present as contamination. Possible cause: Cutting and drilling operations during installation and setup of fall protection. Cutting and grinding operations, generator or equipment failure, crane contact with power lines during roof installation.	A	L	Concrete structure	Combustible material control, hot work permits, and associated controls per the Fire Protection Program.	III	The activities have been evaluated by a Fire Protection Engineer and it was determined that no additional controls are needed. A postulated fire on the roof deck would have no structural effect on the 18" concrete roof structure.

Table 1. Hazard Evaluation. (2 pages)

ID	Potential Event/ Location	Hazard Type	Event and Possible Causes	Event Ranking		Preventive and Mitigative Features		Risk Class	Comments
				F*	C*	Engineered	Administrative		
3.	Load Drop/ Facility Roof	Radioactive material, hazardous materials	Potential roof failure could result in loss of confinement and potential release of radiological and hazardous materials to the environment. Possible cause: Human error, equipment failure.	A	L	Concrete structure	Trained crane operators, Project work plan controls, Hoisting and Rigging Manual, Project work plan controls	III	Accident is evaluated in Section 2.4.2, *Partial Collapse of the PUREX Roof.*
4.	Roof Overload/ Facility Roof	Radioactive material, hazardous materials	Potential roof failure could result in loss of confinement and potential release of radiological and hazardous materials to the environment. Possible cause: Human error.	U	M	Concrete structure	Trained crane operators, Project work plan controls, Hoisting and Rigging Manual, Project work plan controls	II	Accident is evaluated in Section 2.4.1,*Catastrophic Failure of the PUREX Roof.*
5.	Crane Accident/ Facility Ancillary Equipment (deep bed filters, stack, etc.)	Radioactive material, hazardous materials	Potential roof failure could result in loss of confinement and potential release of radiological and hazardous materials to the environment. Possible cause: Human error, equipment failure (crane tip or boom), ground instability.	A	L	Concrete structure, use of load spreader for crane outriggers	Trained crane operators, Project work plan controls, Hoisting and Rigging Manual, Project work plan controls	III	Accident is evaluated in Section 2.4.3, *Deep Bed Filter Release Adjacent Structures.*

*F – Frequency (estimated annual): A – Anticipated, U – Unlikely
*C – Consequence (estimated): L – Low, M - Moderate

In performing the hazard analysis, a crane staging diagram was developed and is included in Appendix A. The diagram shows the planned staging locations for the crane during the PUREX roof repair work. The diagram is not intended to illustrate the exact and only locations where the crane may be placed during the roof work. The diagram illustrates the types of locations considered and the potential impact to the facility structures.

Institutional safety programs (i.e., engineering, industrial safety, and fall protection) and work plans were identified by the hazard analysis team as the primary means to prevent or mitigate potential hazards to the workers from the roof replacement activities. However, three hazard events were identified for more detailed accident analysis and for confirmation of applicable control requirements.

The hazards analysis team identified hazards related to the installation of the roof structures with the potential to affect nuclear safety (potential release of radionuclides). In particular, the job requires that roofing material be placed onto the roof using a crane, which creates the potential for excess weight or load concentrations during lifting and staging operations. Additional engineering evaluations (HNF-11733, *PUREX and B Plant Canyon Roof Drop Inventory)* were prepared to evaluate and define the necessary precautions to prevent a load drop that would damage the roof structure and its confinement function.

2.3 ACCIDENT ANALYSIS METHODOLOGY

The PUREX safety analysis (HNF-SD-CP-ISB-004) analyzed structural adequacy due to natural phenomena. The evaluation bases for seismic forces were those defined for a 0.1 g peak acceleration event (HNF-SD-CP-ISB-004, Section 4.3.1, *Hanford Regional Historical Earthquake*). An evaluation of the potential consequences associated with a roof failure at the PUREX facility is presented in the following sections. The methodology used in determining the potential consequences meets the requirements of HNF-PRO-700, *Safety Basis Development,* and DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports.*

Source term development was based on the guidance in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Section 1.2. The formula used is shown in Equation (1).

$$Q = (MAR)(DR)(ARF)(RF)(LPF) \qquad \text{Equation (1)}$$

Where:

Q = Source term
MAR = Material-at-risk (curies)
DR = Damage ratio
ARF = Airborne release fraction
RF = Respirable fraction
LPF = Leak path factor.

The source term was then used to determine the potential consequences to the target receptors. Doses calculated are 50-year committed effective dose equivalents. The total of all the doses for the releases in a given accident scenario are then added together, to arrive at a total effective dose equivalent. In this case, submersion and direct doses are not significant, so the total effective dose equivalents are equal to the committed effective dose equivalents, as shown in Equation (2).

$$D = (Q)(X/Q')(BR)(DCF) \qquad \text{Equation (2)}$$

Where:

D = Committed effective dose equivalent (CEDE) in rem
Q = Source Term – material released (Ci)
X/Q' = Atmospheric dispersion coefficient (s/m^3)
BR = Receptor breathing rate (m^3/s)
DCF = Dose per unit activity inhaled (rem/Ci)

The atmospheric dispersion coefficients (X/Q') were determined using the GXQ Code Version 4.0A (WHC-SD-GN-SWD-30002, *GXQ Program Users' Guide*, and WHC-SD-GN-SWD-30003, *GXQ Program Verification and Validation*). The breathing rate used for all receptors was the light activity breathing rate of 3.3E-04 m^3/s.

The dose conversion factors used are those given in International Commission on Radiological Protection (ICRP) 72 for offsite receptors and ICRP 68 for onsite receptors. Use of these dose conversion factor values is directed by DOE guidance in DOE-02-ABD-053, *Contract Number DE-AC06-96RL13200 – Fluor Hanford Nuclear Safety Basis Strategy and Criteria.*

2.4 ACCIDENT EVALUATION

Three postulated accident scenarios in Table 1 are identified for further analysis for PUREX. One scenario results in excessive roof loading from staging activities and postulates catastrophic failure of the entire PUREX roof, resulting in a release from the canyon. The other two scenarios are associated with crane tip/boom failure and load drop. These scenarios potentially result in partial roof failure and release of radioactive material from the facility or external damage resulting in release of radioactive materials outside the canyon (deep bed filters).

The design or evaluation basis that relates to the crane and its operations is significant for the accident analysis. Key baseline assumptions for the accident analysis, as defined by the referenced engineering evaluations, include the following:

- No more than a single pallet or bundle of material weighing 1,360.8 kg (3,000 lbs) shall be staged on each north-south section of the existing structure of the canyon roof. A section is defined by the area between column lines of exterior walls. Additional loading of personnel, tools, and building materials shall not exceed the design load of 9.1 kg (20 lbs) per square foot.

- The crane boom shall be a single piece boom with no extensions allowed.

- The weight of the boom shall not exceed 6,758.5 kg (14,900 lbs).

2.4.1 Catastrophic Failure of the PUREX Roof

The potential catastrophic failure of the PUREX roof is postulated from two different types of phenomena:

1. Natural Phenomena (beyond evaluation basis criteria) including seismic, snow/ash load, high winds

2. Excessive loading due to placement of materials onto the roof during this activity.

An engineering evaluation (HNF-11732) verified the design basis loading capacities of the canyon roof structure with the roof structures. Another engineering evaluation (HNF-11733) reviewed loading conditions that could arise during construction. The initial staging plan for crane activities committed to placement of the packaged building material (pallets, purlin bundles, etc.) in units weighing less than 1,360 kg (3,000 lbs). The units would be placed one per east-west section of the canyon roof in the outer third of the roof section. To enhance the evaluation in HNF-11732, an additional loading condition was evaluated to verify a safety margin for load placement. It was concluded that two pallets (1,360 kg [3,000 lbs] each) stacked on top of each other and two bundles of purlins (1,360 kg [3,000 lbs]) also stacked and placed adjacent to the stacked pallets could be safely staged within the mid third area of the roof. Therefore, it is concluded that the initial staging plan, which limits units of staged building materials in each section of the roof to 1,360 kg (3,000 lbs), provides an adequate safety margin.

2.4.1.1 Scenario Frequency

Using the safety analysis for B Plant as a guide, a conservative likelihood for a catastrophic failure of the PUREX roof due to natural phenomena (snow/ashfall) is "unlikely" (HNF-3358, *B Plant Surveillance and Maintenance Phase, Safety Analysis Report*, Section 3.4.2.6).

An accident postulated to result in the catastrophic failure of the PUREX roof from excessive loading of roof materials is conservatively judged to be "unlikely," based on the margins identified in the structural evaluation (HNF-11732).

2.4.1.2 Source Term Analysis

Material at risk (MAR) inventories were taken from Table B-2 of HNF-SD-CP-ISB-004 (Appendix C, *Radiological Inventory in Deactivated PUREX*). MAR-A is the facility inventory excluding the material within L Cell, N Cell, and the PR Room. MAR-B is the facility inventory within L Cell, N Cell, and the PR Room. The distinction in inventory sources was made due to the nature of the material within L Cell, N Cell, and the PR Room. The material in these locations is less susceptible to release from a roof collapse event than material within the remainder of the facility. The material inventories from Table B-2 of HNF-SD-CP-ISB-004 are:

MAR-A	5,700 g Pu 224.2 Ci Sr-90 283.3 Ci Cs-137
MAR-B	6,738 g Pu

The values identified in HNF-SD-CP-ISB-004 consider only Pu and mixed fission products. For conservatism, the Pu values reported in HNF-SD-CP-ISB-004 are assumed to be Pu-239. Other production transuranic isotopes are added, based on the relative ratio distribution of the isotopes for Mark 1A fuel with a burn of 3,000 MWd/t, as identified in Table 4-3 of SD-HS-SAR-001.

Since production activities were discontinued in 1988, selected radioisotopes with short half lives (Pu-238 and Pu-241) were decayed for 14 years. The production inventory of decay daughter radioisotopes (U-234 and Am-241) was determined, and was included in the base inventory for the dose calculation. The PUREX MAR for a catastrophic roof collapse was calculated based on the above assumptions, and is presented in Table 2, *Material at Risk for Catastrophic Roof Collapse – 202 A Building.*

Table 2. Material at Risk for Catastrophic Roof Collapse – 202 A Building.

Isotope	MAR-A (g)	MAR-B (g)	Specific Activity (Ci/g)	MAR-A (Ci)	MAR-B (Ci)
Sr-90	-	-	-	2.2E+02	-
Cs-137	-	-	-	2.8E+02	-
Pu-238 [1,2]	5.7E+00	6.7E+00	1.7E+01	9.7E+01	1.2E+02
Pu-239	5.7E+03	6.7E+03	6.2E-02	3.6E+02	4.2E+02
Pu-240 [1]	8.9E+02	1.0E+03	2.3E-01	2.0E+02	2.4E+02
Pu-241 [1,2]	9.1E+01	1.1E+02	1.0E+02	9.5E+03	1.1E+04
Pu-242 [1]	1.8E+01	2.2E+01	3.9E-03	7.2E-02	8.5E-02
U-234 [3]	-	-	6.3E-03	4.3E-02	4.9E-02
Am-241 [4]	-	-	3.5E+00	3.0E+02	3.6E+02

[1] Quantity based on the isotope distribution for Mark 1A fuel with a burn of 3,000 mwd/t.
[2] Decayed 14 years from 1988 calculated value.
[3] Daughter product of Pu-238.
[4] Daughter product of Pu-241.

2.4.1.2.1 Damage Ratio

The inventory identified as MAR-A in Table 2 is in the form of contaminated equipment and surfaces, dust debris, sludge with some remaining Pu, and oxide (HNF-SD-CP-ISB-004, Section 2.2.3.2). Since the majority of this material is within the equipment or on the cell floors below the coverblocks, evaluation of the potential for impact to this material is performed to determine if application of a damage ratio (DR) is warranted.

To determine a DR for MAR-A material, consideration is first given to material within the tanks/equipment. The material within the tanks/equipment is considered to be a powdery-residue on the lower third of the equipment, following the deactivation flushing activities. For example, to impact the material within a tank, the roof must collapse and fail the coverblocks, which would cause the equipment to fail and result in a release from the tanks. Coverblocks are constructed from 76- to 91-cm (30- to 36-in.) thick reinforced concrete (SD-HS-SAR-001, Section 5.2.2) and tanks were made from Type 304L stainless steel (SD-HS-SAR-001, Section 6.1.2). The tanks vary from 4.6 m to 9.5 mm (0.18 in. to 0.375 in.) in thickness. Tank heights vary and are presented in Table 6-1 of SD-HS-SAR-001. The larger volume tanks (18,927 L [5,000 gal] and greater) are nominally 3.1 m (10 ft) in height. The energy dissipation associated with the reinforced concrete coverblocks and the tanks within the process cells justifies the use of a 0.5 DR for the material contained within these cells.

Similarly, the material on the cell floor (except L Cell) that, for conservatism, is considered a powder rather than sludge of the nature noted within L Cell, cannot be released in a roof failure without being impacted by significant force. The dissipation of kinetic energy associated with the impact to the coverblocks and the subsequent impact to equipment by failed coverblocks supports the use of a 0.5 DR for the material on the floor, as well. The result is application of a 0.5 DR to the entire MAR-A inventory identified in Table 2.

The use of a 0.5 DR for the entire MAR-A inventory is conservative, based on the results of the structural analysis performed on the Reduction Oxide (REDOX) facility. Analyses referenced in BHI-01142, *REDOX Facility Safety Analysis Report*, Section 3.4.2.1.1 indicate that the coverblocks could withstand impact of roof debris without failure. While there are similarities between the construction of the PUREX and REDOX coverblocks, it is conservatively assumed that the coverblocks will fail under roof debris impact and a 0.5 DR is applied to the material release.

With regard to MAR-B, inventory within the N Cell and PR Room was fixed with a polymer barrier system similar to paint and is therefore strongly fixed within the gloveboxes. The combination of the polymer barrier within the gloveboxes provides the basis for selection of a 0.25 DR for this material. Damage to the gloveboxes from the roof failure would have to result in a stripping of the polymer barrier system material for appropriate application of the airborne release fraction (ARF) and respirable fraction (RF) values identified for this scenario. The inventory within the gloveboxes is largely in the lower portion of the gloveboxes and on the floor where the cleaned and disassembled equipment was located. Since the N Cell gloveboxes are two floors high (SD-HS-SAR-001, Figure 5-13) the ratio of the lower area, with significant material present, to the total surface area is estimated at 0.25 and is the basis for the assigned DR.

The material inventory within the L Cell has been characterized as stable, immobile sludge on the floor of the cell (HNF-SD-CP-ISB-004, page 2-48). In activities to sample this material to develop an estimate of the inventory, personnel had to scrape the material from the floor. The material is on the floor and failure of coverblocks and equipment will be necessary to impact the material and result in release. The loss of energy combined with the more impact resistant form of the L Cell material supports the application of a 0.25 DR for this material.

2.4.1.2.2 Airborne Release Fraction/Respirable Fraction

DOE-HDBK-3010-94 was used to determine the ARF/RF value selected to represent radioactive releases from the structural failure of the roof or coverblocks due to natural phenomena. Section 4.4.3.3.2, *Large Falling Object or Induced Air Turbulence* indicates that an ARF of 1.0E-03 and an RF of 0.1 are bounding.

2.4.1.2.3 Leak Path Factor

No credit was taken for the potential reduction in material release through confinement deposition. Therefore, a leak path factor of 1.0 was used.

2.4.1.2.4 Source Term

Using the factors discussed above the source term (Ci) is presented in Tables 3, *Source Term Excluding Material within L Cell, N Cell, and the PR Room,* and 4, *Source Term for material within L Cell, N Cell, and the PR Room.*

Table 3. Source Term Excluding Material within L Cell, N Cell, and the PR Room.

Isotope	MAR-A (Ci)	DR	ARF x RF	Leak Path Factor	Q_A (Ci)
Sr-90	2.2E+02	5.0E-01	1.0E-04	1.0E+00	1.1E-02
Cs-137	2.8E+02	5.0E-01	1.0E-04	1.0E+00	1.4E-02
Pu-238	9.8E+01	5.0E-01	1.0E-04	1.0E+00	4.9E-03
Pu-239	3.6E+02	5.0E-01	1.0E-04	1.0E+00	1.8E-02
Pu-240	2.0E+02	5.0E-01	1.0E-04	1.0E+00	1.0E-02
Pu-241	9.5E+03	5.0E-01	1.0E-04	1.0E+00	4.7E-01
Pu-242	7.2E-02	5.0E-01	1.0E-04	1.0E+00	3.6E-06
U-234	4.2E-02	5.0E-01	1.0E-04	1.0E+00	2.1E-06
Am-241	3.0E+02	5.0E-01	1.0E-04	1.0E+00	1.5E-02

Table 4. Source Term for Material within L Cell, N Cell, and the PR Room.

Isotope	MAR-B (Ci)	DR	ARF x RF	Leak Path Factor	Q_B (Ci)
Pu-238	1.2E+02	2.5E-01	1.0E-04	1.0E+00	2.9E-03
Pu-239	4.2E+02	2.5E-01	1.0E-04	1.0E+00	1.0E-02
Pu-240	2.4E+02	2.5E-01	1.0E-04	1.0E+00	6.0E-03
Pu-241	1.1E+04	2.5E-01	1.0E-04	1.0E+00	2.8E-01
Pu-242	8.5E-02	2.5E-01	1.0E-04	1.0E+00	2.1E-06
U-234	4.9E-02	2.5E-01	1.0E-04	1.0E+00	1.2E-06
Am-241	3.6E+02	2.5E-01	1.0E-04	1.0E+00	9.0E-03

Table 5, *Source Term Total*, summarizes the source term for material released from the entire facility.

Table 5. Source Term Total.

Isotope	Q_A (Ci)	Q_B (Ci)	Q_{total} (Ci)
Sr-90	1.1E-02	-	1.1E-02
Cs-137	1.4E-02	-	1.4E-02
Pu-238	4.9E-03	2.9E-03	7.8E-03
Pu-239	1.8E-02	1.0E-02	2.8E-02
Pu-240	1.0E-02	6.0E-03	1.6E-02
Pu-241	4.7E-01	2.8E-01	7.5E-01
Pu-242	3.6E-06	2.1E-06	5.7E-06
U-234	2.1E-07	1.2E-07	3.3E-07
Am-241	1.5E-02	9.0E-03	2.4E-02

2.4.1.3 Consequence Analysis

The most restrictive X/Q' values (Appendix D, *GXQ X/Q' Output Files*) were calculated for an onsite worker receptor at 100 m [328 ft] and offsite receptors at the site boundary (15,290 m [50,164 ft] east). The X/Q' calculation assumed an area release (release diameter of 20 m [66 ft]) at ground level. This is conservative given the actual distribution of materials throughout the facility. The receptor height was assumed to be 0 m [0 ft]. The breathing rate for light work 3.3 E-4 m^3/s is used for all dose calculations. The maximum dose for 100 m [328 ft] east is presented in Table 6, *Potential Dose Consequences to the Maximum Onsite Receptor*.

Table 6. Potential Dose Consequences to the Maximum Onsite Receptor.

Isotope	Q total (Ci)	X/Q' (100 m)	BR (m^3/s)	Dose Conversion Factor ICRP 68 (Sv/Bq)	Sv/bq to rem/ci	Dose – 100 m (rem)
Sr-90	1.1E-02	1.8E-02	3.3E-04	3.0E-08	3.7E+12	7.4E-03
Cs-137	1.4E-02	1.8E-02	3.3E-04	6.7E-09	3.7E+12	2.1E-03
Pu-238	7.8E-03	1.8E-02	3.3E-04	3.0E-05	3.7E+12	5.1E+00
Pu-239	2.8E-02	1.8E-02	3.3E-04	3.2E-05	3.7E+12	2.0E+01
Pu-240	1.6E-02	1.8E-02	3.3E-04	3.2E-05	3.7E+12	1.1E+01
Pu-241	7.5E-01	1.8E-02	3.3E-04	5.8E-07	3.7E+12	9.6E+00
Pu-242	5.7E-06	1.8E-02	3.3E-04	3.1E-05	3.7E+12	3.9E-03
U-234	3.3E-06	1.8E-02	3.3E-04	2.1E-06	3.7E+12	1.5E-05
Am-241	2.4E-02	1.8E-02	3.3E-04	2.7E-05	3.7E+12	1.4E+01
					Total Dose	6.0E+01

The maximum dose at the site boundary (15,290 m [50,164 ft] east) is presented in Table 7, *Potential Dose to the Maximum Receptor at the Site Boundary.*

Table 7. Potential Dose to the Maximum Receptor at the Site Boundary.

Isotope	Q total (Ci)	X/Q' (15290 m)	BR (m^3/s)	Dose Conversion Factor ICRP 71 (Sv/Bq)	Sv/bq to rem/ci	Dose – 15290 m (rem)
Sr-90	1.1E-02	1.5E-05	3.3E-04	3.6E-08	3.7E+12	7.4E-06
Cs-137	1.4E-02	1.5E-05	3.3E-04	4.6E-09	3.7E+12	1.2E-06
Pu-238	7.8E-03	1.5E-05	3.3E-04	4.6E-05	3.7E+12	6.6E-03
Pu-239	2.8E-02	1.5E-05	3.3E-04	5.0E-05	3.7E+12	2.6E-02
Pu-240	1.6E-02	1.5E-05	3.3E-04	5.0E-05	3.7E+12	1.5E-02
Pu-241	7.5E-01	1.5E-05	3.3E-04	9.0E-07	3.7E+12	1.2E-02
Pu-242	5.7E-06	1.5E-05	3.3E-04	4.8E-05	3.7E+12	5.1E-06
U-234	3.3E-07	1.5E-05	3.3E-04	3.5E-06	3.7E+12	2.1E-08
Am-241	2.4E-02	1.5E-05	3.3E-04	4.2E-05	3.7E+12	1.9E-02
					Total Dose	7.9E-02

2.4.1.4 Risk Evaluation

The unmitigated dose of the catastrophic event to the onsite worker receptor is 6.0E+01 rem (moderate consequence) and 7.9E-02 rem (low consequence) to the offsite receptor, at the site boundary. Since this event is considered to be "unlikely," the accident is categorized as risk class (RC) II for the onsite worker receptor and RC III for the maximum offsite receptor, under U.S. Department of Energy, Richland Operations Office (RL) Safety Analysis Criteria.

2.4.1.5 Controls

This accident does not require any additional safety class or safety significant systems, structures or components. To reduce the risk associated with the planned activities, administrative controls will be implemented.

Staging and hoisting materials on the roof shall be performed in accordance with an approved staging plan. The staging plan shall include, as a minimum, the following key elements:

- No more than a single pallet or bundled material weighing 1,360.8 kg (3,000 lbs) shall be staged on each north-south section of the existing structure of the canyon roof. A section is defined by the area between column lines of exterior walls. Additional loading of personnel, tools, and building materials shall not exceed the design load of 9.1 kg (20 lbs) per square foot.
- The boom of the crane shall be a single piece boom with no extensions allowed.
- The weight of the boom shall not exceed 6,758.5 kg (14,900 lbs).

2.4.1.6 Mitigated Risk

Implementation of the controls identified in Section 2.4.1.5 result in the reduction of frequency associated with a catastrophic failure of the PUREX roof resulting from the planned activities. Structural evaluation (HNF-11733) determined that four 1,360.8 kg (3,000 lb) loads placed in the same section does not result in a roof failure. Since multiple failures of the control are required to cause a roof failure, implementation of the controls result in a reduction of frequency to "extremely unlikely." The corresponding risk category is RC III for the onsite worker receptor and RC IV for the maximum offsite receptor.

2.4.2 Partial Collapse of the PUREX Roof

The potential for a partial collapse of the PUREX roof is postulated to occur as a result of crane failure and drop of materials onto the roof during the roof repair activities. The postulated accident assumes that the localized roof failure results in damage to two adjacent process cells within the 202-A building structure. For simplicity and conservatism it is assumed that the cell structures fail when subjected to the load drop of the roof structure and construction material.

2.4.2.1 Scenario Frequency

The frequency of a crane failure resulting in a localized failure of the PUREX roof is conservatively assumed to be "anticipated."

2.4.2.2 Source Term Analysis

The radiological inventories considered in this analysis were the same as previously discussed in Section 2.4.1.2. Individual cell inventory information, Table B-2 (Appendix C) of HNF-SD-CP-ISB-004, was reviewed to determine the two adjacent cells that would result in the maximum source term considering both MAR-A and MAR-B inventory information.

2.4.2.2.1 Damage Ratio

As previously discussed in Section 2.4.1.2.1 the MAR-A inventory is characterized by a 0.5 DR while MAR-B is characterized by a 0.25 DR.

After considering both the inventory distribution and the respective DR values it was determined that damage to L Cell and M Cell results in the maximum quantity of radiological material available for release within two adjacent cells.

MAR-A	1.0 Ci Sr-90	(L Cell)
	0.1 Ci Cs-137	(L Cell)
	1.0 Ci Sr-90	(M Cell)
	1.0 Ci Cs-137	(M Cell)
MAR-B	3,896 g Pu	(L Cell)

The values identified in HNF-SD-CP-ISB-004 consider only Pu and mixed fission products. For conservatism, the Pu values reported in HNF-SD-CP-ISB-004 are assumed to be Pu-239 and other production transuranic isotopes are added based on the relative ratio distribution of the isotopes for Mark 1A fuel with a burn of 3,000 MWd/t, as identified in Table 4-3 of SD-HS-SAR-001.

Since production activities were discontinued in 1988, selected radioisotopes with short half lives (Pu-238 and Pu-241) were decayed for 14 years. The production inventory of decay daughter radioisotopes (U-234 and Am-241) was determined and was included in the base inventory for the dose calculation. The material inventory for a partial collapse of the roof was calculated based on the above assumptions and is presented in Table 8, *Material at Risk - L Cell and M Cell (202-A Building)*.

Table 8. Material at Risk - L Cell and M Cell (202-A Building).

Isotope	MAR-A (g)	MAR-B (g)	Specific Activity (Ci/g)	MAR-A (Ci)	MAR-B (Ci)
Sr-90	-	-	-	2.0E+00	-
Cs-137	-	-	-	1.1E+00	-
Pu-238 [1,2]	-	3.9E+00	1.7E+01	-	6.7E+01
Pu-239	-	3.9E+03	6.2E-02	-	2.4E+02
Pu-240 [1]	-	6.1E+02	2.3E-01	-	1.4E+02
Pu-241 [1,2]	-	6.2E+01	1.0E+02	-	6.5E+03
Pu-242 [1]	-	1.3E+01	3.9E-03	-	4.9E-02
U-234 [3]	-	-	-	-	2.8E-03
Am-241 [4]	-	-	-	-	2.1E+02

[1] Quantity based on the isotope distribution for Mark 1A fuel with a burn of 3,000 MWd/t.
[2] Decayed 14 years from 1988 calculated value.
[3] Daughter product of Pu-238.
[4] Daughter product of Pu-241.

2.4.2.2.2 Airborne Release Fraction/Respirable Fraction

DOE-HDBK-3010-94 was used to determine the ARF/RF value selected to represent radioactive releases from the structural failure of the roof or coverblocks due to natural phenomena. Section 4.4.3.3.2 indicates that an ARF of 1.0E-03 and an RF of 0.1 are bounding.

2.4.2.2.3 Leak Path Factor

No credit was taken for the potential reduction in material release through confinement deposition. Therefore, a leak path factor of 1.0 was used.

2.4.2.2.4 Source Term

Using the factors discussed above the source term (Ci) is presented in Tables 9, *MAR-A Source Term from L Cell and M Cell*, and 10, *MAR-B Source Term from L Cell and M Cell.*

Table 9. MAR-A Source Term from L Cell and M Cell.

Isotope	MAR-A (Ci)	DR	ARF x RF	Leak Path Factor	Q_A (Ci)
Sr-90	2.0E+00	5.0E-01	1.0E-04	1.0E+00	1.0E-04
Cs-137	1.1E+00	5.0E-01	1.0E-04	1.0E+00	5.5E-05

Table 10. MAR-B Source Term from L Cell and M Cell.

Isotope	MAR-B (Ci)	DR	ARF x RF	Leak Path Factor	Q_B (Ci)
Pu-238	6.7E+01	2.5E-01	1.0E-04	1.0E+00	1.7E-03
Pu-239	2.4E+02	2.5E-01	1.0E-04	1.0E+00	6.1E-03
Pu-240	1.4E+02	2.5E-01	1.0E-04	1.0E+00	3.4E-03
Pu-241	6.5E+03	2.5E-01	1.0E-04	1.0E+00	1.6E-01
Pu-242	4.9E-02	2.5E-01	1.0E-04	1.0E+00	1.2E-06
U-234	2.8E-03	2.5E-01	1.0E-04	1.0E+00	7.1E-08
Am-241	2.1E+02	2.5E-01	1.0E-04	1.0E+00	5.2E-03

Table 11, *L Cell and M Cell Source Term*, summarizes the source term released from L Cell and M Cell.

Table 11. L Cell and M Cell Source Term.

Isotope	Q_A (Ci)	Q_B (Ci)	Q_{total} (Ci)
Sr-90	1.0E-04	-	1.0E-04
Cs-137	5.5E-05	-	5.5E-05
Pu-238	-	1.7E-03	1.7E-03
Pu-239	-	6.1E-03	6.1E-03
Pu-240	-	3.4E-03	3.4E-03
Pu-241	-	1.6E-01	1.6E-01
Pu-242	-	1.2E-06	1.2E-06
U-234	-	7.1E-08	7.1E-08
Am-241	-	5.2E-03	5.2E-03

2.4.2.3 Consequence Analysis

The most restrictive X/Q′ values (Appendix D) were calculated for an onsite worker receptor at 100 m [328 ft] and offsite receptors at the site boundary (15,290 m [50,164 ft] east). The X/Q′ calculation assumed an area release (release diameter of 20 m [66 ft]) at ground level. This is conservative given the actual distribution of materials within the cells. The receptor height was assumed to be 0 m [0 ft]. The breathing rate for light work 3.3 E-4 m^3/s is used for all dose calculations.

The maximum dose for 100 m [328 ft] east is presented in Table 12, *Potential Dose Consequences to the Maximum Onsite Receptor*.

Table 12. Potential Dose Consequences to the Maximum Onsite Receptor.

Isotope	Q_{total} (Ci)	X/Q' (100m)	BR (m^3/s)	Dose Conversion Factor ICRP 68 (Sv/Bq)	Sv/bq to rem/ci	Dose - 100m (rem)
Sr-90	1.0E-04	1.8E-02	3.3E-04	3.0E-08	3.7E+12	6.6E-05
Cs-137	5.5E-05	1.8E-02	3.3E-04	6.7E-09	3.7E+12	8.1E-06
Pu-238	1.7E-03	1.8E-02	3.3E-04	3.0E-05	3.7E+12	1.1E+00
Pu-239	6.1E-03	1.8E-02	3.3E-04	3.2E-05	3.7E+12	4.3E+00
Pu-240	3.4E-03	1.8E-02	3.3E-04	3.2E-05	3.7E+12	2.4E+00
Pu-241	1.6E-01	1.8E-02	3.3E-04	5.8E-07	3.7E+12	2.1E+00
Pu-242	1.2E-06	1.8E-02	3.3E-04	3.1E-05	3.7E+12	8.4E-04
U-234	7.1E-08	1.8E-02	3.3E-04	2.1E-06	3.7E+12	3.3E-06
Am-241	5.2E-03	1.8E-02	3.3E-04	2.7E-05	3.7E+12	3.1E+00
					Total Dose	1.3E+01

The maximum dose at the site boundary (15,290 m [50,164 ft] east) is presented in Table 13, *Potential Dose to the Maximum Receptor at the Site Boundary*.

Table 13. Potential Dose to the Maximum Receptor at the Site Boundary.

Isotope	Q total (Ci)	X/Q' (15290m)	BR (m^3/s)	Dose Conversion Factor ICRP 71 (Sv/Bq)	Sv/bq to rem/ci	Dose - 15290m (rem)
Sr-90	1.0E-04	1.5E-05	3.3E-04	3.6E-08	3.7E+12	6.6E-08
Cs-137	5.5E-05	1.5E-05	3.3E-04	4.6E-09	3.7E+12	4.7E-09
Pu-238	1.7E-03	1.5E-05	3.3E-04	4.6E-05	3.7E+12	1.4E-03
Pu-239	6.1E-03	1.5E-05	3.3E-04	5.0E-05	3.7E+12	5.6E-03
Pu-240	3.4E-03	1.5E-05	3.3E-04	5.0E-05	3.7E+12	3.2E-03
Pu-241	1.6E-01	1.5E-05	3.3E-04	9.0E-07	3.7E+12	2.7E-03
Pu-242	1.2E-06	1.5E-05	3.3E-04	4.8E-05	3.7E+12	1.1E-06
U-234	7.1E-08	1.5E-05	3.3E-04	3.5E-06	3.7E+12	4.6E-09
Am-241	5.2E-03	1.5E-05	3.3E-04	4.2E-05	3.7E+12	4.0E-03
					Total Dose	1.7E-02

2.4.2.4 Risk Evaluation

The unmitigated dose to the onsite worker receptor is 1.3E+01 rem (low consequence) and 1.7 E-02 rem (low consequence) to the offsite receptor at the Columbia River. This unmitigated event is considered to be "anticipated" and is categorized as RC III under RL Safety Analysis Criteria for both the onsite and offsite receptors.

2.4.2.5 Controls

This accident does not require any additional safety class or safety significant systems, structures or components. To reduce the risk associated with the planned activities, administrative controls will be implemented.

Staging and hoisting materials on the roof shall be performed in accordance with an approved staging plan. The staging plan shall include, as a minimum, the following key elements:

- No more than a single pallet or bundled material weighing 1,360.8 kg (3,000 lbs) shall be staged on each north-south section of the existing structure of the canyon roof. A section is defined by the area between column lines of exterior walls. Additional loading of personnel, tools, and building materials shall not exceed the design load of 9.1 kg (20 lbs) per square foot.

- The boom of the crane shall be a single piece boom with no extensions allowed.

- The weight of the boom shall not exceed 6,758.5 kg (14,900 lbs).

- The maximum weight of any bundle, package or pallet that is lifted over the roof of the PUREX structure shall not exceed 1,360.8 kg (3,000 lbs).
- Picks involving loads greater than 680.4 kg (1,500 lbs) to the maximum of 1,360.8 kg (3,000 lbs) shall not exceed 1.5 m (5 ft) from the bottom of the load to the top of the existing PUREX roof structure.
- Picks involving loads less than or equal to 680.4 kg (1,500 lbs) shall not exceed 3.1 m (10 ft) from the bottom of the load to the top of the existing PUREX roof structure.
- No lifts over a roof section with a staged pallet or bundle shall be allowed.

2.4.2.6 Mitigated Risk

Implementation of the controls identified in Section 2.4.2.5 result in the reduction of frequency associated with a localized failure of the PUREX roof resulting from the planned activities. Structural evaluation (HNF-11733) determined that four 1,360.8 kg (3,000 lb) loads placed in the same section does not result in a roof failure. Implementation of these controls reduces the frequency of occurrence to "unlikely." The reduction in frequency does not result in a reduction in the RC. The corresponding risk category is RC III for both the onsite worker receptor and the maximum offsite receptor.

2.4.3 Deep Bed Filter Release

Appendix A shows that crane placement will include placing the crane in close proximity to the deep bed filters. As a result, the potential for a crane failure/overturn that could result in failure of the deep bed filters must be considered.

2.4.3.1 Scenario Frequency

The frequency of a crane tip over is categorized as anticipated. However, the frequency of this event is considered "unlikely" based on the combination of the design of the below grade deep bed filter structures and the crane orientation necessary to result in the failure.

2.4.3.2 Source Term Analysis

The radiological inventories for the Deep Bed Filters were taken from Table B-2 (Appendix C) of HNF-SD-CP-ISB-004. The inventory of Deep Bed Filter No. 1 is indicated as 20-200 g of Pu, 20-200 Ci of Cs, 20-200 Ci of Sr and 0.25 Ci of Am. The inventory of Deep Bed Filter No. 2 is indicated as 20-200 g of Pu, 20-200 Ci of Cs, 20-200 Ci of Sr and 0.25 Ci of Am. The upper bounding values were used in the dose calculation.

The values identified in HNF-SD-CP-ISB-004 consider only Pu and mixed fission products. For conservatism the Pu values reported in HNF-SD-CP-ISB-004 are assumed to be Pu-239 and other production transuranic isotopes are added based on the relative ratio distribution of the isotopes for Mark 1A fuel with a burn of 3,000 MWd/t as identified in Table 4-3 of SD-HS-SAR-001.

Since production activities were discontinued in 1988, selected radioisotopes with short half lives (Pu-238 and Pu-241) were decayed for 14 years. The production inventory of decay daughter radioisotopes (U-234 and Am-241) was determined and was included in the base inventory for the dose calculation. The MAR resulting from a failure of the deep bed filters is presented in Table 14, *Material at Risk for Deep Bed Filters Nos. 1 and 2.*

Table 14. Material at Risk for Deep Bed Filters Nos. 1 and 2.

Isotope	MAR (g)	Specific Activity (Ci/g)	MAR (Ci)
Sr-90	-	-	4.0E+02
Cs-137	-	-	4.0E+02
Pu-238 [1,2]	4.0E-01	1.7E+01	6.8E+00
Pu-239	4.0E+02	6.2E-02	2.5E+01
Pu-240 [1]	6.2E+01	2.3E-01	1.4E+01
Pu-241 [1,2]	6.4E+00	1.0E+02	6.6E+02
Pu-242 [1]	1.3E+00	3.9E-03	5.1E-03
U-234 [3]	-	-	2.9E-04
Am-241 [4]	-	-	2.2E+01

[1] Quantity based on the isotope distribution for Mark 1A fuel with a burn of 3,000 MWd/t.
[2] Decayed 14 years from 1988 calculated value.
[3] Daughter product of Pu-238.
[4] Quantity based on calculated daughter product of Pu-241 and inventory values of Table B-2 of HNF-SD-CP-ISB-004.

2.4.3.2.1 Damage Ratio

No credit was taken for the potential fractional reduction in the MAR impacted by the accident-generated conditions. Therefore, a 1.0 DR was used in the analysis.

2.4.3.2.2 Airborne Release Fraction/Respirable Fraction

DOE-HDBK-3010-94 was used to determine the ARF/RF value selected to represent radioactive releases from the deep bed filter failure due to crane failure. Section 4.4.3.3.2 indicates that an ARF of 1.0E-03 and an RF of 0.1 are bounding.

2.4.3.2.3 Leak Path Factor

No credit was taken for the potential reduction in material release through confinement deposition. Therefore, a leak path factor of 1.0 was used.

2.4.3.2.4 Source Term

Using the factors discussed above the source term (Ci) is presented in Table 15, *Source Term for Deep Bed Filters Nos. 1 and 2.*

Table 15. Source Term for Deep Bed Filters Nos. 1 and 2.

Isotope	MAR (Ci)	DR	ARF x RF	Leak Path Factor	Q (Ci)
Sr-90	4.0E+02	1.0E+00	1.0E-04	1.0E+00	4.0E-02
Cs-137	4.0E+02	1.0E+00	1.0E-04	1.0E+00	4.0E-02
Pu-238	6.8E+00	1.0E+00	1.0E-04	1.0E+00	6.8E-04
Pu-239	2.5E+01	1.0E+00	1.0E-04	1.0E+00	2.5E-03
Pu-240	1.4E+01	1.0E+00	1.0E-04	1.0E+00	1.4E-03
Pu-241	6.6E+02	1.0E+00	1.0E-04	1.0E+00	6.6E-02
Pu-242	5.1E-03	1.0E+00	1.0E-04	1.0E+00	5.1E-07
U-234	2.9E-04	1.0E+00	1.0E-04	1.0E+00	2.9E-08
Am-241	2.2E+01	1.0E+00	1.0E-04	1.0E+00	2.2E-03

2.4.3.3 Consequence Analysis

The most restrictive X/Q′ values (Appendix D) were calculated for an onsite worker receptor at 100 m [328 ft] and offsite receptors at the site boundary (15,290 m [50,164 ft] east). The X/Q′ calculation assumed an point source release at ground level. The receptor height was assumed to be 0 m [0 ft]. The breathing rate for light work 3.3 E-04 m^3/s is used for all dose calculations.

The maximum dose for 100 m [328 ft] east is presented in Table 16, *Potential Dose Consequences to the Maximum Onsite Receptor.*

Table 16. Potential Dose Consequences to the Maximum Onsite Receptor.

Isotope	Q (Ci)	X/Q' (100m)	BR (m3/s)	Dose Conversion Factor ICRP 68 (Sv/Bq)	Sv/bq to rem/ci	Dose - 100m (rem)
Sr-90	4.0E-02	3.4E-02	3.3E-04	3.0E-08	3.7E+12	5.0E-02
Cs-137	4.0E-02	3.4E-02	3.3E-04	6.7E-09	3.7E+12	1.1E-02
Pu-238	6.8E-04	3.4E-02	3.3E-04	3.0E-05	3.7E+12	8.5E-01
Pu-239	2.5E-03	3.4E-02	3.3E-04	3.2E-05	3.7E+12	3.3E+00
Pu-240	1.4E-03	3.4E-02	3.3E-04	3.2E-05	3.7E+12	1.9E+00
Pu-241	6.6E-02	3.4E-02	3.3E-04	5.8E-07	3.7E+12	1.6E+00
Pu-242	5.1E-07	3.4E-02	3.3E-04	3.1E-05	3.7E+12	6.5E-04
U-234	2.9E-08	3.4E-02	3.3E-04	2.1E-06	3.7E+12	2.6E-06
Am-241	2.2E-03	3.4E-02	3.3E-04	2.7E-05	3.7E+12	2.5E+00
					Total Dose	1.0E+01

The maximum dose at the site boundary (15,290 m [50,164 ft] east) is presented in Table 17, *Potential Dose to the Maximum Receptor at the Site Boundary*.

Table 17. Potential Dose to the Maximum Receptor at the Site Boundary.

Isotope	Q (Ci)	X/Q' (15290m)	BR (m3/s)	Dose Conversion Factor ICRP 71 (Sv/Bq)	Sv/bq to rem/ci	Dose - 15290m (rem)
Sr-90	4.0E-02	1.5E-05	3.3E-04	3.6E-08	3.7E+12	2.7E-05
Cs-137	4.0E-02	1.5E-05	3.3E-04	4.6E-09	3.7E+12	3.4E-06
Pu-238	6.8E-04	1.5E-05	3.3E-04	4.6E-05	3.7E+12	5.8E-04
Pu-239	2.5E-03	1.5E-05	3.3E-04	5.0E-05	3.7E+12	2.3E-03
Pu-240	1.4E-03	1.5E-05	3.3E-04	5.0E-05	3.7E+12	1.3E-03
Pu-241	6.6E-02	1.5E-05	3.3E-04	9.0E-07	3.7E+12	1.1E-03
Pu-242	5.1E-07	1.5E-05	3.3E-04	4.8E-05	3.7E+12	4.5E-07
U-234	2.9E-08	1.5E-05	3.3E-04	3.5E-06	3.7E+12	1.9E-09
Am-241	2.2E-03	1.5E-05	3.3E-04	4.2E-05	3.7E+12	1.7E-03
					Total Dose	7.0E-03

2.4.3.4 Risk Evaluation

The unmitigated dose to the onsite worker receptor is 1.0E+01 rem (low consequence) and maximum dose of 7.0E-03 rem (low consequence) to the offsite receptor at the Columbia River.

This unmitigated event is considered to be "unlikely" and is categorized as RC III under RL Safety Analysis Criteria for both the onsite and offsite receptors.

2.4.3.5 Controls

This accident does not require any additional safety class or safety significant systems, structures or components. To reduce the risk associated with the planned activities, administrative controls will be implemented.

Staging and hoisting materials on the roof shall be performed in accordance with an approved staging plan. The staging plan shall include, as a minimum, the following key elements:

- The *Hanford Site Hoisting and Rigging Manual* (DOE/RL-92-36) shall be applied.
- The boom of the crane shall be a single piece boom with no extensions allowed.
- The weight of the boom shall not exceed 6,758.5 kg (14,900 lbs).

2.4.3.6 Mitigated Risk

Application of the requirements of DOE/RL-92-36 will reduce the frequency of this scenario. The reduction in frequency does not result in a reduction in the RC. The corresponding risk category is RC III for both the onsite worker receptor and the maximum offsite receptor.

3.0 INTERIM TECHNICAL SAFETY REQUIREMENT CONTROLS

To ensure the safety of roof upgrade activities at the B Plant facility, interim technical safety requirement (TSR) controls will be implemented. Derivation of these controls is based on the accident analysis results presented above. The summary results of the accident analysis are provided in Table18, *PUREX Accident Analysis Summary Table.*

Table 18. PUREX Accident Analysis Summary Table.

Event	Unmitigated			Mitigated		
	Frequency	Consequence (rem)	RC	Frequency	Consequence (rem)	RC
Total Roof Failure	Unlikely	6.0E+01 (onsite) 7.9E-02 (offsite)	II (onsite) III(offsite)	Extremely unlikely	6.0E+01 (onsite) 7.9E-02 (offsite)	III(onsite) IV(offsite)
Partial Roof Failure	Anticipated	1.3E+01 (onsite) 1.7E-02 (offsite)	III (onsite) III(offsite)	Unlikely	1.3E+01 (onsite) 1.7E-02 (offsite)	III (onsite) III(offsite)
Deep Bed Filters	Unlikely	1.0E+01 (onsite) 7.0E-03 (offsite)	III (onsite) III(offsite)	Unlikely	1.0E+01 (onsite) 7.0E-03 (offsite)	III (onsite) III(offsite)

From the accidents analysis results, no safety class or safety significant systems structures or components are identified for the prevention or mitigation of the accidents evaluated. To minimize the potential impacts of the roof upgrade activities to the existing facility structure and materials TSR level administrative controls will be implemented. The TSR administrative controls associated with these planned activities are:

- Staging and hoisting materials on the roof shall be performed in accordance with an approved staging plan. The staging plan shall include, as a minimum, the following key elements:
    - The *Hanford Site Hoisting and Rigging Manual* (DOE/RL-92-36) shall be applied.
    - The boom of the crane shall be a single piece boom with no extensions allowed.
    - The weight of the boom shall not exceed 6,758.5 kg (14,900 lbs).
    - No more than a single pallet or bundled material weighing 1,360.8 kg (3,000 lbs) shall be staged on each north-south section of the existing structure of the canyon roof. A section is defined by the area between column lines of exterior walls. Additional loading of personnel, tools, and building materials shall not exceed the design load of 9.1 kg (20 lbs) per square foot.
    - The maximum weight of any bundle, package or pallet that is lifted over the roof of the PUREX structure shall not exceed 1,360.8 kg (3,000 lbs).
    - Picks involving loads greater than 680.4 kg (1,500 lbs) to the maximum of 1,360.8 kg (3,000 lbs) shall not exceed 1.5 m (5 ft) from the bottom of the load to the top of the existing PUREX roof structure.
    - Picks involving loads less than or equal to 680.4 kg (1,500 lbs) shall not exceed 3.1 m (10 ft) from the bottom of the load to the top of the existing PUREX roof structure.
    - No lifts over a roof section with a staged pallet or bundle shall be allowed.

4.0 REFERENCES

10 CFR 835, *Occupational Radiation Protection*, U.S. Department of Energy, Washington, D.C., 1998.

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BHI-01142, *REDOX Facility Safety Analysis Report,* Rev. 3, Bechtel Hanford, Inc., Richland, Washington, 2001.

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HNF-11733, *PUREX and B Plant Roof Drop Investigation,* Rev. 0, Fluor Hanford, Inc. Richland, Washington, 2002.

HNF-3358, *B Plant Surveillance and Maintenance Phase, Safety Analysis Report*, B&W Hanford Company, Richland, Washington, 1999.

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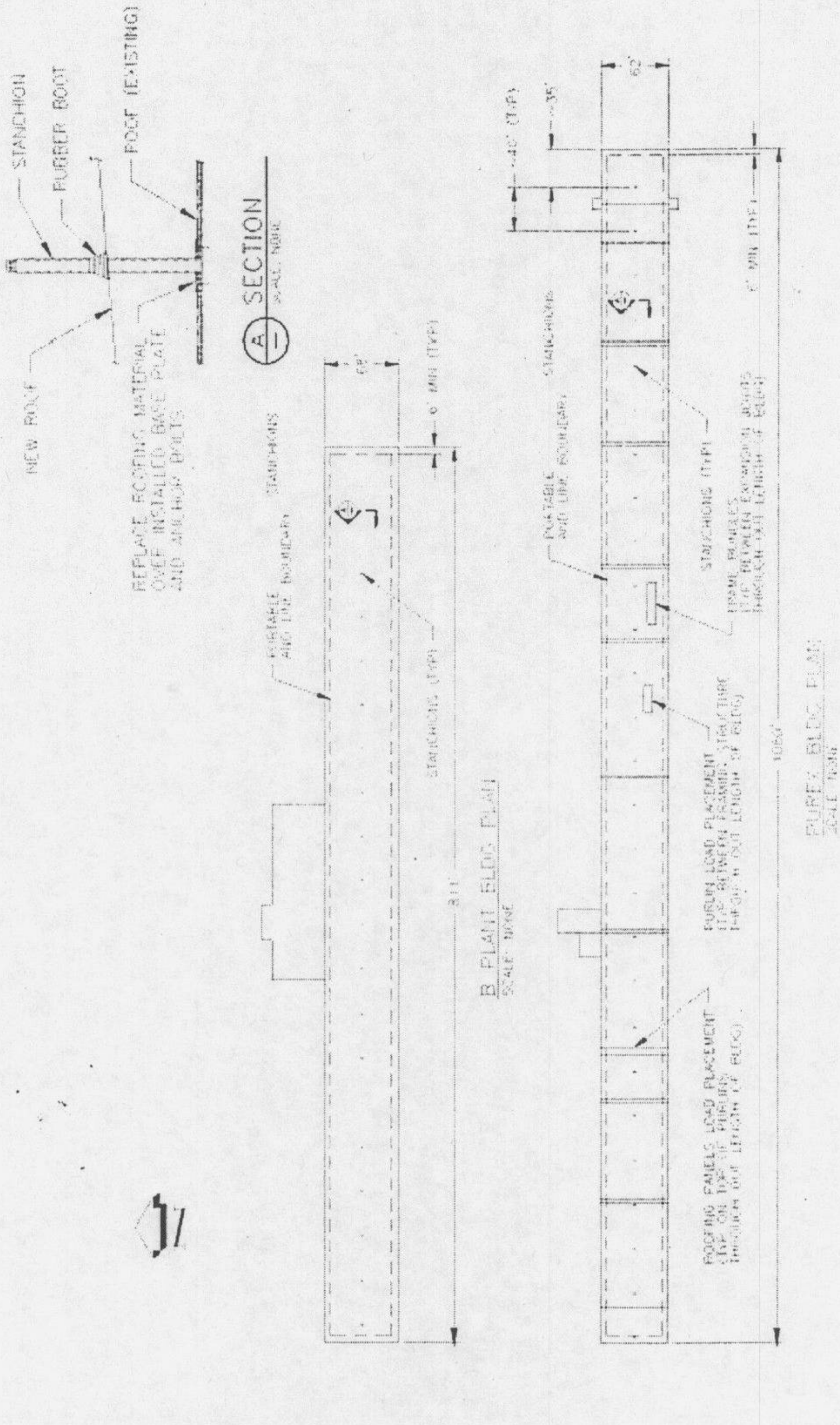
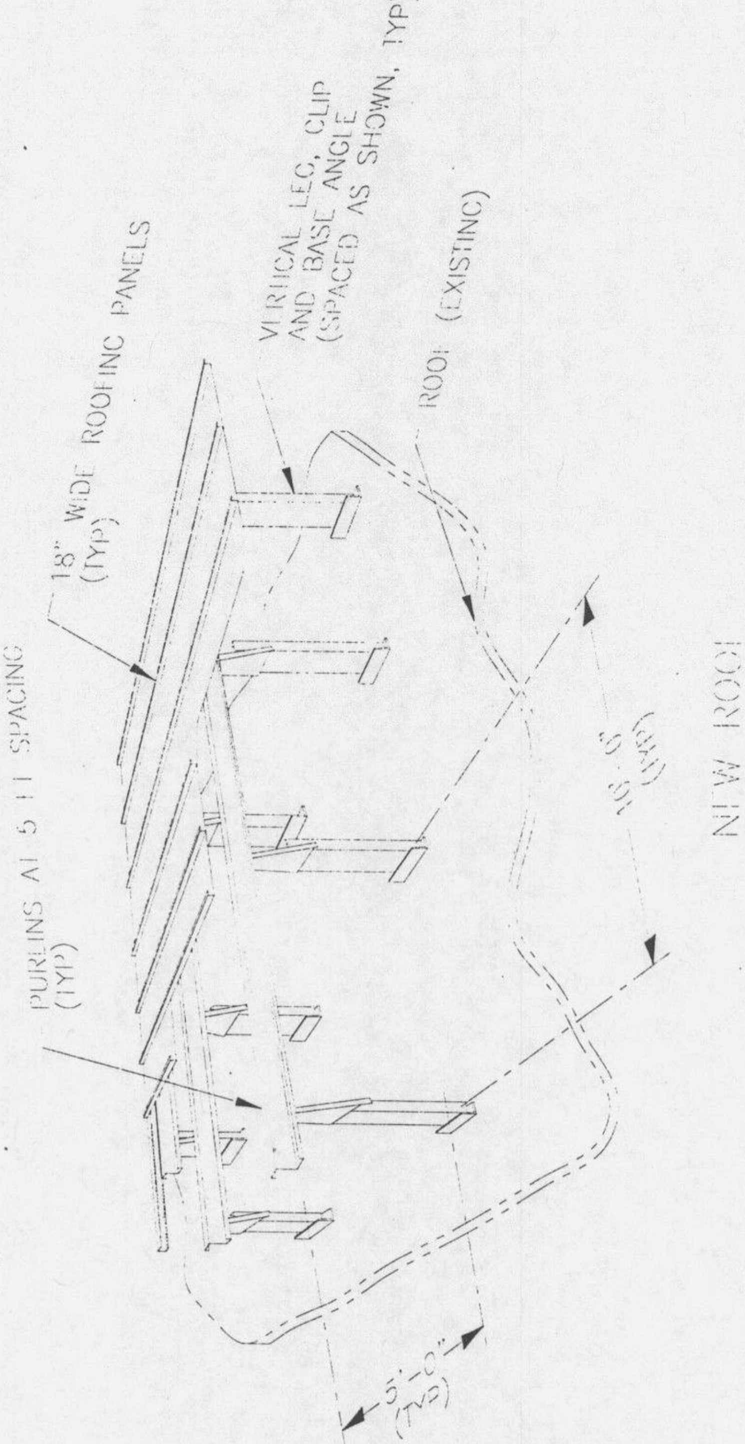
WHC-SD-GN-SWD-30002, *GXQ Program Users' Guide*, Rev. 1, Westinghouse Hanford Company, Richland, Washington, 1994.

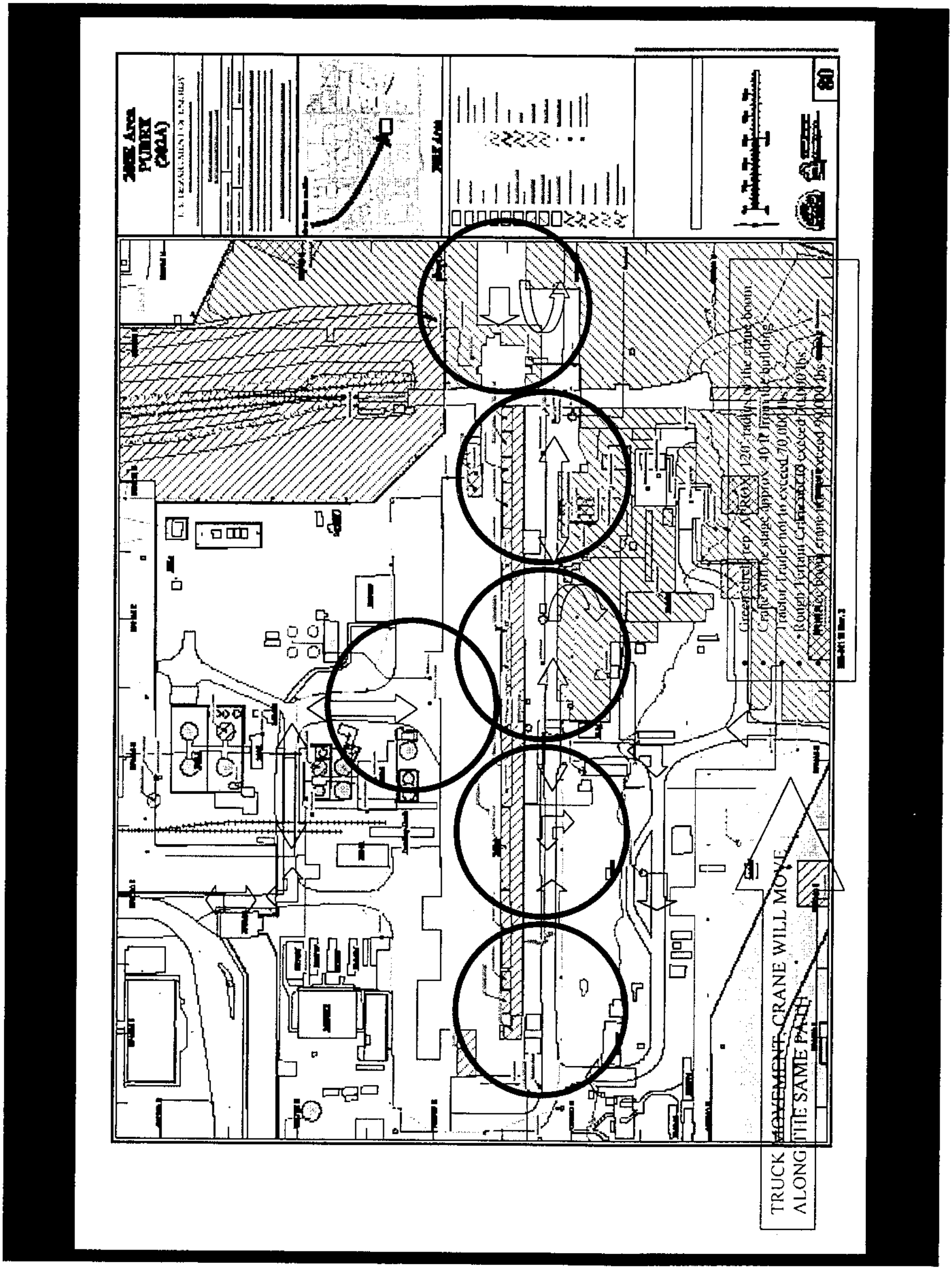
WHC-SD-GN-SWD-30003, *GXQ Program Verification and Validation*, Rev. 1, Westinghouse Hanford Company, Richland, Washington, 1994.

APPENDIX A

FIGURES


SECTION
B PLANT BLDG PLAN
PUREX BLDG PLAN


18" WIDE ROOFING PANELS
(TYP)
VERTICAL LEG, CLIP
AND BASE ANGLE
(SPACED AS SHOWN, TYP)
ROOF (EXISTING)
PURLINS AT 5 FT SPACING
(TYP)
NEW ROOF
5'-0"
(TYP)


TRUCK MOVEMENT, CRANE WILL MOVE ALONG THE SAME PATH

APPENDIX B

HAZARD ANALYSIS

APPENDIX B. HAZARD ANALYSIS.

Task	Hazard	Control(s)	Remarks
1. Mobilization	• Routine industrial hazards	• Industrial Safety/Industrial Health Programs • Automated Job Hazards Analysis process	Industrial risk associated with construction – no impact on nuclear safety – no further evaluation required.
	• Vehicle Impact to facility (fire)	• Vehicle access/operation controls	Fire resulting from vehicle impact evaluated in hazard evaluation table (HNF-11698, Table 1).
2. Fall Protection Installation and Setup (assumes use of a man-lift device to lift material and personnel)	• Personnel and material at heights	• Contractor fall protection plan • Automated Job Hazards Analysis process • Fluor Hanford oversight	Industrial risk associated with construction – no impact on nuclear safety – no further evaluation required.
	• Exposure to or release of radiological contamination as a result of construction activities	• Radiological Protection Program	Programmatic controls HNF-5173 and HNF-MP-003 apply.
	• Localized roof failure – from load drop on the roof	• Not credible based load sizes (man-lift limit to lift material) and the structural analysis	No further evaluation required.
	• Generators, cables, equipment, drilling/cutting, power tools	• Industrial safety • Fire Protection Programs • Job Safety Analysis process	Industrial risk associated with construction – no impact on nuclear safety – no further evaluation required.
	• Material Handling	• Industrial safety controls	Industrial risk associated with

Task	Hazard	Control(s)	Remarks
		• Personal Protective Equipment (hard hats)	construction – no impact on nuclear safety – no further evaluation required.
	• Fire/sparks from cutting and drilling	• Fire Protection Programs	Fire evaluated in hazard evaluation table (HNF-11698, Table 1).
3. Roof Installation. • Framing Base Plates and Misc. Framing Components • Wall Panels • Purlins • Roofing Panels Activities: o Crane used to place materials on the roof. o Picked from truck to roof o Forklift may be used o Crane enters south gate (see staging map)	• Load Drop o Onto roof o Onto facility ancillary equipment (deep bed filters, stack, etc.)	• Crane operating procedures/Hoisting and Rigging Manual • Load limited to 3000 lbs • Administrative control to limit the lift height of loads.	Load drop evaluated in hazard evaluation table (HNF-11698, Table 1).
	• Overload of roof structure	• Engineering controls for staging and placement • Project Work Plan controls (staging plan)	Roof overload evaluated in hazard evaluation table (HNF-11698, Table 1).
	• Localized Fire o Vehicle impact o Generator/ equipment failure o Cutting/grinding o Crane contact with power lines	• Vehicle access/operation controls • Industrial safety controls • Fire Protection Program • Crane operating procedures/Hoisting and Rigging Manual	Fire evaluated in hazard evaluation table (HNF-11698, Table 1)..
	• Crane tip or boom failure o Ground instability (e.g., collapse of air tunnel, electrical duct banks on north side of PUREX) o Crane equipment failure o Crane operator	• Project Work Plan controls • Use of load spreader for crane outriggers • Crane operating procedures/Hoisting and Rigging Manual • Operator training	Crane accident evaluated in hazard evaluation table.

Task	Hazard	Control(s)	Remarks
	error		
	• Industrial safety o Construction injury o Personnel fall o Electrical o Fire o Operating equipment	• Industrial safety controls • Fire Protection Program • Operator training	Industrial risk associated with construction – no impact on nuclear safety – no further evaluation required.
	• Exposure to or release of radiological contamination as a result of construction activities	• Radiological Protection Program	Programmatic controls HNF-5173 and HNF-MP-003 apply.
	• Collapse of equipment travel and staging surfaces	• Inspection and field verification of bearing capacity and use of load dispersion or equivalent (as applicable) • Industrial/construction safety • Work packages, staging plan	Industrial and construction safety issues-no impact on nuclear safety Note: overturn of cranes impact is evaluated in the hazard evaluation.
	• Overhead utilities (electrical shock, gravitational hazards)	• Inspection and field verification of potential overhead interface • Industrial/construction safety • Work packages, staging plans	Industrial and construction safety issues-no impact on nuclear safety.
4. Cleanup and Project Closure	• See Item # 2 above	• See Item # 2 above	See Item # 2 above

APPENDIX C

RADIOLOGICAL INVENTORY IN DEACTIVATED PUREX

Table B-2. Radiogical Inventory in Deactivated PUREX. (2 sheets)

	Measurable Pu		Estimated Pu		Mixed Fission Products	
Location	Grams	Form	Grams	Form	Curies	Form
A Cell	N/A	N/A	100-700	dust; debris; sludge; spills	20 Sr^{90} 30 Cs^{137}	debris, sludge, absorbed spills
B Cell	N/A.	N/A	100-700	dust; debris; sludge; spills	20 Sr^{90} 30 Cs^{137}	debris, sludge, absorbed spills
C Cell	N/A	N/A	100-700	dust; debris; sludge; spills	20 Sr^{90} 30 Cs^{137}	debris, sludge, absorbed spills
D Cell	N/A	N/A	300-1200	dust; debris; sludge; spills	20 Sr^{90} 30 Cs^{137}	debris, sludge, absorbed spills
E-Cell (excluding skip)	N/A	N/A	200-800	dust; debris; sludge; spills	20 Sr^{90} 30 Cs^{137}	debris, sludge, absorbed spills
H Cell	N/A	N/A	50-400	dust; debris; sludge; spills	20 Sr_{90} 30 Cs^{137}	debris, sludge, absorbed spills
J Cell (J5A)	N/A	N/A	30-100	dust; debris; sludge; spills	<0.1 Sr^{90} <0.1 Cs^{137}	debris, sludge, absorbed spills
J Cell (excluding J5A)	N/A	N/A	50-200	dust; debris; sludge; spills	<0.1 Sr^{90} <0.1 Cs^{137}	debris, sludge, absorbed spills
F Cell (includes E Cell skip)	400	debris, sludge, spills	Negl	N/A	100 Sr^{90} 100 Cs^{137}	debris, sludge, absorbed spills
G Cell	N/A	N/A	Negl	N/A	0.1 - 1	debris, sludge, absorbed spills
K Cell	N/A	N/A	Negl	N/A	<0.1 Sr^{90} <0.1 Cs^{137}	debris, sludge, absorbed spills
L Cell	3896		N/A	N/A	<0.1 Sr^{90} <0.1 Cs^{137}	debris, sludge, absorbed spills
M Cell	N/A	N/A	Negl	decon work residues	0.1 - 1	debris, sludge, absorbed spills
N Cell	1643	fixed with PBS	N/A	N/A	N/A	
PR Room	1199	fixed with PBS	N/A	N/A	N/A	
Q Cell	N/A	N/A	Negl	N/A	N/A	
White Room	N/A	N/A	50-500	Pu fixed under multiple coats of paint.	N/A	
R Cell	N/A	N/A	Negl	N/A	N/A	debris, sludge, absorbed spills
Deep bed filter #1	N/A	N/A	100-200	Pu trapped in glass fiber matrix along with traces of TBP, dirt, debris & Ammonia Nitrate	250,000 μ - Am^{241} 20-200 Ci - Cs-Sr	Americium 241 trapped in fiber Cs/Sr trapped in fiber

Table B-2. Radiogical Inventory in Deactivated PUREX. (2 sheets)

	Measurable Pu		Estimated Pu		Mixed Fission Products	
Deep bed filter #2	N/A	N/A	100-200	Pu trapped in glass fiber matrix along with traces of TBP, dirt, debris & Ammonia Nitrate	250,000 μ - Am^{241} 20-200 Ci - Cs/Sr	Americium 241 trapped in fiber Cs/Sr trapped in fiber

APPENDIX D

GXQ X/Q' OUTPUT FILES

```
                    GXQ Version 4.0D
                    February 8, 1999

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest, Inc.

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest, Inc.
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 07/31/02
Run Time = 10:40:36.75


INPUT ECHO:
z   X/Q-PUREX, 0m Recept, Grnd Rel, 20m Area Source, L&FR
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
  mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F

c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    2     0     0     0
  EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
   (irise igrnd)iwash igrav
```

```
   0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
        = 2 then X/Q adjusted by wind speed function
  iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on

c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                     reference                           frequency
c   release           anemometer     mixing               to
c   height            height         height               exceed
c   hs(m)             ha(m)          hm(m)                Cx(%)
c   ___________       ___________    ___________          ___________
    0.00000E+00       1.00000E+01    1.00000E+03          5.00000E-01
c
c   initial           initial                                             gravitational
c   plume             plume          release              deposition      settling
    width             height         duration             velocity        velocity
    Wb(m)             Hb(m)          trd(hr)              vd(m/s)         vg(m/s)
c   ___________       ___________    ___________          ___________     ___________
    2.00000E+01       0.00000E+00    1.00000E+00          1.00000E-03     1.00000E-03
c
c                     initial        initial                              convective
c   ambient           plume          plume                release         heat release
c   temperature       temperature    flow rate            diameter        rate(1)
c   Tamb(C)           T0(C)          V0(m3/s)             d(m)            qh(w)
c   ___________       ___________    ___________          ___________     ___________
    2.00000E+01       2.20000E+01    1.00000E+00          1.00000E+00     0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q               Wind
c   scaling           Speed
c   factor            Exponent
c   c(?)              a(?)
c   ___________       ___________
    1.00000E+00       7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)          sector distance receptor-height
c 2 (by class & wind speed)  class windspeed distance offset receptor-height
c 3 (create plot file)       class windspeed xmax imax ymax jmax xqmin power
c
  RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
```

```
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
  xmax = maximum distance to plot or calculate to (m)
  imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
MACCS Virtual source building wake model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)

Created 8/26/92 KR

X/Q-PUREX, 0m Recept, Grnd Rel, 20m Area Source, L&FR

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	1.04E-02	1.04E-02	E	0.89
SSW	100	0	4.53	1	6.15E-03	6.15E-03	F	2.65
SW	100	0	2.93	1	6.69E-03	6.69E-03	F	2.65
WSW	100	0	2.72	1	6.75E-03	6.75E-03	F	2.65
W	100	0	4.80	1	1.21E-02	1.21E-02	G	2.65
WNW	100	0	3.98	1	1.11E-02	1.11E-02	G	2.65
NW	100	0	4.72	1	1.24E-02	1.24E-02	G	2.65
NNW	100	0	4.58	1	1.26E-02	1.26E-02	G	2.65
N	100	0	4.36	1	1.49E-02	1.49E-02	G	2.65
NNE	100	0	2.49	1	9.73E-03	9.73E-03	E	0.89
NE	100	0	3.90	1	1.03E-02	1.03E-02	E	0.89
ENE	100	0	6.17	1	1.18E-02	1.18E-02	G	2.65
E	100	0	14.05	1	1.80E-02	1.80E-02	F	0.89
ESE	100	0	18.80	1	1.62E-02	1.62E-02	F	0.89
SE	100	0	10.83	1	1.44E-02	1.44E-02	G	2.65
SSE	100	0	4.78	1	1.07E-02	1.07E-02	E	0.89
S	17900	0	6.30	1	5.32E-06	5.32E-06	E	0.89
SSW	16780	0	4.53	1	3.66E-06	3.66E-06	F	2.65
W	16780	0	2.93	1	4.69E-06	4.69E-06	F	2.65
SW	20660	0	2.72	1	3.63E-06	3.63E-06	F	2.65

W	20650	0	4.80	1	8.59E-06	8.59E-06	G	2.65
WNW	20650	0	3.98	1	4.81E-06	4.81E-06	G	4.70
NW	21160	0	4.72	1	8.65E-06	8.65E-06	G	2.65
NNW	21160	0	4.58	1	8.69E-06	8.69E-06	G	2.65
N	22480	0	4.36	1	8.64E-06	8.64E-06	G	2.65
NE	20090	0	2.49	1	4.38E-06	4.38E-06	E	0.89
E	16210	0	3.90	1	6.15E-06	6.15E-06	E	0.89
ENE	15290	0	6.17	1	1.13E-05	1.13E-05	G	2.65
E	15290	0	14.05	1	1.51E-05	1.51E-05	F	0.89
ESE	18340	0	18.80	1	1.15E-05	1.15E-05	F	0.89
SE	20320	0	10.83	1	9.64E-06	9.64E-06	G	2.65
SSE	19530	0	4.78	1	4.90E-06	4.90E-06	G	4.70
S	8730	0	6.30	1	1.35E-05	1.35E-05	E	0.89
SSW	8550	0	4.53	1	8.53E-06	8.53E-06	F	2.65
SW	8550	0	2.93	1	1.10E-05	1.10E-05	F	2.65
WSW	8730	0	2.72	1	1.08E-05	1.08E-05	F	2.65
W	11380	0	4.80	1	1.80E-05	1.80E-05	G	2.65
WNW	13350	0	3.98	1	8.29E-06	8.29E-06	G	4.70
NW	12920	0	4.72	1	1.59E-05	1.59E-05	G	2.65
NNW	12920	0	4.58	1	1.60E-05	1.60E-05	G	2.65
N	13620	0	4.36	1	1.60E-05	1.60E-05	G	2.65
NNE	11780	0	2.49	1	8.78E-06	8.78E-06	E	0.89
NE	10980	0	3.90	1	1.01E-05	1.01E-05	E	0.89
ENE	10980	0	6.17	1	1.70E-05	1.70E-05	G	2.65
E	11530	0	14.05	1	2.15E-05	2.15E-05	F	0.89
ESE	12230	0	18.80	1	1.90E-05	1.90E-05	F	0.89
SE	12230	0	10.83	1	1.81E-05	1.81E-05	G	2.65
SSE	10310	0	4.78	1	1.11E-05	1.11E-05	G	4.70
S	100	2	6.30	1	8.61E-03	8.61E-03	E	0.89
SSW	100	2	4.53	1	6.85E-03	6.85E-03	E	0.89
SW	100	2	2.93	1	7.15E-03	7.15E-03	E	0.89
WSW	100	2	2.72	1	7.15E-03	7.15E-03	E	0.89
	100	2	4.80	1	1.06E-02	1.06E-02	G	0.89
NW	100	2	3.98	1	8.71E-03	8.71E-03	E	0.89
NW	100	2	4.72	1	9.40E-03	9.40E-03	E	0.89
NNW	100	2	4.58	1	9.12E-03	9.12E-03	E	0.89
N	100	2	4.36	1	1.13E-02	1.13E-02	G	0.89
NNE	100	2	2.49	1	7.13E-03	7.13E-03	E	0.89
NE	100	2	3.90	1	7.51E-03	7.51E-03	E	0.89
ENE	100	2	6.17	1	8.29E-03	8.29E-03	E	0.89
E	100	2	14.05	1	1.23E-02	1.23E-02	G	0.89
ESE	100	2	18.80	1	1.13E-02	1.13E-02	G	0.89
SE	100	2	10.83	1	1.08E-02	1.08E-02	G	0.89
SSE	100	2	4.78	1	8.44E-03	8.44E-03	E	0.89
S	8730	2	6.30	1	1.34E-05	1.34E-05	E	0.89
SSW	8550	2	4.53	1	8.52E-06	8.52E-06	F	2.65
SW	8550	2	2.93	1	1.10E-05	1.10E-05	F	2.65
WSW	8730	2	2.72	1	1.08E-05	1.08E-05	F	2.65
W	11380	2	4.80	1	1.79E-05	1.79E-05	G	2.65
WNW	13350	2	3.98	1	8.27E-06	8.27E-06	G	4.70
NW	12920	2	4.72	1	1.59E-05	1.59E-05	G	2.65
NNW	12920	2	4.58	1	1.59E-05	1.59E-05	G	2.65
N	13620	2	4.36	1	1.60E-05	1.60E-05	G	2.65
NNE	11780	2	2.49	1	8.77E-06	8.77E-06	E	0.89
NE	10980	2	3.90	1	1.01E-05	1.01E-05	E	0.89
ENE	10980	2	6.17	1	1.70E-05	1.70E-05	G	2.65
E	11530	2	14.05	1	2.15E-05	2.15E-05	F	0.89
ESE	12230	2	18.80	1	1.90E-05	1.90E-05	F	0.89
SE	12230	2	10.83	1	1.80E-05	1.80E-05	G	2.65
SE	10310	2	4.78	1	1.10E-05	1.10E-05	G	4.70

```
                              GXQ Version 4.0D
                              February 8, 1999

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest, Inc.

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest, Inc.
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 07/31/02
Run Time = 11:03:46.80


INPUT ECHO:
z   X/Q-PUREX, 0m Recept, Grnd Rel, Point Source, L&FR
c   mode
    1
c
c MODE CHOICE:
  mode = 1 then X/Q based on Hanford site specific meteorology
  mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F

c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
  EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
  (irise igrnd)iwash igrav
```

```
   0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
        = 2 then X/Q adjusted by wind speed function
  iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on

c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                   reference                       frequency
c   release         anemometer      mixing          to
c   height          height          height          exceed
c   hs(m)           ha(m)           hm(m)           Cx(%)
c   ____________    ____________    ____________    ____________
    0.00000E+00     1.00000E+01     1.00000E+03     5.00000E-01
c
c   initial         initial                                         gravitational
c   plume           plume           release         deposition      settling
    width           height          duration        velocity        velocity
    Wb(m)           Hb(m)           trd(hr)         vd(m/s)         vg(m/s)
c   ____________    ____________    ____________    ____________    ____________
    2.00000E+01     0.00000E+00     1.00000E+00     1.00000E-03     1.00000E-03
c
c                   initial         initial                         convective
c   ambient         plume           plume           release         heat release
c   temperature     temperature     flow rate       diameter        rate(1)
c   Tamb(C)         T0(C)           V0(m3/s)        d(m)            qh(w)
c   ____________    ____________    ____________    ____________    ____________
    2.00000E+01     2.20000E+01     1.00000E+00     1.00000E+00     0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
c   c(?)            a(?)
c   ____________    ____________
    1.00000E+00     7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make           RECEPTOR DEPENDENT DATA
c 1 (site specific)           sector distance receptor-height
c 2 (by class & wind speed)   class windspeed distance offset receptor-height
c 3 (create plot file)        class windspeed xmax imax ymax jmax xqmin power
c
  RECEPTOR PARAMETER DESCRIPTION
  sector = 0, 1, 2... (all, S, SSW, etc.)
```

```
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
  xmax = maximum distance to plot or calculate to (m)
  imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

z X/Q-PUREX, 0m Recept, Grnd Rel, Point Source, L&FR

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	1.56E-02	1.56E-02	E	0.89
SSW	100	0	4.53	1	1.13E-02	1.13E-02	F	2.65
SW	100	0	2.93	1	1.21E-02	1.21E-02	F	2.65
WSW	100	0	2.72	1	1.22E-02	1.22E-02	F	2.65
W	100	0	4.80	1	2.80E-02	2.80E-02	G	2.65
WNW	100	0	3.98	1	1.60E-02	1.60E-02	G	4.70
NW	100	0	4.72	1	2.89E-02	2.89E-02	G	2.65
NNW	100	0	4.58	1	2.90E-02	2.90E-02	G	2.65
N	100	0	4.36	1	3.12E-02	3.12E-02	G	2.65
NNE	100	0	2.49	1	1.54E-02	1.54E-02	E	0.89
NE	100	0	3.90	1	1.57E-02	1.57E-02	E	0.89
ENE	100	0	6.17	1	2.52E-02	2.52E-02	G	2.65
E	100	0	14.05	1	3.41E-02	3.41E-02	F	0.89
ESE	100	0	18.80	1	3.25E-02	3.25E-02	F	0.89
SE	100	0	10.83	1	3.07E-02	3.07E-02	G	2.65
SSE	100	0	4.78	1	1.58E-02	1.58E-02	G	4.70
S	17900	0	6.30	1	5.35E-06	5.35E-06	E	0.89
SSW	16780	0	4.53	1	3.68E-06	3.68E-06	F	2.65
SW	16780	0	2.93	1	4.72E-06	4.72E-06	F	2.65
WSW	20660	0	2.72	1	3.65E-06	3.65E-06	F	2.65
W	20650	0	4.80	1	8.64E-06	8.64E-06	G	2.65

WNW	20650	0	3.98	1	4.84E-06	4.84E-06	G	4.70
NW	21160	0	4.72	1	8.71E-06	8.71E-06	G	2.65
NNW	21160	0	4.58	1	8.74E-06	8.74E-06	G	2.65
N	22480	0	4.36	1	8.68E-06	8.68E-06	G	2.65
NNE	20090	0	2.49	1	4.39E-06	4.39E-06	E	0.89
E	16210	0	3.90	1	6.19E-06	6.19E-06	E	0.89
NE	15290	0	6.17	1	1.14E-05	1.14E-05	G	2.65
E	15290	0	14.05	1	1.52E-05	1.52E-05	F	0.89
ESE	18340	0	18.80	1	1.16E-05	1.16E-05	F	0.89
SE	20320	0	10.83	1	9.69E-06	9.69E-06	G	2.65
SSE	19530	0	4.78	1	4.93E-06	4.93E-06	G	4.70
S	8730	0	6.30	1	1.36E-05	1.36E-05	E	0.89
SSW	8550	0	4.53	1	8.62E-06	8.62E-06	F	2.65
SW	8550	0	2.93	1	1.11E-05	1.11E-05	F	2.65
WSW	8730	0	2.72	1	1.09E-05	1.09E-05	F	2.65
W	11380	0	4.80	1	1.82E-05	1.82E-05	G	2.65
WNW	13350	0	3.98	1	8.37E-06	8.37E-06	G	4.70
NW	12920	0	4.72	1	1.61E-05	1.61E-05	G	2.65
NNW	12920	0	4.58	1	1.61E-05	1.61E-05	G	2.65
N	13620	0	4.36	1	1.62E-05	1.62E-05	G	2.65
NNE	11780	0	2.49	1	8.83E-06	8.83E-06	E	0.89
NE	10980	0	3.90	1	1.02E-05	1.02E-05	E	0.89
ENE	10980	0	6.17	1	1.72E-05	1.72E-05	G	2.65
E	11530	0	14.05	1	2.17E-05	2.17E-05	F	0.89
ESE	12230	0	18.80	1	1.92E-05	1.92E-05	F	0.89
SE	12230	0	10.83	1	1.82E-05	1.82E-05	G	2.65
SSE	10310	0	4.78	1	1.12E-05	1.12E-05	G	4.70
S	100	2	6.30	1	1.38E-02	1.38E-02	E	0.89
SSW	100	2	4.53	1	7.77E-03	7.77E-03	F	2.65
SW	100	2	2.93	1	9.18E-03	9.18E-03	G	2.65
WSW	100	2	2.72	1	9.00E-03	9.00E-03	G	2.65
W	100	2	4.80	1	1.75E-02	1.75E-02	E	0.89
NW	100	2	3.98	1	1.41E-02	1.41E-02	E	0.89
W	100	2	4.72	1	1.52E-02	1.52E-02	E	0.89
NNW	100	2	4.58	1	1.48E-02	1.48E-02	E	0.89
N	100	2	4.36	1	1.86E-02	1.86E-02	F	0.89
NNE	100	2	2.49	1	1.13E-02	1.13E-02	G	2.65
NE	100	2	3.90	1	1.20E-02	1.20E-02	E	0.89
ENE	100	2	6.17	1	1.32E-02	1.32E-02	E	0.89
E	100	2	14.05	1	2.23E-02	2.23E-02	F	0.89
ESE	100	2	18.80	1	1.86E-02	1.86E-02	F	0.89
SE	100	2	10.83	1	1.79E-02	1.79E-02	E	0.89
SSE	100	2	4.78	1	1.35E-02	1.35E-02	E	0.89
S	8730	2	6.30	1	1.36E-05	1.36E-05	E	0.89
SSW	8550	2	4.53	1	8.61E-06	8.61E-06	F	2.65
SW	8550	2	2.93	1	1.11E-05	1.11E-05	F	2.65
WSW	8730	2	2.72	1	1.09E-05	1.09E-05	F	2.65
W	11380	2	4.80	1	1.82E-05	1.82E-05	G	2.65
WNW	13350	2	3.98	1	8.35E-06	8.35E-06	G	4.70
NW	12920	2	4.72	1	1.60E-05	1.60E-05	G	2.65
NNW	12920	2	4.58	1	1.61E-05	1.61E-05	G	2.65
N	13620	2	4.36	1	1.61E-05	1.61E-05	G	2.65
NNE	11780	2	2.49	1	8.83E-06	8.83E-06	E	0.89
NE	10980	2	3.90	1	1.02E-05	1.02E-05	E	0.89
ENE	10980	2	6.17	1	1.72E-05	1.72E-05	G	2.65
E	11530	2	14.05	1	2.17E-05	2.17E-05	F	0.89
ESE	12230	2	18.80	1	1.92E-05	1.92E-05	F	0.89
SE	12230	2	10.83	1	1.82E-05	1.82E-05	G	2.65
SE	10310	2	4.78	1	1.12E-05	1.12E-05	G	4.70