CHAPTER 6
SAFETY ANALYSIS

6.1 Introduction

On May 12, 2020, the licensee certified to the NRC that IP2 had both permanently ceased operations (final shutdown 4/30/2020) and that all fuel had been removed from the reactor vessel and placed in the spent fuel pit (SFP) (Reference 6.6-1). Since IP2 will never again enter any operational mode, reactor related accidents, abnormal operational transients, and special events are no longer a possibility.

This chapter discusses: (a) a postulated fuel handling accident (FHA) associated with fuel movement until the fuel has been transferred to the Independent Spent Fuel Storage Installation (ISFSI), (b) accident release-recycle of waste liquid, (c) accidental release of waste gas, and (d) the postulated drop of a high integrity container (HIC) containing radioactive resins. Bounding conditions, conservatism in equipment design, conformance to high standards of material and construction, the control of loads and strict administrative controls over facility operations all serve to assure the integrity of the fuel while in the SFP and during fuel transfer to the ISFSI.

Accidents involving fuel and the storage system utilized at the ISFSI are discussed in the storage system Final Safety Analysis Report.

New hazards, new initiators or new accidents that may challenge offsite guideline exposures, may be introduced as a result of certain decommissioning activities. These issues will be evaluated when the scope and type of decommissioning activities are finalized.

6.2 Fuel-Handling Accidents

The possibility of a fuel-handling incident is very remote because of the many administrative controls and physical limitations imposed on fuel-handling operations. The fuel-handling manipulators and hoists are designed so that fuel cannot be raised above a position that provides adequate shield water depth for the safety of personnel. This safety feature applies to handling facilities in the spent fuel pit area. In the spent fuel pit, the design of storage racks and manipulation facilities is such that:

1. Fuel at rest is positioned by positive restraints in an eversafe, always subcritical, geometrical array. Even if an assembly is not placed in the correct location, sub-criticality is ensured because a minimum boron concentration of 2000 ppm is required at all times in the pool.

2. Fuel can be manipulated only one assembly at a time.

3. Violation of procedures by placing one fuel assembly in juxtaposition with any group of assemblies in racks will not result in criticality.

In addition, administrative controls do not permit the handling of heavy objects above the fuel racks under conditions specified in the Technical Requirements Manual.

Adequate cooling of fuel during underwater handling is provided by convective heat transfer to the surrounding water. The fuel assembly is immersed continuously while in the spent fuel pit.

The fuel-handling equipment is described in detail in Section 3.5. Special precautions are taken in all fuel-handling operations to minimize the possibility of damage to fuel assemblies. All handling operations on irradiated fuel are conducted under water. The handling tools used in the fuel-handling operations are conservatively designed, and the associated devices are of a fail-safe design.

In the fuel storage area, the fuel assemblies from Unit 2 and Unit 3 are spaced in a pattern that prevents any possibility of a criticality accident. As required by 10 CFR 50.68, "Criticality Accident Requirements," if the spent fuel pit takes credit for soluble boron, then "the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with borated water, and the k-effective must remain below 1.0 (subcritical), at a 95 per cent probability, 95 percent confidence level, if flooded with unborated water. Northeast Technology Corporation report NET-28091-003-01, "Criticality Safety Analysis for the Indian Point Unit 2 Spent Fuel Pool with No Adsorber Panel Credit" and Northeast Technology Corporation report NET-173-02, "Indian Point Unit 2 Spent Fuel Pool (SFP) Boron Dilution Analysis," determined that 10 CFR 50.68(b)(4) will be met during normal SFP operation and all credible accident scenarios if: a) spent fuel pit boron concentration is maintained within the Technical Specification limits and, b) fuel assembly storage location within the spent fuel pit is restricted based on the fuel assembly's initial enrichment, burnup, decay of Pu^{241} (i.e., cooling time) and number of Integral Fuel Burnable Absorbers (IFBA) rods. Note that no Boraflex is credited in Northeast Technology Corporation report NET-28091-003-01. As such there is no need to continue the Boraflex monitoring program.

Northeast Technology Corporation report NET-28091-003-01 also evaluated credible abnormal occurrences in accordance with ANSI/ANS-57.2-1983. This evaluation considered the effects of the following: a) a dropped fuel assembly or an assembly placed alongside a rack; b) a misloaded fuel assembly; c) abnormal heat loads; and, d) multiple misloads. Northeast Technology Corporation report NET-28091-003-01 determined that the SFP will maintain a keff of $\leq$0.95 under the worst-case accident scenario if the SFP is filled with a soluble boron concentration of $\geq$ 1495 ppm.

Therefore, Northeast Technology Corporation report NET-28091-003-01 confirmed that the requirements in 10 CFR 50.68, "Criticality Accident Requirements," will be met for both normal SFP operation and credible abnormal occurrences if:

a) Spent Fuel Pit boron concentration is maintained within the limits Technical Specifications, and;

b) Fuel assembly storage location within the spent fuel pit is restricted in accordance with Technical Specifications based on the fuel assembly's initial enrichment, burnup, decay of Plutonium-241 (i.e. cooling time), and number of Integral Fuel Burnable Absorbers (IFBA) rods.

Northeast Technology Corporation report NET-173-02 evaluated postulated unplanned SFP boron dilution scenarios assuming an initial SFP boron concentration within the Technical Specification limit. The evaluation considered various scenarios by which the SFP boron concentration may be diluted and the time available before the minimum boron concentration necessary to ensure subcriticality for the non-accident condition (i.e. it is not assumed an assembly is misloaded concurrent with the spent fuel pit dilution event). Northeast Technology

Corporation report NET-173-02 determined that an unplanned or inadvertent event that could dilute the SFP boron concentration from 2000 ppm to 786 ppm is not a credible event because of the low frequency of postulated initiating events and because the event would be readily detected and mitigated by plant personnel through alarms, flooding, and operator rounds through the SFP area.

The motions of the cranes that move the fuel assemblies are limited to a low maximum speed. Caution is exercised during fuel handling to prevent a fuel assembly from striking another fuel assembly or structures in the fuel storage building.

The fuel-handling equipment suspends the fuel assembly in the vertical position during fuel movements.

All these safety features and precautions make the probability of a fuel handling incident very low. Nevertheless, since it is possible that a fuel assembly could be dropped during the handling operations, the radiological consequences of such an incident were evaluated.

Sections 6.2.1 and 6.2.2 specifically address evaluations performed for the following accidents:

1. Fuel-handling accident in the fuel storage building.

2. Fuel-handling cask drop accident.

6.2.1 Fuel-Handling Accident in Fuel Storage Building

An FHA may occur in the Fuel Storage Building (FSB) during movement of a fuel assembly. The fuel assembly is moved under water and the accident is assumed to occur when one fuel assembly is damaged. The fission product activity present in the fuel gap of all of the fuel pins in the damaged fuel assembly is released to the spent fuel pool while the FSB exhaust fan is not operating.

The source term and basic assumptions for evaluating the Total Effective Dose Equivalent (TEDE) doses associated with a postulated FHA during refueling were selected to be consistent with Regulatory Guide 1.183 (Reference 6.6-2). The IP2 Control Room (CR) doses were evaluated assuming that the CR ventilation systems were in the normal operation mode for 30 days (i.e., for the entire accident duration).

The radiation fields from external sources including overhead radioactive clouds were calculated. This contribution applies only during the 0 - 2 hours period over which the release was assumed to occur (Reference 6.6-2). The radiation fields from external sources are discussed in Section 6.2.1.7.

6.2.1.1 Method of Analysis

Post-accident FHA radiation fields and exposures in the IP2 CR, Exclusion Area Boundary (EAB), and Low Population Zone (LPZ) were computed using the following:

a) The methodology and assumptions in Regulatory Guide 1.183 (Reference 6.6-2)

b) Appropriate source terms, release pathways, and other assumptions, as described in Table 6.2-1,

c) Post-accident atmospheric dispersion factors (χ/Qs), and

d) The NRC sponsored computer code RADTRAD, Revision 3.03 (Reference 6.6-3) was used to model the design basis FHA and estimate the dose consequences. The CR, EAB, and LPZ doses in terms of TEDE were calculated for the FHA.

Calculations IP-CALC-11-00073 and IP-CALC-11-00074 (References 6.6-4 and 6.25) contain a case for 84 hours of decay that models a ground level release from the limiting FSB surface. The "Normal Mode" case in these calculations does not credit FSB filtration, the high-rad alarm, or dispersion from the FSB ventilation system. This case also does not credit any CR isolation or emergency filtration.

To determine the time following permanent shut down required for the dose at the EAB to be < 1 rem (i.e., the Environmental Protection Agency (EPA) Protective Action Guidelines (PAGs), Reference 6.6-6, Section 2.2) following the FHA, the "Normal Mode" RADTRAD 3.03 model from the IP3 FHA (IP-CALC-11-00074, Reference 6.6-5) is used. The IP3 model used as the EAB dose consequences bounds the IP2 model from IP-CALC-11-00073 (Reference 6.6-4) as shown from the dose consequences presented in References 6.6-4 and 6.6-5. The decay period in this RADTRAD model, originally 84 hours, is increased until the resulting EAB TEDE dose is less than 1 rem.

6.2.1.2 Fission Product Inventory

The fission product inventory in the core is based on full power operation (3216 MWt + 2% uncertainty, i.e., 3280.3 MWt). The core inventory of radionuclides of interest at 84 hours decay is shown in Table 6.2-2 (Reference 6.6-7).

6.2.1.3 Release Fractions and Composition

The fission product gap release fractions, for each radionuclide group for the DBA FHA are shown below:

I-131	0.12
Kr-85	0.30
Other iodines and noble gases	0.10

The values for Kr-85 and the other iodines and noble gases are from Regulatory Guide 1.25 (Reference 6.6-8). The I-131 value originates in Reference 6.6-9. Note that there are lower values identified in Table 3 of Regulatory Guide 1.183 (Reference 6.6-2) but these cannot be used because the conditions for their use (specified in footnote 11 in Regulatory Guide 1.183) cannot be assured.

Appendix B of Regulatory Guide 1.183 specifies that the iodine released from the fuel rods is 95% cesium iodine, 4.85% elemental and 0.15% organic. It also states that it should be assumed that all the cesium iodine is converted instantaneously to elemental iodine. Therefore, the iodine species release should be 99.85% (95% + 4.85%) elemental and 0.15% organic.

Appendix B of Regulatory Guide 1.183 also states that if the depth of water above the damaged fuel is 23 feet or greater, the overall effective decontamination factor (DF) is 200 (per the IP2 Technical Specifications, there are requirements for ≥ 23 feet of water above the stored spent fuel). Therefore, from the following equation the DF of 285 for elemental iodine (based on an overall DF of 200) can be calculated:

$$100 / [(99.85 / x) + 0.15] = 200$$

Where, x is the DF for elemental iodine and is calculated to be 285. The fraction of the iodine released from the water pool that is in the elemental form thus becomes:

$$99.85/285 = 0.35 \text{ elemental and } 0.15/1 = 0.15 \text{ organic}$$

The elemental fraction is:

0.35 (elemental released) / (0.35 + 0.15)(total released, elemental and organic) = 0.7

and the organic fraction is:

0.15 (organic released)/ (0.35 + 0.15)(total released, elemental and organic) = 0.3

These values (70% elemental and 30% organic) were used in the RADTRAD computer code.

6.2.1.4 Control Room Dose Consequences

For the IP2 CR, the TEDE analysis should consider all sources of radiation that will cause exposure to CR personnel (Reference 6.6-10) specifically:

- Internal radiation in the CR atmosphere by the intake of airborne radioactive material contained in the radioactive plume released from the accident.
- External Cloud exposure.

The χ/Qs associated with the transport of released radioactivity to the CR intake are as follows:

IP2 CR χ/Q s from FSB Releases (Reference 6.6-11)

Interval	Release Location	
0 – 2 hrs	FSB Surface	FSB Door
χ/Q (sec/m^3)	8.31E-04	5.39E-04

Note: Without the FSB exhaust fan operating, the CR χ/Q value from the FSB surface release is higher than that from the FSB door release. Therefore, the CR TEDE dose was only calculated for an FSB Surface (i.e., FSB roof) release.

The atmospheric dispersion factors for the application of site meteorology for Indian Point Unit 2 FHA analysis in the FSB were calculated using the meteorological data consisted of 4 years-worth of onsite hourly values. The meteorological data obtained during calendar years 2007 through 2010. Data were presented as hourly average and were representative of overall site conditions and were free from local effects such as building and cooling tower wakes, brush and vegetation. The 4 years of hourly data used in the atmospheric dispersion factors assessment were enough to reflect long-term site-specific meteorological trends.

Since releases are assumed to be completed in the first 2 hours [Regulatory Guide 1.183 (Reference 6.6-2)], no additional time periods are presented.

The CR characteristics are as follows:

Free air volume	102,400 ft^3 (Reference 6.6-12)
Normal Operation Air Flows	(Reference 6.6-12)
Filtered makeup	0 cfm
Filtered recirculation	0 cfm
Unfiltered makeup	920 cfm
Unfiltered inleakage	700 cfm
Intake filter efficiencies	Elemental iodine 95%, methyl (organic) iodines 90%, and particulates 99%

The breathing rate was set at 3.5E-04 (m^3/sec) for the duration of the accident (Reference 6.6-2, Sec. 4.2.6). Regulatory Guide 1.183 requires 100% occupancy of the CR during only the first 24 hours of a postulated accident; for days 2, 3 and 4 the occupancy factor is reduced to 60%, and for periods beyond 4 days 40% occupancy is allowed (Reference 6.6-2, Sec. 4.2.6).

6.2.1.5 Offsite Dose Consequences

The χ/Qs associated with the transport of released radioactivity to the offsite outdoor receptors are as follows (Reference 6.6-12):

χ/Qs Ground Level Released

Interval	0-2 hours	Interval	0-8 hours
χ/Q (sec/m^3)	(EAB) 7.50-04	χ/Q (sec/m^3)	(LPZ) 3.5E-04

The breathing rate at the various receptors of interest for the duration of the accident is as follows (Reference 6.6-2, Sec. 4.1.3):

Receptor Location	Time Interval (hours)	Breathing Rate (m^3/second)
EAB	0 - 2	3.5E-4
LPZ	0 – 8 8 – 24 24 - 720	3.5E-4 1.75E-4 2.32E-4

6.2.1.6 Activity Released from the SFP

To find the activity released from the water pool, the following calculation is used:

$$\text{Activity} = \frac{[\text{Core Activity (Ci)} \times \text{Radial Peaking Factor} \times \text{Gap Fraction}]}{[\text{Decontamination Factor} \times \text{Number of Fuel Assemblies}]}$$

Example: I-131 activity at 84 hours = 6.94E+07 x 1.7 x 0.12 / (200 x 193) = 3.67E+02 Ci

For all other halogens, Decontamination Factor is also 200.

Example: I-130 activity at 84 hours = 3.44E+04 x 1.7 x 0.10 / (200 x 193) = 1.52E-01 Ci

Example: Kr-85 activity at 84 hours = 1.10E+06 x 1.7 x 0.30 / (1 x 193) = 2.91E+03 Ci

For all others noble gases, Decontamination Factor is one.

Example: Xe-131m activity at 84 hours = 9.85E+05 x 1.7 x 0.10 / (1 x 193) = 8.68E+02 Ci

The activity released from the spent fuel pool for an accident occurring 84 hours after shutdown is shown in Table 6.2-3. All leakage is immediately released to the environment from the FSB without holdup, plate-out or dilution.

The radial peaking factor is from Reference 6.6-12.

The CR, EAB and LPZ radiation exposures following a design-basis FHA were calculated using the RADTRAD 3.03 computer code and the data and assumptions listed above. Copies of the RADTRAD 3.03 inputs and outputs are provided in References 6.6-4 and 6.6-13.

6.2.1.7 Gamma Radiation from External Sources

In addition to the dose calculated above from the activity entering the CR, there are dose contributions to the operators from the gamma radiation emanating by the cloud of activity around the CR. The dose contribution to the CR operators from the cloud external to the CR was determined using the LPZ TEDE doses from Reference 6.6-14 and adjusting those doses by the ratio of the χ/Q associated with the CR intake to the LPZ χ/Q and applying the shielding factor which is equivalent to 0.5 inch thickness of steel.

The ratio of CR χ/Q to LPZ χ/Q is: 8.31E-04 / 3.5E-04 = 2.37

Therefore, the dose contribution to the IP2 CR operators from the cloud external would be:

2.630E-02 (from Reference 6.6-14) x [2.37 / 1.84 (from Reference 6.6-14)] = 3.388E-02 rem

6.2.1.8 Time Frame for Doses to be Less than the EPA PAG

Using the IP3 RADTRAD model from IP-CALC-11-00074 (Reference 6.6-5), a Decay Period of 636 hours was determined to reduce the EAB dose to below the EPA PAG of < 1 Rem. When added to the original 84 hours that the accident source term is based on, results in a total time following permanent shut down of 720 hours or 30 days.

6.2.1.9 Results

The IP2 CR, EAB and LPZ doses were calculated in the event a design basis FHA occurs in the FSB without the FSB Exhaust Fan. The CR doses were calculated without credit for CR filtration (normal mode). The following table shows the summary of results. The results indicate that the EAB, LPZ and CR doses are within the allowable limits established in 10 CFR 50.67 and Regulatory Guide 1.183.

IP2 FHA - CR, EAB, and LPZ TEDE Doses (at 84 Hours Decay)

Location	Dose (Rem)	TEDE Limit (Rem)
CR	3.88	5.0
EAB	4.2	6.3
LPZ	2.0	6.3

Following a total decay time of 720 hours or 30 days, the TEDE dose at the EAB from a potential FHA is 0.47 Rem. This dose is below the 1 rem PAG limit with considerable margin. While the results could be refined to reduce the decay time even further, this is not required. The zirconium fire calculation requires a decay time of 16.5 months (Reference 6.6-15). This 30-day required decay time for the FHA is significantly shorter than the time established in the zirconium fire calculation.

6.2.2 Fuel Cask Drop Accident

As discussed in Sections 3.5.5.4, 3.5.5.5, and 3.5.6.1, the IP2 fuel storage building spent fuel cask handling operations are now conducted using a single-failure-proof 110-Ton Ederer Gantry Crane that conforms to the requirements in NUREG-0554 (Single-Failure-Proof Cranes for Nuclear Power Plants, May 1979). The Ederer Gantry Crane performs spent fuel cask handling activities without the necessity of having to postulate the drop of a spent fuel cask. With the Ederer crane's 110-ton main hoist qualified as single-failure-proof, the crane is used as part of a single-failure-proof handling system for critical lifts as discussed in Revision 1 of Section 9.1.5, Overhead Heavy Load Handling Systems, Sub-section III.4.C of NUREG-0800, and a cask drop accident is not a credible event and need not be postulated. Even though the IP2 fuel storage building 40-ton bridge crane is no longer used for spent fuel cask handling, the following fuel cask drop accident provisions and results are being retained since the analysis bounds other drop accidents that may be postulated in the fuel storage building and cask loading pit even though a cask drop accident is no longer credible.

Performing an evaluation using the analysis assumptions for the fuel-handling accident shows that even with damage to a full core of recently discharged fuel assemblies by a fuel cask dropped into the spent fuel pool, the calculated fuel-handling accident doses would not be exceeded if 90 days had elapsed after shutdown. Since the fuel cask is handled by the single failure proof 110-ton gantry crane approved for use by the NRC in Technical Specification Amendment #244, this accident is not probable. Additional protections making this accident highly improbable are outlined below. In addition, Technical Requirements Manual Sections B 3.9.C and 3.9.E preclude movement of a spent fuel cask over any spent fuel storage racks.

During normal operation, if a spent fuel cask were placed in or removed from its position in the spent fuel pit, limit switches on the rails and logic built into the single-failure-proof control system would not allow for the cask to be moved any farther north or east of the spot reserved for the cask in the pit.

It is extremely improbable that the cask would be inadvertently or otherwise dropped during the process of transfer. This is due to the following provisions:

1. Conservative design margins used for the cask-related handling equipment (crane, rigging, hooks, etc.).

2. Periodic nondestructive equipment tests and inspection procedures.

3. Use of qualified crane operators and riggers.

4. Use of approved operating and administrative procedures.

These provisions will be rigorously met so that the inadvertent drop of the cask into the pool is highly improbable. However, should such a highly unlikely accident occur, the basic assumptions for analysis are as follows:

1. The drop would be from the highest position of the cask, which is 5-ft above the water surface and 43-ft above the bottom of the pool.

2. The cask is fully loaded and weighs 40 tons.

The results of the analysis indicate that the cask would hit the bottom of the pit with a velocity of approximately 40-ft/sec, assuming a conservative drag coefficient of 0.5. In comparison, the cask would have reached a velocity of 52-ft/sec if dropped through 43-ft in air.

Using the Ballistic Research Laboratories formula for the penetration of missiles in steel, the depth of penetration of the cask into the 1-in. wear plate covering the 1/4-in. pit liner plate would be 0.35-in., assuming the cask struck the wear plate while in a perfectly vertical position. In the event that the cask falls through the water at an angle, terminal velocity of the cask would be somewhat less because of the increased drag. However, the cask would strike the wear plate with an initial line contact and would penetrate the wear plate and the pit liner plate, causing some cracking of the concrete below. This reinforced concrete is a minimum of 3-ft thick and rests on solid rock.

Water would initially flow through the punctured liner plate and fill the cracks in the concrete. Since the pit is founded on solid rock and since the bottom of the pit is approximately 24 feet below the surrounding grade, very little water can be lost from the pit. The capacity of the makeup demineralized water supply to the pit is 150 gpm. In addition, the spent fuel pit cooling system piping has a 4-in. flange connection for temporary cooling and/or makeup water.

Because the bottom of the spent fuel pit is 24-ft below grade and no equipment areas are in the vicinity, there can be no flooding of other areas with subsequent damage to equipment.

Table 6.2-1
Fuel Handling Accident - Design Input Data*

Parameter	Data
Plant Power	Section 6.2.1.2
Core Inventories	Table 6.2-2
Activity Released from the SFP	Table 6.2-2
Fission Product Gap Fraction	Section 6.2.1.3
Decay Period (hours)	84
Amount of Fuel Damage	1 assembly
Radial Peaking Factor	1.70
Duration of Releases	2 hours
Water Depth	23 feet
Iodine Decontamination Factor	Section 6.2.1.3
Chemical Form Release	Section 6.2.1.3
CR χ/Q	Section 6.2.1.3
CR Free Air Volume	102,400 ft^3
CR Parameters	Section 6.2.1.4
CR Breathing Rate	Section 6.2.1.4
CR Occupancy Factors	Section 6.2.1.4
Offsite χ/Q	Section 6.2.1.5
Offsite Breathing Rate	Section 6.2.1.5
Operation of the CR HVAC	Normal Operation
FSB Ventilation System	None

* Data from Reference 6.6-7

Table 6.2-2
Core Inventories of Nuclides for use in Radiological Design-Basis Applications
(at 84 Hours Decay)*

Nuclide Halogens	Activity (Ci)		Nuclide Noble Gases	Activity (Ci)
I-130	3.44E+04		Kr-85m	0.00E+00
I-131	6.94E+07		Kr-85	1.10E+06
I-132	6.39E+07		Kr-87	0.00E+00
I-133	1.17E+07		Kr-88	0.00E+00
I-134	0.00E+00			
I-135	2.62E+04		Xe-131m	9.85E+05
			Xe-133m	2.91E+06
			Xe-133	1.36E+08
			Xe-135m	4.20E+03
			Xe-135	7.83E+05
			Xe-138	0.00E+00

* Data from Reference 6.6-7

Table 6.2-3
Activity Released from the SFP*

Nuclide Halogens	Activity (Ci)		Nuclide Noble Gases	Activity (Ci)
I-130	1.52E-01		Kr-85m	0.00E+00
I-131	3.67E+02		Kr-85	2.91E+03
I-132	2.81E+02		Kr-87	0.00E+00
I-133	5.15E+01		Kr-88	0.00E+00
I-134	0.00E+00			
I-135	1.15E-01		Xe-131m	8.68E+02
			Xe-133m	2.56E+03
			Xe-133	1.20E+05
			Xe-135m	3.70E+00
			Xe-135	6.90E+02
			Xe-138	0.00E+00

* See Section 6.2.1.6 for calculation of activity released from the SFP

6.3 Accidental Release - Waste Gas

6.3.1 Method of Analysis

The FHA RADTRAD model for normal ventilation is taken from IP-CALC-11-00074 (Reference 6.6-5), because this provides the most limiting results for the two units. The RADTRAD input decks for the FHA are presented in Reference 6.6-13.

For a potential waste gas decay tank rupture accident, the RADTRAD model is modified to instantaneously release an inventory of 50,000 Ci of Xe-133. This activity is the IP3 release limit per Offsite Dose Calculation Manual (ODCM) D 3.2.6 (Reference 6.6-16) and bounds the IP2 release limit of 29,761 Ci of Xe-133.

A conservative ground level release χ/Q for the IP3 CR intake from the nearest large gas decay tank in the IP3 Primary Auxiliary Building (PAB) is calculated using Equation (7) of Regulatory Guide 1.194 (Reference 6.6-17) for use in the RADTRAD model.

$$\chi/Q = 1 / [3*\prod*U*\sigma_y*\sigma_z]$$

Where,

χ/Q = Atmospheric dispersion factor (sec/m^3)
U = Wind speed at 10 meters (m/sec)
σ_y= Lateral dispersion coefficient (m)
σ_z = Vertical dispersion coefficient (m)
3 = Building wake factor

6.3.2 Dose Conversion Factors

The dose conversion factor (DCF) for determining equivalent Xe-133 is 1.56E-15 Sv-m^3/Bq-s, taken from the RADTRAD input decks (References 6.6-4 and 6.6-5) and based on Federal Guidance Report No. 12 (Reference 6.6-18, Table III.1).

6.3.3 Fuel Storage Building and Offsite χ/Qs

The χ/Qs are taken from IP3 calculations IP-CALC-11-00074 (Reference 6.6-5) and IP-RPT-11-00025 (Reference 6.6-19). These are based on a distance of 69.9m for the CR χ/Q (Reference 6.6-19) and 350m for the EAB χ/Q (Reference 6.6-20). IP2 FHA calculation IP-CALC-11-00073 (Reference 6.6-4) was reviewed and the IP2 χ/Qs are bounded by Unit 3 χ/Qs.

Atmospheric Dispersion Factors

Location	χ/Q (sec/m^3)
IP3 FSB Surface to IP3 CR	1.07E-3
IP3 EAB	1.03E-3
IP3 LPZ	3.8E-4
IP3 FSB Surface to IP2 CR	2.46E-4

6.3.4 Control Room Atmospheric Dispersion Parameters

For a release from the waste gas decay tanks to the IP3 CR a bounding χ/Q is developed. The release point is assumed to be the centerline of the closest large waste gas decay tank. The following inputs are used to develop this χ/Q (Reference 6.6-13).

Control Room Atmospheric Dispersion Parameters

Parameter	Value
IP3 CR Intake Location (ft)	5783.75 North 1476.0 East
Centerline Location of the IP3 Gas Decay Tank #31 (ft)	5841.25 North 1552.5 East
Lateral Dispersion Coefficient for a 30m Release, Stability Class F	1.5
Vertical Dispersion Coefficient for a 30m Release, Stability Class F	0.85

6.3.5 Control Room Inputs

The following inputs for the CR model for the waste gas tank decay rupture are from the IP3 FHA calculation IP-CALC-11-00074 (Reference 6.6-5) for the normal ventilation case.

Parameter	Value
CR Volume	4.72E4 ft^3
Unfiltered Makeup (Intake)	1,500 ft^3/minute
Unfiltered Inleakage	700 ft^3/minute
Outflow	2,200 ft^3/minute
Filtered Recirculation	0 ft^3/minute

6.3.6 Additional Assumptions

The wind speed is assumed to be 1 m/sec and the stability class is assumed to be ‘F’ for calculating a bounding atmospheric dispersion coefficient from the PAB to the CR (Reference 6.6-17). These are generic meteorology conditions that will be used to calculate a bounding atmospheric dispersion coefficient. An additional significant conservatism is the implicit assumption that the wind direction is directly toward the CR Room intake at all times.

The CR intake χ/Q for IP3 determined using the parameters in Section 6.3.4 are assumed to be applicable to IP2. This assumption is conservative as the distance between the IP2 CR intake at 6476 ft North – 1373 ft East (Reference 6.6-15) and the southwest corner of the Unit 2 PAB at approximately 6550 ft North – 1476 ft East (Reference 6.6-22) equates to a tangential distance of approximately 39 m. With a longer distance and the same direction to the CR intake for IP2, the dispersion to the IP2 CR would be greater. Therefore, the IP3 atmospheric dispersion factor is bounding.

6.3.7 Calculation

The RADTRAD model for the waste gas decay tank accident is developed using the following inputs to model an instantaneous ground level release of 50,000 Ci of Xe-133:

- 3 RADTRAD compartments – Waste Gas Decay Tank (modeled as a volume of 1 ft^3), Environment, and CR (volume = 4.72E4 ft^3)
- Plant power level – 1 MWt – Nominal power level used to release activity of 50,000 Xe-133 from the associated RADTRAD nuclide inventory file
- Activity release fractions – noble gas fraction = 1.0 over a duration of 1E-5 hour – This represents an instantaneous release in the RADTRAD release file
- Assumed high flow rate from Waste Gas Decay Tank volume to the Environment of 1E4 ft^3/minute to model an instantaneous release from the tank compartment to the environment.
- CR Inputs from Section 6.3.5
- Offsite χ/Qs from Section 6.3.3

To evaluate the impact of removal of the mitigating support systems, a CR ground level release χ/Q is calculated for use in the waste gas decay tank rupture RADTRAD model. This is because the waste gas tanks are located in the PAB, whereas an FHA occurs in the FSB. The PAB is considerably closer to the CR than the FSB and thus less atmospheric dispersion can be credited. Therefore, rather than use the χ/Q of 1.07E-3 sec/m^3 as was done in the FHA analysis (Reference 6.6-5), a new bounding atmospheric dispersion factor is determined. The χ/Q is calculated as follows which conservatively assumes a ground level release, no holdup or dilution in the PAB as well as bounding meteorological conditions in Section 6.3.6.

The distance from the nearest IP3 large gas decay tank to the IP3 CR intake was determined to 96 ft or approximately 30 m.

The lateral and vertical dispersion coefficients for 30 m are defined in Section 6.3.4. Thus, a bounding χ/Q can be calculated utilizing the equation from Section 6.3.1:

$$\chi/Q = 1 / 3 * \prod * 1 * 1.5 * 0.85 = 8.3E\text{-}2 \text{ sec/m}^3$$

The resulting Unit 3 CR χ/Q for the Waste Gas Decay Tank release is conservatively calculated and bounds the value of 2.3E-3 sec/m^3 that was used to model a ground level release in Reference 6.6-20 for a Gas Decay Tank Rupture. The IP3 CR χ/Q also does not credit holdup of the activity in the PAB which would delay or disperse activity within the building.

6.3.8 Results

The calculated dose consequences, following a waste gas decay tank rupture without credit for any limiting systems or the PAB ventilation system post shut down, are given below. These results are applicable to both IP2 and IP3 with an individual gas decay tank inventory limit of 50,000 Ci Dose-Equivalent Xe-133.

Waste Gas Decay Tank Rupture Results with 50,000 Ci Dose-Equivalent Xe-133 Limit per Tank

Location	TEDE (rem)	Limit (rem)
CR	0.77	5.0
EAB	0.30	0.5
LPZ	0.11	0.5

The radiological consequences following a waste gas decay tank rupture are less than the dose consequences following an FHA presented in Section 6.2.1.9. They are also less than the 10 CFR 50.67 limit of 5 rem TEDE to the control room operators and the 500 mrem EAB and LPZ dose limit following a waste gas tank accident.

Note: while the gas decay inventory limit given above for post shutdown conditions for IP2 exceeds the current ODCM limit of 29,761 Ci Dose-Equivalent Xe-133 for IP2, the current limit, as well as the administrative control of 6,000 Ci Dose-Equivalent Xe-133 per tank, can be maintained because these ODCM limits are more conservative than the activity limit utilized in this analysis.

6.4 Accidental Release-Recycle of Waste Liquid

Any potential liquid waste release collects in building sumps or is retained in building vaults. It is not released to the environment. As such, the hazard from these releases is derived only from any volatilized components. The volatilized components are what comprise the waste gas accident. Thus, the release of liquid waste is already evaluated in Section 6.3. Furthermore, a liquid waste release accident is not one of the accident analyses required for EP exemption as specified by ISG-02 (Reference 6.6-23). Therefore, a separate liquid-specific release accident evaluation is not required.

6.5 High Integrity Container Drop Event

A calculation (Reference 6.6-13) was conducted to establish the limiting dose-equivalent Xe-133 activity from a potential High Integrity Container (HIC) drop. Each HIC's source term needs to remain below this dose-equivalent activity to demonstrate the release resulting from the HIC drop event is bounded by the FHA and the consequences remain below the 1 rem PAG limit.

Dose-equivalent activities are used since the isotopic inventory of the HICs is not known, so this can easily be compared to an "equivalent" isotope, Xe-133. For the HIC drop accident, new dose-equivalent activity limits are calculated to ensure the results are bounded by the analyzed FHA.

A calculation was conducted to correlate the TEDE and dose-equivalent Xe-133.

The HICs are located in the IP2 303 Alleyway between the PAB and FSB, the IP3 Annex building, and the IP1 Fuel Handling Floor. Since χ/Qs for IP1 are not available, a bounding atmospheric dispersion value of 1 sec/m^3 (i.e. no wind dispersion) will be used for the HIC drop accident. However, aerosolized fractions will be credited. Since these casks are in dry storage, the only way for a release to occur is for the contents to become aerosolized. The bounding scenario for this accident is taken to be one HIC dropping on top of another, the entire contents of both being released, and then the contents becoming engulfed in a fire. A release fraction of 0.78% (Reference 6.6-24) is utilized, this is the percentage of the contents anticipated to become aerosolized due to the fire. The resulting dose-equivalent Xe-133 activity for a HIC drop accounting for the two (2) HICs and the aerosolized fraction (0.78%) and an EAB dose of 0.47 rem, was determined to be 5.2E3 Ci.

To summarize, the dose-equivalent Xe-133 activity is calculated for a potential HIC drop accident where one HIC falls on top of another and both catch on fire. The release resulting from the HIC drop event needs to remain below this activity limit to meet the EPA PAG of 1 Rem.

6.6 References

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6. EPA-400/R-17/001, "PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents," January 2017

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18. Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil September 1993

19. Calculation No. IP-RPT-11-00025, "Analysis of Control Room and Technical Support Center X/Q Values for Releases at Indian Point Generating Station Unit Number 3 Fuel Handling Building Using the ARCON 96 Computer Code"

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