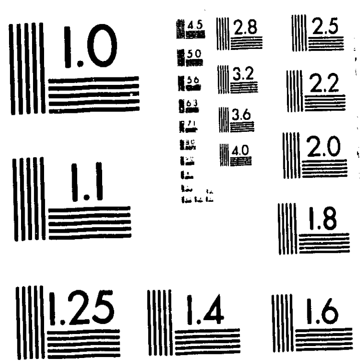
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CRITICAL PROTECTION ITEM CLASSIFICATION FOR A WASTE PROCESSING FACILITY AT SAVANNAH RIVER SITE

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DISCLAIMER

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ABSTRACT

This paper describes the methodology for Critical Protection Item (CPI) classification and its application to the Structures, Systems and Components (SSC) of a waste processing facility at the Savannah River Site (SRS).

The WSRC methodology for CPI classification includes the evaluation of the radiological and non-radiological consequences resulting from postulated accidents at the waste processing facility and comparison of these consequences with allowable limits. The types of accidents considered include explosions and fire in the facility and postulated accidents due to natural phenomena, including earthquakes, tornadoes, and high velocity straight winds.

The radiological analysis results indicate that CPIs are not required at the waste processing facility to mitigate the consequences of radiological release. The non-radiological analysis, however, shows that the Waste Storage Tank (WST) and the dike spill containment structures around the formic acid tanks in the cold chemical feed area and waste treatment area of the facility should be identified as CPIs. Accident mitigation options are provided and discussed.

INTRODUCTION

As a part of its compliance with the Department of Energy (DOE) requirements for safety of nuclear facilities[1] at the Savannah River Site (SRS), Westinghouse Savannah River Company (WSRC) assigns functional classifications to structures, systems and components (SSCs). As a result of these classifications, changes in design, operations, maintenance, testing, and inspections of SSCs are performed and backfit requirements are established. This paper describes the Critical Protection item (CPI) Classification for a waste processing facility (WPF) at SRS.

The CPI functional classification applies to the SSCs necessary to protect the health and safety of the public from non-radiological hazardous material and for the protection of the health and safety of the co-located worker from both radiological hazards and non-radiological hazardous material.

The proposed WSRC methodology[2] and procedure[3] are used in the CPI classification. The methodology includes the evaluation of the radiological and non-radiological consequences resulting from postulated accidents at the waste processing facility and the comparison of these consequences with allowable frequency-dependent limits. The descriptions of the facility and the processes considered are provided in References [6] and [9]. The types of accidents considered include explosions and fire in the facility and postulated accidents due to natural phenomena. When the allowable limits are exceeded, CPIs are identified to mitigate the accident consequences.

The radiological analysis results indicate that CPIs are not required at the waste processing facility to mitigate the consequences of radiological releases. The non-radiological analysis results, however, indicate that the structures identified as CPIs include the Waste Storage Tank and the dike spill containment structures around the formic acid storage tanks in the cold chemical feed area and waste treatment area.

Mitigation options to reduce either the consequences or the frequency of the most limiting accident are provided and discussed.

METHODOLOGY

The methodology used in the CPI classification is based on the WSRC Functional Classification Methodology described in Reference 2 and supports the functional classification procedure described in Reference 3. This methodology includes the allowable onsite dose limits for radiological hazards at SRS facilities and the onsite and offsite allowable concentration limits for hazardous chemicals.

For the radiological assessment, accidents with consequences greater than the allowable onsite dose limits require CPIs to mitigate the consequences to an acceptable range. The allowable onsite dose limits are derived from the frequency (F) of the events using the following criteria[2]:

Frequency (per/yr)	Dose Limit (rem)
F=1.0E-02	5
1.0E-06<F<1.0 E-02	$1.12 \times F^{(-0.325)}$
F=1.0E-06	100

For the non-radiological assessment, the allowable onsite and offsite concentration limits are derived from the frequency (F) of the events using the following criteria [2]:

Frequency (per/yr)	Onsite Exposure Limits	Offsite Exposure Limits
F=1.0E-02	ERPG-1/ 5E-5 ICR	PEL-TWA/ 1E-6 ICR
1.0E-04≤F<1.0E-02	ERPG-2/ 5E-4 ICR	ERPG-1/ 5E-5 ICR
1.0E-06≤F<1.0E-04	ERPG-3/ 1E-2 ICR	ERPG-2/ 5E-4 ICR

where: ERPG = Emergency Response Planning Guideline

PEL-TWA = Permissible Exposure Limit, Time Weighted Average

ICR = Incremental Cancer Risk

The chemical concentrations corresponding to the onsite and offsite exposure limits shown above are established according to each type of chemical release considered according to the methodology reported in Reference 4.

ASSUMPTIONS

The assumptions used in the radiological analysis include:

- Onsite radiological consequences resulting from a postulated accident scenario are the primary criterion in the selection of CPIs.
- Onsite radiological consequences are evaluated in terms of the dose to the co-located worker at a distance of 640 meters from the point of release assuming 50% meteorological conditions [2].
- The onsite release model is based on the AXAIR89Q computer code[5]. In particular:

  (a) The onsite receptors are assumed to be located downwind at a range of distances in the worst meteorological sector.

  (b) The release duration is 2 hours.

  (c) All releases are assumed to occur from ground level. Building wake effects or plume-terrain interaction are conservatively not considered.

  (d) The ICRP-30 dose conversion factors in AXAIR89Q are used.

  (e) The release is considered unfiltered.

  (f) Site-specific atmospheric dispersion factors (χ/Qs) are used from the meteorological database.

  (g) Daughter ingrowth is limited to parents with a half-life of less than 24 hours.

The assumptions used in the non-radiological analysis include:

- The benzene in the WST is assumed to be stored at a concentration of 100 wt%. The nitric acid is assumed to have a concentration of 70 wt %; the formic acid, 100 wt %.
- The quantity of each chemical (benzene, nitric acid, formic acid) entrained in the ambient air as a result of splashing is assumed to be 0.001% of the chemical liquid volume released in each accident[6].
- The quantity of each chemical (benzene, nitric acid, formic acid) entrained in the ambient air as a result of splashing is assumed to be fully entrained after a period of 1 minute.
- The co-located receptor is assumed to be located at a distance of 640 meters from the point of release associated with each postulated accident scenario[7]. The offsite receptor is assumed to be located at the closest site boundary, approximately 10.99 km from the processing facility[8].

- The spill containment dike structures around the formic acid tanks in the cold chemical feed area and waste treatment area are assumed to remain intact during and following the earthquake, tornado, and high velocity straight wind accident scenarios.
- The onsite and offsite ambient concentrations are determined by using AXAIR89Q computer code[5] results.

ANALYTICAL METHODS AND CALCULATIONS

Radiological Dose Calculations

The radiological dose calculations are based on the frequencies and radiological dose results calculated for the Waste Processing Facility Safety Class Item (SCI) determination reported in Reference 8. The accidents analyzed in this determination are:

(1) Design Basis Earthquake (DBE))

The DBE corresponds to an earthquake with a peak horizontal ground acceleration of 0.2g. In this accident, structures such as the Precipitate Reactor (PR) and Precipitate Reactor Feed Tank (PRFT) are damaged, resulting in explosive aerosolization of the PR and PRFT solutions, splashing of the solutions from tank failure and/or collapse of cell blocks, entrainment of radionuclides in the boiling liquid due to benzene fire, evaporation of the spilled solutions, and burning of dried solid wastes.

(2) Pump Pit Explosion

This accident is due to the formation and ignition of an explosive mixture of benzene and air in the tank vapor space.

(3) PR/PRFT Explosion

The explosion is initiated by the presence of an ignition source with appropriate concentrations of benzene and N_2O in the tank vapor space of the PR. As a result, the PR explodes and may cause a benzene-air deflagration in the PRFT, with benzene spills and fire as secondary effects.

(4) Canyon Fire

The fire is due to the presence of benzene in the Salt Process Cell (SPC) vessels used in the purification of recovered benzene and the dried precipitate from the PR and PRFT.

(5) Pump Pit Cell Fire

In this accident, the spilled solution from the precipitate tank is eventually dried out and is assumed to ignite by an ignition source in the cell.

The methodology for calculating the onsite doses is based on the use of the known offsite and the onsite-to-offsite dose ratios for each accident considered. This is accomplished by:

(a) Using the offsite dose results as evaluated and reported in Reference 8.

(b) Using the AXAIR89Q code for evaluating the onsite-to-offsite dose ratios for the release of 1 Ci of radioactive material under specific atmospheric dispersion conditions.

(c) Evaluating the onsite doses from the results of (a) and (b) above.

Chemical Concentration Calculations

Ambient concentrations of chemical vapors were calculated at the co-located receptor location and at the offsite receptor location for postulated releases of hazardous chemicals at the waste processing facility.

Accident scenarios involving the release of chemicals were analyzed for the following components and areas:

1. Waste Storage Tank (WST)

The WST is used to store organic waste (primarily benzene) produced in the SPC until it can be sent to an incinerator for final disposal. This tank is a 150,000-gallon double-wall tank[9].

2. Chemical and Industrial Waste Treatment Area

The chemical and industrial waste treatment system provides for treatment of acid waste and organic waste. Acid waste is stored in a 2100 gallon tank. The acid waste consists of a solution of approximately 50 wt % nitric acid. Organic acid waste is stored in two 3150-gallon tanks. The organic acid waste consists of an approximately 90 wt % solution of formic acid[9].

3. Cold Chemical Feed Storage Area

A 50 wt % solution of nitric acid is stored in a 1000-gallon portable storage tank on a diked pad in this area. A 90 wt % solution of formic acid is stored in two 6500-gallon storage tanks located in a separate diked area[9]. However, the inventory of formic acid in the Cold Feed Area is limited to 3000 gallon by operational safety requirements.

The following release accidents are evaluated at the three waste processing areas:

1. Explosion

The benzene vapor in the WST explodes, aerosolizing a portion of the benzene liquid inventory. The remainder of the liquid benzene is assumed to be released from the tank, further aerosolizing a portion of the tank inventory by splashing. The released pool of benzene then ignites and burns. All aerosolized benzene is entrained in the ambient air after a period of 1 minute. The aerosolized benzene is assumed to drift as a vapor cloud away from the failed tank under 50% meteorological conditions that include a wind speed of 4.5 m/sec.

2. Tornado

The tank fails catastrophically due to a tornado. Splashing occurs, causing a fraction of the tank content to become aerosolized. The tank contents flow to the ground. A portion of the liquid is assumed to evaporate for a period of 1 minute as a result of the 110 mph winds. The evaporation continues from the ground once the tornado has passed under 50% meteorological conditions. A wind speed of 4.5 m/sec is assumed.

3. High Winds

The tank fails catastrophically due to high velocity straight winds. Splashing occurs, causing a fraction of the tank content to become aerosolized. The tank contents flow to the diked area and evaporates under sustained 110 mph high winds. The high winds are assumed to remain in the vicinity of each failed tank for a period of 15 minutes[7].

4. Earthquake

The tank fails catastrophically due to an earthquake. Splashing occurs, causing a fraction of the tank content to become aerosolized. The remainder of the tank contents flows in the area surrounding the tank and evaporates under 50% meteorological conditions. A windspeed of 4.5 m/sec is assumed.

The methodology for calculating the onsite and offsite chemical consequences is based on the evaluation of the airborne chemical concentration calculated as:

$$C = R \times (\chi/Q)$$

where
- C = ambient air concentration, mg/m^3
- R = evaporation release rate, mg/sec
- χ/Q = atmospheric dispersion factor, sec/m^3

The evaporation rate for each chemical is evaluated by using the EPA Open Dump Model[10]. A 50% meteorology atmospheric dispersion factor, χ/Q, calculated with the AXAIR89Q computer code[5], is used for both onsite and offsite chemical releases for each accident, except the tornado and high velocity straight wind accidents. For these accidents, the integrated dispersion factor, χ/Q, reported in Reference [11] is used.

CPI EVALUATION

Radiological Evaluation

Table 1 summarizes the postulated accidents and the associated radiological consequences calculated for the WPF CPI analysis.

The calculated onsite doses resulting from the postulated accidents are compared to the allowable dose limits. Two cases are considered. The first case, in which the doses are calculated for onsite co-located workers at 640 meters, is based on the standard methodology[2]. As can be seen, the onsite doses are lower than the allowable onsite dose limits for each accident considered. These results indicate that the WPF does not require any CPIs for radiological accident consequence mitigation. In the second case, doses were calculated for the postulated accidents at a distance of 460 meters from the point of release. This distance represents the minimum distance at which the dose received by a co-located worker would not exceed the allowable onsite dose limit and, therefore, not require mitigation through the classification of any WPF systems as Critical Protection Items.

Non-radiological Evaluation

Tables 2 and 3 summarize the onsite and offsite chemical consequences of the WPF accidents, respectively. The results indicate that the facility or structures included in the non-radiological analysis that produced either onsite or offsite accident consequences that would necessitate the use of CPIs is the Waste Storage Tank (WST).

POTENTIAL CPIs AND RECOMMENDATIONS

Based on the radiological analysis, CPIs are not required at the WPF to mitigate the consequences of radiological releases. The non-radiological analysis, however, indicates that the only facility or structure that requires CPIs is the WST. This CPI is in addition to the dike spill containment structures around the formic acid tanks in the cold chemical feed area and waste treatment area that qualify as CPIs since it was assumed that these structures remain intact during and after each accident.

The WST presently is equipped with a nitrogen blanketing system as well as a backup system. However, the current system only lowers the frequency of an explosion in the WST to 2.7E-04 per year. Mitigation of explosions using the nitrogen blanketing system involves the reduction of the event frequency to less than 1.0E-06 per year. A modification to the nitrogen blanketing system to provide for further redundancy would be required to make a benzene vapor explosion in the tank an incredible event.

It should be noted that the nitrogen blanketing system includes a nitrogen gas injection system as well as oxygen analyzers and benzene vapor detection equipment. Using oxygen analyzers for normal operation and for backup, with setpoints below the oxygen content for benzene vapor explosion, may also be required. The proposed setpoints would be at 5% oxygen in the blanketing system.

As an alternative, consequences resulting from a vapor explosion in the WST could be significantly reduced if the volume of liquid waste stored in the WST is greatly reduced. Operational safety requirement controls on the maximum tank inventory could limit the accumulation of benzene vapor available for explosion. As an extra control measure, the Hi-Hi level alarm system may need to be qualified as a CPI since a failure of this system could lead to the unintentional transfer of excess benzene to the tank.

CONCLUSIONS

This paper has provided the WSRC methodology for Critical Protection Item (CPI) classification. The methodology was applied to evaluate the radiological and non-radiological consequences resulting from postulated accidents at a Waste Processing Facility at SRS. The types of accidents considered include explosions and fire in the facility and postulated accidents due to natural phenomena, including earthquakes, tornadoes, and high velocity straight winds.

The radiological analysis results indicate that CPIs are not required at the facility to mitigate the consequences of radiological release. The non-radiological analysis, however, indicates that the structures identified as CPIs are the Waste Storage Tank and the dike spill containment structures around the formic acid storage tanks in the cold chemical feed area and waste treatment area. Mitigation options include a nitrogen blanketing system, oxygen analyzers, and a reduced benzene tank inventory.

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Table 1. Radiological Consequences of WPF Design Basis Accidents

	Frequency of Event* (per year)	Offsite Doses (rem)	Onsite Dose [640 meters] (rem)	Onsite Dose [460 meters] (rem)	Allowable Onsite Dose Limits (rem)
Design Basis Earthquake	2.0e-4	4.39	10	18	18
Pump Pit Explosion	3.8e-5	0.115	0.9	1.6	31
PR/PRFT Explosion	2.2e-5	0.436	3	5.4	37
Canyon Fire	1.5e-3	0.495	4	7.2	9
Pump Pit Cell Fire	1.8e-1	0.262	2	3.6	5

* From Reference 8

Table 2. Onsite Co-located Chemical Consequences of WPF Design Basis Accidents

Chemicals	Location	Event	Occurrence Frequency (per year)	Consequence Level	Air Conc. [640 m.] (mg/m^3)	WSRC Guide (mg/m^3)
Benzene	WST	Explosion	2.7E-4	ERPG-2 / 5.0E-4 ICR	8685	163
		Tornado	1.0E-4	ERPG-2 / 5.0E-4 ICR	163	163
		High Winds	1.0E-3	ERPG-2 / 5.0E-4 ICR	0.39	163
Formic Acid	Cold Feed Area	Tornado	1.0E-4	ERPG-2	5.1	19
		High Winds	1.0E-3	ERPG-2	0.01	19
		Earthquake	2.0E-4	ERPG-2	4.6	19
	Chem. & Ind. Waste Treatment Area	Tornado	1.0E-4	ERPG-2	2.7	19
		High Winds	1.0E-3	ERPG-2	5.8E-3	19
		Earthquake	2.0E-4	ERPG-2	2.6	19
Nitric Acid	Cold Feed Area	Tornado	1.0E-4	ERPG-2	0.22	39
		High Winds	1.0E-3	ERPG-2	5.0E-4	39
		Earthquake	2.0E-4	ERPG-2	0.24	39
	Chem. & Ind. Waste Treatment Area	Tornado	1.0E-4	ERPG-2	0.22	39
		High Winds	1.0E-3	ERPG-2	5.4E-4	39
		Earthquake	2.0E-4	ERPG-2	0.30	39

Table 3. Offsite Chemical Consequences for WPF Design Basis Accidents

Chemicals	Location	Event	Occurrence Frequency (per year)	Consequence Level	Air Conc. [10.99 km] (mg/m^3)	WSRC Guide (mg/m^3)
Benzene	WST	Explosion	2.7E-4	ERPG-1 / 5.0E-5 ICR	123.4	16
		Tornado	1.0E-4	ERPG-1 / 5.0E-5 ICR	2.83	16
		High Winds	1.0E-3	ERPG-1 / 5.0E-5 ICR	0.12	16
Formic Acid	Cold Feed Area	Tornado	1.0E-4	ERPG-1	0.12	19
		High Winds	1.0E-3	ERPG-1	3.4E-3	19
		Earthquake	2.0E-4	ERPG-1	0.07	19
	Chem. & Ind. Waste Treatment Area	Tornado	1.0E-4	ERPG-1	0.06	19
		High Winds	1.0E-3	ERPG-1	1.8E-3	19
		Earthquake	2.0E-4	ERPG-1	0.04	19
Nitric Acid	Cold Feed Area	Tornado	1.0E-4	ERPG-1	5.3E-03	5
		High Winds	1.0E-3	ERPG-1	1.5E-4	5
		Earthquake	2.0E-4	ERPG-1	3.5E-03	5
	Chem. & Ind. Waste Treatment Area	Tornado	1.0E-4	ERPG-1	5.5E-03	5
		High Winds	1.0E-3	ERPG-1	1.7E-4	5
		Earthquake	2.0E-4	ERPG-1	4.2E-03	5

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