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Summary

A radiological consequence analysis of a propagated fire accident in a Savannah River Site (SRS) radiochemical separations facility has been performed. This analysis supports the safety documentation for the SRS plutonium reprocessing facility. Included are the evaluation of the doses resulting from the exposure to the radioactive airborne release for co-located facility worker and the off-site individual receptors.

Atmospheric dispersion calculations using qualified five-year (1987-1991) meteorological data were performed with the computer code AXAIR89Q[1], a validated computer code for radiological dose calculations. Radioactive source term estimates and assumptions of material composition and isotope distribution were based on existing permissible storage levels as defined in approved safety documentation.

The fire accident scenario assumes that the fire propagates in the entire facility on four structural levels. Approximately 97% of the radioactive materials released occurs from levels three and four of the facility, which are not included in the ventilation pathway to the sand trap filter. Radiological analysis results indicate that the doses to co-located worker and off-site individual receptors are equal to 4.4 rem and 3.3 rem, respectively.

Accident mitigators that were identified include provision for filtration capacity from levels three and four of the facility, and relocation of stored radioactive materials. Provision for filtration capacity would reduce the source term from an unfiltered activity of 53.6 Ci to a filtered activity of 2.0 Ci. Relocation of stored radioactive materials would result in a source term reduction from 53.6 Ci to 20 Ci. Limitations exist, however, that may make implementation of the identified mitigators difficult or prohibitive.

Introduction

Revised safety studies indicate that a credible scenario exists where a fire occurs and propagates throughout an SRS radiochemical separations facility. By 'credible', it is estimated that the likelihood of occurance for the propagated fire is greater than 1.0E-6 per year. Previously, safety documentation for the facility had assumed a smaller scope fire as limiting. Included in the propagated fire are all of the third, fourth, fifth, and sixth levels of the facility.

In order to determine the most conservative possible consequences of the propagated fire, the facility safety authorization basis was reviewed to determine the maximum amount of plutonium allowed in the facility. These maximum source term values replace the smaller previous source terms that had been used in analyzing the limiting fire. A description of the facility and the nuclear and chemical processes involved are provided.

Facility Description

The radiochemical separations facility processes convert plutonium nitrate to Pu metal or Pu oxide. The purified Pu is in a dilute solution. Concentration and additional purification of the Pu product by cation exchange is the initial process operation; subsequent processing operations include precipitation and filtration, drying and conversion of Pu, and finally reduction of Pu to the metal. The processing equipment is enclosed within process enclosures (either cabinets or glove boxes) and is confined to the fifth and sixth levels, with the exception of the receiving tank for Pu product on the third level.

The process layout includes the feed tanks, and the reagent tanks, located on the sixth level, that feed to the cation exchange columns and precipitators by gravity. In a series of mechanical operations, the Pu precipitate is dried, roasted, and converted to metal. The filtrate from the filtration process is transferred to the sixth level for neutralization before transfer to another facility. Dissolvers used in the recovery process are located on the sixth level. Special recovery accountability tanks and recovery anion columns are located on the fifth level.

Calculational Model

1)Source Terms
The plutonium mass released due to the propagated fire in the facility is shown in Table 1. Also shown are the Airborne Release Fractions (ARF) and the Respirable Fraction (RF) that were applied to the various chemical forms of the plutonium to estimate the amount of material dispersed as a result of the fire. The plate out factor indicated accounts for depletion of the dispersed material inside the facility onto building vent ductwork and walls.

The sand filter provides protection against releases, but is only available for exhaust from the fifth and sixth levels of the facility. Exhaust from the third and fourth levels bypass the sand filter and is sent directly to the 62 meter stack without filtration. A sand filter efficiency of 4.9E-03 was used for releases from filtered levels[2].

The source terms for releases from each level of the facility are shown in Table 1. The initial inventory limits in Table 1 are given as plutonium without respect to its isotopic breakdown. Since the radio-toxicity of plutonium can vary greatly by isotope, the percentage of each isotope present is important to determining the outcome of the analysis. Also, because of large variations in specific activity from isotpe to isotope, the contribution to total radioactivity contained in the overall isotopic mixture (or Curie fraction) will not correspond to the mass present in the mixture. The isotopic Curie fraction and the specific activity of plutonium present in the facility are shown in Table 2 [3].

2) AXAIR89Q
AXAIR89Q [1], a validated computer code for radiological dose calculations was used to analyze the impact of the radiological airborne releases from the fire. The code has recently been revised to incorporate new features that include:
1)the most recent available meteorological data for the period 1987-1991.
2) updated population data for both on-site and off-site locations.

The AXAIR89Q code was used to create facility specific dose conversion factors (DCFs) based on one curie of released material. Each radionuclide has a specific dose conversion factor for release from the facility stack. Dose conversion factors were calculated using 99.5% worst-sector and 50% (or median) meteorological data. The worst sector meteorology data are used for the Maximum Off-Site Individual (MOI), Off-Site Population, and On-Site population receptors. Median meteorology data were used to evaluate the dose to the on-site co-located worker at a distance of 640 meters from the release. The 1 Curie dose conversion factors generated from the AXAIR89Q code for releases from the 62 meter facility stack are shown in Table 3.

3)Assumptions
A plate out factor of 10% has been assumed in the analysis. Ninety percent of the material dispersed in the fire is assumed to be released by the building ventilation system, with the remaining ten percent being retained within the facility. The ventilation system is assumed to be operable throughout the fire, and the integrity of the facility is assumed to be maintained such that the only release point is through the 62 meter stack.

The Airborne Release Fractions (ARF) and the Respirable Fractions (RF)assumed to characterize the releases that result from the fire[4] are shown in Table 1.

Correction factors are applied to the amount of material released through leakage in the ventilation ductwork between the exhaust airflow from levels 5 and 6 into the exhaust flow from levels 3 and 4, and are provided in Table 1.

Analysis Results

Table 2 provides the isotopic distribution of material released as a result of the propagated fire in the facility. The computed source terms for each form of the material discharged and for each level of the facility are presented in Table 1. The source term accounts for the mass inventory of material available for release and the fractional release factors discussed earlier. The 1-Curie dose conversion factors calculated with the AXAIR89Q code for each isotope type considered are provided in Table 3. The conversion factors were calculated for a) the maximum exposed off-site individual, b) the on-site co-located worker (evaluated at a distance of 640 meters), c) the off-site population evaluated from the site boundary to a distance of 50 miles, and d) the on-site population evaluated within the site boundary.

The doses due to releases from levels 3 through 6 of the facility, and the total dose calculated for the receptors described above are presented in Table 4. For every level of the facility, the breakdown of the dose due to each form of the material released is provided.

The analysis results indicate that the doses to the co-located worker and the off-site individual are 4.4 rem and 3.3 rem, respectively. These results also show that about 97% of the total doses received are due to release of material from levels 3 and 4 of the facility, which are not included in the ventilation path to the sand trap filter.

Accident mitigators of the radiological consequences that were identified include provision for filtration capacity from the third and fourth levels, and relocation of stored radioactive materials. Provision for filtration capacity to the unfiltered third and fourth levels would reduce the released radioactivity from 53.6 Curies (unfiltered) to 2.0 Curies (filtered). Relocation of stored radioactive materials would result in a reduction of the amount of released activity from 53.6

Curies to 20 Curies. Limitations and other facility restrictions exist, however, that may make implementation of the identified mitigators difficult or prohibitive.

Conclusions

This paper has provided a radiological airborne consequence analysis of a propagated fire accident in a Savannah River Site radiochemical separations facility. Radiological doses resulting from exposure to the radioactive plume for a co-located facility worker and the off-site individual have been evaluated using the computer code AXAIR89Q.

The analysis results indicate that the doses to the co-located worker and the off-site individual are equal to 4.4 rem and 3.3 rem, respectively. About 97% of the doses were found to be due to the release of material from levels three and four of the facility, which are not included in the ventilation pathway to the sand trap filter.

Accident mitigators, such as provision for filtration capacity from levels three and four of the facility, and relocation of stored radioactive materials, have been identified as effective in reducing the calculated doses. Existing limitations and other facility restrictions, however, may make implementation of the identified mitigators difficult or prohibitive.

References

1. J. C. Huang, Use of the AXAIR89Q Code, WSRC-TR-90-0569, Westinghouse Savannah River Company, Aiken, SC, 1990.

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3. W.S. Durant, Safety Analysis - 200 Area Savannah River Plant FB-Line Operations, DPSTA-20-10 SUPP-9, E.I. DuPont de Nemours & Co., Savannah River Laboratory, Aiken SC, February 1986.

4. DOE-HDBK-0013-93, Recommended Values and Technical Bases for Airborne Release Fractions (ARF), Airborne Release Rates (ARR), and Respirable Fractions (RF) at DOE Non-Reactor Nuclear Facilities, U.S. Department Of Energy, July 1993.

Table 1. Propagated Fire Source Terms

Sixth Level	Mass Inventory (kg)	ARF	RF	10% Plate Out Factor	Sand Filter	Specific Activ. (Ci/kg)	Curies Released
Liquid	53.24	1.0E-3	1	0.9	4.9E-3	872	2.05E-01
Powder	148.00	6.0E-3	0.01	0.9	4.9E-3	872	3.41E-02
Metal	45.00	5.0E-4	0.5	0.9	4.9E-3	872	4.33E-02

Fifth Level	Mass Inventory (kg)	ARF	RF	10% Plate Out Factor	Sand Filter	Specific Activity	Curies Released
Liquid	114.84	1.0E-3	1	0.9	4.9E-3	872	4.42E-01
Powder	122.00	6.0E-3	0.01	0.9	4.9E-3	872	2.81E-02
Substrate	6.20	6.0E-3	0.01	0.9	4.9E-3	872	1.43E-03
Metal	137.25	5.0E-4	0.5	0.9	4.9E-3	872	1.32E-01
Resin	32.66	7.8E-3	0.9	0.9	4.9E-3	872	8.82E-01

Fourth Level	Mass Inventory (kg)	ARF	RF	10% Plate Out Factor	Sand Filter	Specific Activity	Curies Released
Liquid	33.96	1.0E-3	1	0.9	1.0E+0	872	2.67E+01
Metal	45.00	5.0E-4	0.5	0.9	1.0E+0	872	8.83E+00

Third Level	Mass Inventory (kg)	ARF	RF	10% Plate Out Factor	Sand Filter	Specific Activity	Curies Released
Metal	55.00	5.0E-4	0.5	0.9	1.0E+0	872	1.08E+01
Substrate	117.67	6.0E-3	0.01	0.9	1.0E+0	872	5.54E+00
						Total Curies Released	5.36E+01

TABLE 2. Mix of Principal Radionuclides for Facility Process

Isotope	Weight Percent	Activity of Pure Isotope, Ci/gm	Activity, Ci/gm	Curie Fraction
238-Pu	7.00E-03	1.68E+01	1.20E-03	1.38E-03
239-Pu	9.34E+01	6.16E-02	5.80E-02	6.65E-02
240-Pu	5.86E+00	2.27E-01	1.30E-02	1.49E-02
241-Pu	7.00E-01	1.15E+02	8.00E-01	9.17E-01
242-Pu	3.00E-02	3.98E-03	1.20E-06	1.38E-06
		Total:	8.72E-01	1.00E+00

TABLE 3. AXAIR89Q One Curie Dose Conversion Factors

Isotope	Maximum Off-Site Individual (MOI), mrem	Co-Located On-Site Worker (*), mrem	Off-Site Population, person-rem	On-Site Population, person-rem
238-Pu	5.57E+02	7.36E+02	4.30E+03	1.29E+03
239-Pu	6.18E+02	8.16E+02	4.76E+03	1.43E+03
240-Pu	6.18E+02	8.16E+02	4.76E+03	1.43E+03
241-Pu	1.21E+01	1.60E+01	9.34E+01	2.80E+01
242-Pu	5.81E+02	7.68E+02	4.48E+03	1.35E+03

(*) 640 meters using 50% Meteorology Data
Note: - Using 99.5% Meteorology Data unless specified otherwise
- 200 Foot Stack Release

TABLE 4. Plutonium Releases and Doses from Propagated Fire

Sixth Level	Curies Released	Ventilation Leakage Factor (1)		Maximum Off-Site Individual (MOI), mrem	Co-Located On-Site Worker (*), mrem	Off-Site Population, person-rem	On-Site Population, person-rem
Liquid	2.05E-01	1.028		1.31E+01	1.73E+01	1.01E+02	3.03E+01
Powder	3.41E-02	1.028		2.18E+00	2.88E+00	1.68E+01	5.05E+00
Metal	4.33E-02	1.028		2.76E+00	3.65E+00	2.13E+01	6.40E+00
			Sub-total:	1.80E+01	2.38E+01	1.39E+02	4.18E+01
Fifth Level	Curies Released						
Liquid	4.42E-01	1.028		2.82E+01	3.73E+01	2.17E+02	6.53E+01
Powder	2.81E-02	1.028		1.80E+00	2.38E+00	1.39E+01	4.16E+00
Substrate	1.43E-03	1.028		9.14E-02	1.21E-01	7.04E-01	2.12E-01
Metal	1.32E-01	1.028		8.43E+00	1.11E+01	6.50E+01	1.95E+01
Resin	8.82E-01	1.028		5.63E+01	7.44E+01	4.34E+02	1.30E+02
			Sub-total:	9.49E+01	1.25E+02	7.31E+02	2.20E+02
Fourth Level	Curies Released						
Liquid	2.67E+01	N/A		1.66E+03	2.19E+03	1.28E+04	3.83E+03
Metal	8.83E+00	N/A		5.49E+02	7.25E+02	4.23E+03	1.27E+03
			Sub-total:	2.21E+03	2.91E+03	1.70E+04	5.10E+03
Third Level	Curies Released						
Metal	1.08E+01	N/A		6.71E+02	8.86E+02	5.17E+03	1.55E+03
Substrate	5.54E+00	N/A		3.44E+02	4.55E+02	2.65E+03	7.97E+02
			Sub-total:	1.02E+03	1.34E+03	7.82E+03	2.35E+03
			Grand Total	3.33E+03	4.40E+03	2.57E+04	7.72E+03

(*) 640 meters using 50% Meteorology Data

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Abstract

As part of the Department of Energy Safety Program at the Savannah River Site (SRS), a radiological consequence analysis of a propagated fire accident in a Savannah River Site radiochemical separations facility has been performed. The analysis includes the evaluation of the doses resulting from the exposure to the radioactive airborne release for a co-located facility worker and the off-site individual. The fire accident scenario assumes that the fire propagates in the entire facility on four structural levels.

Atmospheric dispersion calculations using qualified four-year meteorological data were performed with the computer code AXAIR89Q, a validated computer code for radiological dose calculations. Radioactive source term estimates and assumptions of material composition and isotope distribution were based on existing permissible storage levels.

Radiological analysis results indicate that the doses to the co-located worker and the off-site individual are equal to 4.4 rems and 3.3 rems, respectively. Approximately 97% of the radioactive materials released occurs from levels three and four of the facility, which are not included in the ventilation pathway to the sand trap filter.

Accident mitigators that were identified include provision for filtration capacity from levels three and four of the facility, and relocation of stored radioactive materials. Provision for filtration capacity would reduce the source term from an unfiltered activity of 53.6 Ci to a filtered activity of 2.0 Ci. Relocation of stored radioactive materials would result in a source term reduction from 53.6 Ci to 20 Ci. Limitations exist, however, that may make implementation of the identified mitigators difficult or prohibitive.