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ACCIDENT SIMULATION IN A CHEMICAL PROCESS FACILITY AT THE SAVANNAH RIVER SITE (U)

by

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ACCIDENT SIMULATION IN A CHEMICAL PROCESS FACILITY AT THE SAVANNAH RIVER SITE

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Abstract

The U. S. Department of Energy requires Westinghouse Savannah River Company to safely operate the chemical separations facilities at the Savannah River Site (SRS). As part of the safety analysis program, simulation of a proposed frame waste recovery (FWR) system is needed to determine the possible accident consequences that may affect public safety. This paper details the simulation process for the proposed frame waste recovery process and describes the analytical tools used in order to make estimates of accident consequences.

Since the process in question has been operated, historical data and statistics about its operation are available. Software tools have been developed to allow analysis of the frame waste recovery system, including the generation of system specific dose conversion factors for a number of unique situations. Accident scenarios involving spilled liquid material are analyzed and account for the specific floor geometry of the facility. Confinement and filtration systems are considered.

Analysis of source terms is a limiting factor which affects the entire evaluation process. In the past, facility source terms were generally constant with occasional variations from established patterns. As new site missions unfold, significant variations in source terms can be expected. The impact of these variations on the safety analysis is discussed.

Introduction

The Savannah River Site (SRS) occupies 300 square miles in South Carolina adjacent to its namesake, the Savannah River. The U. S. Department of Energy and its predecessors have used the facility since the early nineteen fifties to produce nuclear materials for the nation's weapons program. Currently the Westinghouse Savannah River Company is the operating contractor, providing technical and engineering support enabling the site to achieve its mission.

Part of the site's traditional mission has required chemical reprocessing of reactor materials. Recent modifications to the facility have resulted in removal of an entire process line of equipment and discontinuation of that process. However the waste recovery system for that process has proved to be a useful and versatile asset to the facility. The frame waste recovery (FWR) system is capable of handling a variety of materials, and processing them into forms that can be re-utilized for other missions, or safely and conveniently stored in preparation for final disposal. Currently the FWR system is playing an important role in the CASSINI project [1], where isotopic power sources for a deep space probe are being produced.

This paper provides an overview of the safety analysis of the FWR system at SRS. Recalculation of values presented in the SAR is an ongoing part of the safety program. Results of this work for nominal source term events are presented. The simulation of several types of postulated accidents is described and discussed.

Software tools used in quantifying the consequences of each accident are described. Uncertainty estimates applied to the simulation are discussed, and the future impacts of changing missions at the facility are estimated. A comparison of the results obtained with approved safety criteria is provided.

Accident Simulations

The SRS safety analysis program requires the analysis of several postulated accident scenarios [2]. The accident scenarios simulated for the FWR system include: transfer error, process leak and uncontrolled reaction. These process-induced scenarios were selected because of their contributions to total risk. Accidents induced by natural phenomena are not considered.

Fire

Based on a separated fire hazard assessment program, the fire determined to represent the maximum hazard is a resin fire. This event is postulated to result from a leak of one of the resin columns and drying of the process material. Upon sufficient drying a significant fire ensues. There is a containment inside the process building and filtration to mitigate the release. This scenario is simulated by dispersion of the radioactive and chemical inventory in a medium energetic process by species, with a specific factor applied to each species to calculate the released activity. This activity is then subjected to mitigation by filters and dispersion in the atmosphere. A nominal fire is assumed to burn a fractional amount of material present in the column. The maximum fire is assumed to consume the entire volume of the column at the maximum concentration. Table 1 lists the release fractions specific to nuclide contents taken from reference 3. These factors were used to recalculate the radiological releases of the fire.

Transfer Error

There has been a historical precedence for transfer errors to occur at SRS. A transfer error results from moving material to an unintended location. The safety program considers a wide range of transfer errors, and an extensive data bank of these errors has been compiled [4]. This data bank can be used to construct frequency curves. Analysis of incidents described in the data bank shows that transfer errors which have occurred in the past are small, involving only a portion of the total capacity of the vessels involved [5]. The safety analysis assumes a maximum consequence accident which consists of a transfer error of the entire contents of the largest available vessel. This accident assumes that the largest possible volume at the highest concentration is transferred to the location where a complete atmospheric release is possible. The probability of such an accident to occur is still being determined. The existing safety analysis computes the consequences of such an event, without its associated risk.

Process Leak

Leaks occur periodically in the chemical separations process. The data base contains a large amount of data characterizing leaks of various types [4]. Leaks in the separations operation result in filling the building sump with process material. Normal operating procedure consists of pumping leaked material from the sumps to storage tanks for disposition. While on the building floor, the material is evaporated and released after filtration through the stack. The safety analysis program assumes a large time interval for evaporation in order to maintain a conservative margin regarding corrective responses by operators to leaks. The nominal events are characterized based on historical data from the database [5]. Maximum consequence events are computed using the complete volume of the largest available tank in a particular separation process.

original source term, and uses the event specific dose conversion factors to compute radiological consequences. Gerrard [8] documents the mathematical model used by the software, and McKinney et al [9] document the testing and validation of the software. The dispersion model is not based on first principles, but employs referenced data to compute radiological consequences. Typically data from Table 1 or other appropriate sources are used to make estimates of dispersed fractions of the original source term. As with the evaporation code, event-specific dose conversion factors are used to compute radiological consequences. McKinney [9] has described the testing and validation of the dispersion software.

Source Terms

Source terms for the FWR system were based on using the system in conjunction with the FRAMES process [1]. As needs have changed, this process has been withdrawn from service and the equipment removed. The FWR system has remained and is used in a number of applications that require its unique capabilities. Recently the system has been utilized to provide support for several projects including CASSINI [1]. Re analysis of the baseline SAR accident scenarios was performed with uprated source terms. Results are provided in Table 2. The FWR system also offers the capability to process materials with existing equipment and facilities, in a way that reduces the availability of nuclear materials for proliferation. As missions for the facility change, safety analysis and application of Technical Safety Requirements will ensure that the facility is operated within an acceptable margin of safety.

Results

The consequences calculated using uprated source terms for various postulated accidents are presented in Table 2 for the maximally exposed off-site individual at the boundary of the Savannah River Site. These results for nominal source term events are plotted and compared with operational limits [11] in Figure 1. As can be seen, ample margin exists between the calculated dose results and the operational limits of the FWR facility.

Conclusions

Variations in source terms can be expected to occur in the future, and as a result, safety margins in the current analysis may be affected. Current work is assessing the impact of newly published airborne release fractions [12]. It is expected that these new airborne release fractions will increase safety margins. Further work is in progress to characterize both the frequency and doses of the maximum consequence accidents considered in this analysis.

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Uncontrolled Reaction

It is possible for a non-critical uncontrolled reaction to occur in a process vessel due to unforeseen error. Such an uncontrolled reaction is expected to aerosolize a portion of the process volume, followed by a leak of material to the building sump. This event is analyzed in two portions: the release of aerosols and the evaporation of leaked material. For each portion, the material is transported through the filter system for release from the building stack. Nominal events are computed using historically available data from the database. Maximum consequence events are computed using maximum available tank volumes and concentrations.

Computational Models

The Westinghouse Savannah River Company has developed a program of software management that complies with the requirements of the U.S. Department of Energy [6]. For a complex system of engineering software, the methodology involved is wide, ranging among many different disciplines and applications. Dealing with a single set of administrative and quality requirements for software developed in many arenas over long time frames is a complex task that is not easily achieved. This section describes several of the software tools that have been developed for use in the analysis of chemical separations facilities at SRS.

Safety Database

Since the early nineteen seventies, data has been collected that describes safety-related operational events that occurred at the chemical separations facilities. Currently this database covers hundreds of thousands of separate events over a time span of more than 40 years, ranging from failure of power systems to off-site releases of radioactive materials. A facility for searching the database and building indexes of events, systems, failure modes, consequences, mitigating systems, resolution and other relevant factors is available. This database is described by Townsend, et al. [4] and represents an important tool in understanding and predicting the behavior of the chemical separations facilities. Nominal source terms and frequencies for normal and off-normal events are predicted from historical data whenever data exists. The Frame Waste Recovery system was able to use this database to characterize the fire, transfer error and leak to sump events described above.

Atmospheric Transport Model

WSRC has developed an in house code for computing atmospheric dispersion [7]. Based on the NRC Reg Guides 1.145 and 1.70, this software uses site specific meteorological data and plant coordinates to produce dispersion factors (X/Q) and dose conversion factors per curie released from the stack or building vent. Considerable effort has been expended upon quality assurance of both the code mathematical models and the sizable meteorological data used by the software. Site specific factors for radiological assessment purposes were used with the software. In analyzing the frame waste recovery system, this software was used to compute dose conversion factors for co-located workers and the off-site population. Each dose conversion factor is specific to the isotope mix, release pathway and source location.

Evaporation and Dispersion Model

Having established release mechanisms, source terms with related isotope mixes and incident-specific dosimetry factors, it is possible to complete the analysis by simulating the event to characterize the release. WSRC has developed software to compute the effects of material being evaporated from the building floor [8]. Similarly a code to compute the creation of aerosols in an energetic reaction has also been created [10]. The evaporation code computes fractions dispersed from the

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Table 1. Fractions of Material Released in Process Fires

Burning Solvent containing PU, UO2	0.003
Burning Solvent containing CS	0.01
Burning Solvent containing TH	0.003
Burning Solvent containing RU-RH	0.01
Burning Solvent containing ZR-NB	0.0077
Burning Solvent containing CE	0.0077

Table 2. Revised Radiological Risk to the Maximum Exposed Off-Site Individual from Nominal Source Term Events

Event	Approved SAR Addendum Consequence (mrem)	Uprated Source Term Consequence (mrem)	Frequency (yr^-1)	Approved SAR Addendum Risk (mrem/yr)	Uprated Source Term Risk (mrem/yr)
Fire	1.1E+02	5.3E+01	3.6E-2	4.0E+00	1.9E+00
Uncontrolled Reaction	7.8E+00	1.1E+01	7.9E-2	6.2E-01	8.4E-01
Leak to Sump	3.8E-01	7.2E-01	1.1E+1	4.2E+00	7.9E+00
Transfer Error to Outside Fac.	2.1E+01	4.8E+1	4.0E-4	8.5E-03	2.0E-02

Figure 1. Calculated Doses and Operational Limits for FWR Postulated Accidents from Nominal Uprated Source Terms