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AVOIDANCE OF ACCIDENTS

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MASTER

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ABSTRACT

A summary is presented of the subjects that should be included in safety analysis documents to avoid accidents during reprocessing of nuclear fuel. As a specific example, a potential criticality accident is used to illustrate how this accident is avoided in the dissolvers at the Savannah River Plant (SRP).

Documentation

Safety documentation for accident avoidance should contain, as shown in Slide 1, a discussion of hazards analysis and risk assessment. Cost-benefit analysis is also important in the design stage to evaluate the efficiency of capital dollars in providing safety margins. Our Safety Technology Group at the Savannah River Laboratory (SRL) is developing the methods and tools for each of these as we carry out analyses of the reprocessing facilities in the 200-Areas at SRP.

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Before methods were developed for quantitative calculations, most safety analyses took the deterministic approach. That is, an accident was assumed to occur and its consequences were analyzed without regard for the probability of its occurrence. One starting point for this deterministic analysis (the hazards analysis) is still very useful and should be documented. Simply put, the hazards analysis identifies what can go wrong and what the designer can do about it. The identification of potential accidents involves recognizing the basic dangers (or hazards) inherent in reprocessing and then understanding their role in accident situations. We have compiled a databank at SRL listing over 300 generic and specific safety-related incidents that cover the full spectrum of reprocessing activity, from spent fuel receiving through vitrification of high-level waste. Those incidents bearing on a specific safety analysis are extracted and modified to apply to that case.

We have found this method most effective if the Preliminary Hazards Analysis is applied early in the design stage so that safety concerns are addressed as an integral part of the design effort. Such early application can avoid expensive retrofitting of safety features.

That brings me to the important subject of how to prevent the incidents we identify. Included in the SRL databank is a list of safety features to prevent each incident by preventing its causes. These safety features were collected from a variety of sources including Safety Analysis Reports for SRP, the Idaho Chemical Processing Plant, and commerical reprocessing plants such as Barnwell Nuclear Fuels Plant. Features are also included from the EUROCHEMIC Plant at Mol, Belgium.

The databank also includes the equally-important safety features to detect each incident and to mitigate its consequences, should it occur in spite of preventive measures.

Therefore, safety documents treating avoidance of accidents should include the causes and consequences of every identifiable incident and list safety features for prevention and mitigation.

Now that frequency data are more available, probabilistic methods of risk assessment are becoming more popular than the deterministic method. Risk is defined and calculated as the product of frequency and consequence. Two different methods of obtaining frequencies are available. Rare event methods can be used to derive numbers for the very low frequency event. Another method is applicable to those less-rare events for which some data are available. Databases are available for this work. Many of the component-failure type originated from military studies on fail-safe weapon systems and have been expanded with data from non-nuclear industries. At SRL, we also draw on over 50 SRP plant-years of experience with the Purex Process.

A useful result of risk assessment is that, once risks are calculated, comparisons can be made across a process flowsheet to find the riskiest parts. Then, additional safety features can be efficiently added at any point of unacceptable risk.

That brings me to cost-benefit studies. Most safety features are quite expensive. Capital investment should provide the maximum risk reduction for the money. Risk assessment is the best available method for determining the benefit phase of this analysis.

Accident Avoidance

Two popular concepts are used in combination at SRP to avoid nuclear accidents (SLIDE 2). Our basic strategy relies on mass-concentration controls. In some cases, capacity demands require equipment with geometry that ensures subcriticality. A third concept, neutron poisons, are also used at SRP, but no credit is taken for fixed poisons in our safety analyses.

As an illustration of how these two concepts work together, let us consider the chemical dissolution of fuel assemblies containing highly-enriched uranium or ^{239}Pu. The aluminum cladding and cores of these reactor assemblies are codissolved in a nitric acid solution.

First, for every charge of assemblies to any SRP dissolver, a safety analysis is made to determine the maximum safe number of those assemblies that can be charged and to determine the maximum safe concentration of fissile material in the solution after the dissolution is complete. No material is charged to a dissolver until such analysis is made nor until the assemblies are clearly identified by the shippers and the receivers in each unit operation. To be conservative, we assume that the dissolver contains twice the actual total quantity of fissile material. That is, the solid fuel is assumed to be undissolved, but the liquid is assumed to have the concentration that would result after complete dissolution.

The geometric advantage applies to the charging operation. Identified assemblies are placed in a specific pattern in the charge holder, called an insert, shown in Slide 3. This pattern is selected for each different assembly so as to provide the optimum margin for nuclear safety. Our inserts use either slab or cylindrical geometry. They not only control the shape of a dissolving charge, but also allow measurement of undissolved solid residues by probing the bottom of the insert.

Notice that the bottom of the insert is a distance above the bottom of the solution. Should the solution be accidentally overheated and evaporated, the bottom of the insert will come out of solution, thereby reducing the degree of neutron reflection. The heating coils would come out of solution next so that the heating rate will slow down. The concentration of all of the charged fissiles in solution at this low volume must be safe in an acceptable SRP process.

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SLIDE 1

SAFETY DOCUMENTATION

Hazards Analysis

- Identification of Potential Accidents
- Prevention Methods
- Detection and Mitigation

Risk Assessment

- Consequence Analysis
- Frequency Data
- Reduction of Risk

Cost-Benefit Analysis

SLIDE 2

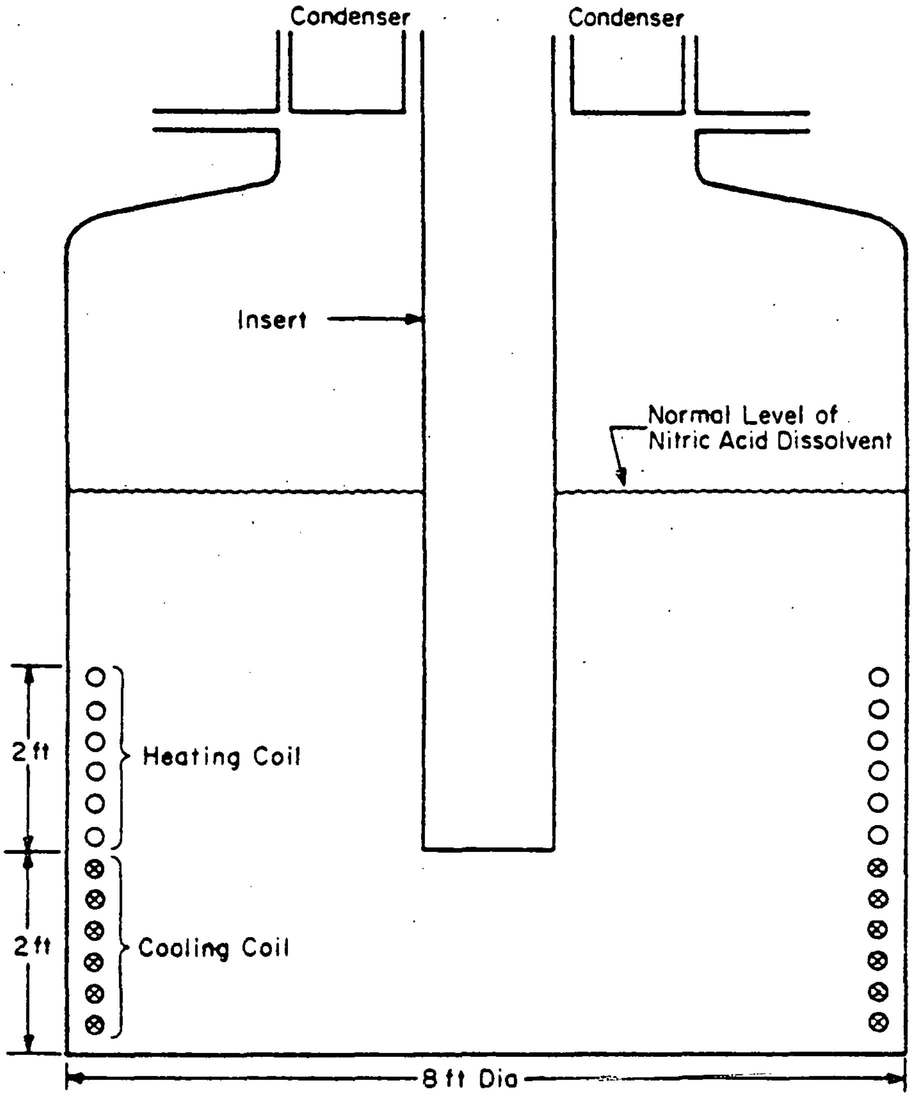
AVOIDANCE OF NUCLEAR ACCIDENTS DURING REPROCESSING

Concepts

- Geometric Advantages
- Mass-Concentration Controls

Example: SRP Dissolver

- Fuel Identification
- Geometric Safety
- Concentration Control



SLIDE 3

Schematic of SRP Dissolver