IDENTIFICATION OF POTENTIAL SAFETY-RELATED INCIDENTS APPLICABLE TO A BREEDER FUEL REPROCESSING PLANT

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The current emphasis on safety in all phases of the nuclear fuel cycle requires that safety features be identified and included in designs of nuclear facilities at the earliest possible stage (Slide 1). A popular method for the early identification of these safety features is the Preliminary Hazards Analysis. Here, the hazards in each unit operation of a process are identified and analyzed for possible ways to reduce the hazard and to mitigate its consequences to workers and the public.

An extension of this analysis is to illustrate the nature of a hazard by its effects in accident situations (Slide 2), that is, to identify what are called safety-related incidents. These are unplanned events that potentially could cause either the

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exposure of operating personnel to a hazard, such as unusual radiation levels, or a release into the environment of hazardous material, such as airborne activity. Safety-related incidents provide important system events for the construction of the fault trees that have become a popular tool in safety analysis and risk assessment. Analysis of these safety-related incidents can lead to the identification of important safety features that should be included in a facility design to prevent or mitigate these incidents.

Today I will describe some useful tools (Slide 3) we have been using at the Savannah River Laboratory, SRL, to make Preliminary Hazards Analyses as well as safety analyses of facilities for processing spent nuclear fuels from both power and production reactors. These tools have also been used in safety studies of waste handling operations at the Savannah River Plant. The tools are the SRL Incidents Data Bank and the "What If" meeting. Next, I will illustrate the application of this methodology to a proposed facility which has breeder fuel reprocessing capability, the Hot Experimental Facility (HEF).

The SRL Incidents Data Bank (Slide 4) is a compilation of safety-related incidents; their causes and consequences; and possible safety features to prevent or detect such incidents, or to mitigate their consequences. The data were compiled from a variety of sources (Slide 5), including: (1) safety analysis reports (SAR) on reprocessing plants for light water reactor (LWR)

fuels, (2) safety reviews at the Idaho Chemical Processing Plant, (3) special studies by various organizations, and (4) process experience at SRP. The principal SARs are those for LWR plants at:

Morris, Ill.	(General Electric Co.)[1]
West Valley, N.Y.	(Nuclear Fuel Services, Inc.)[2]
Barnwell, S.C.	(Allied-General Nuclear Services, Inc.)[3]
Oak Ridge, Tenn.	(Exxon Nuclear Co.)[4]

Safety-related incidents in a reprocessing plant are significantly different from those in a nuclear reactor. In addition to loss of coolant, the dominant incident for a reactor, a wide variety of other incidents can occur in a reprocessing plant. Accordingly, the incidents in the data bank are grouped into General Incidents and Specific Incidents. General Incidents are generic incidents that can occur in many unit operations and processes. These are grouped according to type, as shown in Slide 6. Specific Incidents are grouped according to operation, for example, product evaporation, as shown in Slide 7.

Currently, the data bank contains 64 General Incidents and about 260 Specific Incidents. The procedure (Slide 8) for using the bank is as follows:

- Select a system for analysis
- Identify the process operations and equipment
- Obtain General and Specific Incidents for each
- Delete incidents that do not apply for reasons such as differences in fuel, equipment, or process methods.

The result is a working list of potentially applicable incidents and their safety features for further consideration with the second of our tools, the "What If" meeting (Slide 9). These meetings could be called brainstorming sessions, or think tanks. They have a definite structure, as follows:

- The process and equipment are described so that all participants are prepared.
- The leader selects an event from a working list of incidents prepared from the data bank as well as from the experience and intuition of the participants.
- Causes of the incident are proposed and discussed.
- Ways to prevent the incident by avoiding its causes are proposed. (These are the safety features for prevention.)
- Potential consequences are explored to determine the effects of the incident (under the assumption that the facility has no mitigating safety features).
- Then, safety features for mitigation are proposed until the expected consequences are considered acceptable or it is decided that additional research and development are required.
- Methods are suggested to detect the incident, either by detecting its causes or its consequences.

A written record of these proceedings should be made to document causes, consequences, safety features, and consensus as to the efficiency of available safety features or the need for further research and development work. In the process of identifying causes and consequences, new incidents are identified and accident sequences are established which can be used in the construction of fault trees. Also, additional safety features for inclusion in the design are identified.

As indicated earlier, this methodology has been applied in a Preliminary Hazards Analysis of the Hot Experimental Facility (HEF) currently being designed by Bechtel Corp. and the Oak Ridge National Laboratory.[5] One of its purposes is to demonstrate advanced technology for reprocessing fuels from several types of reactors, including the Clinch River Breeder Reactor (Slide 10). The HEF will be a versatile pilot-scale facility that will meet or exceed the currently defined Federal requirements for reprocessing plants. The assumed nominal capacity is 0.5 metric ton of uranium-plutonium fuel per day with a minimum cooling time for reprocessing of 90 days for U-Pu fuels. (Slide 11) The products will be: natural and depleted uranium as UO_3, mixed uranium and plutonium oxides, thorium oxide, vitrified high-level waste, and packaged solid waste.

Incidents applicable to the HEF were obtained by the procedures outlined above. The "What If" meetings were conducted with scientists and engineers at SRL and ORNL. About 500 safety-related incidents and a list of safety features for each were

identified as potentially applicable to the HEF process systems (Slide 12). It should be emphasized that many safety features were identified for prevention, detection, and mitigation of each incident.

The time allotted today does not permit a discussion of all of these safety features or even a listing of all of the incidents identified for the HEF. These will be published in full detail later. However, for this discussion I have selected some examples.

The first example is the "red-oil" explosion in a product evaporator. One form of "red-oil" includes a concentrated adduct of tributyl phosphate (TBP) and a metal nitrate. The mixture decomposes exothermally when heated above 130°C. Consequences and safety features are shown in Slide 13. Some of the safety features are somewhat abbreviated for the purposes of the table.

A list of other incidents applicable to evaporation in general is given in Slide 14. Where Slide 13 applies specifically to product evaporation, Slide 14 applies to any evaporator, including waste and intercycle evaporators. For brevity, these incidents are listed by title only; no safety features are given. Let met re-emphasize that appropriate safety features have been identified.

The second example involves a criticality incident in the first cycle of solvent extraction in a modified Purex process. As shown in Slide 15, the causes may arise in feed preparation,

from reflux of fissile materials in the contactors, or in the solvent recycle system. Again, the safety features are listed in somewhat abbreviated form. Some additional incidents applicable to solvent extraction of breeder fuels, and more specifically to the solvent recovery system, are listed by title in Slide 16.

Some General Incidents applicable to many of the HEF operations are given by title in Slide 17. This slide is similar to Slide 14 in that these incidents may affect any of the process operations, although these were selected from the analysis of solvent extraction operations.

Specific Incidents that are expected to have the potential for major consequences in each process system are listed in Slides 18, 19, and 20. These selections are highly subjective, however, because quantitative analyses of the consequences have not been made for HEF. These incidents serve to illustrate the additional hazards which are characteristic of breeder fuels, principally the presence of sodium and the high concentrations of fission products, in comparison with LWR fuels.

Further details of the incidents in the SRL Incidents Data Bank are being published and will be available soon.[6]

REFERENCES

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Slide 1. Identification of Potential Safety-Related Incidents Applicable to a Breeder Fuel Reprocessing Plant

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Slide 2. Incident Identification

Objective: Include Safety Features as an Integral Part of Early Design

Method: Preliminary Hazards Analysis

Identify Hazards	Safety-Related Incidents
Reduce Hazards	Prevention
Mitigate Consequences	Mitigation

Slide 3. Tools for Preliminary Hazards Analysis

SRL Incidents Data Bank

"What If" Meeting

Slide 4. SRL Incidents Data Bank

Safety-Related Incidents

- Causes
- Consequences

Safety Features

- Prevention of Causes
- Detection
- Mitigation of Consequences

Slide 5. Data Bank Sources

Safety Analysis Reports
- GE - Morris, Ill.
- NFS - West Valley, N.Y.
- AGNS - Barnwell, S.C.
- EXXON - Oak Ridge, Tenn.

Safety Reviews of ICPP

Special Studies

SRP Process Experience

HEF Interim Design Report

Slide 6. Types of General Incidents for a Reprocessing Plant

1. Airborne Activity in a Process Area
2. Externally Induced Events
3. Fires
4. Uncontrolled Reactions
5. Leaks
6. Electrical Failures
7. Ventilation Problems
8. Off-Gas Treatment Malfunctions
9. Process Upsets

Slide 7. Operations for a Typical Fuel Reprocessing Plant

1. Fuel Receiving and Storage
2. Shearing
3. Voloxidation
4. Dissolving
5. Solvent Extraction
6. Product Evaporation
7. Waste Evaporation
8. Acid Recovery
9. Recovery Ion Exchange
10. Off-Gas Treatment
11. UF_6 Production
12. Co-conversion Process (UO_2-PuO_2 Production)
13. Waste Vitrification
14. Vitrified High-Level Waste Storage
15. Solid Waste Processing
16. Solidification of Intermediate-Level Liquid Waste

Slide 8. Data Bank Procedure

Select System

Identify Operations and Equipment

Obtain General Incidents

Obtain Appropriate Specific Incidents

Delete Inapplicable Incidents

Slide 9. "What If" Meeting

Description

Event Selection

Causes

Safety Features for Prevention

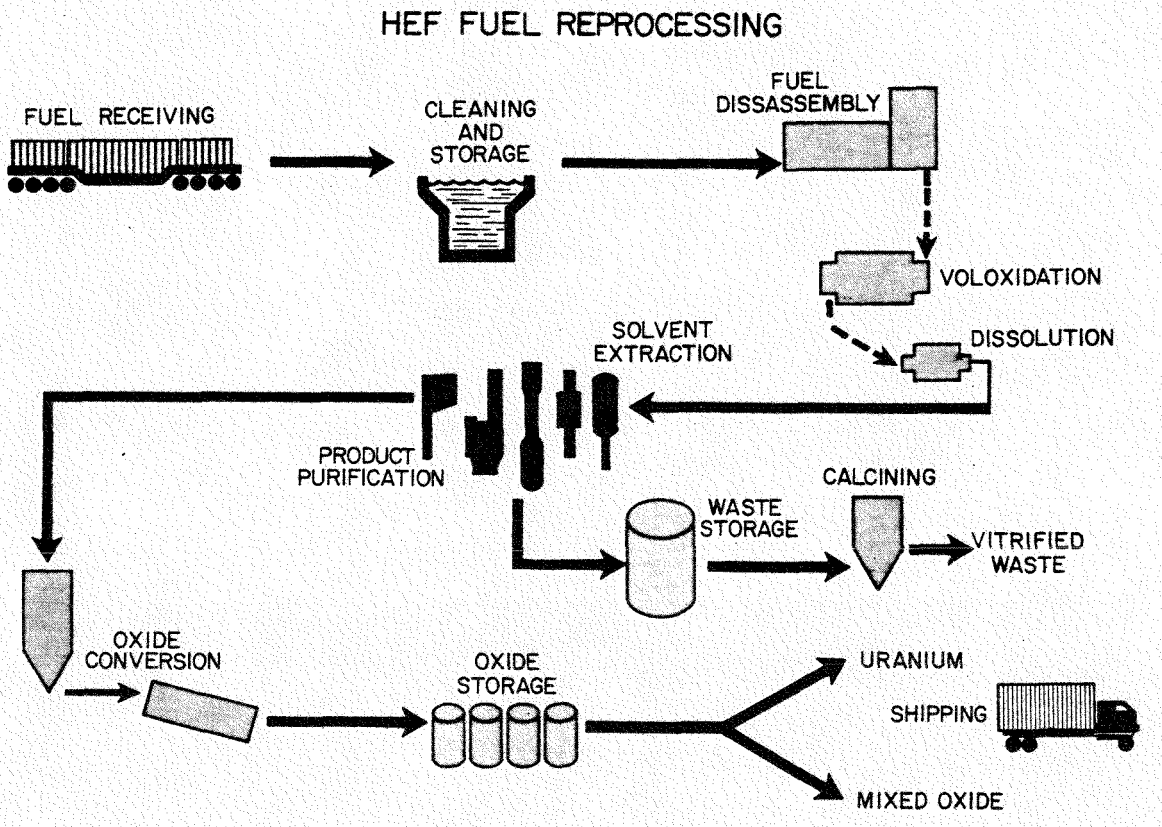
Consequences

Safety Features for Mitigation

Detection

Documentation

Slide 10. HEF FUEL REPROCESSING



Slide 11. HEF Features

Fuels	Pu Breeder
	Th Breeder
	FFTF
	LWR's, Zy or SS Clad
	Gas Cooled (Not HTGR)
Cooling	Receive at 60 Days
	Process U-Pu Fuels at 90 Days
	Process Th Fuels at 250 Days
Capacity	0.5 T/d U-Pu
	0.2 T/d Th

Slide 12. Process Systems in the Hot Experimental Facility

Fuel Receiving and Storage

Mechanical Processing and Feed Preparation

Solvent Extraction

Product Conversion and Storage

Off-Gas Treatment

Aqueous Waste Processing and Solidification

Miscellaneous Systems

Slide 13. "Red-Oil" Explosion in Product Conversion

Causes	Consequences	Safety Features
		Prevention:
Uncontrolled Decomp. of "Red-Oil" Organics in Feed	Damage to Equip. and Off-gas System	Steam Decanters Tank Agitators Sampling and Analysis
High Temp. (>130°C)	Release to Process Cell	Oil Retainers on Shafts
	Cell Pressurization	Temp.-Steam Interlocks
		Detection:
		Pressure Monitors
		Mitigation:
		Sealed, Low-Flow Cells Inert Atmosphere Sand Filter

Slide 14. Potential Incidents for General Evaporation

Operation	Number	Incident Title
Containment	1	Suckback into Gang Valves
	2	Boilover
	3	Coil or Tube Failure
	4	Steam Coils Not Submerged
	5	Uncontrolled Reaction
	6	Red-Oil Explosion
Control	1	Pluggage
	2	Transfer Error
	3	Siphoning
	4	Loss of Cooling to Condenser
	5	High Steam Pressure in Evaporator Reboiler
	6	High Temperature in Evaporator

Slide 15. Criticality in Solvent Extraction

Causes	Consequences	Safety Features
Excessive Solids in Centrifuge	High Local Radiation	Prevention: Geometric Safety Neutron Poison Flow-Rate, Pu, Density Monitors
Pu Reflux from: Pu(6) in HAF Low HAX Flow Low H^+ in Scrub Low Scrub Flow Low Strip Flow	Release of Fission Products to Cell and to Off-Gas System	Detection: Neutron, NIM, Airborne Activity Monitors
Pu in Solvent Tank	Damage to Equipment	Mitigation: Vessel Off-Gas System Shielded, Low-Flow Process Cells

Slide 16. Potential Incidents for Solvent Recovery

Number	Incident Title
1	Failure of Solvent Cooler
2	Steam Leak
3	Steam Leak Sprays on Hot Equipment
4	Steam Leakage through Steam Jet into Solvent Surge Tank
5	Solvent Filter Pluggage
6	Transfer Error
7	Solvent Fire in Solvent Treatment System
8	Resin Fire in Solvent Ion Exchange Beds
9	Fissile Material Accumulation in Solvent Surge Tank
10	Hydrazoic Acid Explosion

Slide 17. General Incidents

Type	Number	Incident Title
Ventilation	1	Air Reversal
	2	Process Vessel Pressurization
	3	Airborne Activity
Electric Power	1	Loss of Normal Electric Power
	2	Failure of Emergency Power System
	3	Fire in Emergency Power System
Fire	1	Fire in a Process Cell
	2	Electrical Fire
	3	Fire Suppression System Failure
Process Control	1	Instrument Failure
	2	Loss of Instrument Air
	3	Steam Leak
	4	Heater/Cooler Failure
	5	Criticality Potential
Containment of Process Materials	1	Solvent Leak
	2	Tank Overflow
	3	Tank or Vessel Leak
	4	Tank Rupture
	5	Backup of Process Material through Air Pulser Lines

Slide 18. Major Incidents for Head End

Unit Operation	Incident Title
Fuel Unloading	Water Pumped into Sodium Storage Tank
Fuel Cleaning	Hydrogen Explosion
Fuel Storage	Loss of Cooling/Criticality Potential
Sodium Handling	Sodium Fire
Dissolution	Inadequate Poison in Dissolvent; Criticality
Feed Adjustment	Hydrogen Explosion in Tank

Slide 19. Major Incidents for Purification and Finishing

Process Operation	Incident Title
Solvent Extraction	1. Solvent Fire
	2. Criticality
	3. Evaporator Explosion
	4. Hydrogen Explosion
Solvent Recovery	5. Hydrazoic Acid Explosion
	6. Ion Exchange Resin Fire or Explosion
Product Conversion	7. Explosion in U Evaporator-Denitrator or in Centrate Evaporator
	8. Criticality
Mixed Oxide Conversion	9. Hydrogen Explosion in Product Storage Tank
	10. Hydrogen Explosion in Calciner

Slide 20. Major Incidents for Off-Gas and Waste Treatment

Process Operation	Incident Title
DOG Iodine Recovery	Failure of DOG Iodine Absorption System
DOG Krypton Recovery	Failure of a Kr Storage Cylinder
	Failure of Kr Absorber
VOG Treatment	Hydrogen Explosion in VOG Header
HAW Concentration	Explosion in HAW Concentrator
HLLW Storage	Rupture of a HLLW Storage Tank