The Experience of Risk Assessment and its Future Utilization at Rokkasho Reprocessing Plant

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Mr. Kazumi Takebe, Mr. Yoshikazu Tamauchi, Mr. Katsuyoshi Omori, Mr. Kunihiro Ogiya, Mr. Yoshiaki Hayashi, and Dr. Shingo Matsuoka.

Safety Technology Office, Japan Nuclear Fuel Limited (JNFL).
Contents

• Safety features of Rokkasho Reprocessing Plant (RRP)

• Identification of events and PSA of RRP

• An example of detailed PSA

• Development and application of the Simplified PSA

• Possible utilization of risk information

• Conclusion
Outline of Rokkasho Reprocessing Plant

- **Receiving & Storage of Spent Fuel**
  - Cooling and Storage in the Pool

- **Head-end**
  - Shearing and Dissolution

- **Separation**
  - Separation of Fission Products, U and Pu

- **Purification**
  - Removing a Negligible Quantity of FP

- **Uranium Denitration**
  - Removal of Nitric Acid and Making Product (Powder)

- **Uranium-Plutonium Co-denitration**
  - Removal of Nitric Acid and Making Product (Powder)

- **Low Active Solid Waste Treatment**
  - Conversion and Package

- **Sample Analysis**
  - LALW*1 Treatment
  - HALW*2 Vitrification

- **Product Storage**
  - Emergency Power Supply

*1LALW: Low Activite Liquid Waste
*2HALW: High Activite Liquid Waste
Safety features of RRP

- Confinement of Radioactive Materials
- Radiation Shielding
- Criticality Safety
- Decay Heat Removal
- Fire & Explosion Protection
- A-seismic Design
- Aircraft Crush Protection
- Discharge Control of Radioactive Effluents
- Multiple Protection Policy
Identification of events and PSA of RRP

HAZOP study at basic design phase
- AT: about 450 events
- BAT: about 600 events

Detailed PSA
- 15 events selected
- 3 events up-dated reflecting detail design and operation procedure
  
Output

A Simplified PSA developed
- 655 events to be assessed

Utilization of Risk Information
- Risk Profile
- The Risk Importance
An example of detailed PSA

Loss of Hydrogen Gas Scavenging Function in Plutonium Solution vessels

Outline of scavenging air supply system

Schematic diagram of the scavenging air supply system

P: Pressure gauge
F: Flow meter
Accident scenarios and evaluation method

**Initiating Events (IE)**
- Failure of three safety compressors
- Leakage from piping or valves

**Safety functions**
- Connecting Normal compressed air to the safety scavenging system
  - **Success**
  - Keep scavenging air
- Using service air supply system
  - **Success**

**Evaluation Method and Database**

**Accident frequency assessment** : ET/FT method
**Human error probability** : THERP method
**Failure rate of equipment** : Selected from Published literatures
**Failure rate of air compressor, air operated valve, etc.**:
  → referred from database of THORP and Tokai Reprocessing Plant
## Results of the assessment

<table>
<thead>
<tr>
<th>Items</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summation of occurrence frequencies of IE</td>
<td>$4 \times 10^{-3}$ per year</td>
</tr>
<tr>
<td>Occurrence frequency of loss of hydrogen scavenging function</td>
<td>$8 \times 10^{-6}$ per year</td>
</tr>
<tr>
<td>Uncertainty of the frequency at 90% reliability level</td>
<td>$1 \times 10^{-6} \sim 2 \times 10^{-5}$ per year</td>
</tr>
<tr>
<td>Importance evaluation of each basic input events</td>
<td></td>
</tr>
<tr>
<td>● Operator action of valve open for service air supply</td>
<td></td>
</tr>
<tr>
<td>● Leakage from piping and valves</td>
<td></td>
</tr>
<tr>
<td>● Operator action of valve open for normal compressed air supply</td>
<td></td>
</tr>
</tbody>
</table>

### Importance Evaluation

- **RAW**
- **FV**
Development and application of the Simplified PSA

A Simplified PSA has been developed

- It can evaluate systematically evaluate the risk of RRP
- It can evaluate the importance of systems, components and Human action
- It is possible to use the MS Excel sheet for all evaluation
- The formula corresponding FTA are inputted in the sheet
Outline of simplified PSA procedure 1

Simplified PSA consist of several MS Excel sheet as follow,

Input sheets
(a) Safety function/System Matrix
(b) Utilities/Systems datasheet
(c) Consequence evaluation sheet

Output sheets
(d) Event tree display sheet for each event
(e) Consequence evaluation result display sheet for each event
(f) Importance evaluation result display sheet for each event
(g) Risk of all events display sheet
(h) Importance related to risk of reprocessing plant
Outline of simplified PSA procedure 2

- Identification of hazards and accident sequences
- Identification of safety functions
- Identification of systems, components and human actions essential to the safety functions

Design information

Design and Operation Information input and summarized in (a) Safety function/System Matrix
Outline of simplified PSA procedure 3

Excerpt from (a) Safety function/System Matrix

Input the component and kind of event for evaluation

Safety functions

The contents of safety functions

PS-1 Continuous feeding of scavenging air from "Safety Compressed Air Supply System" - - - -
-2 - - - -
MS-1 Emergency feeding of service air from "Safety Compressed Air Supply System" by low warning of flow rate 0 0.01 - -
-2 Compressed air feeding from "Normal Compressed Air Supply System" by low alarm of pressure 0 0.01 - -
-3 Compressed air feeding from "Normal Compressed Air Supply System" by low warning of flow rate 0 0.01 - -
-4 - - - -

The value considering time margin

Function of on-duty Function of on-demand The value considering time margin

Systems, components and human actions related to safety functions

A list “Database of system, component and human action” have been set conservatively based on the published documents. Human error rate was determined based on detailed PSA.
### Outline of simplified PSA procedure 4

**Unavailability of redundant system**

Analyst enters the operating information such as component type, redundancy, maintenance period and test interval, etc.

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**Safety function/System Matrix**

- **Calculation result is entered**

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**Utilities/Systems datasheet**
## Outline of simplified PSA procedure 5

### Excerpt from (a) Safety function/System Matrix

<table>
<thead>
<tr>
<th>Systems, components and human actions related to safety functions</th>
<th>Prevention</th>
<th>Safety function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PS-1</td>
<td>PS-2</td>
</tr>
<tr>
<td>Support system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal cooling water supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal cooling water supply system for F facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backup cooling water supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety cooling water supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety cooling water supply system for F facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General cooling water supply system 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General cooling water supply system 2</td>
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<td></td>
</tr>
<tr>
<td>Normal/bakcup compressed air supply system</td>
<td></td>
<td></td>
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<tr>
<td>Safety compressed air supply system</td>
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<td></td>
</tr>
<tr>
<td>Normal steam supply system</td>
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</tr>
<tr>
<td>Electric system</td>
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<td></td>
</tr>
<tr>
<td>Normal electric supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backup electric supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency electric supply system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency electric supply system for F facility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unavailability of such support systems related to many events, has been set in (a), with simplified fault tree equation based on detailed PSA results. Therefore, analysts should select the support system essential to the safety functions and mark the symbols.
Outline of simplified PSA procedure 6

Input time margin to accident occurrence from initiating event

Input relation of initiating events and detection

(a) Safety function/System Matrix

Running macro program

Calculated occurrence frequency is automatically shown in form of ET (d)
Outline of simplified PSA procedure 7

Quantification of consequence

In the simplified PSA, consequence is represented as radiation dose to the public.

The radiation dose is calculated in (c) Consequence evaluation sheet.

The result is showed on (e) Consequence evaluation result display sheet based on five-factors formula *

\[ ST = MAR \times DR \times ARF \times RF \times LPF \]

\[ Di = ST \times R \times X/Q \times H \]

Where,

MAR: Material At Risk
DR: Damage Ratio
ARF: Airborne Release Fraction
RF: Respirable Fraction
LPF: Leak path Factor
ST: Source Team
Di: Effective Dose due to inhalation
R: Inhalation ratio
X/Q: Relative concentration
H: Coefficient for ingestion and inhalation
Outline of simplified PSA procedure 8

Consequence evaluation result

Risk of each accident scenarios

Running macro

(e) Consequence evaluation result display sheet for each event

(d) Event tree display sheet for each event

(f) Importance evaluation result display sheet for each event
(g) Risk of all events display sheet

(h) Importance related to risk of reprocessing plant.
Comparison of the Results of it and Detailed PSA

Results of Simplified PSA method

- Leakage of piping or valves in Pu facility: 37%
- Leakage of piping or valves in denitration facility: 3%
- Leakage of piping or valves in safety air supply system: 57%

Results of detailed PSA method

- Leakage of piping of valves in Pu facility: 22%
- Leakage of piping of valves in denitration facility: 1%
- Stop of 3 units of compressors: 3%
- Leakage of piping or valves in safety air supply system: 73%

The frequency calculated by the simplified PSA method well agrees with the result of detailed PSA with the reliability of 90%
Possible utilization of risk information
An example of risk profile dotted according to the calculated results as of September 2007
Risk importance for each components

An example of risk importance dotted according to the calculated results as of September 2007
Utilizing the risk information - future plan

- Risk profile in 2 years
- Classification of components and systems into three classes of risk importance
- Determination of allowable outage time (AOT), examination of on-line maintenance and inspection period
- “Residual risk” and seismic PSA
Mt. Fuji-san 3776m
Shizuoka, Yamanashi Prefectures

Mts. Hakkouda-san <1600m
Aomori Prefecture