Criteria 1.4.3

In-Plant Severe Accident Management

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# INPRO Criteria 1.4.3 Accident Management

## User Requirements and Criteria

**Basic Principle BP1 (Defense in Depth):** *Installations of an Innovative Nuclear Energy System shall incorporate enhanced defence-in-depth as a part of their fundamental safety approach and ensure that the levels of protection in defence-in-depth shall be more independent from each other than in existing installations.*

<table>
<thead>
<tr>
<th>User requirements (UR)</th>
<th>Criteria (CR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UR1.4 ((Release into containment): The frequency of a major release of radioactivity into the containment / confinement of an INS due to internal events should be reduced. Should a release occur, the consequences should be mitigated.)</td>
<td>Indicators (IN)</td>
</tr>
<tr>
<td>CR1.4.3 accident management</td>
<td>IN 1.4.3: In-plant severe accident management.</td>
</tr>
</tbody>
</table>
# INPRO Criteria 1.4.3 Accident Management

## Defense-in-Depth

<table>
<thead>
<tr>
<th>DID Level</th>
<th>INSAG Objectives</th>
<th>Innovation Direction (INPRO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prevention of abnormal occurrences and accidents</td>
<td>Enhance prevention by increased emphasis on inherently safe design characteristics and passive safety features, and by further reducing human actions in the routine operation of the plant.</td>
</tr>
<tr>
<td>2</td>
<td>Control of abnormal operation and detection of failures</td>
<td>Give priority to advanced control and monitoring systems with enhanced reliability, intelligence and the ability to anticipate and compensate abnormal transients.</td>
</tr>
<tr>
<td>3</td>
<td>Control of accidents within the design basis</td>
<td>Achieve fundamental safety functions by optimized combination of active &amp; passive design Features.</td>
</tr>
<tr>
<td>4</td>
<td>Control of severe plant conditions</td>
<td>Increase reliability and capability of systems to control and monitor complex accident sequences; decrease expected frequency of severe plant Conditions.</td>
</tr>
<tr>
<td>5</td>
<td>Mitigation of radiological consequences</td>
<td>Avoid the necessity for evacuation or relocation measures outside the plant site.</td>
</tr>
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</table>
INPRO Criteria 1.4.3 Accident Management

Evaluation Parameters and Acceptability

- Specific Evaluation parameter is not defined in the INPRO methodology for this CR.

- The Accident Management Actions:
  - *Injection of Boron into the Core*
  - *Depressurization of RPV*
  - *Restoration of Water Injection into RPV*
  - *Restoration of Heat Removal*
  - *Spraying into the Containment Atmosphere*
  - *Containment Venting*

- The Accident Management Procedure:
  - *Demonstration of Feasibility and Effectiveness*
  - *Sufficient Training*
APR1400 SA Design Characteristics

Severe Accident Phenomena

SA Phenomena

- Overpressurization
- High Pressure Melt Ejection
- Direct Containment Heating
- Steam Explosion
- Molten Corium Concrete Interaction
- Hydrogen Mixing & Combustion

Severe Accident Issues

- Condensation
- \( H_2 \) Management
- DCH
- DCC
- In-Vessel Cooling
- Ex-Vessel Cooling
- FCI

Melt Spread / MCCI
APR1400 SA Design Characteristics

Severe Accident Mitigation Design Features

- Containment with IRWST and HVT
- Safety Depressurization & Vent System
- Reactor Cavity Design
- Convoluted Flow Path
- Cavity Flooding System (CFS)
- IVR/ERVC
- Hydrogen Mitigation System
- CS System & ECSBS
APR1400 SA Design Characteristics

Containment Design

Pre-stressed concrete structure
- Height: 229.5 ft, Diameter: 150 ft, Thickness: 4 ft
- Design Pressure: 60 psig

Steel-lined inner surface for leak-tightness

In-containment Refueling Water Storage Tank (IRWST)
- Eliminates switch-over operation during LOCA
- Heat sink for feed and bleed operation
- Minimizes contamination of Reactor Containment Building
APR1400 SA Design Characteristics

Rapid Depressurization

- Provide a reliable depressurization
- Depressurize the RCS below 250 psia (1.7MPa) before the rupture of reactor vessel to prevent HPME and DCH
  - POSRV : 4 EA
  - 3-way valve : 2 EA
  - Discharge the steam of pressurizer(RCS) to S/G compartment (containment)

![Diagram of APR1400 SA Design Characteristics]
APR1400 SA Design Characteristics

- Reactor Cavity Design
- Convoluted Flow Path
APR1400 SA Design Characteristics

Corium Control

**Reactor Cavity Flooding System**
- Flooding reactor cavity to cool molten core
- Water Source: IRWST
- Water driving force: Gravity
- Designed in accordance with SECY-93-087
  - Cavity floor area > 0.02 m²/MWₜ

**In-Vessel Retention – ERVC strategy**
- Submerging reactor vessel lower head to cool and to retain molten core in reactor vessel
- Water source: IRWST
- Water driving force: SCP, BAMP
Maintaining hydrogen concentration below design criterion

Design characteristics:
- 30 Passive Autocatalytic Recombiners (PAR)
- 10 Glow plug type igniters
APR1400 SA Design Characteristics

Emergency Containment Spray Backup System (ECSBS)

- Water from external sources delivered by fire engine truck to ECSBS spray header
- The external water sources
  - Reactor Makeup Water Tank
  - Demineralized Water Storage Tank
  - Fresh Water Tank, Raw Water Tank
APR1400 SA Design Characteristics

Emergency Make-up System

- Water from external sources delivered by fire engine truck to Primary and Secondary Systems
- Emergency make-up provisions for the Spent Fuel Pool is also designed
APR1400 SA Management

Severe Accident Management Guideline

- APR1400 Severe Accident Management Guidelines (SAMGs) are developed for plant specific application
- SAMG reflects APR1400 design features for the severe accident prevention/mitigation as well as all available instrumentation for plant monitoring
- APR1400 SAMG consists of
  - Entry Guideline
  - 7 Recovery Guidelines
  - Exit Guideline
  - 2 Supporting Guidelines
Recovery Guidelines

1. Reactor Coolant System Depressurization
2. Steam Generator Feeding
3. Reactor Coolant System Injection
4. Reactor Cavity Flooding
5. Fission Product Release Control
6. Reactor Containment Control
7. Reactor Containment Hydrogen Control

Each Recovery Guideline are supported by the corresponding Technical Basis Document
# APR1400 SA Management

## Severe Accident Management Guideline

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Action</th>
<th>Purpose</th>
<th>System &amp; Comp.</th>
</tr>
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</table>
| 01  | RCS Depressur -  | RCS direct depress.          | • Prevention of direct containment heating  
|     | ization          |                             | • Containment integrity  
|     |                  | SG depress.                 | • Core cooling                                                              | • SDS  
|     |                  |                             |                                                                             | • Przr aux. spray                        |                                             |
| 02  | SG Feeding       | SG feedwater injection      | • Heat sink for RCS  
|     |                  | SG Depressurization         | • SG integrity  
|     |                  |                             | • Prevention of containment bypass  
|     |                  |                             | • Reduction of fission product release                                         | • Any feedwater pumps                    |                                             |
| 03  | RCS Injection    | Water injection into RCS    | • Core cooling  
|     |                  |                             | • Prevention of reactor vessel failure  
|     |                  |                             | • Reduction of fission product release                                         | • SIPs  
|     |                  |                             |                                                                             | • CSPs                                  |                                             |
|     |                  |                             |                                                                             | • Charging pumps                        |                                             |
### APR1400 SA Management

#### Severe Accident Management Guideline

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</table>
| 04  | Reactor Cavity Flooding        | Water injection into containment          | - Heat sink for RCS  
- Containment integrity  
- Containment basemat integrity  
- Reduction of fission product release | CSP/ECSBS  
IVR–ERVCS  
Cavity flooding system |
| 05  | Fission Product Release Control| Containment depress.  
Steam dump  
Aux. building venting | - Reduction of release from containment  
- Reduction of release to aux. building  
- Reduction of release from aux. building | CSP/ECSBS  
Containment fan cooler  
MS ADV and TBV  
Venting system in aux. building |
# APR1400 SA Management

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| 06  | Reactor Containment Control | Actuation of containment heat sink | • Containment integrity  
• Reduction of release from containment  
• Environment of instrument and equipments | • Containment spray  
• Containment fan cooler |
| 07  | Reactor Containment H2 Control | H2 control  
Intentional H2 burning  
Inertness of containment | • Prevention of H2 explosion | • Ignitor  
• Recombiner  
• Spark equipment  
• Stop heat sink operation  
• RCS valve opening |
Summary

- APR1400 is designed with advanced Severe Accident Mitigation design features

- Severe Accident Management Guidelines (SAMGs) are developed reflecting APR1400 design features for the severe accident prevention/mitigation as well as all available instrumentation for plant monitoring

- APR1400 Design incorporates sufficient equipment with recovery guidelines to prevent large release to environment during severe accident

- Therefore, APR1400 design meets Criteria 1.4.3
Thank you!