REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Title	**Accident Management Procedures**
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  - ➢ Equipment important to safety (but no safety system)

- Summary

Defence in Depth (DiD) concept

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Level of defence Approach 1		Objective	Essential design means	Essential operational means	Level of defence Approach 2	
Level 1		Prevention of abnormal operation and failures	Robust design and high quality in construction of normal operation systems, including monitoring and control systems	Operational limits and conditions and normal operating procedures	Level 1	
Level 2		Control of abnormal operation and detection of failures	Limitation and protection systems and other surveillance features	Abnormal operating procedures and/or emergency operating procedures	Level 2	
Level 3	3a	Control of design basis accidents	Safety systems	Emergency operating procedures	Level 3	
	3b	Control of design extension conditions to prevent core melting	Safety features for design extension conditions without significant fuel degradation	Emergency operating procedures	4a	Level 4
Level 4		Control of design extension conditions to mitigate the consequences of severe accidents	Safety features for design extension conditions with core melting[2] Technical support centre	Severe accident management guidelines	4b	
Level 5		Mitigation of radiological consequences of significant releases of radioactive substance	On-site and off-site emergency response facilities	On-site and off-site emergency plans and procedures	Level 5	

Accident Management

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- Automated response in a design accident was not able to prevent accident progression
- In this case, AM provides a strategy to use all still available equipment of the NPP to either prevent core damage or at least to prevent releases of radioactive materials
- Equipment may range from still available safety systems, to systems for normal operation, to non-standard equipment available on site like fire brigade trucks and systems foreseen for such events, like mobile pumps

EOPs / SAMGs / EDMGs

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- Emergency Operating Procedures (EOPs) are applied to manage Design Bases Accidents (DBA), as well as to manage design extension conditions up to core damage (DEC A)
- EOPs are part of **preventive** accident management – main goal is to prevent core damage
- In case the EOPs are not successful and core damage cannot be avoided, focus changes to prevent containment failure (DEC B conditions)
- => Switch from EOPs to Severe Accident Mitigation Guidelines SAMGs

EOPs / SAMGs / EDMGs

- Transition from EOPs to SAMGs usually based on criteria indicating core damage or imminent core damage

- Usually based on Core Exit Temperature, examples:
  - CET > 650°C (Belgium, Korea, Finland, …)
  - CET > 1100°C (Pressure depended, France, Hungary …)

- Once SAMGs are entered, accident management changes from **preventive** to **mitigative**

EDMGs

- Development of concept of EDMGs started after 9/11 attack
- Renewed interested after Fukushima Accident
- Use mainly in US

"EDMGs are guidelines that provide strategies to maintain or restore core cooling, containment, and SFP cooling capabilities under the circumstances associated with the loss of large areas of the plant due to explosions or fire." (NEI 14-01, Emergency Response Procedures and Guidelines for Beyond Design Basis Events and Severe Accidents, 2016)

Difference between “Procedure” and “Guideline”

- Procedure: clear set of sequential instructions to address a plant condition, operators are expected to follow instructions step-by-step

- Guideline: does not necessarily provide set of instructions, rather a suggested strategy to respond to unpredictable and dynamic situations

Emergency Operating Procedures

- Two approaches – event based (older approach)
  - Accident can be clearly identified by operator, procedure indicates optimal recovery strategy
- Symptom based approach (current approach)
  - The operator identifies the status of the plant by working through critical safety functions (CSF) (e.g. subcriticallity, core cooling, heat sink, …)
  - Each critical safety function may be satisfied or challenged
  - Based on the status of the CSFs a suitable EOP is identified.
- EOPs should have clear entry condition and exit condition and shows procedure as flow-chart and text

Example Critical Safety Functions

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CSF	Status		
	Unsatisfactory	Severe Challenge	Extreme Challenge
	Symptom	Symptom	Symptom
Equipment			total loss of electrical power of the unit, OR loss of possibility to manage unit from control room, OR flooding of equipment located in "minus" elevations of reactor department. VF-01, VF-02, VF-03, VF-04
Subcriticallity	there is neutron power in and velocity of reactor run-away in the source range is positive VF-P.2	positive velocity of reactor run-away in the intermediate range VF-P.1	neutron power value above 5% after reactor trip VF-P.1
Core cooling	Subcooling is less than 10 deg C VF-Z.2	Five core outlet thermocouples exceed 350(*) deg C, OR the difference between core outlet and hot leg temperatures is more than 20 deg C VF-Z.1	Five core exit thermocouples exceed 400 deg C VF-Z.2

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CSF	Status		
	Unsatisfactory	Severe Challenge	Extrem Challenge
	Symptom	Symptom	Symptom
Heat sink	Pressure in one or more SG above 7.4 MPa, VF-T.2 OR Level in one more SG above 390 cm, VF-T.3 OR SG in one or more SG below 150 cm VF-T.4		SG level in three or four SG below 150cm AND feed water flow rate below 90 m3 / h VF-T.1
Primary circuit integrity		Cool down in the last half hour exceeded 60 deg C / h in one ore more cold legs, and PS pressure is above the permitted value for the current temperature OR - cold leg temperatures are below 130 deg C and primary pressure is higher than maximal pressure of cold-overpressure VF-C.1	Cool down in the last half hour exceeded 60 deg C / h in one ore more cold legs, and PS pressure is above the permitted value for the current temperature VF-C.1
Containment integrity	Containment pressure above 0.13 MPa VF-G.2		Containment pressure above 0.4 MPa, VF-G.1
Primary coolant inventory	after reactor trip or actuation of safety injection: the pressurizer level is below 350 cm and containment sump level is above 150 cm VF-N.2		after reactor trip or actuation of safety injection: pressurizer level is below 350 cm AND containment sump level is below 150 cm. VF-N.1

Equipment important for safety

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- After the Fukushima accident robustness of NPPs was improved by adding equipment
- Examples are additional emergency diesel generators, mobile pumps, additional provisions of cooling water for primary and secondary system, connection points to supply cooling water to primary and secondary system from external sources, provisions for filtered containment venting, additional safety systems for long term containment heat removal, additional safety systems for core cooling
- Equipment typically not classified as safety system for design basis accidents (e.g. safety concept not 4x50%)
- Typically equipment specifically for Design Extension Conditions

Summary

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- Safety Systems and part of EOPs manage DBAs
- In conditions more severe, e.g. because of multiple failures, EOPs lead operator through Design Extension Conditions A (DEC A)
- If not successful and core damage is imminent, Design Extension Conditions B, (DEC B), operator changes to SAMGs

- Strategy for DEC A – try to make as much water available to cool down the reactor core
- Strategy for DEC B – try to make as much water available to remove heat from containment – keep SGs secondary side covered

Thank you!

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