Data requirements during a severe accident

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Gary Johnson
gljohnson@ieee.org

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International Atomic Energy Agency

Introduction

- Fukushima Daiichi highlighted the need to re-examine accident monitoring instrumentation
- IAEA developed a report that provides an overview of accident monitoring and describes:
  - Basic principles,
  - Selection of accident monitoring parameters,
  - Criteria to be considered in design,
  - Methodology for implementation, and
  - New technologies that may be needed
- This report is now available as IAEA NP-T-3.16

Accidents happen and operators need information to deal with them

- There have been no limiting design basis accidents
- There have been at least 20 accidents that involved fuel melt (severe accident or nearly a severe accident)
  - Four of them involved current generation nuclear power plants
    - If you count by sites it is two
      - Fukushima Daiichi and Three Mile Island
- No accident has ever caused deterministic fatalities among the <u>public</u>
- Only Chernobyl resulted in identifiable stochastic fatalities
  - This number was surprisingly low considering the release
- The industry has done a good job of protecting the public from radiation

The main effects of accidents have been trauma to the affected people

- At Fukushima Daiichi
  - 210,000 people initially displaced
    - 80,000 still can't return home
  - 1000 km^2 of land initially removed from habitation
    - 330 km^2 will probably not be habitable for the foreseeable future
    - 50 deaths during evacuation
- Chernobyl
  - 330,000 people initially displaced
  - 15,000 km^2 of land initially removed from habitation
- At both locations
  - Post traumatic stress syndrome, depression, and suicides

Accident response must prevent such effects

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Accident monitoring instrumentation is key …

- To supporting the implementation of
  - Emergency operating procedures
  - **Severe Accident Monitoring Guidelines (SAMG)**
  - **Broader incident response**
- There should always be a “no-information” path in the SAMGs, but
  - The operators need information about the plant to have a fighting chance to minimize the effects

Plant monitoring needs follow from the plant state

Plant states	Operational states		Accident conditions		
	Normal operation	Anticipated operational occurrences	Design basis accidents	Design extension conditions	
				See note	Severe accidents
Safety objectives	Prevent any significant damage to items that are important to safety or which lead to accident conditions.		Prevent significant fuel degradation and keep releases within acceptable limits.		Terminate fuel damage. Maintain the integrity of the containment for as long as possible. Minimize on-site and off-site releases and their adverse consequences.
Accident management strategy	None needed	Preventative			Mitigative
Credited plant equipment	All plant equipment except as allowed by operating limits and conditions	Safety systems		All available equipment	
Operating procedures	Normal operating procedures	Abnormal operating procedures	Emergency operating procedures ('emergency response procedures' and 'functional restoration procedures'		Severe accident management guidelines
Typical decision making responsibility	Plant operators		Plant operators with assistance of shift technical advisors		Emergency response managers with assistance of plant operators
Expected environmental conditions	Normal		Harsh		Severe

Mitigative accident management

- Deals with unforeseen or implausible events
- Instrumentation is needed to:
  - Detect the need to transition from emergency operating procedures to severe accident management guidelines,
  - Execute SAMG's,
  - Assess the state of the fuel and containment, and
  - Recognize when a controlled state is reached.
- Parameter trends are more useful for implementing SAMG
- Instruments might see environmental conditions that are worse than design basis conditions
  - Qualification for these conditions might not be possible
  - Actual conditions might be worse than predicted

For mitigative accident management the operators & accident managers need to know

- Information that will help them
  - Limit fuel degradation
  - Maintain containment integrity for as long as possible
  - Minimize radioactive releases and their consequences
  - Understand radiation and radioactivity levels
    - Around the plant
    - In the main control room and other areas where operators will need access
  - Prepare any offsite response
    - Aid to the plant
    - Actions by the public
- The particular variables that can provide this needed information are plant specific
  - Even for the same design there may be several equivalent options

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Japan has made an initial identification of key variables for severe accident management

BWR	PWR
RPV Level & Pressure	Containment Pressure
Drywell Level & Pressure	Main steam Line Radiation
Suppression chamber Level, Pressure, Radiation, Air temperature, Water Temperature	
Injection Flow	

↑ Instruments exposed to not so severe environments

Instruments exposed to severe environments ↓

BWR	PWR
RPV Surface Temp.	Core Exit Temperature
Drywell Temperature & Radiation	RPV Level
Atmospheric temperature near RPV Pedestal	RCS Pressure
Reactor building $[H_2]$	Containment Temperature
	RPV Cavity Temperature & Level
	Neutron flux
	Containment $[H_2]$

Japan's study also identified other, less critical, variables that aren't listed here

Design criteria for designated severe accident instruments

- Mitigative instruments don't need to meet extraordinary reliability criteria, but
  - Provisions should be made for loss of plant power to instruments
  - Should be independent of preventative accident monitoring[1]
- Japan has estimate the environmental conditions in SA

	BWR in containment	PWR in containment
Temperature[2]	170° C to 1000° C	190° C to 200° C
Pressure	0.3 MPa to 1 MPa	0.4 MPa to 1.6 MPa
Radiation[2]		2 MGy to 5 MGy
Operating time	3 days	3 – 4 days

Notes: 1) Independent doesn't mean that channels can't be shared between preventative and mitigative instrument channels. 2) Conditions will be design specific and containment conditions will vary by location. Sub-compartment analysis can reduce the requirement on specific instruments. 3) NSNI has proposed to make a generic report on expected severe accident conditions

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The information should be available to all organizations involved in accident response

- This may include, for example:
  - Technical support center
  - Local emergency response center
  - Corporate engineering offices
  - Government emergency response center
- The communications paths should be reliable and diverse
  - Multiple and different communications paths
  - Reliable and diverse power supplies
  - The ability to route data to new locations in the event that a planned response location becomes untenable

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Coping with doubt about instrument survivability

- Two kinds of monitoring instruments are identified for severe accidents
  - Designated instruments
    - Instruments installed in the control room
    - Sufficient for implementing SAMG
    - Best effort to ensure availability when needed
  - Other available information sources
    - Existing plant instrumentation that may be useful
      - Generally these are already identified for use with SAMG
      - Perhaps not special consideration of SA environments
    - Non-instrument sources, e.g., gas sampling

There may be several hundred sources for other available information

Aides are vital to use of accident monitoring instruments

- Help the data users to:
  - Assess the operability of instruments
  - Assess the validity of instrument readings
  - Estimate the value of parameters
  - Use the available information
- These aids may be computerized, e.g., SPDS
  - Aids should also be available that do not depend upon plant power or complex equipment, e.g., paper aids.
  - This is especially the case for severe accidents
- For Fukushima MELCOR and MAAP analyses done after the event gave significant insights into accident progression
  - Analyses tools that could be run during an event and calibrated to instrument readings might be a significant aid

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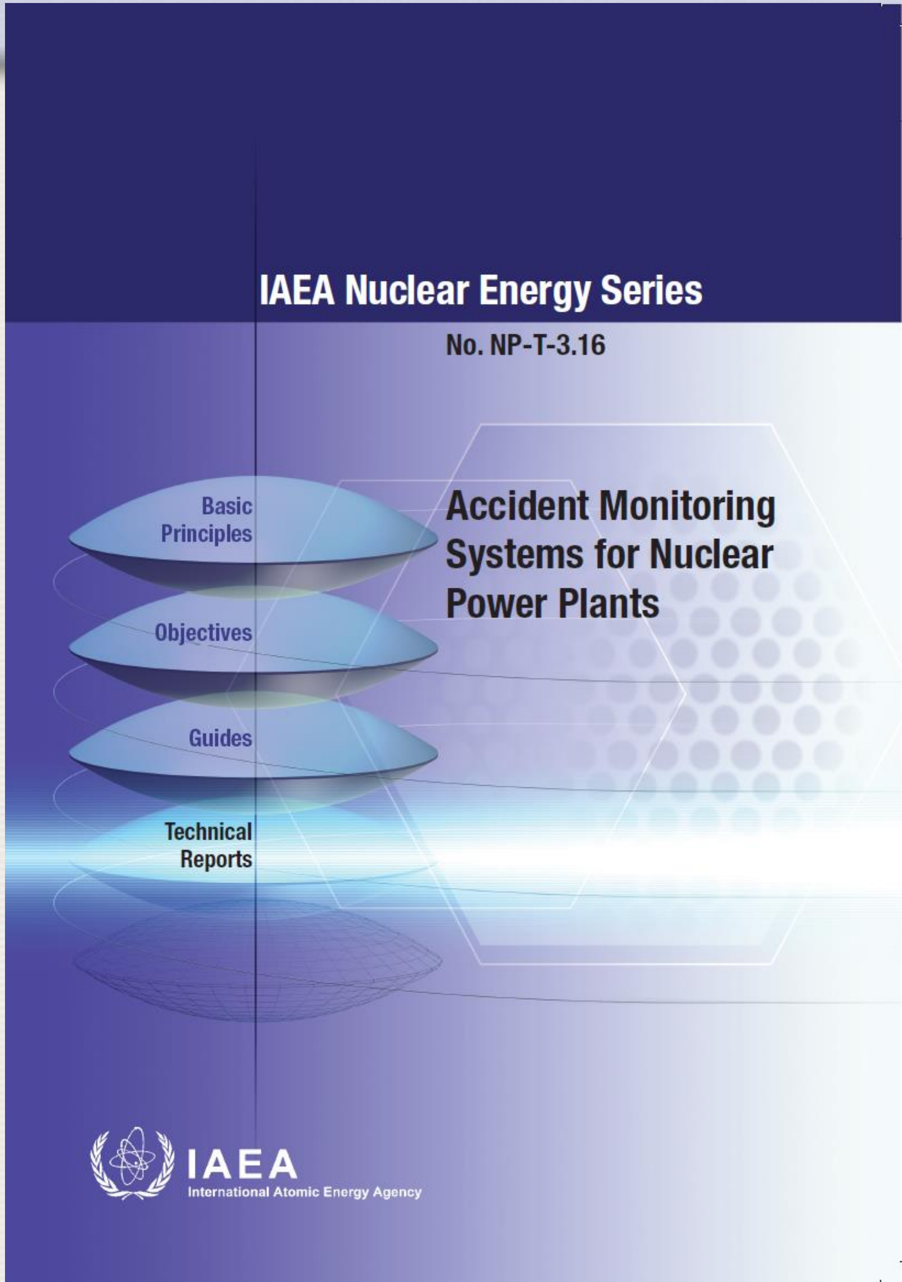
Accident monitoring systems for nuclear power plants

- Introduction
- Accident management for nuclear power plants
- Selection of plant parameters for accident monitoring
- Establishing criteria for designated accident monitoring instrumentation
- Design and implementation considerations for accident monitoring instrumentation
- Technology needs for accident monitoring
- Summary and conclusions



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