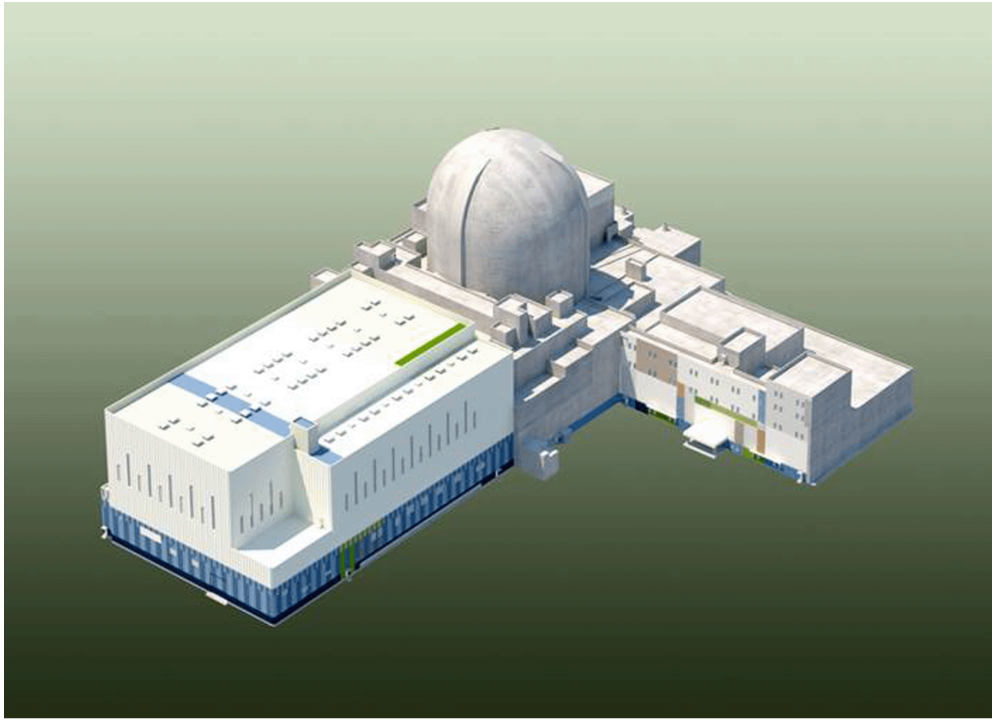
NON-PROPRIETARY

APR1400
Accident Monitoring Instrumentation



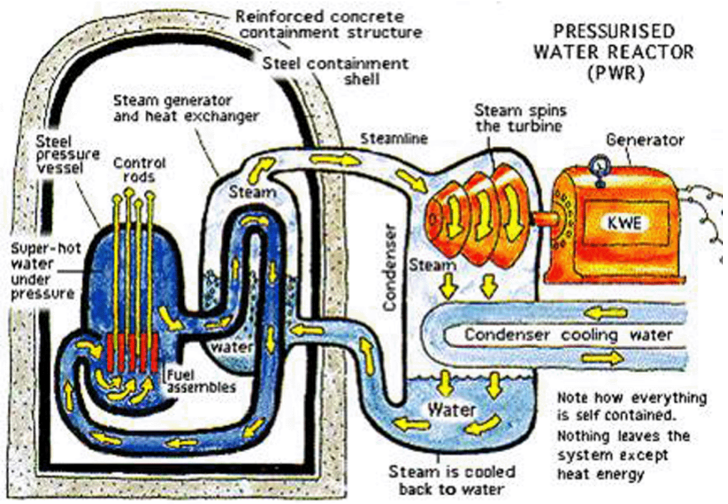
KEPCO/KHNP

May 2-3, 2016

Contents

- Background
- Type A Variables
- APR1400 Operator Action Review
- Summary

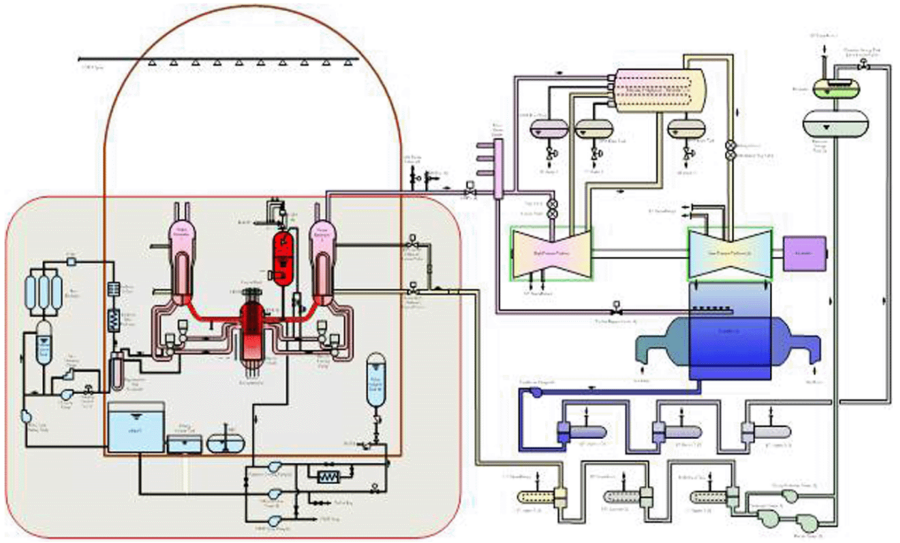
Background


Reinforced concrete containment structure
Steel containment shell
PRESSURISED WATER REACTOR (PWR)
Steam generator and heat exchanger
Steamline
Steam spins the turbine
Generator
Steel pressure vessel
Control rods
Steam
KWE
Super-hot water under pressure
Condenser
Steam
Condenser cooling water
water
Fuel assemblies
Water
Note how everything is self contained. Nothing leaves the system except heat energy
Steam is cooled back to water

NRC RAIs

- **RAI 294-8302, Question 07.05-6**
  - Additional request for RAI 38-7878, Question 07.05-2
  - Operator actions required by Chapter 15
  - All indications that the operator would rely on
  - Locations and qualification for each indications
  - Provide basis for why there are no Type A variables for APR1400

Type A Variables



Type A Variables (1/5)

- **Type A variable is first defined in ANS-4.5 and modified by RG 1.97 Rev. 03-1983**
  - Those variables to be monitored that provide primary information required to permit the control room operators to take the specified manually controlled actions for which no automatic control is provided and that are required for safety systems to accomplish their safety functions for design basis accident events.
  - Primary information is information that is essential for the direct accomplishment of the specified safety functions; it does not include those variables that are associated with contingency actions that may also be identified in written procedures.

Type A Variables (2/5)

- **RG 1.97 Rev. 04-2006:**
  - Application to new advanced reactor design and digital plants
  - Endorses IEEE Std 497-2002 with some exceptions
  - Type A definition further includes actions for AOO:
    - Type A variables are those variables that provide the primary information required to permit the control room operating staff to:
      - Take specific planned manually-controlled actions for which no automatic control is provided and that are required for safety systems to perform their safety-related functions as assumed in the plant Accident Analysis Licensing Basis.
      - Take specific planned manually-controlled actions for which no automatic control is provided and that are required to mitigate the consequences of an AOO.
    - Type A variables include those variables that are associated with contingency actions that are within the plant licensing basis and may be identified in written procedures.
    - Type A variables provide information essential for the direct accomplishment of specific safety-related function that require manual action.

Type A Variables (3/5)

- **Ideal Accident Monitoring System:**
  - Automatically diagnose the accident and provide guidance for sequential operator actions or make the operator actions automatic.
  - RG 1.97 Rev. 01-1979 required: Monitored variables and systems should be used by the operator in accident surveillance (1) to help determine the nature of an accident, (2) to help predict the course that an accident will take.
  - Automatically diagnose the safety systems performance and provide guidance for contingency operator actions
  - Operator should not depend on a few plant parameters for accident diagnosis and should be very careful when terminating ESF actuation.

Type A Variables (4/5)

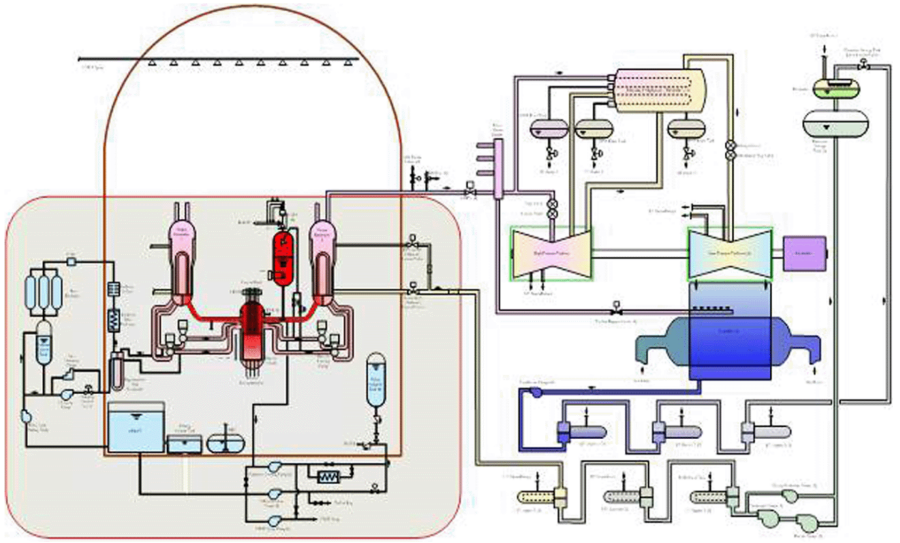
- **Narrow Interpretation of Type A variable:**
  - The “safety systems” was limited to reactor protection system and ESF system in the context of ANS 4.5.
  - Discussion in RG 1.97 Rev. 03 includes:

    At the start of an accident, it may be difficult for the operator to determine immediately what accident has occurred or is occurring and therefore to determine appropriate response. For this reason, reactor trip and certain other safety actions (e.g., emergency core cooling actuation, containment isolation, or depressurization) have been designed to be performed automatically during the initial stage of an accident.
  - With some reason of system design, safety systems actuation could not be provided in automatic for specific event. And safety analysis must assume that the safety system actuation is performed by manual.
  - If the operator should rely on some variables for system level actuation of safety system at certain setpoint, then the variables should be Type A variables.

Type A Variables (5/5)

- **Screening questions to select Type A variable:**
  - What happens if the operator action is not taken? Are there any safety functions not satisfied?
  - Do we need any plant variable to perform the action?
  - For an AOO, is the operator action to meet the safety analysis a cceptance criteria?
    - Acceptance criteria of safety analysis for AOO:
      - Fuel integrity: DNBR is above specified value.
      - Reactor Coolant Pressure Boundary Integrity: Overpressure protection requirement is met.
      - Radiation Release: Radiation release is not a major concern without fuel failure.

APR1400 Operator Action Review



APR1400 Operator Action Review

- **RAI Response:**
  - Operator Actions for DCD Tier 2 Safety Analysis will be listed in RAI 294-8302 Question 07.05-6 Response.
  - Operator actions are reviewed to select Type A operator action.
  - Discussions are provided for Type A variable selection.

APR1400 Operator Action Review (1/13)

- **Manual actions for accident analyses**

	Title of Event	Event Frequency	Manual Actions
15.1	Increase in Heat Removal by the Secondary System		
15.1.1	Decrease in Feedwater Temperature	AOO	None
15.1.2	Increase in Feedwater Flow	AOO	None
15.1.3	Increase in Steam Flow	AOO	None
15.1.4	Inadvertent Opening of a Steam Generator Relief or Safety Valve	AOO	Manual reactor trip Isolation of inadvertent open valve Plant cooldown
15.1.5	Steam System Piping Failure Inside and Outside the Containment (MSLB)	PA	Plant cooldown Termination of AFW (EOG)

APR1400 Operator Action Review (2/13)

- **Basis for Type A selection**

Title of Event	Manual Actions	Indication to take Manual Action	Location/ Qualification	Basis for Type A Selection
IOAGADV (15.1.4, AOO)	Manual Rx Trip	Neutron flux SG pressure	MCR/1E	Note 1
	Isolate IO valve	Valve position indications	MCR/ 1E or non-1E	Note 2
	Plant cooldown			Note 3
MSLB (14.1.5, PA)	Termination of AFW (EOG)	Diagnosis of event		Note 4
Boron Dilution (15.4.6, AOO)	Turn off charging pump Increase RCS boron concentration	Neutron flux Reactor makeup flow Boric acid flow	MCR/1E MCR/non-1E MCR/non-1E	Note 5
CEA Ejection (15.4.8, PA)	Plant cooldown			Note 3
CVCS Malfunction (15.5.2, AOO)	Plant cooldown			Note 3

APR1400 Operator Action Review (3/13)

- **Basis for Type A selection (cont.)**

Title of Event	Manual Actions	Indication to take Manual Action	Location/ Qualification	Basis for Type A Selection
15.6.2 LDLB	Manual reactor trip Isolate broken line	Letdown line pres. PZR level	MCR/non-1E MCR/1E	Note 6
SGTR (15.6.3, PA)	SG isolation	NA		Note 7
	Plant cooldown using unaffected SG	Radioactivity detector SG water levels	MCR/non-1E MCR/1E	Note 7
	Termination of SIS (EOG)	SIS termination criteria	MCR/1E	Note 8
LOCA (15.6.5, PA)	Hot leg injection	Time		-

APR1400 Operator Action Review (4/13)

- **Note 1. Manual Reactor Trip for AOO**
  - During an inadvertent opening of a secondary system valve, reactor power stabilizes at 113% due to increased steam flow.
  - Manual reactor trip is required to terminate the transient. However, reactor trip is not necessary to meet the safety analysis acceptance criteria.
  - One of the safety analysis acceptance criteria for an AOO event is to ensure that there is no fuel failure. Without fuel failure, the radiation release limit is not challenged.
  - Therefore, the manual reactor trip for AOO is not selected as a Type A operator action.

APR1400 Operator Action Review (5/13)

- **Note 2. Restoring Event Initiating Cause for AOO**
  - Operator actions are cited in AOO analyses for restoring event initiating cause. Isolation of inadvertent open valve (15.1.4), or isolation of broken small line (15.6.2), stopping boron dilution (15.4.6) are in this type of operator actions.
  - Position indications on the secondary valves are necessary to identify IO valve position. This is applicable for all SGADVs, MSSVs, and turbine bypass valves. KHNP does not believe the intent of the AMI requirements is to make all the valve positions 1E indications and Type A variables.
  - Plant parameters for event diagnosis are considered different from the plant parameters for Type A operator actions. Event diagnosis should be performed with all available plant indications. Plant parameters for Type A operator actions are primary variables for an operator to perform specific actuations on safety systems by monitoring if the variables will reach specified setpoints after the cause of the initiating event is diagnosed. “Planed action” means “planed action for a certain diagnosed accident”.
  - Therefore, Type A variables are not necessary for restoring the cause of an initiating event.

IO: inadvertent open
MSSV: Main Steam Safety Valve

SGADV: Steam generator Atmospheric Dump Valve
AMI: Accident Monitoring Instrumentation

APR1400 Operator Action Review (6/13)

- **Note 3. Initiating Plant Cooldown**
  - Safety analysis in Tier 2 Chapter 15 concludes that when an operator initiates plant cooldown, the plant can be brought to a safe condition. In most of the events, plant parameters are in a controlled state (not changing in an adverse direction) before the operator initiates plant cooldown.
  - In a few events such as CEA ejection (15.4.8), CVCS malfunction (15.5.2) and SGTR(15.6.3), MSSV cycling operation continues until the operator initiates plant cooldown using SGADV(s).
  - The initiation of plant cooldown is to ensure the heat removal function. An operator is required to take action to initiate cooldown according to the APR1400 DCD Emergency Operation Guide (EOG) even without diagnosis of the accident.
  - Therefore, there is no need to specify Type A variables for initiating plant cooldown.

APR1400 Operator Action Review (7/13)

- **Note 4. Termination of AFW**
  - Termination of Auxiliary Feedwater (AFW) is required as an operator action to mitigate the Main Steam Line Break (MSLB) accident in the APR1400 DC EOG. For the APR1400 DCD MSLB analysis, auxiliary feedwater is assumed to be provided to both steam generators. The peak reactivity occurs at about 400 seconds and then it gradually decreases. Therefore, the isolation of auxiliary feedwater is not a required operator action to meet the Tier 2, Chapter 15 safety analysis acceptance criteria.
  - Also, the “termination of safety system” is not considered to conform to the Type A definition of a variable which enables “safety systems to perform their safety-related functions.” The safety-related function of the AFWS is to provide SG water inventory for safe shutdown.
  - Therefore, the operator action to isolate the auxiliary feedwater to the affected steam generator is not considered a Type A operator action for APR1400.

APR1400 Operator Action Review (8/13)

- **Note 5. Boron Dilution Event**
  - The corrective action for the boron dilution event is to restore the event initiating cause. Refer to Note 2.
  - Boron dilution can be caused by failure of the makeup control system or charging system misalignment. Any specific operator action cannot be pre-planned. The cause of boron dilution cannot be identified with neutron flux indication only.

APR1400 Operator Action Review (9/13)

- **Note 6. Letdown Line Break**
  - Letdown line break (LDLB) is an AOO event. Safety analysis confirms that the radiation release meets the acceptance criteria when the operator isolates the break flow at 30 minutes after the initiation of the event. As discussed in Note 2, manual reactor trip is not to satisfy safety analysis acceptance criteria.
  - Operator action to isolate the break flow is necessary to limit the radiation release and restore the plant. A pipe break, such as a letdown line break, charging line break, sampling line break, or instrument tubing line break, will have a similar transient. During AOO events, there is no fuel failure and the radiation release limit acceptance criteria is not challenged.
  - Increase in charging flow may indicate excessive loss of reactor coolant due to a pipe break. However, using only this indication cannot inform the operator of the location of the break. As in the case for IOSGADV (note 2), KHNP does not agree that Type A variables shall be selected based on identification of the cause of all AOO initiating events.

IOSGADV: Inadvertent open steam generator atmospheric dump valve

APR1400 Operator Action Review (10/13)

- **Note 7. Manual Actions for SGTR**
  - Initiating plant cooldown by opening of SG ADV and actions to terminate break flow are cited as necessary operator action for SGTR. Termination of break flow includes RCS depressurization and termination of safety injection.
  - These operator actions are basic process of ensuring heat removal and plant cooldown even without diagnose of the SGTR accident.
  - Isolation of affected SG can be performed after EOG SGTR diagnosis using available plant variables.
  - SI termination is performed after verifying 'SI termination criteria' as in for all other SI actuating accidents according to EOG.

APR1400 Operator Action Review (11/13)

- **Note 8. Termination of Safety Injection for SGTR**
  - Termination of safety injection (SI) is required by the SGTR EOG. If SI is not terminated, RCS pressure maintains high, break flow continues, and the main steam safety valves are opened and release radiation. If SI is not terminated, more radiation release would occur than assumed in the safety analysis.
  - However, termination of SI can be considered to be included in the EOG plant cooldown process. Variables for SI termination are classified as Type B variables.
  - Also, “termination of safety system” is not considered to conform to the Type A definition of a variable which enables “safety systems to perform their safety-related functions.” The safety-related function of the SIS is to make up the core coolant.
  - Therefore, the operator action to termination of SI during SGTR is not considered a Type A operator action for APR1400.

APR1400 Operator Action Review (12/13)

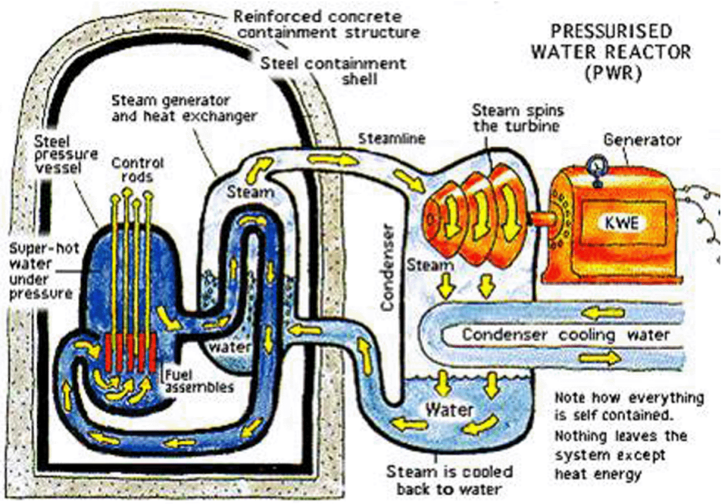
- **Diagnostic actions for SGTR in EOG**
  - At least one SG level is acceptable.
    - Total feedwater flow rate is acceptable. -> No: Loss of All Feedwater
  - Pressurizer pressure is lower than required.
  - Pressurizer level is lower than required.
  - Both SG pressures are higher than required or rising -> No: ESDE
  - There is no containment radiation -> Yes: LOCA
  - Containment pressure is less than required -> No: LOCA
  - There are indications of SGTR if there is a(n):
    - Unexplained rise in SG level in one SG
    - Unexplained feed flow mismatch between the SGs
    - Unexplained loss of RCS inventory
    - Steam plant activity higher than the alarm setpoint

ESDE: Excessive Steam Demand Event

APR1400 Operator Action Review (13/13)

- **Emergency Operation Guidelines for APR1400**
  - SPTA (Standard Post Trip Actions)
    - Check safety function acceptance criteria (reactivity, heat removal, etc.)
    - If not, go to Diagnostic Actions
  - Diagnostic Action (DA) Guide
    - Detail LOCA, SGTR, ESDE, SBO DAs provided.
    - If diagnosed, go to specific accident Optimal Recovery Guideline
    - If not diagnosed, go to Functional Recovery Guideline (Safety Function Success Path)
  - Functional Recovery Guidelines
    - If accident is not diagnosed, success path for non-satisfied safety functions implemented
  - Optimal Recovery Guidelines
    - For specific diagnosed accident

Summary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Note how everything is self contained. Nothing leaves the system except heat energy
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Summary

- Plant variables for accident diagnoses are not limited to Type A variables. Some of operator actions do not need plant variables after accident is diagnosed.
- KHNP considered Type A variables may be limited to the variables for system level actuation of reactor protection and ESF systems.
- Type A variables for mitigation of AOO shall be limited to the variables for operator action to satisfy safety analysis acceptance criteria.
- Candidates of Type A operator actions are reviewed, and KHNP concluded that there is no Type A accident monitoring variables in the APR1400.