

2012 Regulatory Information Conference – W19

Significant Operating Experience

Insights & lessons-learned from “Inadvertent Containment Spray during the Commissioning Stage”

March 2012

LEE DH leedh@kins.re.kr

Korea Institute of Nuclear Safety

Status of NPPs in Korea

- Location of Shin-Kori nuclear power plants

Status	Unit	PWR		Total
		Unit	MWe	
In Operation	Unit	17	4	21
	MWe	15,937	2,779	18,716
Under Construction	Unit	7	7	7
	MWe	8,600		8,600
Under Planning	Unit	2	2	2
	MWe	2,800		2,800
Total	Unit	26	4	30
	MWe	27,337	2,779	30,116

Shin-Kori Unit 1&2

- Specification of Shin-Kori unit 1&2 (OPR-1000)
 - Reactor type: PWR with 2 loops
 - Core thermal power: 2,815MW_{th}
 - Electric power: 1,053MW_e
 - Designer:
 - NSSS supplier:
 - Nuclear fuel supplier:

Fig. RCS of OPR-1000 (Optimized Power Reactor 1000)

Results of the Event

- Severe transient of RCS experienced
 - Rapid decrease of pressure from 28kg/cm² to 3.9kg/cm²
 - Rapidly lowered temperature and water level
- 423 tons of borated water sprayed into the containment
 - Most of SSCs inside the containment affected
 - Reactor cavity and containment floor level flooded
- Plant safety systems actuated automatically as designed

Results of the Event

Responsive Actions by Operators

- Implementation of EOP
 - including stop of RCP, isolation of the letdown line, increase of the charging flow
- Actuation of the SI and containment isolation
 - recovering the RCS inventory and
 - preventing radioactive material release to the environment
- Manual closure of the abnormal opened valve (CS-V035)
 - resulting in the stable condition of plant
- Declaration of emergency (Alert level)
 - Taking into account the leakage rate of reactor coolant

Causes of Event

• Direct cause

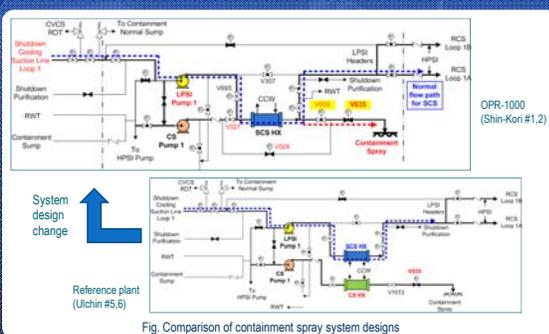
- Inadvertent opening of containment spray isolation valve due to human error caused by
 - MCR operator's mishandling of the CS-V035 hand-switch and
 - test engineer's local equipment manipulation without approval of the MCR
 - In detail, acknowledging that the thermal overload relay tested on the previous day was not reset after the test, test engineer pressed the "RESET" button installed at the local breaker to make it clear without approval from MCR. That action made supplying electric power to the valve CS-V035 possible and it led to opening of CS-V035 which already had erroneous opening signal by MCR operator's mishandling of the CS-V035 hand-switch.

Causes of Event

• Root cause

- Inadequate test procedure not reflecting system design change
 - the shutdown heat exchanger outlet isolation valve (CS-V033), which should be closed during the heat-up operation, had been opened
- Inappropriate organization attitude toward plant commissioning
 - delayed organization for commissioning operation
 - insufficient training for the operating staff, resulting in the poor plant familiarization

Design Changes

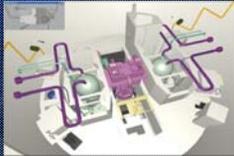


Safety Assessment

- Integrity of reactor core confirmed
 - Coolant boiled but DNB condition not reach due to small decay heat
 - Limited increased of fuel surface temperature (5~6 °C)
 - Low fission products concentration within the reactor coolant
- Integrity of equipment confirmed
 - Exceeded cool-down rate of RCS but satisfied the allowable criteria of KEPIC (Korea Electric Power Industry Code)
- Integrity of major components (RCP, LPSI pump) confirmed
 - Sound performance through the manufacturer review, starting test, etc.

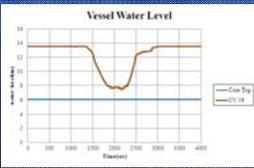
Safety Assessment

- Almost all of SSCs within the containment affected by the sprayed borated water
- After recover, however, its integrity including functions confirmed based on the results of inspections and evaluations in detail

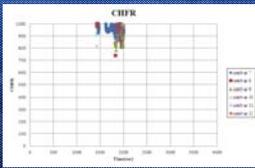


Safety Assessment

- Hydraulic Analysis



Vessel Water Level



CHF

- Collapsed Water Level : Core Top(6.12m)+1.3m
- No Challenge to DNBR

Corrective Actions

- For short-term items,
 - Removing borated water in the containment and inspecting/reviewing the integrity of the major SSCs affected
 - Re-verifying the operating procedure and documentation to ensure proper identification of the plant's characteristics focused on design changes
 - Reinforcing the organizations and the workers responsible for conducting the commissioning and linking operating experiences to the following-up units

Corrective Actions

- For long-term items,
 - To establish the general management plan for SSCs affected by the sprayed reactor coolant, including the impact evaluation of boric acid corrosion
 - To establish and implement the plan regarding the prevention of human error and improving levels of safety culture for the commissioning plant

Regulatory Actions

- Regulatory body dispatched the event investigation team, approved the restart on Oct. 15, 2010 based on the KINS investigation and safety review result
 - 16 additional recommendations (Action Items) are issued and implemented
- IAEA INES rating : Level 2
 - Up-rated considering deficiency of safety culture

Lessons Learned

- For the prevention of reoccurrence and safe operation of plant, the following lessons-learned should be focused on:
 - reinforcing commissioning organization composed of the experienced staff
 - requiring plant familiarization to commence the commissioning operation
 - reflecting design changes into procedures and training in timely/adequate manner
 - requesting attitudes that commissioning nuclear power plant is equivalent to the normal operating one in terms of safety culture

Summary

- Due to the human error, the containment spray valve located in the downstream of shutdown cooling pump is inadvertently opened
 - Containment spray lasted for 37 minutes and
 - A total of 423 tons of reactor coolant sprayed into containment
- Safety assessment
 - No radiation exposure to the workers
 - No release of radioactive materials to the environment
 - No significant degradation of SSCs and core
