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Braidwood Station Regulatory Conference

1SI8811B Failure to Stroke Full Open

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Introduction

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Agenda

✓ Finding and Introduction	A. Shahkarami
✓ Root Cause Evaluation	L. Coyle
✓ ECCS and RH System Overview	T. McCool
✓ Control Room Operator Response to Failure	T. McCool
✓ Local Valve Operation	T. McCool
✓ SDP Evaluation	G. Krueger
✓ Conclusion	A. Shahkarami

Finding

✓ Preliminarily determined to be Yellow

- Substantial safety significant finding and associated apparent violation of 10 CFR 50, Appendix B, Criterion III, "Design Control" for failure to prevent water from entering the 1SI8811B valve actuator that resulted in binding of the torque switch

Introduction

- ✓ Provide information regarding the event, root cause evaluation, and corrective actions taken
- ✓ Provide information on the system's design and expected accident sequence and response
- ✓ Demonstrate credit for local operator action (recovery) is appropriate and consistent with the Braidwood design and operation
  - Valve accessible under postulated conditions
  - Time is available to take required actions
  - Procedures and training support confidence in manual operator action
- ✓ Provide insights gained from dominant scenarios and risk significance determination process evaluation

Introduction (cont.)

✓ Braidwood takes its obligation for safe operation seriously

- We agree with the performance deficiency
- The design deficiencies and organizational response at Braidwood do not meet Exelon standards

Root Cause Evaluation

Larry Coyle

Plant Manager

Event Timeline

- ✓ September 20, 2007 – 1SI8811B successfully stroked full open (last successful full stroke)
- ✓ June 24, 2009
  - 1SI8811B failed to stroke full open (opened approximately 34%)
  - Troubleshooting found water in actuator limit switch compartment and torque switch bound
- ✓ June 26, 2009 - 1SI8811B repaired and restored to operable after successful diagnostic testing

Event Timeline (cont.)

✓ August 18, 2009

- Equipment Apparent Cause Evaluation (EACE) completed
- Concluded torque switch bound due to water intrusion into the actuator limit switch compartment through the open end of electrical conduit
- Actions included replacing parts, performing diagnostic tests, and sealing susceptible open conduits

Event Timeline (cont.)

- ✓ October 30, 2009
  - Water was identified on 1SI8811B valve and actuator surfaces
  - Source of water was leakage through roof removable concrete slabs
- ✓ November 1, 2009
  - Boroscope inspection of limit switch compartment identified the presence of water in the compartment
  - Valve was successfully stroked full open for operability verification
  - Initiated Root Cause Evaluation (RCE)

Root Cause Evaluation

- ✓ RCE determined that water intrusion must be rain water
- ✓ Root Cause:
  - Lack of sensitivity to the effects of water spills, sprays, or leaks in the curved wall area (CWA)
    - Previous instances of CWA roof leakage documented in Corrective Action Program

Root Cause Evaluation (cont.)

✓ Contributing Causes

- CWA concrete removable slabs did not conform to roof design drawings which resulted in CWA water leakage
- Sealtight conduit connector for the 1SI8811B valve actuator was not properly installed – while not designed to be watertight, proper installation could have mitigated the water intrusion event

Root Cause Evaluation (cont.)

✓ Corrective Actions to Prevent Recurrence

- Provide training to applicable Braidwood site personnel on the event, consequences, and actions to be taken for water intrusion identification. This will include general design configurations and the need to ensure proper controls within specific Equipment Qualification (EQ) zones.
- Develop and implement processes and controls to evaluate electrical components affected by potential water intrusion in safety related areas

Root Cause Evaluation (cont.)

✓ Corrective Actions

- Repaired Unit 1 and 2 CWA roof removable concrete slab area per original design
- Performed inspections of risk significant MOVs
- Inspected safety related structures with removable hatches to ensure proper installation
- Performed plant walkdown and evaluated for leakage
- Risk significant MOVs evaluated to add T-drains and/or bypass the torque switch logic

Organizational Insights

- ✓ Organization has not had proper sensitivity to the impact of degraded conditions and missed opportunities to learn from previous events
  - Accepted periodic water spills and leakage in CWA – treated events as housekeeping issues, not events requiring robust investigation and aggressive actions
  - Under-reacted to June 24, 2009 failure to stroke
    - EACE not comprehensive
    - Corrective actions did not address all potential water sources and intrusion paths
  - NRC provided challenges to weaknesses in site response

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Summary

- ✓ Actions to prevent recurrence
  - Organizational
  - Physical repairs
- ✓ Significant learnings for Braidwood
  - Intolerance for spills and leakage
  - React appropriately from both a significance and Corrective Action Program standpoint

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ECCS and RH System Overview

Tom McCool

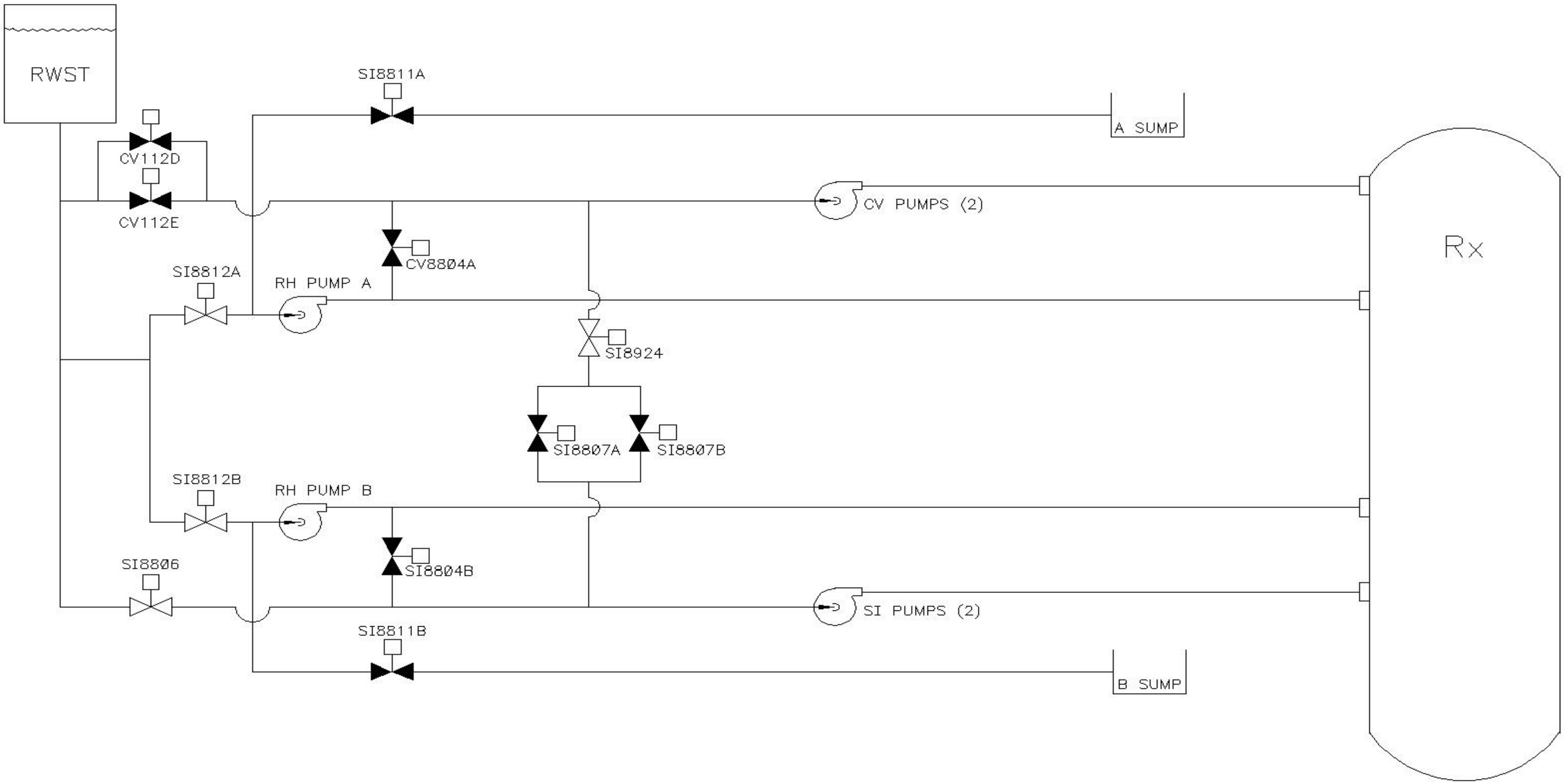
Operations Director

Introduction

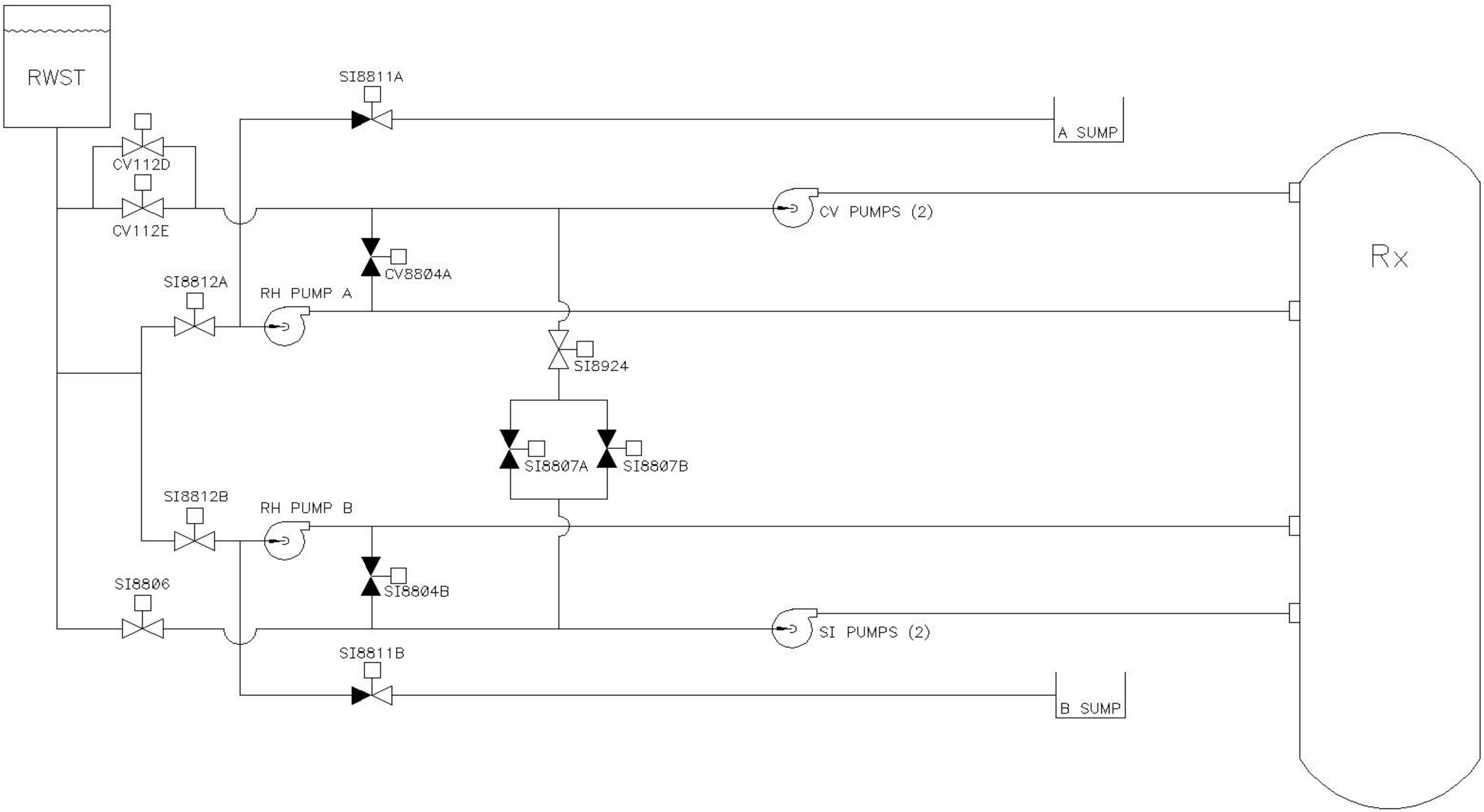
Three main focus areas

- ✓ Describe how Emergency Core Cooling System (ECCS) is designed to function and the required manual actions to transfer to cold leg recirculation
- ✓ Discuss operator response if the SI8811A/B valve fails to open or partially opens (dual indication)
- ✓ Describe actions to access and locally operate the SI8811A/B valve

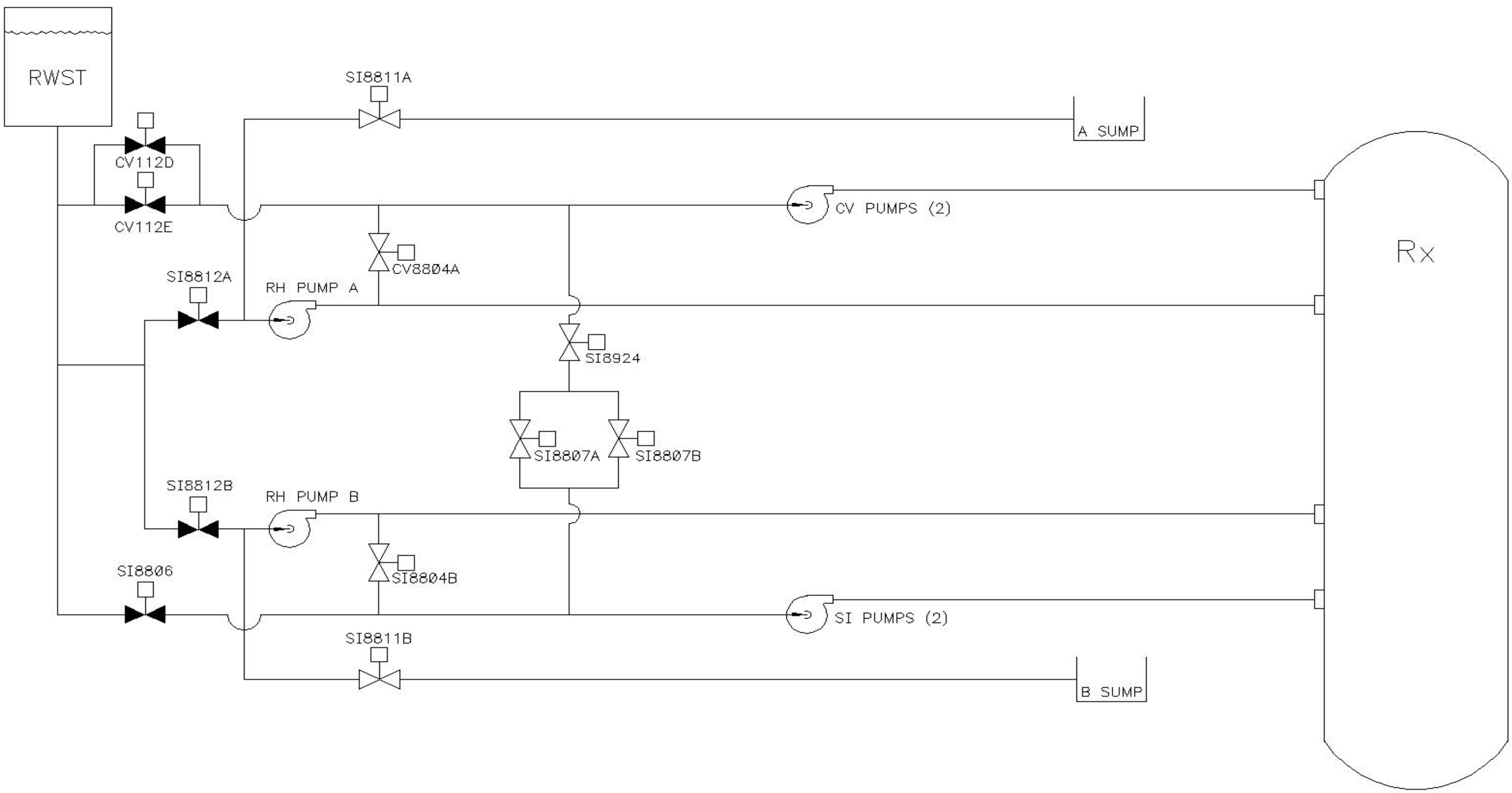
Emergency Core Cooling System
Normal Alignment



Emergency Core Cooling System Injection Phase



Emergency Core Cooling System Recirculation Phase



ECCS System Design

- ✓ ECCS has two phases of operation in response to an accident (note: all valves listed are outside containment)
  - Injection Phase
    - RWST is source of water to ECCS pumps
    - ECCS pumps (Charging (CV), Safety Injection (SI), and Residual Heat Removal (RH)) transfer water to the reactor
    - Injected water cools core and spills out the break into the containment sumps
  - Recirculation Phase
    - Initiated on low (46.7%) RWST level
    - Both SI8811A/B automatically open with low RWST level (46.7%)
    - Alerts Control Room operator to manually transfer ECCS to cold leg recirculation per procedure BwEP ES-1.3, "Transfer to Cold Leg Recirculation"
      - o Perform initial steps without delay
      - o Functional Restoration (FR) procedures should <u>NOT</u> be implemented prior to establishing cold leg recirculation

Transfer to Cold Leg Recirculation

- ✓ Control Room manual actions
  - Establish cooling water to RH heat exchangers and check containment sump level
  - Align RH pumps to containment sump
    - Verify both SI8811A/B open
    - Close both SI8812A/B from the Control Room
    - Align SI and CV for cold leg recirculation – open RH to CV and SI valves (CV/SI8804A/B)
- ✓ Time from low RWST level to CV/SI8804A/B valves open is approximately 6 minutes
  - Operators trained and evaluated to demonstrate proficiency in establishing cold leg recirculation

Summary

- ✓ Transfer to cold leg recirculation requires Control Room operator manual actions to complete plant alignment per design
- ✓ Procedures are in place to direct the operators to establish cold leg recirculation. Procedure steps are performed without delay and FR procedures are not implemented (sense of urgency and importance).
- ✓ Operators have the required knowledge through training and evaluation to perform the transfer function in a timely manner without error

Control Room Operator Response to Failure

Tom McCool
Operations Director

Both SI8811A/B Show Dual Indication

- ✓ Impact of torque switch binding on 1SI8811B
  - Valve required to open to support Recirculation Phase of accident mitigation (long term cooling)
  - Valve was capable of opening approximately 34% electrically using the motor operator
    - Provide sufficient flow to support RH pump net positive suction head
    - Interlocks at the full open position were not met – supply to high pressure pumps not possible, and local action required for remaining 66% valve travel
- ✓ Procedures provide clear direction and actions to establish long term core cooling
  - If SI8811A/B are not considered open, procedural direction is provided for manual operation of valves
  - Loss of Emergency Coolant Recirculation procedure directs operator to locally open SI8811A/B if valve can not be opened from Control Room
    - Critical valve locations are provided in the procedures

Both SI8811A/B Show Dual Indication

- ✓ Operators have demonstrated the ability to use procedures to achieve cold leg recirculation during response to both SI8811A/B valves failing to fully open (i.e., dual indication)
  - Either classification of the SI8811A/B valve's status ("closed" or "not closed") procedurally directs Control Room operators to dispatch an operator to locally open SI8811A/B
  - Control Room operators demonstrated that an RH pump would not be operated without a clear suction path
    - Pumps were stopped and RWST suctions valves (SI8812A/B) were isolated

Summary

- ✓ Actions are performed by licensed operators who demonstrated the knowledge and proficiency necessary to establish timely cold leg recirculation
- ✓ Operating crews are periodically evaluated in simulator scenarios that involve loss of emergency coolant recirculation and require dispatching equipment operators to locally open SI8811A/B
- ✓ The SI8811A/B valve motor operator handwheel is not encapsulated and is accessible
  - There is procedural direction to manually open the valve
  - Equipment operators are trained to manually operate motor operated valves

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Local Valve Operation

Tom McCool
Operations Director

SI8811A/B Local Valve Operation

✓ Evaluation of local valve operation considers the following:

- Valve location
- Historical valve operation
- Manual cycle time

SI8811A/B Local Valve Operation (cont.)

✓ Valve Location

- Operation and Radiation Protection personnel report to Control Room at onset of event
- CWA is an accessible High Radiation Area
- Handwheel on valve (platform) approximately 6 feet off floor – accessible by installed ladder
- Emergency Operating Procedures provide valve locations

✓ Historical Valve Operation

- Open stroke every 18 months and manually cycled every 36 months
- Based on actual Operations and Maintenance experience force required to rotate handwheel well within operator capability
  - Installed single hand operator for ease of use, very little resistance

SI8811A/B Local Valve Operation (cont.)

✓ Manual Cycle Time

- Equipment operator demonstrated knowledge and ability to manually operate valve
- Manually cycled from full closed to full open with local area temperature of 79°F
- Single operator total stroke time 38 minutes from 0 to 100%, stroke time for 66% of travel approximately 21 minutes
- Highest CWA temperature during exposure time was 90°F and area dose rates of 35 mr/hr

Conclusion

- ✓ Actions required to respond to an accident and SI8811A/B failure are proceduralized
- ✓ Licensed Control Room operators periodically demonstrate proficiency to transfer to cold leg recirculation and respond to events involving SI8811A/B failure
- ✓ Simulator runs with SI8811A/B valves failure to fully open validated Control Room operator training and response
- ✓ Local valve operation is possible due to valve location and design (accessible handwheel)
- ✓ Equipment operators are trained on motor operated valve design and manual operation

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SDP Evaluation

Greg Krueger
Director
Corporate Risk Management

Key Elements for SDP Evaluation

- ✓ Braidwood PRA model dominant sequences
- ✓ Thermal-hydraulic analysis to support operator action timing
- ✓ SI8811A/B valve accessibility
- ✓ Probabilistic assessment of operator actions
- ✓ Assessment of conservatisms and sensitivities in analysis

Dominant Accident Sequences

✓ LOCAs with Failure to Establish ECCS Recirculation[1]

Braidwood PRA Model		Braidwood NRC Model	
Initiator	Failures	Initiator	Failures
Small LOCA (0.86"- 2")	Common Cause Failure of Both 1SI8811 Valves	Small LOCA (<2")	Common Cause Failure of Both 1SI8811 Valves
	Failure of 1SI8811B and Random Failures of A RH Train		Failure of 1SI8811B and Random Failures of A RH Train
Medium LOCA (2"-5.2")	Common Cause Failure of Both 1SI8811 Valves	Medium LOCA (2"-5.2")	Common Cause Failure of Both 1SI8811 Valves
	Failure of 1SI8811B and Random Failures of A RH Train		Failure of 1SI8811B and Random Failures of A RH Train

(1) Modeled as Failure of 1SI8811B with no Recovery

Thermal-hydraulic Analysis

✓ Detailed T-H evaluation of the different LOCA break sizes to obtain system and operator response timing was performed

- Largest LOCA break size was used to represent the spectrum of sizes for the small and medium LOCA Initiators
- Consideration of RWST flow diversion and operator response was accounted for in the evaluations
  - The relationship between LOCA size, RWST flow diversion, and operator response actions were modeled
- Time to key RWST tank levels and procedure direction were determined

Time Available to Locally Open 1SI8811A/B Valves

Initiator	Time to 46.7% RWST Level (1)	ΔTime to Top of Active Fuel	Δ Time Available to Open Valves
0.86" LOCA	5.2 hours	28 hours	23 hours
2" LOCA	2.5 hours	12 hours	9.5 hours
5.2" LOCA	44 minutes	2.7 hours	2 hours

(1) Time at which ECCS Recirculation Begins

Time Required to Locally Open 1SI8811A/B Valves

Event or Action	Procedure step or Cue	Cumulative Time(1)
1SI8811 Valves Open	RWST Lo-2	0
Recognition of 1SI8811B dual indication	1BwES-1.3 Step 3c	2 – 3 minutes
RH pumps secured and 1SI8812 valves closed	1BwES-1.3 Att A Step 4	7 minutes
Dispatch Operator to Open 1SI8811B	1BwCA-1.1 Step 1c	11 minutes
Transit time to 1SI8811B	7.5 minutes transit time	19 minutes
Time required to open 1SI8811B	24 minutes stroke time	43.5 minutes
	Time available based on T-H analysis =	~2 to 23 hours

(1) Time is measured from RWST Lo-2 (46.7%) Level

SI8811A/B Valve Accessibility

- ✓ CWA Radiological Conditions
  - LOCA scenarios were evaluated to assess potential for dose impact
    - No local fuel damage would occur
    - No transport mechanisms from the vessel to the CWA exist
  - Conservative dose assessment utilizing bounding TS activity levels concluded CWA dose rates to be 1,444 mRem/hr
  - Historical dose rates in the CWA have been low
  - Operator actions occur prior to level reaching TAF
- ✓ Radiation Protection Technician is part of safe shut-down team dispatched to the Control Room at the onset of the event

SI8811A/B Valve Accessibility

✓ CWA Temperature Conditions

- Evaluation performed to determine ambient temperature in CWA under scenario-specific LOCA conditions
  - Maximum Temperature in CWA determined to be 90°F
- Effects of temperature on valve manipulation are minimal based on published literature
- Heat Stress procedures allow normal work under these temperature conditions
- 24 minutes is reasonable time for use in the analysis
- SDP sensitivity evaluation indicates increased time for valve manipulation does not impact conclusion

Credit for Local Operation of 1SI8811 A/B valves

✓ Credit for local operator operation of the valves is warranted because:

- Procedures specifically direct dispatching an operator to locally open 1SI8811 A/B valves
- Sufficient time is available to open the valves
- Environmental conditions allow access to valves
- Regardless of how dual indication is interpreted, Emergency Operating Procedures will direct operators to locally open valves to establish ECCS recirculation

Quantitative Human Reliability Results

Locally Open 1SI8811 A/B valves

Initiator	BWD PRA Exelon Method
Small LOCA (2")	6.5E-03
Medium LOCA (5.2")	6.0E-03

Additional SDP Considerations - External Events

✓ NRC IM 0609 Appendix A, requires consideration of external events when the internal events CDF results are greater than 1E-07

✓ Internal Fires
- Fire Induced Small LOCAs
- Bleed and Feed

✓ Seismic Events
- Seismic Induced LOCAs

SDP Results

	Braidwood PRA Model
Internal Events	7.1E-07
Fire	2.2E-07
Seismic	1.9E-09
Total	9.3E-07

SDP Conservatisms

✓ Most limiting timing for a particular LOCA initiator is used for the spectrum of break sizes within a LOCA category

- Refinement of break sizes would reduce CDF

✓ No credit is taken for restarting RH pumps if 1SI8811A/B valves cannot be opened further

- Operators would attempt to inject with RH

✓ All LOCAs are assumed to be Hot Leg Breaks to minimize the time for operator response

- Cold leg breaks extend the time window for operator action

SDP Sensitivities - Time Impact (1)

	Cold Leg Break	RWST Diversion 10 min.	LOCA Cooldown Rate (2)	Double Time to Open SI8811
2" LOCA Nominal	**9.5 hours**	**9.5 hours**	**9.5 hours**	**9.5 hours**
2" LOCA Sensitivity	23.6 hours	8.6 hours	23.6 hours	9.1 hours
5.2" LOCA Nominal	**2 hours**	**2 hours**	**2 hours**	**2 hours**
5.2" LOCA Sensitivity	3.9 hours	1.8 hours	2 hours	1.6 hours

(1) Time from RWST 46.7% to Top of Active fuel

(2) 50F/hr versus 100F/hr

SDP Sensitivities (CDF Impact)

	RWST Diversion 10 min.	LOCA Cooldown Rate (1)	Double Time to Open SI8811
Nominal	**7.1E-07**	**7.1E-07**	**7.1E-07**
Sensitivity	7.1E-07	7.1E-07	7.3E-07

(1) 50F/hr versus 100F/hr

SDP Conclusion

- ✓ Credit for operator action to open the 1SI8811A/B valves is appropriate, and reduces the risk significance of the event to less than 1E-06
- ✓ Credit for operator action is warranted because:
  - Environment conditions provide access to valves
  - Control room cues/indication drive need for local operator actions
  - Sufficient time is available to locally open 1SI8811 A/B valves
  - Sufficient resources are available to support opening the valves
  - Procedures direct and training reinforces actions to locally open the valves
- ✓ Sufficient conservatism in evaluation to account for variations in time or boundary conditions

Conclusion

Amir Shahkarami

Site Vice President

Conclusion

- ✓ Event identified weaknesses in our understanding of 1SI8811B design basis and our responsiveness to water intrusion events
- ✓ Operations personnel have the required training and procedures to respond to the identified valve failure
- ✓ Evaluation of event and conditions concluded credit for local operator action is appropriate
  - Valve accessible under postulated conditions
  - Time is available to take required action
- ✓ PRA Conclusion – Very Low Risk Significance