Personnel Performance during Challenging Events: Lessons from Operating Experience

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Event #1 – Electrical Fire

- Circuit breaker failed to open
- Consequential transformer fault
- Loss of power at two 4kV buses, three 480V buses, nine motor control centers

2

Event #1 – Additional Complications

Air-operated valve closed during power transfer
- Unexpected equipment response
- Isolated cooling water to RCPs

Secondary plant heater drain valves failed open
- Design response to loss of power
- Excessive cooldown and safeguards actuation

Charging suction did not transfer to RWST
- Error during prior control circuit modification
- Loss of RCP seal injection flow if VCT drained

3

Event #1 – Personnel Performance

Control room team focused on response to fire and AC power recovery

- BOP operator dedicated to fire procedures for ~30 minutes
- RO partially distracted by fire response
- Supervisors distracted by Emergency Action Level reviews
- Frequent crew updates diverted attention from plant status

Operators quickly started two charging pumps per EOPs

- Did not monitor VCT level
- Did not recognize failure of suction transfer to RWST

4

Event #1 – Personnel Performance

Crew did not recognize loss of RCP cooling

- RCP bearing high temperature alarms at ~35 minutes
- Reopened cooling water valve at ~40 minutes
- VCT drained, loss of all charging and RCP seal injection at ~45 minutes
- Aligned charging pumps suction to RWST at ~60 minutes

Crew did not recognize cause for overcooling

- Overcooling stopped after ~35 minutes
- Local operator investigating power failures bumped DC circuit breaker
- Momentary loss of instrument bus power caused MSIVs to close

5

Event #1 – Personnel Performance

Attempt to AC restore power

- Reset generator lockout relay at ~3-1/2 hours per procedure
- Did not confirm cause for lockout
- Reconnection of power to faulted transformer caused second fire in another location
- Second fire caused ground faults on both DC power trains

6

What Have We Learned?

Personnel actions depend on overall plant response context
- Often focus on correction of initial condition
- Complications from support system failures
- Personnel often not familiar with subtle effects
- Unexpected plant behavior differs from experience and training
- Non-safety systems and functions can divert attention
- Conflicting priorities
- Procedures do not always address actual plant conditions
- Confusing conditions can persist for extended time
- Problems can occur during recovery

7

Event #2 – Loss of Offsite Power

- Diesel generators started
- Safety buses reenergized
- Standby instrument air compressor failed to start (not safety-related, but powered from safety bus)
- Loss of instrument air

8

Event #2 – Additional Complications

Charging valve open fully, normal letdown isolated
- Design response to loss of instrument air
- Increasing pressurizer level

Loss of plant process computer
- Unexpected response
- Loss of alarms and trend information

Several fire alarms actuated
- Unexpected response

9

Event #2 – Personnel Performance

Control room team partially preoccupied with fire alarms
- Concern that power failure was caused by a fire
- Coordination with local plant operators checking alarm locations

Loss of process computer
- Power panels deenergized automatically at 30 minutes
- STA left control room often to locally check required indications

Crew recognized mismatch between charging and letdown
- Reduced charging flow to minimum for RCP seals, pressurizer continued to fill
- PORV opened automatically at ~50 minutes (6 times)
- PORV opened manually at ~60 minutes (5 times)

10

Event #2 – Personnel Performance

Alternate letdown alignment
- Aligned alternate letdown to VCT through reactor vessel head vent valves at ~1-1/2 hours, per procedure
- VCT level did not increase, due to closed air-operated valve
- Operators concluded that flow path was blocked (it wasn't)
- Realigned head vent flow to pressurizer relief tank at ~2 hours
- Pressurizer relief tank filled, rupture disc opened at ~2-1/2 hours

11

Event #2 – Personnel Performance

Restored instrument air at ~2-1/2 hours
- Air compressor starting relay contacts degraded
- Delay due to concerns about cooling water flowing onto floor

Aligned letdown to VCT at ~3 hours
- Recovery of instrument air reopens hydrogen supply to VCT
- VCT pressure sensor remains deenergized, control valve fails, full hydrogen pressure supplied to VCT
- Letdown relief valve opens, release of water into Auxiliary Building from drain tank
- Manually diverted letdown to reduce VCT pressure
- Normal charging and letdown established at ~6-1/2 hours

12

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13

The Goals of Human Reliability Analysis (HRA)

Evaluating human performance in a PRA

- How will personnel respond during an evolving event scenario?
- What is the likelihood that personnel will perform the desired actions?
- What are the consequences of alternate personnel responses?

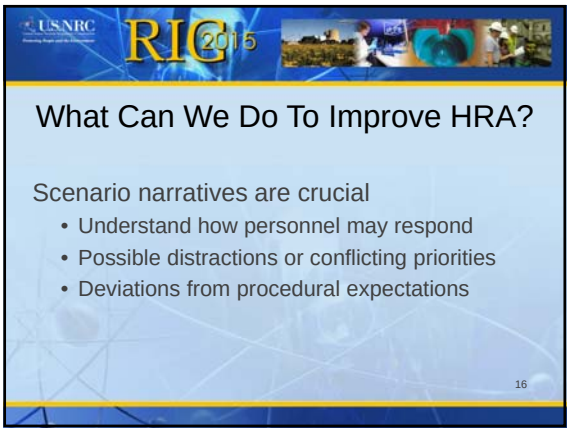
14

What Have We Learned?

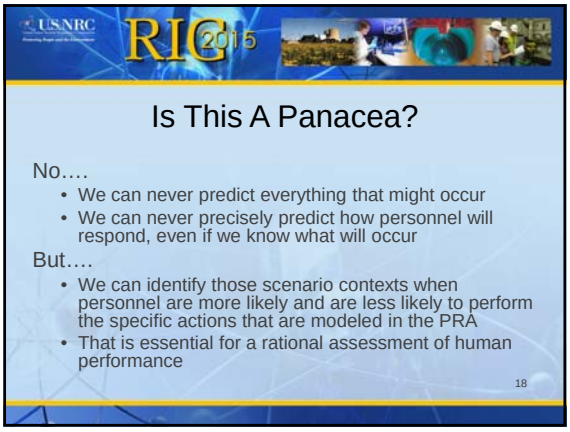
PRA models and HRA are often myopic

- Focus on modeled systems, functions, and personnel actions
- Overlook response of non-safety systems, secondary plant, and ancillary functions

15


U.S.NRC
RIC 2015
What Can We Do To Improve HRA?
Scenario narratives are crucial
• Understand how personnel may respond
• Possible distractions or conflicting priorities
• Deviations from procedural expectations
16


U.S.NRC
RIC 2015
What Can We Do To Improve HRA?
Characteristics of a good scenario narrative
• Understanding of integrated plant response
• Developed from the operators' perspective
• Not focused only on systems and desired personnel actions in the PRA model
• Not a summary of expected procedural compliance
• Not tailored to perceived needs of specific HRA model
17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RIC 2015
Is This A Panacea?
No….
• We can never predict everything that might occur
• We can never precisely predict how personnel will respond, even if we know what will occur
But….
• We can identify those scenario contexts when personnel are more likely and are less likely to perform the specific actions that are modeled in the PRA
• That is essential for a rational assessment of human performance
18


USNRC
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Acronyms
BOP Balance of Plant
EOPs Emergency Operating Procedures
HRA Human Reliability Analysis
MSIVs Main Steam Isolation Valves
PORV Power-Operated Relief Valve
PRA Probabilistic Risk Assessment
RCP Reactor Coolant Pump
RO Reactor Operator
RWST Refueling Water Storage Tank
STA Shift Technical Advisor
VCT Volume Control Tank
19