Validation of Instrumentation Response

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Topics

Validation of Instrument Readings:

- RPV Water Level - 1F1, 1F2, 1F3
- RPV Pressure - 1F1, 1F2, 1F3
- DW Pressure - 1F1, 1F2, 1F3
- SC Pressure - 1F2
- DW Radiation - 1F1, 1F2, 1F3
- SP Temperature - 1F2
- RPV Metal and DW Temperatures - 1F1, 1F2, 1F3

These principles help in validating instrument readings:

- Confirm each fact with two or three witnesses
- For each action that reaches core, there should be a reaction (look for feedback)
- Trends and changes in trends may be true even when absolute values are not
- Look for physical explanations
- Keep in mind the sequence of events
RPV Water Level Instruments: 1F1

Time: T+ 0 to T+ 51 minutes

RPV Water Level until the Tsunami:
- All containment and RPV parameters in normal range
- No reason to indicate that the instrumentation is not accurate

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RPV Water Level Instruments: 1F1

Time: T+ 0.9 to T+ 7.2 hours

Wide Range Readings
16:45 -26.6” (108.3")
17:00 -46.4” (88.5")
17:07 -51.3” (83.6")
() is Inches above TAF

1F1 Wide Range Trend

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21:50 Access to RB restricted to High Dose Rates

RPV Water Level Instruments: 1F1

Time: T+ 0.9 to T+ 19.2 hours

- RPV Pressure lowers from SRV setpoint to 116 psig by 02:45
- RPV water level A rises +30” between 23:24 and 00:30
- RPV water level begins lowering at 06:30
- DW pressure small bump at 06:30 (92.6 to 98.4 psig)
- At 04:19 SC pressure 1.4 psig above DW
- At 06:30 DW pressure 1.45 psig above SC pressure

No useful information from level transmitters after this point in time (it is likely that the reference and variable legs evaporated)

DOE Forensics work helped industry understand this transient.

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1F1 - Pressure, DW Pressure & SC Pressure
(Time: T+12 hours)

- RPV pressure 0 to 1,500 psig
- DW pressure 0 to 100-300 psig
- Instruments calibrated to be most accurate near normal operation

Trends accurate:
- At 03:45 March 12 (T+12 hours) workers attempted to enter RB; as soon as door was open, steam was observed and door closed
- Transmitters working 105 hours into event even with steam environment

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1F1 - RPV Pressure, DW Pressure & SC Pressure
Time: T+ 346 hours

- Injection Into FW sparger
- Both RPV pressures follow injection; transmitters still working
- DW and SC follow injection
- Transmitters still working
- Approximately 15 psig difference between RPV and DW/SC pressures
- Based on ranges DW and SC would be considered to be more accurate

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1F1 - RPV Metal Temps & SRV Temps
Time: T+346.2 hours

- Power restored to many AC indicators
- Initially upscale indicating possibly temperatures above 400°C (752°F)
- Slightly more than 5.5 hours to drop on-scale
- Where are the temperatures dropping to?
  - 56.84 psig (304°F)
  - DW/SC pressure 23.8 psig (265°F)
  - Lowest value 278°F

DOE Forensics helped industry understand this transient. This became SAWA/SAWM

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1F1 - Pressure

- RPV B pressure transmitter begins drifting at 11:30 on March 26
- Still sees the change in injection flow on March 28
- DW/SC pressures 22 psig
- Tsat (22 psig) is 262°F
- Lowest Metal Temp is 274°F

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1F1 - Pressure

- RPV A and B pressure drift and fail high
- DW and SC pressure lower to near atmospheric

DOE Forensics Team has been asked to help understand why RPV pressure instruments failed

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1F1 - RPV, DW & SRV Temps

- All temperatures trend with the saturation temperature for DW and SC pressures
- Many are essentially equal to saturation temperature by 3/29/2011

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1F1 - RPV, DW & SRV Temps

All below saturation by August 19, 2011

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1F2 - Can These Parameters Be Trusted?

RPV pressure changes:
- When suction of RCIC was changed
- When RCIC quit
- Pressure went to SRV lift pressure—Physical indication it is still correct
- SC above DW confirms
- Calculations and second level confirm RPV water is above Reference leg

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1F2 - Can RPV Pressure be Trusted?

- When RPV pressure reached the SRV lift setpoint, RPV pressure readings should be between the lift pressure and the reseat pressure
- From INPO 11-005 the relief function is 1,080.3 for 1 valve; the safety function is 1,120.1 for 3 valves
- All values look reasonable except for 1,142.6 at 17:33

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1F2 - Can RPV Water Level be Trusted?

RPV water level should be corrected for off-calibration conditions:
- Doing so gives corrected water level
- Lower in range indicated and corrected converge
- Why does level stop going down (bottom of scale/bottom of fuel)
- Can level be trusted three days into event - Yes; Why?

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1F2 - What about DW Pressure?

When does DW pressure begin lowering?
What could cause that?
- Venting (sequence of events)
- Hole in DW (what would be seen?)

What happens at same time?
Mixing of SP (DW Press 43.3 psig) 290°F

This transient is understood with help from DOE Forensics team.

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1F2 - What about SP Temperature?

- March 14, 07:00 SP Temp reading of 295°F
- March 14, 12:30 Reading of 301°F
- SC 55.77 psig (Tsat is 303.4°F) at 12:30
- DW pressure 52.7 psig (Tsat is 300.4°F) at 12:30
- After Mixing of SP (DW Press 43.3 psig) Tsat is 290°F

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Look for feedback
What causes the bumps in DW pressure?
- Injection reaching overheated core
What has core been doing since level reached BAF?
What would cause the pressure rises?

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1F2 – A Closer Look at the First Two Peaks

Look for feedback
What causes the bumps in DW pressure?
The Fire Engines have a capability of about 150 psig.

The Combined head that the fire engines must overcome must be less than 143 psig if the first bump is from injection.
The second bump in DW pressure corresponds to time operations opened the second SRV.

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1F2 - What Sequence Explains these Parameter Trends?

Can you trust absolute value of water level here? No, why?
Can you trust level trend? Yes, why?
Radiation begins rising with injection reaching core
Can’t see it but hydrogen is being generated

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1F2 - Should DW or SC Pressure be Trusted?

Which do you trust? DW pressure or SC pressure?
Two or more witnesses:
For SC pressure: So far vent hasn’t opened:
- Rupture disc should open above 62 psig
For DW pressure:
- SRV cannot physically lower pressure below its discharge location
- RPV pressure agrees with DW pressure

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1F2 – Vessel Breach Signature

Can RPV water level be trusted:
- Not for absolute value

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1F2 - Can DW Radiation be Trusted?

Can DW radiation be trusted?
- Plot on pre-calculated curves; trend is reasonable

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1F2 - Metal Temps

Initial Temperatures appear reasonable:
• 221 to 302°F

When injection went into core spray header, the points dropped below 212°F

Based on what muon tomography shows these values appear to be reasonably accurate

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1F3 - RPV Water Level

• RCIC tripped 11:36. Level drops from 172" to 116" (~48") at 12:35 when HPCI stops and restores level
• Use TSG-2 to estimate the time for level to lower indicates the levels appear accurate
• The narrow range is not responding much because level is near the variable leg tap
• Once HPCI begins lowering RPV pressure WR must be corrected to be accurate
• Also possibility of reference leg flashing

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1F3 - Reactor Level

- Last Wide Range reading at 20:30; notice it rose until pressure was maintained at 119 psig
- At 03:51 batteries exhausted
- At 03:00 Narrow range is back at bottom of scale
- 04:15 Reported TAF reached
- At 05:00 WR is back at bottom of scale
- FZ stopped lowering at 08:00 at -118"
1F3 - Drywell Pressure

- Can see RPV pressure and level instruments respond to something
- DW and SC do not
- All respond to apparent breach at 12:40

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1F3 - Drywell Pressure

Time: T+60 hours

- DW pressure and SC pressure respond to containment venting
- Some drift in parameters (water level no longer any good)
- RPV pressure too low for actual value
- SC and DW pressure crossing when vent is from SC

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1F3 - Drywell Pressure

Time: T+67 hours

- DW leading SC after venting stopped
- Leading SC indicating heat source to DW 1st
- DW radiation and DW pressure and SC pressure indicate leak from containment is now taking place

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After unit 3 RB explosion:

- DW and SC continue to confirm the other
- RPV pressure confirms trend

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Containment pressure is lowered below 10 psig and near atmospheric
- RPV pressure did not lower as far
- Consider instrument range

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Compare to pre-calculated curves

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Temperatures respond to Core Spray and lower below 212°F when injection through CS is raised above Decay Heat Removal Rate

Conclusion

A key goal of the US. Department of Energy sponsored Expert Assessments of Fukushima Forensics is Enhancing Safety for Beyond Design Basis Accidents.

This presentation has focused on the importance of understanding instrumentation in a severe accident.

As understanding comes from forensic and research, this is filtered into the industry guidelines for beyond design basis transients and accidents.

Validation of Instrumentation

Thank You