

# Exclusion of 25 deg F Embrittlement in Topical Report PWROG-15109-NP

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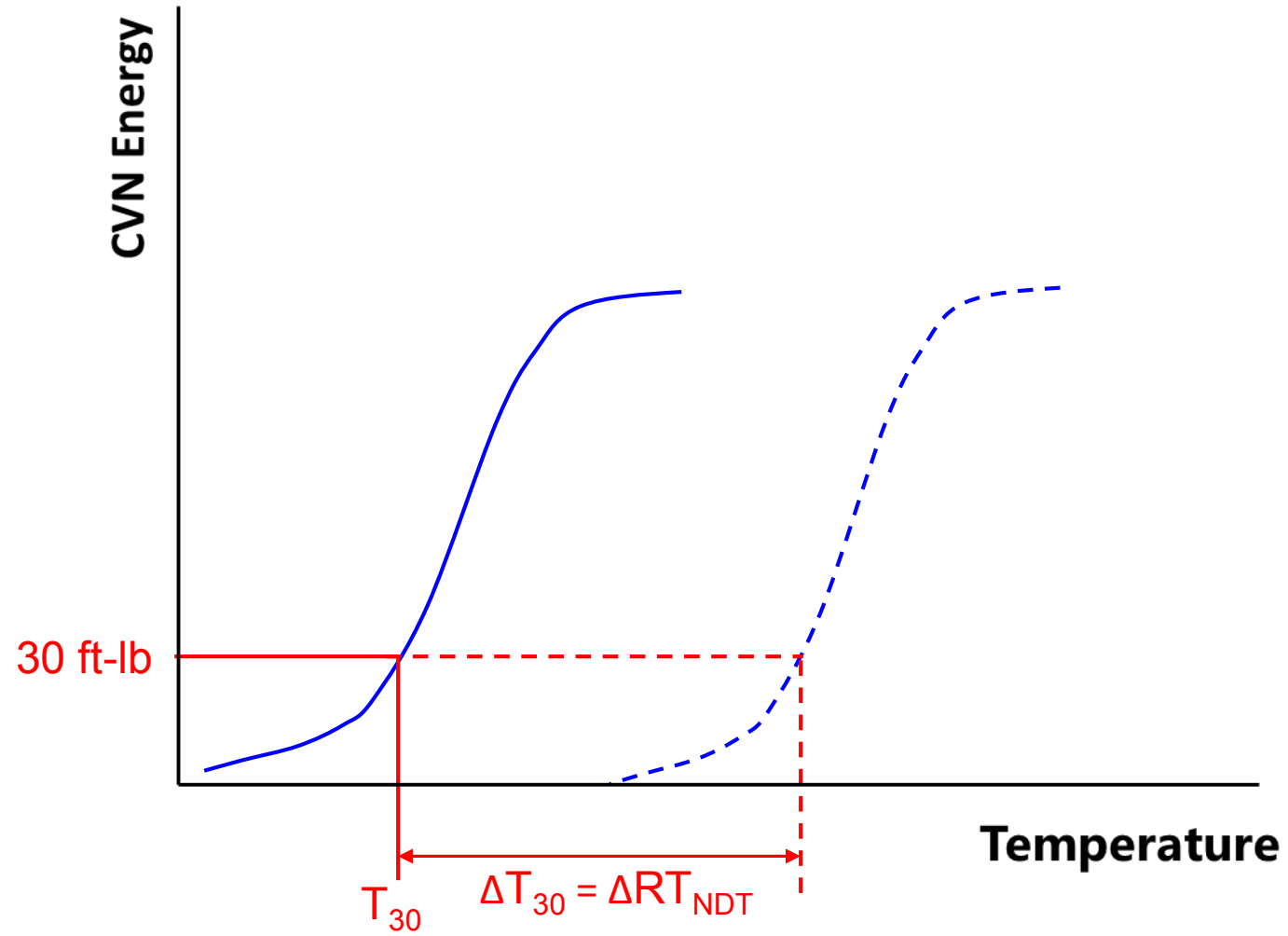
# Topics

- Exclusion of 25F embrittlement – what is it?
- NRC's position (May 2018 public meeting)
- Summary of PWROG-15109-NP and technical basis in the report for excluding 25F embrittlement
- Summary of NRC's evaluation of PWROG-15109-NP technical basis

# What is the 25F embrittlement exclusion?

- Recommendation from TLR-RES/DE/CIB-2013-01 (ML14318A177)
  - Details in the TLR; presented by EPRI in May 2018 (ML18141A392)
  - Embrittlement may be excluded if  $\Delta RT_{NDT} < 25F$
  - Considered scatter in  $\Delta RT_{NDT}$  surveillance capsule data (prior 2002) in the neighborhood of  $1 \times 10^{17}$  n/cm<sup>2</sup> (E > 1 MeV)

# What is $\Delta RT_{NDT}$ ?



# NRC's position

(May 2018 Public Meeting, ML18141A456)

- TLR is not an acceptable basis for neglecting embrittlement effects if  $\Delta RT_{NDT}$  or  $\Delta T_{30}$  less than 25F.
- Current NRC position is described in RIS 2014-11: RPV toughness calculations must account for radiation effects for those materials with fluence greater than  $10^{17}$  n/cm<sup>2</sup> (E > 1 MeV), without exclusion even if  $\Delta RT_{NDT}$  or  $\Delta T_{30}$  less than 25F.
- NRC staff is prepared to review any industry proposal which provides an adequate technical basis for the proposal.

# Summary of PWROG-15109-NP

- Objective is to demonstrate that pressure-temperature (P-T) limits for reactor pressure vessel (RPV) nozzles are bounded by the P-T limits in the traditional beltline location (RPV shell).
- Developed generic P-T limits for RPV nozzles and compared with all NRC-approved P-T limits in the RPV shell to show nozzles are bounded.
- Topical report can be referenced if nozzle fluence is below a threshold corresponding to  $\Delta RT_{\text{NDT}}$  of 25F.

# Summary of PWROG-15109-NP

- Need a generic adjusted reference temperature (ART) for RPV nozzles
- ART = initial properties + embrittlement  
= initial  $RT_{NDT}$  +  $\Delta RT_{NDT}$  + margin

# Summary of PWROG-15109-NP

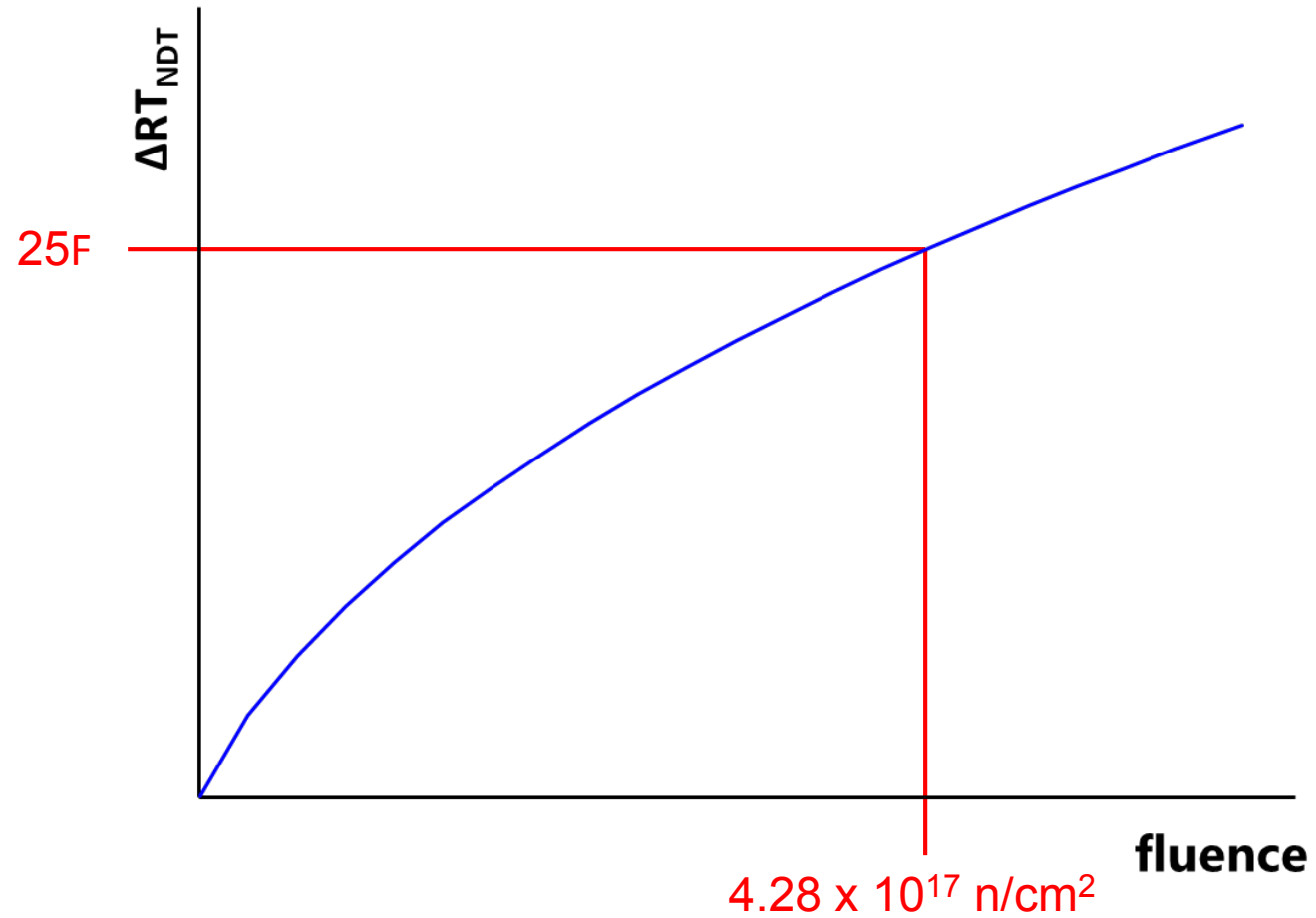
- RG 1.99, Revision 2

$$\Delta RT_{\text{NDT}} = f(\text{Cu, Ni, fluence})$$

- Best-estimate Cu wt. % from 178 inlet and outlet nozzle forgings
- Upper limit Ni wt. % for SA-508 Cl 2
- Cu, Ni → CF table in RG 1.99

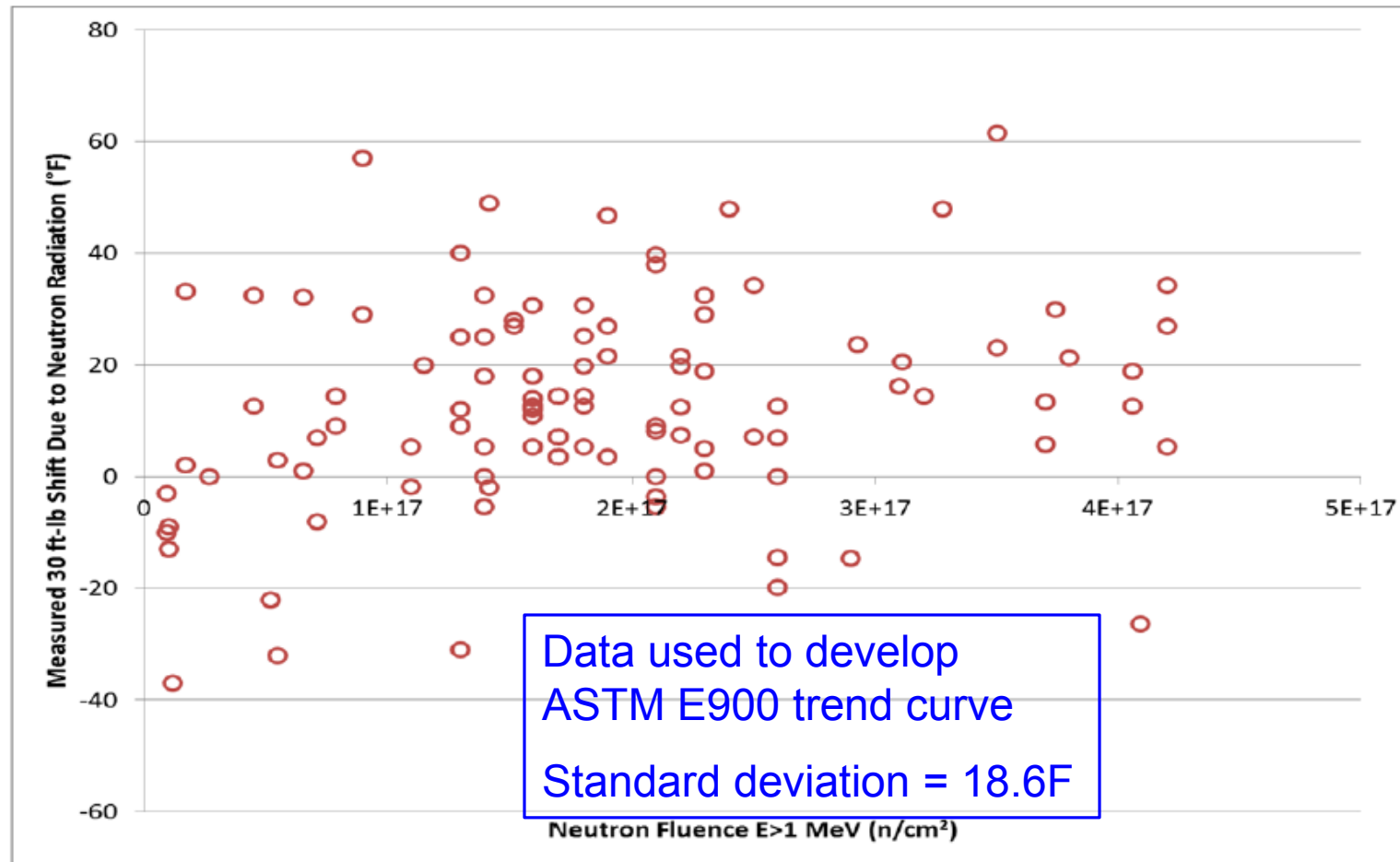


# Summary of PWROG-15109-NP



The supplement to PWROG-15109-NP (ML19091A089) included a technical basis for excluding  $\Delta RT_{\text{NDT}}$  of 25F.

# Summary of Technical Basis in PWROG-15109-NP for excluding 25°F



# Summary of Technical Basis in PWROG-15109-NP for excluding 25°F

- 18.6F < 25F  
but
  - Reasonable compared to standard deviation from known embrittlement trend curves for forgings:
    - 17F (RG 1.99, Rev 2)
    - 18.6F (10 CFR 50.61a, Cu ≤ 0.072 wt %)
    - 19.6F (10 CFR 50.61a, Cu > 0.072 wt %)
- and
  - For RPV mat'l with high Cu (highly embrittled),  $\Delta RT_{NDT}$  at  $0.99 \times 10^{17}$  n/cm<sup>2</sup>
    - 24.5F (Cu = 0.30 wt %)
    - 25.4F (Cu = 0.28 wt %)
    - 29.6F (Cu = 0.35 wt %)

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- The technical basis presents compelling reasons for excluding 25F but to ensure reasonable assurance, the staff performed an independent assessment of the safety impact of including 25F in the generic nozzle P-T limits developed in the report.

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  - Focused on PWRs in which the nozzle has largest potential to become limiting
    - Shell mat'ls (inc shell welds) with low Cu content (screen in)
    - Nozzle fluence at end of life  $< 1 \times 10^{17}$  n/cm<sup>2</sup> (screen out)
    - Plant-specific P-T limit analyses show shell P-T limits bound the nozzle (screen out)

18 units

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  - Further screening by taking the generic nozzle ART calculated in the report for 1/4T flaw (43F) and adding the 25F (and corresponding margin) to it in the ART formula.
  - Two ways:

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  1. Conservative

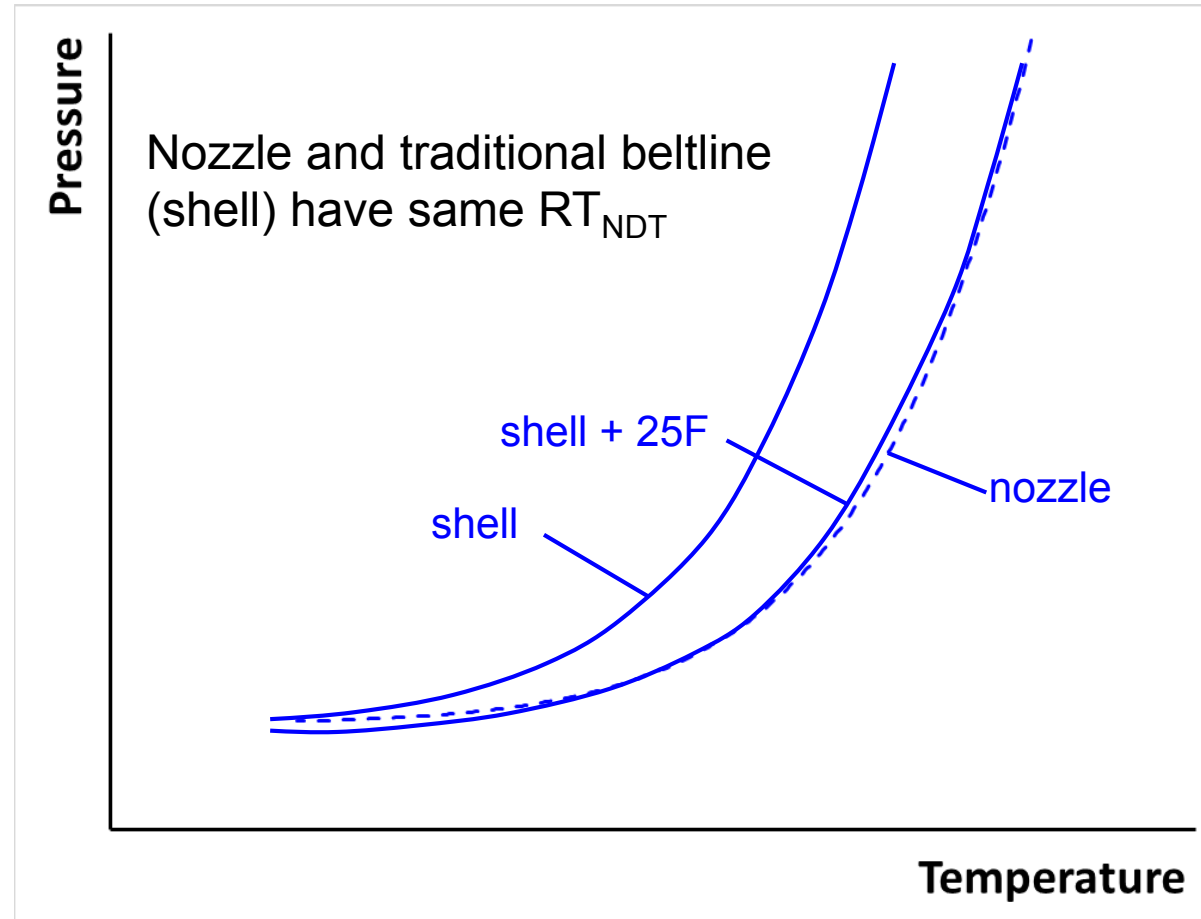
$$\text{ART} = \underset{\substack{\uparrow \\ 43F}}{\text{init RT}_{\text{NDT}}} + \underset{\substack{\uparrow \\ 25F}}{\Delta \text{RT}_{\text{NDT}}} + \underset{\substack{\uparrow \\ 2\sqrt{(0^2 + 12.5^2)}}}{2v(\sigma_i^2 + \sigma_{\Delta}^2)} + \underset{\substack{\uparrow \\ 25F}}{25F}$$

$$= 118F$$

due to bounding stress difference between nozzle corner and shell geometry



# Summary of NRC's evaluation of PWROG-15109-NP technical basis



# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  - 2. RG 1.99, Rev 2

$$\text{ART} = \underset{\substack{\uparrow \\ -66.4F}}{\text{init RT}_{\text{NDT}}} + \underset{\substack{\uparrow \\ 25F}}{\Delta\text{RT}_{\text{NDT}}} + \underset{\substack{\uparrow \\ 2\sqrt{(54.5^2 + 12.5^2)}}{2\sqrt{(\sigma_i^2 + \sigma_{\Delta}^2)}}} + 25F$$

$$= 95F$$

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  - Further screening of 18 units by looking at limiting  $RT_{NDT}$  values
  - $RT_{NDT} < 95F$  (very suspect, screen in)
  - $95F < RT_{NDT} < 118F$  (questionable, screen in)
  - $RT_{NDT} > 118F$  (ok, screen out)

4 units

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

- Independent safety assessment
  - For 4 units, compared generic nozzle P-T limits with their approved traditional beltline (shell) P-T limits
  - Used generic nozzle ARTs, but have to remove 25F due to stress
  - Thus, 118F → 93F and 95F → 70F
  - For two units, shell P-T limits bound 93F nozzle P-T limits
  - For one unit, shell P-T limit coincides with 93F nozzle P-T limit
  - For last unit, shell P-T limit coincides with 70F nozzle P-T limit
    - Given conservatisms in generic nozzle ART, P-T limit methodology, 1/4T flaw → no safety impact

# Summary of NRC's evaluation of PWROG-15109-NP technical basis

## Conclusions:

- The staff's independent safety assessment and acceptance of the use of the 25F embrittlement exclusion are specific only to PWROG-15109-NP.
- For other applications, the NRC will need adequate technical basis for acceptability of 25F embrittlement exclusion.

**END**