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# NRC Public Webinar

## Basis for NRC Requirements on Pressurized Thermal Shock

*March 19, 2013*

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# Welcome

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# Introductions

- **Cynthia Pederson**
  *Deputy Regional Administrator, Region-III*
- **Jack Giessner**
  *Chief, Project Branch 4*
- **Mark Kirk**
  *Senior Materials Engineer, Office of Nuclear Regulatory Research*
- **Mel Holmberg**
  *Senior Reactor Inspector, Region III*

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# Agenda

- Properties of metals
- Nuclear reactors: designed against embrittlement
- Pressurized thermal shock (PTS)
  - What is it?
  - How is safety ensured?
  - Specifics of Regulations
- Status at Palisades

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# Purpose

- Provide a perspective on vessel embrittlement and PTS, as regulated by the NRC
- Discuss the vessel at the Palisades plant
- Answer questions from the public

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# Ductility & Embrittlement

## Definitions

**Ductile** metals bend (absorb energy) when pulled upon

**Embrittlement**

**Embrittlement** (a **loss of ductility**) reduces how much a metal can bend before it breaks

**NRC Regulations limit embrittlement to ensure safety**

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# Reactor Pressure Vessels (RPV)

## Designed Against Embrittlement

- The reactor coolant system produces forces on the RPV
  - Pressure
  - Thermal
- RPV designed to resist these forces, even after embrittlement
  - RPV steel has adequate toughness
  - Toughness measures ductility
- NRC limit on embrittlement keeps the probability of fracture extremely low


**RPV: Pressurized Cylinder**

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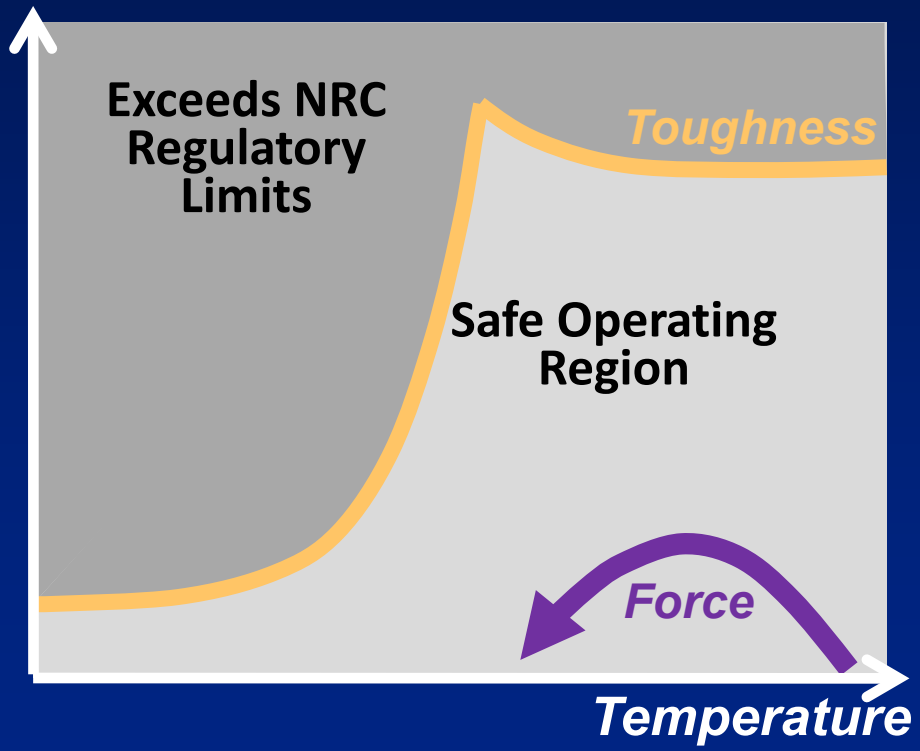
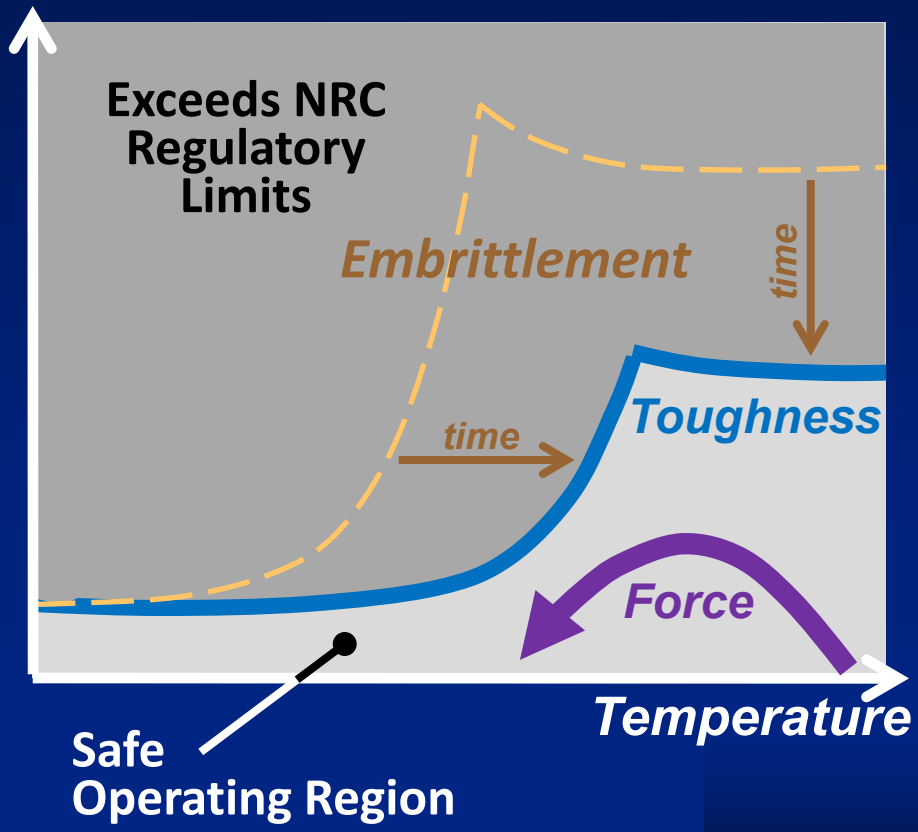
# Toughness *vs.* Force

## Toughness Always Greater

**Before reactor operation**
***force < toughness***




**After operation (& embrittlement)**
***force (still) < toughness***



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# Embrittlement is Measured

## NRC Requires: 10 CFR 50 Appendix H

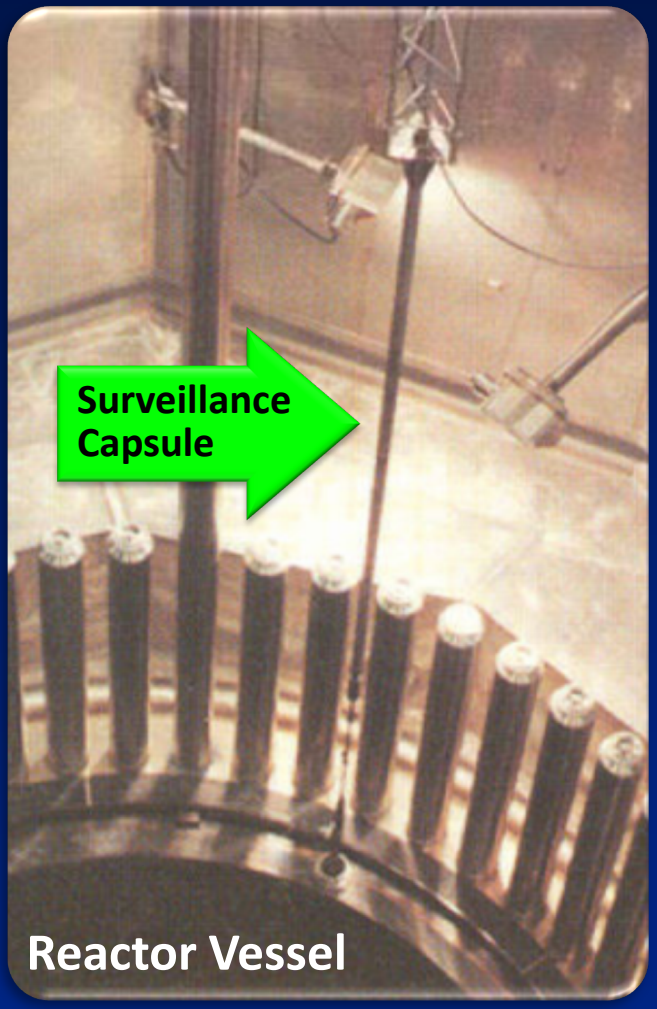
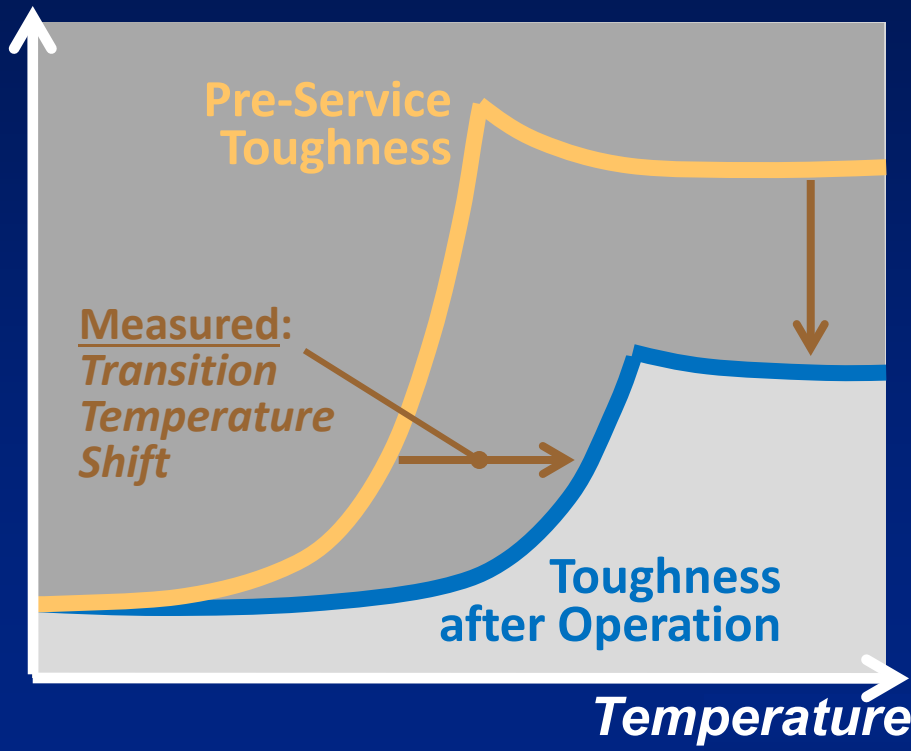



*Photo courtesy of J. May, AREVA NP GmbH*

**Embrittlement monitored by surveillance programs & limited by regulations**



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# Brittle (or Embrittled) Materials
## Used Safely

## Nuclear RPVs

- Steel embrittles over time
- Embrittlement is
  - Understood
  - Measured
  - Limited
- NRC limits transition temperature shift so that toughness always exceeds force
  - Ensures safety

## Non-Nuclear Example

- Aircraft landing gear
- Very high strength steels needed to resist landing forces
- High strength steels have lower toughness
  - Less ductile
  - More brittle
- Nuclear RPV toughness exceeds landing gear toughness (even after embrittlement)

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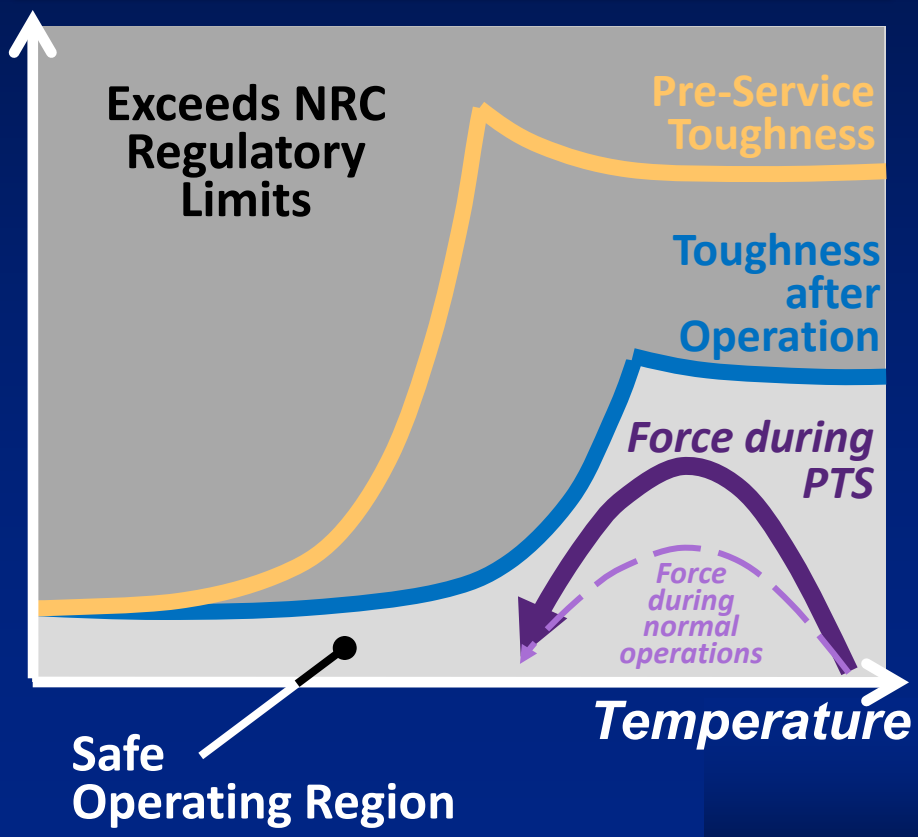
# Pressurized Thermal Shock
## PTS

- **A rare event**
  - Designed against
  - Regulated for safety
- **More force applied to RPV during PTS**
  - Injection of cold water
  - Rapid cooling

**Even during PTS**
**(& after embrittlement)**
***force (still) < toughness***



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# NRC PTS Rules

## 10 CFR 50.61 (1984)

- Significant conservatisms restrict operations with no safety benefit
- Conservatisms include
  - Over-estimated force
  - Under-estimated toughness
- Conservatisms evidenced by
  - Additional toughness data
  - More realistic & thorough analyses
  - Scale model experiments that validate predictions

## 10 CFR 50.61a (2010)

- Considerations
  - Conservatisms in 50.61 limits will cause many plant-specific submittals
  - All submittals would address the same fundamental issues
- Alternative approaches
  - Many plant-specific assessments reviewed individually
  - **Comprehensive re-assessment of PTS risk performed proactively & with thorough review by technical experts**

Selected

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# Alternative PTS Rule

## Rigorous Development Process

- Joint effort of NRC, national labs, universities, and industry (providing data & operating experience)
- Approximately 10 year project duration
- Many opportunities for public involvement
- Extensive expert technical reviews
  - Advisory Committee for Reactor Safeguards
  - Independent expert panel
- Full documentation available on NRC website

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# Alternative PTS Rule

## Technical Approach & Insights

- Three analyses performed

| Analysis | | Purpose |
|---|---|---|
| PRA | Probabilistic Risk Assessment | Establish events that cause rapid cooling. Assess human factors. |
| TH | Thermal Hydraulics | Quantify force produced by rapid cooling |
| PFM | Probabilistic Fracture Mechanics | Quantify resistance to rapid cooling, accounting for embrittlement. |

- Detailed assessments of three plants (Palisades, Beaver Valley, Oconee)
- Results generalized to all plants in USA
  - Only the most severe forces produce any risk
    - Similar across the fleet
  - Rapid cooldown to 200 °F below operating temperature needed to produce any risk
    - Operational controls limit the likelihood of such cooldowns occurring

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# Comparison of PTS Rules

## 10 CFR 50.61 & 10 CFR 50.61a

| Aspect of Rule | 10 CFR 50.61 REQUIRED | 10 CFR 50.61a VOLUNTARY |
|---|---|---|
| Embrittlement Limits | More restrictive | Less restrictive |
| Plant-specific surveillance data check | Required: 1 test | Required: 3 tests |
| Plant specific inspection for flaws | Not required | Required |

- 10 CFR 50.61a embrittlement limits are less restrictive than 10 CFR 50.61
  - Justification: More thorough, consistent, & realistic assessment
- Limits can only be used once screening criteria are met
- Screening criteria ensure that key features of the 50.61a model apply to the plant being assessed
  a. The embrittlement of specific RPV materials
  b. The flaws in a specific RPV

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# Current Status at Palisades

## Relative to PTS Limits

### 10 CFR 50.61

- One of the most embrittled plants in USA
- Palisades operates in compliance
- Embrittlement limits will be exceeded in 2017
- Palisades must
  - Address limit exceedence in 2014 (2017 minus 3 years), or
  - Shut down in 2017
- Options for operation beyond 2017
  - Annealing to reverse embrittlement,
  - Analysis to provide a plant specific safety justification, or
  - Use 10 CFR 50.61a

### 10 CFR 50.61a

- One option Palisades has to continue operation after 2017
- Would need to
  - Analyze data
  - Check embrittlement
  - Check flaws
- Generic analysis of US fleet in NUREG-1874 suggests this is a viable option for Palisades

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# Palisades Summary

- The vessel at Palisades is one of the most embrittled in the USA
- Palisades continues to operate as long as it demonstrates compliance with NRC regulations
- Palisades continues to operate safely
- There are several options by which continued safe operation of the Palisades vessel after 2017 could be demonstrated
  - The licensee decides what option to take

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# Questions

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# Meeting Closure

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# Meeting Contacts

- Followup Questions - Contact the NRC Region III Office of Public Affairs
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  - OPA3@nrc.gov