Application of Representative Operational Constraints and Experience for a Limiting PWR Vessel

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Presentation Outline

1. Key Operating Constraints for Westinghouse PWR Plants
   - Design Basis Cool-down Transients
   - Residual Heat Removal (RHR) System Capabilities
2. Operating PWR Plant Cool-down History
   - Temperature and its rate of change
   - Pressure and its rate of change
3. Two Bounding Cool-down Transients
   - No pressure or temperature hold times
   - With bounding pressure and temperature hold times
4. Cool-down Failure Probabilities for Limiting PWR

Representative Vessel Design Transients

- Cool down from operating temperature to 70˚F at 100˚F per hour
  - Operating temperature is approximately 550˚F but varies somewhat with plant design (number of loops)
- Cool down from operating pressure of 2250 psia to 400 psia at 740 psi per hour
- Heat up is the exact opposite of cool down

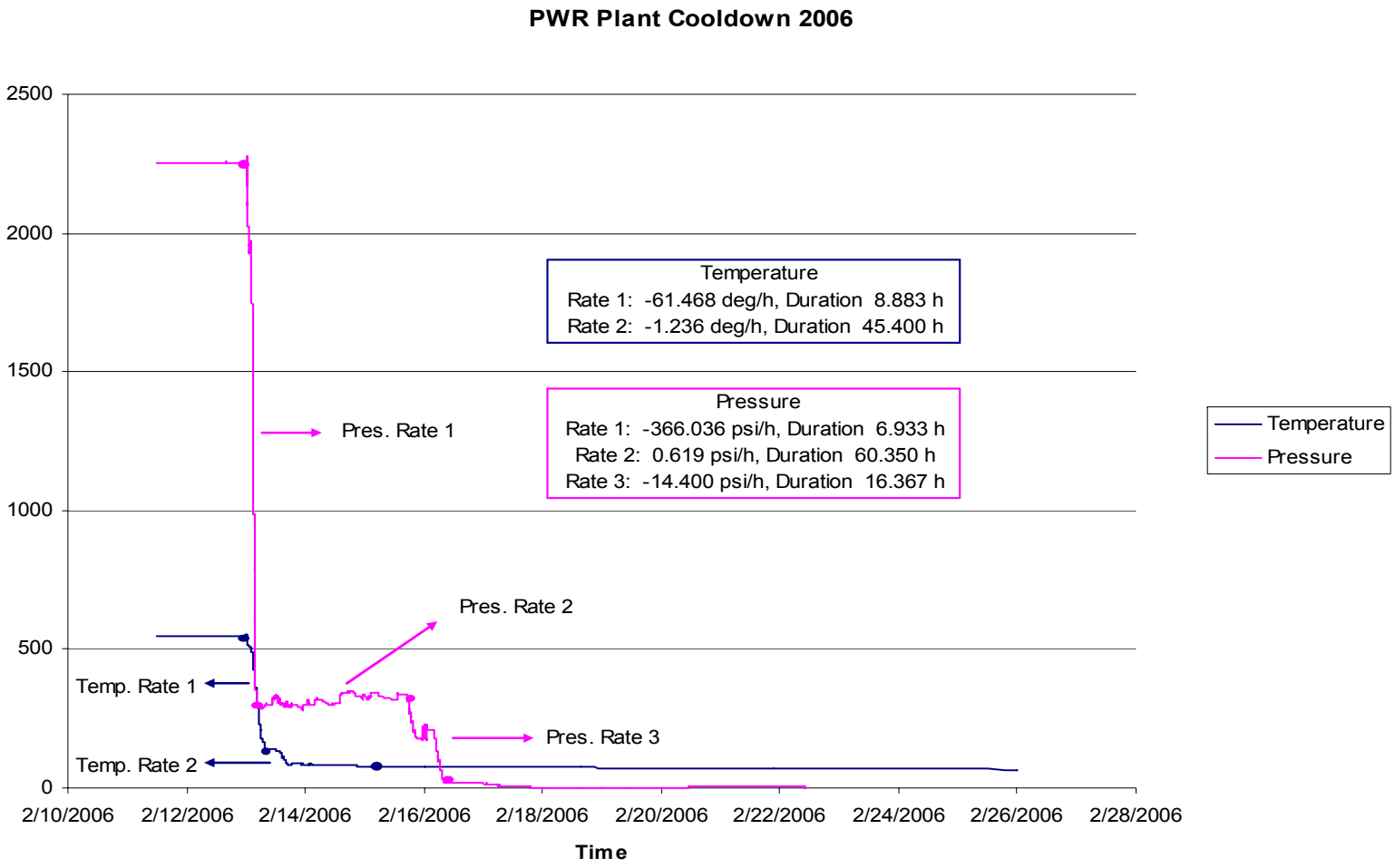
Residual Heat Removal System Capabilities

- Below the changeover temperature (310˚F to 350˚F), vessel heat up and cool down is limited by the capabilities of the residual heat removal (RHR) system:
  - Designed for cool-down of 50˚F/hour for a component cooling water (CCW) system temperature of 120˚F
  - Cool down of 100˚F/hour is possible for short periods of time at high temperature if CCW temperature is low (60˚F)
  - Maximum possible heat-up rate is 50˚F/hour
  - Maximum possible RHR pressure is 450 psia

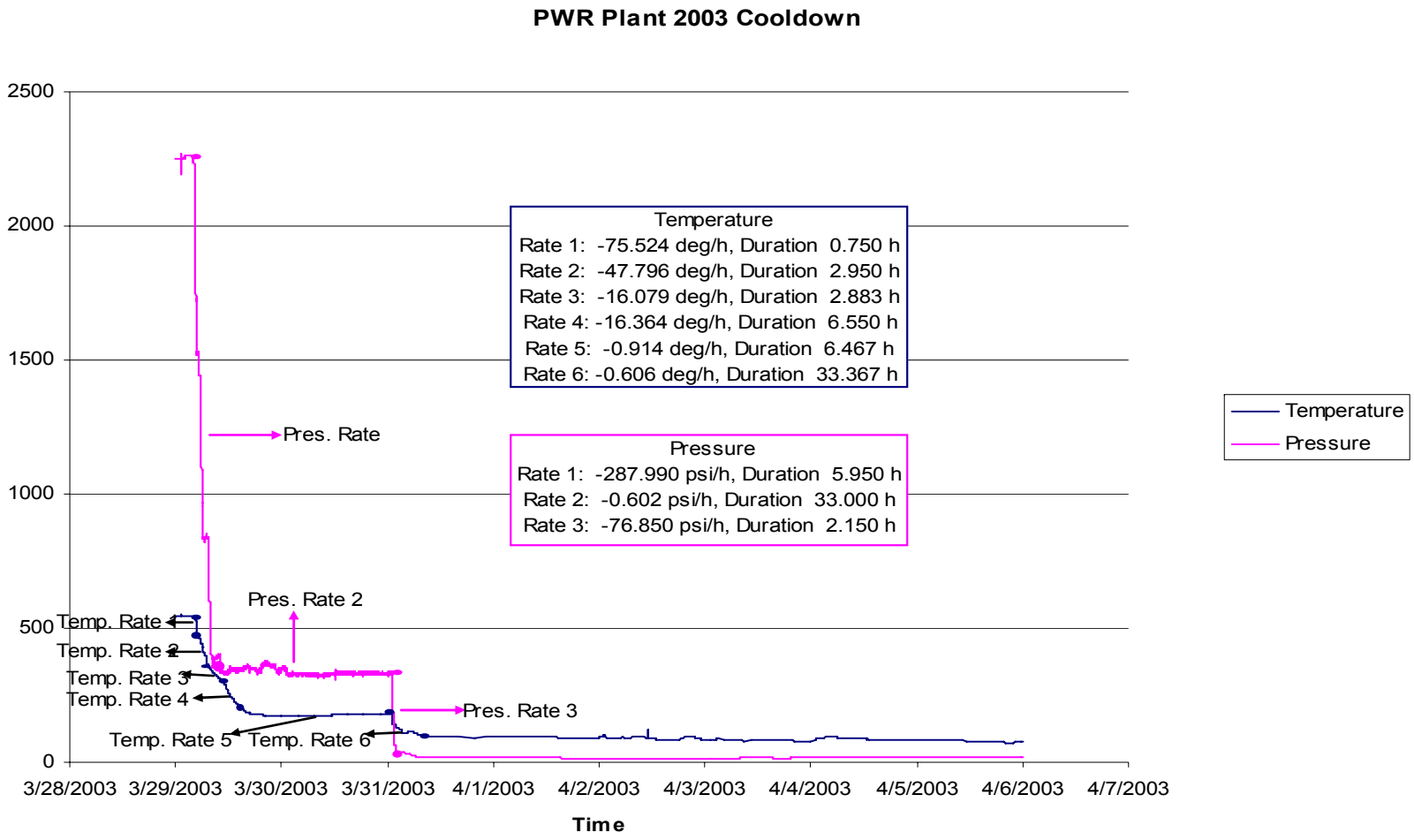
Operating PWR Plant Cool-down History

- Operating history obtained for 36 cool-down transients from 1991 to 2007 at 11 Westinghouse PWR Plants (9 Domestic and 2 International)
- Each individual cool-down transient was represented as a number of segments with average linear rates of change for both temperature and pressure
- Segments with higher rates of change were further subdivided to determine the maximum rate of change in any one hour

PWR Plant Example Cool-down History 1



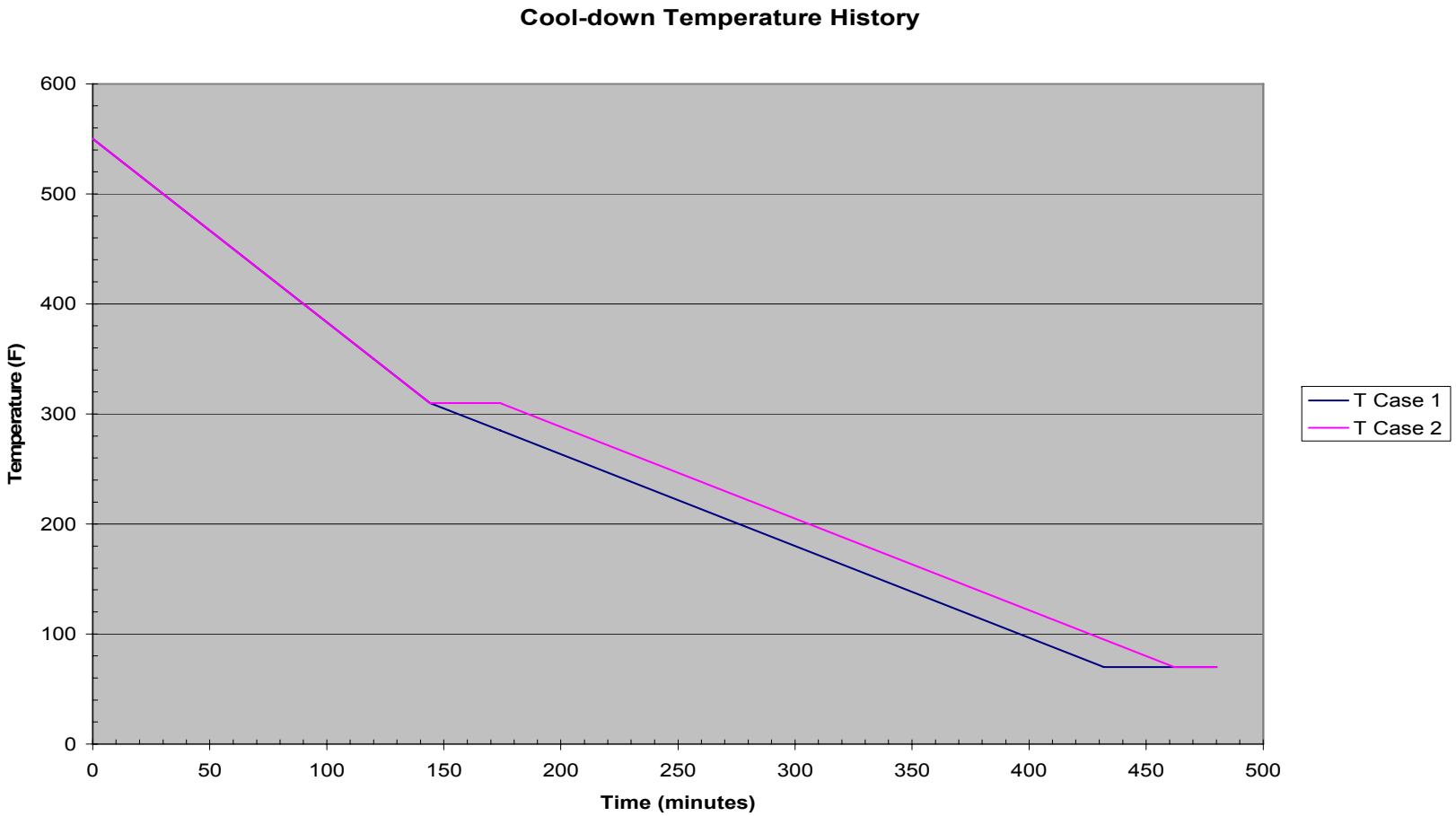
PWR Plant Example Cool-down History 2



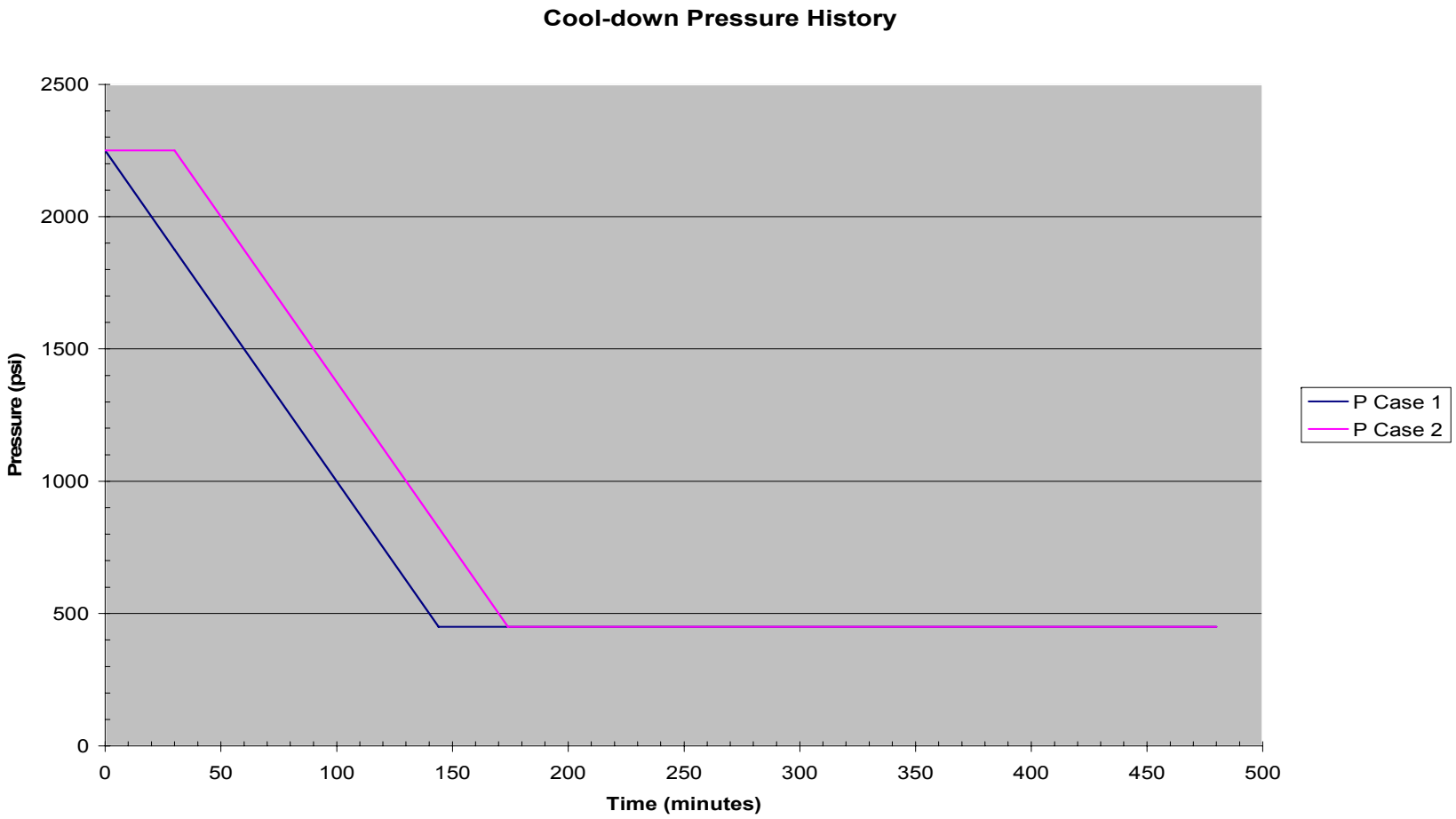
Operating PWR Plant Cool-down Results

- All average cool-down rates were less than 100˚F/hour above RHR changeover
- The maximum temperature change in any one hour was also less than 100˚F/hour above RHR changeover
- All cool-down rates were less than 50˚F/hour below RHR changeover
- Maximum hold time for initial pressure was 30 minutes
- All average pressure rates were less than 740 psi/hour
- The maximum pressure change in any one hour was much greater than 740 psi/hour on several occasions

Bounding Cool-down Transient Temperature



Bounding Cool-down Transient Pressure



Cool-down Failure for Limiting PWR Vessel

- Limiting PWR vessel based upon through-wall cracking frequency (TWCF) for PTS is Indian Point Unit 3
- Limiting vessel fluence based upon 54 EFPY for 60 years
- Probabilities of initiation and failure calculated with 20,000 vessel simulations using Rev. 2 of FAVOR 06.1 (ΔT30 per proposed voluntary PTS Rule 10CFR50.61a)
  - With and without pressure and temperature hold times
  - With and without effects of warm pre-stress (WPS)

FAVOR Calculated Cool-Down Probabilities

Case Number	Hold Time (minutes)	Warm Pre-Stress	Cond. Prob. Initiation	Cond. Prob. Failure
1a	0.0	Yes	0.0	0.0
1b	0.0	No	2.76E-09	1.62E-11
2a	30.0	Yes	0.0	0.0
2b	30.0	No	4.61E-09	2.29E-09

Conclusions for Preliminary PWR Results

- Design and operational constraints on cool-down transients are applicable based upon operating experience.
- Limiting cool-down transients can be developed that satisfy these constraints and the following Appendix G conditions:
  - Pressure margin of 1.0 vs. 2.0,
  - RT_{NDT} margin of 0.0˚F vs. 60˚F,
  - Hold times of 30 minutes vs. 0.0 minutes.
- FAVOR calculated initiation and failure probabilities are extremely low for the limiting PWR vessel, even without the benefit of warm pre-stress