

Evaluation of Pressure-Temperature Limits for Normal RPV Startup and Shutdown

Ron Gamble

NRC Public Meeting, Rockville MD

August 28, 2012



Conclusions

- Review of several plant operating pressure and temperature time histories indicate that startup and shutdown sequences do not coincide with the ASME XI Appendix G pressure-temperature (P/T) limit curves.
- Protective devices provide additional assurance that normal operation does not occur on or near the Appendix G P/T limits.
- The through-wall cracking frequency (TWCF) for low-temperature overpressure (LTOP) event pressures up to the Appendix G limits for normal reactor startup and shutdown are less than $1\text{E-}7$ per operating year.
- The conventional and risk-informed (RI)-Appendix G allowable P/T limits provide adequate margins against RPV failure for the range of postulated flaws important to reactor safety, including 0.03t surface breaking flaws.

ASME Section XI, Appendix G P/T Limits

- Relationship between P/T Limits and P/T Operating Conditions
 - The operational pressure and the Appendix G allowable pressure limits coincide, e.g., BWR pressure test.
 - The operational pressure is lower than Appendix G allowable pressure, e.g., normal plant startup and shutdown.
- Events such as normal startup and shutdown proceed according to procedure and some abnormal occurrence (operator error or equipment malfunction) is required to reach the Appendix G P/T limits.
- In this instance, the Appendix G P/T limits are avoidance limits, and the frequency with which the Appendix G P/T limits are reached is much less than 1.

PWR Events

- Service experience indicates that the only major challenge to PWR Appendix G P/T limits is from overpressure events at low temperature (LTOP) where the system pressure exceeds the pressure conditions associated with normal plant startup and shutdown.
- Experience shows that LTOP events almost always occur during reactor startup. The temperature range where these events occur is between 100 and 200°F.
- The current frequency for LTOP events has been estimated as 10^{-2} /operating year. (resolution of Generic Safety Issue 94: NUREG-0933,)

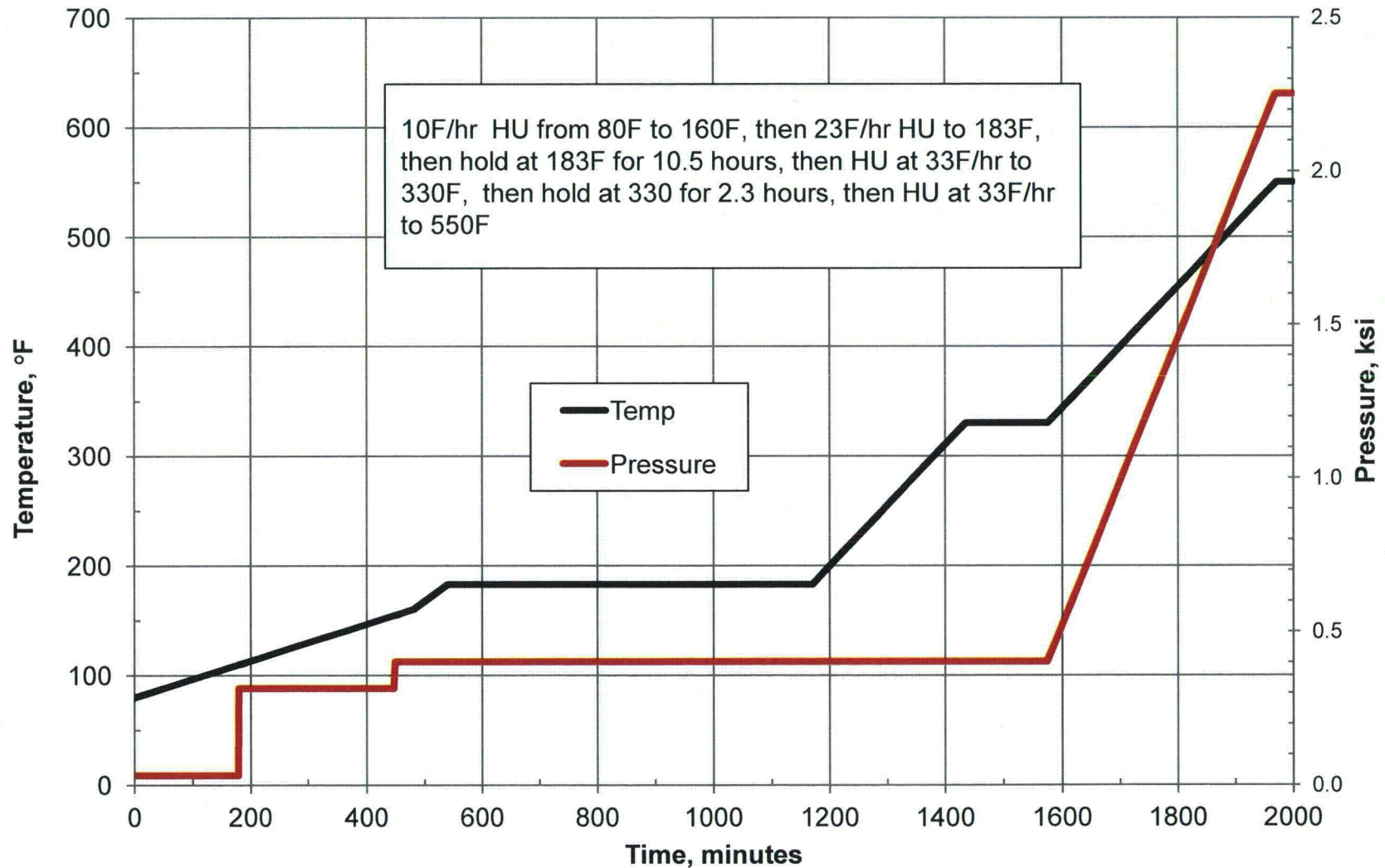
Example Assessments of PWR Normal Operating and LTOP Events

- Startup
 - Definition of a representative PWR normal startup sequence (i.e., heatup [H/U])
 - Deterministic and probabilistic analyses of a representative normal PWR startup sequence
 - Deterministic and probabilistic analyses of a previous LTOP event during startup
- Shutdown
 - Definition of a representative PWR normal shutdown sequence (i.e., cooldown transient [C/D])
 - Deterministic and probabilistic analyses of a representative PWR shutdown sequence
 - Deterministic and probabilistic analyses of a postulated LTOP event during shutdown

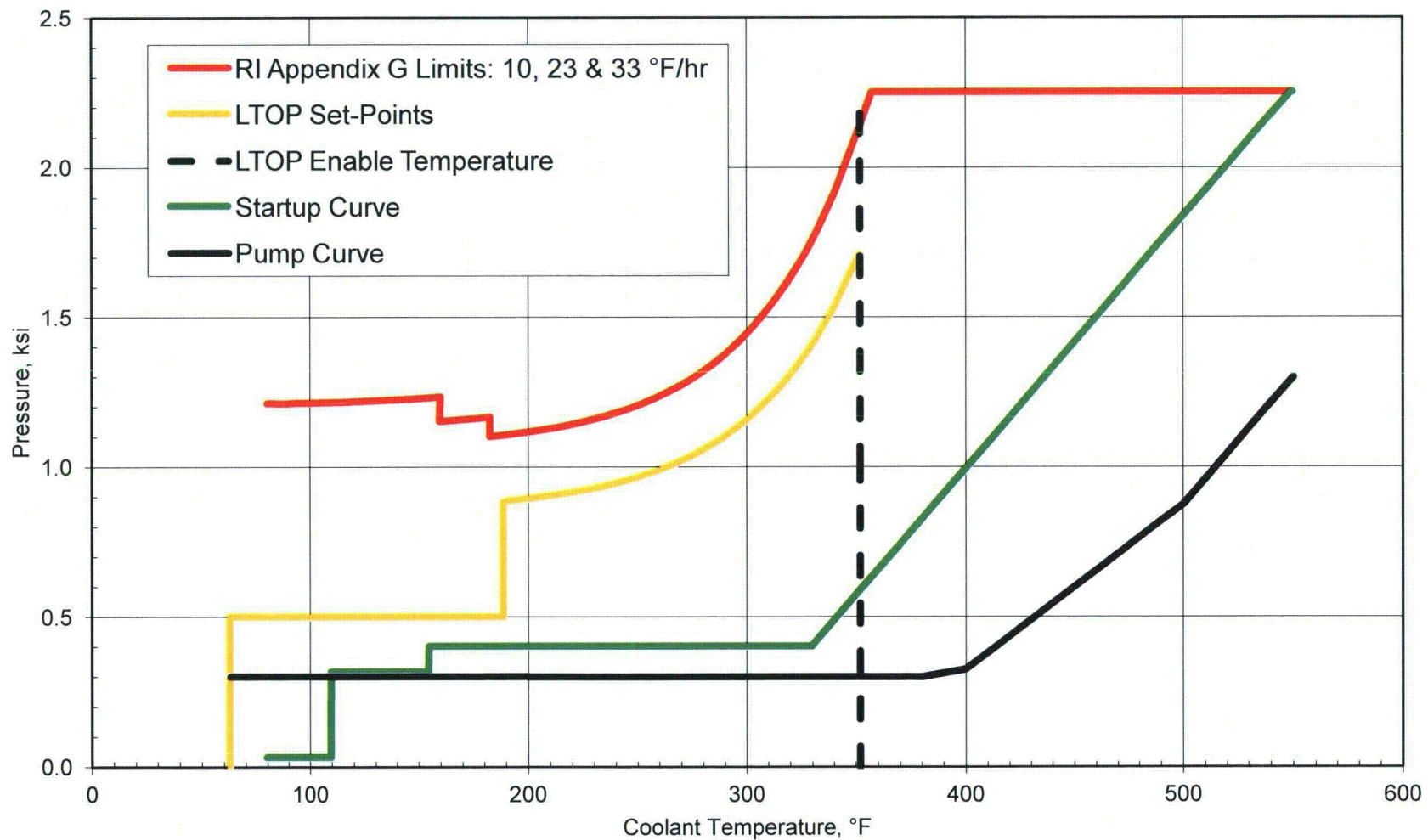
Example Assessments of PWR Normal Operating and LTOP Events

- Fluence at limiting axial weld = $4.83\text{E}19$ n/cm² (60 EFPY)
- Cu = 0.213, Ni = 1.110, P = 0.19, Mn = 1.32 wt%
- Initial $RT_{NDT} = -56^{\circ}\text{F}$
- RT_{NDT} at CBMI at 60 EFPY = 266°F
- Analysis includes weld residual stress
- Cladding stress free temperature = 488°F
- Cladding thickness = 0.25-inch
- Through clad circumferential flaw with total depth equal 0.2625-inch
- Total wall thickness (including cladding) = 8.75-inch
- Vessel inside radius = 86-inch
- Analyses performed with FAVOR 09.1 (includes weld residual stress)

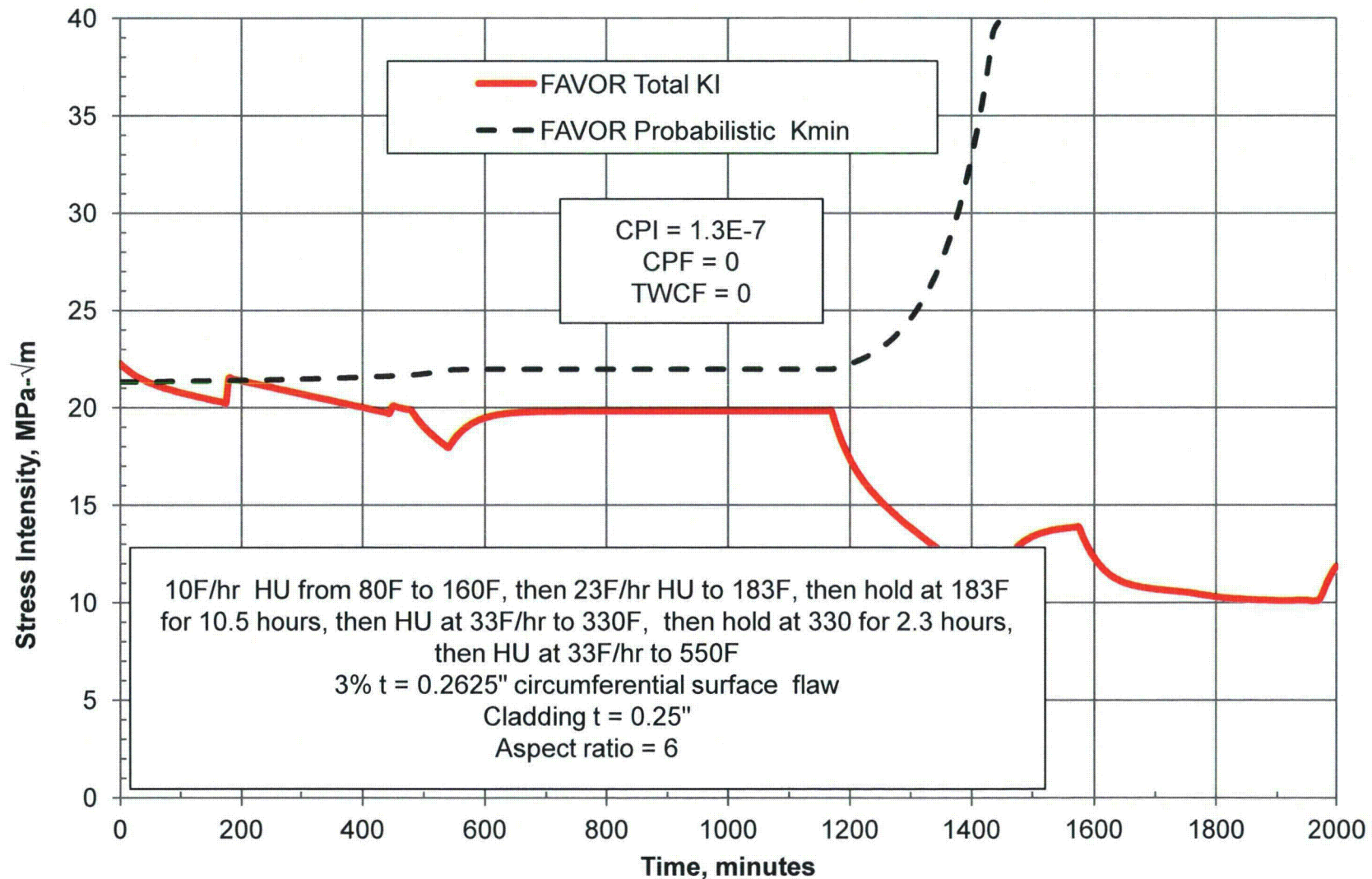
Representative PWR Plant Startup Sequence



P/T Curves for Normal Startup, Appendix G Limits and Operational Constraints



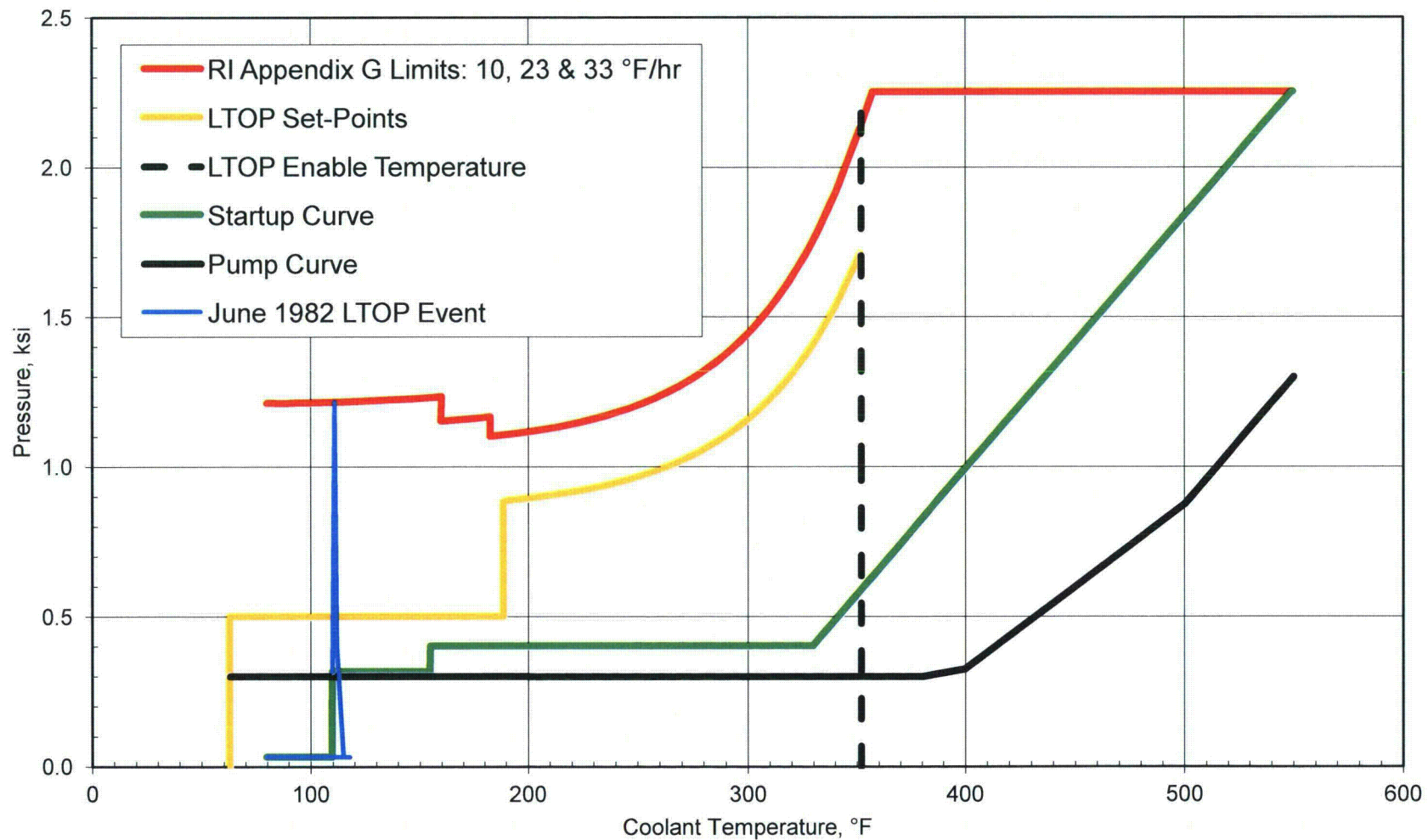
Evaluation of Representative PWR Plant Startup Sequence



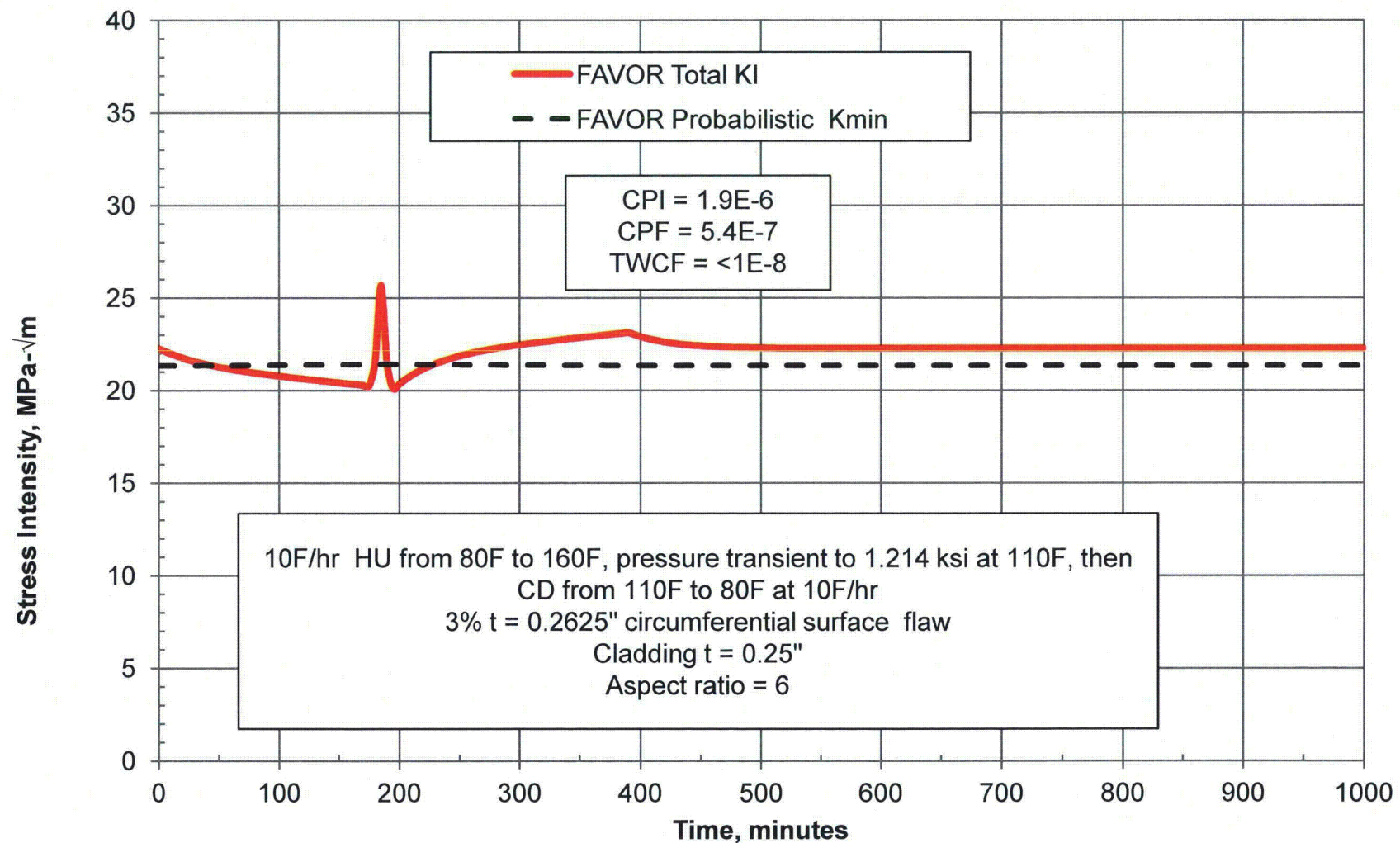
Example Assessment of a PWR LTOP Event During Startup

- LTOP event during normal plant startup.
 - IN 82-17, June 11, 1982
 - Event occurred during startup after a refueling outage
 - The reactor was shutdown and the RCS was water solid
 - Event initiated at 110°F following start of the RC pumps, the pressure exceeded the normal operating pressure in the low temperature region (310 psi), the overpressure mitigation system failed to operate, the Appendix G pressure limit of 480 psi was exceeded, and the pressure reached 750 psi before operator action terminated the event.
 - This illustration will assume the pressure reached the RI-Appendix G limit of 1,214 psi. before the event was terminated.

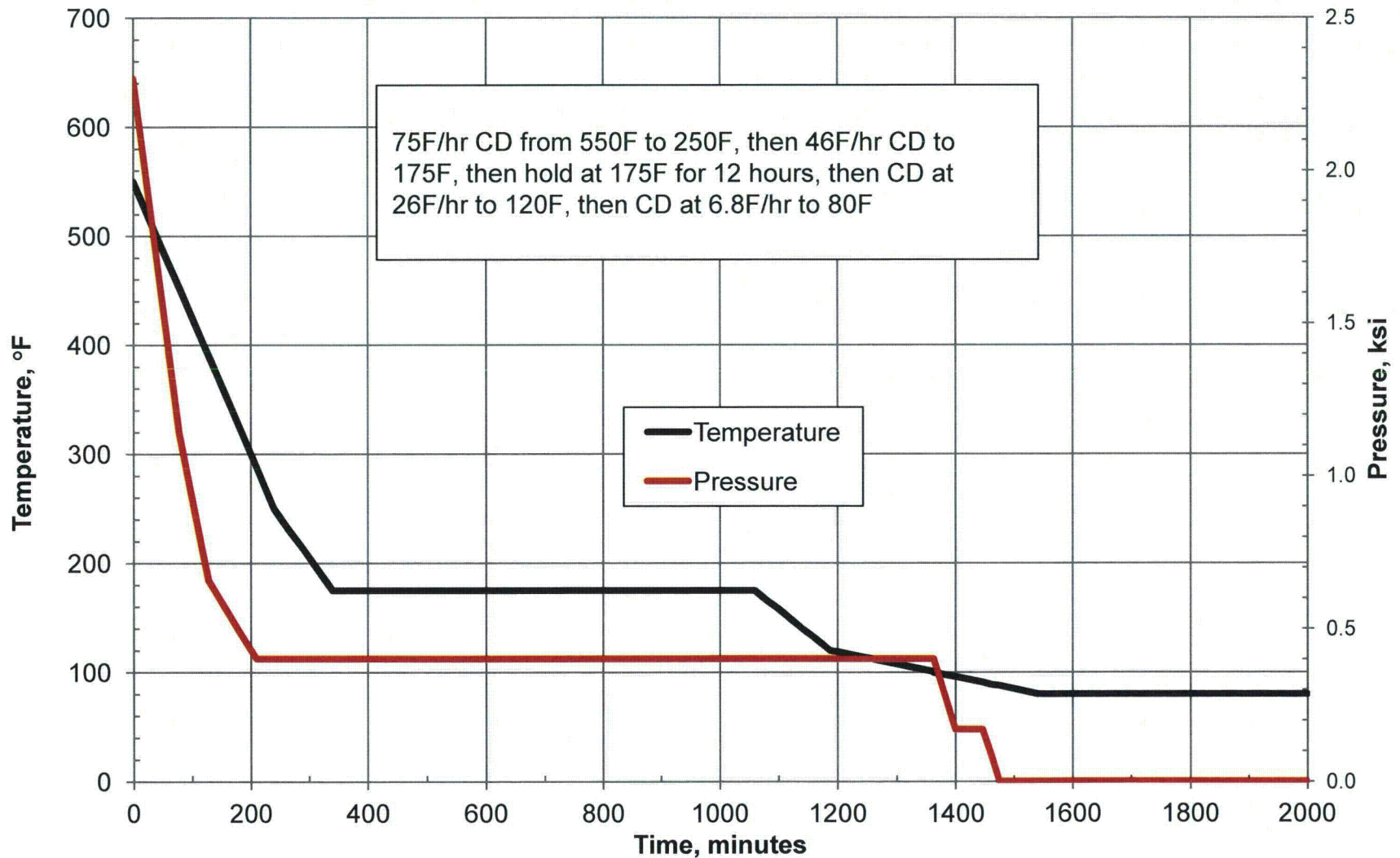
P/T Curves for Normal Startup, Appendix G Limits, Operational Constraints and LTOP Event



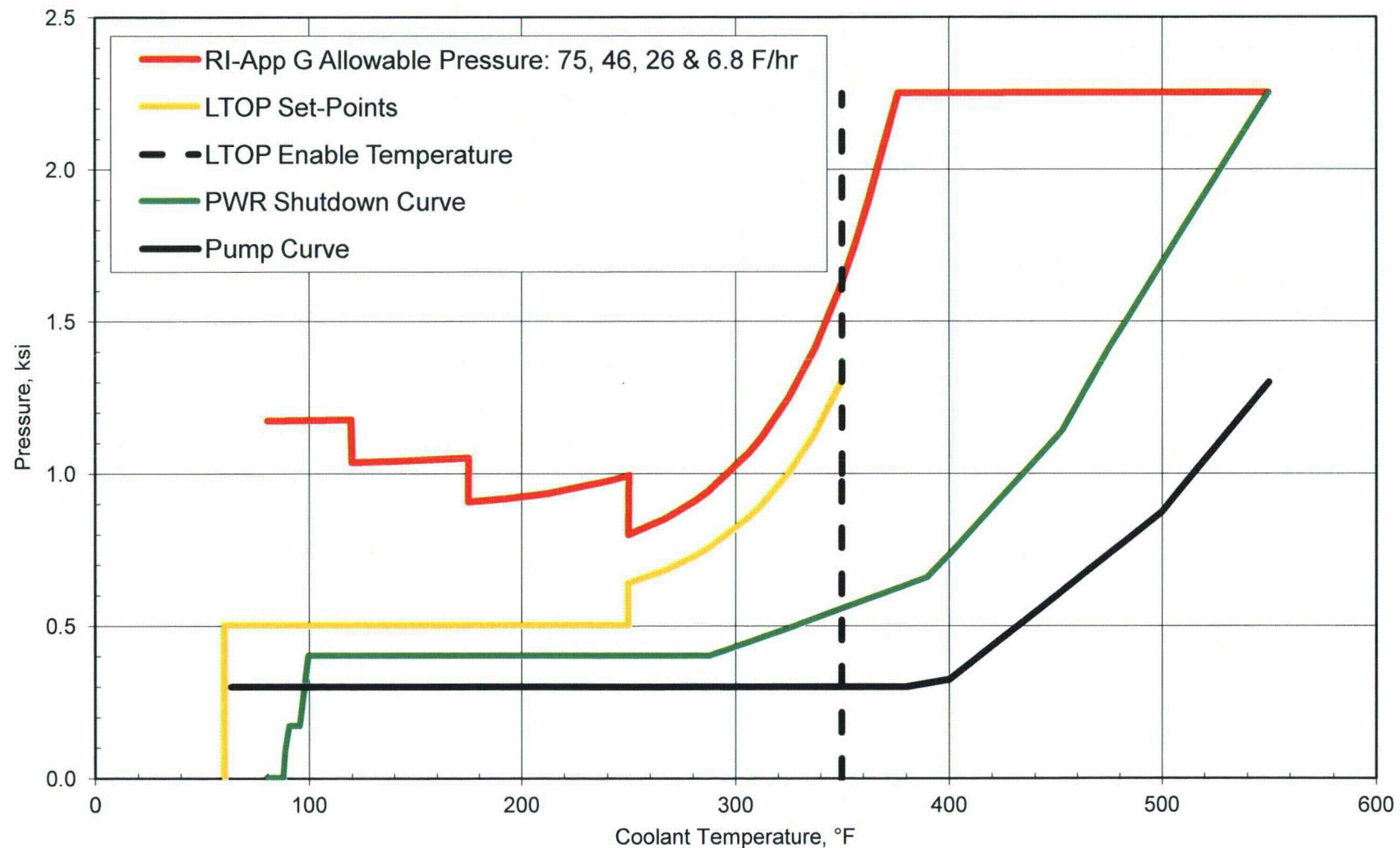
Evaluation of PWR Plant Startup with Pressure Transient



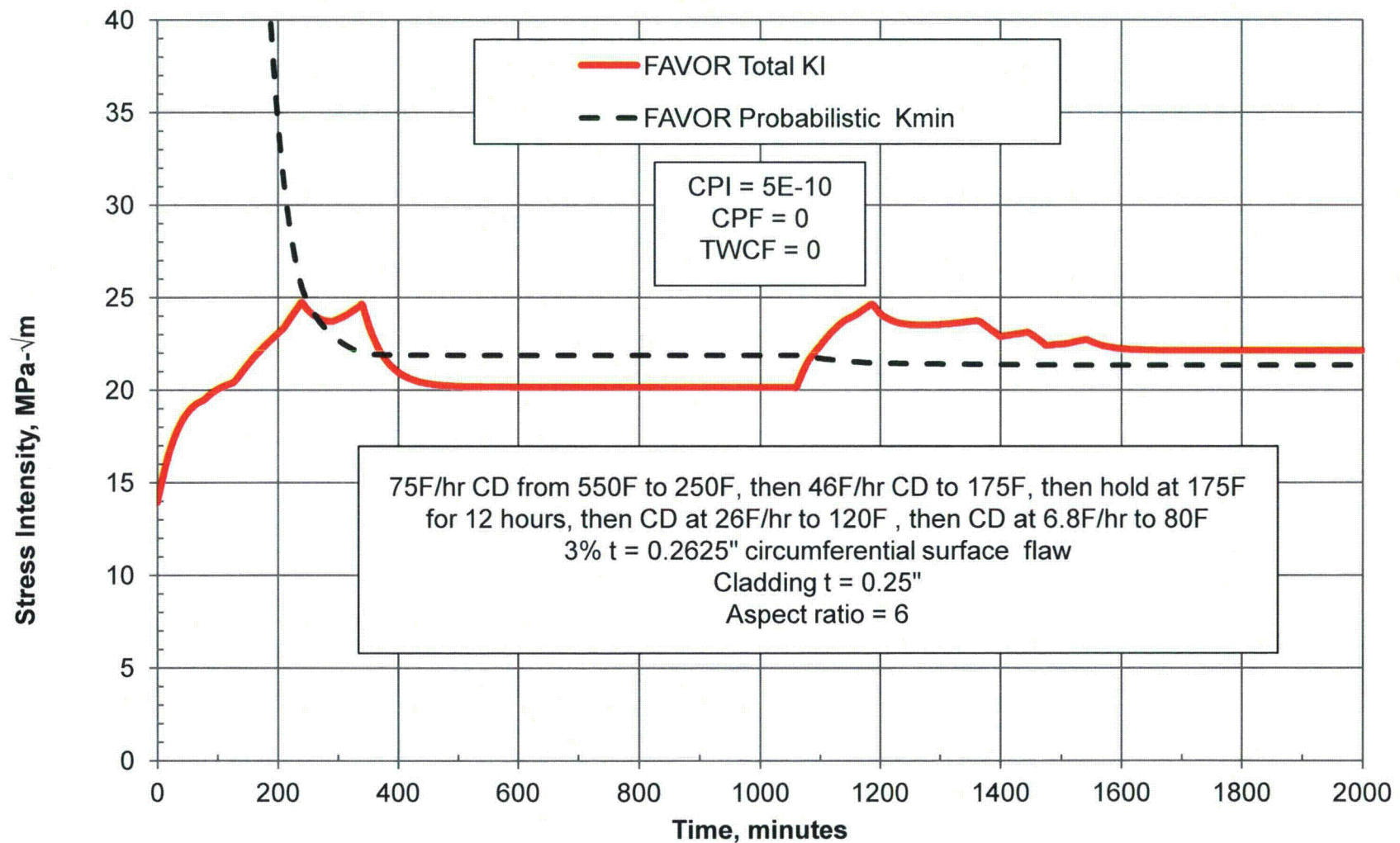
Representative PWR Plant Shutdown Sequence



P/T Curves for Normal Shutdown, Appendix G Limits and Operational Constraints



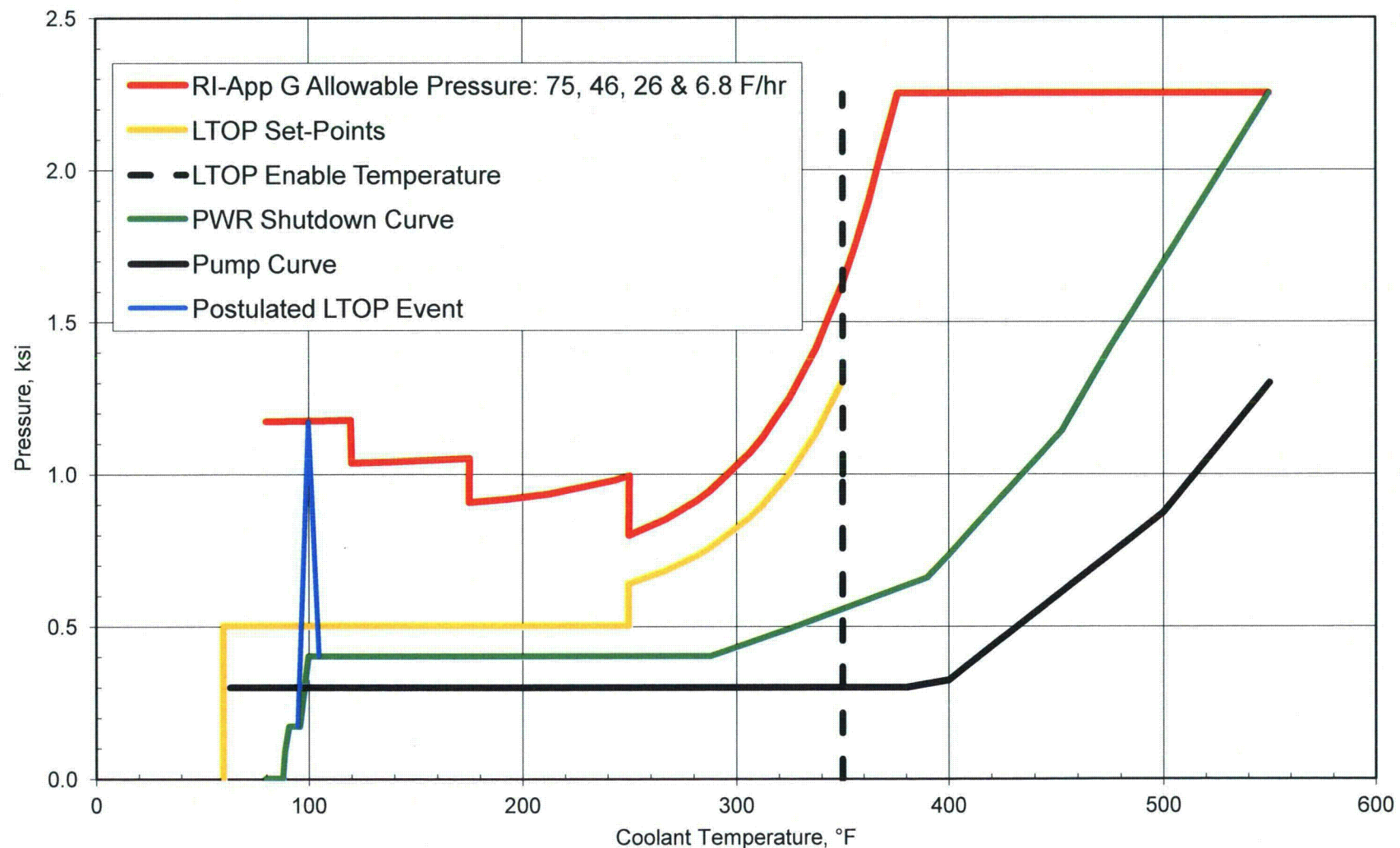
Evaluation of Representative PWR Plant Shutdown Sequence



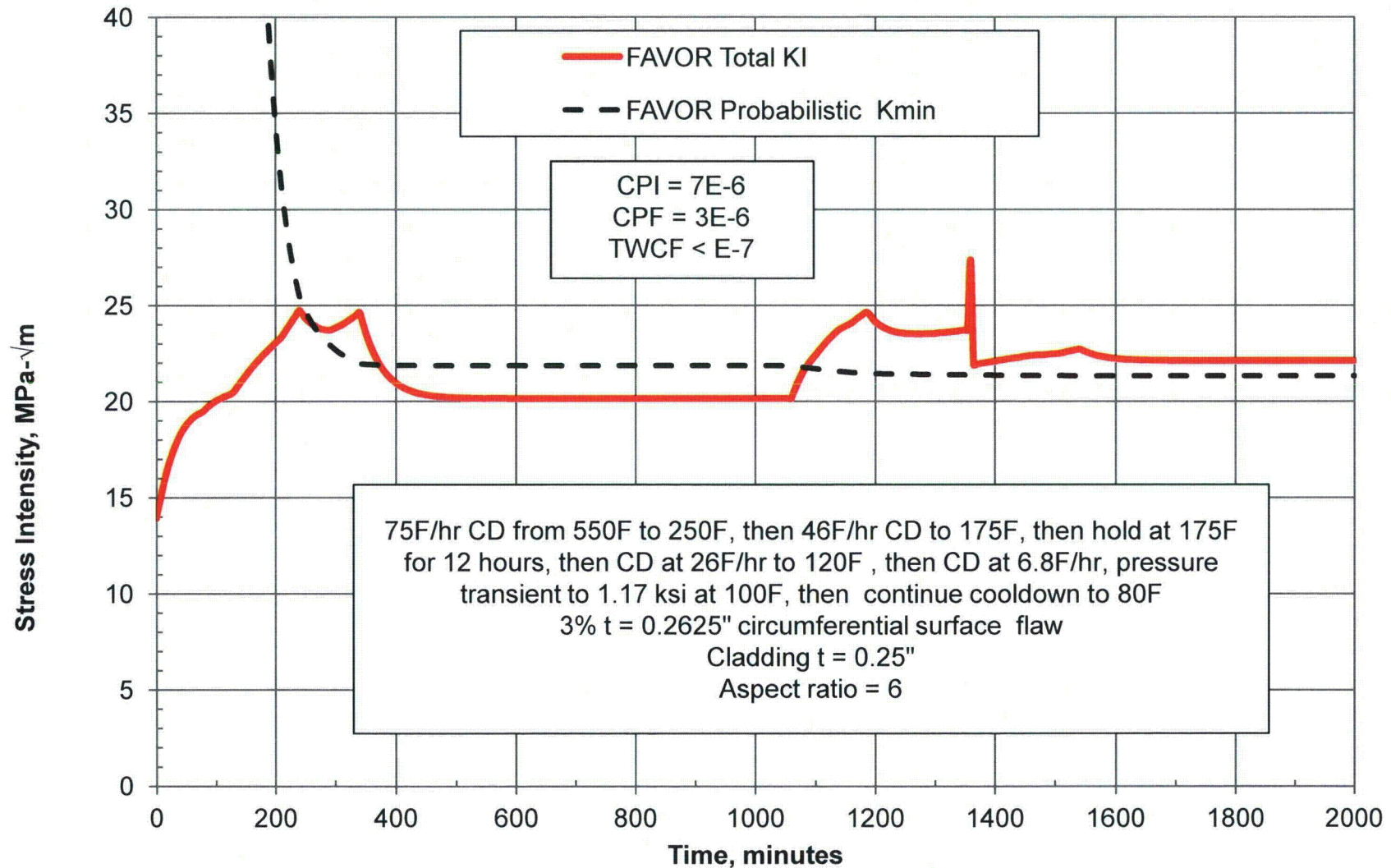
Example Assessment of a Postulated PWR LTOP Event During Shutdown

- LTOP event during normal plant shutdown.
 - Although LTOP events typically don't occur during shutdown an example is provided for illustration purposes.
 - The LTOP event is postulated to occur at 100°F, which corresponds to the temperature at which the system is near the end of cold shutdown, and the Appendix G allowable pressure is 1,170 psi.

P/T Curves for Normal Shutdown, Appendix G Limits, Operational Constraints and LTOP Event



Evaluation of PWR Plant Shutdown with Pressure Transient



Conclusions

- Review of several plant operating pressure and temperature time histories indicate that startup and shutdown sequences do not occur on the Appendix G P/T limits.
- Protective devices provide additional assurance that normal operation does not occur on or near the Appendix G P/T limits.
- The TWCF for LTOP event pressures up to the Appendix G limits for normal reactor startup and shutdown are less than $1\text{E-}7$ per operating year.
- The conventional and RI-Appendix G allowable P/T limits provide adequate margins against RPV failure for the range of postulated flaws important to reactor safety, including 0.03t surface breaking flaws.



Together...Shaping the Future of Electricity

Mark Burzynski
Rolls-Royce
Civil Nuclear Business, Instrumentation & Controls
5959 Shallowford Road, Suite 511
Chattanooga, Tennessee 37421

SUBJECT: AUDIT REPORT REGARDING THE ROLLS-ROYCE "SPINLINE 3 DIGITAL
SAFETY INSTRUMENTATION AND CONTROL PLATFORM" TOPICAL
REPORT (TAC NO. ME3600)

Dear Mr. Burzynski:

By letters dated July, 1, 2009, December 23, 2009, January 8, 2010, and February 2, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML092160017, ML093570361, ML100120087 and ML100330793, respectively), Rolls Royce submitted licensing topical report (LTR) "SPINLINE 3 Digital Safety I&C [Instrumentation and Control] Platform" and supporting documentation in accordance with Interim Staff Guidance (ISG) Document-06 to the U.S. Nuclear Regulatory Commission (NRC) staff for review.

The NRC Instrumentation and Controls Branch (EICB) conducted a regulatory audit on June 11 - 15, 2012, at the Rolls-Royce facility in Grenoble, France. The audit results will provide additional support for the safety evaluation of the LTR being conducted by the NRC staff. The audit report is enclosed.

If you have any questions, please contact me at 301-415-4053 or by e-mail at Jonathan.Rowley@nrc.gov.

Jonathan Rowley, Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulations

Project No. 773

Enclosure: Audit Report