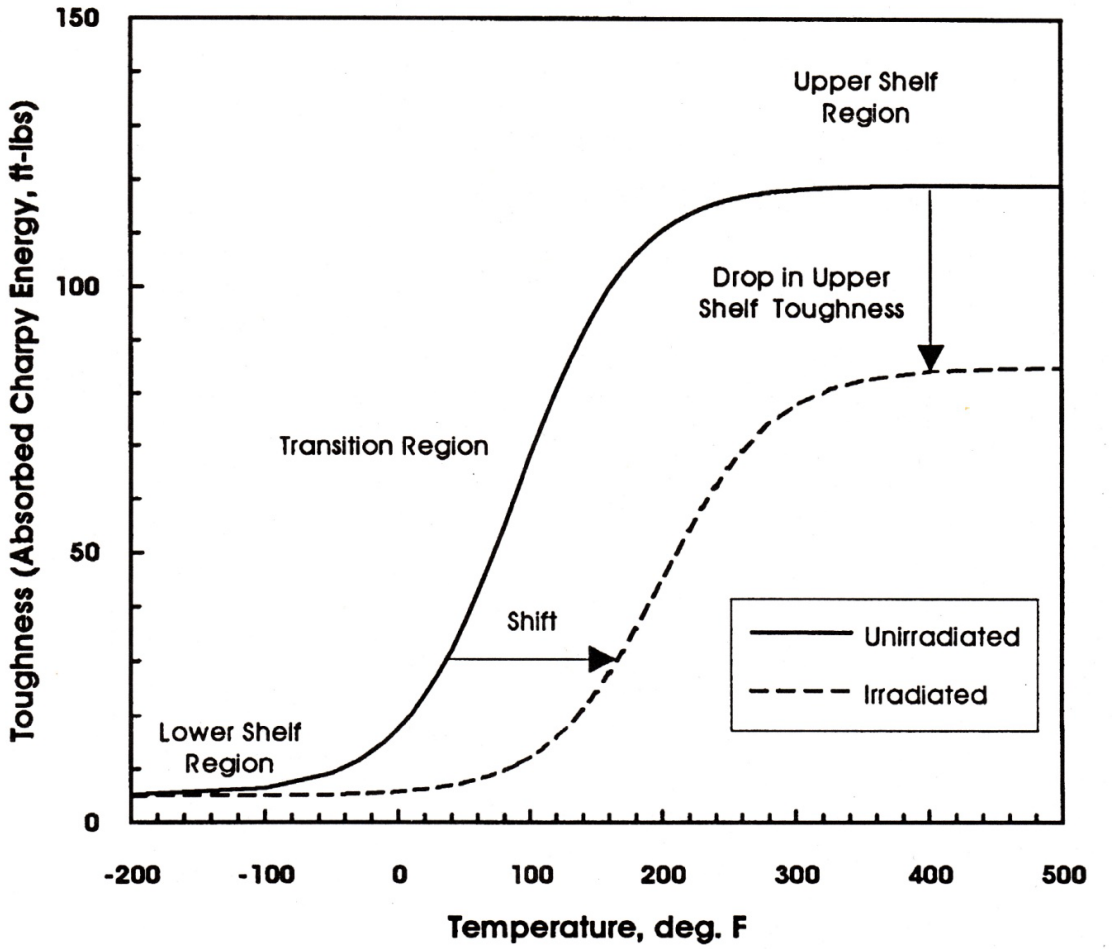
Reactor Pressure Vessel (RPV) Integrity Approach

RPV Life Extension Analyses

What is Reactor Vessel Integrity?

Charpy V-notch Curves



Primary Reactor Vessel Integrity Regulations

Low Upper Shelf Toughness	Pressure-Temperature Limits	Reactor Vessel Material Surveillance	Pressurized Thermal Shock
10CFR50 Appendix G	10CFR50 Appendix G	10CFR50 Appendix H	10CFR50.61, PTS Rule
Reg. Guide 1.99 Rev. 2 (for calculating embrittlement effects) Reg. Guide 1.161 (for Equivalent Margins Analysis [EMA]) Reg. Guide 1.190 (Calculation & Dosimetry Methods for Determining RPV Neutron Fluence)	Reg. Guide 1.99 Rev. 2 (for calculating embrittlement effects) Reg. Guide 1.190 (Calculation & Dosimetry Methods for Determining RPV Neutron Fluence)	Reg. Guide 1.190 (Calculation of Capsule Fluence) NUREG-1801 Rev. 2 and NUREG-2191 (re: Surveillance Requirements in License Renewal and Subsequent License Renewal, respectively)	10CFR50.61a, Alternate PTS Rule Reg. Guide 1.230 for implementation of 10CFR50.61a Reg. Guide 1.190 (Calculation & Dosimetry Methods for Determining RPV Neutron Fluence)
ASME Section XI Appendix K (for Equivalent Margins Analysis [EMA])	ASME Section XI Appendices G & E	ASTM E185 (-73, -79, -82) (Testing & reporting per ASTM E185-82)	

What Do I Do When…My plant goes for License Extension?

- Key License Extension Point – NEW end-of-life EFPY with projected fluence values thus being higher
- Report will be titled **T**ime-**L**imit **A**ging **A**nalysis (TLAA) – defined later
- Requires reassessment or update to ALL RPV Evaluations
  - New USE, ART and PTS values are developed
  - May need to withdraw and test another Surveillance Capsule to provide data for 60 or 80 years of operation
  - Typically, only check existing P-T curves, new ones can be developed later per 10 CFR 50, Appendix G
  - This is a good time to update or fully confirm material properties
    - May need to include extended beltline materials or RPV nozzles per NRC RIS 2014-011
- Inputs from this report will be provided to the NRC via a License Renewal Application (LRA)

Appendix G to 10 CFR 50

- Upper Shelf Energy (USE):
  - Fracture toughness requirements for protection against ductile failure
  - RPV beltline materials at the 1/4 thickness (1/4T) location must have Charpy upper-shelf energy of no less than 75 ft-lb (102J) and must maintain upper-shelf energy throughout the life of the vessel of no less than 50 ft-lb (68J), unless equivalent margins of safety can be shown
  - If the minimum USE requirement at end of life is not met, an Equivalent Margins Analysis (EMA) is required
- Pressure-Temperature (P-T) Limits
  - Fracture toughness requirements for protection against brittle failure
  - Utilize Adjusted Reference Temperature (ART) values calculated at 1/4T and 3/4T
  - Provides Minimum Temperature Requirements and invokes ASME Section XI, Appendix G
    - Minimum temperatures for performing any hydrostatic test involving pressurization of the reactor vessel after installation in the system
    - Minimum temperatures for all leak and hydrostatic tests performed after the plant is in service
    - Maximum pressure-minimum temperature curves for operation, including startup, upset, and cooldown conditions
    - Maximum pressure-minimum temperature curves for core operation

Appendix H to 10 CFR 50

- Establishes requirement for comprehensive surveillance programs
  - Prior to the introduction of Appendix H in 1973, plants had installed irradiation test samples using the guidance of the 1961 (tentative), 1962, 1966, 1970 or the then-emerging 1973 version of ASTM E-185
- RPVs that exceed 10^{17} n/cm^2 (E > 1 MeV) at the end-of-license are required to have an RPV material surveillance program
- The intent of surveillance programs is to monitor changes in the fracture toughness properties of ferritic materials in the RPV beltline that result from exposure to neutron irradiation and the thermal environment
- Augmented with License Renewal NUREGs:
  - Withdraw one capsule that receives a neutron fluence of between one and two times the peak reactor vessel wall neutron fluence at the end of the period of extended (60-years, then 80-years) operation
  - Can necessitate additional capsule withdrawal and testing and/or capsule reinsertion for further irradiation and/or new capsule fabrication, etc.

10 CFR 50.61 – PTS Rule

- Fracture toughness requirements for protection against pressurized thermal shock events
- RT_{PTS} is determined for all RPV beltline plates and/or forgings, and axial and circumferential welds
  - RT_{PTS} is ART at the vessel ID surface (not the 1/4T as for P-T curves)
    - PWR RT_{PTS} values will also be impacted by the BTP 5-3 issue discussed earlier
  - Based on end of license (EOL) fluence
  - Screening limits:
    - 270°F (132°C) for plates, forgings, and axial welds
    - 300°F (149°C) for circumferential welds
- If RT_{PTS} exceeds these screening limits, most common actions required:
  - Implement flux reduction programs reasonably practicable
  - Or apply for licensing under the Alternative PTS Rule, 10 CFR 50.61a

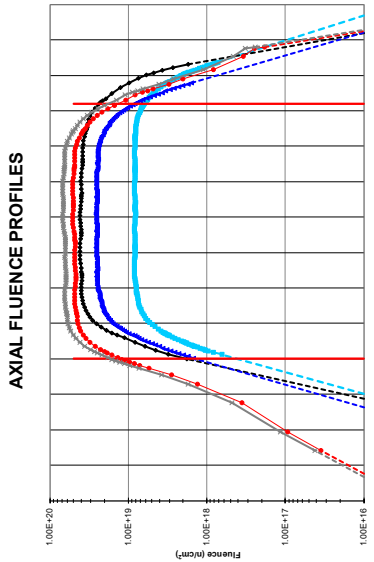
Consideration of Extended Beltline in RPV Evaluations

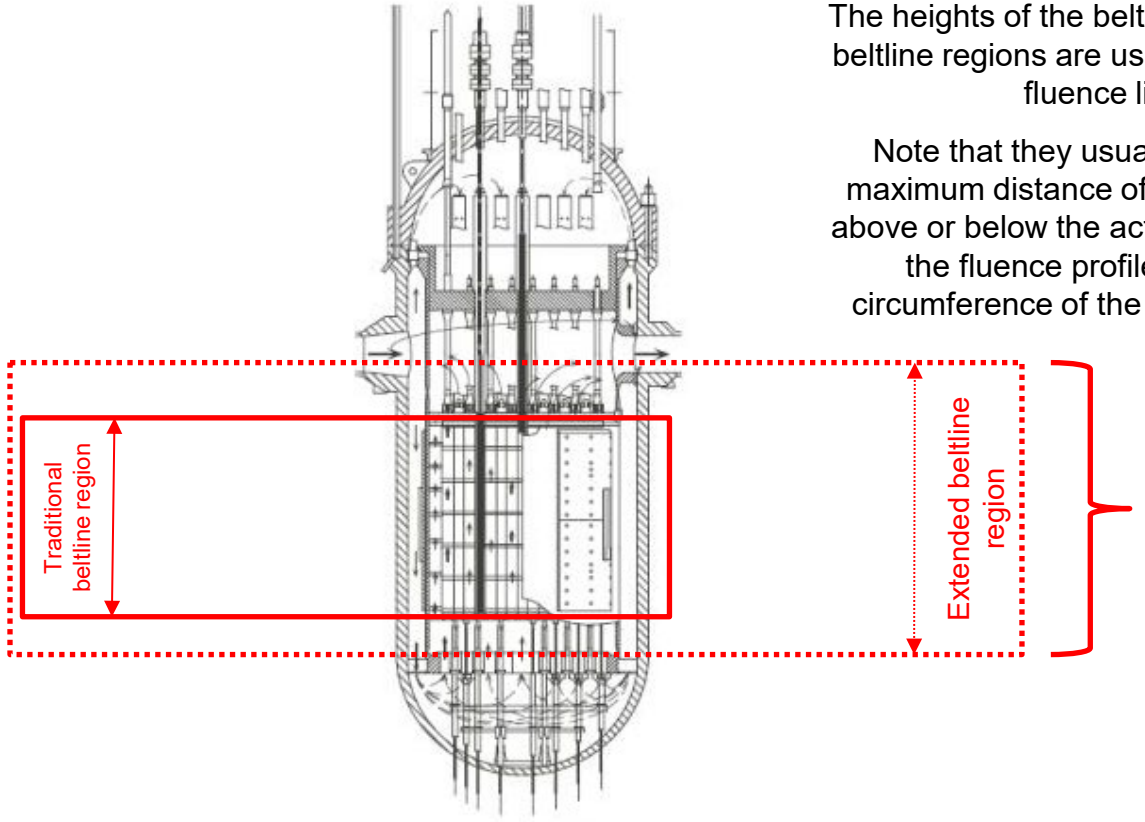
- For developing P-T limits and evaluating other aspects of RPV integrity, it is important to know which portions of the RPV are located within the projected extended beltline region
  - Based on the applicable fluence limit
  - Based on the end of the operating period, i.e., the time when the fluence will be greatest (so the beltline region will be largest)
- This may include components that were not evaluated for embrittlement effects as a part of the original RPV design
  - Other components may require embrittlement evaluation for longer term operation (e.g., 60 years compared to original 40-year design)
- Definition has evolved over-time, most recently clarified in RIS 2014-11*
  - "…the beltline definition in 10 CFR Part 50, Appendix G is applicable to all reactor vessel ferritic materials with projected neutron fluence values greater than 1 x 10^{17} n/cm^2 (E > 1 MeV)"

***U.S. NRC Regulatory Issue Summary (RIS) 2014-11, "*Information on Licensing Applications for Fracture Toughness Requirements for Ferritic Reactor Coolant Pressure Boundary Components*" October 2014 (ML14149A165)**

Extended Beltline Definition continued

- As plants operate for longer periods, the beltline region can “grow”
- This is sometimes referred to as the “extended beltline” region
- Despite the different terminology, these definitions are intended to define the region where embrittlement effects are significant and must be evaluated





The heights of the beltline and extended beltline regions are usually defined by a fluence limit.

Note that they usually indicate the maximum distance of the fluence limit above or below the active fuel (because the fluence profile around the circumference of the RPV is not flat).

Height expands with increased length of plant operation

Time-Limited Aging Analyses (TLAAs)

Time-Limited Aging Analyses (TLAAs)

- Per 10 CFR 54.3*, TLAAs are:
  - Involve systems, structures, and components {SSCs} within the scope of license renewal, as delineated in § 54.4(a);
  - Consider the effects of aging;
  - Involve time-limited assumptions defined by the current operating term, for example, 40 years;
  - Were determine to be relevant by the licensee in making a safety determination;
  - Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, and component to perform its intended functions, as delineated in § 54.4(b); and
  - Are contained or incorporated by reference in the CLB {Current Licensing Basis}

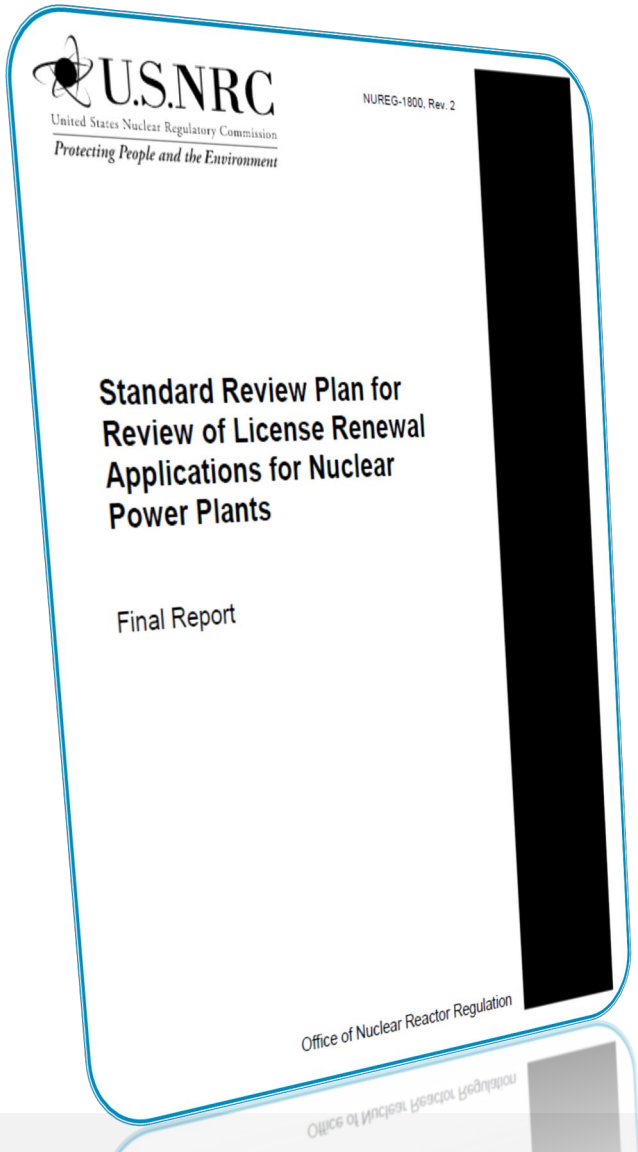
***Code of Federal Regulations, 10 CFR 54.3, "Definitions," U.S. Nuclear Regulatory Commission, Washington, D.C., Federal Register, Volume 72, dated August 28, 2007.**

Time-Limited Aging Analyses (TLAAs)

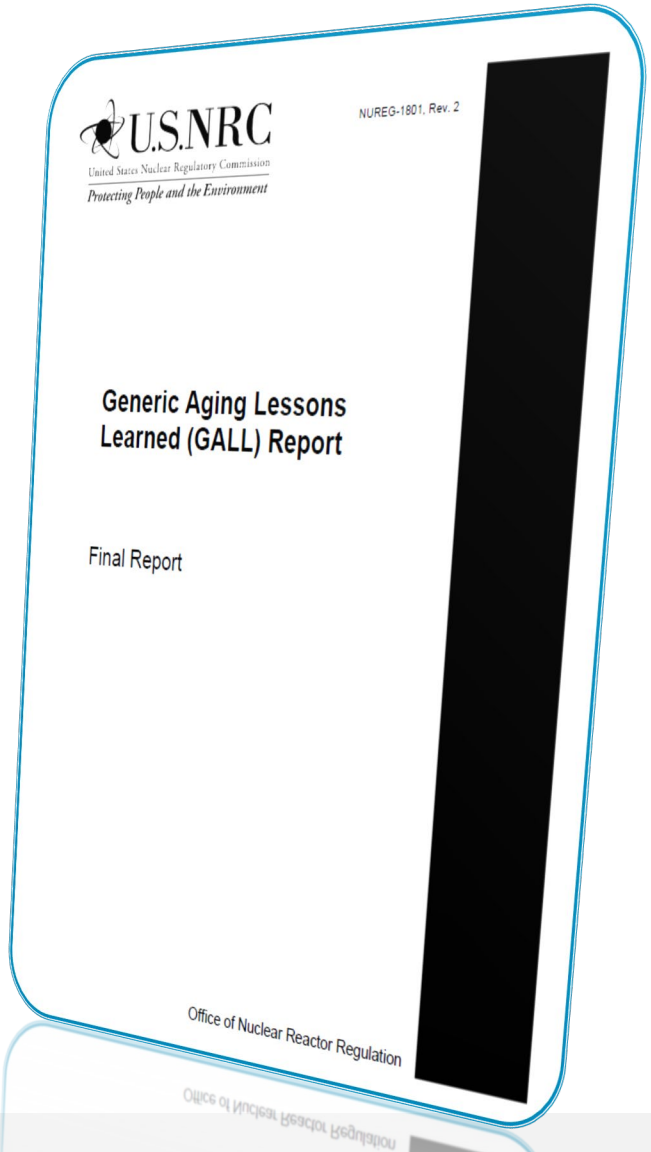
Time-Limited Aging Analysis	Calculated Fluence	Pressurized Thermal Shock (PTS)	Upper-Shelf Energy (USE)	Pressure-Temperature (P-T) Limits for Heatup and Cooldown
Considers the Effects of Aging	YES	YES	YES	YES
Involves Time-Limited Assumptions Defined by the Current Operating Term	YES	YES	YES	YES
Involves SSC Within the Scope of License Renewal	YES	YES	YES	YES
Involves Conclusions or Provides the Basis for Conclusions Related to the Capability of SSC to Perform Its Intended Function	YES	YES	YES	YES
Determined to be Relevant by the Licensee in Making a Safety Determination	YES	YES	YES	YES
Contained or Incorporated by Reference in the CLB	YES	YES	YES	YES

Pertinent NRC Documents → First License Renewal

NUREG-1800, Revision 2



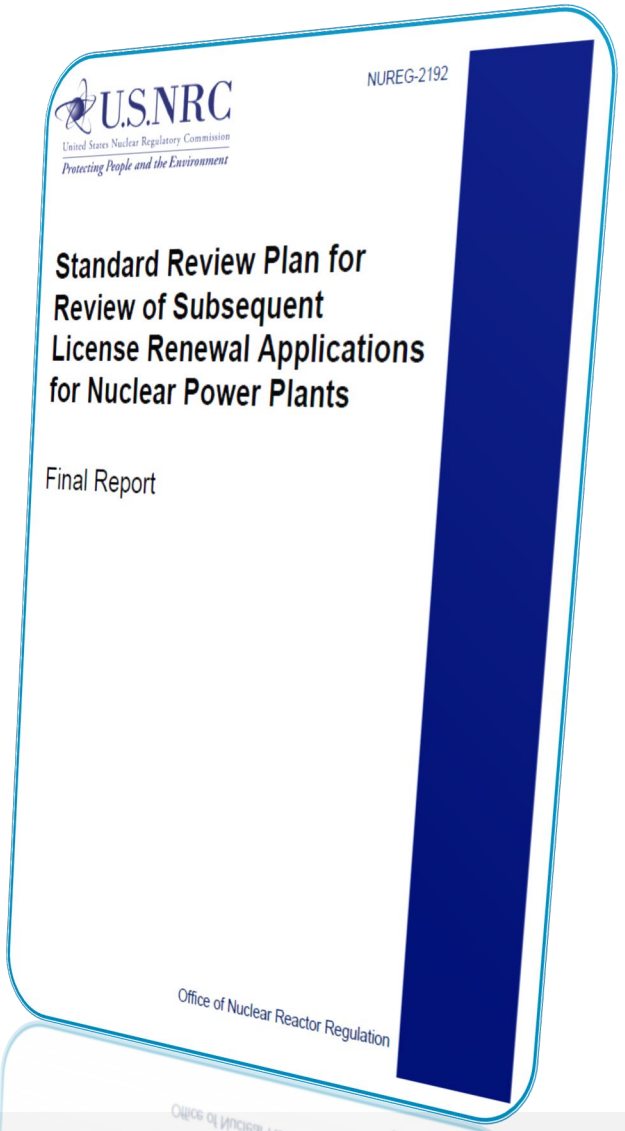
NUREG-1801, Revision 2



Pertinent NRC Documents → Second License Renewal

NUREG-2191, Volumes 1 and 2

NUREG-2192



Where to find additional TLAA Information and Examples

Home ▸ Nuclear Reactors ▸ Operating Reactors ▸ Operating Reactor Licensing

Navigation

- Technical Specifications
- License Transfers & Mergers
- Power Uprates
- Reactor License Renewal
- Resource Estimator for Operating Reactor Licensing

Spotlight

Choose a Section

Reactor License Renewal

This section of our site describes the process, regulations, guidance, opportunities for public involvement, and status of current activities associated with renewal of licenses for commercial operating power reactors.

- Overview
- Process
- Regulations
- Guidance
- Public Involvement
- Commission Papers Discussing Staff Recommendations
- Status of Initial License Renewal Applications and Industry Initiatives
- Status of Subsequent License Renewal Applications
- Introduction to License Renewal Tutorial

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Page Last Reviewed/Updated Tuesday, March 10, 2020

Related Information

- Fact Sheet on Reactor License Renewal
- Frequently Asked Questions on License Renewal of Nuclear Power Reactors (NUREG-1850)
- Frequently Asked Questions About License Renewal Inspection Procedure (IP) 71003, "Post-Approval Site Inspection for License Renewal"
- Office of the Inspector General (OIG) Report on License Renewal Program (OIG-07-A-15)

License Renewals Granted

(View Larger)

***https://www.nrc.gov/reactors/operating/licensing/renewal.html**

Wrap-up

So, what Do I Do When…My plant goes for *Second* License Extension *(60→80 years)?*

- The Key License Extension Point *still* holds – NEW end-of-life (EOL) EFPY with projected fluence values thus being higher
  - Report will *still* be titled **T**ime-**L**imit **A**ging **A**nalysis (TLAA)
- Secondly, remember our common theme for RPV Integrity
  - There is a well established & successful framework of what to do to go from 40 – 60 years of operation, and now 60 – 80 years.
  - Any given licensing period with a +20-year extension is no different.

Discussion / Questions

Backup Slides
P-T Limit Curves for RPV Nozzles

Extended Beltline / P-T Limits for Nozzles

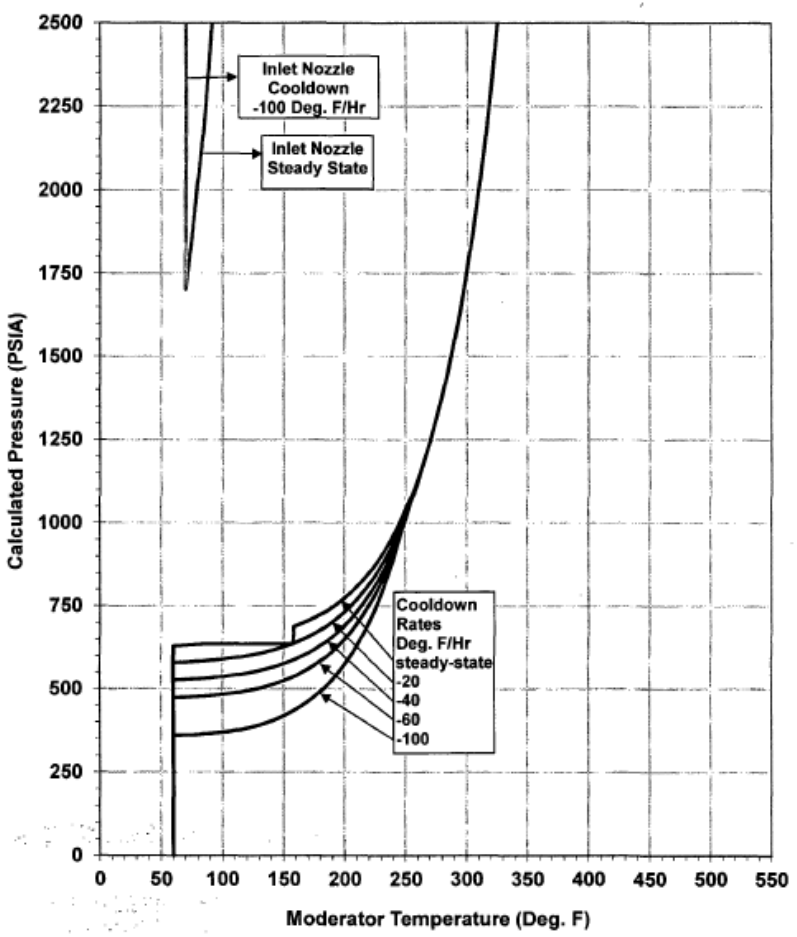
Extended Beltline P-T Curves – Current U.S. Status for PWRs

- U.S. PWRs already considered the cylindrical shell portion of the extended beltline in their P-T limit curve submittals
  - However, they did not consider RPV nozzles to be limiting, so nozzles were not specifically addressed in the submittals
  - Several plants received Requests for Additional Information (RAIs) from the NRC on new P-T limit curve submittals and were requested to address nozzles
- In response, the PWROG initiated a program to generically disposition RPV nozzles with respect to P-T limits through 60 years of plant operation
  - Report PWROG-15109-NP was issued and sent to the NRC for review in March 2018 (ADAMS Accession No. ML18067A229)

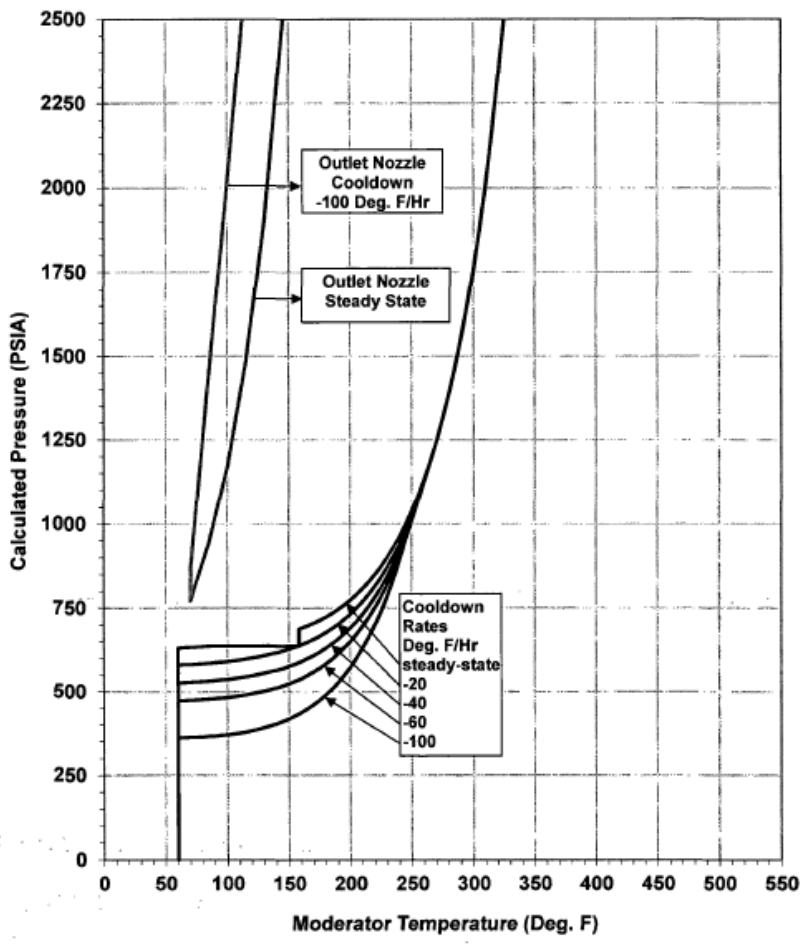
Extended Beltline / P-T Limits for Nozzles

Example of Plant-Specific Assessment -- PWR

Inlet Nozzles vs. Beltline P-T Limits



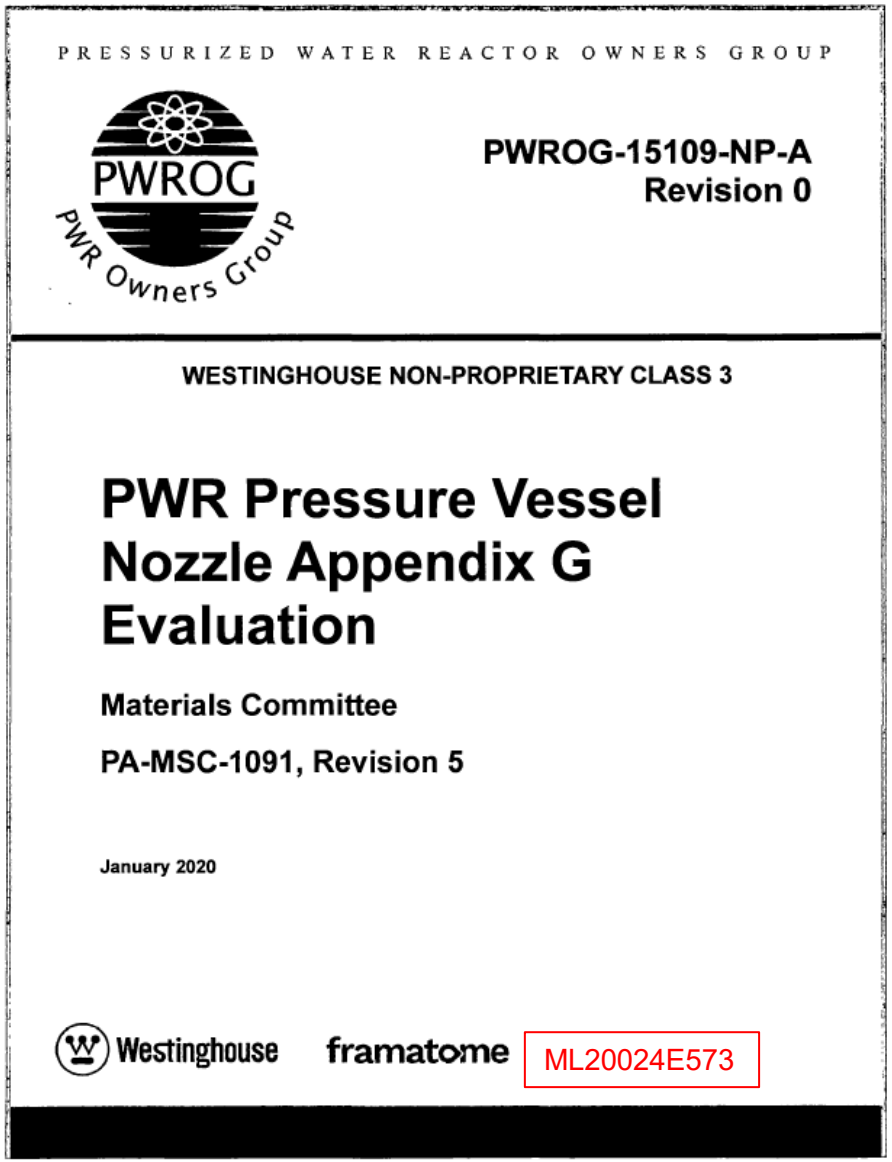
Outlet Nozzles vs. Beltline P-T Limits



Source: ADAMS Accession No. ML15061A277

PWROG-15109-NP-A, Revision 0

- PWROG addressed NRC RAIs in March of 2019
- Final, safety evaluated report issued in January of 2020
- Key Conclusions:
  - RPV Inlet and Outlet nozzles are NOT limiting in comparison to RPV beltline Cylindrical Shell P-T limit curves
- Limitations:
  - Projected nozzle corner fluence must remain below 4.28×10^{17} n/cm^2
  - Such that the conclusions of NRC TLR-RES/DE/CIB-2013-01 remain valid [embrittlement shift less than 25°F can be excluded
  - SE on this topical is NOT a generic endorsement of the NRC technical letter report



PRESSURIZED WATER REACTOR OWNERS GROUP

PWROG
PWR Owners Group

PWROG-15109-NP-A
Revision 0

WESTINGHOUSE NON-PROPRIETARY CLASS 3

PWR Pressure Vessel Nozzle Appendix G Evaluation

Materials Committee

PA-MSC-1091, Revision 5

January 2020

Westinghouse framatome

ML20024E573