Optimization of Select NDE Examination Requirements

Robert Grizzi, Program Manager
EPRI - Plant Support / NDE

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Background - Problem Statement

There are many examinations being performed that are **perceived** to have **low value** based on a history of **few or no relevant indications** being identified during routine inspections **on prescribed intervals.**

When were these intervals established?

- Generally, 40+ years ago during the construction and early operation era

Who established these intervals?

- Codes and Standards organizations

How were these intervals established?

- Engineering judgment
- No supporting technical bases were developed

Background - Impetus

- EPRI led, industry member focus group (circa 2017)
- Focus Group
  - Established metrics
  - Deliberated and selected examinations of interest

Metrics Used to Prioritize Examinations – Value

Item	Metric (unit)	Point Value Assigned		
		15	4	1
1	Perceived Value of The Exam *Considerations: probability of finding flaws, component criticality, reactor type applicability, NSSS design applicability* (Qualitative – *Subjective*)	Low	Med	Hi

Metrics Used to Prioritize Examinations-Impact

Item	Metric (unit)	Point Value Assigned		
		1	2	3
2	Impact to Critical Path (hours)	≤ 2	>2 and ≤ 12	> 12
3	Expected Accumulated Dose (mrem)	≤ 100	>100 and ≤ 1000	>1000

- <u>EPRI Report 3002012965:</u> *Identification and Assessment of Low-Value NDE examinations with High Outage Impacts (LVHOI)*
  - Surveyed utility members, ranked and prioritized results
  - 34 individual ASME Section XI Code-required examinations

Scope of Components - PWR & BWR Designs

- Accessible Areas of Reactor Vessel Interior (Visual Examination, ASME Item B-N-1)
- Reactor Vessel Studs
- Non-Reactor Vessel Pressure-Retaining Bolting (< 2” / 51 mm in diameter)
- PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections
- PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds and Nozzle Inside Radius Sections
- PWR Steam Generator Primary Nozzle-to-Shell and Pressure Vessel Welds
- PWR Pressurizer Nozzle-to-Shell and Pressure Vessel Welds
- BWR Class 2 Heat Exchanger Nozzle-to-Shell Welds; Nozzle Inside Radius Sections; and Vessel Welds

Objective

Optimize component examination requirements using:

- Historical operating experience,
- Historical inspection data and results,
- Fundamental engineering methods,
- Modern day analysis tools to develop robust and comprehensive technical bases, and
- All without any adverse impact to the safe and reliable operation of nuclear facilities

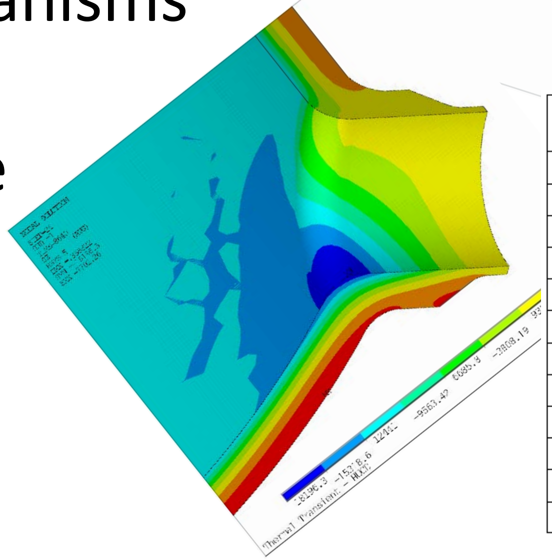
Steam Generator & Pressurizer Examinations (thru 2019)

- Steam Generators
  - 2,101 examinations performed based on survey responses (some did not respond)
  - 3 indications reported
    - 1 linear indication was reported on the OD of a nozzle to shell weld, found by magnetic particle inspection. It was dispositioned with light grinding/blending to acceptable standards
    - 2 exceeded ASME Section XI acceptance criteria but were determined to be fabrication (not service induced) flaws. They were evaluated and found to be acceptable without repair
- Pressurizers
  - 1,162 examinations performed based on survey responses (some did not respond)
  - 4 indications reported (all from a 2 unit, single site plant)
    - Flaw evaluations were performed to show acceptability of these indications, and follow-on examinations showed no change in flaw sizes since the original inspections

3,263 Reported Examinations, No Unacceptable Indications

Technical Bases Overview

- Introduction
- Review of Previous Related Work
- Review of Inspection History and Examination Effectiveness
- Survey of Components and Selection of Representative Components for Analysis
- Material Properties, Operating Loads, and Transients
- Evaluation of Potential Degradation Mechanisms
- Component Stress Analysis
- Probabilistic and/or Deterministic Fracture Mechanics Evaluation
- Plant Specific Applicability
- Summary and Conclusions



Sensitivity Study Variable	Importance Factor (%) for Probability of Leakage
Fatigue Crack Growth Rate Coefficient	87.82
Crack Length	9.39
Crack Depth	0.00
Fatigue Crack Growth Rate Threshold	0.01
Fracture Toughness	0.01
Crack Face Pressure	0.04
Pressure	1.82
Residual Stress	0.00
Heat-Up/Cooldown	0.01
Loss of Load	0.04
Load Increase (5%)	0.69
Load Decrease (5%)	0.16

Generalized Conclusions

- ✓ Analyses showed success in **considering 80 years of operation**
- ✓ Results are **acceptable relative to safety margins** (probability of leak or rupture < $1x10^{-6}$ failures per reactor year of operation)
- ✓ Results **support mitigation of personnel health and safety risks** through reduction of unnecessary inspections
- ✓ Results **promote ALARA** through reduction of unnecessary inspections
- ✓ Results allow **resources and schedule to be focused on higher priority** outage activities

Technical bases support optimizing examination intervals out to 30 years

Results (1/2)

- EPRI developed a **series of technical reports** establishing the technical bases **for optimizing examination intervals** for the components listed in each report title below.
- Following publication of the EPRI technical bases for optimization of NDE examination intervals, several pilot plants submitted "Requests for Alternative" to the US NRC and were granted permission to use the new intervals via Safety Evaluation Reports (SERs)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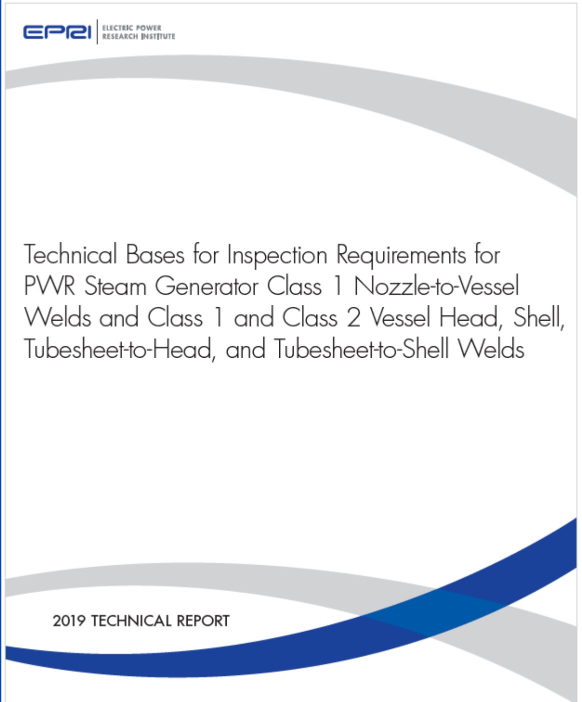
Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections

2019 TECHNICAL REPORT

EPRI Report 3002014590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Technical Bases for Inspection Requirements for PWR Steam Generator Class 1 Nozzle-to-Vessel Welds and Class 1 and Class 2 Vessel Head, Shell, Tubesheet-to-Head, and Tubesheet-to-Shell Welds

2019 TECHNICAL REPORT

EPRI Report 3002015906


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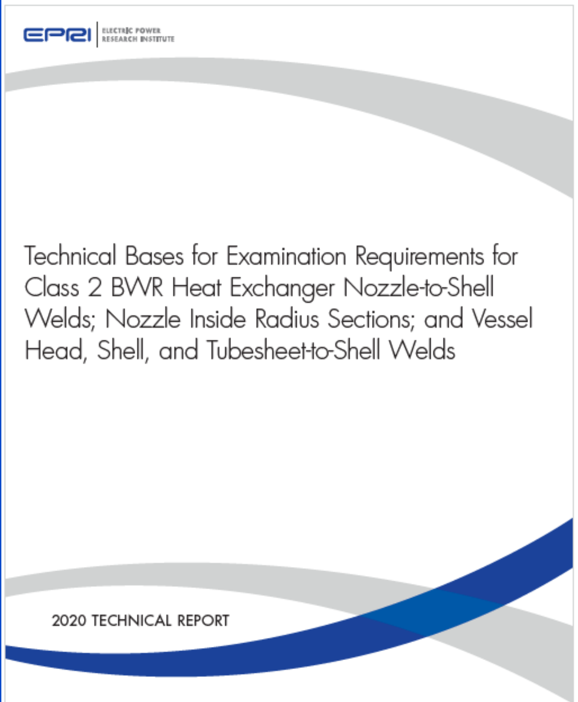
Technical Bases for Inspection Requirements for PWR Pressurizer Head, Shell-to-Head, and Nozzle-to-Vessel Welds

2019 TECHNICAL REPORT

EPRI Report 3002015905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Technical Bases for Examination Requirements for Class 2 BWR Heat Exchanger Nozzle-to-Shell Welds; Nozzle Inside Radius Sections; and Vessel Head, Shell, and Tubesheet-to-Shell Welds

2020 TECHNICAL REPORT

EPRI Report 3002018473

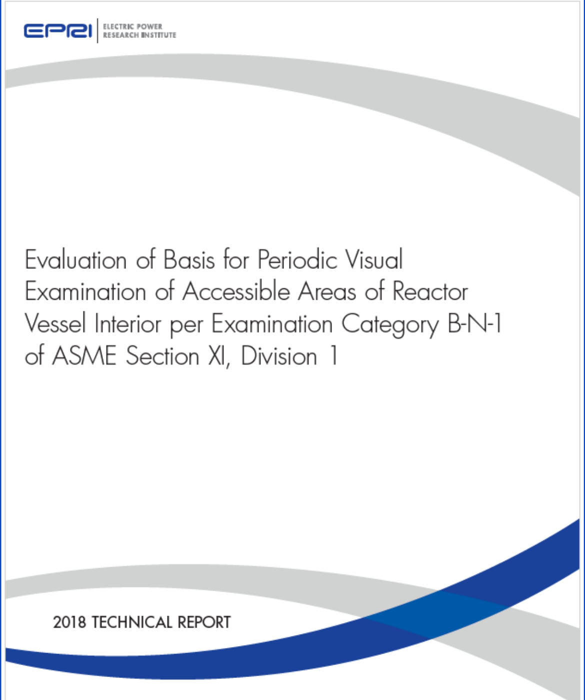
Results (2/2)

- EPRI developed a **series of technical reports** establishing the technical bases **for optimizing examination intervals** for the components listed in each report title below.
- Following publication of the EPRI technical bases for optimization of NDE examination intervals, several pilot plants submitted “Requests for Alternative” to the US NRC and were granted permission to use the new intervals via Safety Evaluation Reports (SERs)

Technical Bases for Inspection Requirements for PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds

2022 TECHNICAL REPORT

EPRI Report 3002023713



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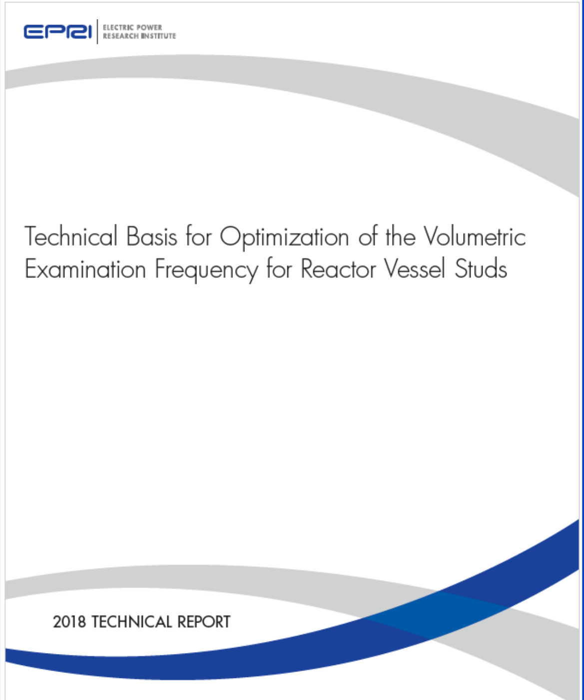
Evaluation of Basis for Periodic Visual Examination of Accessible Areas of Reactor Vessel Interior per Examination Category B-N-1 of ASME Section XI, Division 1

2018 TECHNICAL REPORT

EPRI Report 3002012966



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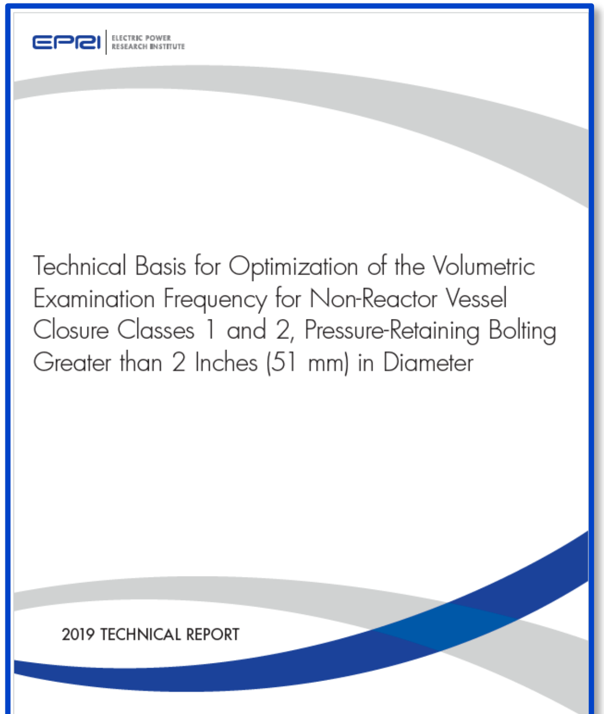
Technical Basis for Optimization of the Volumetric Examination Frequency for Reactor Vessel Studs

2018 TECHNICAL REPORT

EPRI Report 3002014589



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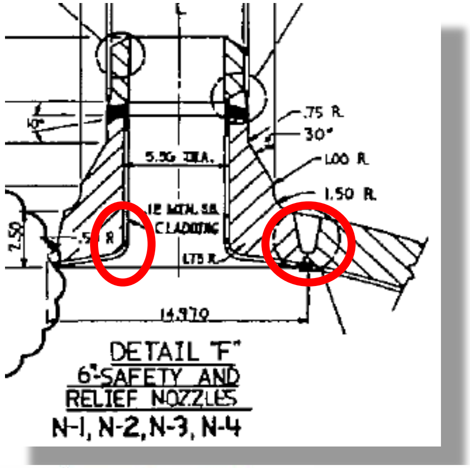
Technical Basis for Optimization of the Volumetric Examination Frequency for Non-Reactor Vessel Closure Classes 1 and 2, Pressure-Retaining Bolting Greater than 2 Inches (51 mm) in Diameter

2019 TECHNICAL REPORT

EPRI Report 3002015907

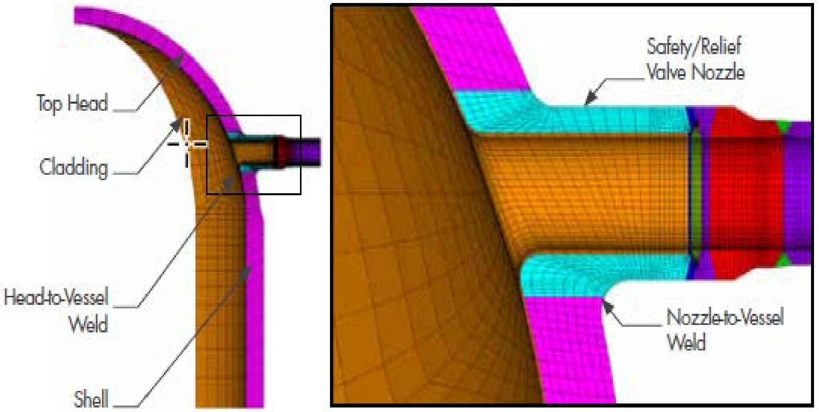
Initial US Implementation Strategy & Benefits



Industry leading utilities piloted the implementation of a series of EPRI NDE technical reports establishing the technical bases for optimizing inspection intervals of mandatory ASME component examination requirements, paving the way for other industry members to follow.

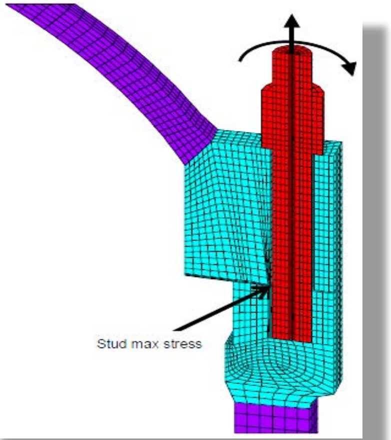
Highlights of Implementation

1. Used the NRC Request for Alternative process
2. First-of-a-Kind applications utilizing PFM as a cornerstone of the analysis
3. SERs received for all pilots allowing for optimized examination intervals up to 30 years
4. Current ASME Code actions leverage Technical Bases and SERs
5. EPRI has compiled a Lessons Learned document and relief request templates to support future submittals



Benefits

1. Maximize overall plant safety by focusing resources where they are needed (higher valued examinations)
2. Minimize health & safety risk profile of plant personnel by reducing low-value work activities
3. Potential dose savings (per unit) is on the order of multiple man-rem years
4. Potential cost savings (per unit) is on the order of millions of dollars



Industry’s Strategic Shift to Fleet-wide Performance Monitoring Approach

Focus on Select Technical Bases

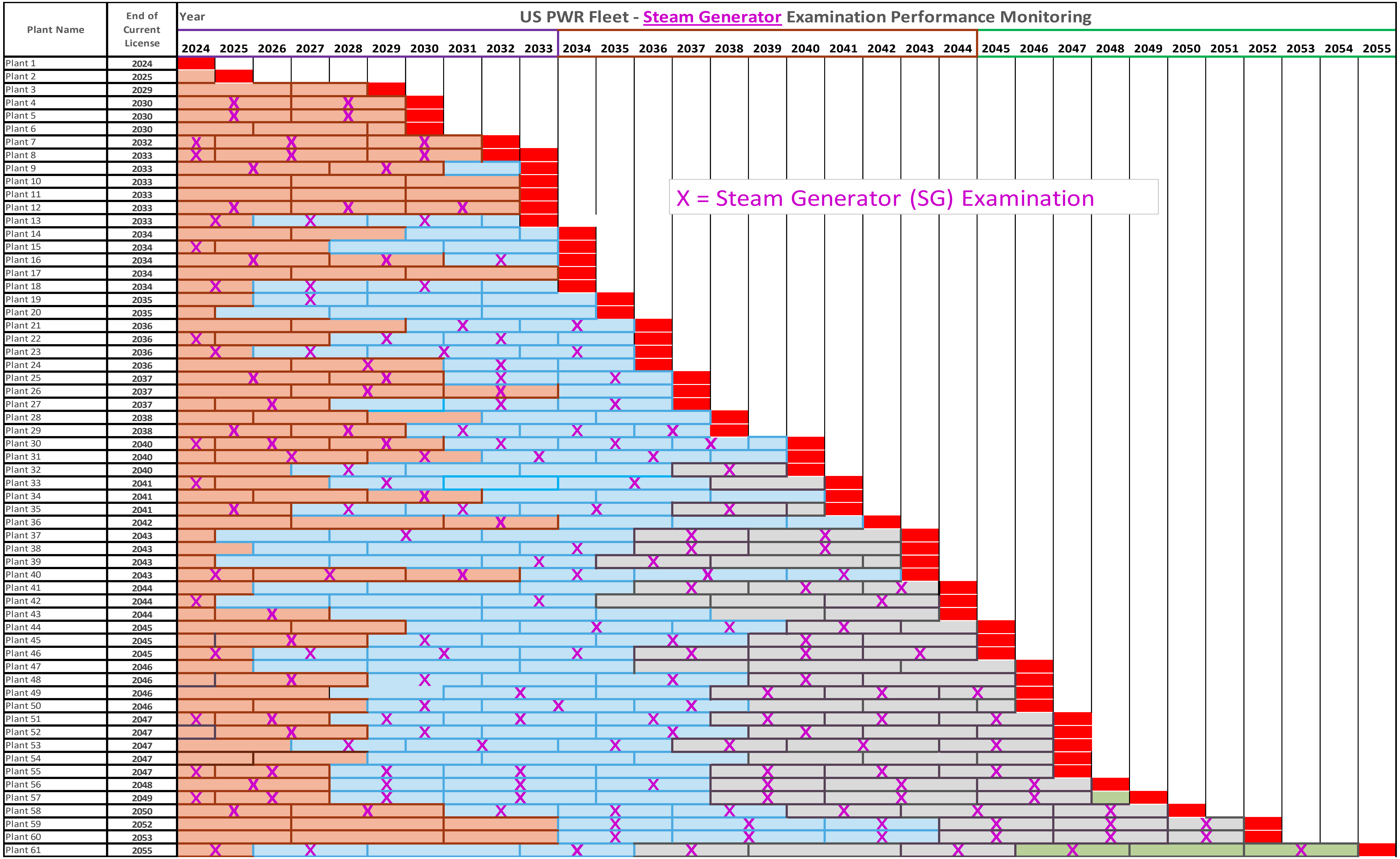
- Focus is on Steam Generator (SG) and Pressurizer (PZR) component examinations:
  - **EPRI 3002014590** - *Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections*
  - **EPRI 3002015906** - *Technical Bases for Inspection Requirements for PWR Steam Generator Class 1 Nozzle-to-Vessel Welds and Class 1 and Class 2 Vessel Head, Shell, Tubesheet-to-Head and Tubesheet-to-Shell Welds*
  - **EPRI 3002023713** - *Technical Bases for Inspection Requirements for PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds*
  - **EPRI 3002015905** - *Technical Bases for Inspection Requirements for PWR Pressurizer Vessel Head, Shell –to-Head and Nozzle-to-Vessel Welds*
- The probabilistic and deterministic analyses for 80-years of operating life produced results that show safety margins meet or exceed the benchmark threshold of **$1X10^{-06}$**.

Shift in Implementation Strategy

- The US started with pilot plant applications to assess feasibility of the technical bases and process
- Relative to steam generators (SG) and pressurizers (PZR);
  - 23 (out of 61) plant sites, so far, have followed the pilot plants lead and submitted for relief through the US regulatory process
- Collectively, the US utilities have decided to shift to a fleet-wide approach; facilitating a broader, streamlined implementation strategy.
- This fleet-wide approach carries with it some additional considerations for overall performance monitoring of the SG and PZR components across the US fleet.
- There are ongoing discussions with the US NRC to determine the best approach.

The US Industry's Understanding of NRC Concerns

- How does the fleet-wide performance monitoring plan conform to:
  1. The NRC's binomial distribution model defining a minimum number of inspections that need to occur across the fleet during the current operating licenses for all plants.
  2. Sufficient, continuous collection of inspection data points, over the range of time aligned with current operating licenses for all plants, to identify known and unknown degradation mechanisms in a timely manner.
- The US utilities and EPRI are currently working to address these two concerns.
- Surveys of the US fleet were conducted to collect ISI program information for when and how many of these examinations are planned, collectively, for the entire fleet of US operating plants, through the remainder of their current operating licenses



US PWR Fleet - Steam Generator Examination Performance Monitoring
Plant Name
End of Current License
Year
2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055
Plant 1 2024
Plant 2 2025
Plant 3 2029
Plant 4 2030
Plant 5 2030
Plant 6 2030
Plant 7 2032
Plant 8 2033
Plant 9 2033
Plant 10 2033
Plant 11 2033
Plant 12 2033
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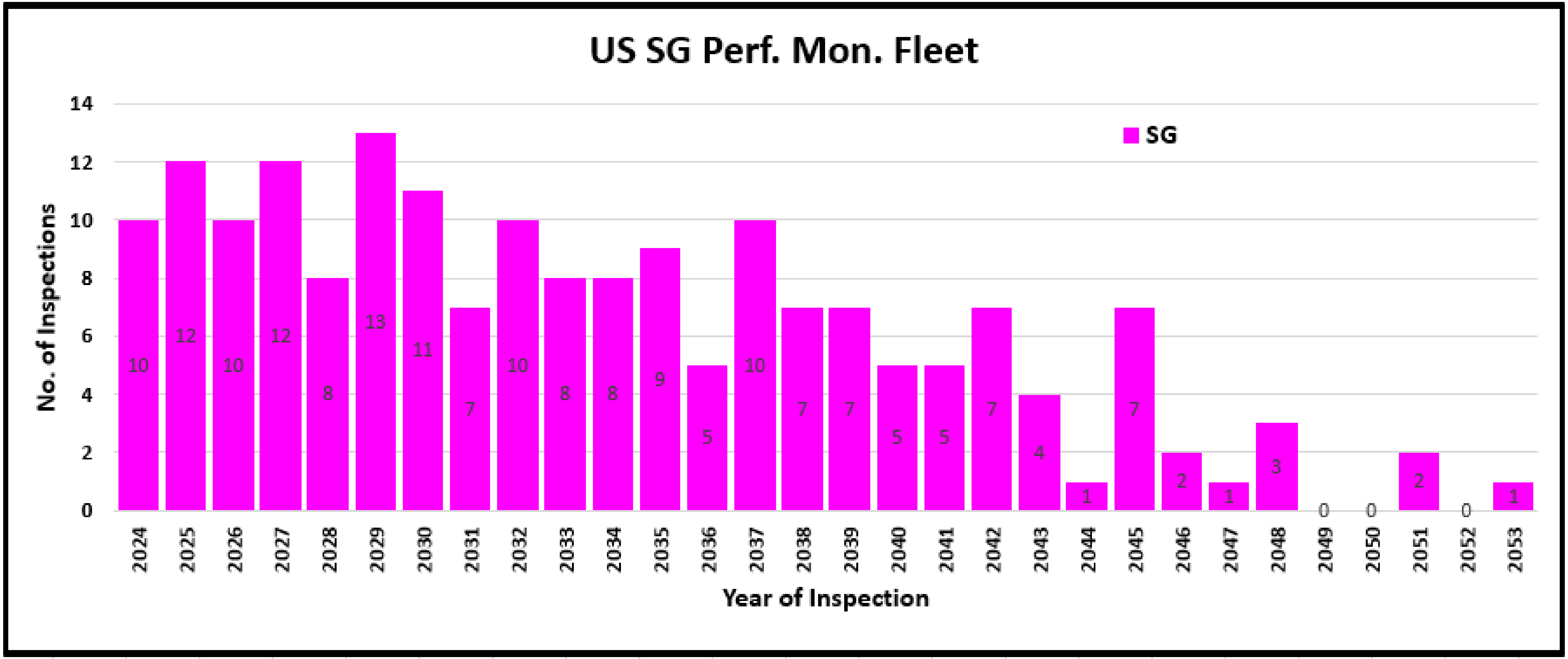
Plant 58 2050
Plant 59 2052
Plant 60 2053
Plant 61 2055
X = Steam Generator (SG) Examination

US PWR Fleet-wide Inspection Data Points Over Range of Current Operating Licenses



EPRI

Fleet-wide Performance Monitoring
How Many? Which Ones? & When?

How Many? - Fleet-wide Performance Monitoring

Applying the NRC Binomial Distribution Model Criterion

Parameter	SG Exams
Total # of Inspection Opportunities	930
Number of Fleet-wide Performance Monitoring (PM) Inspections to Meet 25% Criterion	232
Total number of Fleet-wide PM Inspections to be Proposed	308
Percentage of Total Opportunities for Inspection	33%

Which Items Should be Examined? – Applied Logic

- When applying the binomial distribution model, the number of examinations can range from 2 – 17 but average ~5, per unit.
- Items to be examined were determined by choosing the most critical concentrated stress paths from the FEM, per the EPRI Technical Basis

Tubesheet to Head Weld (Class 1)

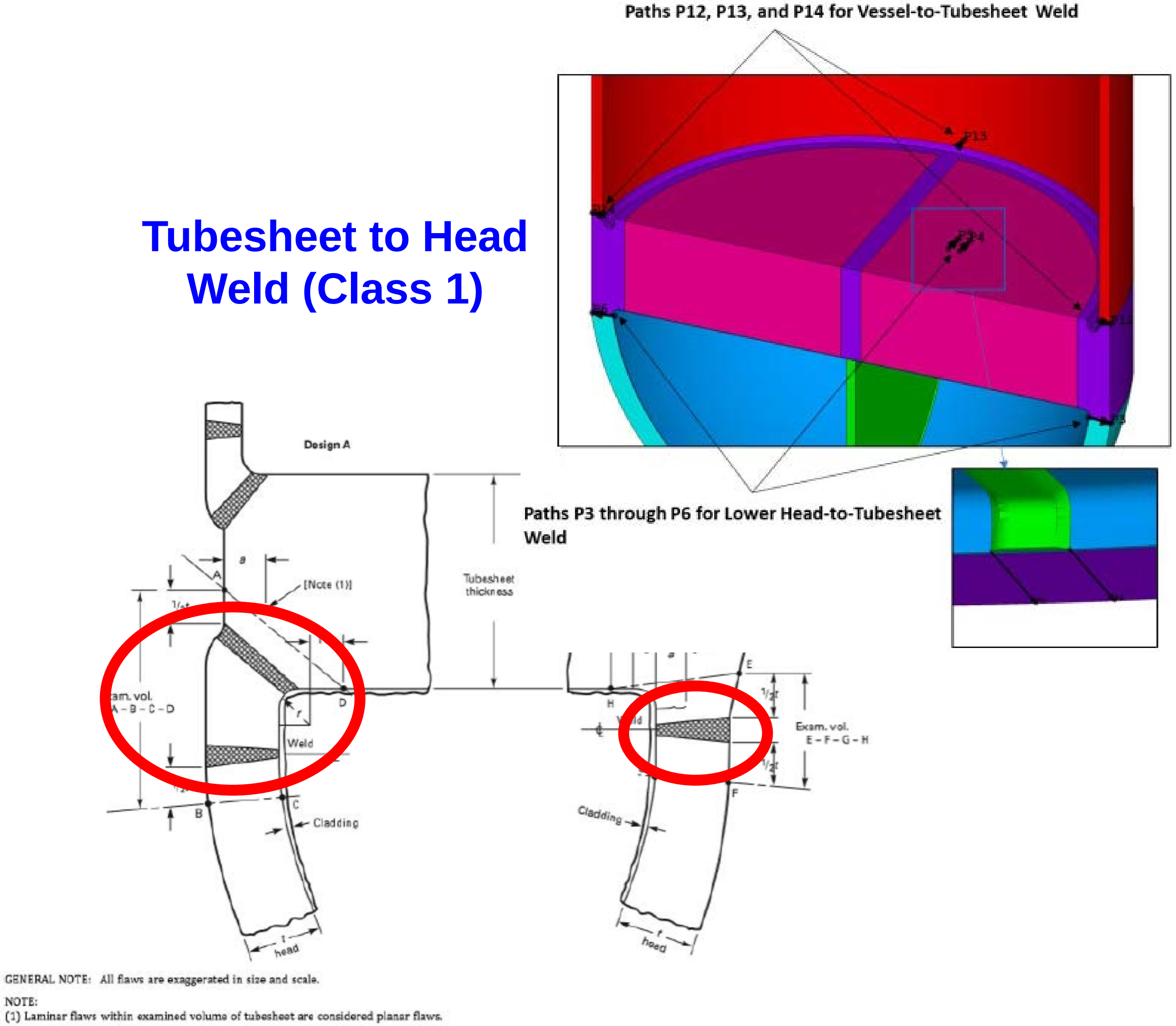


Figure 1-2
ASME Code, Section XI, Figure IWB-2500-6, Typical Tubesheet-to-Head Weld Joints (Item No. B2.40)

When Should Examinations Happen? – Distribution

- Example - Comparison of applied reduction in examination data points and distribution (Figures 1 & 2)

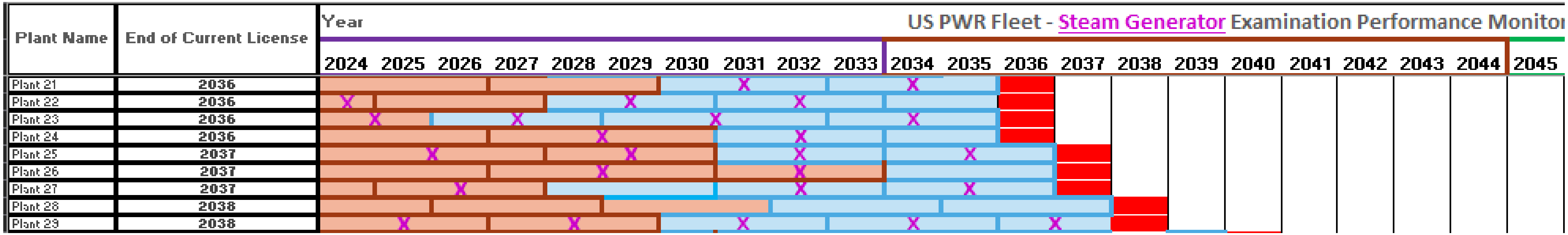


Figure 1 = 25 Examinations on original ASME 10-year interval

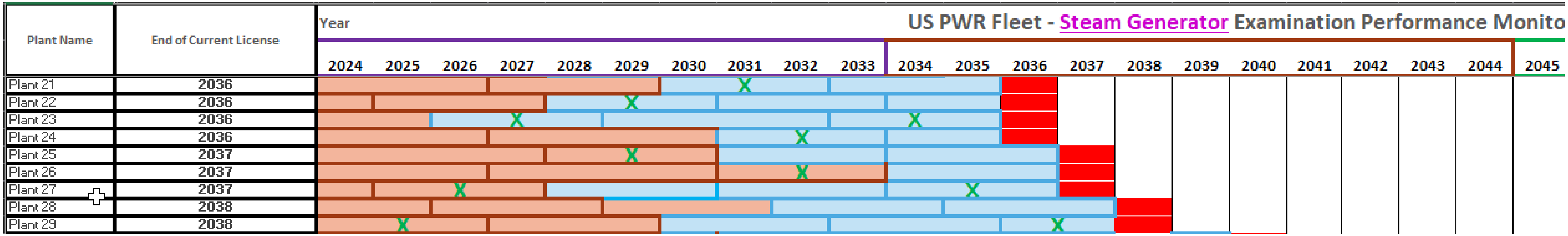


Figure 2 = 11 (Proposed) examinations based on a reduction of data points

Next Steps for the US Industry

- Finalize draft of Topical Report on performance monitoring approach
- Schedule a pre-submittal meeting with the NRC
- NEI to assist with communicating and gaining acceptance at the utility CNO level
  - Utilities will be obligated to perform the examinations as prescribed in the EPRI Topical Report
  - Utilities, through EPRI, will monitor and update the Letter Addendum
    - Periodic review
    - Reviews based on plant licensing changes
- Letter Addendum reviews and assessment will ensure regulatory concerns are still being addressed (i.e., the checks & balance on statistical relevance of data points and their distribution)

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