

Technical Basis for Application of ASME Section XI Appendix E to Vessel Nozzles

Status Update



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EPRI MRP – China Meetings

Appendix E Update

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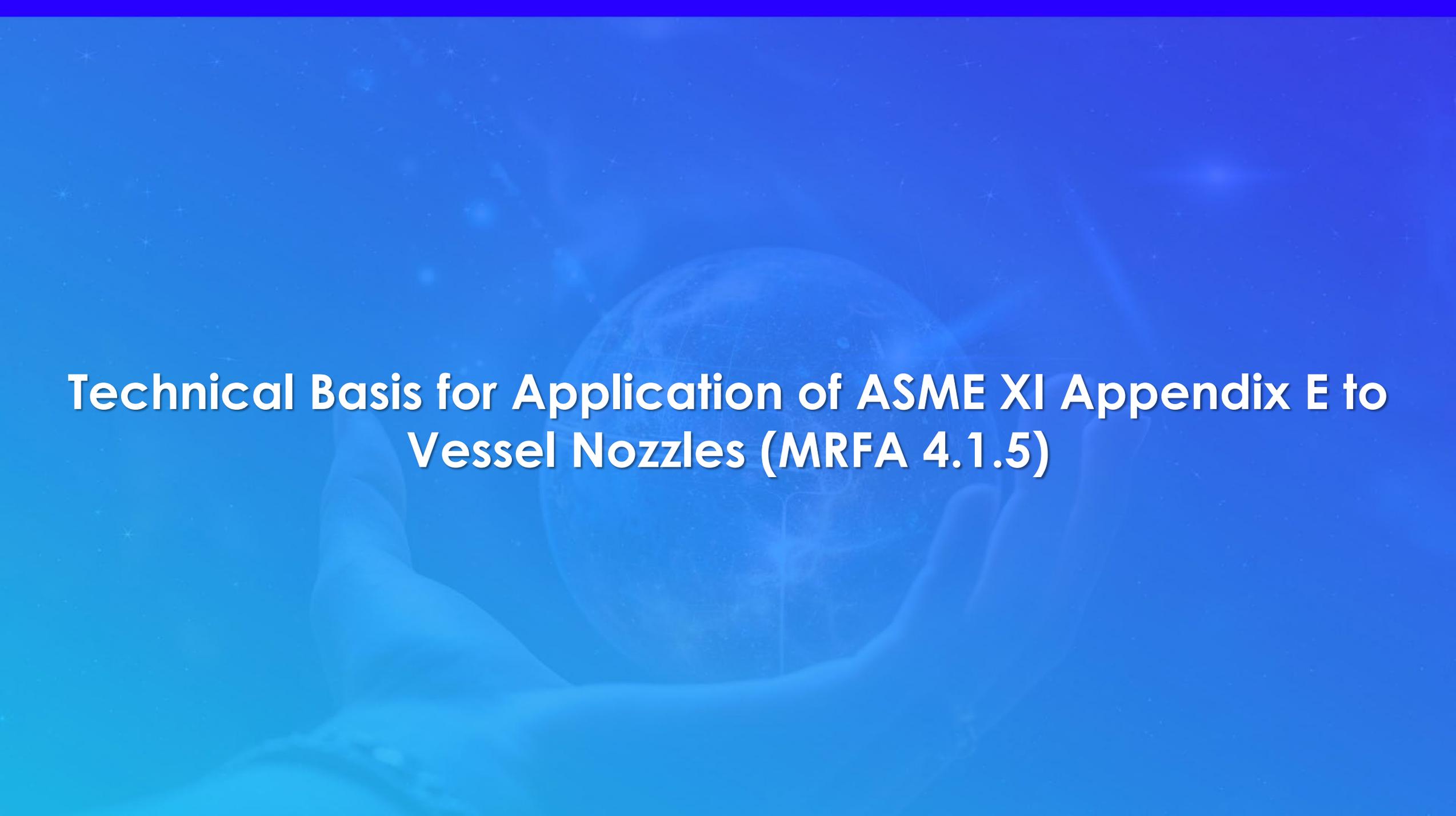


EPRI MRP – China Meetings

Appendix E Update

■ Presentation Outline

- Technical Basis for Application of ASME XI Appendix E to Vessel Nozzles (MRFA 4.1.5)
- Recent Uses of Appendix E in the US
- Where we stand – Now
- Draft Revision to Appendix E



**Technical Basis for Application of ASME XI Appendix E to
Vessel Nozzles (MRFA 4.1.5)**

Technical Basis for Application of ASME XI Appendix E to Vessel Nozzles (MRFA 4.1.5)

- Materials Issue Being Addressed:
 - ASME Section XI, Nonmandatory Appendix E, “Evaluation of Unanticipated Operating Events” provides acceptance criteria and guidance for performing an evaluation of the effects of an out-of-limit condition on the structural integrity of the reactor vessel beltline region
 - i.e., violation of plant Pressure-Temperature (P-T) curves
 - The technical basis for Appendix E addressed the PWR shell only and did not consider RPV nozzles, which now have potential to be limiting for normal operating conditions or out of limit conditions
- Objectives of the Project
 - Develop the technical basis for to change/update to Appendix E so that it covers nozzles as well as the beltline shell. Also, verify the current validity of Appendix E for RPV shells



Recent Uses of Appendix E in the US

Recent Uses of Appendix E in the US

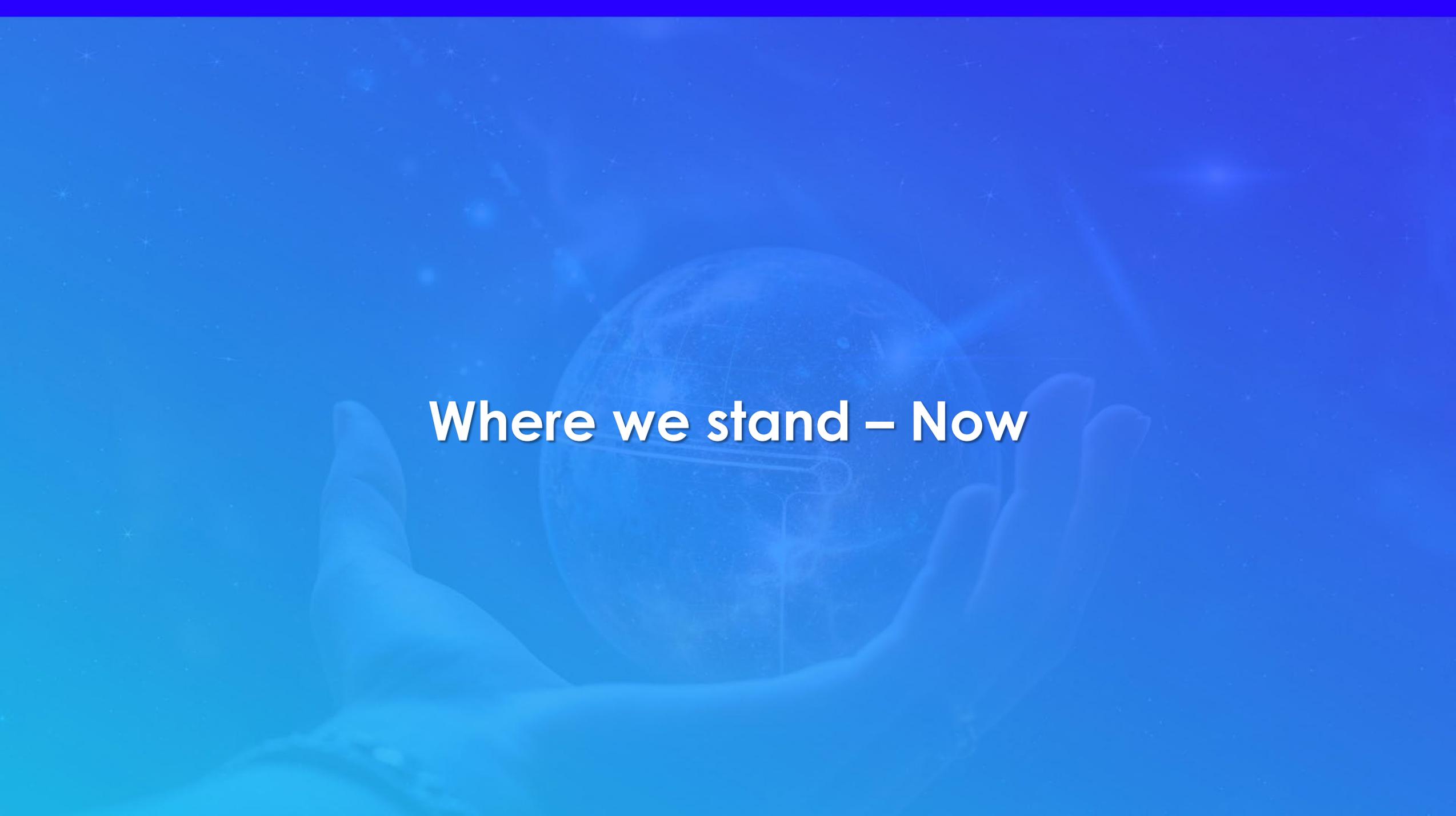
- Point Beach Unit 1 reported during the Spring 2019 outage that the temperatures during cooldown went below 60°F (16°C) which violated the required allowable per their Pressure-Temperature Limit Report (PTLR). Subsequently, during the outage, an ASME Section XI, Appendix E-1200(a) evaluation was conducted to demonstrate that the out-of-limit condition was acceptable and there was no concern for the structural integrity of the reactor vessel.
- H.B. Robinson Unit 2 approached the allowable cool-down rate of 100°F/hr (55.6°C/hr) for a short period during a cooldown transient entering the Spring 2015 outage. This event was evaluated and demonstrated to meet the criteria of ASME Section XI, Appendix E-1200(b).
- During a refueling outage in Fall 2012 at Shearon Harris, one main steam isolation valve (MSIV) failed to close and one MSIV partially closed during shutdown. As a result of these valve failures, an unanticipated event was conservatively assumed to bound this condition. A PTS analysis was performed, and a detailed Appendix E-1300 assessment was evaluated to demonstrate structural integrity of the RPV.

MRP-489, Section 2

Technical Basis for Application of ASME XI Appendix E to Vessel Nozzles (MRFA 4.1.5)

■ Timeline

- Original Draft report was finalized **Summer 2022**
 - Out for Member and WGOPC Comment in mid-July; were due **September 2, 2022**
 - ASME Letter Ballot 21-1575 has been initiated; votes due by **October 17, 2022**
 - Developed resolutions to NRC and PEAI comments on draft report **January 2023**
- EPRI, the vendor team (Sartrex, Westinghouse, ATI Consulting) met with the NRC in **January 2023** to discuss comment resolution
 - General accord reached with NRC Staff; most comments consistent with PEAI
- All comments initially resolved however, resolution of the final PFM comment discovered a bit of a snag...**May 2023**
- PFM Comment resolution took remainder of **2023**
- Finalized draft completed in **February 2024** for presentation to WGOPC
- Report completed and publish in **September 2024**
- WGOPC Ballot Issued in **November 2024**

The image has a monochromatic blue color scheme. In the center, a pair of hands is shown from the wrists up, cupping a globe of the Earth. The globe is semi-transparent, revealing a grid of latitude and longitude lines. The background is a deep blue with a subtle pattern of white stars and faint, glowing lines, suggesting a cosmic or digital theme. The overall composition is symmetrical and centered.

Where we stand – Now

MRP-489, Revision 0

- MRP-489 developed a technical basis to Update ASME Code Section XI Appendix E
 - Major Changes and Updates throughout entire Appendix
- Next Steps into 2025
 - Work has begun to revise ASME Code Appendix E
 - WGOPC Balloting process completed
 - Received approximately 20 new comments from the WGOPC Members
 - Majority were editorial and/or are easily addressed with minor changes
 - Responses and revisions were brought to the August 2025 Code meeting
 - Resubmit ballot for voting ahead of Nov. meeting
 - Finalize revised Appendix E for 2027 Code Edition





Draft Revision to Appendix E for Code Consideration

ASME Appendix E Update/Changes (1/6)

- General Format of the new ASME Appendix E
 - Article E-1100 Scope (with editorial changes)
 - Article E-1200 Nozzle Corner Evaluation (*NEW* for this draft)
 - Article E-1300 Beltline (Cylindrical Shell) Acceptance Criteria
 - This was previously E-1200
 - Includes
 - *Updated and expanded* Table E-2 (was Table E-1)
 - *Revised* Article E-1300(b) and *new* Article 1300(c)
 - *New* Article E-1300(d) with PFM-based solution path
 - Article E-1400 Analytical Evaluation
 - This was previously E-1300
 - Includes *new* Article E-1400(c)
 - *New* Table E-1 and Figure E-1
 - Existing Tables bumped down by 1, now Tables E-2, E-3a and b, E-4
 - Due to increased complexity of the new Appendix E, a flow chart was developed and added to the proposed update as Figure E-1

ASME Appendix E Update/Changes (2/6)

■ RPV Nozzles Updates

- Original evaluation concluded that nozzles are not an issue for extended operation
 - The irradiated beltline material is always controlling once the reactor has begun operation
- However, based on NRC comment resolution, a limiting table was added for new vessels or very low embrittlement vessels where the nozzles *could* be controlling
- This is now included as a first check, for a new Article E-1200 and Table E-1
 - If $RT_{MAX_AppE} > 60^{\circ}F$, nozzles are not limiting, proceed to Article E-1300
 - If $RT_{MAX_AppE} < 60^{\circ}F$, nozzles may be limiting, unless the provisions of Table E-1 are met
 - If Table E-1 is violated, proceed to Article E-1400 and include RPV nozzles in the Analytical Evaluation
- RT_{MAX_AppE} is for your limiting RPV material in this case
 - RT_{MAX_AppE} is the material property which characterizes resistance to fracture initiating from flaws found in plates, forgings, axial welds, or circumferential welds using approved values that do not include additional Margin; e.g., $RT_{MAX} = RT_{NDT} - \text{Margin}$.

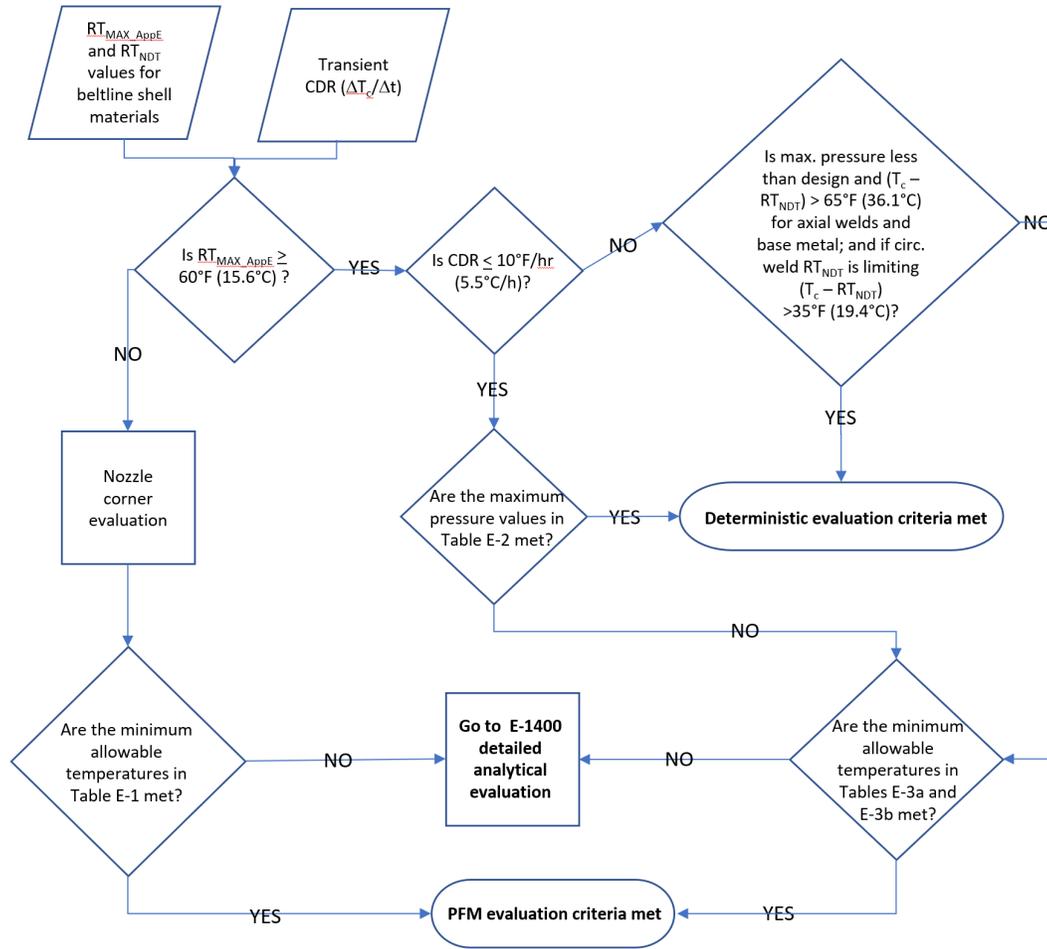
ASME Appendix E Update/Changes (3/6)

- Cylindrical Shell Beltline Updates
 - These are now listed as Article E-1300 (a)
 - Note that these solutions are only applicable to PWRs; BWRs can utilize the methodologies allowable under E-1400, if necessary/as-needed
 - Article E-1300 changes include
 - Updated Table E-2 is *slightly more restrictive* for Axial Flaws
 - Dedicated case confirmed new Circumferential Flaws values
 - Additional $T_C - RT_{NDT}$ values added for lower temperatures/higher embrittlement
 - Article E-1300 (b) – Axial Flaws
 - $T_C - RT_{NDT} \geq 65^\circ\text{F}$ is *slightly more restrictive*
 - **New** Article E-1300 (c) – Circumferential Flaws
 - $T_C - RT_{NDT} \geq 35^\circ\text{F}$ is *less restrictive* than the axial flaw value

ASME Appendix E Update (4/6)

- Cylindrical Shell Beltline Changes
 - *New* Article E-1300 (d)
 - New Table E-3 utilizes lines of constant 1E-6 probability for various pressure, temperature and cooldown rate scenarios
 - Table E-3a is for axial flaws
 - Table E-3b is for circumferential flaws
 - *New* Article E-1400 (c)
 - Defines a new alternate analytical action that can be taken, if necessary, using a PFM equivalent K_{Ic_AppE} curve coupled with the deterministic evaluation shown in Article E-1400 (a)
- Two new analytical arrows in the proverbial RPV Integrity Quiver

ASME Appendix E Update (5/6)



Pressure, ksi (MPa)	Allowable Minimum Temperatures, °F [°C] for CDR = 100°F/hr (55.6°C/h)
2.50 (17.2)	116 (47)
2.00 (13.8)	110 (43)
1.50 (10.3)	100 (38)
1.00 (6.9)	88 (31)
0.50 (3.4)	70 (21)
0.25 (1.7)	59 (15)
0.0 (0.0)	50 (10)

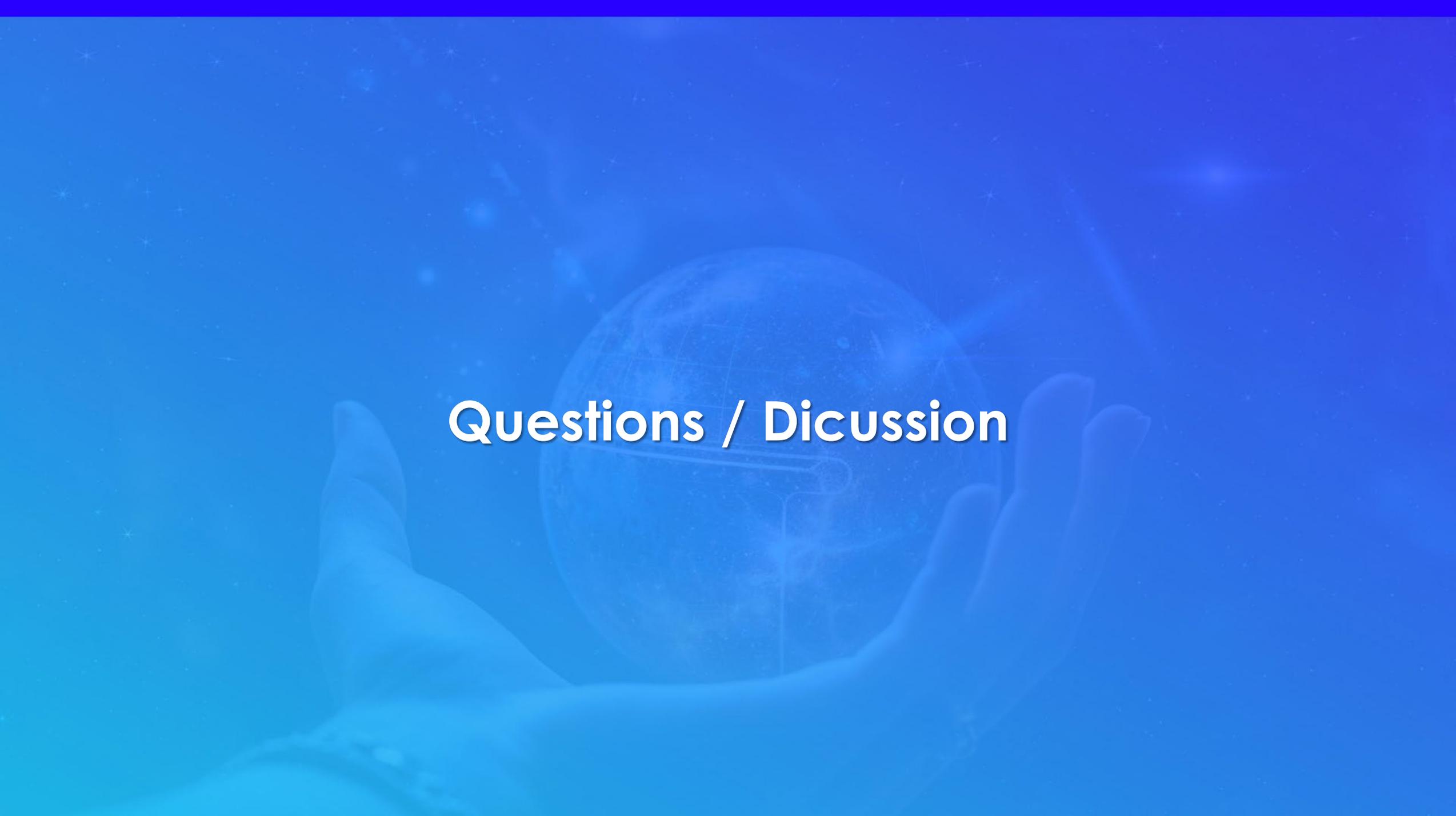
Figure E-1. Flow Diagram for Assessment Approaches Used in Appendix E

Table E-1 Allowable Minimum Temperature as a Function of Pressure for the Outlet Nozzle Corner, Limiting CDR of 100°F/hr (55.6°C/h)

ASME Appendix E Update (6/6)

RT _{MAX_AppE}	Pressure,	Allowable Minimum Temperatures, °F [°C] for CDR, °F/hr (°C/hr)				
°F (°C)	ksi (MPa)	≤10 (≤5.5)	20 (11.1)	50 (27.8)	100 (55.6)	≥ 250 (≥ 121)
245 (118)	2.50 (17.2)	293 [145]	300 [149]	337 [169]	345 [174]	345 [174]
	2.00 (13.8)	246 [119]	252 [122]	310 [154]	327 [164]	345 [174]
	1.50 (10.3)	186 [86]	195 [91]	265 [129]	295 [146]	345 [174]
	1.00 (6.9)	120 [49]	132 [56]	215 [102]	255 [124]	345 [174]
	0.50 (3.4)	50 [10]	60 [16]	153 [67]	210 [99]	345 [174]
	0.25 (1.7)	50 [10]	50 [10]	120 [49]	185 [85]	345 [174]
	0.0 (0.0)	50 [10]	50 [10]	90 [32]	160 [71]	345 [174]
175 (79)	2.50 (17.2)	225 [107]	235 [113]	258 [126]	268 [131]	275 [135]
	2.00 (13.8)	180 [82]	188 [87]	235 [113]	255 [124]	275 [135]
	1.50 (10.3)	131 [55]	140 [60]	202 [94]	232 [111]	275 [135]
	1.00 (6.9)	81 [27]	94 [34]	165 [74]	203 [95]	275 [135]
	0.50 (3.4)	50 [10]	65 [18]	125 [52]	174 [79]	275 [135]
	0.25 (1.7)	50 [10]	50 [10]	105 [41]	158 [70]	275 [135]
	0.0 (0.0)	50 [10]	50 [10]	85 [29]	142 [61]	275 [135]
121 (49)	2.50 (17.2)	165 [74]	172 [78]	181 [83]	202 [94]	221 [105]
	2.00 (13.8)	126 [52]	140 [60]	150 [66]	196 [91]	221 [105]
	1.50 (10.3)	87 [31]	100 [38]	118 [48]	180 [82]	221 [105]
	1.00 (6.9)	50 [10]	65 [18]	82 [28]	160 [71]	221 [105]
	0.50 (3.4)	50 [10]	50 [10]	60 [16]	126 [52]	221 [105]
	0.25 (1.7)	50 [10]	50 [10]	50 [10]	110 [43]	221 [105]
	0.0 (0.0)	50 [10]	50 [10]	50 [10]	95 [35]	221 [105]
75 (24)	2.50 (17.2)	92 [33]	109 [43]	116 [47]	131 [55]	175 [79]
	2.00 (13.8)	78 [26]	95 [35]	105 [41]	125 [52]	175 [79]
	1.50 (10.3)	50 [10]	80 [27]	91 [33]	116 [47]	175 [79]
	1.00 (6.9)	50 [10]	50 [10]	75 [24]	104 [40]	175 [79]
	0.50 (3.4)	50 [10]	50 [10]	50 [10]	83 [28]	175 [79]
	0.25 (1.7)	50 [10]	50 [10]	50 [10]	68 [20]	175 [79]
	0.0 (0.0)	50 [10]	50 [10]	50 [10]	50 [10]	175 [79]
45 (-7)	2.50 (17.2)	68 [20]	84 [29]	90 [32]	100 [38]	145 [63]
	2.00 (13.8)	50 [10]	70 [21]	81 [27]	95 [35]	145 [63]
	1.50 (10.3)	50 [10]	50 [10]	71 [22]	86 [30]	145 [63]
	1.00 (6.9)	50 [10]	50 [10]	50 [10]	73 [23]	145 [63]
	0.50 (3.4)	50 [10]	50 [10]	50 [10]	57 [14]	145 [63]
	0.25 (1.7)	50 [10]	50 [10]	50 [10]	50 [10]	145 [63]
	0.0 (0.0)	50 [10]	50 [10]	50 [10]	50 [10]	145 [63]

RT _{MAX_AppE} , °F (°C)	Pressure, ksi (MPa)	Allowable Minimum Temperatures, °F [°C] for CDR, °F/hr (°C/hr)				
		≤10 (≤5.5)	20 (11.1)	50 (27.8)	100 (55.6)	≥250 (≥121)
251 (122)	2.50 (17.2)	271 [133]	275 [135]	280 [138]	315 [157]	350 [177]
	2.00 (13.8)	238 [114]	243 [117]	250 [121]	290 [143]	350 [177]
	1.50 (10.3)	181 [83]	188 [87]	209 [98]	260 [127]	350 [177]
	1.00 (6.9)	115 [46]	126 [52]	162 [72]	225 [107]	350 [177]
	0.50 (3.4)	50 [10]	62 [17]	115 [46]	190 [88]	350 [177]
	0.25 (1.7)	50 [10]	50 [10]	90 [32]	170 [77]	350 [177]
	0.0 (0.0)	50 [10]	50 [10]	65 [18]	150 [66]	350 [177]



Questions / Discussion