Issues Regarding the Technical Basis for Reactor Pressure Vessel Closure Flange Rulemaking

Westinghouse Owners Group

Presentation to NRC

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Background

Summary of Revisions to WCAP-14040

Reactor Pressure Vessel (RPV) Closure Flange Requirement

Basis of the RPV Closure Flange Requirement

Plant Geometries Considered

Stress Analyses

Fracture Analysis Methods

RPV Closure Flange Integrity Evaluation

Proposed Elimination of RPV Closure Flange Requirement

Safety Impact of Eliminating RPV Closure Flange Requirement for PWRs

Summary and Conclusions

Future Actions

Background

- WCAP-14040 Submitted to NRC to Obtain Review and Approval of Methodology used to Develop RCS Heatup (H/U) and Cooldown (C/D) Limit Curves and Cold Overpressure Mitigating System (COMS) Setpoints

- Approved Methodology Allows Relocating RCS H/U and C/D Limit Curves and COMS Setpoints from Tech Specs to a Pressure and Temperature Limits Report (PTLR)

- NRC approved WCAP-14040 in October 1995

Background (cont.)

- Several changes have been made in H/U and C/D Limit Curve Development Methods, and Incorporated into Appendix G of Section XI of the ASME Code since 1995

- WCAP-14040 is being revised to incorporate these changes into an updated Topical Report that contains the current Methodology used to Develop H/U and C/D Limit Curves

- These changes are incorporated as options, to allow plants the flexibility of implementing the changes, if desired

Summary of Revisions to WCAP-14040

- Code Case N514: Low Temperature Overpressure Protection (February 12, 1992)
- Code Case N640: Alternate Reference Fracture Toughness for Development of P-T Limit Curves (February 26, 1996)
- Code Case N588: Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in the Reactor Vessel (December 12, 1997)
- Code Case N641: Alternative Pressure-Temperature Relationship and Low Temperature Overpressure Protection System Requirements (January 17, 2000)
- Proposed Elimination of Flange Requirement

RPV Closure Flange Requirement

- Required to be Included by 10CFR50 Appendix G
- High stresses in the closure head flange region during boltup
- OD surface stresses don't increase much between boltup and normal operating pressure, but the distribution changes from bending to membrane

RPV Closure Flange Requirement (cont.)

- Since boltup is performed at low temperatures, fracture margin is important there

- The original flange requirements were developed because of the relatively low toughness used at the time: K_{Ia}

- The recent approval of the use of K_{ic} eliminates the need to include the flange requirement

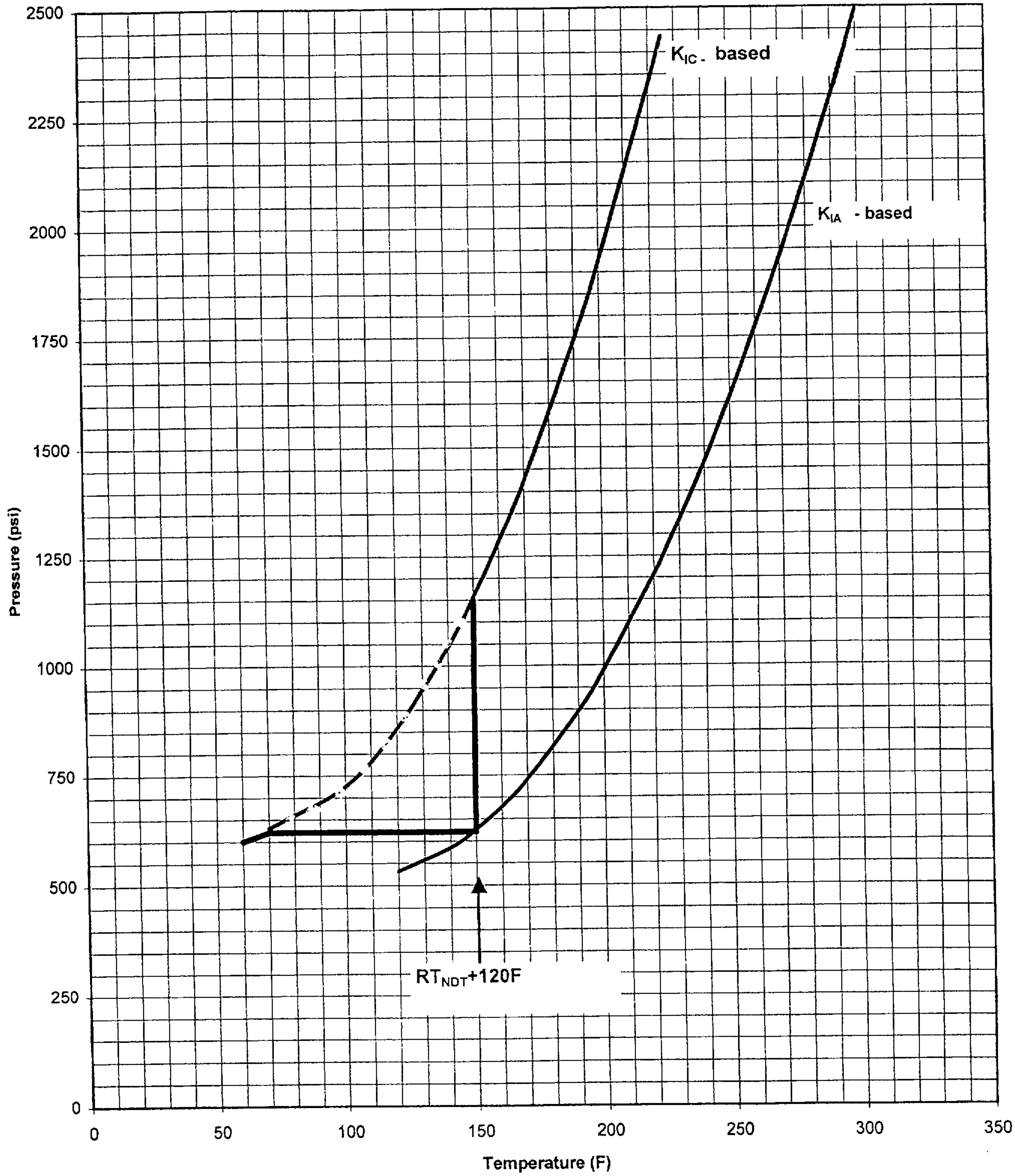
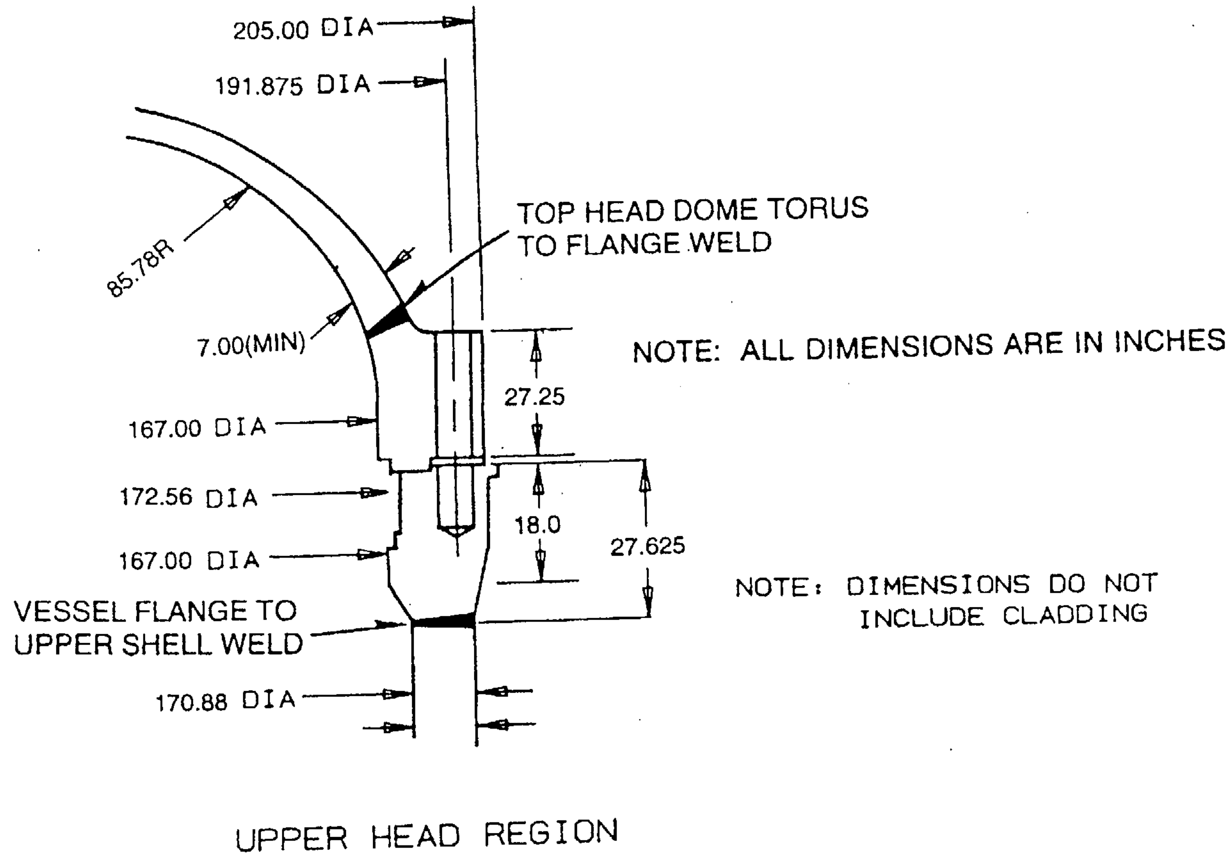


Figure 1-1 Illustration of the Impact of the Flange Requirement for a Typical PWR Plant



Typical Geometry - Closure Head/Flange Region

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Basis of the RPV Closure Flange Requirement
(From Neil Randal's discussion in the FR, 11/14/80)

- Consider closure head/flange region
- Stresses are higher at OD; use outside surface flaw
- A/T = 0.25
- Safety factor = 2
- For this combination, K* = 92.7 ksi in.
- Neil Randall's calculation was more conservative; K* = 98.3 ksi in. (A/T = 0.1, stress = 40-50 ksi)
- Using the K_{IA} curve, boltup should be at RT_{NDT} + 120
- Since this is unrealistic, the requirement was changed to allow pressure up to 20% of design hydro before imposing the temperature requirement

Plant Geometries Considered

Design	Thickness
Westinghouse (2 loop)	5.7
Westinghouse (3 loop)	5.8
Westinghouse (4 loop)	7.0
CE	7.4
B&W	6.8
GE (design 1)	3.6
GE (design 2)	4.0
GE (design 3)	4.8

Stress Analyses

- All cases were finite element results
- ASME code minimum properties are used
- Axisymmetic models are used
- Steady state stress is very similar for all designs
  - Mostly membrane stress
  - Bending stresses higher for BWRs
- Boltup stress is mostly bending
- Comparisons were not available for the Westinghouse 2 loop plants
  - Conservatively covered by the 4 loop results

Axial Stress Comparison: Steady State Operation @ 2250 psi

Plant	OD Stress	Membrane Stress	Bending Stress
W 4 Loop	22.8	10.0	12.8
W 3 Loop	20.9	11.6	9.3
CE	46.4	12.8	33.6
B&W	55.7	19.0	36.7

Stress Comparison: Boltup vs Steady State

Plant	Boltup Membrane	Boltup Bending	SS Membrane	SS Bending
W 4 Loop	1.1	14.2	10.0	12.8
W 3 Loop	2.1	14.5	11.6	9.3
CE	0.8	22.8	12.8	33.6
B&W	4.3	27.6	19.0	36.7

Fracture Analysis Methods

- Stress Intensity Factor: Raju and Newman
- Fracture Toughness: K_{Ia} and K_{Ic}
- Irradiation Effects Negligible

RPV Closure Flange Integrity Evaluation

- Semi-elliptic surface flaw postulated on head OD
- Orientation parallel to the weld
- Boltup cases analyzed to determine maximum value of K for any flaw depth
- PWR and BWR cases considered
- Typical boltup temperatures are:
  - 60 F for PWRs
  - 80 F for BWRs
- Using the K_{Ic} toughness, significant margin exists in all cases
  – Not true for K_{Ia}, the reason for the original concern

Proposed Elimination of RPV Closure Flange Requirement

- Consider developing a set of boltup requirements, using the following assumptions:
  - Postulated flaw depth - T/10
  - Safety factor = 2.0
  - K_{Ia} or K_{Ic} lower bound curves

- Using K_{Ia}, the governing case is RT_{NDT} + 118F, closely matching the original requirement of RT_{NDT} + 120F

- Using K_{Ic} , the requirement for PWRs is RT_{NDT} to RT_{NDT} + 41F
  Since RT_{NDT} is typically 10F, boltup would be at 10-51F
  Typically boltup is at 60F ⇨ no requirement needed

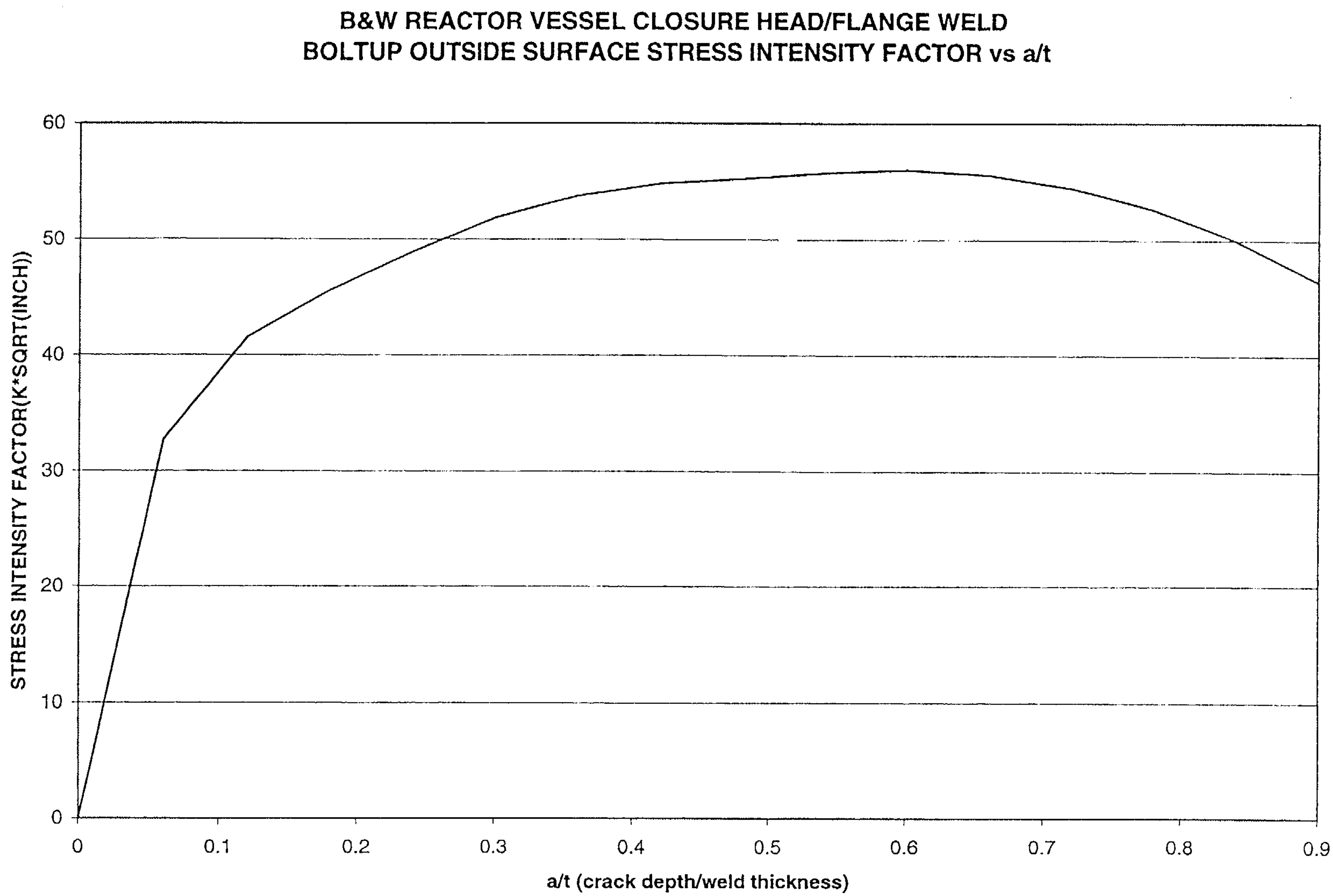
- Using K_{Ic}, the requirement for BWRs is RT_{NDT} to RT_{NDT} + 56F
  Since RT_{NDT} is typically 10F, boltup would be at 10-66F
  Typically boltup is at 80F ⇨ no requirement needed

Boltup Requirements: K_{Ic} VS K_{Ia}
Comparison of Stress Intensity Factors

Plant	K (a/t=0.1)*	K (SF=2)*	T-RT_{NDT} (K_{Ic})	T-RT_{NDT} (K_{Ia})
W 4 Loop	19.7	39.4	0.0 F	1.0 F
W 3 Loop	19.4	38.8	0.0 F	0.0 F
CE	30.0	60.0	13.0 F	68.0 F
B&W	39.4	79.8	41.0 F	100.0 F

* Note: All units in ksi $\sqrt{}$ in.

BWR (1)	38.7	77.4	38.0	97.0
BWR (2)	48.0	96.0	56.0	118.0
BWR (3)	25.1	50.2	0	43.0



Stress Intensity Factor vs Flaw Size: B&W Plant (t = 6.82 inches)

RPV Closure Flange Integrity Summary

Design	(Depth, a/t)	K_{Ic}	K_{Ia}
CE	41 (0.42)	89.6	52.7
B&W	56 (0.60)	89.6	52.7
W 4 Loop	31 (0.44)	89.6	52.7
W 3 Loop	32 (0.44)	89.6	52.7
BWR Design 1	56 (0.42)	117.3	61.4
BWR Design 2	69 (0.40)	117.3	61.4
BWR Design 3	37 (0.42)	117.3	61.4

Safety Impact of Eliminating RPV Closure Flange Requirement for PWRs

- Current RPV closure flange requirements can cause severe operational limitations, after accounting for instrument uncertainty

- The lower limit of pressure is 20% of hydrotest, or 621 psig until the flange limit of RT_{NDT} + 120F is exceeded

- Minimum pressure to cool the RCP seals is 325 psi

Safety Impact of Eliminating RPV Closure Flange Requirement for PWRs (cont.)

- The operating window can become very small
- Example: For one plant, the operating window would increase from 121 psig to 262 psig
- This change would significantly reduce the potential of an RCP seal failure (small LOCA)

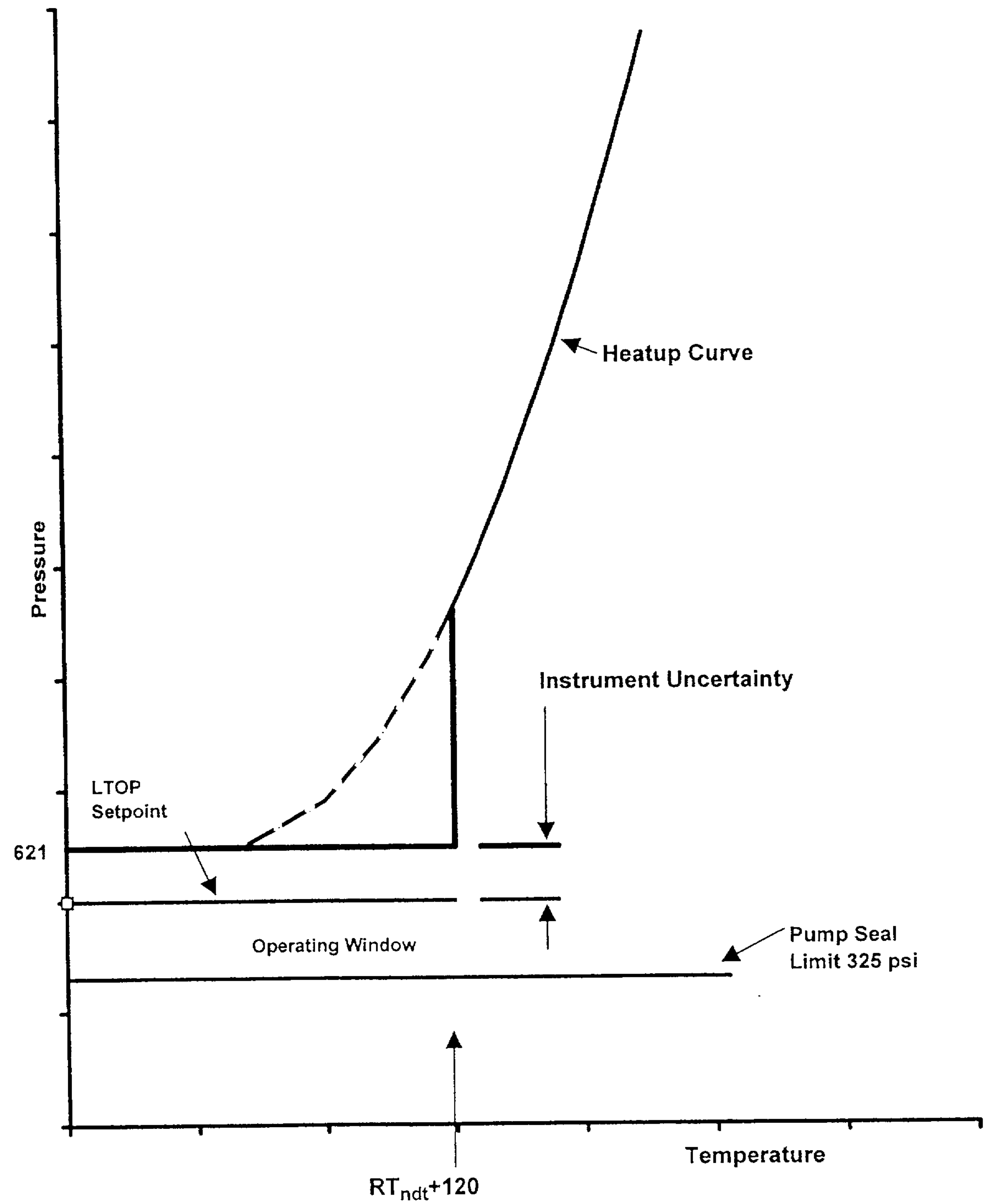


Figure 6-1 Illustration of the Flange Requirement and its Effect on the Operating Window for a Typical Heatup Curve

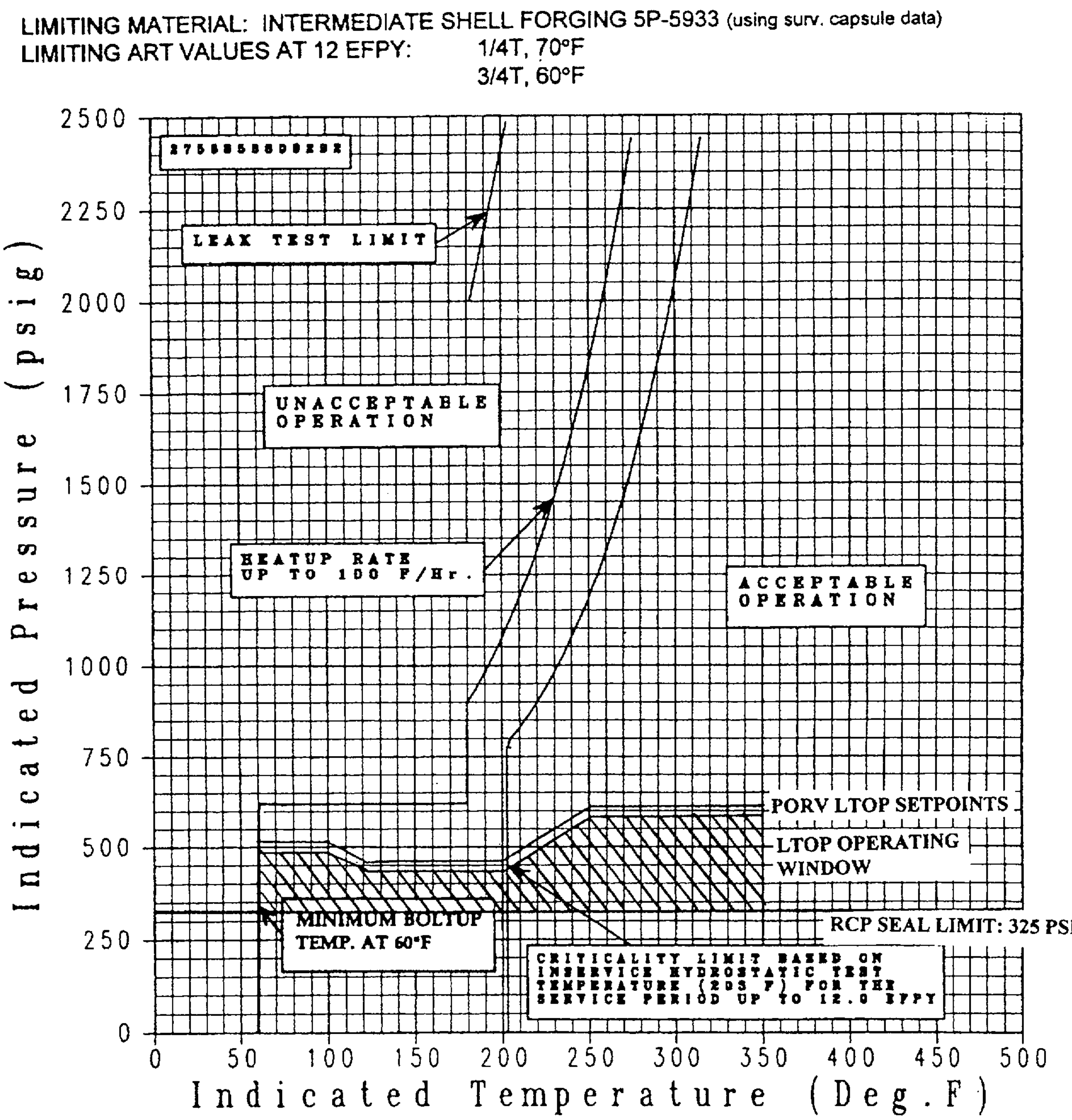


Figure 6-2 Illustration of the Actual Operating Window for Heatup of Byron Unit 1, a Low Copper Plant at 12 EFPY

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 5P-5933 (using surv. capsule data)
LIMITING ART VALUES AT 12 EFPY: 1/4T, 70°F
3/4T, 60°F

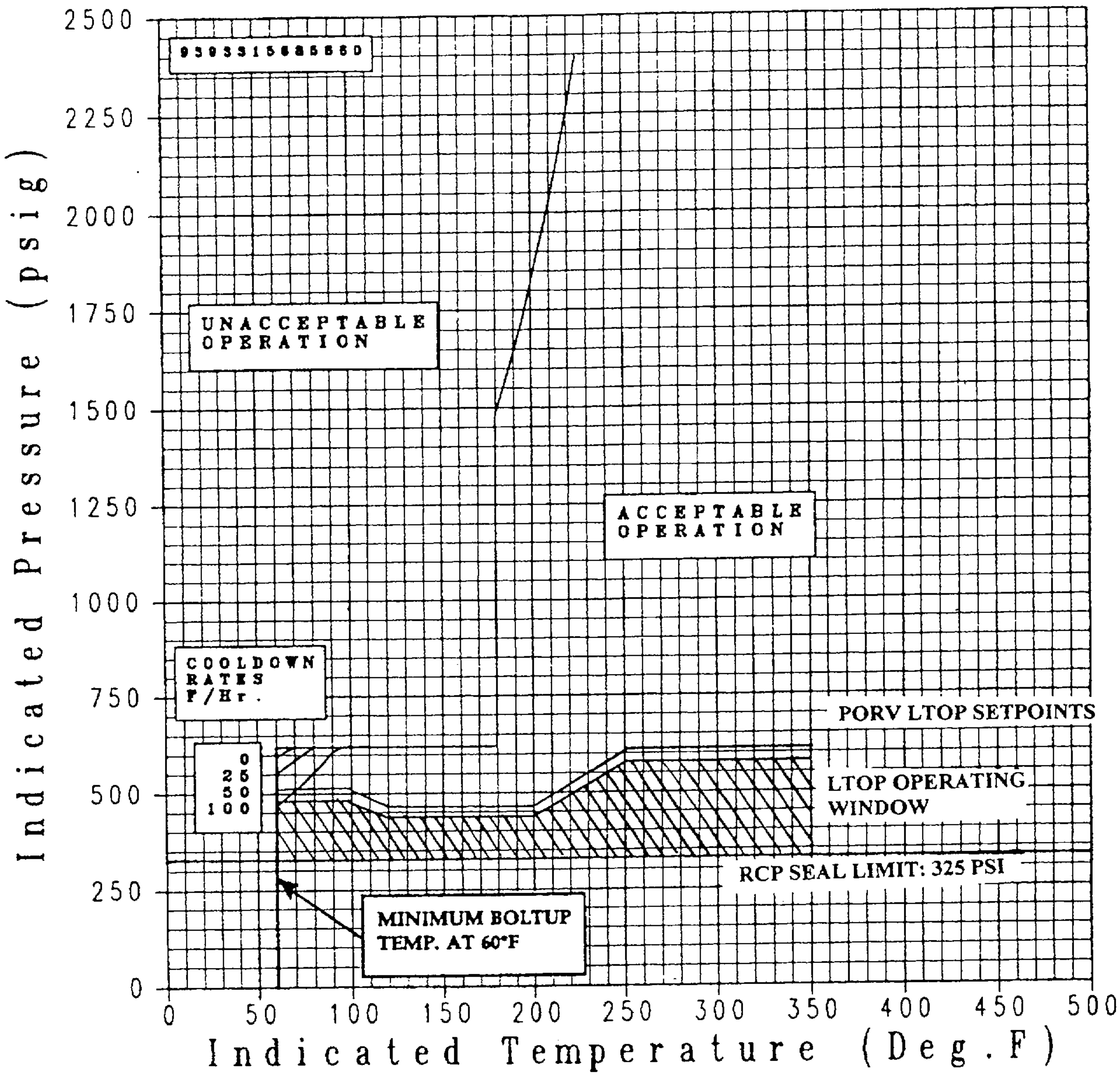


Figure 6-3 Illustration of the Actual Operating Window for Cooldown of Byron Unit 1, a Low Copper Plant at 12 EFPY

Summary and Conclusions

- The RPV closure flange requirement originated over 20 years ago, when the standard practice was to use the K_{Ia} reference toughness curve

- The development and approval of Code Case N640, allowing the use of K_{IC} has significantly improved the H/U and C/D curves

- Use of Code Case N640 significantly improves operational safety, by increasing the operating window between the P-T curve and the RCP Seal cooling pressure

Summary and Conclusions (cont.)

- The benefits of Code Case N640 are severely limited by the RPV closure flange requirement

- Use of K_{IC} has demonstrated that the RPV closure flange requirement is not required

Future Actions

- Schedule for Rulemaking
- Treatment of Exemption Requests
- Schedule for submittal of WCAP 14040 Rev. 3