Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Impact of Applying Code Case N-641 Methodology on the Enable Temperature and Allowable Pressure for LTOP System

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1. Introduction

Recently, several code cases were promulgated to provide alternative methodologies to existing methodologies for developing pressure-temperature (P-T) limits and low temperature overpressure protection (LTOP) system [1~4]. They take into account alternative fracture toughness, circumferential and axial reference flaws, and plant-specific LTOP enable temperature. These provisions of code cases were incorporated into ASME Sec. XI, App. G in the 1998 edition through 2000 addenda which is codified in 10CFR50.55a. Also, NRC permitted the use of these code cases without the need for an exemption [5].

The present study investigates the impact of applying these alternative methodologies on the LTOP system enable temperature and allowable pressure. Thus, the LTOP system enable temperature and allowable pressure of sample reactor pressure vessel (RPV) are calculated using alternative methodologies given by Code Case N-641, and the results are quantitatively compared with those calculated according to existing SRP 5.2.2 requirement and App. G methodology [6].

2. Requirements of Enable Temperature and Allowable Pressure for LTOP System

The purpose of LTOP system is to protect RPV from being exposure conditions of brittle fracture when the residual heat removal system (RHRS) relief valve is unavailable. Thus, LTOP system is designed to be available under low temperature and overpressure conditions. The requirements for enable temperature and allowable pressure of LTOP system are specified. Table 1 summarizes the enable temperature and allowable pressure required by SRP 5.2.2, ASME Sec.XI App.G, and Code Case N-641.

Usually, P-T limit is determined to satisfy Eq. (1) in all specifications presented in Table 1,

$$2K_{IM}+K_{IT} < \text{Fracture Toughness of RPV} \qquad (1)$$

where K_{IM} and K_{IT} are stress intensity factor of postulated crack corresponding to membrane stress and thermal stress, respectively. As fracture toughness of RPV in Eq. (1), K_{IA} is only allowed to use up to App. G of ASME Sec.XI in 1998 edition. Code Case N-641 methodology allowed to alternatively use K_{IC} instead of K_{IA}. K_{IA} is lower bound on all static, dynamic, and arrest fracture toughness of RPV, and K_{IC} is lower bound on static fracture toughness only. Fig. 1 presents the K_{IA} and K_{IC} as a function of material RT_{NDT} and temperature. As presented in Table 1, the allowable pressure was determined based on this P-T limit.

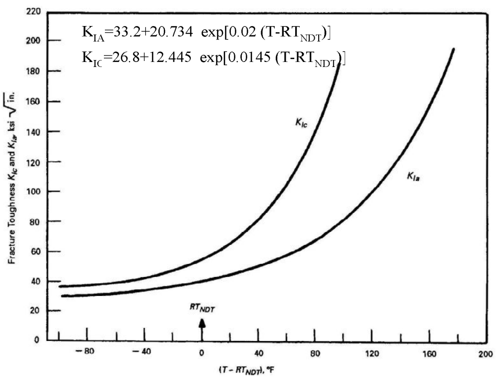


Fig. 1 Lower bound K_{IA} and K_{IC} for reactor pressure vessel materials

3. Evaluation of the Enable Temperature and Allowable Pressure

According to the requirements summarized in Table 1, the enable temperature and maximum allowable pressure for LTOP system were evaluated on two sample RPVs (YG unit 1 and YG unit 2). Table 2 lists the values of RT_{NDT} for two RPVs, which are the maximum at 32EFPY given by 5th surveillance capsule test. Using these values, the enable temperatures of LTOP system and fracture toughness (K_{IA} and K_{IC}) were directly calculated.

The allowable pressure for LTOP system was determined by considering margin of 100% and 110%

Table 1 Requirement of the enable temperature and allowable pressure for LTOP system

Specifications	Enable temperature	Max. allowable pressure
SRP 5.2.2	$RT_{NDT}+90^{o}F$	100% of P-T limit
ASME Sec.XI App. G, 98ed.	Max [$RT_{NDT}+50^{o}F$, $200^{o}F$]	110% of P-T limit
Code Case N-641	Max [$RT_{NDT}+40^{o}F$, $200^{o}F$] or Max [Ψ , $200^{o}F$]	110% of P-T limit for using K_{IA} 100% of P-T limit for using K_{IC}

$\Psi = RT_{NDT}+50\ln[((1.1M_m(pRi/t))-33.2)/20.734]$

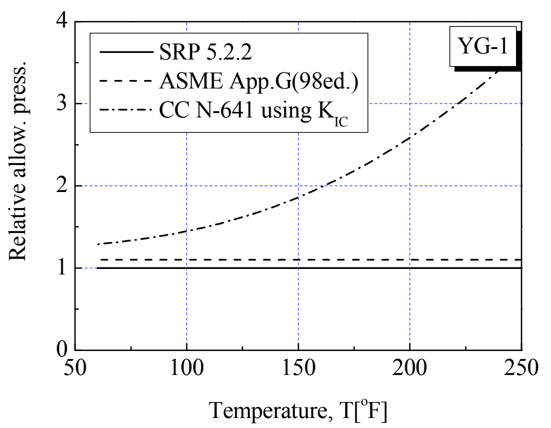
to the maximum pressure of P-T limit, which was calculated by Eq. (2). In this case, since low temperature overpressure events most likely occur during isothermal conditions in the reactor coolant system (RCS), it was assumed that the temperature gradient in the RPV wall was negligible.

$$P = \frac{K_{IA}\ or\ K_{IC}}{2M_m}\left(\frac{t}{R_i}\right) \qquad (2)$$

In the calculation, K_{IA} was used when SRP 5.2.2 and App. G of ASME Sec. XI methodologies were applied, and K_{IC} was used when Code Case N-641 methodology was applied.

Table 2 RT_{NDT} and calculated enable temperature of LTOP system for two sample RPVs

	YG-1	YG-2
RT_{NDT}(°F)	84.2	133.2
SRP 5.2.2	174.2 °F	223.2 °F
ASME App. G, 98ed.	200 °F	200 °F
Code Case N-641	200 °F	200 °F



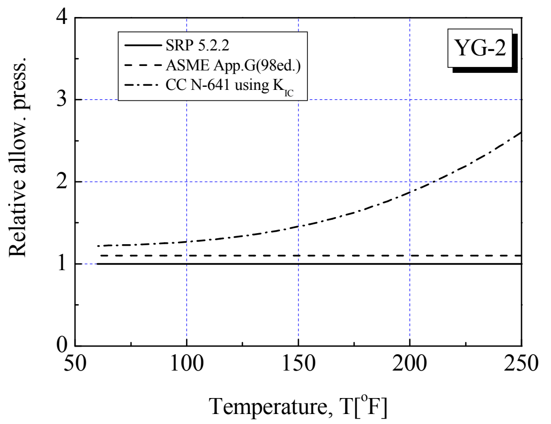


Fig. 2 Normalized allowable pressure for two sample RPVs.

4. Results and Discussion

Table 2 shows the enable temperature calculated by each specification. For less embrittled RPV (YG-1), the enable temperature calculated by SRP 5.2.2 was lower than that calculated by App. G of ASME Sec.XI and Code Case N-641 methodologies. However, for higher embrittled vessel (YG-2), the App. G of ASME Sec.XI and Code Case N-641 methodologies gave lower enable temperature compared to SRP 5.2.2 methodology. Therefore, it is known that, for a severely embrittled RPV, an improvement in the enable temperature can be obtained by applying of Code Case N-641.

Fig. 2 shows the allowable pressures for LTOP system of sample RPVs, which are normalized by the allowable pressure calculated by existing SRP 5.2.2 requirement. For both RPVs, the allowable pressure calculated by App. G of ASME methodology was higher 10% than that calculated by existing SRP 5.2.2 requirement. This is associated with the difference of margin on the allowable pressure for each methodology. On the other hand, the allowable pressure considerably increased by applying Code Case N-641 methodology compared to existing SRP 5.2.2 and App.G of ASME methodologies. The degree of increment was influenced by the temperature and degree of embrittlement of RPV. With increasing temperature and decreasing degree of embrittlement, the increment of allowable pressure was clear. The significant increase in allowable pressure for LTOP system by applying Code Case N-641 is mainly associated with the use of K_{IC} instead of K_{IA}.

5. Summary

In this work, the impact of applying alternative methodology of Code Case N-641 was investigated by evaluating the enable temperature and allowable pressure of LTOP system for two sample RPVs. By applying Code Case N-641, the allowable pressure for LTOP system was considerably increased compared with results obtained by existing methodologies.

REFERENCES

[1] ASME Code Case N-514, Sec.XI, "Low Temperature Overpressure Protection," Feb. 12, 1992.
[2] ASME Code Case N-588, Sec.XI, "Alternative to Reference Flow Orientation of App. G for Circumferential Welds in Reactor Vessels," Dec. 12, 1997.
[3] ASME Code Case N-640, Sec.XI, "Alternative to Reference Fracture Toughness for Development of P-T Limit Curves," Feb. 26, 1996.
[4] ASME Code Case N-641, Sec.XI, "Alternative Pressure-Temperature Relationship and Low Temperature Overpressure Protection System Requirements," Jan. 17, 2000.
[5] NRC Regulatory Issue Summary 2004-04: Use of Code Cases N-588, N-640, and N-641 in Developing Pressure-Temperature Operating Limits
[6] ASME B & PV, Sec. XI, "Rule for Inservice Inspection of Nuclear Power Plant Components," App.G, Fracture Toughness Criteria For Protection Against Failure.