STP-NU-008

CONSERVATISM IN THE B_2 AND B_2' INDEX

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CONSERVATISM IN THE B_2 AND B_2' INDEX

Prepared by:

ASME Task Group on Seismic Issues
R. P. Deubler (Chair)
T. Adams
H. Kobayashi
D. Landers
J. Minichiello

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FOREWORD

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ABSTRACT

This paper presents the reasoning and justification for using the $B_2' = (2/3)*B_2$ in Paragraphs NB-3656(b) and NC/ND-3655(b) of Section III. Concern has been expressed that since the tests that form part of the basis for setting $B_2' = (2/3)*B_2$ were conducted at ambient temperature, the effect of dynamic strain aging of carbon steels could reduce the seismic margins at temperatures in excess of 300˚F (150˚C). In response to this concern, the authors prepared this paper as a team working under the Piping Seismic Task Group. This paper demonstrates that:

- For typical carbon steel under seismic strain rate loading, at elevated temperature [(above 300˚F (150˚C)] and at stress levels permitted by the alternative Code equation [NB-3556(b)(2) and NB-3556(b)(3)], the margin to failure is at least 1.5, as recommended by Dr. R.P. Kennedy. Thus, the use of $B_2' = (2/3)*B_2$ results in a component with acceptable margin.
- The B_2 index itself is a conservative estimate of the stress in the component, both from the method of application in the Code (use for prediction of seismic stresses) and from the value itself. Thus, the use of $B_2' = (2/3)*B_2$ results in a component with acceptable margin.

1 BACKGROUND

ASME revised the rules for piping subjected to seismic and other building filtered loads in the 1994 addenda to the 1992 Code to provide an alternative to the existing rules. The purpose of the revision was to recognize the results of significant testing and experience that supported a decrease in the multiplier (B index) of the moment term, among other changes. The use of a B_2' index set equal to 2/3 of the current B_2 index effectively raised the Level D allowable 50%. As part of its review in 10CFR50.55a, the NRC noted that use of the new rules was not permitted, due to disagreements in the approach.

Since the 1994 addenda were published, the NRC and ASME have worked together to revise the changes. At this time, it is ASME's understanding that the rules proposed for inclusion in the 2007 Code will be accepted by the NRC, with the exception of the use of a B_2' index equal to 2/3 of B_2 for bends and tees. For those items, the NRC believes a multiplier of 3/4 is more appropriate for ferritic steels at temperatures above 300˚F, due to dynamic strain aging.

2 PURPOSE

The purpose of this paper is to present the ASME position in support of setting $B_2' = (2/3)*B_2$ in Paragraphs NB-3656(b) and NC/ND-3655(b) of Section III. The ASME position is supported in two ways:

- Work by the Japanese Seismic Research Team, using actual high temperature stress-strain curves, to indicate that the use of the 2/3 factor is acceptable.
- A summary of the conservatism in the current Code stress indices, showing that there is sufficient margin in the Code methodology to make up the difference between 2/3 and 3/4.

3 PRESENT CODE RULES

The current ASME Section III rules for seismic evaluation of P1 through P9 piping materials permit an alternate evaluation method for standard to thick-walled piping ($D_o/t_n < 40$). The alternate rules are presented in NB-3656(b) and NC/ND-3655(b) and are essentially the same across all three Classes. These alternate rules use the same stress allowable as permitted in the standard rules ($3S_m$ or $3S_h$, depending on Class). The main difference between the standard and alternate rules is in the multiplier for the moment stresses. Using NC as an example:

$$\frac{B_1 P_{\max} D_o}{2t_n} + B_2\left(\frac{M_A + M_B}{Z}\right) \le 3S_h \text{ or } 2S_y \text{ (lesser)} \quad (1)$$

Standard equation per NC-3655(a)

$$\frac{B_1 P_{\max} D_o}{2t_n} + B_2' \frac{D_0}{2I} M_E \le 3S_h \quad (2)$$

Alternate equation per NC-3655(b)(3)

Where:

B_1, B_2 = Primary stress indices for the specific product under investigation

B_2' = B_2 except for certain components, which is the topic of this paper

P_{max} = Peak pressure

P_D = the pressure coincident with the reversing dynamic load

D_o = outside diameter of pipe

t_n = nominal wall thickness

M_A = resultant moment on cross-section due to weight and other sustained loads

M_B = resultant moment on cross-section due to reversing and non-reversing dynamic loads

M_E = the amplitude of the resultant moment due to weight and inertial loads from reversing dynamic loads

Z = Section modulus of pipe

S_h = material allowable stress at temperature consistent with the loading under consideration

S_y = material yield strength at temperature consistent with the loading under consideration

The appropriate NC Code sub-articles are provided for information in Appendix 1.

The major difference between the two equations is the multiplier of the moment terms. In the standard rules, B_2 is used. In the alternate rules, B_2' is used. For welding elbows, bends and tees, the relationship between B_2 and B_2' is:

$B_2' = 0.667 * B_2$

The NRC has submitted work (Appendix 2) indicating that the relationship should be different for ferritic material above 300˚F:

$B_2' = 0.75 * B_2$

The main basis for the NRC position is that ferritic material exhibits dynamic strain aging at elevated temperature and elevated strain rate (Appendix 3).