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OFFICE OF SECRETARY
RULEMAKINGS AND
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Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ATTN: Rulemakings and Adjudications Staff

Subject: Comments on Docket ID NRC-2008-0554
Incorporate by Reference 2005 Addenda through 2008 Addenda of Section III, Division 1

NRC proposes to incorporate, by reference, the 2005 Addenda through 2008 Addenda of Section III Division 1 into 10 CFR 50.55a for construction of nuclear power plant components. By this action, NRC accepts the Section III piping code rules (NB/NC/ND-3600) for evaluation of "reversing dynamic loads" (piping seismic rules) subject to certain conditions

I have been actively involved in this issue since the early 1980s. My technical position is that there are significant safety concerns with the piping seismic rules. The rules should not be approved by NRC for use in new construction.

The main safety concern is adequacy of the rules for preventing a fatigue failure for a Level D earthquake event. There are also technical concerns with the Level B rules that apply for an OBE.

The concern on preventing a fatigue failure for a Level D earthquake extends to the 1993 code rules. The original Section III rules for Level D were developed under the premise that a one-time event is not a concern for fatigue. The EPRI/NRC Piping and Fitting Dynamic Reliability Program demonstrate that a fatigue failure in a single earthquake event is possible. Therefore, the 1993 Section III Level D code rules need to be examined for applicability for a Level D earthquake.

The prudent regulatory approach is to reject the 1994 and later piping seismic rules. Additional requirements need to be added to the 1993 rules to provide protection against a fatigue failure for a Level D earthquake event. The Level D fatigue rules must include consideration of the detrimental effects of hoop ratchet strains on fatigue life. At the Level D pressure allowable limit, hoop stresses are greater than the minimum yield strength of the material. The combination of high hoop pressure stress and high cyclic moments causes hoop ratcheting.

The technical justification for the 1994 and later piping seismic rules has changed during the long code deliberations on this topic. The core data has always been the PFDRP component test results. But, the interpretation of how to apply those results to piping seismic design has changed. The most recent technical justification is a "Seismic Capacity Margin" approach where the seismic capacity margin is specified in terms of MUD "the ultimate moment achieved in any component under dynamic cyclic loading prior to failure". Calculating the seismic margin in this

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manner is obviously considering the failure mode to be collapse. However, the ultimate moment approach was assumed to prevent a low cycle fatigue failure.

This assumption is completely wrong and in conflict with the "ETEC minimum fatigue margin study results" reported in NUREG/CR-5361. A measured moment from a dynamic test has no relationship to fatigue life of the tested component.

My technical concerns on the piping seismic rules are discussed below.

1. There is a significant safety concern due to the possibility of a fatigue failure from a Level D earthquake. The ability of the plant to safely shutdown after a Level D earthquake is severely compromised.

Explanation – The piping component tests in the EPRI/NRC Piping and Fitting Dynamic Reliability Program demonstrate that a fatigue failure in a single earthquake event is possible. The data also show that a fatigue failure is more likely than a collapse failure although a collapse failure is possible. There are no explicit fatigue protection rules in NB/NC/ND-3600 for Level D events.

2. A fatigue failure at the Level D stress levels allowed by NB-3600 is likely.

Explanation – Ignoring pressure stress, the primary bending stress amplitude from seismic inertial load, as predicted by B_2M/Z, is allowed to reach $4.5S_m$. For many fittings, the secondary stress from seismic inertia loads could be significantly higher. And for some fittings and for weld joints, there is an applicable K_2 stress index to account for local stress concentrations. Assuming a factor of 2 to account for secondary and peak stress effects, the alternating stress for a fatigue calculation for this example is $9S_m$. For carbon steel with S_m of 20ksi, S_{alt} is 180ksi without consideration of the K_e penalty factor that would apply. From the fatigue design curve for carbon steel, the allowable number of cycles for 180 ksi is around 100. The maximum K_e of 5 will probably apply. Including the K_e factor, the allowable number of cycles is much less than 10. The secondary stress range from seismic anchor motions is allowed to reach $6.0S_m$. The fatigue damage from seismic anchor motions by itself will be less than for seismic inertia loads but in the same order of magnitude. Seismic inertia stresses and anchor motion stresses can combine. A fatigue failure at the Level D seismic stress levels allowed by the code is probable as shown by this example calculation.

In addition, the entire fatigue life could be "used up" by thermal expansion and thermal gradient stress cycles. If this condition occurred, there is no design fatigue margin for an SSE occurring near the end of plant life.

In addition, the code fatigue evaluation does not account for the extremely detrimental effects of ratcheting on fatigue life. The Level D limits allow pressure hoop stress to be above yield. At these stress levels, hoop ratchet effects on fatigue life are severe.

The NB-3600 Level D seismic rules allow stress levels that are excessive and fatigue failures are likely.

3. A fatigue failure at the Level D stress levels allowed by NC/ND-3600 is likely.

Explanation – The Class 2/3 Level D seismic stress limits are similar to the Class 1 rules discussed in item 2 above. Hence, a fatigue failure in a single earthquake event at these limits is possible. In addition, thermal expansion cycling could use up most of the fatigue life. A fatigue

failure from a Level D earthquake that occurs near the end of plant design life is likely if the predicted piping system stresses are near the Level D stress limits.

4. The technical justification for the piping seismic rules is inadequate.

Explanation – The data given in NUREG/CR-5361 demonstrate an unacceptable margin of safety against fatigue failure for certain test conditions. "Dynamic Margins" as calculated by ETEC are provided in Table 4 of this NUREG. A dynamic margin of 2 was considered to be an acceptable level of margin. Results of margin calculations for 19 PFDRP component tests are reported in column V of Table 4. Of the 19 reported test values, 8 tests have margins of less than 2. Six tests have margins less than 1.5. Four tests have margins less than 1. A margin less than 1 indicates a predicted fatigue failure.

The margin calculations were performed for seismic inertia effects only. NUREG/CR-5361 identified the technical issue of the reduction in margin due to concurrent seismic anchor motion moments.

The NUREG margin calculations on the PFDRP component tests indicate that the Level D rules for reversing dynamic loads are unacceptable.

5. The technical justification for the changes to the NB-3600 Level B piping seismic design rules is not valid, and the rules are not valid.

Explanation – Seismic inertia moments were removed from the NB-3600 Level B Equation (9) on the basis that collapse is not a potential failure mode. As discussed in NUREG/CR-5361 (5.1.1) that assumption is incorrect. PFDRP component tests #37 and #40 failed by a collapse mode. The NUREG also discusses analytical studies at Caltech that indicate the existence of an unstable behavior for certain regimes.

The removal of seismic inertia moments from Level B Equation (9) is in conflict with the technical basis for the Level D rules. The technical basis for the Level D rules used an "ultimate moment M_{UD} achieved under dynamic cyclic loading which is reliably reached prior to failure irrespective of whether the ultimate failure mode is low cycle fatigue or excessive deformation" [Appendix III-B of NUREG/CR-5361]. Hence, the collapse mode (excessive deformation) is considered in the technical basis for the Level D rules

The seismic inertia moments must be included in NB-3600 Level B Equation (9) to ensure that there is an appropriate safety factor against a collapse failure.

6. The technical justification for the changes to the NB-3223 Level B Service Limits for piping seismic design is not valid, and the rule is not valid.

Explanation – Seismic inertia moments are removed from the NB-3223 Level B primary stress intensity limit on the basis that collapse is not a potential failure mode. As discussed in NUREG/CR-5361 (5.1.1) that assumption is incorrect. PFDRP component tests #37 and #40 failed by a collapse mode. The NUREG also discusses analytical studies at Caltech that indicate the existence of an unstable behavior for certain regimes.

The removal of seismic inertia moments from Level B primary stress limits is in conflict with the technical basis for the Level D rules. The technical basis for the Level D rules used an "ultimate moment M_{UD} achieved under dynamic cyclic loading which is reliably reached prior to failure irrespective of whether the ultimate failure mode is low cycle fatigue or excessive

deformation" [Appendix III-B of NUREG/CR-5361]. Hence, the collapse mode (excessive deformation) is considered in the technical basis for the Level D rules.

The seismic inertia moment must be included in the NB-3223 Level B primary stress intensity limit to ensure that there is an appropriate safety factor against a collapse failure.

7. The technical justification for the changes to the NB-3225 Level D Service Limits for piping seismic design is not valid, and the rule is not valid.

Explanation – NB-3225 with requirements for Level D service limits allows the use of the NB-3600 Level D piping seismic rules as an alternative to those contained in Appendix F. The NB-3600 Level D piping seismic rules do not protect against a fatigue failure as noted in item 2 above.

8. There is no appropriate technical justification for the changes to the NC/ND-3600 Level B piping seismic design rules, and the rules are not valid.

Explanation – The NC/ND-3653.1 rules for Level B "occasional loads" Equation (9a) are revised for seismic loads by changing the B_2 factor to the B_2' factor. This change allows the Level B seismic inertia moment to be 50% higher for most piping fittings and joints.

There is no appropriate technical justification for this change. The net result of the change is a significantly reduced and unacceptable safety factor against collapse failure for a Level B earthquake.

9. Seismic margins for the lug component tests have not been evaluated.

Explanation – Two of the PFDRP components tested were a four-lug configuration on straight pipe. Both of these lug component tests failed during the first high level excitation. Hence, the seismic performance of the lug configuration was amongst the lowest of all the component tests. These two component tests were not evaluated in NUREG/CR-5361, and margins were not established. From my evaluation of the component test data and the lug test configuration, I concluded that the predicted test levels were grossly overestimated because the load applied to the lugs is limited by yielding in the 6-inch, sch 40 branch pipe [refer to JPVT, November 1998, Vol. 120, pg. 454]. Hence, the seismic performance of the lug configuration in the PFDRP component tests is judged to be much less than that of a "girth butt weld between items that do not have nominally identical wall thicknesses" (a tapered transition joint). These specific girth butt welds have a reduced allowable seismic moment in the piping seismic rules.

The Level D allowable seismic moment at lugs and trunnions should be less than that at tapered transition joints. But the Level D piping seismic design rules do not penalize trunnion and lug configurations.

10. Reduced Level D piping seismic stress limits need to be specified for girth fillet welds and threaded joints.

Explanation – Other seismic testing and earthquake experience data has demonstrated that socket welded joints and threaded joints perform poorly in comparison to butt welded pipe. However, the Level D piping seismic rules do not penalize socket welded joints or threaded joints.

11. Trends in the PFDRP component test data have not been evaluated.

Explanation – The technical justification for the piping seismic rules is based on evaluating the minimum seismic margin on the PFDRP component tests. There are distinct trends in the data. The lower the component frequency, the lower the margin. Carbon steel has a lower margin than stainless steel. Margins are significantly less in going from schedule 80 to schedule 40 components. And margins are reduced when going to schedule 10. But only stainless steel schedule 10 was tested. A carbon steel schedule 10 tested component would have a lower margin. Based on the stress indices for tees and branch connections, the fatigue life is expected to be less than tested as the D/t of the tee or branch connection increases.

The minimum margins demonstrated by the PFDRP component tests have to be extrapolated to non-tested configurations to verify that the Level D piping seismic stress limits are appropriate for all possible configurations.

12. The detrimental effect of ratcheting on Level D seismic fatigue life has not been included in the seismic margin studies.

Explanation – The combination of high hoop pressure stress (in terms of the yield stress of the material) and high cyclic seismic bending moment causes high hoop ratchet strains. Other dynamic testing (see WRC Bulletin 423) demonstrate that the cyclic fatigue life is drastically reduced if hoop ratchet strains occur. The PFDRP component tests had fairly low hoop stress to actual material yield stress ratios. The Level D code rules allow the pressure hoop stress to be greater than the material minimum yield strength.

The PFDRP component test fatigue failures will occur at much lower seismic input levels if tested with pressures at the Level D allowable pressure.

Sincerely,

Gerry C. Slagis

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Rulemaking Comments

From: Gerry Slagis [gerryslagis@comcast.net]
Sent: Wednesday, July 14, 2010 10:36 PM
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Attached is a file with my comments on Docket ID NRC-2008-0554.
The file is in Microsoft Work 2007 format.

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