G C Slagis Associates
CONSULTING ENGINEERING
258 Hillcrest Place Pleasant Hill California 94523-2184 phone 925-687-8941

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Rules and Directives Branch
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments on Draft Regulatory Guide DG-1144

Draft Regulatory Guide DG-1144 should be withdrawn. The DRG provides "guidelines" for performing the ASME Section III Class 1 code compliance analyses for suitability of pressure-retaining components for cyclic conditions (fatigue analysis). Two specific revisions to the Section III requirements are being made by NRC. NRC is revising the Section III design fatigue curve for stainless steel. And NRC is specifying environmental correction factors to be used with the code fatigue curves to account for the effects of LWR coolant environments. The DRG is based on evaluation of research test data given in NUREG/CR-6909.

The research test data used as a basis for the DRG is incompatible with the Section III design fatigue curves. The wrong failure criterion was used, the test specimens were much smaller than those used to establish the Section III design fatigue curves, and effects of elevated temperature and variable strain rates are included in the data.

In the late 70s, there was a proposal to revise the Section III design fatigue curve for stainless steel based on more recent test data. This proposal was rejected by the Section III committee. There were sound, documented, technical arguments for rejecting the proposal from experts on fatigue design. Those experts on fatigue design are no longer with us. However, the same arguments apply to rejection of the DRG revision of the stainless steel design fatigue curve.

As a regulatory agency, I can understand NRC taking exception to Section III requirements if there is a verified safety concern. But, I don't see a verified safety concern. I suspect that there is no legal basis for NRC to unilaterally revise Section III, which is how I interpret the guidelines in the DRG. In addition, based on my review of the DRG and NUREG/CR-6909, I have to conclude that the NRC staff does not understand the code methodology for fatigue design. As stated in the first paragraph of this letter, I request that the DRG be withdrawn. If there is a technical concern with the Section III requirements, I recommend that NRC officially document that concern with supporting technical data for consideration by the Section III committee. Please don't provide research data that is incompatible with the design methodology.

Background on Section III fatigue design

The Section III fatigue design methodology was developed in the late 50s early 60s. There are three main parts – elastic analysis methods to predict stress, specific procedures for cyclic evaluation and cumulative damage, and a <u>design</u> fatigue curve. All three parts are dependent on each other. The Section III design fatigue curves (to 10^6 cycles) were developed in the early 60s. Langer was the principal contributor and the curves are based on the low-cycle strain fatigue work of Coffin and applicable fatigue data from the late 50s. The Section III methodology is an extension of well-established machine design methods for fatigue. The main improvement was the use of strain-controlled cyclic data to establish the <u>material</u> S-N curve. The other improvement was the "cyclic operation" procedures. For design, the sequence of events in a nuclear plant is unknown, and therefore, the cyclic history is an unknown. A conservative procedure is defined [NB-3222.4] to ensure that the worse possible cyclic stresses are evaluated.

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The Section III material S-N curve used for fatigue design is based on the tests performed in the late 50s. These were uniaxial, fully-reversed, strain-controlled cyclic tests on "small polished specimens" [from the ASME Criteria document] to separation (specimen fracture). The stainless steel data included 146 experimental values [Langer, 1962]. A best-fit curve was determined based on the Coffin relationship. The design fatigue curve is "... based on the best-fit curve and with a safety factor of either 2 or 20 on cycles, whichever is more conservative at each point. It is believed that these safety factors are sufficient to cover the effects of size, environment, surface finish, and scatter of data." [Langer, 1962].

In 1977, a technical paper on fatigue by Jaske & O'Donnell was published [77-PVP-12]. This paper included "new technology and data". It also included load-controlled axial and bending-fatigue data. A revised design curve was proposed for stainless steel. This proposal was reviewed by the Section III code committee. The code committee correspondence shows that the experts on fatigue design concluded that there was no need to revise the Section III stainless steel low-cycle design fatigue curve.

Specific Comments

1. The NRC environmental correction factors are not appropriate for use with the Section III design fatigue curves. The NUREG/CR-6909 data is from cyclic tests on a much smaller specimen size, of a different configuration (tubular), with failure defined as 25% load drop. The Section III design fatigue curves are based on cyclic tests of much larger, solid, specimens with failure defined as separation. The NRC use of 25% load drop data, which is essentially crack initiation data, is such a fundamental error as to be inexcusable.

2. The NRC environmental correction factors include variable strain rate effects. For use with the Section III design fatigue curves, material testing should be performed at the same strain rate as the original tests. Variable strain rate effects should not be included in design since the cyclic strain history is not known. The Section III cyclic operation analysis procedures are sufficiently conservative to account for strain rate effects.

3. The NRC environmental correction factors include temperature effects. For use with the Section III design fatigue curves, material testing should be performed at room temperature. If temperature effects are a technical concern, NRC should provide technical data to ASME for consideration.

4. The NRC revision of the Section III stainless steel air curve is not valid. It is inappropriate to collect cyclic data that is not consistent with the original test methods, and plot that data to construct a design fatigue curve. According to NUREG/CR-6909, the stainless steel air data include the Jaske and O'Donnell data, the JNUFAD database from Japan, studies at EDF in France, and the results of Conway et al. and Keller. The Jaske and O'Donnell data has already been considered by ASME (as discussed in the background section above) and the decision was made not to revise the Section III design fatigue curve for stainless steel. I have not reviewed the other data cited, but I expect that the test methods are inconsistent with the test methods used to construct the Section III design fatigue curves.

5. The test data to determine environmental effects is not being properly evaluated. Each unique set of test parameters should be individually evaluated. The test parameters are specimen material, specimen size, specimen configuration, strain rate, and temperature (I assume that all tests are uniaxial, fully reversed, and strain-controlled). Each unique test parameters should be tested in air and in water. The reduction in cycles (the environmental factor) should be calculated for each unique set of test parameters.

6. There is a simple test to properly determine LWR coolant environmental effects on the Section III design fatigue curve. Use polished bar specimens of the same size as used in the original tests. Do fully-reversed, strain-controlled tests to separation at the same strain rate used in the original tests. Perform testing at the same strain amplitude in air and in LWR water. Compare the cycles to failure to determine environmental effects. I expect that these tests will demonstrate that the environmental effects are well within the 2/20 factors.

General Comments

The DRG endorses a new stainless steel air design curve for use with the Section III Class 1 fatigue analysis rules. The stated reasons are "nonconservatism of the current ASME stainless steel air design curve" and "More recent evaluations of stainless steel test data indicate that the ASME curve is inconsistent with the appropriate test materials and conduct of the fatigue test". Both of these stated reasons are incorrect. Rather than the ASME curve being inconsistent, the more recent testing is inconsistent with the test methods used to construct the design fatigue curve. Because more recent testing uses much smaller specimens does not mean that the Section III design fatigue curve is incorrect. It means that the more recent testing is not directly applicable to construction of a Section III design fatigue curve. If the more recent testing includes load-controlled data, that data is not directly applicable. If the more recent testing uses 25% load drop as a failure criterion, that data is NOT applicable for construction of a Section III design fatigue curve.

DG-1144, Page 3 – discussion of margins of 2 on strain and 20 on cyclic life – "(including temperature differences between specimen test conditions and reactor operating experience)" – I believe the temperature comment is not correct. I have not seen the temperature effects discussed in this manner in the historical literature. I think there was a different "consideration" for temperature effects.

Page 3 – "More recent fatigue test data from the United States, Japan, and elsewhere show that the LWR environment can have a significant impact on the fatigue life . . ." – The data show a significant impact on crack initiation of a very small test specimen. To equate significant impact on crack initiation of a very small test specimen with significant impact on low-cycle fatigue life of a nuclear component is wrong and misleading in the extreme.

Page 3 – ". . . the researchers analyzed existing data to predict fatigue lives as a function . . ." – The data does NOT predict fatigue lives of nuclear components. The data predicts the occurrence of crack initiation in a very small material test specimen.

Page 4 – There is a discussion of "an evaluation of the ASME design curve margins." – ". . .the researchers reviewed data available in the literature to assess the subfactors . . ." – It is meaningless to evaluate specimen data to evaluate the subfactors. To evaluate the subfactors requires evaluation of actual nuclear component fatigue failure data.

Page 4 – "This methodology involves a strain-based integral for evaluating conditions for which temperature and strain rate change, resulting in variation of F_{en} over time." From a design standpoint, the strain-based integral approach has no technical basis and is nonsense. The specimen tests are done at controlled strain rates. To extrapolate from those controlled strain rates to a cyclic evaluation of a nuclear component with unknown cyclic history is unreasonable and meaningless.

Comments on Regulatory Analysis

"The evaluations used in resolving GSI-166 and GSI-190 relied on conservatism in the existing component fatigue analyses". I have been involved in Class 1 piping fatigue analyses on many different nuclear plants. My experience leads me to believe that, unless knowledgeable engineers with expertise in code fatigue evaluations performed the analyses, the existing component fatigue analyses are probably unconservative. And therefore, I question the resolution of GSI-166 and GSI-190. Definition of the design thermal transients is the only conservatism that I am aware of.

"The staff based this conclusion primarily on the negligible calculated increase in core damage frequency in extending a plant's operating life from 40 to 60 years." and *"Argonne National Laboratory (ANL) developed statistical correlations that can be used to evaluate the fatigue life of ASME Code components in LWR environments."* These two statements are alarming to me. It appears that NRC is taking the statistical evaluation of small material specimen data to predict the failure probability of actual nuclear plant components. If this is the case, I question the technical capability of the NRC staff and the technical adequacy of the core damage frequency calculations.

Sincerely,

Gerry C. Slagis

Gerry C. Slagis
Member Section III WGPD and SG Design