November 27, 2000

MEMORANDUM TO: William H. Bateman, Chief
Materials and Chemical Engineering Branch
Division of Engineering

FROM: Keith R. Wichman, Chief ***/ra/***
Component Integrity Section
Materials and Chemical Engineering Branch
Division of Engineering

SUBJECT: PUBLIC MEETING SUMMARY OF DISCUSSIONS ON REACTOR PRESSURE VESSEL AND PIPING INTEGRITY EVALUATION COMPUTER PROGRAMS DEVELOPED BY KOREA INSTITUTE OF NUCLEAR SAFETY

On October 18, 2000, a public meeting was held at the U.S. Nuclear Regulatory Commission (NRC) headquarters in Rockville, Maryland, with the participation of Materials and Chemical Engineering Branch (EMCB) staff and Dr. Youn Won Park from Korea Institute of Nuclear Safety (KINS). The purpose of the meeting was to discuss the NRC comments on two computer programs developed by KINS: Reactor Vessel Integrity Evaluation System (RVIES) and Nuclear Piping Integrity Expert System (NPIES). A list of the meeting attendees is provided in Attachment 1, and the NRC comments on KINS's computer programs are provided in Attachment 2.

In addition to the main subject, the discussion covered the possible impact on current RPV and piping integrity evaluations due to new technical issues related to these areas which have been identified in the NRC license renewal effort. In the meeting, the possibility of getting comments from additional NRC staff and spot-checking pertinent submittals from U.S. utilities using RVIES and NPIES was also discussed. However, any report derived from this more extensive effort will not be available until six months later.

Attachments: As stated

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(301) 415-2708

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MEETING ATTENDEES

OCTOBER 18, 2000

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2. S. Sheng, NRR/NRC
3. B. Elliot, NRR/NRC
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ATTACHMENT 1

NRC COMMENTS ON RVIES PROGRAM (BASED ON OLD CD)

This computer program is very friendly to use. One can complete an analysis without referring to the user's manual. However, I have some comments for your consideration for the next revision of RVIES:

1. Comments on PTS Analysis

1.1 For the temperature, stress, and applied K distribution and the critical crack size plots, the color codes do not align with the legends for the curves.

1.2 Calculated results in plots are available for (1) applied transient, (2) temperature distribution, (3) stress distribution, (4) applied K distribution, (5) critical crack depth diagram, (6) RT_{NDT} calculation, and (7) temperature-K diagram, however, direct "print" is only available for the last item. It is beneficial for users to have the option to select all or some of the seven sets of plots mentioned above, not just the last one.

1.3 The reference of Equation (2.15) for the film coefficient, h, is missing, not consistent with the presentation of Equations (2.14a), (2.14b), and (2.14c), of which the references are given in the user's manual.

1.4 Several suggestions regarding Section 2.3 of the user's manual.

It may be better to use "Stress Analysis" instead of "Stress Analysis by Finite Difference Method" as the title for Section 2.3 because Sections 2.3.1 and 2.3.3 have nothing to do with finite difference method.

Section 2.3 states that the stress analysis procedure by ASME Section XI, Appendix A is overly conservative. Appendix A leaves the stress polynomial coefficients simply as A_0, A_1, A_2, and A_3, which may be determined by your finite difference method. Therefore, RVIES fills the gap in Appendix A. Appendix A is not complete in the sense that it needs input of stress distribution, but it is not overly conservative as stated in RVIES.

There is a misprint in the following sentence under Section 2.3: "Therefore, RVIES analyzes using the finite element method in order to achieve more accurate results." The finite element method in the sentence should be finite difference method.

Section 2.3.3 described the derivation of thermal stress distribution only, not stress intensity factor due to thermal gradient. Therefore, you may want to revise the title from "Calculation of Stress Intensity Factor due to Thermal Gradient" to "Calculation of Stress due to Thermal Gradient."

1.5 You may want to include the effect due to residual stresses and cladding to the applied K calculation.

1.6 RVIES has the PTS module for a deterministic analysis. You may want to use this as a basis to develop modules for probabilistic PTS analysis in the future.

ATTACHMENT 2

2.0 Comments on P-T Limit Curve

2.1 For the temperature distribution plot, the color codes do not align with the legends for the curves.

2.2 The user has to get out of RVIES to view the output data files.

2.3 Calculated results in plots are available for (1) temperature distribution, (2) K_{IT} distribution, and (3) P-T limit curve, however, direct "print" is not available for any of them. It is beneficial for users to have the option to select all or some of the three sets of plots mentioned above.

2.4 In the computer flow chart on page 89, σ_T has not been defined in the preceding text related to P-T limits. The following note is suggested to add to page 89:

"Note: σ_T is the stress due to thermal gradient, see page 71 for details"

2.5 The calculation of temperature distribution and σ_T are absent in the text related to P-T limits. It may be worthwhile to add a sentence on page 83 to lead the user to the discussion of the temperature distribution and σ_T in the text related to PTS. Further, when the user selects Equation (3.5a) or (3.5b) to calculate K_{It}, which solely depends on heatup or cooldown rate, the P-T limit curve can be determined independent of time. How does this P-T limit curve relate to your temperature distribution from the thermal analysis? Also, do you need film coefficient, h, and thermal diffusivity, π, in your temperature distribution analysis? They are not input parameters for the P-T limit module. I believe a few paragraphs in the user's manual could clarify this.

2.6 The methodology for the P-T limits is ASME Appendix G modified by Code Case N-588, you may want to add an option to use Code Case N-641. Code Case N-641 combines Code Case N-588, N-640 (use of K_{Ic} instead of K_{Ia}) , and N-514 (10% over Appendix G allowable for LTOP determination.)

2.7 To include cladding in the thermal and structural analyses may be something to think about in the future.

3.0 Comments on USE Analysis

3.1 Please confirm that the Appendix K analysis described in Section 4.3 (page 93 to page 99) has not been implemented in RVIES.

3.2 It is misleading to state on page 92 that "USE can be predicted by the expected diagram of 0.05% weld metal and 0.10% base metal curve." Since, literally, diagram of 0.05% weld metal and 0.10% base metal curve implies only one curve, it may be better to reference the diagram as "the USE diagram of RG 1.99, Revision 2."

3.3 The USE decrease calculation in RVIES differs from that of RG 1.99, Revision 2 in several places:

In the U.S., only one fluence value is needed for each surveillance material, which is the calculated fluence at the center of the capsule. In the sample input (page 53) provided by RVIES, two fluence values are needed for each surveillance data: fluence of specimen and fluence of I.D. In the subsequent calculation, a 1/4T fluence was calculated for the surveillance data based on the input I.D. fluence. I am not sure about the meaning of 1/4T fluence for a surveillance data.

In the U.S., a bounding curve was plotted parallel to the curves of the USE diagram of RG 1.99, Revision 2, to bound the two or more surveillance data. In the sample output (page 38) provided by RVIES, a straight line was plotted to connect the two surveillance data. RVIES's approach has been confirmed by several test runs by me.

In the U.S., the bounding curve approach works as well to the case if "the second test result is less than the first one (page 92)." In the approach provided by RVIES, the user's manual on page 92 states: "If the second test result is less than the first one, the horizontal line becomes the prediction line." RVIES's approach will produce completely different results than the NRC's.

NRC COMMENTS ON NPIES PROGRAM
(SECTIONS 1.0 to 3.0 ARE BASED ON OLD CD)

This computer program is not as friendly as RVIES. To complete an analysis, one needs to consult the user's manual frequently. I have some comments for your consideration for the next revision of NPIES:

<u>1.0 NPIES Page Design</u>

1.1 The design of the NPIES System Main Page is not straightforward. I recommend the separation of the main page into three parts: the upper 80% is designated to piping integrity analysis and the remaining 20% is designated to LBB analysis (on the right) and Section XI analysis (on the left). Appropriate titles such as "OPTION 1: PIPING INTEGRITY ANALYSIS," "OPTION 2: LBB ANALYSIS," and "OPTION 3: SECTION XI ANALYSIS," maybe added to each part. Under the title "OPTION 1: PIPING INTEGRITY ANALYSIS," I suggest the following revision: change the caption "↕ DATABASE" to "STEP 1: INPUT MATERIAL DATA;" the caption "↕ CRACK GEOMETRY" to "STEP 2: INPUT CRACK GEOMETRY AND LOADING;" and the caption "USER OPTION" to "STEP 3: SELECT METHODOLOGY." I also recommend changing the icon description "Database" to "Material Database," "Input Data" to "Crack + Loading," and "CDFD" to either "EPFM" or "J Analysis." In the second part of the main page, with the title "OPTION 2: LBB ANALYSIS," there is no need for the caption "↕ DLC CALCULATION." I also recommend changing the icon description "DLC" to "LBB."

1.2 The icon on the "Database Search Dialog" page for clicking on data selection may need revision. I suggest changing the icon description "USE" to "SELECT," because, intuitively, the word "SELECT" is better than "USE" to describe the process of choosing one set of material data from a database of thousands of material data sets.

1.3 The icon on the "MATPRO" page for clicking to return to the main page may need revision. I suggest changing the icon description "Back" to "Continue," because, intuitively, the word "Continue" is better than "Back" to indicate that the material selection has been completed and the user can proceed to the next step.

2.0 LEFM Analysis

2.1 In the discussion of LEFM, CDFD, J/T, DPFAD, and the limit load method on pages 69 to 75, references are given for CDFD, J/T, DPFAD, and the limit load method, but not for LEFM. To be consistent, references should be given for LEFM also.

2.2 NPIES provides 12 cases for the crack geometry and loading condition for various piping integrity analyses. References are given for all cases except Case 2 and Case 3. To be consistent, references should be given for Case 2 and Case 3 also. Further, describing F_b function as "reference table" for these two cases is not clear. My suggestion is to revise it to "reference table on page xx."

2.3 Case 1 of the 12 cases is designated in the user's manual as "circumferential surface flaw (semi-elliptical) - **tensile loading**." Since piping pressure is also an input parameter, Case 1 may be classified as "circumferential surface flaw (semi-elliptical) - **pressure + tensile loading.**" I have run the LEFM analysis for Case 1 using the input on page 128 and verified that for the load case of pressure and tensile loading, one can either input both pressure and tensile loading or input the adjusted pressure or tensile loading alone by converting one into another through:

$$T(\text{tensile loading}) = [(pR_i)/(2t)] \times [2\pi R_i t], \text{ or}$$
$$T(\text{tensile loading}) = p\pi(R_i)^2$$

2.4 Case 2 is designated in the user's manual as "circumferential surface flaw (semi-elliptical) - **bending moment**." I used the input on page 132 to run the LEFM analysis for this case and could not repeat the results on page 133. Instead, I got the warning message: "F_b function load error." I set pressure and tensile loading to zero and left the moment of 5000 in-kips unchanged for another try. Again, NPIES failed with the same warning message. To make sure that Case 2 works, I run another simulation with the input:

a = 0.2 inch
$2c$ = 4 inch
t = 1 inch
R_i = 10 inch
K_{Ic} = 35 ksi$\sqrt{}$(inch)
M = 8000 inch

NPIES was run successfully this time. The results indicate that K_I is 6.262 ksi$\sqrt{}$(inch) and the safety factor (SF) is 5.589. However, the resulting SF versus a/t plot showed a sudden drop around a/t = 0.2. The programming related to Case 2 should be reexamined carefully.

2.5 Using the input in the user's manual for Case 3 would give the warning message: "F_b function load error," on the screen during the execution of NPIES using LEFM, when NPIES was run successfully and gave identical results as in the user's manual for Case 3. Warning should not coexist with acceptable results. For Case 4 to Case 12, there are no problems in executing and repeating manual results.

2.6 There is a misprint on page 142. "Tensile Loading" in the second line should be revised to "Tensile Loading + Bending Moment."

3.0 Limit Load Analysis

3.1 I verified that the principle of superposition also works here for the pressure and tension loading as the LEFM analysis. Therefore, revision of "circumferential surface flaw (semi-elliptical) - **tensile loading**," to "circumferential surface flaw (semi-elliptical) - **pressure + tensile loading**," applies to limit load analysis also. Again, for the load case of pressure and tensile loading, one can either input both pressure and tensile loading or input the adjusted pressure or tensile loading alone by converting the other loading into pressure or tensile loading through the following equation.

$$T(\text{tensile loading}) = [(pR_i)/(2t)] \times [2\pi R_i t], \text{ or}$$
$$T(\text{tensile loading}) = p\pi(R_i)^2$$

3.2 I used the input on page 132 to run the limit load analysis for Case 2. Although I was able to repeat the results given by the user's manual, a warning, "Warning: Out of bound (R/t>=10 and sigma_t/sigma_f<0.25)," appeared in the process. It is recommended that you also provide R/t and sigma_t/sigma_f values in the output to help the user decide whether he can still use the NPIES results.

3.3 For cases of circumferential flaw with tension only, i.e., Case 1, 4, and 7, NPIES will ignore any entry for the moment. For cases of axial flaw with internal pressure only, i.e., Case 10, 11, and 12, NPIES will ignore any entry for the tension and moment. However, for cases of circumferential flaw with moment only, i.e., Case 2, 5, and 8, any entry for the tension will change NPIES results for Cases 2 and 5, but not for Case 8. Since NPIES is not consistent in ignoring undesired data, it should alert the user on the screen to not leave undesired data in the three entries for loading.

3.4 For the limit load analysis, thick-wall solutions are only available for Case 8, circumferential through-wall flaw - bending moment, and Case 9, circumferential through-wall flaw - tensile loading + bending moment. I recommend you to make thick-wall solution available for other cases (crack geometry and loading conditions) also.

(SECTIONS 4.0 to 5.0 ARE BASED ON NEW CD)

4.0 CDFD Method

4.1 I verified that the principle of superposition also works here for the pressure and tension.

4.2 The caption on each plot summarizing the CDFD analysis result describes the J-R curve as, “J-a curve at the Pini,” and the applied J curve as, “J-a curve at the Pmax.“ I suggest the use of the more common terminology “J-R curve” to replace “J-a curve at the Pini,” and “Applied J curve at the Pmax” to replace “J-a curve at the Pmax” in NPIES.

4.3 Except for crack geometry and loading cases designated as Cases 1,4, and 10, I can not reproduce the results for Cases 5, 7, 8, and 11. For Case 5, my results for the critical crack depth, maximum load, and safety factor, are 1.67, 535937.5, and 53.59, instead of 1.812, 543671.875, and 54.367 in the user’s manual. For Case 7, my results for the critical crack depth, maximum load, and safety factor, are 46.19, 12988.28, and 12.99, instead of 48.066, 12891.602, and 12.892 in the user’s manual. For Case 8, my results for the critical crack depth, maximum load, and safety factor, are 46.19, 365781.25, and 36.58, instead of 48.066, 367714.844, and 36.771 in the user’s manual. For Case 11, my results for the critical crack depth, maximum load, and safety factor, are 2.39, 1.46, and 0.49, instead of 2.52, 1.533, and 0.511 in the user’s manual. Although the discrepancies are not much, a revision may be needed.

4.4 The plots that summarizes the CDFD analysis for circumferential flaws contain an applied J curve and a J-R curve. However, for the plots for axial flaws (Cases 10 and 11), a third curve appears in the plot that summarizes the CDFD analysis. This curve, which I suspect is another applied J curve, should be removed in the next revision to maintain consistency with the plots for circumferential flaws.

5.0 ASME SEC. XI Evaluation

5.1 I ran the example using Appendix C on page 33 of the user's manual, and found that the user has to input "Estimated flaw depth" to execute the example successfully. Maybe you want to advise the user on the screen or in the user's manual to input estimated flaw depth to avoid execution failure. Further, the entry for the estimated flaw depth has been blocked (shaded), and I have to try different evaluation options to unblock it and enter the estimated flaw depth. For another issue, if I specified the output file, c:\program files\npies1\isi.res, in the monitor screen, the program will run successfully with the content of the output file shown on the left side of the screen. However, if I use the default file directory and file name, the output file will not show on the left side of the screen. A check of the output file, c:\program files\npies1\isi.res, for the latter case indicate that the output file only contains partial results. Although the graphic results indicate that the maximum allowable flaw depth is 1.862 inch, the same as in the user's manual, for both runs, this bug should be removed. Out of curiosity, I ran the old version for comparison and found the old version does not have the problems mentioned above (The old version will not show the content of the output file on the screen.)

5.2 Some comments on the user's manual:

Page 34, "For fatigue crack growth analysis, select **Appendix A** button, and input ...."
Please consider the revision, "For fatigue crack growth analysis, click on **fatigue crack (af)** at the top of right screen to make **Appendix A** button and its evaluation button appear, select the **Appendix A** button, and input ...."

Page 35, "Select one of an evaluation method either from using bending moment or using crack length."
Please consider the revision of deleting the sentence because the new version of NPIES does not provide different evaluation methods for the user to choose.