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Dear Mr. Hardies:

The enclosed CD contains the latest version of the NRC's embrittlement calibration database. The purpose of this letter is to request your assistance in reviewing this database to ensure that all of the information is complete, accurate, and consistent.

NRC regulations require that assessments of nuclear reactor pressure vessel integrity consider the effects of radiation on fracture toughness. In 1988, the NRC published Regulatory Guide 1.99 Revision 2 (RG 1.99 Rev. 2), "Radiation Embrittlement of Reactor Vessel Materials" to describe NRC-approved procedures for estimating the effects of neutron irradiation on the increase in the Charpy V-notch (CVN) transition temperature at 30 ft-lb (41 J) of absorbed energy. It is assumed that the shift in fracture toughness transition temperature is equal to these Charpy curve shifts.

The procedures described in RG 1.99 Rev. 2 were based, in part, upon analyses of US commercial power reactor surveillance data. In the 15 years since this regulatory guide was published, the amount of available surveillance data has more than tripled, and continued research on radiation effects has produced a much deeper scientific understanding of the physical processes responsible for radiation embrittlement. The first major revisions of the RG 1.99 Rev. 2 models were published in NUREG/CR-6551 in 1998. The transition temperature shift model in NUREG/CR-6551 was further modified and recalibrated to an expanded surveillance database in July 2000. In addition to these NRC-developed embrittlement trend curves, the American Society for Testing and Materials (ASTM) has developed the consensus standard E900-02, "Standard Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials." The ASTM and NRC developed embrittlement trend curves are similar but not identical.

Since NUREG/CR-6551 was completed, approximately 150 additional surveillance data points have been generated. A preliminary analysis of the new data indicates that neither the NRC nor the ASTM model predictions agree with the new data as well as anticipated. As a result, the NRC plans to review and include the acceptable new surveillance data in the development of a revised embrittlement model for Revision 3 to RG 1.99.

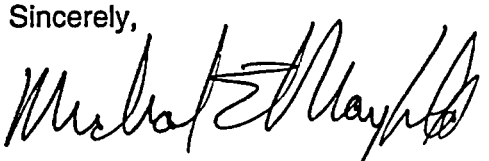
As part of this effort, the 150 new surveillance data points were added to the calibration database used in the development of the earlier embrittlement models. A copy of the expanded calibration database is provided in the enclosed CD. A detailed review of this database has raised several questions which must be answered before a revised embrittlement

trend curve can be developed. These questions involve records with missing information, duplication of records, and discrepancies between records. Attachment A (Expanded Embrittlement Calibration Database, 10/2003) describes the format of the database and discusses in more detail the issues which need to be resolved. Some of the requested information is consistent with that requested in NRC Generic Letter 92-01, Revision 1 (Reactor Vessel Structural Integrity). The specific missing items, duplicates, and discrepancies are highlighted and commented upon in the database on the CD.

I request that you review the calibration database to ensure that all of the information is complete, accurate, and consistent. In addition, please update the database with the requested information as described in Attachment A and highlighted in the database and return it to the NRC by January 31, 2004. Data that is incomplete, duplicates previous records, or contains unresolvable discrepancies will not be included in the NRC's revised model. Attachment A describes the required protocol for providing input to the database.

If you have any questions regarding this request for information, please contact Cayetano Santos at (301) 415-6004 or cxs3@nrc.gov.

Sincerely,



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ATTACHMENT A

Expanded Embrittlement Calibration Database, 10/2003

1.0 Description of Database File

The Excel spreadsheet entitled Dups+Discreps10-03.xls contains four worksheets:

1. The first worksheet, "Database," is a concatenation of the calibration database used for the 7/00 Draft NRC and ASTM E-900 models and the 180 points recently provided by Stan Rosinski (EPRI) in NewEmbrittlementData.xls (the "new" data).
2. The second worksheet is a sorted version of the first, entitled "Dups&Discreps," in which records are grouped by heat, orientation, and plant.
3. The third worksheet is the list of "References" for the new data and other updates.
4. The fourth worksheet is the "Plan" for filling in and changing data.

2.0 Database Worksheet

The first worksheet, "Database," contains 606 records used to develop the NUREG/CR-6551 model, followed by the 130 records added for the 7/00 and ASTM calibrations, followed by 180 records that are the "new" surveillance data results. The last 4 records are the Chauvenet outliers from the NUREG 6551 and 7/00 modeling efforts. In addition to adding in the new data and adding back the outliers, the "Database" sheet has been modified from earlier, similar spreadsheets in several ways, as listed below.

1. The first column has been redefined to display a mnemonic code for each dataset, as detailed in comments on the sheet (see the first point in each dataset). This change was made so the vintage of points would be clear after sorting. The order of points within each dataset is the same as in the 5/00 database and in the NewEmbrittlementData worksheet, except for moving all outliers back into the sheet at the end (with blue background fill).

2. Some columns have been hidden, particularly those with interim or incomplete entries, and columns have been moved around to group the heat and plant related descriptors together so that (at least on some screens) all the critical information can be seen in one screen width.

3. The EPRI heat codes, which were manufacturer designations, have been included as a hidden column, while the displayed HEAT_ID column is the one containing Embrittlement DataBase (EDB) codes from Oak Ridge National Laboratory (ORNL). The HEAT_ID codes and various changes to MAT_ID and PLANT_ID codes to be consistent with EDB are based on emails from Jy-An Wang of ORNL to Ernest Eason of Modeling and Computing Services dated10/18/03, 10/23/03, and 11/2/03. Note that the meaning of PLANT_ID has been defined by ORNL to be the plant where the specimen was irradiated, consistent with the previous treatment of SRMs, to avoid the need for the "Irr location" column in the NewEmbrittlementData.xls file. As before, the PLANT_ID associated with the

original source of the material is reproduced as the $2^{nd} - 4^{th}$ characters of the HEAT_ID. The VESSEL_MFG generally refers to that original source, not to the vessel in which the material was irradiated. An exception is VESSEL_MFG for SRMs, which currently refers to the irradiation location (this may change).

4. All earlier background fill and font colors have been reset to black font on white, except in the column headings of greatest interest, which are now red bold font on white. The data were set up as a list for easy sorting.

5. Some missing flux values in the new data were calculated from fluence and time, as noted in comments in the file. The older data in the flux_used column were also developed that way and most of the new data are consistent with such calculations to 3 significant digits.

3.0 Dups&Discreps Worksheet

The second sheet, entitled "Dups&Discreps," started as a copy of the Database sheet. Then it was sorted on HEAT_ID, Specimen orientation, and PLANT_ID, in that order, and blank lines were inserted to visually separate different heat/orientation combinations, and in some cases, the same heat tested at two plants. This sorted version makes it easier to see duplicates and discrepancies, which are flagged on the sheet by using colored background fill.

This worksheet is also liberally annotated with comments that display on mousing over a cell, documenting sources of data, data issues and planned resolutions for future updates. All future changes and updates are to be made on the Dups&Discreps worksheet, as detailed in the "Plans" Section below. Those changes which were made on the Database worksheet before producing the Dups&Discreps worksheet are listed above and documented with comments in the file.

The meaning and expected action associated with the different colors of background fill are as follows:

The blue background fill denotes the four outliers identified in earlier fitting efforts. These records may or may not remain outliers in future fitting efforts, so they are currently treated like any other record. **Please review these records for any possible errors and contribute, if possible, comments that could explain why these points proved to be outliers in past fitting efforts.**

The green background fill denotes apparent duplicate records, included in both the "new" dataset and the earlier datasets. **Please review these records to verify that they are, in fact, duplicates, so that they may be deleted from future copies of this database.**

The yellow background fill on the Dups&Discreps sheet is used to flag all changes made and potential changes that should be checked, as well as cells that are missing information. **Please review these fields to verify that the changes made are accurate**

and the proposed changes are reasonable, and to provide the missing information where possible.

The tan background fill refers to items that ORNL is in the process of checking or developing to ensure consistency with EDB. Some of these fields have already been updated as indicated by red font and comments. **No action on these items is expected except from ORNL, but any clarifying comments that can be contributed on the fields are welcome.**

3.1 Comments about missing information

All missing information cells are highlighted with yellow fill (and also denoted by –999 codes, ####, or blank cells), but not all missing items are of equal importance. The most commonly missing information of ***highest priority*** is ***specimen orientation, type of weld flux, VESSEL_MFG,*** and ***Mn***, which are needed for previous models, possible future models, and/or to compare with IVAR results. Other than Ni, Cu, P, and Mn, the missing chemistry information is of lesser importance; it should be filled in whenever available in source documents that are being checked for other purposes.

3.2 Comments about Tc discrepancies

Many of the yellow highlighted cells are coolant temperature (Tc), which is used as a surrogate for the generally unavailable actual specimen temperature. In all cases, the Tc values for Oyster Creek (OYS) are highlighted, because that plant is now the irradiation location for a significant fraction of the BWR data, and temperature has a known, significant effect on shift. The value given currently in the database for all 61 OYS observations was originally for a single capsule (210D) examined in the NUREG 6551 analysis, and the same value was used for all the recent capsules. In some other plants an attempt was made to estimate Tc by capsule location from thermal hydraulic or other analyses. **Please review the Tc values for all of the OYS capsules and, if possible, provide more accurate Tc data for each capsule.**

Other coolant temperatures are flagged because they vary by more than 2° F among two or more datapoints on the same heat/plant, and it may be uncertain what to use for the new points in the same heat/plant. The flagged variations in Tc may be real, produced by capsule location differences or operating changes, but it is possible that one of the previous temperatures is more representative of the new data than the others, due to location, a power rating change or similar known operational factor. In some cases, large variations (> 5° F) in temperature that involve only older data are also flagged for checking.

Some substantial variations in Tc are not flagged in yellow because the source of variation is clear, such as in several BWRs where there were atypical high flux, high temperature capsules (denoted BWa and BWb) versus more typical low flux, low temperature capsules (denoted BWR). These results pertain to deliberate, known differences in capsule location and exposure.

Some variations in Tc are believed not to be real, such as BWR temperatures of 550° and 532° F in the same plant at similar low flux. Other temperatures are highlighted because they are unusually high or low, such as 550° F and higher for BWRs and 525° F and lower for PWRs.

Please review all of the flagged Tc fields to verify that all data are accurate and represent reasonable temperature variations in a reactor. In general, the ASTM E10.02 committee prior to 2000 focused more quality assurance on PWR plant data than BWR plant data, so all coolant temperatures for BWRs should be reviewed for reasonableness.

3.3 Comments about UTT30 discrepancies

Values of unirradiated Charpy transition temperature at 30 ft-lb (UTT30) were highlighted in yellow where they varied by more than 1° F within the same heat and orientation. Variations of less than 1° F are frequent between the NRG6551 and 5-00Calib datasets – these are not highlighted and are of no concern. UTT30 variations in some cases may have resulted from differences in orientation, but the orientation of one datapoint is currently missing, so the results need to be re-examined after the missing orientation information is recorded. In other cases the variation may be from use of different unirradiated specimens in the older datasets and in the new data. There also may be variations between new and older data from the use of symmetric and asymmetric fits to the Charpy curves.

Modeling & Computing Services (M&CS) intends to look into the highlighted UTT30 discrepancies as part of the effort to fit the new Charpy data to the asymmetric hyperbolic tanh function for consistency with the earlier data. It is expected that differences up to 5° F will occur frequently from the difference in fitting function, since the new data used a symmetric form and the older data used an asymmetric form. Larger differences may indicate a difference in which Charpy specimens were included in the fitting of UTT30 or other factors that need to be understood.

Please provide details on the basis (which specimens were considered, etc.) for any new UTT30 results that deviate substantially (> 5° F) from the earlier data on the same heat and orientation.

3.4 Comments about chemistry discrepancies

Values of chemistry variables are highlighted when they vary in the second significant digit from the values for the same heat in the earlier NUREG 6551 and 5/00 databases. The rationale for relying on the older values is that the best estimate values of Ni, Cu, and P for surveillance purposes were formally requested by the NRC and were provided by industry in the early 1990s. The estimates from the EDB and the industry update values were reviewed in detail by the ASTM E10.02 committee prior to the NUREG 6551 modeling effort. In addition, considerable effort was spent by ASTM E10.02

members in reviewing the chemistry values prior to the refitting in 2000. Thus deviations from these previously reviewed and accepted values require justification.

Chemistry variables are also highlighted when there are discrepancies in the new data and older data are not available for comparison. The intent is to resolve the discrepancies so there is a single value for each new heat that is representative of the Charpy specimens.

The chemistry is the same for all results in a given heat throughout most of the database. It is intended to be the best estimate for all Charpy specimens in that heat, which could be different from the overall heat average for a material used in a vessel, since the Charpy specimens generally come from a relatively small part of the total heat. In many cases the estimate was originally the average of available measurements in EDB, using specimen chemistries whenever possible, then it was modified if necessary by the industry review efforts mentioned above. The use of a best estimate was done deliberately, to get a single value of chemistry that would be representative of all the unirradiated and irradiated specimens, and hence the shifts. The same approach is planned for the current database additions for consistency. Thus many of the new chemistry values may be changed to the old values for the same heat, or all results for the heat would be changed to a new average value, as noted in comments, unless there is some justification to do otherwise.

Please review the highlighted chemistry fields and, where possible, provide the best estimate chemistry values for all Charpy specimens within a heat.

3.5 A note on the relationship of the chemistry approach to location variability in a vessel

It is worthwhile noting that the way chemistry estimates are developed for modeling shifts causes the location-to-location chemistry differences that may exist between individual Charpy specimens and between groups of unirradiated and irradiated specimens within a heat to be averaged away. The chemistry differences among the surveillance specimens for a given heat are usually not well characterized in the available data, and the chemistry variability among surveillance specimens, even if it were well characterized, is smaller than the location-to-location variability in chemistry of a typical heat or weld in a vessel. This is because the surveillance specimens represent a much smaller, generally localized part of a heat or weld. For these and other reasons, an average chemistry for the specimens from each heat has been used each time the calibration database has been expanded. This approach should correspond reasonably well to the use of a local measurement or estimate of vessel chemistry near a postulated or actual flaw, where the local estimate is representative of a volume of vessel material comparable to the volume of all the surveillance specimens in a typical surveillance heat. The standard error of the model that results from this specimen-average chemistry approach does not account for the possible range of chemistries throughout a vessel heat if the heat average chemistry were used instead of a local estimate.

3.6 Other database QA needs

In addition to filling in missing data, deleting duplicates, and resolving discrepancies, there are some specific quality assurance (QA) needs. Checking the BWR and any unusual PWR coolant temperatures, whether they are clear discrepancies or not, is one example already discussed above. All the new fluence, exposure time, and flux data also should be checked against original source documents for possible transcribing or calculation errors. The new HEAT_IDs have been checked to some extent by both ORNL and M&CS, a process that is continuing. All DTT30 values were checked to ensure that DTT30 = ITT30 – UTT30 after a case where that equation was not satisfied was found.

Two of the new records (WTP301 capsule V and WZN101 capsule Y) were identified as possible duplicates by ORNL, based on earlier records with the same recorded capsule, heat, and plant, but they appear not to be duplicates when sorted next to the earlier records in the Dups&Discreps sheet. In fact, they have different fluence, time, and temperature. Comments in the NewEmbrittlementData file by Brian Burgos indicate that each of these records depends in some way on the fluence and temperature in two plants, TP3 and DB1 and ZN1 and DB1, respectively. Complete details on the history of these specimens and a reference to relevant reports would be helpful for checking these cases and determining whether they are consistent with the rest of the database.

Other specific QA needs may be identified as the database scrubbing effort proceeds. **Please identify and describe any discrepancies or other QA needs you may identify during your review of this database.**

4.0 References Worksheet

The third worksheet is the list of "References" for the new data and other updates. **Please list any references required to understand changes and additions on the References worksheet and put the corresponding reference number in the Reference column of the Dups&Discreps sheet for the affected records.**

Jy-An Wang (ORNL) has identified 7 surveillance reports which are needed for documentation in order to update the Power Reactor Embrittlement Database (PR-EDB). **Please provide copies of the following reports so that the PREDB can be updated:**

1. Evaluation of Capsule PWR-5: EPRI-CRIEPI Integrated Reactor Vessel Surveillance Program (IRVSP) Capsule Irradiated in Davis Besse (PWRMRP-08), EPRI, Palo Alto, CA: 1999. TR-113891.
2. WCAP-15046, "Analysis of Capsule U from the Tennessee Valley Authority Watts Bar Unit 1 Reactor Vessel Radiation Surveillance Program," June 1998.
3. "River Bend 183 Degree Surveillance Capsule Report," MPM Report Number MPM-1202971, January 2003.
4. "Fracture Toughness of Reactor Pressure Vessel Steel Welds," EPRI Research Project RP2180-6, (Unpublished) Final Report, M.T. Wang, August 1983.

5. T. A. Caine, "Procedure Report on Phase 2 of the BWR Owners' Group Supplemental Surveillance Program," GE-NE-523-101-1290, GENE, San Jose, CA, January 1992.
6. "Integrated Reactor Vessel Surveillance Program, A Joint EPRI-CRIEPI RPV Embrittlement Study," Program Update Report, Volume 1, ATI Consulting, December 1995.
7. Letter, W. L. Server (ATI Consulting) to R. G. Carter (EPRI), Reassessment of EPRI-CRIEPI Joint Program Material Heat Identities, October 25, 2002.

5.0 PlanforChanges Worksheet

The fourth worksheet is the "Plan" for filling in and changing data in the Workbook, containing the same information given below.

It is important to take an organized approach to the changes that will result from review of the Dups+Discreps10-03.xls workbook. **All changes and additions should be made on the Dups&Discreps sheet,** to make it easy to put the change in context with other data on the same heat. **The changes should be made in red font, leaving the background fill as is (or adding yellow fill if there was none) so that they are easy to find.** Examples are cell Y822 in the Dups&Discreps worksheet, which resolves an obvious discrepancy, and cell G212, which is an updated heat code entered after the Database sheet was sorted. In addition, the comment feature should be used as described below.

1. Any time a cell is filled in or changed, document that change with an inserted comment. Within the comment, the following information must be provided:
    a. Name of Individual changing the data.
    b. Date the change was made.
    c. Reason for change.
    d. Document the original value or state it was missing, and give the value it is being changed to (e.g., changed from 2.5 ft-lbs to the new value of 3.2 ft-lbs).
2. Ensure that the reference column (BD) is still accurate or that a reference is added (with a comment) as applicable.
3. Update Cell G1 with the last date changes were made and put the name of the reviewer making the changes in cell P1.
4. Update the References worksheet with the new reference (if applicable).

When changes are received from the reviewers, they will be integrated by M&CS on a master copy, disagreements will be addressed, and the revised result will be sent out to the reviewers. The plan is to eventually delete the blank lines and do the fitting with the revised database defined by the updated Dups&Discreps worksheet.