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POWER REACTOR EMBRITTLEMENT DATA BASE

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ABSTRACT

Regulatory and research evaluations of embrittlement prediction models and of pressure vessel integrity can be greatly expedited by the use of a well-designed, computerized data base. The Power Reactor Embrittlement Data Base (PR_EDB) is such a comprehensive collection of data for U.S. commercial nuclear reactors(1). The Nuclear Regulatory Commission (NRC) has provided financial support, and the Electric Power Research Institute (EPRI) has provided technical assistance in the quality assurance (QA) of the data to establish an industry-wide data base that will be maintained and updated on a long-term basis. Successful applications of the data base to several of NRC's evaluations have received favorable responses and support for its continuation. The future direction of the data base has been designed to include the test reactor and other types of data of interest to the regulators and the researchers.

BACKGROUND

The PR_EDB is a collection of computerized data files that contain information about the irradiated and unirradiated properties of steels used in U.S. power reactor pressure vessels. These data were accumulated directly from surveillance reports and other published reports provided, for the most part, by the NRC, EPRI and the Materials Property Council.

This data base is funded by the NRC and has been designed and generated for research evaluations of embrittlement prediction models and pressure vessel integrity issues. Based on the favorable comments from data evaluations completed, NRC has indicated continued future support for the data base. The elapsed time to complete an evaluation and the QA of the data were critical factors in their decision.

The EPRI Reactor Vessel Embrittlement Management Program has adopted PR_EDB as the basis for an industry-wide data base. Under EPRI subcontracts, the reactor vendors are providing assistance in the QA of this data base and will provide additional data and documentation. The QA checks by the vendors are in progress; the anticipated date for completion of this phase is September 30, 1990.

ARCHITECTURE, DATA COLLECTION, AND SOFTWARE

In keeping with current data base technology, the information in the PR_EDB is contained in a collection of data files. Only similar or logically related data are stored in the same file, and the information from several single files can be combined by means of "key identifiers" that code in a unique manner the reactor (PLANT_ID) and surveillance capsule (CAPSULE), the material (HEAT_ID) and specimen orientation (SPEC_ORI), and the reference to the document (REF_ID). For instance, chemistry information is contained in the file CHEM_PR, neutron fluences and related information are in REAC_PR, and the Charpy transition temperature shifts and the upper-shelf energies are in SHFT_PR. Tables relating transition temperature shifts with fluences and chemistry can be constructed by combining these three files using the key identifiers PLANT_ID and CAPSULE for the irradiation environments and HEAT_ID for the materials. Each record of every file is also connected to its source document via the REF_ID so that every data item can be traced unambiguously to its source. Because the structure and content of each file is independent of the others, new data types can be added easily without disturbing the existing files. The same features, which are characteristic of relational data bases, make it relatively simple to update, maintain, and perform quality control on the data files.

All data are collected first into "raw data files," and all information, including numbers, is entered as characters to preserve as much as feasible the details of the original documentation of the experimental results

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NRC and EPRI groups have decided temporarily against having evaluated files until reliable and consistent data sets can be confirmed. As a result, in the raw data files, multiple determinations of the same quantity are given in different records, each with its proper references. All different determinations are kept in PR-EDB, and it is up to the user as to which determination to use for a particular application or whether averages should be obtained from several of them. Hence, to analyze the data, the user must make some decisions reflecting on the credibility of the data in the raw data files and prepare a processed data file for the analysis.

The current compilation contains data from 92 reactors and consists of 79 different weld materials (161 data points) and 110 different base materials (381 data points). The different types of data that are implemented or planned for this data base are shown in Fig. 1.

The PR_EDB can be used with any personal computer that runs under a disk operating system (DOS) above Version 2.0. A fixed disk with at least 5 Mbytes of free space and 512 kbytes of random access memory (RAM) is required for efficient use of the data and software. The data files are given in dBASE format, which allows the use of dBASE III Plus, and higher versions as well, as any compatible software (e.g., CLIPPER) to inspect, manipulate, and process the data. However, many routine tasks can be greatly expedited and simplified with the use of special-purpose software. For this reason, a menu-driven software program, EDB-Utilities, has been written to perform many processing steps, such as the retrieval and selection of data, data-manipulation calculations, saving data in files, displaying data to the screen or printer, and the fitting and plotting of Charpy impact data. The computer programs for all the data evaluations performed for the NRC and other researchers are maintained in a file as a guide to the future direction of the software development.

APPLICATIONS

A comparison of the PR_EDB with the Regulatory Guide 1.99 (Rev. 2) data base showed a larger spread for the base material, but the scatter appears to be random (Fig. 2). The residual parameter shown on the figures is defined to be the observed value of transition temperature shift (ΔRT_{NDT}) minus the value of transition temperature shift calculated by the Regulatory Guide 1.99 (Rev. 2). For the weld materials, the scatter of the new data is of the same magnitude as that for the Regulatory Guide (Fig. 3). A re-evaluation of the two standard deviation values for the base and weld materials in PR_EDB did not show a need to develop separate Charpy trend curves for the two materials (Figs. 4 and 5).

An analysis was made to see if there was any bias in the Charpy specimen orientation (TL vs. LT) to the transition temperature shift and to the decrease in upper-shelf energy curves. No bias was observed for the Charpy specimen orientation in the transition temperature shift curve (Fig. 6). However a bias can be clearly seen in the TL-orientation as compared with the LT-orientation (Fig. 7). The data points contained only pairs with the same fluence in the same capsule.

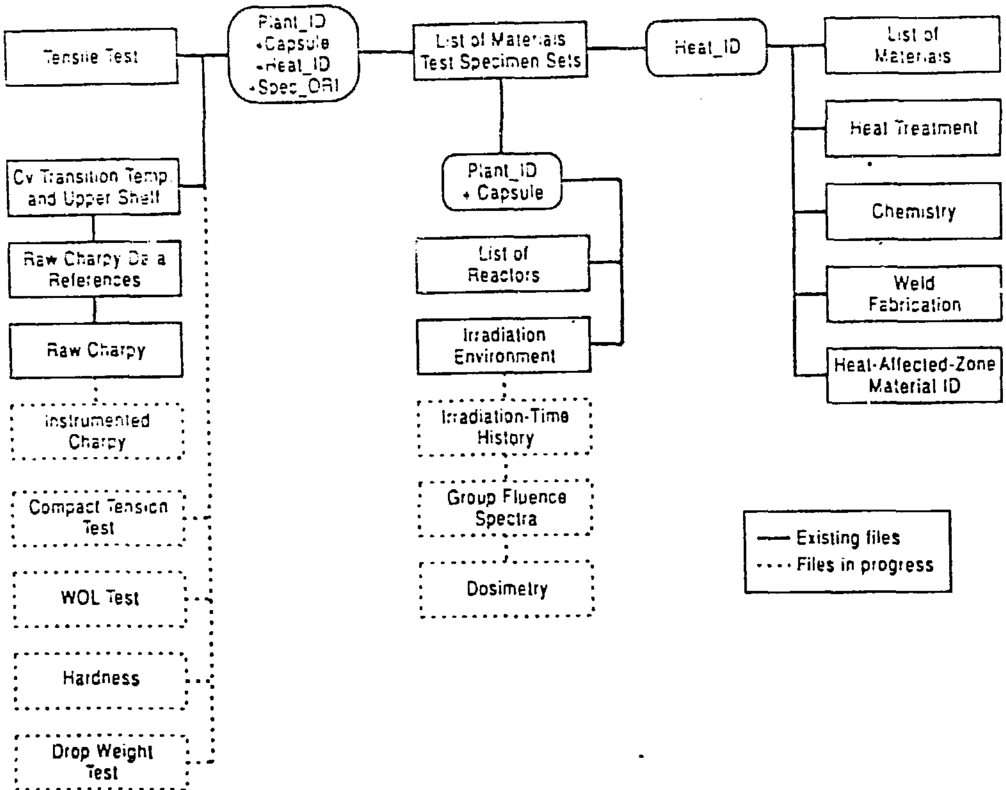

Fig. 1. Architect of the Power Reactor Embrittlement Data Base (PR_EDB).

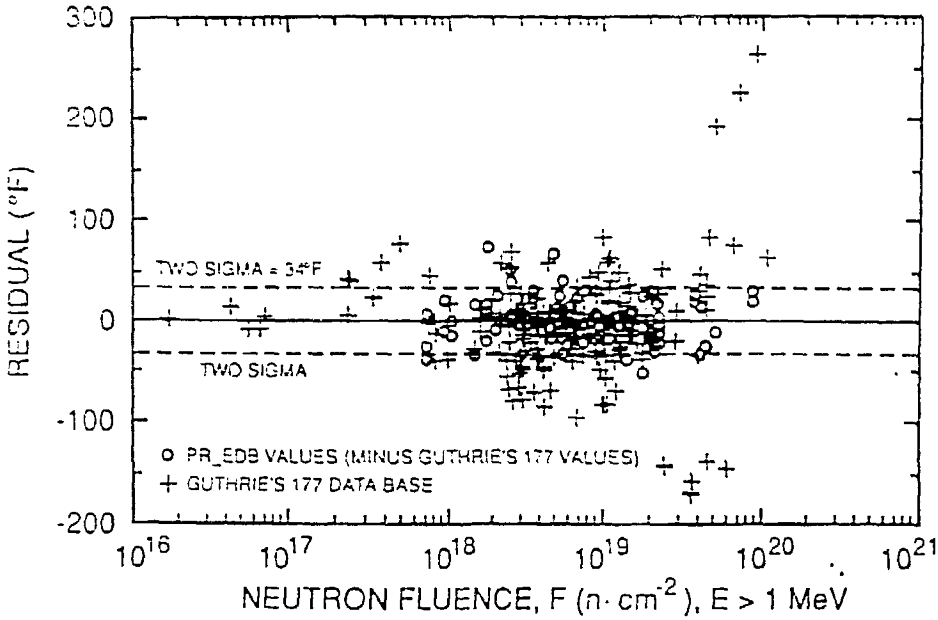

Fig. 2. Comparison of the data for base materials in PR_EDB with Regulatory Guide 1.99 (Rev. 2).

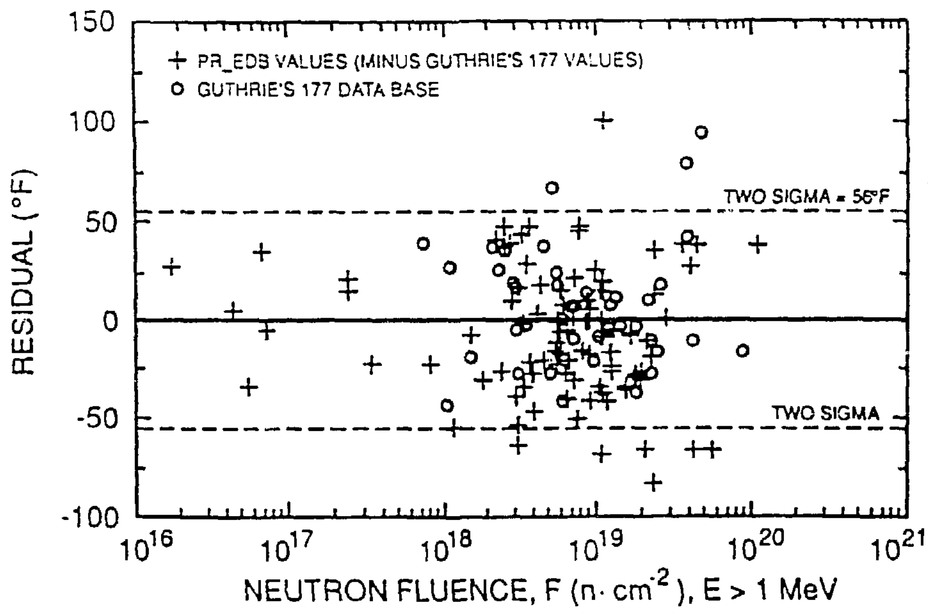

Fig. 3. Comparison of the data for weld materials in PR_EDB with Regulatory Guide 1.99 (Rev. 2).

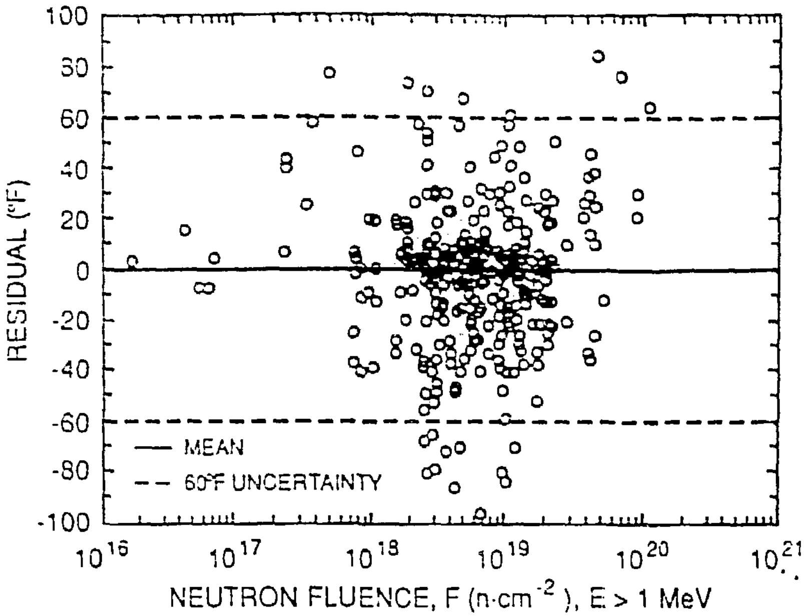

Fig. 4. Comparison of the data for base materials in PR_EDB with Regulatory Guide 1.99 (Rev. 2).

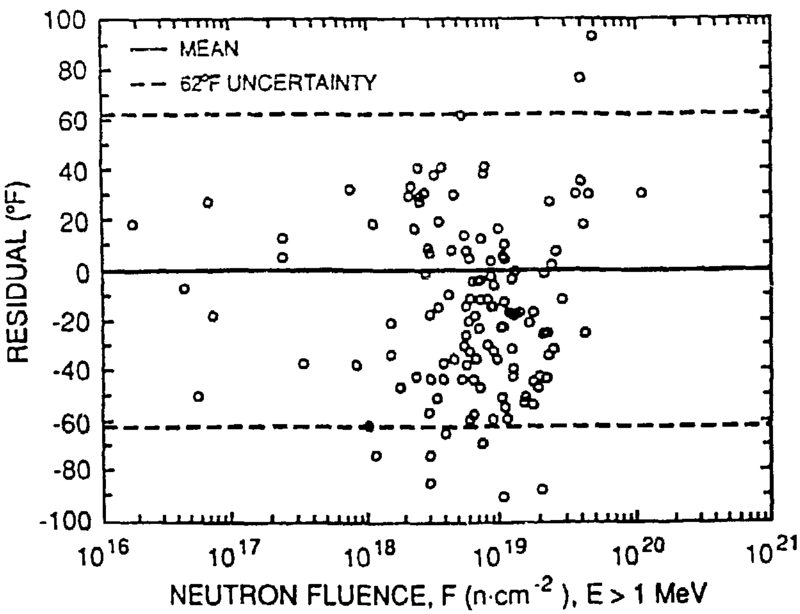

Fig. 5. Comparison of the data for weld materials in PR_EDB with Regulatory Guide 1.99 (Rev. 2).

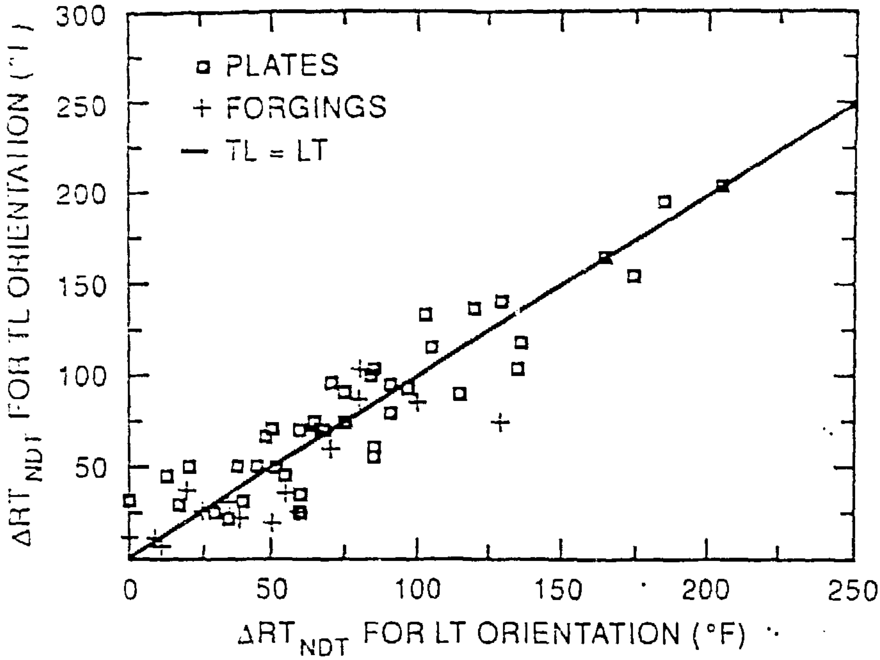

Fig. 6. Comparison of transition temperature shifts for TL and LT orientations.

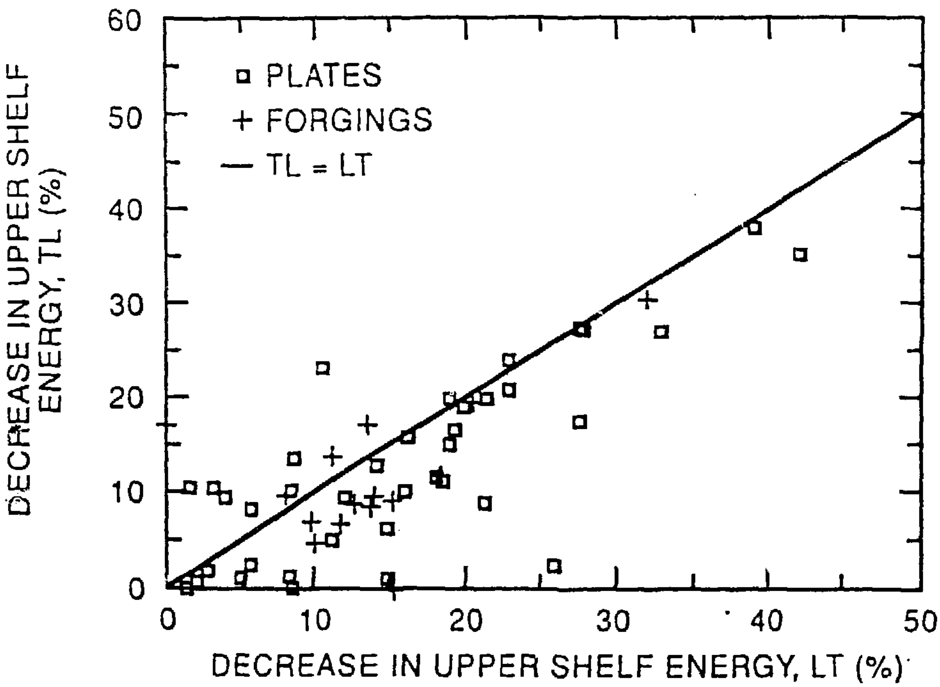

Fig. 7. Decrease in upper-shelf energy for TL and orientations (%).

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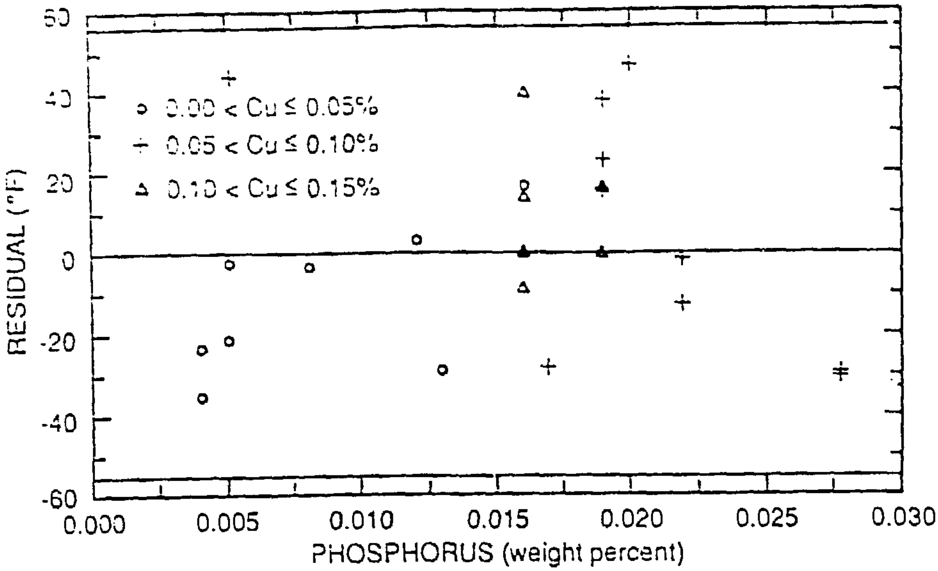

Fig. 8. Residual as a function of phosphorus fow low-copper welds.

Table 1

COMPARISON OF THE UPPER SHELF ENERGIES FOR THE TL- AND LT- ORIENTED CHARPY V-NOTCH SPECIMENS AND THE EFFECT OF SULFUR -- A302B

UNIRRADIATED SPECIMENS		IRRADIATED SPECIMENS		SULFUR
TL VALUES (ft-lbf)	65% OF LT VALUES (ft-lbf)	TL VALUES (ft-lbf)	65% OF LT VALUES (ft-lbf)	(%)
67	68.3	68	62.4	0.024
75	67.6			0.026/0.020*
84	71.5			0.020/0.018*
86	62.4			0.025/0.016*
98	85.2	88	78.0	0.017
102	101.0	84	72.8	0.019
105	107.3	68	61.8	0.019
108	91.0			0.015
108	91.7	106	89.1	0.015
108	91.7	107	89.7	0.015
112	118.0			0.016
115	76.5			0.017

*VALUES FROM TWO DIFFERENT LABORATORIES (LUKENS/KAWIN)

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A discussion of some work by J. R. Hawthorne showed a significant phosphorus effect in low-copper material (about 0.01% copper), but not for high-copper content (0.30% copper). The safety issue for regulatory was: "Does Regulatory Guide 1.99 (Rev. 2) underpredict the Charpy shift for low-copper material when the phosphorus is high?" A preliminary study indicated that some of the surveillance weld data did show a phosphorus effect (Fig. 8). Unfortunately, the large scatter of the residuals plus the fact that a plot of the residuals versus copper showed a similar bias prevented any definitive conclusion.

Lastly, a data evaluation was made to check if test results from longitudinally oriented (LT) specimens reduced to 65% of their value provided conservative estimates of the expected values from transversely oriented (TL) specimens. Also, the effect of sulfur was investigated. Generally, the results in Table 1 indicated that conservative estimates were obtained, and the higher sulfur content showed lower upper shelf energies.

These four data evaluations were just a few of the applications that were performed for the NRC. Completion of the quality assurance task for the PR_EDB will enhance its use by industry and researchers.

FUTURE DIRECTION

Data collection and software development will be a continuing process. A move is under way to establish a program in cooperation with the Nuclear Management and Resource Council (NUMARC) and NRC for long-term maintenance of PR_EDB to ensure that the data base does not become outdated as have previous data bases.

A vast amount of test reactor data has been collected and will be integrated with the PR_EDB to form a larger Embrittlement Data Base (EDB). This data base will contain many more types of data and will be used to explore and test a variety of models for irradiation damage mechanisms and predictions. PR_EDB, however, will be maintained as a separate data base as requested by EPRI who will provide the quality assurance for added power reactor data.

Data collection anticipated in the coming years will include:

1. data from instrumented Charpy impact tests, including digitized graphics representations of these tests;
2. test results from CT and WOL surveillance specimens;
3. calculated group fluences and fluence rates;
4. dosimetry data;

5. power-time history;
6. pressure-temperature data; and
7. beltline materials and their reported properties for all U.S. power reactors.

Simultaneous analytical studies will be made to identify weaknesses and inconsistencies in the structure and content of the data base.

DISTRIBUTION

The distribution of PR_EDB will be made to all users by the Oak Ridge National Laboratory with the approval of the NRC.

ACKNOWLEDGEMENTS

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1. F. W. Stallmann et al., "PR_EDB, Version 1, Power Reactor Embrittlement Data Base: Program Description," USNRC Report NUREG/CR-4816, June 1990.