UNITED STATES
NUCLEAR REGULATORY COMMISSION
Nuclear Safety Research Review Committee
Washington, D.C. 20555

8 July 1993

Mr. Eric S. Beckjord
Director
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Beckjord:

A meeting was held by the Nuclear Safety Research Review Committee(NSRRC) at the Chevy Chase Holiday Inn on April 28-29, 1993, to review the state of steam generator tube nondestructive examination (NDE) practice, technology needs, and the research and development that is underway. Informative presentations were made to the NSRRC by representatives from the Electric Power Research Institute, Westinghouse Nuclear Service Division, Zetec, B&W Nuclear Technologies, NUSON, Oak Ridge National Laboratories (ORNL), Pacific Northwest Laboratories, Electricite de France (EDF), University of Tennessee, and the NRC staff. An excellent technical exchange was engendered between the NSRRC and the participants.

## CURRENT PRACTICE

Eddy current (ET) techniques using a bobbin coil are the methods of choice for nondestructive examination of steam generator tubes. Multiple frequency ET techniques can detect a large number of defects and are chosen primarily due to the speed at which the examination can be made. Rates to traverse the tubes are in terms of feet per second. These bobbin coil pull rates, together with automated systems used for coil insertion into tubes reduce man-rem and speed up examinations. Signal processing and interpretation is primarily done manually. Additional modifications such as the simultaneous insertion of two coils into adjacent tubes should reduce total times further, perhaps by 20-40 percent. If potential defects are detected by the bobbin coils, complementary techniques (rotating pancake coil (RPC) or ultrasonics (UT)), that operate at significantly slower traversal rates, are used to discriminate between actual flaws and false positives due to artifacts. In addition, critical regions such as the top of the tube sheet, where cold work and changes in thickness reduce bobbin coil reliability, often require use of complementary techniques (e.g., RPC or UT) to assure flaw detection, particularly circumferential flaws.

Based upon the presentations there is evidence of evolutionary improvement in the sensitivity of current eddy-current and ultrasonic equipment and systems. Economic pressures to reduce costs and time for the inspections, and to increase the number of tubes inspected are driving these improvements in equipment and systems. Attempts to automate signal processing interpretation through the use of hybrid digital signal processing techniques and neural networks are in their initial stages of development and the feasibility of the concepts has not yet been proven over the diverse range of artifacts encountered in steam generator tubes.

## PROBABILITY OF DETECTION

The probability of detection of real flaws depends upon the equipment used, its calibration, the skill of the operator, and the type of the defect. If the instruments used have relatively low sensitivity and/or are affected by variables such as probe wobble, flaws may be missed because they are below the background noise level. Generally NDE instruments (ET, UT, RPC) are calibrated on arbitrary standards such as notches or drilled holes. Either ET or UT alone can miss flaws, depending on calibration instruments and procedures. Operator training and qualification programs, coupled with the ability to communicate field observations to a central location staffed with highly qualified analysts that can view and interpret data in nearly real time, increase the confidence in detection of flaws.

With the trend toward using high sensitivity instruments, the probability of detection of flaws at or greater than 20-30% through the wall thickness is quite high. Depending upon the probability/confidence levels, a lower bound of 80% for greater than 50% through-the-wall flaw may be achieved. Many false positives are observed at this probability of detection, so complementary techniques (ET with RPC, or ET with UT) are needed for discrimination. Although each type of defect should have a different probability of detection curve, several types of flaws should have closely grouped curves. A general assessment of the information presented at the meeting is that most defects would have acceptable probability-of-detection curves.

One concern, recognized by NSRRC, is the failure to date of some organizations conducting NDE on steam generators to confirm their claims of high detection reliability by providing data from the Program for the Inspection of Steel Components (PISC-III) steam generator tube round robin. Seven United States teams are examining the PISC specimens; however, only two have provided their data as of the end of June; these data were due in March 1993.

## NRC PLUGGING CRITERIA

The so-called 40% through the wall plugging criterion imposes limitations on the probability-of-detection considerations. Less restrictive plugging criteria would raise

the acceptable flaw sizes which would produce larger signals with signal-to-noise values greater than one. This would simplify the signal analysis procedure and reduce the dependence on expert analysis. Procedures based upon computer analysis and different plugging criteria that are currently in use in foreign countries such as France could be adopted in the United States. Additional savings in time and costs could be achieved if the "manual", expert analysis were not needed.

## FUTURE RESEARCH AND DEVELOPMENT

The ongoing research funded by NRC at ORNL and PNL should be continued to provide valuable expertise for the interpretation of NDE and steam generator problems. It is too early to discern whether the research project at the University of Tennessee will yield a useful product.

Based upon a user request from Region I, a major NRC expenditure is being made for a block of test specimens for use in a mobile laboratory. The intended use of the test specimens is unclear. It appears to the NSRRC that the mobile laboratory effort circumvents the ASME Codes. Industry, perhaps through EPRI, rather than NRC, should be encouraged to take the responsibility to provide ultrasonic pipe and vessel specimens containing a spectrum of anticipated defects to comply with Section XI, Appendix VIII.

NSRRC was impressed by the scope and thoroughness of the French program for steam generator NDE. EDF has an improved automatic ET system and incorporates UT for flaw confirmation as a complementary technique to enhance circumferential crack detection. For small radius bends various vibration frequencies are actuated. Laser profilometry is used to generate internal replicas of tube sections where changes in cross section such as denting are observed. The retired Dampierre steam generator is used as a test bed. NRC should incorporate the results of the French program into its steam generator NDE developments as appropriate.

The Committee recommends that the NRC work with the U.S. Navy to incorporate their research results and experience with steam generators into the civilian reactor safety program.

In the interest of maintaining the good record of reactor safety as well as gathering additional data relevant to operating practices and plugging criteria, NRC should encourage and cooperate with industry to develop a more direct and specific correlation between signals gathered by NDE techniques and steam generator tube defects. A more determined program to examine defective steam generators against NDE should be conducted. The Surry program is now seven years old and the tubes did not exhibit some of the types of defects that are now of most concern. Some information will be available from the French program to complement the Surry data. The presence of

several steam generators that have been removed from service in the United States presents a unique opportunity for comprehensive examinations to compare real defects of several kinds with NDE signals. RES should play a vital role in developing initiatives by industry and international entities in pursuing such validation and verification for these NDE techniques.

The NRC has placed major emphasis on steam generator tube failures or gross leakage that goes back to early criteria in 10 CFR and in Regulatory Guides 1.83 and 1.121. Originally, this was based upon the assumption of a highly improbable steam line break and a single tube failure was considered the acceptable design criterion. The emphasis on plugging at flaw depths greater than 40% through-the-wall was based upon reservations concerning sizing and flaw growth rates and concerns regarding gross leaks. The Committee is not aware that there has ever been an accident involving multiple tube ruptures in the steam generators of current pressurized water reactors. If there is new information that suggests that multiple tube failures with greater-than-single-tube-rupture consequences should be of concern, such information should be presented to the NSRRC for its review.

The importance of steam generators and the integrity of their tubing in operating pressurized water reactors continues to merit regulatory attention. It was not apparent from the presentations to the NSRRC that there is evidence of new phenomena or analyses that raise safety issues or present potential risks that have not been identified and successfully dealt with in the past. Use of RES resources beyond what is required for maintaining awareness and technical competence in steam generator engineering, operating, and testing developments is not warranted.

Sincerely,

David L. Morrison

David L. Morrison
Chairman
Nuclear Safety Research Review Committee

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