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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of)	
WISCONSIN ELECTRIC POWER COMPANY)	Docket Nos. 50-266
(Point Beach Nuclear Plant,)	50-301
Units 1 and 2))	(Repair to Steam Generator Tubes)

NRC STAFF'S PROPOSED INITIAL DECISION
ON EDDY CURRENT TESTING ISSUE

This initial decision concerns Wisconsin Electric Power Company's (Licensee) application to amend the operating license for the Point Beach Nuclear Plant, Units 1 and 2, to repair corroded steam generator tubes by inserting within them "sleeves" that span the corroded area and reinforce the tube. A fuller description of the proposed sleeving process and of the early proceedings in this case may be found in LBP-81-55, 14 NRC 1017 (1981) at 1019-1021 (demonstration program decision). In that demonstration program decision, we authorized the use of the sleeving process in six tubes of the Unit 1 steam generator which were degraded beyond the plugging limit.

The initial decision considers the issue of whether the proposed repair by sleeving of steam generator tubes will be adequately inspectable by eddy current testing in order to detect stress corrosion cracking (SCC) or intergranular attack (IGA).

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I. Background

Intervenor Wisconsin's Environmental Decade's (Decade) admitted issue states:

That the license amendment should be denied or conditioned because applicant has not demonstrated that eddy current testing is adequate to detect serious stress corrosion cracking or intergranular attack, in excess of the technical specification prohibiting more than 40 percent degradation of the sleeve wall, in sleeves that would be inserted within steam generator tubes.

This issue was brought before the Board by Decade on July 21, 1982 in its Motion Concerning Litigable Issues (Motion). Both the Licensee and the Staff filed responses to this Motion in the form of motions for summary disposition on August 9 and August 16, 1982, respectively. Licensee's motion was supported by the affidavit of W.D. Fletcher, Manager of Steam Generator Development and Performance Engineering for Westinghouse Electric Corporation. Staff's motion was supported by the affidavits of Messrs. Timothy G. Colburn, Emmett L. Murphy and Patrick G. Easley. Decade filed a reply brief in opposition.

On October 1, 1982, we entered a Memorandum and Order (Concerning Summary Disposition Issues). We granted summary disposition on all but one issue raised by Decade in its Motion, which we have stated above. In our October 1, 1982 Memorandum and Order we further explained the scope of the issue to be litigated, and also voiced some additional concerns we had as follows:

The admitted issue, which will be set for hearing after consultation with the parties, includes our concerns about the appropriate remedy, if any, if the eddy current testing does not have problems within the sleeved area. Were we to find that eddy current testing of sleeves is inadequate, we would

be unable to assess the significance of that finding unless we are informed about the relationship of the inadequacy to the probability of occurrence of events of differing degrees of seriousness. Obviously, no system of measurement is perfect. Errors of measurement are to be expected. The significance of errors of measurement must be assessed in relationship to the resulting risks.

We expect the hearing to address questions concerning the reliability of eddy current testing for detecting stress corrosion cracking in sleeved and unsleeved tubes (this latter evidence is relevant to our developing an adequate understanding of the ability to detect flaws in the sleeved tubes), the reliability with which rates of corrosion may be predicted within the tube-sleeve assemblies and the changing probability, over time, of undetected defects leading to a rupture of one or more sleeved steam generator tubes that: (a) will cause one or more leaks whose combined effect is not a serious safety problem, or (b) will cause one or more leaks whose combined effect is serious either because of the accompanying risk of release of radiation or because it would cause a serious risk of leading to a full or partial core melt condition. We are interested in expert opinion on these questions and in exploring the reasons for these opinions.

Memorandum and Order, at 2.

On November 2, 1982, Licensee filed the testimony of W.D. Fletcher on the admitted issue. The testimony of Mr. Fletcher addressed the plugging limit imposed by the Technical Specification, the general techniques of eddy current testing (ECT) and the expected results from IGA and SCC. ("Licensee's Testimony of W.D. Fletcher, hereinafter "Fletcher", following Tr. 1422). Also on November 2, 1982, the Staff submitted the testimony of two witnesses on the admitted issue and the Board's concerns:

(a) Emmett L. Murphy. The testimony of Mr. Murphy, a systems engineer with experience in the area of steam generator tube degradation, addressed measures taken to ensure tube integrity in the presence of IGA

and SCC. He also discusses the basis for the plugging limit, the ability of ECT to detect IGA and SCC in both sleeved and unsleeved tubes and the Staff's view of IGA and SCC as a safety concern. ("Testimony of Emmett L. Murphy", hereinafter "Murphy", following Tr. 1828).

(b) Ledyard B. Marsh. The testimony of Mr. Marsh, a nuclear engineer with experience in analyzing steam generator tube ruptures, addressed our concern with undetected flaws leading to tube rupture, thus causing serious safety problems. ("Testimony of Ledyard B. Marsh", hereinafter "Marsh", following Tr. 1822).

The admitted issue was fully litigated at the evidentiary hearing held on November 17 and 18, 1982 in Milwaukee, Wisconsin. Tr. 1383-1883. In addition to the witnesses who filed direct testimony, both the Licensee and Staff provided additional witnesses to address the concerns voiced by the Board. The Licensee presented Messrs. Clyde J. Denton (Tr. 1457) and Edward O. McKee (Tr. 1606) of Zetec, Inc. to respond to concerns in the area of interpretation of ECT data (hereinafter "Denton" and "McKee"). The Staff presented Messrs. Timothy G. Colburn, Project Manager for Point Beach (Tr. 1811) and Conrad E. McCracken (Tr. 1812), a chemical engineer with corrosion expertise (hereinafter "Colburn" and "McCracken"). All witnesses were subject to extensive cross-examination by Decade and questioning by the Board. Decade did not file testimony or rebuttal testimony on the admitted issue.

In accordance with the schedule agreed upon at the close of the evidentiary hearing (Tr. 1877), on December 20, 1982, the Licensee submitted its Proposed Findings of Fact and Conclusions of Law in the Form of a Proposed Initial Decision. On December 30, 1982, Decade

filed a Statement of Inadequate Record (Statement), "in lieu of proposed findings of fact." Statement at 1. The Staff filed its Proposed Initial Decision on Eddy Current Testing Issue on January 10, 1983. We base this decision on the proposed findings of the Licensee, the proposed initial decision of the Staff and our own reading of the record. Decade has chosen not to advance its arguments notwithstanding the opportunity to do so provided all parties and our instructions given at the close of the evidentiary hearing. Tr. 1878-80.

II. Applicable Law

The NRC, by regulation (10 C.F.R. § 50.57(a)(3)(i)) requires that there be reasonable assurance that all license activities can be conducted without endangering the health and safety of the public. In furtherance of this objective and within the framework of the issue presently being considered by the Board, and as noted in our October 1, 1982 Memorandum and Order, we find that 10 C.F.R. § 50.40 and § 50.55a (particularly § 50.55a(b)(2)(iii), (d) and (g)) and 10 C.F.R. Part 50, Appendix A, Criterion 14, are relevant. We consider Criterion 14 controlling, requiring that:

The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

It is against this standard that the evidence concerning the adequacy of eddy current testing should be weighed.

III. Discussion

The admitted issue questions the adequacy of eddy current testing (ECT) to detect intergranular attack (IGA) or stress corrosion cracking "in excess of the technical specification prohibiting more than 40 percent degradation of the sleeve wall" in the sleeves Licensee has proposed to use to repair degraded steam generator tubes. Decade is referring to Technical Specification 15.4.2.A, "Steam Generator Tube Inspection Requirements," of the Technical Specifications which are included in the operating licenses for Units 1 and 2 of the Point Beach Nuclear Plant, which specifies the requirements for inservice inspection of the steam generator tubes. Fletcher at 2. Paragraph 6 of this Technical Specification requires the Licensee to plug tubes which leak or have degradation exceeding the 40 percent plugging limit. Id. The 40 percent plugging limit is intended to ensure that degraded tubes are removed from service before they could potentially rupture during normal operating or postulated accident conditions. Murphy at 3. The plugging limit is a conservative limit based upon the worst possible geometry and the complete absence of external constraints against burst. Id.

In order to better understand the mechanism of this degradation, we requested that Licensee's witness Mr. Fletcher define IGA and SCC. Tr. 1427. Mr. Fletcher testified that IGA is an effect from a corrosion process which weakens the grain boundaries. Id. That weakening of grain boundaries can proceed in a three-dimensional fashion, i.e., it can affect a relatively broad area of the material as well as penetrating into the tube surface and proceeding into the tube wall. Id. SCC is also a weakening of the grain boundaries, but it is characterized by the pene-

tration into the tube metal in a very narrow crack-like feature that proceeds into the tube wall in a two-dimensional fashion, i.e., the effect on the tube surface is limited to a very narrow line. Tr. 1428. The two forms of corrosion are quite different in terms of how they affect the tube wall, but are very similar with regard to their cause, which is the presence of caustic, the agent that weakens the grain boundaries in both cases. Tr. 1428-29. With stresses in the tube wall one could expect to see SCC, whereas IGA is weakly dependent upon stresses in the tube wall. Tr. 1429.

Testimony was presented on measures being taken to ensure that sleeved tube integrity will not be impaired by IGA or SCC. The sleeves are fabricated from thermally treated Inconel 600 which is expected to provide enhanced resistance to IGA and SCC as compared to the mill annealed Inconel 600 from which the original tubing was fabricated. Murphy at 2. The addition of the sleeve will also have the effect of reducing the heat flux from the primary water to the secondary water in the region above the tubesheet which further reduces the potential for IGA and SCC attack in this area. Id. The sleeved tubes will be eddy current inspected at periodic intervals to monitor for any degradation and sleeved tubes found to exceed the 40 percent plugging limit will be plugged. Id. For Point Beach, eddy current testing (ECT) will be supplemented by system hydrostatic tests at test pressures substantially in excess of normal operating pressure and approximating those which would be expected to occur during postulated main steam line break (MSLB) and loss of coolant accident (LOCA) events. Id.

NRC's licensing requirements assume that some leakage will occur. Such leakage is monitored constantly while the plant is in operation. The leakage is detected by monitoring the secondary system condenser air ejector and steam generator blowdown for radioactivity. Fletcher at 5.

Technical Specification limits on allowable primary to secondary leakage have been established such that if leaks were to occur, the unit would be shut down before the integrity of the leaking tube(s) would become sufficiently impaired so as to potentially rupture during normal operating and postulated accident conditions. Murphy at 2, Fletcher at 6. Operating experience has demonstrated that the likely consequence of a flaw going undetected beyond the plugging limit and proceeding completely through-wall is a small leak. Murphy at 4.

After exploring the mechanism of tube or sleeve degradation and methods for preventing safety problems, we turned to the adequacy of ECT in sleeved tubes. The Staff testified that overall, the sensitivity of ECT in detecting flaws in sleeved tubes is expected to be similar to that for an unsleeved tube. Murphy at 4.

ECT utilizes an electromagnetic field, emanating from the eddy current probe within the tube or sleeve to examine the tube or sleeve wall. Degradation in the wall of the tube or sleeve causes variations in the effective electrical conductivity and/or magnetic permeability of the wall material. Fletcher at 3. These variations are measured directly by changes in the coil voltage of the eddy current probe. Fletcher at 4. If the tube wall is sound, one gets an A-current pattern. If the tube wall has a flaw, the current pattern is changed and interpretation is

based on the change of the current pattern. Tr. at 1462. For Point Beach, the interpretation of eddy current data collected by Westinghouse is performed by Zetec, Inc., a subcontractor. Tr. 1460. The Licensee provided Messrs. Denton and McKee, employees of Zetec, to respond to questions on the interpretation of ECT data.

The witnesses testified that all of the data collected on any of their inspections is always recorded in its raw form on an eight-channel magnetic tape, so that they always have the option of putting on strip chart any combination of information that they want. Tr. at 1608. This allows the inspector to subtract the signal effects of tube supports or copper. He can also subtract the effects of things on the inner diameter of the tube by judicious selection of frequencies when he does the original inspection. Tr. at 1609.

On a typical strip chart arrangement, if there is a decrease in electrical conductivity in the tube wall caused by a defect, there will be a vertical component to the signal. The inspector can easily screen strip charts to look for indications. He would then go to the magnetic tape and bring it up on the oscilloscope. Tr. at 1610.

Flaws are detected by reading phase angles. The strip charts are used for screening for deflection and for the vertical locations of the indications in the tubes. The flaws are read from the oscilloscope. Tr. at 1473.

The uneven characteristics of the surface of the tubesheet hole cause signals which can interfere with the interpretation of eddy current indications. Fletcher at 4. Signals can also be caused by the magnetite in the sludge surrounding the tube in the vicinity of the

tubesheet, as well as by conductive impurities which may be deposited outside of the tube. Id. These signals, referred to as "noise," can be reduced by the use of multifrequency mixing techniques such that the adequacy of the inspection is maintained, even though some residual interference remains. Id.

After exploring the means of testing for flaws in unsleeved tubes, we examined testimony concerning the effect of the sleeve on ECT. The Staff testified that for the section of sleeve inside the tubesheet, there will be a significant reduction of competing signal noise from the tubesheet. This is due to (1) the sleeve being further away from the tubesheet than the original tube and (2) the fact that sleeves will be inspected at a higher test frequency than the original tubes making the inspection less sensitive to objects located outside the sleeves. As a result of reduced noise from the tubesheet, the signal to noise ratio for the sleeve should actually be improved compared to an unsleeved tube in the tubesheet, thus improving the sensitivity of the test. Murphy at 5.

The Staff also testified that outside the tubesheet, Westinghouse reports a reduction in signal response for the sleeve ranging from 30% for a 40% through-wall standard calibration hole to 0% for a 100% through-wall calibration hole. In the Staff's judgment, this is considered to be too small of a reduction to have a significant bearing on whether a reliable test can be performed. Murphy at 4.

When questioned on this point, Licensee's witness Mr. Fletcher stated that he would not expect that amount of signal reduction for sleeve inspectability at Point Beach. Tr. at 1424. He testified that if one

takes a sleeve standard and set up the eddy current instrumentation with regard to that sleeve in air outside the steam generator, then one takes the sleeve standard and inserts it in a tube, also outside the steam generator, there is in fact a signal reduction. Id. The response for a given setting with the eddy current instrumentation for a sleeve in a tube is less than that for a sleeve in air. Id.

As a result of that finding, the establishment of the proper settings with the appropriate amount of amplification for the signals from a standard are obtained before eddy current tests in a steam generator with a sleeve standard inserted in a tube, so as to accommodate and to account for the signal reduction. Tr. 1424-25. The gains of the instrumentation and the amplification are restored to the value required to see the full range of signals in the standard sleeves. Id.

In other words, there is a different response to the instrumentation because the sleeve is inside the tube, and recognizing that difference in response one uses a different calibration standard and a different amplitude of signal generated, so that the sensitivity of the instrument is the same as it would be for a sleeve not inside of a tube. Tr. 1425.

Concerning the reliability of detecting IGA in the proposed sleeves, the Staff testified that in the absence of any significant radial constraint on the sleeves, the Staff believes that postulated IGA penetrations of 40% of the wall thickness will be detectable. However, it is possible that the sleeves could be constrained similarly to tubes in the tube-to-tubesheet crevice if sludge is deposited into the sleeve-to-tube annulus. This could limit the capability of ECT to detect IGA on the sleeves, but not to the same extent as has been the case for the unsleeved tubes. Some

improvement would be expected due to the reduction or absence (outside the tubesheet) of tubesheet noise. Murphy at 6-7.

However, Mr. Fletcher testified that when degradation reaches a depth of 30 to 60 percent, experience has shown there will be SCC present, and with present techniques, conventional ECT is sensitive to SCC. Tr. at 1450. Moreover, the Staff testified that in spite of ECT limitations for IGA detection, ECT has nonetheless been able to detect hundreds of IGA indications within the tubesheet. Murphy at 6.

With regard to SCC, the Staff testified that based upon the Staff's experience with ECT, the Staff believes that an adequate inspection of the sleeves can be performed for SCC detection. Murphy at 8. Conventional bobbin coils are capable of reliably detecting axially oriented 40% through-wall SCC in the absence of significant noise effects. Id. Thus, the Staff does not anticipate difficulties with SCC detection outside the tubesheet area. Noise in the tubesheet region is expected to be less of a problem for the sleeves than for the unsleeved tubes in this region. Murphy at 8-9. Should future experience indicate that additional sensitivity is necessary to provide a fully reliable test in this region, this can be achieved through refinements to the test procedure. Murphy at 9.

Finally, we examined the safety significance of the adequacy of ECT in detecting IGA and SCC.

The Staff testified that the 40 percent plugging limit itself is conservative. The plugging limit is determined on the basis that the tube is uniformly thinned over its length and circumference. In addition, it is assumed that there is no external constraint on the tube which could

help restrain a rupture. With these assumptions, the minimum acceptable wall thickness to preclude rupture of the sleeve is calculated conservatively to be 39% for a postulated MSLB and even less for LOCA. This is equivalent to saying that the sleeve would exhibit acceptable margin against rupture during accidents for uniform wall thinning ranging to 62% and the 40% plugging limit provides added structural margin including allowance for eddy current error and incremental corrosion penetration between inservice inspections. Murphy at 3, Fletcher at 9.

When the plugging limit is applied to a sleeved tube, additional conservatisms apply. The plugging limit for the sleeve has taken no credit for reinforcement against burst which may be provided by the tube, and the fact that any leakage from the sleeve may be severely restricted by the narrow tube-to-tubesheet and sleeve-to-tube gaps. Exactly what influence the tube would have in providing reinforcement against sleeve rupture and in minimizing leakage will depend on the condition of the tube at the location of a sleeve defect, if a sleeve defect is located above the tubesheet. If a sleeve defect were located within the tubesheet, the tube would be very effective in both respects. Murphy at 4.

It is important to note that ECT is not the only line of defense against tube/sleeve rupture caused by IGA or SCC. Mr. Fletcher testified that the characteristics of the tube and sleeve material, Inconel 600, are such that, whether or not IGA is present, SCC progressing through the tube wall will result in leakage before the time when the tube has the potential for rupture during accident or normal operating conditions. Fletcher at 7. This "leak-before-break" characteristic is based on

the concept that corrosion cracks, initiating from the outer diameter, would penetrate through-wall and result in a small but detectable leak before the crack would propagate to the "critical crack length," i.e., such a length that the tube could develop a large leak rate in the event of a postulated accident. Id. This concept is particularly applicable to materials such as Inconel 600 with high ductility and toughness, that is, with the capability to withstand high stresses by deforming rather than fracturing. Id.

The Staff agreed with the Licensee to the extent that ECT in conjunction with other measures which have been taken to reduce the rate of attack on the tubes has permitted Point Beach Unit 1 to be operated in a relatively leak free mode since early 1980. Murphy at 6. The tight radial constraint of the tube by the tubesheet minimizes any potential for tube rupture. Id. Further, the narrow tube-to-tubesheet annulus severely restricts any possible leakage from the tubes. Id. Additional actions, including more frequent ECT inspections, periodic hydrostatic tests, and reduced primary to secondary leakage rate limits, have been taken to ensure continued safe operation of the facility. Id.

The Staff testified that, in its belief IGA and SCC were not a safety concern. ECT in conjunction with restrictive limits on primary to secondary leakage ensure that the occurrence of IGA and SCC will be detected and that timely diagnostic and/or corrective actions will be taken as necessary to ensure that the tubes will retain adequate integrity against rupture during normal operating and postulated accident conditions. Any leakage would be expected to be small based upon operating experience. Of over 200 leaking tubes from domestic pressurized

water reactors reported to the NRC to date, only four have involved tube ruptures. None of the rupture occurrences resulted in any unacceptable offsite radiological consequences. The Licensee is planning to perform periodic hydrostatic tests, as discussed previously, which will provide added assurance of tube integrity. Should IGA or SCC degradation occur, diagnostic actions can be taken to evaluate the nature of the problem, its safety significance, and whether there is a need to perform a more sensitive eddy current test or to refine data interpretation methods. Murphy at 10.

The Licensee essentially agreed with the Staff and concluded that eddy current inspectability of sleeves, the leak-before-break characteristics of the sleeves, the additional corrosion resistance of the sleeve material, and the added margin in the ability of the corroded material to resist rupture provide reasonable assurance of the protection of public health and safety against unacceptable leakage during normal operating and accident conditions. Fletcher at 11.

A Staff witness, Mr. Marsh, testified on the safety significance of a through-wall defect in the sleeved portion of a steam generator tube. He stated that a through-wall defect in the sleeve may not result in the same leak rate as a through-wall defect (of equivalent size) in an unsleeved tube. If a through-wall defect in the sleeve occurs at a location hydraulically far from the original defect (presuming the tube contains a large through-wall defect or rupture), then the pressure drop occurring in the small narrow sleeve-to-tube gap would act to throttle the flow. In other words, if a through-wall crack in the sleeve occurred, and there was a large through-wall defect in the tubing outside the

sleeve, primary coolant would pass first through the sleeve, then through the annular region between the tube and the sleeve, then through the original defect in the tube and then into the steam generator secondary side. It is the existence of this torturous path that may, if the sleeving defect is far from the original defect, reduce the leak rate as compared to the leak rate for a through-wall-defect in an unsleeved tube. If the sleeving through-wall defect occurs close to the original tube defect, then the leak rate would be no greater than for the case of an unsleeved tube with a through-wall defect on the same size. Marsh at 2-3.

IV. Conclusion of Law

Based on the weight of the evidence, we find that, coupled with other precautions such as leak detection, the eddy current testing of sleeved tubes at Point Beach Nuclear Plant is adequate to present an extremely low probability of abnormal leakage, rapidly propogating failure and gross rupture of the reactor coolant pressure boundary consistent with 10 C.F.R. Part 50, Appendix A, Criterion 14. Therefore, Decade's admitted issue is dismissed.

V. Order

For all the foreoing reasons and based on consideration of the entire record in this matter, it is this ____ day of _____, 1983,

ORDERED

(1) The Director of Nuclear Reactor Regulation is authorized to make the findings required by the Atomic Energy Act of 1954, as amended, and the Commission's rules and regulations, and to issue a license amendment to

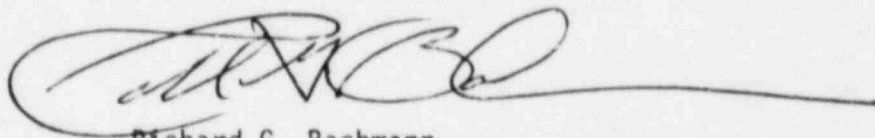
Wisconsin Electric Power Company authorizing the operation of Point Beach Nuclear Plant, Units 1 and 2, with steam generator tubes which have been repaired by sleeving.

(2) This is an initial decision of the Atomic Safety and Licensing Board and in accordance with 10 C.F.R. Sections 2.760, 2.762, 2.764, 2.785 and 2.786, this initial decision shall be effective immediately and shall constitute the final action of the Commission forty-five (45) days after the issuance thereof, subject to any review pursuant to the above-cited Rules of Practice. Exceptions to this initial decision may be filed within ten (10) days after service of this initial decision. A brief in support of the exceptions shall be filed within thirty (30) days thereafter (forty (40) days in the case of the NRC Staff).

Within thirty (30) days of the filing and service of the brief of the Appellant (forty (40) days in the case of the NRC Staff), any other party may file a brief in support of, or in opposition to, the exceptions.

IT IS SO ORDERED.

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'R. G. Bachmann', with a long horizontal line extending to the right.

Richard G. Bachmann
Counsel for NRC Staff

Dated at Bethesda, Maryland
this 10th day of January, 1983

