ENCLOSURE

OMB No.: 3150-0011
NRCB 89-01

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

May 15, 1989

NRC BULLETIN NO. 89-01: FAILURE OF WESTINGHOUSE STEAM GENERATOR TUBE MECHANICAL PLUGS

Addressees:

All holders of operating licenses or construction permits for pressurized water reactors (PWRs).

Purpose:

The purpose of this bulletin is to request that addressees determine whether certain mechanical plugs supplied by Westinghouse are installed in their steam generators and if so, that an action plan be implemented to ensure that these plugs will continue to provide adequate assurance of reactor coolant system (RCS) pressure boundary integrity under normal operating, transient, and postulated accident conditions. Thus, the actions are to ensure compliance with General Design Criteria 14 and 31 of 10 CFR 50, Appendix A and the quality assurance requirements of 10 CFR 50, Appendix B. The actions requested by this bulletin, with the exception of Action 2e, apply only to Westinghouse mechanical plugs which have been fabricated from thermally treated Inconel 600, heat numbers 3279, 3513, 3962, and 4523.

Description of Circumstances:

Numerous plants have experienced primary water stress corrosion cracking (PWSCC) and leaks of Westinghouse mechanical plugs. On February 25, 1989, North Anna Unit 1 experienced a mechanical plug failure following a reactor trip during a feedwater isolation transient. The plug failure caused a 75-gallon-per-minute (gpm) primary-to-secondary leak and was the subject of NRC Information Notice No. 89-33, "Potential Failure of Westinghouse Steam Generator Tube Mechanical Plugs." The failure mechanism involved a full circumferential severance of the top portion of the plug from the body of the plug. The top portion of the plug was propelled up the length of the affected tube by primary system pressure to a point just above the u-bend tangent point where it impacted and punctured the outer curvature of the tube. The top portion of the plug subsequently impacted and dented an adjacent tube. The failed plug was installed in November 1985.

Westinghouse provided its preliminary assessment of the plug problem in meetings with the NRC staff on March 23 and April 5, 1989. This assessment was documented in Revision 1 to Westinghouse reports WCAP-12244 (proprietary version)

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and WCAP-12245 (non-proprietary version), "Steam Generator Tube Plug Integrity Summary Report," April 1989 (Reference 1). Westinghouse stated that the bulk of problems to date, including the North Anna Unit 1 plug failure, involved thermally treated Inconel 600 plugs fabricated from heats 3513 and 3962. Westinghouse stated that material from these heats has been found to exhibit only minimal (i.e., less than semi-continuous) intergranular carbide precipitation which, in turn, Westinghouse attributes to a low mill annealing temperature. Heat 3279 is a third heat exhibiting a similar microstructure which was used to fabricate Westinghouse mechanical plugs. Westinghouse noted that resistance to PWSCC has been shown to be related to the degree of intergranular carbide precipitation. The heats exhibiting only a minimal degree of intergranular carbide precipitation (i.e., heats 3279, 3513, and 3962) are referred to by Westinghouse as Category 1 heats.

Non-Category 1 heats are those characterized by Westinghouse as exhibiting continuous or semi-continuous intergranular carbide precipitation. Based on preliminary corrosion test results, Westinghouse had expected plugs fabricated from non-Category 1 heats to exhibit significantly smaller PWSCC corrosion rates than plugs fabricated from Category 1 heats. However, on April 28, 1989, Westinghouse informed the NRC staff that certain plugs from heat 4523 (a non-Category 1 heat exhibiting a semi-continuous carbide distribution in the grain boundaries) had been found to contain significant circumferential cracking indicative of corrosion rates comparable to those which have been observed for Category 1 heats.

At the staff's request, the Regulatory Response Group (RRG) of the Westinghouse Owners Group (WOG) met with the NRC staff on April 5, 1989, to discuss the causes of problems experienced to date with Westinghouse plugs, the potential safety implications and consequences of plug failures, and the WOG recommendations for ensuring plug integrity over both the near and long term. The WOG endorsed the action plan developed by Westinghouse that was described during the April 5, 1989 meeting with the staff and which is documented in Section 4 of WCAP-12244, Revision 1. A summary description of the action plan has been incorporated into this bulletin as Appendix I. The Appendix includes the NRC staff's understanding of commitments made by Westinghouse to the utilities which have installed the subject plugs.

Discussion:

The actions requested by this bulletin are consistent with the Westinghouse action plan described in Appendix I herein with the modifications as noted in the Actions Requested. The indicated modifications reflect the following staff conclusions regarding the Westinghouse action plan:

1. The need for remedial actions for plugs from Category 1 heats and from heat 4523 should be determined on the basis of corrosion rate estimates benchmarked against the field data from Millstone Unit 2 since this represents the most conservative data of a limited data base.

2. The absence of PWSCC on a sample of removed plug specimens does not provide an adequate basis on which to defer remedial actions for plugs where the acceptable lifetimes of the plugs do not extend to the next scheduled refueling outage.

Remedial measures may be deferred (See Actions Requested, item 3) for plants where the steam generator tubes are partially depth expanded within the tubesheet (i.e., length of tube expansion within the tubesheet is less than 3 inches). Analyses by Westinghouse indicate that a tube which is partially depth expanded precludes a failed plug from becoming a high energy missile within the tube. Remedial measures may also be deferred (see Actions Requested, item 4) for "sentinel related" Westinghouse mechanical plugs. This is justified on the basis that tubes plugged with "sentinel related" plugs are filled with water. This water precludes a broken plug from acting as a high energy missile inside the tube. "Sentinel related" plugs are those which are either of the following:

- "Sentinel" type Westinghouse mechanical plugs [Sentinel plugs are plugs with a small diameter hole in the top of the plug which allows the plugged tube to fill with water. The hole in the sentinel plug is sized to limit leakage to less than the plant Technical Specification limit for primary-to-secondary leakage assuming that the plugged tube is completely severed.]

- Non-"sentinel" type Westinghouse mechanical plugs which are installed in tubes containing sentinel type plugs on the opposite leg of the tubes.

The actions requested by the bulletin, with the exception of Action 2e, are limited to Westinghouse mechanical plugs supplied from Category 1 heats (heats 3279, 3513, and 3962) and heat 4523. Additional actions pertaining to Westinghouse mechanical plugs supplied from other heats may be requested at a later time in a supplement to this bulletin, if found to be warranted. In the meantime, addressees should give careful consideration to any future Westinghouse recommendations which may be applicable to their plants concerning plugs supplied from these other heats.

Actions Requested:

1. Addressees are requested to verify that information contained in References 1 and 2 relating specifically to their plants is correct for plugs supplied from heat numbers 3279, 3513, 3962, and 4523. The specific information to be verified is the number of Westinghouse mechanical plugs installed in the hot and cold legs broken down by steam generator number, heat number, and date of installation. If information from these references is incorrect, appropriate corrections should be identified. Addressees are requested to so state if their plants have not installed Westinghouse mechanical plugs from the subject heats.

2. Addressees are requested to take the following actions, to be implemented initially during any refueling outage or extended outage (greater than four weeks) which ends 30 days or more following receipt of this bulletin and during all future refueling outages.

   a) Steam generator tube plug lifetime for plugs from heats 3279, 3513, 3962, and 4523 should be estimated using the methodology from References 1 and 2 and should be based on the Millstone Unit 2 benchmark subject to any corrections per item 1 above. Lifetime estimates in Reference 2 for plugs fabricated from heat 4523 are based on the Farley Unit 2 benchmark. These estimates should be adjusted to reflect the Millstone Unit 2 benchmark using the methodology described in Section 4.1.2 of Reference 1.

   b) Addressees should implement appropriate remedial actions (i.e., repair and/or replacement) for all plugs whose estimated lifetimes in 2a, above do not extend to the next refueling outage. If operation is planned beyond a refueling outage that represents the last outage before any plug exhausts the predicted lifetime, an alternative schedule with the appropriate technical justification should be submitted to the NRC at least 30 days before the end of this refueling outage.

   c) Prior to any plug repairs or replacement, addressees are reminded that their responsibilities under ALARA require analysis of the various plug repair or replacement methods available to determine which method will result in the lowest overall personnel radiation exposure while still remaining cost-effective. In choosing a plug repair or replacement method, the licensee should consider the accessibility of the plugs and the dose reduction benefit of using robotic manipulators. Prior to plug repair or replacement, the licensee should consider steam generator decontamination and/or local shielding to reduce working area dose rates.

   d) Installation of Westinghouse mechanical plugs from heats 3279, 3513, 3962, and 4523 should be discontinued.

   e) Westinghouse mechanical plugs removed from steam generators, regardless of heat number, should be examined for PWSCC on a sample basis for each heat. Addressees should maintain a record of these examinations and the results should be provided to Westinghouse to improve the database concerning the susceptibility of plugs to PWSCC.

3. Remedial actions at plants where the steam generator tubes are partially-depth-expanded within the tubesheet as described above may be deferred on a one time basis to the next scheduled refueling outage if the outage that immediately follows receipt of this bulletin ends before October 1, 1989.

4. Remedial actions for "sentinel related" mechanical plugs described above may be deferred on a one time basis to the next refueling outage if the outage that immediately follows receipt of this bulletin ends before October 1, 1989.

Reporting Requirements:

Addressees shall submit a letter within 30 days of receipt of this bulletin containing:

1. The information under Actions Requested, item 1.

2. A commitment to Actions Requested, items 2, 3, and 4 or proposed alternative actions with supporting justification.

The written reports required above shall be addressed to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, D.C. 20555, under oath or affirmation under the provisions of Section 182a, Atomic Energy Act of 1954, as amended and 10 CFR 50.54(f). In addition, a copy shall be submitted to the appropriate Regional Administrator.

This request is covered by Office of Management and Budget Clearance Number 3150-0011 which expires December 31, 1989. The estimated average burden hours is 100 person-hours per licensee response, including assessment of the new recommendations, searching data sources, gathering and analyzing the data, and preparing the required letters. These estimated average burden hours pertain only to these identified response-related matters and do not include the time for actual implementation of the requested actions. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Records and Reports Management Branch, Division of Information Support Services, Office of Information Resources Management, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555; and to the Paperwork Reduction Project (3150-0011), Office of Management and Budget, Washington, D.C. 20503.

If you have any questions about this matter, please contact one of the technical contacts listed below or the Regional Administrator of the appropriate regional office.

References:

1. Westinghouse reports WCAP-12244 (proprietary version) and WCAP-12245 (non-proprietary version), "Steam Generator Tube Plug Integrity Summary Report," Revision 1, April 1989. NRC Accession Nos. 8904250229 and 8905030163.

2. Westinghouse letter to NRC dated May 1, 1989 (NS-NRC-89-3432) "Steam Generator Tube Plug Integrity Update." NRC Accession No. 8905040092 (Proprietary). Westinghouse has agreed to provide copies of this letter to the affected utilities by May 17, 1989.

Charles E. Rossi

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Attachment: List of Recently Issued NRC Bulletins

Appendix I

The following are the major elements of an action plan developed by Westinghouse and applicable to all the mechanical steam generator tube plugs installed by them.

A. Westinghouse Short-Term Plan

1. Plants Currently in a Scheduled Refueling Outage

a. The need for immediate remedial actions should be determined on the basis of planned effective full-power days (EFPD) until the next refueling outage compared to the acceptable lifetime of the plugs before they become potentially vulnerable to failure by PWSCC. The acceptable lifetime is calculated using the Westinghouse corrosion rate algorithm described in Section 4.1.2 of WCAP 12244, Revision 1. This algorithm was developed on the basis of laboratory and field data and yields the acceptable plug lifetime as a function of (1) the known degree of carbide distribution in the grain boundaries for the heat from which the plug was supplied and (2) the operating temperature of the plug.

Alternatively, the need for immediate remedial action can be assessed by removing a statistically significant sample of plugs and examining them for PWSCC. Remedial actions can be deferred to at least the next refueling outage (see item B., "Westinghouse Long Term Plan"), provided the removed plugs exhibit no significant PWSCC.

b. Remedial actions, if necessary, should include

- Removing plugs and examining them to improve the data base concerning the susceptibility of the plugs to PWSCC, and
- Implementing plug repairs*, and/or
- Removing and replacing plugs with mechanical plugs having a preferred microstructure (i.e., non-Category 1). Before the fall of 1989, the replacement plugs for installation in hot legs will be supplied from thermally treated Inconel-600 having a continuous grain boundary carbide distribution. For installation in the cold legs where PWSCC corrosion rates are significantly reduced compared to the hot legs, a semi-continuous microstructure may be employed. Starting in the fall of 1989, new and replacement mechanical plugs will be made from thermally treated Inconel-690 which is expected to further improve the PWSCC resistance of the plugs.

*Westinghouse and Babcock & Wilcox have developed plug repair techniques involving insertion of a new plug into the original plug.

2. Plants in Operation

The need for remedial actions should be assessed and the remedial actions implemented, as necessary, per item A.1. at the next scheduled refueling outage. Westinghouse plans to monitor the performance of each and every installed mechanical plug in service.

3. Areas for Additional Development by Westinghouse

a. Development of a robotic plug repair method to reduce radiation exposure of workers.

4. Additional Testing and Analysis by Westinghouse

a. Analysis and tests to confirm that the rupture of an adjacent tube is not a credible consequence of a plug failure.

b. Corrosion tests to refine the corrosion algorithm for plugs.

B. Westinghouse Long-Term Plan

Westinghouse will continue to monitor all Westinghouse mechanical plugs in operating plants to support recommendations to utilities for implementing remedial actions on a timely basis, where necessary.

WCAP-12244, Revision 1 (Reference 1), includes a listing of the following information for each plant employing Westinghouse mechanical plugs fabricated from Category 1 heats:

1. Number of Westinghouse mechanical plugs, classified as follows:

a. date of installation
b. heat number
c. steam generator number
d. whether hot leg or cold leg

2. Hot leg and cold leg temperature

3. Accumulated EFPD of each plug

4. Remaining lifetime of each plug as determined from the Westinghouse corrosion rate algorithm

Note: WCAP-12244, Revision 1, provides three different lifetime estimates for each plug based on three different corrosion rate benchmarks determined from the field data. These benchmarks are the maximum corrosion rates observed for plugs at Millstone Unit 2 supplied from heat 3513, for plugs at North Anna Unit 1 supplied from heat 3962, and for plugs at North Anna Unit 2 supplied from heat 3962. Westinghouse recommends that the lifetime estimates for plugs supplied from heats 3513 and 3962 be based on the

Millstone Unit 2 and North Anna Unit 2 benchmarks, respectively, since these are the most conservative benchmarks for the respective heats. Westinghouse has made no specific recommendation concerning plugs fabricated from heat 3279 since Westinghouse believes that all plugs from this heat have been removed from service.

The above information will be expanded by Westinghouse in a quarterly update report to include plugs from non-Category 1 heats. Westinghouse will provide this information to the affected utilities, when it becomes available. Westinghouse has already provided such information for heat 4523, including lifetime estimates.

Attachment
NRCB 89-01
May 15, 1989

LIST OF RECENTLY ISSUED
NRC BULLETINS

Bulletin No.	Subject	Date of Issuance	Issued to
88-08, Supplement 3	Thermal Stresses in Piping Connected to Reactor Coolant Systems	4/11/89	All holders of OLs or CPs for light-water-cooled nuclear power reactors.
88-07, Supplement 1	Power Oscillations in Boiling Water Reactors	12/30/88	All holders of OLs or CPs for BWRs.
88-11	Pressurizer Surge Line Thermal Stratification	12/20/88	All holders of OLs or CPs for PWRs.
88-10	Nonconforming Molded-Case Circuit Breakers	11/22/88	All holders of OLs or CPs for nuclear power reactors.
88-05, Supplement 2	Nonconforming Materials Supplied by Piping Supplies, Inc. at Folsom, New Jersey and West Jersey Manufacturing Company at Williamstown, New Jersey	8/3/88	All holders of OLs or CPs for nuclear power reactors.
88-08, Supplement 2	Thermal Stresses in Piping Connected to Reactor Coolant Systems	8/4/88	All holders of OLs or CPs for light-water-cooled nuclear power reactors.
88-09	Thimble Tube Thinning in Westinghouse Reactors	7/26/88	All holders of OLs or CPs for W-designed nuclear power reactors that utilize bottom mounted instrumentation.
88-08, Supplement 1	Thermal Stresses in Piping Connected to Reactor Coolant Systems	6/24/88	All holders of OLs or CPs for light-water-cooled nuclear power reactors.
88-08	Thermal Stresses in Piping Connected to Reactor Coolant Systems	6/22/88	All holders of OLs or CPs for light-water-cooled nuclear power reactors.

OL = Operating License
CP = Construction Permit