U.S. NUCLEAR REGULATORY COMMISSION

Region I

Report Nos. 50-317/84-14
50-318/84-14

Docket Nos. 50-317
50-318

License Nos. DPR-53
DPR-69 Priority - Category C
C

Licensee: Baltimore Gas and Electric Company

Post Office Box 1475

Baltimore, Maryland 21203

Facility Name: Calvert Cliffs Nuclear Power Plant, Units 1 and 2

Inspection At: Lusby, Maryland

Inspection Conducted: May 29 and 30, 1984

Inspector: Lewis Narrow /for 6/20/84
S. D. Reynolds, Jr., Lead Reactor Engineer date

Approved By: Lewis Narrow /for 6/20/84
J. P. Durr, Chief, Materials and Processes date
Section, DETP

Inspection Summary: Inspection on May 29 and 30, 1984 (Combined Report Nos. 50-317/84-14 and 50-318/84-14)
Areas Inspected: Routine, announced inspection of licensee's activities in taking corrective actions to salt water graphitic corrosion of component cooler heat exchanger (CCHX) and service water heat exchanger (SWHX) channel heads (water boxes). The inspection involved 10 hours onsite by one regional based inspector.

Results: No violations were identified.

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DETAILS

1.0 Persons Contacted

Baltimore Gas and Electric Company (BG&E)

A. Thorton, Engineer, Electric Engineering Department
R. Pond, Manager, Principal Metallurgist, Materials Engineering and Analysis Unit
K. Cramblitt, Corrosion Engineer
* L. Russell, Plant Superintendent
* J. Carroll, General Supervisor, Operations
* R. Heibel, Plant Engineering Technical Support
* M. Miernicki, Principal Engineer, Plant Engineering
* L. Wenger, Senior Engineer

Factory Mutual Insurance Company

N. Hewett, Authorized Nuclear Inspector

Nuclear Regulatory Commission (NRC)

* T. Murley, Region I Administrator
* R. Starostecki, Director, Division of Project and Resident Programs
* D. Trimble, Senior Resident Inspector
W. Hazelton, Materials Technology Engineering Branch
R. Bosnak, Chief, Mechanical Engineering Branch, NRR
E. Wenzinger, Chief, Reactor Projects Section 1A, DPRP
D. Jaffe, Project Manager, NRR

* Indicates those present at exit interview.

2.0 Graphitic Corrosion of CCHX and SWHX Cast Iron Water Boxes

The inspector reviewed the licensee's activities and corrective actions related to the subject corrosion problem. The inspectors activities included technical discussions with the licensee's Principal Metallurgist and members of his staff, visual observation and inspection of corroded parts removed from service, and inspection of all of the subject water box repairs. This report is addressed solely to this specific corrosion topic.

Gray cast iron may suffer a form of corrosion termed graphitic corrosion in which the iron matrix is preferentially attacked by dissolution, leaving only the over lapping graphitic flake structure. When connected to a more noble material, such as a copper alloy tube sheet and tube bundle the cast iron corrosion is accelerated by the galvanic currents induced by the couple.

The ASME Section VIII component cooling heat exchangers (CCHX) and service water heat exchangers (SWHX) were affected. Other power plant parts such as gray cast iron salt water pump components were previously reported to be affected by graphitic corrosion.

Description of Circumstances

During a recent outage at Calvert Cliffs, Unit No. 2, gross graphitic corrosion was found in the gray cast iron CCHX and SWHX water boxes (channels). It was previously known that corrosion conditions in the service water system were sufficient to cause graphitic corrosion of cast iron as this form of corrosion was observed and reported in the circulating water pump guide vanes. The extent of this corrosion was shown while needle gun cleaning marine growth. This operation resulted in a hole completely through the channel in an area near the tube sheet. The licensee examined the CCHX channels on Unit 1 while at full power and observed seepage in both heat exchangers.

Heat Exchanger Design

The component cooling heat exchangers (CCHX) and service water heat exchangers (SWHX) are ASME Section VIII straight tube units which utilize gray cast iron water boxes (channels), aluminum bronze tube sheets and copper-nickel tubes. The service water is on the tube side. The water boxes are of the TEMA (Tubular Exchanger Manufactures Association) Standards, Figure N-1.2, Type A design for a stationary channel head with removable cover. The materials of construction are as follows:

Channel:	SA278, Class 30 (Modified with 2% Ni) Cast Iron
Tube Sheet:	SB171, Alloy C61400 (Aluminum Bronze D)
Tubes:	SB111, Alloy C70600 (90-10 Copper-Nickel)

The dissimilar materials of construction result in potential galvanic couples with the following estimated emf's in flowing salt water:

Material	Voltage
90-10 Cu-Ni	- 0.25
Aluminum Bronze	- 0.35
Cast Iron	- 0.68

The effective anode to cathode area ratios of the CCHX and SWHX vary with the CCHX
having the worst ratio (and the greatest attack). Methods to provide galvanic electrical isolation of the tube sheet and water box are impractical on these heat exchanger designs.

The channels are designed for 50 psig, the pump shut off pressure is approximately 40 psig and the normal operating pressure is approximately 20 psig.

Extent of Corrosion Damage

Inspection of the channels removed from the CCHX indicated adherent marine growth and barnacles on the entire ID surface. The marine growth attaches to areas with and without galvanic corrosion; therefore, visual inspection for galvanic corrosion is not possible. Although the licensee has chlorination equipment, the combination of environmental regulations and equipment problems has rendered this equipment totally ineffective in eliminating marine growth. The licensee has not determined if the marine growth or excretions from the marine growth have a significant effect on the corrosion reaction. Water box turbulence also does not appear to be significant to the reaction.

The graphitic corrosion occurred in localized areas approximately 6" in diameter and in an annular band adjacent to the tube sheet. The localized areas showed less attack than the area near the tube sheet where it was deduced that the galvanic couple enhanced the corrosion (dissolution) rates. The CCHX channels were attacked more than the SWHX. This was attributed to a smaller effective anode to cathode area ratio in the CCHX as compared to the SWHX.

Effectiveness of Pencil Zincs

The original cast iron channels employed pencil zincs for attempted sacrificial anode protection. Evaluation of this system by the licensee indicated it to be ineffective initially and observation of the performance of the zincs indicated that even fresh zincs became inoperative shortly after being put in service. The use of sacrificial anodes requires a thorough analysis to determine the selection of the proper anode material, shape of the anode, anode spacing and "throwing power" effectiveness to produce an engineered system capable of providing protection of the channel.

The licensee has determined that the locations for anodes are acceptable; however, the shape and composition of the anodes can be engineered to provide satisfactory and reliable protection to materials less noble than the tube sheet and tubes. These anodes are being obtained and will be installed as soon as practicable. In the mean time, new pencil zincs will be utilized. The purpose of the sacrificial anode protection at this time is to protect "holidays" in the applied coatings.

Ultrasonic Thickness Determination

Tests were conducted to evaluate the capability of ultrasonics to determine the thickness of the unattacked (by graphitic corrosion) portion of the gray cast iron channels. Methods using both pitch-catch and pulse echo techniques with large diameter 1 MHz crystals were proven by calibration methods using actual channel thickness measurements. Ultrasonic test of cast iron is discussed in the technical literature in "Ultrasonic Testing of Materials" by J. Krautkramer and H. Krautkramer.

The remaining unaffected thickness of the channels was checked using a grid system method with 4" to 6" spacing. Where thickness measurements indicated loss of metal, the spacing was decreased to improve mapping accuracy.

Accurate thickness measurements assume relatively uniform acoustic velocity characteristics of the cast iron. Consideration must be given to the metallurgical facts that the flake size and flake density may vary within the body of the cavity due to specific solidification characteristics. This will affect the acoustic velocity. The total carbon content and alloying elements also affect the flake formation. In the case of 2% nickel cast iron, the nickel acts as a graphitizer and produces finer, but denser flakes of graphite.

Heat Exchanger Repairs

The subject heat exchanger channels are designed to ASME Section VIII (SCVIII) requirements. There is no established ASME repair method for cast iron pressure vessels. Repair of cast iron by welding methods is not permitted in the ASME Code. The licensee researched SCVIII and utilized three repair methods. For affected areas smaller than 2" OD, they authorized a pipe plug repair method (per intent of SCVIII UCI-78). For larger localized areas, they utilized a bolted gasketed cover plate within the bolting dimensions and layout consistent with the 1968 SCVIII, Part UR, design rules. For the annular ring areas, they utilized a gasketed "belly band" also designed to meet the 1968 SCVIII, Part UR, requirements.

Application of Corrosion Resistant Coating Systems

Various coating systems have been evaluated by the licensee to provide a corrosion resistant surface on the inside of the cast iron (or carbon steel replacement) channels. Of the systems evaluated, it was determined that a coal tar epoxy had the best overall characteristics. This material has had considerable service life experience in the raw salt water environment. The success of the coating is related to the ability to apply the first coat on a dry surface with all remnants of the graphitic corrosion (remaining flakes w/o iron matrix) removed. Abrasive blasting to apparent "white" metal is not sufficient. The areas must be checked with a "needle" gun or equivalent to insure that all of the "flake-only" material has been removed. The epoxy is normally applied in 4 to 5 heavy coats totally approximately 100 mils.

Licensee Corrective Actions

The inspector reviewed the following documents related to the subject corrosion problem.

1. Licensee's event description entry number 1047-OE dated 5/16/84.

2. Jennings and Brant (BG&E) memorandum "Salt Water System Status Report" dated 2/24/84.

3. Safety Analysis Number 1, FCR 84-1044, Supplement 0.

4. Safety Analysis Number 5, FCR 84-1044, Supplement 4.

5. Safety Analysis Number 4, FCR 84-1044, Supplement 3.

6. Facility Change Request (FCR) 84-1044, dated 5/9/84 and Supplements 1 (definition of minimum acceptable wall), 2 (pipe plug and bolted patch repair methods) and 3 (minor changes).

The licensee took steps to evaluate the wall thickness of all channels considered to be affected by taking UT thickness measurements.

Wherever practicable, the corroded channels were replaced with fabricated carbon steel channels with a coal tar epoxy coating systems on the ID surface and engineered sacrificial anode protection. The multi-layer coatings were inspected for lack of continuity with holiday testing equipment. The channels will be re-examined for holidays after the first month of service and on a quarterly basis following the first check. Local coating defects will be repaired as required.

Channels which had sufficient wall thickness to meet design requirements (as determined by UT) were mechanically cleaned of marine growth, blasted to white metal, and probed mechanically for areas which lacked the matrix iron. The soft graphitic areas were locally removed by grinding and the coal tar epoxy system applied.

Channels which had localized or general areas where the wall thickness was insufficient, and in which cases immediate replacement was not practicable, were repaired by engineered patches and belly band repairs. These repairs were engineered to meet the mechanical requirements of ASME SCVIII, UR. The leak tightness was achieved by the use of rubber gaskets or sealants, where there was a concern for pressure loading on the liquid sealant areas, metal retaining seals were used to support the sealant. Following repair, the channels were hydro-tested at approximately 40 psig which is the pump shutoff pressure and about twice the service water pressure.

The Authorized Nuclear Inspector (ANI) who represents both the insurance company and the State of Maryland is not satisfied that the mechanical repair methods utilized by the licensee result in a repair which can be termed as "ASME Code" repair. He does believe that the repaired water boxes can operate safety. He believes the repair to be an engineered fix and should only be considered a "temporary" repair. The basis for his concern is that the ASME Code does not clearly indicate how repairs to cast iron pressure vessels are to be made. Discussions between the regionally based inspector and the NRC representative on the ASME Main Committee indicated that the ASME Code per se, does not address this subject and only is applicable through another jurisdiction chain. In this case, the

National Board of Boiler and Pressure Vessel Inspectors (National Board) Standards indicate that the original fabrication and design code should be utilized in repair. It is the normal position of the National Board that the cognizant authorized inspector shall determine the acceptability of the repair for continued service.

The ANI has requested from the licensee complete documentation of engineering calculations and engineering approach to the repair for review by his management. The purpose of this information is to permit review of the advisability of acceptance for a full 18 month period. This is not required prior to restart.

The licensee conducted a 10 CFR 50.59 review and safety analysis. They concluded there are no unresolved safety questions and that the margin of safety defined in the Technical Specification is not reduced.

Both units now have one CCHX with replacement channels and one CCHX with belly band repaired channels. Both units also have one SWHX with the original casting with more than minimum design wall and a coal tar epoxy coating system, and one SWHX with patch type repairs.

The licensee has established a maximum leakage rate above which the units are considered to be technically inoperable. This leakage rate is based on the capacity limits of the floor drains and maximum leakage permissible without decreasing the performance of the heat exchanger below acceptable limits. The leakage rate is 5 GPM. The licensee has also taken actions to prevent water leaking from the water boxes from adversely affecting other equipment.

No violations were identified.

3.0 Exit Interview

The inspector met with licensee representatives (denoted in Paragraph 1) at the conclusion of the inspection on May 30, 1984. The inspector summarized the scope and findings of the inspection. No written information was given to the licensee by the inspector during the course of the inspection.