UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W.
ATLANTA, GEORGIA 30323

Report Nos.: 50-338/89-07 and 50-339/89-07

Licensee: Virginia Power Company
Glen Allen, VA 23060

Docket Nos. 50-338 and 50-339 License Nos.: NPF-4 and NPF-7

Facility Name: North Anna 1 and 2

Inspection Conducted: March 13 - 17, 1989

Inspector: Michael M. Glasman 4/11/89
Date Signed

Approved by: Jerome J. Blake, Chief 4/11/89
Date Signed
Materials and Processes Section
Engineering Branch
Division of Reactor Safety

SUMMARY

Scope

This routine unannounced inspection was conducted in the areas of inservice inspection work observation, inservice inspection data review, and observation of the licensee's recovery efforts from the February 25, 1989, hot leg mechanical plug failure and subsequent tube rupture in Unit 1, steam generator "C".

Results

This inspection documents an effective inservice inspection (ISI) program. Management involvement in assuring quality was evident in that the ISI program was well-documented, and procedures examined were technically sound and well-written. Another feature of the Licensee's program is contractor NDE personnel must demonstrate competence by passing method examination(s) administered by the licensee. This adds confidence that contract personnel are qualified and competent. The inspectors contacted and observed during this inspection were well-trained, and experienced individuals. At the time of this inspection, the licensee also determined that a mechanical plug on the hot leg side of steam generator (S/G) "C" had failed in such a way that the upper portion of the plug accelerated under reactor coolant system (RCS) pressure, exited the tube at the U-bend transition, struck and dented an adjacent tube above, then came to rest in its original tube. For a summary of events leading up to this event, refer to NRC Report Nos. 50-338, 339/89-03. The plug, its exit point and the adjacent dented tube were observed via remote video equipment.

Licensee personnel were very responsive to the inspector's initiatives in that information was provided in a timely manner, and personnel in contact with the inspector were knowledgeable and well-informed. In addition, the recovery efforts relative to the mechanical tube plug failure in Unit 1 were well-organized; daily information sheets and action plans were issued each morning. The licensee's efforts in the recovery effort were augmented by strong Westinghouse support in the removal and failure analysis of the failed plug, as well as assisting in support of the NRC inspector's initiatives.

REPORT DETAILS

1. Persons Contacted

*R. Driscoll, Manager, Quality Assurance
*S. Hamill, Inservice Inspection Engineer
*G. Kane, Station Manager
*J. Leberstien, Licensing Engineer
*E. Smith, Nuclear Operations Support
L. Spain, Metallurgist Power Engineering Services
*H. Travis, Supervisor, Nondestructive Evaluation

Westinghouse Employees

*R. Andersen, Westinghouse Site, Service Manager
R. Easterling, Westinghouse Program Manager, Virginia Power Steam Generator Maintenance Agreement

NRC Resident Inspectors

J. Caldwell, Senior Resident Inspector
*L. King, Resident Inspector

*Attended Exit Interview

2. Inservice Inspection (ISI) Units 1 and 2

The inspector examined documents, procedures, records, and observed work to determine whether ISI was being conducted in accordance with applicable procedures, regulatory requirements and licensee commitments. The applicable code of record for both Units 1 and 2 is American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV), Section XI, 1974 Edition, Summer 1975 Addenda.

Units 1 and 2 are in the 3rd period of the first 10 year ISI interval. Inservice inspection is performed both by contractors and Virginia Power personnel under the Virginia Power Quality Assurance (QA) program. Contract personnel performing NDE were from Westinghouse and Virginia Corporation of Richmond. In addition, contract NDE personnel must pass tests administered by Virginia Power and, in most cases, use Virginia Power procedures. Virginia Power procedures for NDE vendor/contractor surveillance also require review and sign-off on all test results.

a. Observation of Work and Work Activities, Unit 2 (73753)

The inspector was limited in the amount of ISI work activity that could be observed because a decision was made to close Unit 2 containment for a full day for decontamination work, and ISI was not in progress in Unit 1 at the time of the inspection. In addition, Health Physics (HP) coverage required by the applicable Radiation Work Permit for the ISI-NDE activities in the containment was not always available in a timely manner. This caused considerable delays.

For the methods observed, the inspector verified that:

- An approved procedure for the activity was in use
- Examination personnel were knowledgeable in the examination method, and operation of the test equipment
- Examination personnel with proper level of qualification and certification were performing the various examination activities, including designation of examination methods to be used; equipment calibration; examination; and interpretation; evaluation; and acceptance of test results
- Applicable procedures and travelers clearly specified the test procedure, and a copy of the test procedure was available in the work area
- Acceptance limits were specified and were in accordance with the applicable ASME Code
- Examination results, evaluation of results, and any corrective actions/repairs/replacements were being recorded as specified in the ISI program and NDE procedures

The ISI-NDE work observed by the inspector is listed below:

System/ Component	Line No.	Location/ Weld No.	Drawing	Method
RHR	10"-RHR-414	05	VGB-1-4303 R0	UT
RHR	10"-RHR-414	06	VGB-1-4304 R0	UT
SI Accum Disc	12"-SI-469	06	VGB-1-4302 R0	UT
RCP "B" Flywheel	N/A	Peripheral	N/A	UT
RCP "B" Flywheel	N/A	Shaft Hole and Keyways	N/A	PT

The inspector noted that the lower portion of the Reactor Coolant Pump (RCP) "B" Flywheel shaft hole was damaged by what appeared to be misalignment between the flywheel and RCP shaft during installation or removal. The damage consisted of gouges and deep score marks which showed up as indications during the Liquid Penetrant (PT) test. At the time of the inspection, it was not possible to determine if the indications were relevant because additional preparation in the area of the indications was required due to the presence of galled and lapped-over surfaces.

The inspector also noted that prior to this inspection, an item relative to the assembly procedure for the RCP flywheel was opened, 50-339/86-12-01, "RCP Flywheel Assembly Procedure." The inspector of record indicated that the Virginia Power assembly procedure did not include sufficient detail to enable the craft to remove/replace the flywheel without reference to the pump manufacturer's procedure. The subject item was closed in Report No. 50-339/87-07 when the licensee revised the assembly procedure to include the necessary instructions. Relative to this inspection, it should be noted that the "B" RCP was dissambled/assembled using the previous revision of the subject procedure.

Certification and calibration records for the UT equipment used in the above examinations were also reviewed by the inspector. The inspector verified that the UT instrument was within its current calibration interval, that certification records were on file for the transducers used, and the couplant certifications stated conformance to ASTM D-129, and D-108 for sulphur and halogen content.

The certification records for the following were reviewed by the inspector:

Item	Serial No. or Batch
Transducer, KB-A 2.25 mHz 0.5" dia	41030
UT Instrument, Sonic MK I	11223E
Couplant, Ultragel	8557

b. Review of Procedures, Units 1 and 2 (73052)

The inspector reviewed the procedures indicated below to determine if they were consistent with regulatory requirements and licensee commitments. The procedures were also reviewed to determine if requirements for NDT personnel were specified; equipment and supplies were appropriately certified and/or calibrated; accept/reject levels were specified; data recording requirements were specified; proper review, approval, and concurrence was indicated; and if applicable, division of responsibility existed between licensee and contractor personnel.

Procedure	Title
NDE 6.2 R2	"Review of Contractor Nondestructive Examination Interpretation by Virginia Power Company Personnel"
NDE 7.3 RO	"General Requirements for ISI Nondestructive Examination"
NDE PT-301 RO	"Liquid Penetrant Examination"
NDE UT-301 RO	"Manual Ultrasonic Examination of Piping Welds"

(1) Technical Review, Liquid Penetrant Procedure

The inspector reviewed Procedure NDE PT-301 RO to ascertain conformance with ASME Code, Section V, Article 6, in the following areas: specified method; penetrant material identification; penetrant test materials analyzed for sulphur and total halogen content; acceptable pre-examination test surfaces; test temperature; cleaner application method and drying time; method of penetrant application; test piece temperature; solvent removal and drying time; type of developer and application technique; evaluation technique; light level; and procedure requalification.

(2) Technical Review, Ultrasonic Procedure

The inspector reviewed Procedure NDE UT-301 RO to ascertain conformance with ASME Code, Section V, Article 5, in the following areas: Method specified; apparatus specified; linearity and signal attenuation accuracy requirements; beam coverage/angle; scan rate/direction; scan technique; calibration before and after examination; calibration block requirements, including size and location of defects within the block; sizes and frequencies of search units specified; methods of distance-amplitude correction techniques specified and consistent with equipment used; reference level for scanning; methods of demonstrating penetration and coverage; levels for evaluation of defects specified; methods for recording significant indications; and acceptance limits specified.

c. Inservice Inspection Data Review and Evaluation, Unit 2 (73755)

Records of completed nondestructive examinations were selected and reviewed to ascertain whether: the method(s) technique, and extent of the examination complied with the ISI plan and applicable NDE procedures; findings were properly recorded and evaluated by

qualified personnel; programmatic deviations were recorded as required; personnel, instruments, calibration blocks, and NDE materials (PT materials, couplant) were designated. Records selected for this review are listed below:

System	Line	Weld/Location	Drawing	Method
SI	6"	62	VGB-2-2526 RO	UT
SI	8" SI-440	1	VGB-2-2531 RO	UT
SI	8" SI-440	3	VGB-2-2531 RO	UT
SI	8" SI-440	4	VGB-2-2531 RO	UT
CH	8" CH-604	WS-1	VGB-2-2532 RO	PT
MAIN STM	32" SHP-601	BPL-104	3C-90	PT
MAIN STM	32" SHP-457-601	BPL-335	3C-90	PT
MAIN STM	32" SHP-459-601	BPL-200	3C-90	PT
MAIN STM	6" SHP-438	WS-1	VGB-2-2202 R1	MT

Within this area of inspection, no violations or deviations were identified.

3. Mechanical Tube Plug Failure, Steam Generator "C", Unit 1

On February 25, 1989, Unit 1 experienced a trip following a loss of feedwater when the "C" Main Feedwater Regulating Valve closed. Shortly after the trip, primary-to-secondary leakage was detected in the "C" steam generator (S/G). For additional details regarding the events surrounding the trip and response to the transient, refer to NRC Inspection Report Nos. 50-338, 339/89-03. Remote visual examination of S/G "C" revealed a leaking hot leg plug at row 3, column 60 (R3C60) with the steam generator filled to approximately 58% on the wide range instruments. This corresponds to the region above the 7th support plate. Historical eddy current data, however, indicated that the tube R3C60 was not plugged for through-wall indications. Discussion of historical eddy current data relative to this event may be found in NRC Report Nos. 50-338, 339/89-06.

Preliminary video examination using a Welch Allyn (W/A) video probe revealed that the top of the plug had become separated from the body of the plug; the bottom section of the plug was firmly in place, along with the mechanical expander, however, the top was missing. Subsequent W/A video examination located the missing plug section above the 7th support plate, on the hot leg side, and lodged in a semi-inverted position above a jagged tear in the extrados at the transition between the straight and U-bend portion of tube R3C60. The tear appeared to be about 3" long. In addition, the tube above, and adjacent to tube R3C60, R4C60, was dented in three adjacent locations. These dents were clearly visible through the hole torn in R3C60.

Shortly after the inspector viewed the failed lower section of the R3C60 plug recovered from Unit 1, it, along with the cold leg R3C60 plug and plugs from tube R24C8, also from S/G "C", Unit 1 were shipped to (W) laboratories in Pittsburgh for analysis; plug R24C8 was observed to be dripping, however, this plug reportedly was not fabricated from a heat known to be susceptible to PWSCC. Preliminary information returned from Pittsburgh indicated that this plug had also failed due to PWSCC.

Within the areas inspected, no violations or deviations were identified.

4. Action on Previous Inspection Findings (92701)

Inspection was not conducted in this area.

5. Exit Interview

The inspection scope and results were summarized on March 17, 1989, with those persons indicated in paragraph 1. The inspector described the areas inspected and discussed in detail the inspection results. Although reviewed during this inspection, proprietary information is not contained in this report. Dissenting comments were not received from the licensee.

During the inspection, the inspector was able to view the lower section of the failed plug which was recovered from the S/G, as well as the intact cold leg plug. These plugs were visually examined in the Unit 1 containment by the inspector, and a licensee metallurgist. The following observations were made:

> The lower section of the plug exhibited a flat circumferential fracture at the root of the second sealing land. The fracture was approximately perpendicular to the axis of the plug and covered with an undisturbed, evenly-distributed layer of brown colored oxide. There was no indication of mechanical rubbing, fretting, or other disturbance to the oxide layer. No evidence of a ductile fracture, such as a shear lip, or necking in the region of the fracture was evident to the unaided eye. In addition, there was no evidence of cracking transverse to the main fracture, or significant branching of the main fracture.

The above remote video observations and examination of the fracture surface of the mechanical plug strongly indicate that the plug failed prior to the February 25, 1989 trip. This is supported both by the presence of undisturbed oxide on the fracture face, and the lack of ductile fracture indicators. At the time of the inspection, the licensee was not able to say with certainty what mechanism was responsible for keeping the fractured plug tip in place prior to the trip.

Following the trip, the now separated plug tip was accelerated up the bore of tube R3C60, with considerable reactor coolant system (RCS) pressure as the driving force. This was sufficient to impart sufficient energy to the plug tip such that it was able to penetrate the tube wall (and damage tube R4C60) instead of following the bend in the tube.

The failed plug was machined from thermally treated Alloy 600 barstock, from heat 3962. This heat, and heat 3513 were both identified as material susceptible to Primary Water Stress Corrosion Cracking (PWSCC). This conclusion was based on information from Westinghouse (W). Westinghouse indicated that these these heats did not receive adequate thermal treatment, resulting in a discontinuous to semi-continuous carbide network in the grain boundaries. PWSCC resistance is enhanced when a continuous network of grain boundary carbides is present in Alloy 600. Both of the above heats are used in North Anna's S/Gs. The licensee is currently trying to locate these plugs as part of their recovery efforts.

While at the site, the inspector reviewed a proprietary (W) Research and Development report which described the analysis of a leaking hot leg mechanical plug removed from North Anna, Unit 2. The particular plug was also fabricated from heat 3962. This plug was removed from Unit 2 "A" S/G during the 1985 outage. The report indicated that the plug contained axial and circumferential cracking, which was intergranular in nature, and caused by stress corrosion. Further, the axial cracks initiated from the inside, or primary side of the plug. An initiation site/direction could not be determined for the circumferential crack.