U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT

Region I

Report No. 50-271/81-01

Docket No. 50-271

License No. DPR-28 Priority _____ Category A

Licensee: Vermont Yankee Nuclear Power Corporation

20 Turnpike Road

Westborough, Massachusetts 01581

Facility Name: Vermont Yankee Nuclear Power Station

Inspection at: Vernon, Vermont

Inspection conducted: January 3-5, 1981

Inspectors: for S. D. Reynolds, Jr., Reactor Inspector — 1/26/81 date signed

_____ date signed

_____ date signed

Approved by: L. E. Tripp, Chief, Engineering Support Section No. 1, RC&ES Branch — 1/26/81 date signed

Inspection Summary:

Inspection on January 3-5, 1981 (Report No. 50-271/81-01)

This inspection was made into the cause of failure of a portion of the piping connecting the waterbox of the last regenerative heat exchanger (HX) to the first non-regenerative HX. Areas examined included: Review of material certifications of subject pipe, review of other applications for identical pipe purchased from the same heat of material, visual inspection of failed portion of pipe, review of welding procedures utilized for replacement pipe fabrication, discussions of service history of regenerative HX, and witness of liquid penetrant examination of portions of pipe adjacent to the failure area. The inspection involved a total of 24 inspector hours, by a regionally based inspector.

Results: No items of noncompliance were identified.

DETAILS

1. Persons Contacted

The personnel listed below were contacted:

Vermont Yankee Nuclear Power Corporation

*W. Murphy, Plant Superintendent
*J. Pelletier, Assistant Plant Superintendent
*R. Kenney, Operations QA
*D. Reid, Engineering Support Supervisor
*W. Wittmer, Maintenance Supervisor

Mercury Company of Norwood, Inc.

P. McAuliffe, Welding Supervisor
J. Dugvay, QA Supervisor
J. Okleyer, QC Technician
M. Parla, QC Technician
*M. Trombley, Project Manager
L. Politas, Pipefitter
T. Jones, Pipefitter

*Denotes those present at exit interview.

2. Event Summary

Routine operational surveillance by an auxiliary operator conducted during a startup period following an extended outage revealed dampness on the insulation of a four (4) foot horizontal section of pipe line (4" CUW-3, pipe line between waterboxes for E-15-1C and E-16-1A heat exchangers). This observation was recorded on Round Sheet C150.02 dated December 29, 1980. Upon removal of the insulation it was noted that there were 2 apparent weeping type leaks in the horizontal run of pipe. On December 29, 1980 this line was isolated and a 37 3/4" section of TP 304L pipe welded in the line to repair the portion containing the leaks. This repair method utilized short (4 1/4" and 6 1/8" stub ends of the original horizontal run of pipe to permit pipe to pipe repair welding and eliminate the requirements of making pipe to elbow welds. During liquid penetrant examination of the completed repair weld on December 31, 1980 linear indications were observed outside the weld heat affected zone (HAZ) in the remaining stub sections. On January 1, 1981 the entire 48 1/8" horizontal pipe section was replaced, the pipe to elbow welds liquid penetrant tested, additional examinations of the remainder of the CUW-3 pipe line (discussed in a later paragraph) were completed, and the cooling water cleanup system reactivated.

3. Review of Material Certifications

The licensee's investigation of the material certifications for the subject failed piping indicated that the pipe was purchased by Grinnell Corporation from U.S. Steel Corporation. The Grinnell Purchase order was W18516 (USS #LC75391, Invoice #41792). The seamless SA312 TP304 solution annealed pipe was manufactured at the Ellwood works of USS and had a certified test report dated March 25, 1970. The test report indicates four (4) pieces of pipe 4.5 OD x 0.337" wall (Heat 2P3564) with 0.058%C, 1.73% Mn, 0.030% P, 0.023%S, 0.47%Si, 10.41% Ni and 18.67% Cr. The mechanical tests met ASME SA 312 requirements. The NRC inspector discussed some of the manufacturing details with the cognizant USS employee who certified the test report. The material is hot extruded, cold drawn, rotary straightened, ID reamed, solution annealed at 2000F in a continuous furnace and water quenched with a water spray curtain, then cold straightened on a crossroll rotary straightener, then OD polished. The cold straightening following solution annealing could produce high levels of residual stress in the hoop direction. The test report and manufacturing sequence meet the requirements for SA312. The standard average length of pipe shipped per piece is 20 feet. The material purchased met the licensee requirements of Ebasco QC-10, Pipe Code SS-6, 1500 psi class (paragraph 3(b)).

No items of noncompliance were identified.

4. Repair of 4" CUW-3 Piping

During routine operational surveillance on December 29, 1980 dampness was observed on the insulation of the four (4) foot horizontal run adjacent to the E-15-1C regenerative HX water box outlet. Upon removal of the insulation, minor weepage was noted at two locations on the subject pipe run. It was reported that the weepage volume was such that after wiping the water off the OD of the pipe, it would take a short period of time for water to reappear. The weepage described was occurring with a approximately 1000 psig internal pressure. The estimated temperature during startup is between 229-260F per VYNPS FSAR Section 4.9 Figure 4.9-2.

The original repair employed replacement of a 37 3/4" section of the pipe that showed leakage. This fix left short (4 1/4" and 6 1/8") stub sections of the original straight run of pipe for ease of welding to eliminate the welding of pipe to elbow joints. This repair is shown in Mercury Company DWG WM-49851-100 Rev. 0 dated December 29, 1980. The welding was conducted in accordance with Mercury WPS-D Rev. 8 dated August 4, 1980 (manual gas tungsten arc welding procedure for joining P8 to P8 materials). The PQR supporting WPS-D was PQR D-1880 dated August 4, 1980. A purge port was welded into the pipe section prior to welding the pipe in the line to facilitate ID purging during welding. This sockolet was

installed per Mercury SPN-49851-700 dated December 30, 1980. The pipe welding was performed in accordance with Mercury Company MR# 80-01471 dated December 29, 1980.

Review of WPS-D by the NRC Inspector indicated a few areas that require clarification to provide more explicit directions to the welder and to QC. The filler metal list should be revised to include the low carbon grades actually utilized or the list changed to indicate only low carbon grades. The paragraph under QW403 on page 5 of WPS-D should be changed to indicate the same base metals as paragraph 10 on page 3. Consideration should be given to eliminating the numerical oscillation parameters for manual welding or to indicating only width dimensions as parameters. The reference to TP-18-8 in the table in paragraph 10 should be eliminated or clarified as this is not a standard composition. The above items are considered unresolved pending satisfactory review and approval of revised documents by the NRC inspector. (271/81-01-01)

During penetrant examination of the completed pipe welds it was noted that the NDE test showed evidence of cracking outside the weld and weld HAZ on the stub ends remaining from the original pipe section. The stub sections were then removed and the weld joint location moved back to the original location at the elbows as shown in Mercury DWG WM-49851-100 Rev. 1 dated December 29, 1980 (MQC Rev. dated December 31, 1980.

The welding was repeated as per the original repair and as recorded on Mercury Co. QC Weld Data Report Job #49851, (Customer Order 14885) Weld W1 and W2. Welders M180, M152, M91, M189, and M33 performed the welding. The welding filler metal utilized was Sandvik 3/32" ER316L Heat 464374 and Arcos 1/8" ER316L.

The NRC inspector reviewed the applicable WPS, PQR, Welder Performance qualifications, filler metal material certifications, filler metal receiving inspection reports, QC weld data reports, and SA312 (seamless) 304L piping material certifications and receiving inspection reports including UT examination.

Due to the defects found in the stub sections, the remainder of the pipe run from the water boxes of E-15-IC to E-16-1A was inspected for OD cracking by VT and PT NDE methods as described in Mercury QCR (Form 211) Job 49851, Customer order #14885, Job Names 4" CUW Repair December 31, 1980 and CUW-3 Repair dated January 5, 1981.

Discussions with Mercury personnel indicated that no evidence of water damage to the insulation was noted on the remainder of the pipe run. PT results revealed no indications in the pipe welds or weld HAZ.

The replacement pipe section material and weld filler metal materials were low carbon grades with the carbon contents below 0.02%.

No items of noncompliance were identified.

5. Visual Inspection - Cross Connect Line Between Regenerative and Non-Regenerative HX (4" CUW-3)(E-15-1C HX Water Box Outlet to E-16-1A Waterbox Inlet).

Approximately a 4 foot section of CUW-3 which was removed from the pipe run was inspected in the containment vessel by the NRC inspector. The pipe was painted on the OD with a black paint to minimize chloride ion corrosion problems. The ID of the pipe had a smooth reddish brown corrosion film which was most probably a deposition film rather than any in-situ corrosion. Due to the high level of oxygen in the system the black iron deficient oxide should not be present. Three areas of OD in-situ corrosion and pitting were noted. These areas have a brown corrosion deposit similar to that noted where there is a ferric chloride attack. The paint was removed adjacent to these areas most probably from steam erosion caused by water leakage and evaporation. There were large areas where the insulation was stuck to the pipe OD which most probably are due to adherence of wet insulation. The areas on the OD surrounding the brown corrosion product appear to contain multi-directional cracks. The areas in the ID below known leakage locations contain brown spots and apparent cracks. Visual inspection was limited due to the requirement for full face masks and observation of small ID dimensions with illumination by a flashlight. The pipe specimen which will be used for laboratory examination was protected by plastic bags and the ends were taped before and after visual examination.

No items of noncompliance were identified.

6. Discussions With Mercury Personnel on Details of Leakage and Repair

At 1000 psi internal pressure at low temperatures, the dampness or weepage could be removed for an instant by wiping with a rubber glove, i.e., the volume of the water coming out of the leak with service pressure on the ID was very low.

Liquid penetrant (PT) examination (reported in Mercury QCR Job 49851 dated January 1, 1981 for portions of the pipe run other than the failed portions) showed no cracklike indications on the horizontal run of pipe which contains valve CU83. This examination also included the weld HAZ of the elbow welds. The PT was conducted after the paint was removed by buffing. A previously existing grinding mark was noted.

When the insulation was removed on the horizontal run containing valve CU-83, there was no evidence of dampness in the insulation nor any evidence of paint removal as noted in the failed portion of the pipe run.

No items of noncompliance were identified.

7. Review of Liquid Penetrant (PT) Examination of the Stub Ends of the Failed Pipe Section

At the request of the NRC inspector the 4 1/4" and 6 1/2" stub ends (as shown in Mercury drawing WM-49851-100, Rev. 0) were re-penetrant tested on the OD and penetrant tested on the ID for information purposes only. The NRC inspector witnessed and reviewed the results of the OD examination and the NRC Resident Inspector witnessed and reviewed the results of the ID examination. The OD examination showed approximately 4-5 more or less axially oriented cracks and 2 areas of omni-directional crack networks. The ID examination indicated no cracks. Attempts were made to photograph the OD cracks, but poor contrast photographs were obtained.

No items of noncompliance were identified.

8. Review of Other Applications of Item #4 Pipe: The licensee indicated that pipe from heat 2P3564 was utilized for the entire pipe run CUW-3, CUW-6 up to valve V-12-68, CUW-2A-5 up to the 4 x 3 reducer and CUW-1-1. This is estimated to be a total of 45 feet of pipe and the total usage of this heat of pipe in the CUW system.

No items of noncompliance were identified.

9. NRC Inspector Preliminary Analysis of the Leakage Problem

The leakage of the pipe constitutes a brittle failure in a ductile material. The only known mechansisms of producing brittle failures in austentic stainless steel materials at relatively low (<600F) temperatures are fatigue or stress corrosion cracking (SCC). There is no evidence of fatigue caused by mechanical or thermally induced mechanisms based on the random orientation of the cracks.

If it is assumed that the failures are SCC, the problem should not be caused by the well known BWR high oxygen IGSCC mechanism because there is no reason to believe that the material is sensitized.

The stress pattern from the observed cracks indicates low level residual stresses. There is a preference in crack orientation (of those cracks observed) to the axial (longitudinal) direction which would be indicative of internal pressurization and/or cross roll straightener residual stress patterns, however, there are also omni-directional crack

networks indicative of complex stress patterns.

The corrosion attack noted at the weepage locations includes a pitting type attack with a rust colored corrosion product which is indicative of a chloride induced attack.

The insulation is reported to contain 200 ppm chlorides which if concentrated could easily cause transgranular SCC of 304 SS in the presence of a sufficiently high tensile stress at service temperatures.

It has been observed by the licensee that flange leakage has occurred on the water box flanges of the 3 vertically stacked heat exchangers.

Leakage from the flanges could easily cause wetting of the insulation of the line which failed which would cause leaching of the insulation.

Visual examination and review of documentation indicates the following as a possible failure mechanism.

a. The corrodant is most probably chloride ions leached from the insulation from flange leakage and concentrated due to the high temperature of the pipe.

b. The tensile stress is probably that produced by internal pressurization and residual cross roll straightening stresses. The stresses are probably low as evidenced by the multidirectional crack networks.

c. The service temperature of 230-280F is more that adequate for chloride induced SCC.

d. The corrosion literature indicates that the observed conditions operating for a prolonged period of time are capable of producing the type of failure noted.

Corrosion failure analysis to be conducted by Battelle Memorial Institute in Columbus, Ohio should verify the proposed mechanism.

10. Unresolved Items

Unresolved items are matters about which more information is required to ascertain whether they are acceptable items, items of noncompliance, or deviations. Unresolved items disclosed during the inspection are discussed in paragraph 4.

11. Exit Interview

The inspector met with licensee representatives (denoted in para. 1) at the conclusion of the inspection on January 5, 1981. The inspector summarized the purpose and the scope of the inspection and the findings.