UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

ENCLOSURE

THIMBLE TUBE THINNING

SAFETY EVALUATION OF PSE&G'S SUPPLEMENT RESPONSE TO NRC BULLETIN NO. 88-09

OF ACTIONS TAKEN AT SALEM GENERATING STATION, UNITS 1 AND 2

1.0 INTRODUCTION

NRC Information Notice No. 87-44 was issued in September 16, 1987, to alert addressees to potential problems resulting from thimble tube thinning in Westinghouse reactors. The thimbles of concern are part of the movable incore neutron flux detection system. The neutron detectors are movable within thimbles that extend into certain fuel assemblies. The thimbles are retracted from the fuel assemblies during refueling. During plant operation the thimble tubes extend from a transfer mechanism, through a seal table, through the reactor vessel bottom head, through the lower core support structures and into fuel assemblies as depicted in Figure 1 (attached). The thimbles are contained and supported over most of the path from the seal table through fuel assembly. The thimble is unsupported for a short distance from the top of the lower core support plate to the point of entry into fuel assembly lower nozzle (a distance of about two inches). The thimbles are closed-ended in the fuel but open at the transfer mechanism to permit insertion of the incore detector. The outer diameter of the thimble and the reactor vessel bottom head guide conduit are isolated at the seal table and form part of the reactor vessel pressure boundary. A penetration of the thimble tube in the reactor provides a leakage path bypassing the vessel pressure boundary.

The notice provided information on thimble thinning and leakage that occurred in foreign and domestic reactors. The domestic leaks were reported to have occurred at Salem Station Unit 1.

Thimble Tube Inspection Programs

NRC Bulletin No 88-09 was issued in July 26, 1988, to request that holders of operating licenses or construction permits for Westinghouse-designed reactors, that utilize bottom-mounted instrumentation, establish and implement an inspection program to periodically confirm incore neutron detection system thimble tube integrity. The Bulletin identified flow-induced vibration as the cause of thimble tube thinning. It was further identified that the vibration severity the tubes experienced was, in part, the result of tubes unsupported between the lower core plate and fuel assembly lower nozzle, the physical tube characteristics, clearances and flow velocity. In the absence of accurately predicting thimble tube wear it was requested that addressees determine thimble tube integrity through plant-specific inspections and periodic monitoring.

Audit of Salem Station Regarding Thimble Tube Wear Action

The staff conducted an audit at the Salem Station during May 15-16, 1989, to review actions taken by the licensee with regard to implementation of the requirements of NRC Bulletin 88-09.

The staff learned the licensee replaced the thimble tubes in Unit 1 and 2 with a new design in 1988. The new assemblies featured a double tube design, with material having better wear resistant characteristics, and the tubes were chrome plated in the potential wear areas. Wear inserts were also installed in the lower core plate to reduce flow induced vibration. The licensee considered that the new design would provide satisfactory thimble tube performance over the balance of the life of the Salem Units. The double tube design precluded the use of eddy current examination to determine outer tube wear, and since this was considered the only viable method for this application, the licensee discontinued the inspection efforts. Further, the licensee considered the inspections were no longer required based on the expected performance of the new design and core plate modifications.

The licensee committed to submit a supplemental response to Bulletin 88-09 to include an evaluation of the improved wear performance of the new thimble tube design, and justification for elimination of the periodic wear inspections after acquiring sufficient operational experience.

Supplemental Response to NRC Bulletin 88-09

By letter dated December 20, 1993, Public Service Electric & Gas (PSE&G) submitted a supplemental response to Bulletin 88-09 with an evaluation of the new design and justification for discontinuing periodic inspections.

2.0 EVALUATION

Leaks developed in three thimble tubes in the neutron flux incore monitoring system at the Salem Station Unit 1 in 1981. The leakage rate was less than 1 gpm, and the licensee did not consider it a significant safety problem. The thimble tubes were isolated by closing manual valves without exposing personnel to excessive exposure. Subsequently PSE&G monitored thimble tube wear in Units 1 and 2 during each refueling. Wear continued in many tubes, and required tube isolation or vertical repositioning to expose new wear surface.

The three leaking thimbles were sectioned and sent to the Westinghouse Nuclear Technology Division hot cell facility for metallurgical evaluation and characterization. It was concluded the tube defects were formed by repeated mechanical wear action, and that the profile of the fuel assembly lower nozzle block was clearly reproduced in the wear patterns that covered almost 45% of the tubes circumferences.

PSE&G contracted the services of Combustion Engineering Nuclear Services (ABB/CE) to conduct tests to model the wear mechanism and design wear resistant thimble tubes. A new thimble tube design was developed, and associated modifications to the lower core plate, fuel assembly nozzle, and thimble tube interface area were included. The new thimble tube design consisted of an outer pressure boundary tube and a concentric dry guide path inner tube for the movable incore neutron detector. The tubes were fabricated from high strength Inconel 600, capable of withstanding reactor pressure and temperature conditions, and the material was more wear resistant than the previously used 300 series stainless steel. In addition the potential areas of wear on the outer tube were chrome plated. The annulus between the tubes contained two thermocouples and spacer wires. The core plate to fuel nozzle area modification consisted of extending a guide insert from the core plate to close proximity with the fuel assembly nozzle thimble tube entry point.

This modification reduces exposure of the thimble tube to flow-induced vibration excitation, and more accurately aligns the thimble with the fuel assembly entry point.

During the Unit 1 seventh refueling outage, and Unit 2 fourth refueling outage all of the thimble tubes were replaced with the new design, and tube guidance was extended to reduce the unsupported gap from the core plate to the fuel assembly nozzle. The construction of the new two concentric tube design with wires filling the annulus precluded eddy current examination of the wear on the outer tube from within the inner tube. Therefore, previous inspection program methods could not be continued. Other viable inspection methods were not available.

During the Unit 1 tenth refueling outage PSE&G removed six thimble tubes as representative samples for an evaluation of tube wall thinning. PSE&G contracted ABB/CE to inspect and evaluate the condition of the outer thimble tubes. The examination was performed using a combination of UT profilometry, eddy current encircling coil technique and underwater camera visual examination. All examinations were conducted underwater using a modified empty spent fuel pool cell as a fixture to support and align the examination equipment and sample tubes. Off-line analysis was used to obtain the axial and circumferential and profile of all OD indications on each thimble tube.

The ABB/CE certified report of the examination concluded that no significant wear was detected on any of the thimble tubes, and no tube had greater than .002 inch wear at any elevation. The wear loss corresponds to a tube cross-sectional wall loss of less than 3% at any elevation.

Based on the ABB/CE evaluation and a conservative factor (twenty) of wear rate reduction achieved, PSE&G concluded that further thimble tube wall thinning inspections are not necessary.

3.0 CONCLUSION

The licensee has taken positive action at the Salem Station to resolve the problem and concerns over incore instrument thimble tube thinning, as highlighted by NRC Information Notice No. 87-44. The licensee proposes no further inspection activity. The licensee developed and implemented an inspection program as required by NRC Bulletin No. 88-09. The licensee determined the problem root cause and developed appropriate corrective action. The licensee had samples of the defective tubes sectioned and metallurgically evaluated and characterized to establish and document the root cause. The licensee had laboratory tests conducted to model the wear phenomenon, and then developed a wear resistant flux thimble tube design. The improved design was used to replace all the thimble tubes in Unit 1 and 2 along with the required core plate modifications. After three cycles of operation, six representative samples of the improved thimble design were removed from Unit 1 for inspection and evaluation. The reported results show no significant wear at any elevation on any of the sample tubes. Further, in the event of the outer tube failure, the inner tube can maintain the reactor vessel pressure boundary integrity.

The staff concludes the actions taken and proposed by the licensee are appropriate and acceptable. The staff suggests that the licensee consider, when an opportunity exists, a check for leakage or a pressure build-up between the concentric tubes be made or that the licensee provide a cautionary note in the disassembly procedure regarding the potential for the leakage or pressure buildup.

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Attachment

TYPICAL WESTINGHOUSE INCORE NEUTRON MONITORING SYSTEM

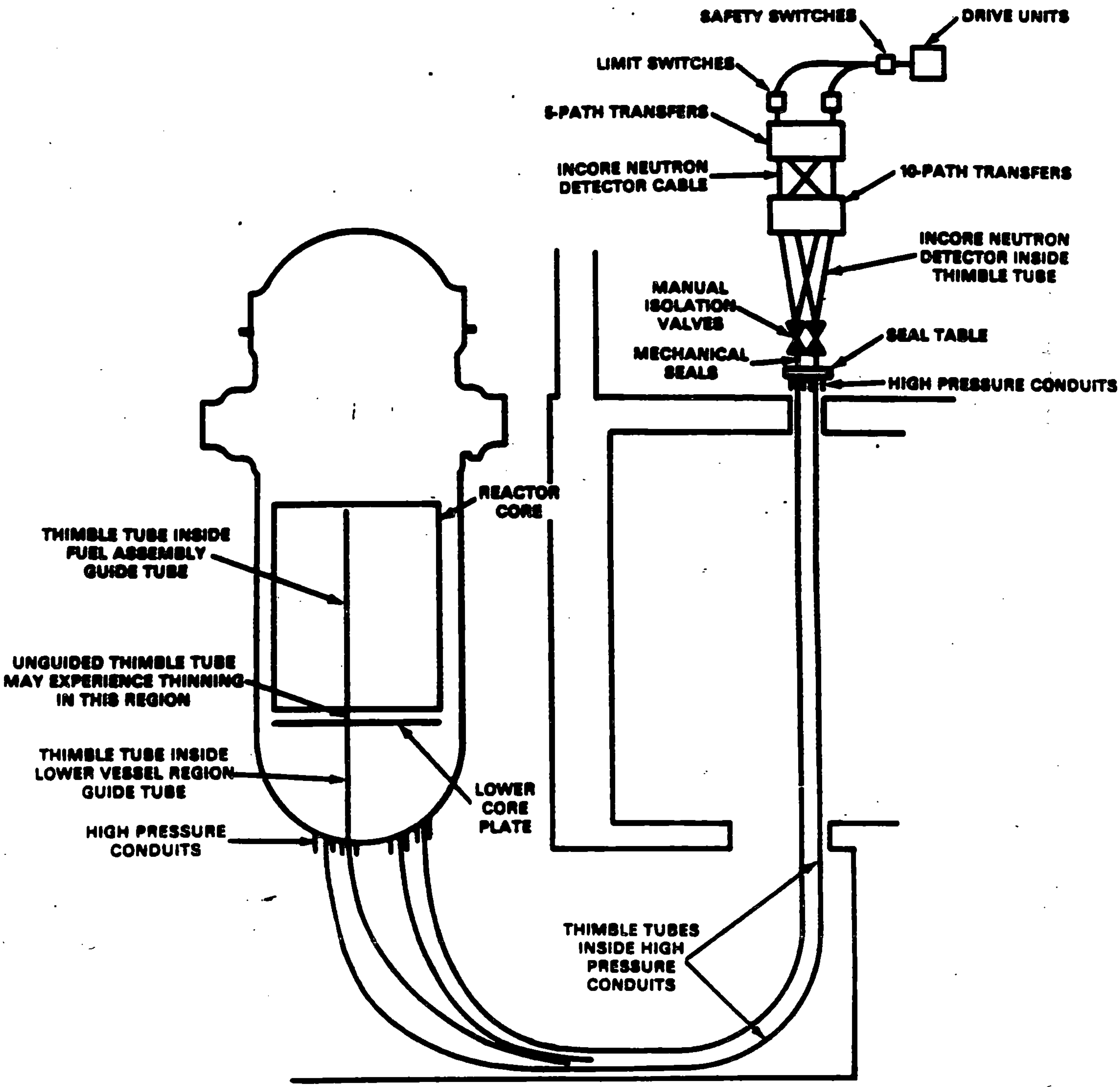

FIGURE 1