SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION CONCERNING THE UPPER CORE BARREL ISSUE AT ARKANSAS NUCLEAR ONE, UNIT NO. 1 DOCKET NO. 50-313

INTRODUCTION

Recent inspections of reactor internals bolting at Sacramento Municipal Utility District's Rancho Seco plant and Florida Power Corporation's Crystal River 3 plant have revealed unexpected indications on a number of bolts during ultrasonic (UT) examinations. The implications of this issue relative to ANO-1 and all efforts of APL in response to this issue are discussed including the basis for AP&L's decision regarding the restart of ANO-1 following the current outage.

Problems with reactor internals bolting at B&W plants were first observed during visual inspections at Duke Power Company's Oconee 1 plant in July of 1981. During the inspection a number of lower thermal shield bolts were observed to be missing or broken. These lower thermal shield bolt failures were discussed in detail in a letter dated August 11, 1981, from Mr. J. H. Taylor of B&W to Mr. Victor Stello of the NRC. As discussed in this letter, failure of the upper or lower thermal shield bolts was deemed not to constitute a safety hazard. As a result of these failures, and subsequent failures of lower thermal shield bolts observed during inspections at Oconee 2 and 3, the lower thermal shield bolts at ANO-1 were inspected and subsequently replaced during the fifth refueling outage which began in November of 1982.

Based on the information available at the time, including UT and laboratory examinations of bolts from the Oconee units, the failures were felt to be restricted to the lower thermal shield bolts and UT inspection of other internals bolting was felt to be unnecessary at ANO-1.

It is interesting to note that at no time in the presentations on the current bolting problems was the aspect of deficient material raised, as it was for the Oconee thermal shield bolt failures in a Duke Power Company letter of January 8, 1982 to Region II, which stated in part:

> "It is concluded that the mechanism of failure of the lower thermal shield bolts was intergranular stress corrosion cracking in a region of pronounced microstructure transition at the head-to-shank fillet. This microstructure transition resulted from the hot forging of heavily cold reduced bar stock used in the manufacture of the lower thermal shield bolts."
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> "It has been concluded that the failure of other joints with A286 bolts is not of concern since thorough examinations have revealed no evidence of distress in these bolts. Also, these bolts were not manufactured from heavily reduced bar stock which caused the pronounced microstructure transition in the lower thermal shield bolts."
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"I. Cause of Failure

The Oconee I lower thermal shield bolt fractures were caused by intergranular stress corrosion cracking (IGSCC) in the bolt head to shank fillet region. IGSCC is classically produced by an unfavorable interaction of material condition, stress and environment. In the case of the lower thermal shield bolts, a unique processing condition has reduced the resistance of the bolt material to IGSCC in the fracture zone. Unlike processing of bolts used in other bolt circles, the lower thermal shield bolts were made by hot heading heavily cold reduced (40-50%) bar stock. The result of this processing was a pronounced microstructural transition which was coincident with the bolt head to shank fillet. The other A286 bolted joints have not been susceptible to this failure similar mechanism since thorough examinations have revealed no evidence of distress in these bolts. Also, these bolts were not manufactured from heavily reduced bar stock which caused the pronounced microstructure transition in the lower thermal shield bolts. Since higher stressed areas of the bolts were not initiation sites, stress is not considered to be a principal cause of the fractures. All fractures initiated in the micro-structure transition zone are described above."

DISCUSSION

Subsequent to the reinstallation of ANO-1 reactor internals and reactor vessel head at ANO-1, but prior to restart, a number of UT indications were observed in the upper core barrel bolts at Rancho Seco and later in the upper and lower core barrel bolts at Crystal River 3. Specifically, at Rancho Seco 19 of 120 upper core barrel bolts exhibited UT indications and at Crystal River 3, 51 of 120 upper core barrel bolts and 4 of 108 lower core barrel bolts showed UT inidications. With the exception of the lower thermal shield bolts and surveillance specimen holder tube bolts, no other UT indications were observed in the remaining internals bolting inspections at these units. Surveillance specimen holder tubes are not installed at ANO-1.

The results of the inspections at Rancho Seco and Crystal River 3, prompted AP&L's decision to delay the restart of ANO-1 following its refueling outage to remove the reactor vessel head and perform an inspection of the upper core barrel bolts. The UT inspection of the ANO-1 upper core barrel bolts was completed on May 3, 1983. Only 7 of the 120 bolts inspected showed UT indications. These indications were near the head to shank transition, consistent with those observed at Rancho Seco and Crystal River 3. The licensee has stated that the locations of the affected bolts appeared to be randomly distributed, but it should be noted that two of these randomly distributed bolts were adjacent.

It should be noted that Rancho Seco with 19 bolts with indications chose to replace their bolts. The licensee has stated that the current failures were intergranular stress assisted cracking. At no time has the licensee identified the current failures as stress corrosion nor has there been any mention of candidate corrodants or search for evidence of corrodant. The licensee has stated that the A286 material used in these bolts exhibits a range of yield strength of from 100 to 134 ksi. It is further stated that the peak stress is within the yield strength range. Stress corrosion data on A286 are limited. A General Electric report APED 4010 "Stress Corrosion Tests on Selected Reactor Structural Steels" dated 1/19/82 shows no failure of A286 when tested below yield stress at times up to 4500 hrs (the maximum length of test). There was some evidence of cracking when exposed to chlorides. Because the thread lubricant makes the environment for a bolt in a tapped hole, the MTEB obtained an analysis performed on Neolube, the thread lubricant stated to be used by the licensee. Neolube is stated by the manufacturer, Huron Industries, to be colloidal graphite in isoproponal and acetone and the Brookhaven analysis on the one lot of Neolube on hand showed only traces of silicon and sulfur as impurities. Unfortunately, no corrosion data for sulfur is available.

One of the sketches presented of a typical B&W bolt failure indicated torsional failure components thus indicating a higher preload than that which was anticipated in the design of the joint. The co-efficient of friction of the thread lubricant used has a very large effect upon the preload resulting from a given installation torque. For this reason, the coefficient of friction for Neolube, the thread lubricant used, was questioned.

The staff had available information indicating that Neolube has a very low coefficient of friction 0.03 to .09 but B&W uses a value of approximately .14 and submitted lab data essentially verifying this value. Coefficient of friction tests performed by Brookhaven also verified the B&W value. These tests were run on dry Neolube as it was assumed that the bolts are installed dry.

Based on the results of this inspection, evaluations conducted by B&W, and review by the Plant Safety Committee and Safety Review Committee, AP&L plans to proceed with the restart of ANO-1 and subsequent power operation without further inspections or repairs. The information discussed above was presented to the NRC staff in a meeting with the B&W Owners Group Task Force on May 6, 1983. During this meeting information was also presented relating to the reactor internals design basis, field inspection methodology, laboratory examinations of sample bolts, safety implications, and future Owners Group plans to address this issue. The detailed information presented in the May 6, 1983 meeting was submitted in the form of a B&W Owners Group report. Although this letter is not intended to duplicate the detail of the planned Owners Group submittal, following is a summary of the key items that form the basis for AP&L's decision to proceed with the restart of ANO-1, without replacing any bolts, as presented to the NRC staff on May 6, 1983.

An evaluation of the loads applied to the upper core barrel bolts indicates that only 8 symmetrically located bolts are required to support the core during normal operations. For faulted conditions (safe shutdown earthquake plus LOCA loads) 45 symmetrically located bolts are required. Since a total of 113 upper core barrel bolts were inspected with no UT indications, a very large margin presently exists in the load carrying capability of the upper core barrel joint. The observed failure rate at ANO-1 (7 failed bolts in 5.5 reactor years at temperature) would not result in a significant degradation of this margin during the next cycle of operation. Even if the failure rate during the next cycle of operation is conservatively postulated to be twice that observed at Crystal River 3 (51 failed bolts in 3.9 reactor years at temperature) a sufficient number of bolts would remain at the end of the cycle to support faulted conditions. Based on this margin AP&L does not consider replacement of the 7 affected bolts to be necessary at this time. Complete failure of these 7 bolts would not result in a significant decrease in the load carrying capability of the joint. The licensee claims that since the bolt heads are held in place by welded clips, no loose parts would result from such failures. (This was not true of the Oconee thermal shield bolt failures.) Replacement of these bolts is a complex operation possibly involving the removal of bolt shanks which have separated from the bolt heads. Such operations would have required the fabrication of special tooling as well as replacement bolts and would have resulted in an extension of the current outage until the end of June 1983. Since the replacement of these bolts would not have significantly increased the available margin, such a delay was not warranted.

For the lower core barrel joint even fewer bolts (only 19 of 108) are required to support the core under faulted conditions. Based on the greater margin available, the favorable results of the upper core barrel bolts inspection at ANO-1, and the results of the lower core barrel bolt inspections at other B&W plants, an inspection of the lower core barrel bolts is not warranted at this time. Such an inspection would require defueling of the reactor and removal of the reactor internals in order to allow access to the lower core barrel bolts.

EVALUATION

As discussed above, due to the extremely large margins in the number of required bolts and the results of the inspection of the upper core barrel bolts, we feel there is adequate assurance that ANO-1 can be operated during the next cycle without failure of the core barrel joints. However, the consequences of such a failure has been evaluated. As presented during the May 6 meeting, in the event of failure of a core barrel joint, the core will be supported by the core support lugs (12) welded to the reactor vessel wall. The evaluation concluded that the support lugs are adequate for both dynamic and long term cyclic loading. The core drop would be limited to approximately 0.5 inches. Such movement would not result in control rod disengagement and, although core bypass flow could increase by approximately 5% in the case of an upper joint failure, core cooling would be maintained. In addition, the core guide blocks and the engagement of the bolt shanks would prevent any significant core tilt and control rod insertion would not be prevented.

Based on the considerations discussed above, the licensee has stated that restart of ANO-1 may proceed without undue risk to the health and safety of the public. Although this issue does not constitute an immediate safety concern, AP&L plans to actively pursue further evaluation of this issue and to participate in the ongoing efforts of the B&W Owners Group Task Force. In addition, as a precautionary measure, AP&L is proceeding with the installation of neutron noise analysis equipment for use during the next cycle of operation. The licensee states that this equipment will provide the capability to detect any significant movement of the core barrel during operation. Inasmuch as the drop would be limited to approximately 0.5 inches as noted above the implication is that significant movement is less than that distance although the licensee has not so stated.

The need for and extent of future inspections and/or repairs will be based on the results of the Task Force investigations and upcoming inspections at other facilities. The licensee will continue to keep the NRC staff informed of developments on this issue.

The concept of operating without intact bolts was advanced in the above mentioned Duke letter and Oconee returned to power with Jpper Thermal Shield Bolts 5, 10, and 19 removed (with holes plugged); Core Barrel to Core Support Shield Bolts 1 and 60 removed; and Flow Distriutor to Lower Grid Assembly Bolt No. 2 removed.

CONCLUSIONS

Based on a review and the evaluation made above, the staff concludes that continued operation of ANO-1 for the remainder of this fuel cycle is justified because the rate of occurrence of bolt cracking is apparently slow and the knowledge that even failure of all of the bolts would not lead to a situation compromising safe shutdown of the plant. It is equally obvious that much is still to be learned of the cause of the bolting failures and the design of a satisfactory fix to correct the condition.