a. Dromerick

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

October 5, 1981

Docket No. 50-269

Room Change

MEMORANDUM FOR: J. F. Stolz, Chief, Operating Reactors Branch #4, DL

FROM: P. C. Wagner, Project Manager, Operating Reactors Branch #4, DL

SUBJECT: FORTHCOMING MEETING WITH DUKE POWER COMPANY (DPC)

Time & Date: 9:00am-2:00pm, October 9, 1981

Location: Phillips Building, Room P-422
Bethesda, Maryland

Purpose: To discuss the broken thermal shield bolts in Oconee Unit 1.

Requested Participants:

NRC	DPC
P. Wagner	R. Gill (DPC), et. al.
T. Novak	
J. Stolz	
W. Johnston	
J. Knight	
W. Hazelton	
R. Bosnak	
K. Wichman	
S. Hou	
A. Dromerick, IE	
G. Georgiev, IE	

Philip C. Wagner

Philip C. Wagner, Project Manager
Operating Reactors Branch #4
Division of Licensing

cc: See next page

cc w/enclosure(s):

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10/7/81

To: Phil Wagner
(NRC)
frm: KS Canady
(11pgs)

DUKE POWER COMPANY

POWER BUILDING

422 SOUTH CHURCH STREET, CHARLOTTE, N. C. 28242

WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

TELEPHONE: AREA 704
373-4083

October 5, 1981

Mr. James P. O'Reilly, Director
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

Re: Oconee Nuclear Station
Docket No. 50-269
RO-269/81-11, Supplement 2

Dear Mr. O'Reilly:

My letter of July 24, 1981 as supplemented on August 5, 1981 provided Reportable Occurrence Report RO-269/81-11 concerning broken core barrel assembly thermal shield bolts. This letter supplements these initial submittals and provides information concerning the present status of examination and repair efforts.

As previously discussed, three bolt shanks and two bolt heads were examined at the Babcock and Wilcox Lynchburg Research Center for failure mode determination. It was concluded that the failure mechanism was either intergranular stress corrosion cracking or intergranular corrosion assisted fatigue or some combination of the two. These laboratory results confirmed the need to perform more extensive investigations relative to the thermal shield bolt manufacturing history, the stress state of the bolts, the thermal shield manufacturing and assembly history, and most importantly, the potential for this mechanism to affect other bolts of the same material (A286) in the reactor internals. Results of these investigations are described in the attached report.

Because A286 bolts are used in four other joints in the internals, a thorough inspection and sample examination was conducted relative to these other joints. These joints are the upper thermal shield restraint blocks, the core barrel to core support shield, the core barrel to lower grid assembly and the flow distributor to lower grid assembly. These investigations consisted of ultrasonic testing of a selected sample of bolts in all of these bolted joints and removal of a small sample of bolts from three of the four joints for laboratory examinations. All results indicated no problems at the other joints.

As a result of the work performed since the August 5, 1981 submittal it has been confirmed that the bolt problem is limited to the thermal shield. Bolts from all other major joints which utilize the A286 material have been examined and no indications of deterioration were found. Our earlier conclusion that there is no significant safety implication associated with the thermal shield bolt failures has, therefore, been confirmed.

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This report also presents a description of the design modifications for the thermal shield.

We are currently planning to attend an October 9, 1981 meeting with the staff to make a presentation and to respond to questions which the staff may have in any of the areas related to the Oconee thermal shield bolt problem. It is hoped that the information contained herein will serve as a good foundation for that meeting.

Very truly yours,

William O. Parker, Jr.

NAR/php
Attachment

cc: B&W Regulatory Response Group:

J. J. Mattimoe, SMUD, Chairman
J. H. Taylor, B&W
W. C. Rowles, TECO
D. C. Trimble, AP&L
G. Beatty, FPC
R. J. Wilson, GPU

Director, Office of Management
and Program Analyisis

Mr. T. M. Novak, U. S. Nuclear
Regulatory Commission

Mr. Bill Lavallee, Nuclear
Safety Analysis Center

October 5, 1981

Attachment 1

Thermal Shield Bolt Failure Supplementary Information

Introduction and Summary

As a result of extensive investigations, it has been concluded that the only distressed areas of the internals are the thermal shield attachments and restraints. All other joints using A286 bolts indicate satisfactory performance. Therefore, the preliminary conclusion that a significant safety issue does not exist has been confirmed.

The sections below present more detailed information in each of the following areas.

Laboratory examinations
Inspections onsite
Bolt fabrication history
Thermal shield manufacturing and assembly review
Thermal shield structural analysis and testing
Potential failure causes of thermal shield bolts
Repair status

Laboratory Examinations

Laboratory examinations were performed at the Babcock and Wilcox Lynchburg Research Center on both broken and unbroken bolts from Oconee and on archive bolts which had never been installed. The objective of these examinations was to determine bolt failure mode and status of other joints using A286 bolting material.

The broken samples consisted of three bolt shanks and two bolt heads. Of the five fracture surfaces, two were damaged from impact, and consequently clean fracture surfaces were not available for examination. The remaining three fracture surfaces (two bolt shanks and one bolt head) were examined and found to contain similar fracture features.

All of the broken bolts examined had fractured in or near the fillet between the head and shank. An island of transgranular fracture (as shown in Figure 1) with evidence of fatigue striations and/or crack arrest marks was surrounded by intergranular fracture, with evidence of grain boundary corrosion attack. No shear lips or other macroscopic indications of ductility were present on the fracture surfaces. The initiation and propagation of intergranular cracks with branch cracking in this material is consistent with a form of an environmentally assisted cracking process - stress corrosion and/or corrosion fatigue.

A tensile test was performed on a specimen machined from the shank of a fractured bolt (irradiated condition) and a specimen from an archive bolt of the same material (base condition). The measured tensile properties were within the range of expected values and met the requirements of the applicable specification. Neutron irradiation had virtually no effect on the tensile properties.

The other A286 bolted joints in Oconee 1 were indicated to be sound from video inspections. To confirm the integrity of these other A286 bolted joints, laboratory examinations were performed on three thermal shield upper restraint bolts, two core barrel to core support shield bolts, and one flow distributor bolt. These bolts were examined visually, with liquid penetrant and with a scanning electron microscope. A surface contamination examination was also performed. The two intact lower thermal shield bolts were also removed, and one of these bolts was included in the above examination. In all cases, the examinations included both the head-to-shank transition and the thread regions.

The archive bolt examinations included one bolt from each of the A286 joints. The thermal shield bolt examination included metallography, tensile, microhardness, spectrographic chemical analysis and reheat tests. The other three bolts received metallography tests. The main finding from these examinations was a radical transition in grain structure (size) at the fillet of the lower thermal shield bolt. In the lower thermal shield bolts from the archive, the transition zone was marked by a band of significantly larger grain size than found on either side of the transition. This band of larger grains also extended into the fillet area. This large change in grain size in the transition zone was not evident in the archive bolts from other bolted joints including the upper thermal shield bolts.

This larger grain size in the lower thermal shield bolts from the archive was not seen in the one unbroken bolt examined from the Oconee Unit 1 lower thermal shield. It is noted that this bolt was one of only two in the lower thermal shield which did not fracture. An examination of a fractured bolt from the Oconee Unit 1 lower thermal shield is planned. The anomaly in the unfractured Oconee Unit 1 lower thermal shield bolt should be confirmed upon the examination of a fractured lower thermal shield bolt.

Additional confirmatory laboratory examinations are currently underway or planned. This additional work involves microscopic analysis of grain structure and scannning electron microscope examinations. Table 1 summarizes the laboratory examinations.

Onsite Inspections

The onsite inspections resulted in the recovery of all pieces of the missing thermal shield bolts.

To supplement the previously reported (Reference 2) visual inspections which have been performed using remote video equipment, two additional types of inspections were made onsite to check for distressed areas in the Oconee 1 reactor internals. This involved in-place ultrasonic testing (UT) for cracked bolts and a combination of UT, feeler gage, and accelerometer testing which would indicate motion and/or wear at the thermal shield interfaces.

In addition, ultrasonic tests were attempted to check preloads on selected bolts.

Ultrasonic testing was conducted on the following bolts for crack indications:

- Thermal Shield Upper Restraint Bolts - Approximately 40% Sample
- Core Barrel to Lower Grid Bolts - Approximately 20% Sample
- Core Barrel to Core Support Shield Bolts - Approximately 20% Sample
- Flow Distributor to Lower Grid Bolts - Approximately 20% Sample

No crack indications were found in any of the bolts examined.

In the early visual inspections of the lower thermal shield bolts, only 13 of the installed 96 bolts appeared to be intact. Of those 13, only two did not have crack indications. The UT examination of the other 11 indicated the bolts were broken.

As input to the overall determination of failure cause and the corrective action, inspections were made to check for gaps which would indicate motion and/or wear of the thermal shield. Gaps were checked in the radial direction between the outer thermal shield restraint block and the upper end of the thermal shield and axial gaps were checked between the lower end of the thermal shield and lower grid flange.

The outer thermal shield restraint block gaps (thermal shield to outer restraint block) were found in the range of 0 to 160 mils. Gaps over 90 mil were confirmed with a weld wire as feeler gage. The as-built gap range was 5 to 11 mils. These gaps indicate some wear at the thermal shield upper restraint. Axial gaps were found between the lower edge of the thermal shield and the grid flange which varied around the circumference from 0 to 40 mils. Gaps over 20 mil were confirmed by a feeler gage. The circumferential variation indicated a slight tilt in the thermal shield. These axial gaps are scheduled to be closed up prior to replacing the thermal shield bolts.

UT bolt preload testing was performed for three thermal shield upper restraint bolts, two thermal shield lower restraint bolts, one flow distributor bolt, and two core barrel to core support shield bolts. The UT was conducted before and after removal of the bolts so that a correlation could be made between bolt extension and preload. Measurements for lower thermal shield bolt preloads were unsuccessful, probably due to the displaced condition of the thermal shield. Results for flow distributor bolts indicate a preload higher than the design value but considerably less than yield. Results for core barrel and upper thermal shield restraint bolts indicate preloads are in the design range.

Bolt Manufacturing History and Materials Investigation

The failure of the lower thermal shield bolts as contrasted with the completely satisfactory performance of the other bolts made from the same material has led to a comprehensive investigation of the A286 bolt manufacturing history. This examination has included a review of vendor records, material test reports, material processing and bolt fabrication processes, as well as metallurgical examinations of archive bolts and mechanical testing of archive bolts and samples of material extracted from the failed thermal shield bolts. The following discussion summarizes the important conclusions from these examinations.

The thermal shield upper and lower restraint bolts were manufactured by Valley Todeco. All other A286 bolts were manufactured by Standard Press Steel. The heat of bar stock material used for the lower thermal shield bolts is different from the heat of bar stock material used in any other A286 bolts including the upper restraint bolts which were made by the same manufacturer, Valley Todeco.

All of the bolts were manufactured by a "hot heading" process which produces a heat affected, transition zone located at the base of the bolt head at or near the fillet region as discussed earlier.

In a review of the processing of the lower thermal shield bolts, it was found that bar stock which was 40 to 50% cold reduced was used in the bolt fabrication. This cold reduced bar stock is apparently unique to the lower thermal shield bolts (none of the other bolts were manufactured from bar stock with such extensive cold reduction). This cold reduced bar stock is considered to be the likely source of the significant change in grain structure in the head-to-shank transition zone from the "hot heading" process.

The relationship of this duplex grain structure transition in the lower thermal shield bolts to the fracture mechanism is undergoing further investigation.

Thermal Shield Manufacturing and Assembly Review

A review of the thermal shield manufacturing and assembly history was conducted in an attempt to discover any step in these processes which could have contributed to the failure of the thermal shield bolts.

It was noted that the Oconee 1 and 2 RV internals were reassembled at the reactor site following the initial hot functional testing at Oconee 1. Oconee 3 internals were assembled in the shop.

The manufacturing review focused on the five main thermal shield interface areas. These are:

1. The radial interference fit at the thermal shield lower end I.D.
2. The radial interference fit at the thermal shield upper end.
3. The restraint block on the core barrel upper end O.D.
4. The preload on the upper restraint block assembly holddown bolts.
5. The preload on the lower thermal shield holddown bolts.

This above review has been completed and did not provide any additional insight as to the cause of the bolt failures.

Thermal Shield Structural Analysis and Testing

A review was made of the structural analysis and structural testing which were used in the design and confirmation of the thermal shield. Bolt preload stresses and thermal stresses were both found to be within the design limits. Flow-induced vibration stresses were measured on two thermal shield bolts during hot functional testing and these stresses were found to be very low.

Potential Failure Causes of Thermal Shield Bolts

The factors which seem most likely at this time to have contributed to the lower thermal shield bolt failure are the rather pronounced microstructure transition at the head-to-shank fillet in the lower thermal shield bolts and the potential for this "metallurgical discontinuity" to increase the sensitivity to stress corrosion cracking and corrosion fatigue.

Repair Status

At the present time, redesign of the lower thermal shield has been completed. All 96 bolts and locking clips will be replaced with stud and nut assemblies as shown in Figure 2 attached. The assembly consists of two studs with a baseplate so that 48 such assemblies will be used. Each stud, nut, locking clip and baseplate is first assembled and the assembly so then installed into the existing threaded holes in the thermal shield. A stud tensioner will then tension the studs and set the nuts. After the tensioning is complete, the locking clip which is welded to the baseplate will be crimped onto the nut at groves machined into the nut. The stud and nut material in Inconel X750 which has been selected because of its availability and stress corrosion resistance and satisfactory experience in PWR environment. The locking clip and baseplate are 304SS.

The need to modify the upper thermal shield restraint has not been determined; i.e., final stress analyses may show that restraint at the upper end is not required, and the restraint can be left as is.

Supplementary Information Regarding Lower Internals Guide Blocks

As reported previously, one guide block was missing from the right side of the "Y" axis as viewed from the outside of the thermal shield. The missing guide block is believed not to have been in place since the time when the internals were last installed in 1976. This is because none of the attachment parts has been located despite a very thorough video inspection.

UT examinations of the bolts in the other guide blocks have been completed and UT indications have been reported in two bolts. The bolts with the indications are in the block which mates with the missing block and the bolt in one of the guide blocks adjacent to the missing one. Video inspections of the vertical surfaces of the guide blocks containing the bolts with the UT indications show no evidence of contact between the core support lug and the guide blocks.

In order to determine whether these indications are truly flaws, the bolts will be removed in two stages for supplementary examinations. The first to be removed will be the bolt from the other half of the missing block. If a flaw is truly present, the second bolt with an indication will be removed and examined.

As a part of the overall repair plan, a review has been performed concerning the guide block function. As a result of this review, it is considered unnecessary to replace the removed guide blocks, i.e., the one believed to have been missing when the internals were installed in 1976 and either one or two additional blocks which will be removed for further bolt examinations.

The as-designed function of the guide blocks is to provide a vertical guide for the core guide lugs in the remote event of a circumferential severence of the core support shield. Removal of three of the twenty-four guide blocks will not significantly affect the function of the guide blocks.

Hot Functional Testing flow-induced vibrational testing showed a 1 to 1.5 mil beam mode displacement of the CSA lower end which is within the 20 mil design gap between a guide lug and guide block. Additional analysis has been performed which shows that removal of three guide blocks will not significantly effect CSA vibrational behavior in the event contact between guide lugs and guide blocks occurs. Also, further justification is based on the acceptable results of the analysis of the effects of asymmetric LOCA loadings (BAW-1621) which was performed taking no credit for the guide blocks.

As a result of further investigations related to the missing guide block, it has been concluded that the above plan for inspection and removal of either one or two additional half blacks is prudent and that the removal of three of the 24 blocks does not represent any significant reduction in safety.

TABLE 1

LABORATORY BOLT EXAMINATIONS

Specimen	Bolt Type	Source	Examinations
3 bolts	MK 375 (Upper Thermal Shield Restraint)	Oconee 1	V, L.P., S.C.
2 bolts	MK 256 (Core Barrel)	Oconee 1	Cyl. Surf.* V., L.P., S.C.
1 bolt	MK 390 (Flow Distributor)	Oconee 1	Cyl. Surf.* V., L.P., S.C.
2 bolts	MK 380 (Lower Thermal Shield)	Oconee 1	Cyl. Surf.* V., L.P., Met.*
1 bolt (A) head	MK 380	Oconee 1	V., Frac.
1 bolt (B) head	MK 380	Oconee 1	V.
1 bolt shank (#1)	MK 380	Oconee 1	V., Frac., Met.
1 bolt shank (#2)	MK 380	Oconee 1	V., T.T.
1 bolt shank (#3)	MK 380	Oconee 1	V., Frac., Met.
1 bolt	MK 380	Archive	V., T.T., Met. Chem. Reh
1 bolt	MK 390	Archive	V., Met.
1 bolt	MK 375	Archive	V., Met.
1 bolt	MK 256	Archive	V., Met.

V. - Visual examination
L.P. - Fluorescent liquid penetrant examination for surface cracking
T.T. - Tensile test
S.C. - Surface contamination examination using replica technique
Cyl. Surf. - SEM examination of cylindrical surface
FRAC - SEM examination of fracture surface
Chem - Spectrographic chemical analysis
Mar - microhardness
Reh - Reheat treatment
Met. - Metallography

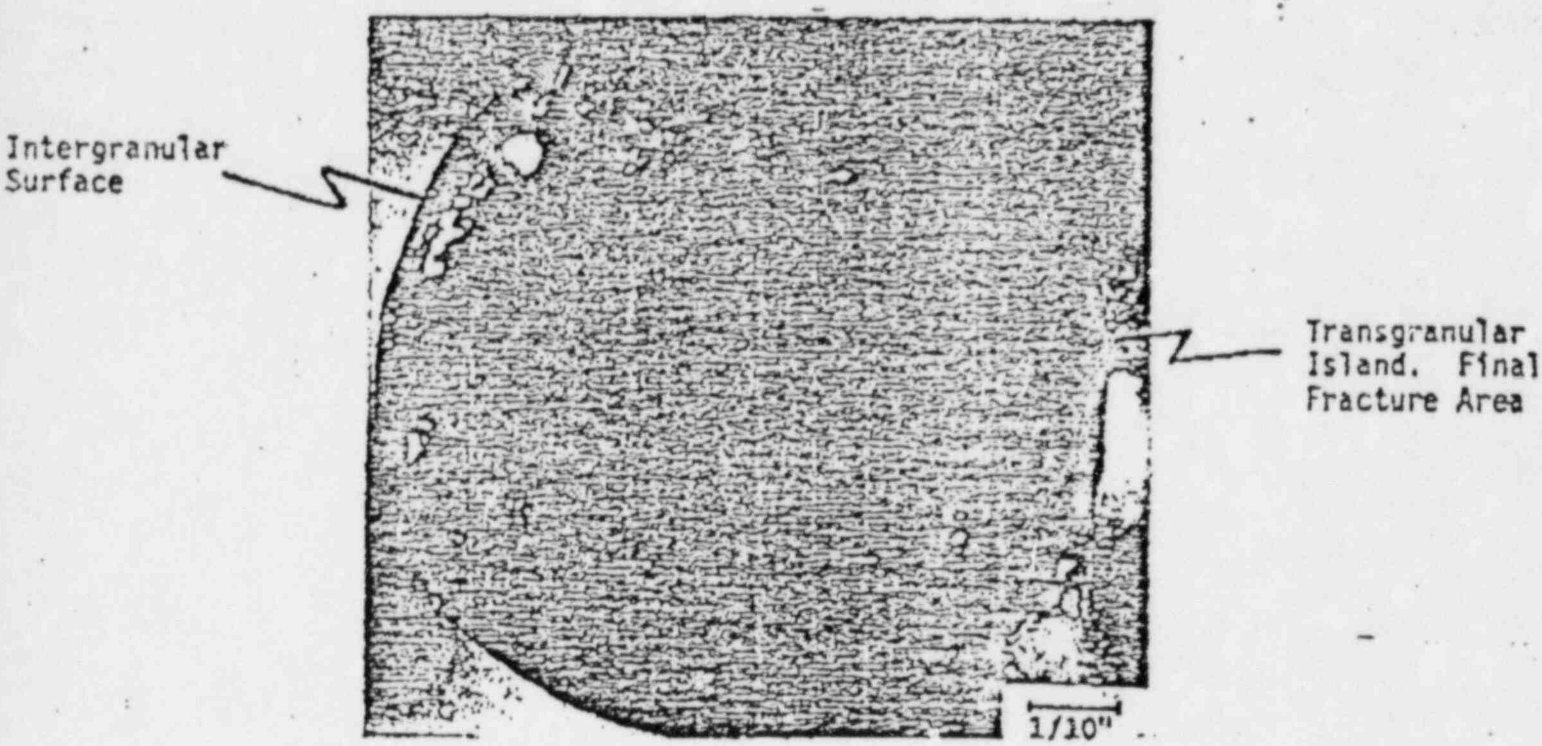
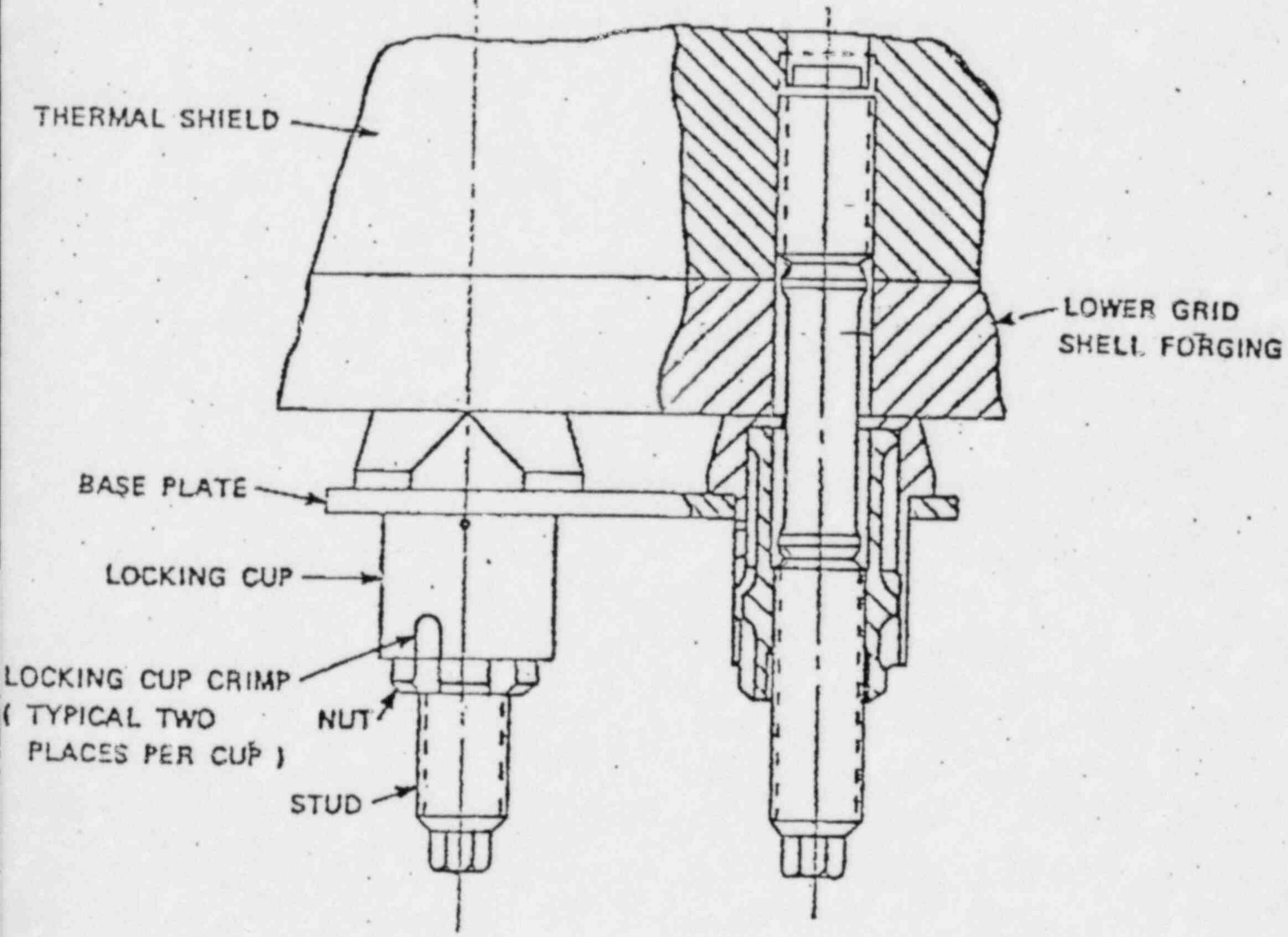


Figure 1. Macrograph of Fracture Surface on Bolt Shank 1

FIGURE 2

LOWER THERMAL SHIELD STUD DESIGN



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

~~E. Blackwood~~
Joe Collins IE

December 24, 1981

Dockets Nos. 50-269, 50-270
and 50-287

Mr. William O. Parker, Jr.
Vice President - Steam Production
Duke Power Company
P. O. Box 33189
422 South Church Street
Charlotte, North Carolina 28242

Dear Mr. Parker:

Reference: Letter from W. O. Parker, Jr. (Duke Power Company) to J. P. O'Reilly (NRC) dated July 24, 1981, Docket No. 50-269

SUBJECT: REQUEST FOR LPMS REPORT AND NEUTRON NOISE DATA

Your analysis of the Oconee-1 broken thermal shield bolts event described in the reference letter indicates that the event poses no threat to public health and safety. However, the information you have provided has led to a staff concern about a loose thermal shield and also about the failure of the Oconee-1 loose parts monitoring system (LPMS) to detect the broken bolts.

The large number of broken and loose thermal shield bolts discovered by inspection implies that most or all of the thermal shield bolts could be broken resulting in a loose thermal shield. In addition, as was learned in the October 9, 1981 meeting of Duke/B&W/NRC at the NRC Bethesda Office, a change in neutron noise level observed midway in the last fuel cycle of Oconee 1 was attributed to a broadening of the 23 Hz noise associated with core barrel shell mode vibration. A loose thermal shield or core barrel would cause reduction in natural frequency of the structure and, therefore, make it more susceptible to flow-induced vibration resulting in significantly higher cyclic stress. This could lead to failure of vessel internals such as the core barrel, thermal shield or even the core support mechanism. A displaced or vibrating thermal shield or core barrel would also affect the calibration and proper operability of the nuclear instrumentation including reactor trip settings. There could be other safety implications from a loose thermal shield or core barrel that were not considered in the design analysis.

Our concern regarding the effectiveness of the LPMS relates to all Oconee Units. Your analysis indicates dependence on the LPMS for de-

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tection of broken thermal shield bolts, but does not explain why it failed to do so previously. An undetected loose part in the primary system could cause component damage and material wear by frequent impacting with other parts in the system. It could also cause partial flow blockage with attendent boiling problem. Other safety concerns about loose parts include increased potential for control rod jamming and for accumulation of radioactive crud in the primary system.

To address our concerns, you are requested to submit the following items for staff review:

1. The LPMS signals from the Oconee-2 startup transient flow test: This will allow detailed analysis that helps detect loose parts which only impact when flow is disturbed.
2. The neutron noise data obtained from Oconee Units 1, 2 and 3: Besides the neutron noise level change observed in Unit 1, it was stated in the October 9, 1981 meeting that a neutron noise level change was also observed in Unit 2, and consultants had been hired to record and analyze neutron noise at the Oconee Units. These data and analyses will be evaluated for evidence of core barrel or thermal shield vibration.
3. The analysis or evidence to support your contention in the reference letter that a loose thermal shield or thermal shield bolts will be detected by the LPMS.
4. The Oconee loose part monitoring program report in accordance with Regulatory Guide 1.133, Rev. 1. The report should include at least a description of LPMS hardware, implementation, plant personnel training, and in particular, the LPMS calibrations and operational procedure.

Since this request for information involves only the Oconee Nuclear Station, fewer than ten respondents are affected and, therefore, OMB clearance is not required under P. L. 96-511. If you have any questions on this subject, please contact your NRC Project Manager.

Sincerely,

John F. Stolz

John F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing

cc:
See next page