

April 17, 2002

Mr. Oliver D. Kingsley, President  
Exelon Nuclear  
Exelon Generation Company, LLC  
4300 Winfield Road  
Warrenville, IL 60555

SUBJECT: QUAD CITIES NUCLEAR POWER STATION  
NRC SPECIAL INSPECTION REPORT 50-254/02-03(DRS)

Dear Mr. Kingsley:

On February 28, 2002, the NRC completed a Special Inspection at Quad Cities Unit 1 reactor facility regarding a failed Unit 1 jet pump hold-down beam (#20). The enclosed report documents the inspection findings which were discussed on February 28, 2002, and April 12, 2002, with Mr. Tulon and other members of your staff.

This inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. The inspector reviewed selected procedures and records, observed equipment, and interviewed personnel.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and its enclosure will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at <http://www.nrc.gov/NRC/ADAMS/index.html> (the Public Electronic Reading Room).

Sincerely,

***/RA by Roy Caniano Acting For/***

John A. Grobe, Director  
Division of Reactor Safety

Docket No. 50-254  
License No. DPR-29

Enclosure: Inspection Report 50-254/02-03(DRS)

See Attached Distribution

cc w/encl: Site Vice President - Quad Cities Nuclear Power Station  
Quad Cities Nuclear Power Station Plant Manager  
Regulatory Assurance Manager - Quad Cities  
Chief Operating Officer  
Senior Vice President - Nuclear Services  
Senior Vice President - Mid-West Regional  
Operating Group  
Vice President - Mid-West Operations Support  
Vice President - Licensing and Regulatory Affairs  
Director Licensing - Mid-West Regional  
Operating Group  
Manager Licensing - Dresden and Quad Cities  
Senior Counsel, Nuclear, Mid-West Regional  
Operating Group  
Document Control Desk - Licensing  
Vice President - Law and Regulatory Affairs  
Mid American Energy Company  
M. Aguilar, Assistant Attorney General  
Illinois Department of Nuclear Safety  
State Liaison Officer, State of Illinois  
State Liaison Officer, State of Iowa  
Chairman, Illinois Commerce Commission  
W. Leach, Manager of Nuclear  
MidAmerican Energy Company

Mr. Oliver D. Kingsley, President  
 Exelon Nuclear  
 Exelon Generation Company, LLC  
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M. Aguilar, Assistant Attorney General  
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W. Leach, Manager of Nuclear  
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U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Docket No: 50-255;  
License No: DPR-29;

Report No: 50-254/02-03

Licensee: Exelon Nuclear

Facility: Quad Cities Nuclear Power Station, Units 1 and 2

Location: 22710 206th Avenue North  
Cordova, IL 61242

Dates: January 15 through April 12, 2002

Inspector: D. Jones, Reactor Inspector

Approved by: J. Jacobson, Chief  
Mechanical Engineering Branch  
Division of Reactor Safety

## SUMMARY OF FINDINGS

IR 05000254-02-03(DRS) on 01/15/2002 - 02/28/2002, Exelon Nuclear, Quad Cities Nuclear Power Station, Unit 1.

This Special Inspection was initiated to evaluate the facts, circumstances and corrective actions surrounding a failed Unit 1 jet pump hold-down beam (#20). The inspection was conducted by a regional inspector. Based on the results of this inspection, there were no findings. The significance of most findings is indicated by their color (Green, White, Yellow, Red) using Inspection Manual Chapter 0609, "Significance Determination Process" (SDP). Findings for which the SDP does not apply are indicated by "No Color" or by the severity level of the applicable violation. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described at its Reactor Oversight Process website at <http://www.nrc.gov/NRR/OVERSIGHT/index.html>.

A. Inspector Identified Findings

No findings of significance were identified.

B. Licensee Identified Findings

No findings of significance were identified.

## Report Details

### Summary of Plant Event

On Wednesday, January 9, 2002, the licensee conducted a Technical Specifications required shutdown due to an indication of jet pump failure of one of the 20 jet pumps inside the Unit 1 reactor vessel. Approximately 30 minutes after the jet pump failure, the 1B reactor recirculation pump tripped. The licensee verified failure of the #20 jet pump hold-down beam (JPHB) following disassembly and inspection of the reactor vessel on Saturday, January 12, 2002.

Based on criteria specified in Management Directive 8.3, "NRC Incident Investigation Program," and Inspection Procedure 71153, "Event Followup," a Special Inspection was initiated in accordance with Inspection Procedure 93812, "Special Inspection." A Special Inspection Charter was developed to focus the review effort on determining: (1) causal factors of JPHB #20 failure; (2) licensee corrective actions for restart; (3) root cause of JPHB #20 failure; and (4) licensee long-term corrective action plans and generic implications. Based on this inspection the Special Inspection Charter is considered complete.

### Summary of Plant Status:

The Quad Cities plant remained in cold shutdown for JPHB replacement activities.

#### **4. OTHER ACTIVITIES (OA)**

##### 4OA3 Event Followup (93812)

##### .1 Sequence of Events

##### a. Inspection Scope

The inspector reviewed documentation and conducted interviews to determine the chain of events regarding the failed Unit 1 JPHB (#20).

##### b. Findings

##### Background

Jet pumps are passive devices used to increase the flow of water through the reactor core (Attachment 1). The mixer section of each jet pump from the entrance to the 180 degree bend to the diffuser slip joint is removable for inspection. This section is held in place by a beam assembly located on the riser transition piece and is centered in the diffuser by a restrainer located on the mixer. The beam ends are positioned in pockets in the transition piece and the beam load is transferred to the elbow through a bolt located in the center of the beam. The bolt is screwed down against a spherical washer in the elbow.

The jet pump assembly is classified as a safety-related component because its structural integrity is a factor in maintaining core flooding following a design basis loss of

coolant accident (LOCA). The jet pumps are designed to be sufficiently leak tight, despite thermal expansion, to permit reflooding of the reactor core to approximately two-thirds core height. As stated in UFSAR Section 3.9.5.2, "The loading conditions that occur during excursions or LOCAs have been examined. The reactor core shroud, shroud support, and jet pump body, which comprise the inner vessel around the core within the reactor vessel, are designed to maintain reflooding capability following a design basis LOCA. Reflooding the reactor core to the top of the jet pump inlets will provide adequate cooling of the fuel."

Technical Specification 3.4.2 requires all jet pumps to be operable while in Modes 1 and 2. An inoperable jet pump can increase the blowdown area and reduce the capability to reflood during a design basis LOCA (TS Bases 3.4.2.A.1).

### Event

On Wednesday, January 9, 2002, indications of jet pump failure (reactor level spiked up by 6 inches and then back down, reactor power dropped from 100% to 91%, reactor and core plate differential pressures decreased and total core flow increased) of one of the 20 jet pumps inside the Unit 1 reactor vessel led to a Technical Specifications required shutdown. Approximately 30 minutes after the jet pump failure, one of the two reactor recirculation pumps (1B), which provides forced circulation of water through the reactor core, tripped.

On Saturday, January 12, 2002, failure of the #20 JPHB was discovered following disassembly and inspection of the reactor vessel (Attachment 2). The jet pump inlet mixer sub-assembly had lifted from the diffuser at the slip fit connection, disassembling the pump. It was found wedged against the swing-gate restrainer bracket assembly after lifting and tilting approximately 20 degrees off vertical. The restrainer gate in the reactor physically limits the displacement of the sub-assembly, which limits consequential failures. Portions of the beam were found on the shroud support plate and in the 1B reactor recirculation pump line. The hold-down spherical washer was not located. The licensee retrieved the two beam pieces and performed a lose part analysis (Quad Cities Unit 1 Lost Parts Evaluation for JPHB Insert, January 18, 2002) for the unrecovered spherical washer. The portion of the beam found in the 1B recirculation line caused severe damage to one of the six pump impeller vanes and significant damage to two other vanes.

## .2 Causal Factors of Jet Pump Beam #20 Failure

### a. Inspection Scope

The inspector reviewed documentation and conducted interviews to determine the causal factors of JPHB #20 failure. This included a review of the adequacy of past JPHB nondestructive evaluation (NDE) (scope and techniques); site beam cracking/repair history; and industry cracking/repair history.



b. Findings

There have been previous instances of single beam failures at Dresden Unit 3, and Grand Gulf. In 1980, Dresden Unit 3 experienced failure of the #13 JPHB which had broken across the ligament sections at the bolt hole area in the center of the hold-down beam. In 1993, Grand Gulf also experienced failure of #10 JPHB at the area between the main body of the beam and the beam ear.

Following the Dresden Unit 3 JPHB failure, IE Bulletin No. 80-07, "BWR Jet Pump Failure," was issued on April 4, 1980. The Bulletin recommended visual and ultrasonic examinations be performed each refueling outage in the "mid length ligament areas bounding the beam bolt." The Bulletin also required initiation of improved surveillance procedures to detect beam failures before the jet pump disassembled. On June 9, 1980, General Electric Services Information Letter (SIL) 330, "Jet Pump Beam Cracks," was issued to describe BWR-3 JPHB failures. The SIL 330 series (SIL #330, Supplements 1 and 2 ) recommended JPHB inspections similar to those delineated in the Bulletin. No specific JPHB replacements were required by the Bulletin nor recommended in the SIL at that time.

The Quad Cities and Dresden Units, were/are the only domestic BWRs with the original JPHBs installed. Other domestic BWRs have either replaced the original beams or have beams of a different design. While G.E. Rapid Information Communication Service Information Letters (RICSIL No. R065, 1992) initially provided a "conservative short term recommendation" to replace jet pump beams, that recommendation was soon supplemented with the alternative of expanded beam inspection, which is now explicitly delineated in BWR Owners Group Vessel Internals Project (BWRVIP) guidelines (BWRVIP-41, "BWR Jet Pump Assembly Inspection and Flaw Evaluations").

The BWRVIP-41 guidelines were developed to provide information to utilities on potential failure locations in BWR/3-6 jet pump components and to recommend an inspection program which would assure the integrity of all jet pump safety functions. Two potential failure locations were identified for jet pump beams; the area adjacent to the threaded hole for the beam bolt, and the beam ear region. The examination of the BWR 3 style jet pump beams performed at Quad Cities and Dresden covered the bolt hole region and the beam ear, which was in conformance with BWRVIP-41 guidelines. The failure that occurred is in a region of the beam (tapered area) that was not specified to be inspected as part of the BWRVIP-41 guidelines.

At Quad Cities, the NRC performed a closeout inspection of Bulletin No. 80-07 in late 1985 (Inspection Report 50-254(265)/85027(85030). The follow-up inspection stated that the "generic aspects of jet pump integrity have been adequately addressed." In addition, "The inspector also verified that visual and ultrasonic examinations were performed at every refueling outage of the JPHBs. Approved procedures were in place to ensure continued compliance." In addition, the reliability of the ultrasonic procedure used (NDT-C-29) for inspection of the Quad Cities and Dresden BWR 3 style jet pump beams was successfully demonstrated on various mockups at the Electric Power Research Institute Nondestructive Evaluation Center.

.3 Root Cause of Jet Pump Beam #20 failure

a. Inspection Scope

The inspectors reviewed the licensee's preliminary investigation and root cause documents.

b. Findings

Quad Cities original design BWR-3 JPHBs are constructed using Alloy X-750 subjected to equalized and aged heat treatment which is susceptible to intergranular stress corrosion cracking (IGSCC). Factors such as stress, material condition, and water chemistry must occur concurrently for IGSCC to initiate. Applied stress is a significant factor, with initiation dependent on the stress magnitude; (i.e., initiation takes much longer at low stress.) As with any IGSCC related degradation, time is a critical element in the initiation and growth of cracks that can cause structural failure. The failure mode of a beam is a crack that grows to a critical flaw size and the beam fails. The flaw can occur in three different regions: the bolt hole, the ears on the beam ends or the transition region, which consists of the remaining portion of the beam.

Following removal, JPHBs 1-4 and 9-20 (beams 5, 6, 7, and 8 are BWR-4 style beams) were sent to the GE metallurgical laboratory for analysis and examination by visual and dye penetrant methods. Hardness measurements, qualitative chemical analysis and microstructural evaluations all indicated that the beam fit the typical properties of Inconel X-750 with an equalized and aged heat treatment.

Jet pump hold down beam #20 fractured approx. 2-1/2" from the end of the beam in the transition area on the reactor side. The cracks propagated over 90% of the beam cross section. The remaining 10% of the beam cross section failed from overload. Laboratory analysis confirmed the fracture to have initiated from IGSCC. There were no material defects or imperfections found associated with the IGSCC initiation sites. These observations were consistent with prior failures at Grand Gulf and Dresden Unit 3. Jet pump hold-down beam #4 and JPHB #15 both had two liquid penetrant Indications each on the transition region which were determined to be IGSCC. The results confirmed that cracking in the transition region was not isolated to JPHB-20.

.4 Licensee Corrective Actions for Restart/long-Term Corrective Actions

a. Inspection Scope

The inspectors reviewed the licensee's initial corrective actions and long-term corrective action plans to assess the adequacy of the corrective actions.

b. Findings

Initial Corrective Actions

There are 20 JPHBs. Four beams in Unit 1(5, 6, 7, and 8) were replaced with BWR-4 style beams during jet pump maintenance during the June 1994 and April 1999 outages.

The licensee performed an extent of condition examination of the remaining 15 old style (BWR-3) beams. The inspection involved ultrasonic examination of the beam ears and center bolt hole region, and visual examination of the transition region. Following the examinations the licensee decided to replace the original design beams (BWR-3) with redesigned beams (BWR-4) which are less susceptible to intergranular stress corrosion cracking. The BWR-4 style beams have improved design with a thicker cross sectional area in the bolt hole region and an age hardened full anneal heat treatment. Jet pump 6 (one of the four new type beams in Unit 1) was not one of the beams to be replaced, however, it was inadvertently de-tensioned and it was subsequently replaced. The licensee also developed operability determinations to justify the continued operation of the jet pumps at Quad Cities Unit 2, and Dresden Units 2 and 3. The damaged 1B recirculation pump impeller was replaced.

#### Long-term Corrective Action Plans

During the February 2002 refueling outage of Quad Cities Unit 2, 18 beams were replaced. Two beams (JPHB-7 and 18) were replaced with the BWR-4 style beams in 1993 during jet pump maintenance. A visual examination (EVT-1) was performed on the 18 old-style beams while under tension in the reactor vessel. Potential indications were noted on 9 beams (Nos. 1, 5, 6, 8, 10, 12, 13, 19, and 20). All 18 JPHBs were sent to the GE metallurgical laboratory for analysis and examination by dye penetrant method. The results of the penetrant examination revealed that 5 JPHBs had short indications ( $\frac{1}{2}$ " -  $\frac{3}{4}$ " in length) in the transition region. Sectioning of the JPHBs showed an indication depth of .044" to .179".

On March 24, 2002, Dresden Unit 3 completed a maintenance outage to replace seventeen of the old-style JPHBs. No indications were found in the seventeen JPHBs that were visually inspected. The licensee plans to replace all the JPHBs in Dresden Unit 2 during the December 2003 refueling outage.

No findings of significance were identified.

#### .5 Quad Cities and Dresden Jet Pump Operability Evaluations

##### a. Inspection Scope

The inspectors reviewed the licensee's Quad Cities and Dresden jet pump operability evaluations to assess the adequacy of the evaluations.

##### b. Findings

#### Quad Cities Unit 2 Evaluation

The Quad Unit 2 evaluation was based on a fracture mechanics approach and consideration of operating time (time at temperature is a critical factor for flaw growth) as compared with Quad 1. The evaluation concluded that Quad 2 was safe to operate until the February 12, 2002 Q2R16 refuel outage wherein all jet pump beams were replaced.

### Dresden Unit 2 Evaluation

The Dresden Unit 2 evaluation was based on a video examination of the beams performed in 1999 which had been independently reviewed by five Level III examination experts and a fracture mechanics approach. Given the largest flaw which could have gone undetected in 1999, the licensee concluded that it would be 5-6 years before a flaw could grow to failure. Additionally, Dresden 2 has been on hydrogen water chemistry since 1983 vs Quad 1 since 1990 (hydrogen chemistry inhibits cracking). The overall conclusion of the operability determination for Dresden Unit 2 was supported by the inspection results from Quad Quad Cities Unit 2 and Dresden Unit 3 (Exelon Letter RS-02-070, dated April 8, 2002). The licensee plans to continue to operate until the December 2003 refueling outage, which is about four years since the 1999 examination.

### Dresden Unit 3 Evaluation

The Dresden Unit 3 evaluation was based on a fracture mechanics approach and consideration of operating time. The evaluation concluded that the unit was safe to operate until a mid cycle outage in March 2002 wherein all jet pump beams were replaced.

No findings of significance were identified.

#### 4OA5 Other

Licensee Event Report 050-254/2002-001 (Closed): Reactor Shutdown Due To Failure of Recirculation Jet Pump. This issue was discussed in Section 4OA3 of this inspection report. The inspector has reviewed the licensee's corrective actions and found them to be appropriate and this Licensee Event Report is considered closed.

#### 4OA6 Management Meetings

##### Exit Meeting Summary

The inspectors presented the inspection results to Mr. Tulon and other members of licensee management at the conclusion of the onsite inspection effort on February 28, 2002, and in a final phone exit meeting held on April 12, 2002. The licensee acknowledged the findings presented. Proprietary information was discussed with the licensee and appropriately handled.

Attachments: As Stated

## KEY POINTS OF CONTACT

### Licensee

T. Tulon, Site Vice President  
R. Gesior, Director, Asset Management  
K. Jury, Director, Licensing MWROG  
W. Beck, Regulatory Assurance Manager  
M. Wagner, Licensing Engineer

### NRC

K. Stoedter, Senior Resident Inspector

## LIST OF ITEMS OPENED, CLOSED, AND DISCUSSED

### Closed

050-254/2002-001    LER    Reactor Shutdown Due To Failure of Recirculation Jet Pump.

## LIST OF ACRONYMS USED

BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DRS	Division of Reactor Safety
EPRI	Electric Power Research Institute
IGSCC	Intergranular Stress Corrosion Cracking
JPHB	Jet Pump Hold-Down Beam
LOCA	Loss Of Coolant Accident
NDE	Nondestructive Examination
NRC	Nuclear Regulatory Commission
OA	Other Activities
RICSIL	Rapid Information Communication Service Information Letters
SDP	Significance Determination Process
SIL	Services Information Letter
TS	Technical Specification
UFSAR	Updated Final Safety Analysis Report

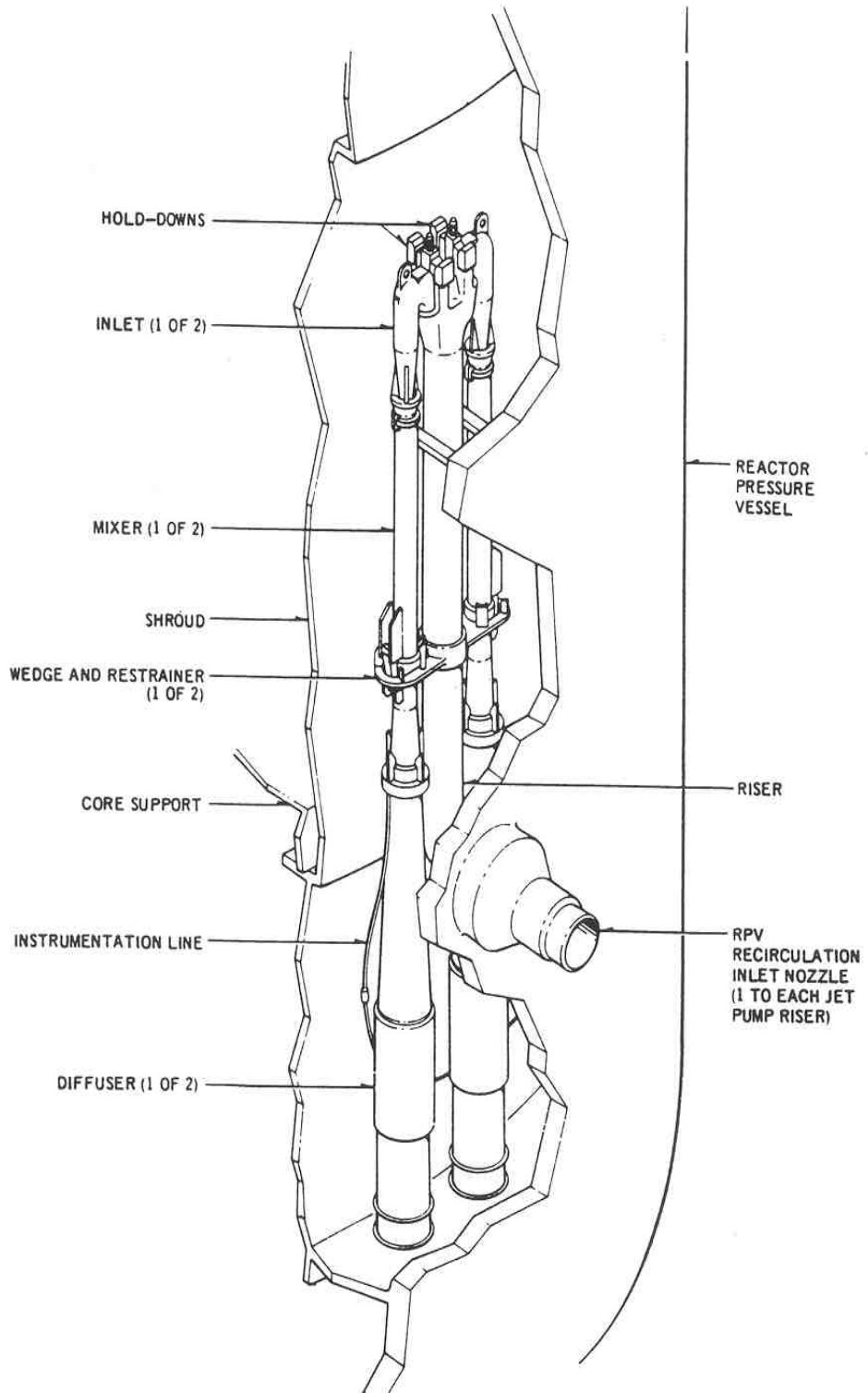
## LIST OF DOCUMENTS REVIEWED

### 4OA3 Event Followup

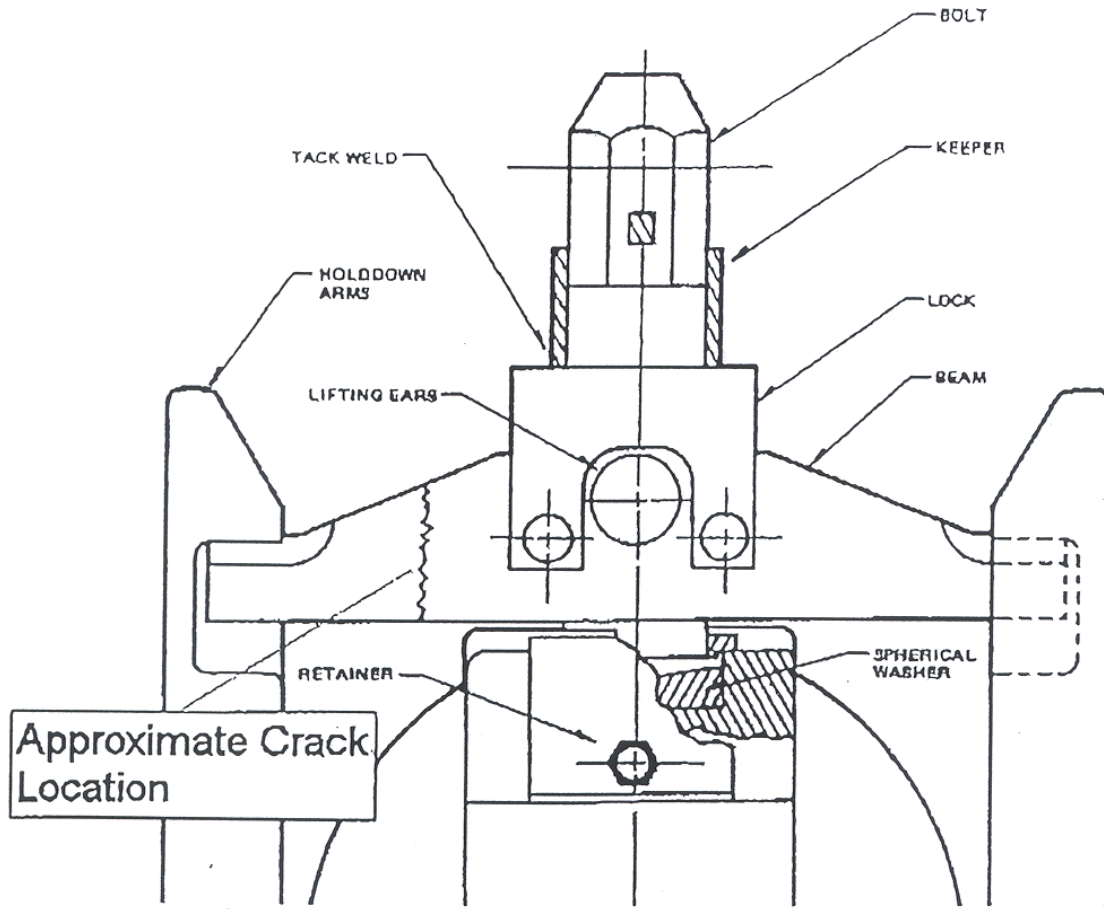
<u>Number</u>	<u>Subject/Title</u>	<u>Date/Revision</u>
Exelon Letter RS-02-070	Final Update Concerning Jet Pump Hold Down Beam Activities at Dresden Nuclear Power Station, Units 2 and 3 and Quad Cities Nuclear Power Station, Units 1 and 2	April 8, 2002
Exelon Letter RS-02-015	Communications with the NRC Regarding the Quad Cities Nuclear Power Station Unit 1 Jet Pump Hold Down Beam Replacement Activities and Continued Operation of Quad Cities Nuclear Power Station, Unit 2 and Dresden Nuclear Power Station, Units 2 and 3	January 18, 2002
DCP Number 334794	Installation of Wedges for Jet Pump #20 Restraint (Unit 1)	January 19, 2002
EPRI Report	Review of Exelon UT Procedure NDT-C-29	January 22, 2002
GE Procedure JP-QUAD1-700	Installation Of Set Screw Gap Wedge Procedure	January 17, 2002
GE Product Quality Certification	Purchase of Jet Pump Beam Bolt Assembly Under Exelon PO 707-12133	January 16, 2002
NRC PNO-III-02-001	Shut Down Due to Jet Pump Inoperability	January 10, 2002
NRC IE Bulletin No. 80-07	BWR Jet Pump Assembly Failure	April 4, 1980
NRC IE Bulletin No. 80-07 Supplement No. 1	BWR Jet Pump Assembly Failure	May 13, 1980
NRC Information Notice 93-101	Jet Pump Hold Down Beam Failure	December 17, 1993
GE SIL No. 330	Jet Pump Beam Cracks	June 9, 1980
GE SIL No. 330 Supplement 1	BWR/4 Jet Pump Beam Cracks	February 1981
GE SIL No.. 330 Supplement 2	GE BWR/6 Jet Pump Inlet Mixer Ejection	October 27, 1993
GE RICSIL 065	Jet Pump Beam Cracking	March 26, 1992

GE RICSIL No. 086	Cracking In The Transition Region of a Jet Pump Beam	January 28, 2002
Supporting Operability Documentation LS-AA-105-1001	Quad Cities Unit Two	January 19, 2002
Supporting Operability Documentation LS-AA-105-1001	Dresden Units D2, D3	January 19, 2002
4OA5 <u>Other</u>		
LER 254/02-001	“Reactor Shutdown due to Failure of Reactor Recirculation Jet Pump”	March 11, 2002

ATTACHMENT 1







**JET PUMP BEAM No. 20**