Florida Power & Light Company, P. O. Box 14000, Juno Beach, FL 33408-0420

FPL

L-2002-185
10 CFR 50.54(f)

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Re: St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
Turkey Point Units 3 and 4
Docket Nos. 50-250 and 50-251
Response to NRC Bulletin 2002-02
Reactor Pressure Vessel Head Penetration Nozzle Inspection Programs

On August 9, 2002, the NRC issued Bulletin 2002-02, "Reactor Pressure Vessel Head Penetration Nozzle Inspection Programs." Florida Power and Light (FPL) hereby supplies the information requested as Attachment 1 for the St. Lucie site response and Attachment 2 for the Turkey Point site response to the Bulletin.

In the discussion section of Bulletin 2002-02, the NRC staff noted six specific concerns about the adequacy of the current industry reactor pressure vessel (RPV) head and vessel head penetration inspection programs that rely solely on a visual examination as the primary inspection method. FPL has reviewed the NRC's position and has taken steps to supplement examination of the RPV head and RPV head nozzles to address the NRC's concerns. Taken together, the supplemental examinations stated herein along with the information provided to address the six NRC concerns ensures continued safe unit operation.

On September 6, 2002, a conference call was held between FPL and members of the NRC staff to discuss the St. Lucie Unit 1 inspection plan for its upcoming refueling outage that is scheduled to start on September 30, 2002. The attached response provides the information necessary to resolve the issues that were discussed during the call. Due to the immediacy of the St. Lucie Unit 1outage, please notify FPL with any concerns at the contact number shown below.

In addition, FPL is evaluating long-term plans for RPV head replacement at Turkey Point Units 3 and 4 and St. Lucie Units 1 and 2. As strategies are developed, FPL will notify the NRC if its plans result in any changes to the examination practices addressed in this bulletin response.

The attached information is provided pursuant to the requirements of Section 182a of the Atomic Energy Act of 1954, as amended and 10 CFR 50.54(f).

Should there be any questions on this response, please contact Raj Kundalkar (561-694-4248).

Very truly yours,

Rajiv S. Kundalkar
Vice President,
Nuclear Engineering

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Attachments
cc: Regional Administrator, Region II, USNRC

STATE OF FLORIDA)
)ss.
COUNTY OF PALM BEACH)

R. S. Kundalkar being first duly sworn, deposes and says:

That he is Vice President, Nuclear Engineering, of Florida Power and Light Company, the Licensee herein;

That he has executed the foregoing document; that the statements made in this document are true and correct to the best of his knowledge, information and belief, and that he is authorized to execute the document on behalf of said Licensee.

R. S. Kundalkar

Subscribed and sworn to before me this

11th day of September 2002,

Judith Ann Creasman

Name of Notary Public (Type or Print)

OFFICIAL NOTARY SEAL
JUDITH ANN CREASMAN
NOTARY PUBLIC STATE OF FLORIDA
COMMISSION NO. CC980677
MY COMMISSION EXP. DEC. 5,2004

R. S. Kundalkar is personally known to me.

ATTACHMENT 1

Bulletin 2002-02 Response for St. Lucie Units 1 and 2

On August 9, 2002, the Nuclear Regulatory Commission (NRC) issued Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs." The NRC requested that specific information be provided within 30 days of the date of the Bulletin. Florida Power and Light Company (FPL) hereby responds to the 30-day information request set forth in the Bulletin with respect to St. Lucie Units 1 and 2.

***NRC Request 1:** Within 30 days of the date of this bulletin:*

A. *PWR addressees who plan to supplement their inspection programs with non-visual NDE methods are requested to provide a summary discussion of the supplemental inspections to be implemented. The summary discussion should include EDY, methods, scope, coverage, frequencies, qualification requirements, and acceptance criteria.*

FPL Response to NRC Request 1.A:
St. Lucie Units 1 and 2 reactor pressure vessel (RPV) head and RPV head penetration nozzle inspections will combine both visual and non-visual methods at the next refueling outage.

The Electric Power Research Institute (EPRI) Material Reliability Program (MRP) Inspection Plan and supporting technical basis documents[1] have been developed by owners and operators of PWR units and have been transmitted to the NRC[2]. The MRP Inspection Plan presents a technically sound inspection regimen that assures to a high degree of certainty that leaks will be detected at an early stage long before wastage or circumferential cracking can challenge the structural integrity of the RCS pressure boundary. Furthermore, implementation of the MRP Inspection Plan will assure continued compliance with the regulatory requirements cited within NRC Bulletin 2002-02, since the MRP Inspection Plan addresses the safety aspects of the six concerns identified in the Bulletin. Therefore, FPL will implement the MRP Inspection Plan and will comply with its requirements, at a minimum, beginning with the next planned refueling outage (RFO).

As requested in the subject bulletin, FPL will supplement the visual inspection with ultrasonic examination of the RPV head penetration base material during the next scheduled RFO for St. Lucie Units 1 and 2. The next RFO for St. Lucie Unit 1 (SL1-18) is scheduled to begin September 30, 2002 and the next RFO for St. Lucie Unit 2 (SL2-14) is scheduled to begin April 21, 2003. Penetrant testing will be used to assist in characterization of any leakage indication not confirmed in the tube material.

FPL is also evaluating its long-term plans for RPV head replacement at St. Lucie Units 1 and 2. Once those plans and schedules are complete, FPL will re-evaluate its commitment with respect to inspection plans. FPL will notify the NRC if its plans result in any changes to the Bulletin 2002-02 response.

The elements (EDY, methods, scope, coverage, frequencies, qualification requirements, and acceptance criteria) of these inspections are provided below:

1. Effective Degradation Years (EDY)

FPL has calculated EDY values for St. Lucie Units 1 and 2 for the next planned RFO according to the methodology described by equation 2.2 of MRP-48 (PWR Materials Reliability Program Response to NRC bulletin 2001-01).

St. Lucie Unit 1 will have approximately 15.8 EDY at the start of its next RFO (SL1-18) on September 30, 2002. St. Lucie Unit 2 will have approximately 14.0 EDY at the start of its next RFO (SL2-14) on April 21, 2003.

2. Supplemental Inspection Methods, Scope and Coverage

2.a. Ultrasonic Testing (UT) of the RPV Head Penetration Base Material

An ultrasonic (UT) examination of all of the CEDMs, ICIs and head vent penetration tube locations will be performed at the next St. Lucie Units 1 and 2 RFOs. The examination scope will include the material starting from approximately 2" above the weld down to the bottom end (to the maximum extent possible) of the respective penetration. The UT examination has been demonstrated to detect both axial and circumferential flaws initiating from the inside diameter (ID) or outside diameter (OD) surface of the tube material. Since this UT examination will detect circumferential cracks in the tube, the concern regarding penetration ejection from crack propagation in the tube material is effectively addressed.

2.b. UT "Leak Path" Examination

A UT back reflection monitoring examination of the interference fit region above the weld will be performed to determine if a reactor coolant leak has occurred into the annulus causing corrosion in the interference fit region. This UT technique is referred to as a "leak path" examination. In all previous UT examinations of CRDMs with known leakage performed by Framatome ANP, the FPL contracted vendor, a leak path has been observed with the UT scan that corresponded to the known leakage. The UT "leak path" examination provides additional confirmation of the visual results and also addresses the concern of potential wastage resulting from a leak. Therefore, a complete UT examination for detection of axial and circumferential flaws combined with a "leak path" examination addresses the wastage concern resulting from leakage and the potential for a nozzle ejection resulting from a circumferential crack above the weld.

2.c. Bare Metal Visual Examination of RPV Head Penetration to RPV Head Surface

A 100 % bare metal visual inspection under the closely conforming metal insulation as previously identified and described in the response to Bulletin 2001-01[3,4] will be performed at the next St. Lucie Unit 1 RFO. The scope of this visual examination is planned for 100%; however, some physical limitations may exist that preclude complete visual examination of all nozzles at St. Lucie Unit 1 as noted in 2.e below.

FPL performed a 100% bare metal visual baseline inspection at St. Lucie Unit 2 in December of 2001, and will follow-up with a visual examination of the reactor head at the next RFO. The St. Lucie Unit 2 examination will be considered a supplemental visual examination on top of the closely conforming rigid insulation as identified in the MRP inspection plan[1]. A bare metal visual examination will be performed at all locations with identified flaws or "leak path" indications from the UT examinations in 2.a and 2.b above, to determine if leakage or degradation has occurred.

The visual examination at St. Lucie Unit 1 is considered "qualified" at all RPV head penetration locations based on a draft plant specific finite element analysis that is being reviewed. The draft analysis shows that a gap would exist between each RPV head penetration and the RPV steel during operation to allow a leak to communicate with the top surface of the reactor vessel head at St. Lucie Unit 1. Therefore a visual examination with no evidence of boric acid leakage addresses the concern that wastage has not occurred on the top of the head or in the nozzle annulus since any leak would provide visual evidence of boron on the head.

2.d. Dye Penetrant (PT) Testing of the J-Groove Weld Wetted Surface

A dye penetrant (PT) examination will be performed on any RPV head penetration J-groove weld surface to disposition a location that has a relevant external visual indication of leakage that is suspected to originate from the RPV head penetration annulus and can not be confirmed as originating from the tube material by a UT examination. A PT examination will also be performed on the RPV head penetration weld surface at any location that the UT of the tube and "leak path" examination can not be performed and bare metal visual information is not available to confirm the absence of a leak. This would be an unlikely case resulting from multiple physical restrictions identified below.

2.e. Potential interferences:

The planned scope of the bare metal visual and UT examinations at St. Lucie Unit 1 is 100% of the RPV head penetrations. However, since FPL has not previously performed a visual examination under the closely conforming metal insulation on the St. Lucie Unit 1 RPV head, it is not known if physical restrictions exist that could preclude examination of some portion of the RPV head penetrations. Physical restrictions may also exist for some portion of the St. Lucie Unit 1 UT examinations. Specifically, the CEDM penetrations have guide/thermal sleeves with a funneled end installed inside the CEDM penetration to position the CEDM shaft. There is also a counterbore step above the weld. This results in an annular gap of approximately 0.175" that reduces to 0.123" for inspection using a thin "gap scanning" UT probe. Each sleeve is centered by three expansion points or tabs made in the sleeve above the weld to contact the CEDM penetration. Examination near these expansions with the gap scanning probe may be limited and could affect examination in the area of interest. Actual coverage can only be determined after scanning and imaging the nozzle. Also at least one thermal sleeve was bent and straightened during a prior RFO that may result in a limitation for the gap scanning UT probe. Where significant limitations exist that preclude a reasonable determination of the integrity of a nozzle to be made, the limitations will be noted and reported as requested by Bulletin 2002-02 request 2.A.

It is noted that the St. Lucie Unit 1 examination will be the first use of a gap scanning probe on a CE designed unit with guide tube/thermal sleeves, which could result in some unforeseen interferences.

For St. Lucie Unit 2, the bare metal visual examination has been performed once and therefore no visual limitations are expected for future examinations. The CEDM penetrations all have an interference in the bottom 1 ¼" due to a threaded guide funnel that is attached to the lower non pressure boundary portion of the nozzle that extends inside the RPV head. However, this guide funnel and threaded region will not prevent UT examination of the nozzle material from approximately 1.5" below the weld region and above. No other interferences inside the St. Lucie Unit 2 RPV head penetration material are expected since this unit does not have guide sleeves.

3. Supplemental Inspection Frequencies:

The additional supplemental examinations described above will each be performed during the next scheduled RFOs for St. Lucie Units 1 and 2 (SL1-18 and SL2-14).

FPL expects that the recommended method of performing supplemental exams, vendor specific inspection methods, as well as the inspection frequency may change over the next operating cycle based on the availability of additional inspection results. FPL will therefore work closely with the NRC, EPRI MRP, and ASME to establish an accepted frequency for performance of these exams during subsequent outages (SL1-19 and SL2-15 and beyond).

4. Qualification Requirements:
Currently, a qualification program similar to the ASME Section XI, mandatory Appendix VIII, "Performance Demonstration For Ultrasonic Examination Systems" does not exist for testing of the CRDM nozzle base material and J-groove weld configuration. The FPL selected vendor, Framatome ANP, has participated in a demonstration of the UT examination procedures to be used for detection of axial and circumferentailly oriented flaws in the RPV head penetration tube material. These procedures and capabilities were demonstrated in blind testing as part of the EPRI MRP, and have been made available to the NRC. The demonstration has shown the procedures being used will detect both axial and circumferential flaws.

The "leak path" UT technique is a recently developed, Framatome ANP proprietary technology that has no formal industry or ASME qualification program. The basis of the "leak path" UT qualification is from empirical data obtained from UT examination of approximately 270 CRDM/CEDM nozzle penetrations to date. In March 2001, Framatome ANP began consistently scanning the nozzle interference fit region during UT examinations. In all subsequent UT examinations of CRDM's with known bare metal visual leakage, and where the interference fit has been scanned, a UT "leak path" has been observed. The "leak path" UT technique has been presented by Framatome ANP to the NRC on three separate occasions. The first meeting occurred on January 23, 2002 at the White Flint NRC offices as part of a pre-outage presentation for a utility specific examination application (ADAMS ML0202403310). The second disclosure of the "leak path" UT technique occurred on January 24, 2002 at the White Flint NRC offices as part of a pre-outage presentation for another utility specific application (ADAMS ML0203806880). Mr. William Bateman, Mr. Allen Hiser and Mr. Tim Steingass of the NRC were in attendance for both meetings. Subsequent to those meetings the NRC requested another meeting at the Framatome ANP Lynchburg offices to review the "leak path" technique in more detail. That meeting took place on February 12, 2002, which included Mr. Tim Steingass, Mr. Wally Norris, and Dr. Steve Doctor of the NRC.

The technical basis of the technique is described in a Framatome ANP proprietary document titled "Reactor Vessel Head Penetration Leak Path Qualification Report," dated February 6, 2002. Due to the proprietary nature of the document, Framatome ANP is willing to meet with NRC personnel for further discussions on the technique and experience to date and to support any review necessary.

The visual examination personnel and procedures will be qualified in accordance with the vendor's written practice, ASME Section XI, and supplemented by March 2002 EPRI report[5].

Dye penetrant examination personnel and procedures will be qualified in accordance with ASME sections V and XI.

Personnel utilized to perform these supplemental examinations will be certified in accordance with vendor's written practices. FPL will review and approve all NDE personnel certifications and procedures prior to examinations being performed.

5. Acceptance Criteria:
The acceptance criteria for the bare metal visual examinations is no evidence of leakage coming from the RPV head penetration at the intersection of the bare metal head. Typical indications of RPV penetration leakage are identified in the March 2002 EPRI report[5] and will be used as an aid for visual examiners. The acceptance criteria for a supplemental visual

inspection at penetrations that have acceptable results from UT examinations identified in 2.a and 2.b above is a minimum detectable condition of any evidence of RCS leakage such as flow emanating from beneath the insulation, bulging insulation, or boric acid accumulation emerging upward through the joints and gaps between adjoining insulation panels from the RPV head surface[1].

The acceptance of ultrasonic inspections will be determined based on the length, location and depth of an identified indication. FPL anticipates that flaws will be removed or evaluated. If the flaws are evaluated, the approach will be to size the flaw, apply the growth rate identified in MRP-55[6] to the next inspection interval, and evaluate using ASME Section XI flaw tolerance methods and acceptance criteria as modified by the NRC recommendation letter of November 21, 2001[7].

The acceptance criteria for any PT examination of the weld metal will be based on the original construction code. However, for PT examination that is performed as a result of positive indication of a leak, the acceptance criteria will be no indications.

Justification for the inspection approach above:
In the discussion section of Bulletin 2002-02, the NRC staff noted six specific concerns about the adequacy of current industry RVP head and VHP inspection programs that rely solely on a visual examination as the primary inspection method. FPL has reviewed the NRC's position and has taken steps to supplement examination of the RPV head and RPV head nozzles to address the NRC's concerns. Taken together, the supplemental examinations stated herein and the information provided below from the EPRI MRP-75 report[1] relating to the six NRC concerns ensures that unacceptable wastage or RPV head nozzle ejection will not occur at St. Lucie Units 1 and 2 between refueling outages.

Concern 1: *Circumferential cracking of CRDM nozzles was identified by the presence of relatively small amounts of boric acid deposits. This finding increases the need for more effective visual and non-visual NDE inspection methods to detect the presence of degradation in CRDM nozzles before nozzle integrity is compromised.*

Response: As stated in section 2.a and 2.b above, a UT examination of all of the RPV head penetration nozzles (subject to the limitations identified) will be performed during the next scheduled St. Lucie Units 1 and 2 RFOs. This UT examination has been demonstrated to detect the presence of circumferential cracks in the RPV head penetration tube material, effectively addressing this concern. Where physical limitations exist that prevent this examination the following justification is provided.

Since the initial industry discovery of circumferential cracks above the J-groove weld in 2001, visual inspection techniques and approaches employed have been dramatically improved and a heightened sense of awareness exists for the range in size and appearance of visual indications that must be further investigated. Non-visual techniques similarly have and continue to evolve to more effectively examine the penetration tube and associated welds for evidence of cracks. Recent events at Davis-Besse have not invalidated the fundamental inspection capability requirements previously established as necessary to identify the presence of PWSCC and subsequent associated wastage. The effectiveness of inspection techniques continues to be evaluated and improved.

EPRI MRP has published detailed guidance for performing visual examinations of RPV heads[5]. A utility workshop[8] was recently conducted to discuss this guidance and lessons learned from recent field experience (including Davis-Besse). RPV head bare metal visual examinations at St. Lucie Units 1 and 2 will be performed and documented in accordance with written procedures and acceptance criteria that comply with the guidance of the MRP Inspection Plan. Evaluations and corrective actions will be rigorous and thoroughly documented.

In order for OD circumferential cracks above the J-groove weld to initiate and grow, a leak path must first be established to the CRDM annulus region from the inner wetted surface of the reactor vessel head (RVH). If primary water does not leak to the annulus, the environment does not exist to cause circumferential OD cracking. Axial cracks in the CRDM nozzles or cracks in J-groove welds must first initiate and grow through-wall. Experience has shown that through-wall axial cracks will result in observable leakage at the base of the penetration on the outer surface of the vessel, even with interference fits. Alloy 600 steam generator drain pipes at Shearon Harris (1988) and pressurizer instrument nozzles at Nogent 1 and Cattenom 2 (1989) were all roll expanded but still developed leaks during operation (Ref. 1, Appendix B). Plant specific top head gap analyses have been performed for a large number of plants including St. Lucie Unit 1, with nozzle initial interference fits ranging from 0 to 0.0034". These analyses have confirmed the presence of a physical leak path in essentially all nozzles under normal operating pressure and temperature conditions (Ref. 1, Appendix B).

The probability of detecting small CRDM leaks by visual inspections alone is high. "Visual inspections of the reactor coolant system pressure boundary have been proven to be an effective method for identifying leakage from primary water stress corrosion cracking (PWSCC) cracks in Alloy 600 base metal and Alloy 82/182 weld metal. Specifically, visual inspections have detected leaks in RPV head CRDM nozzles, RPV head thermocouple nozzles, pressurizer heater sleeves, pressurizer instrument nozzles, hot leg instrument nozzles, steam generator drain lines, a RPV hot leg nozzle weld, a power operated relief valve (PORV) safe end, and a pressurizer manway diaphragm plate[9]." To date, no leaking (CRDM) nozzles have been discovered by non-visual NDE examinations except for the three nozzles at Davis-Besse where leakage would have been detected visually had there been good access for visual inspections and the head cleaned of pre-existing boric acid deposits from other sources (Ref. 1, Appendix B).

Finally, as described under Concern 3 below, detailed probabilistic fracture mechanics (PFM) analyses have been performed to demonstrate the effectiveness of visual inspections in protecting the CRDM nozzles against failure due to circumferential cracking (Ref. 1, Appendix A). Even though the above discussion illustrates that visual inspections performed in accordance with MRP recommendations have a high probability of detecting through-wall leakage, a very low probability of detection was assumed in the PFM analyses. The PFM analyses assume only a 60% probability that leakage will be detected if a CRDM nozzle is leaking at the time a visual inspection is performed. Furthermore, if a nozzle has been inspected previously, and leakage was missed, subsequent visual inspections are assumed to have only a 12% probability of detecting the leak that was previously missed. Even with these conservative probability of detection assumptions, the PFM analyses show that visual inspection every outage reduces the probability of a nozzle ejection to an acceptable level for plants with 18 or more EDY. Visual inspections of plants with fewer than 18 EDY in accordance with the MRP Inspection Plan will maintain the probability of nozzle ejection for these plants more than an order of magnitude lower than that for the greater than 18 EDY plants.

In summary, the industry has responded to the need to detect small amounts of leakage by increased visual inspection sensitivity, increased inspection frequencies, and improved inspection capabilities. Small amounts of leakage can be detected visually and it has been shown that timely detection by visual examination will ensure the structural integrity of the RPV head penetrations with respect to circumferential cracking.

Concern 2: *Cracking of Alloy 82/182 weld metal has been identified in CRDM nozzle J-groove welds for the first time and can precede cracking of the base metal. This finding raises concerns because examination of weld metal material is more difficult than base material.*

Response: Cracks in the J-groove weld do not pose an increased risk regarding nozzle ejection as compared to penetration base metal cracks. Cracking that is completely within the weld metal, even if 360° around the nozzle, will not lead to ejection since the portion of the weld that remains attached to the outside surface of the nozzle will not be able to pass through the tight annular fit[1]. J-groove weld cracks that initiate and grow through-wall will leak the same as cracks in the penetration base metal. Therefore, weld cracks pose a similar risk as cracks in the base material and are equally detectable by visual examination as well as by the supplemental inspections identified above. Although higher crack growth rates have been observed in laboratory testing of weld metal, the industry model of time-to-leakage includes plants that have had weld metal cracking as well as base metal cracking. The visual examination frequencies from the MRP Inspection Plan have been conservatively established based on the risk informed analyses considering leakage due to both weld metal and base metal cracking.

Concern 3: *Through-wall circumferential cracking from the outside diameter of the CRDM nozzle has been identified for the first time. This raises concerns about the potential for failure of CRDM nozzles and control rod ejection, causing a LOCA.*

Response: As stated in section 2.a and 2.b above, a UT examination of all of the RPV head penetration nozzles (subject to the physical limitations identified) will be performed during the next scheduled St. Lucie Units 1 and 2 RFOs. These UT exams have been demonstrated to detect the presence of circumferential cracks in the RVH penetration tube material, effectively addressing this concern. Where limitations exist that prevent this examination the following justification is provided.

Probabilistic fracture mechanics (PFM) analyses using a Monte-Carlo simulation algorithm were performed to estimate the probability of nozzle failure and control rod ejection due to through-wall circumferential cracking (Ref. 1, Appendix A). The PFM analyses conservatively assume that, once a leak path has extended to the annulus region, an OD circumferential crack develops instantaneously, with a length encompassing 30° of the nozzle circumference. Fracture mechanics crack growth calculations are then performed for this initially assumed crack, using material crack growth rate data from EPRI Report MRP-55[6]. The parameters used in the PFM model were benchmarked against the most severe cracking found to date in the industry (B&W Plants) and produced results that are in agreement with experience to date. The analyses were used to determine probability of nozzle failure versus EFPY for various head operating temperatures. Analyses were then performed to estimate the effect of visual and non-visual (NDE) inspections of the plants in the most critical inspection category, using the conservative assumption discussed above (see Concern #1 response) for probability of leakage detection by visual inspection. These analyses demonstrate that performing visual inspections significantly reduces the probability of nozzle ejection, and that performing such examinations on a regular basis (in accordance with the inspection schedule prescribed in the MRP Inspection Plan) effectively maintains the probability of nozzle ejection at an acceptably low level indefinitely.

In the extremely unlikely event that nozzle failure and rod ejection were to occur due to an undetected circumferential crack, an acceptable margin of safety to the public would still be maintained[10]. The consequences of such an event are similar to that of a small-break LOCA, which is a design-basis event. The probability of core damage given a nozzle failure (assuming that failure leads to ejection of the nozzle from the head) has been estimated by the industry to be 1×10^{-3}. The PFM analyses demonstrate that periodic visual inspections are capable of maintaining the probability of nozzle failure due to circumferential cracking well below 1×10^{-3}. Therefore, the PFM analyses demonstrate that the resulting incremental change in core damage frequency due to CRDM nozzle cracking can be maintained at less than 1×10^{-6} (i.e., 1×10^{-3} times 1×10^{-3} equals 1×10^{-6}) per plant year, through a program of periodic visual examinations performed in accordance with the MRP inspection plan. This result is consistent with NRC Regulatory Guide 1.174 that defines an acceptable change in core damage frequency (1×10^{-6} per plant year) for changes in plant design parameters, technical specifications, etc.

Concern 4: *The environment in the CRDM housing/RPV head annulus will likely be more aggressive after any through-wall leakage because potentially highly concentrated borated primary water may become oxygenated. This raises concerns about the technical basis for current crack growth rate models.*

Response: The MRP panel of international experts on SCC (including representatives from ANL/NRC Research), prior to the Davis-Besse incident, gave extensive consideration to the likely environment in the annulus between a leaking CRDM nozzle and the RPV head and revisited this issue subsequently[6]. When revisited, the relevant arguments remain valid for leak rates that are less than 1 liter/h or 0.004 gpm, which plant experience has shown to be the usual case. The conclusions were:

1. An oxygenated crevice environment is highly unlikely because:

   - Back diffusion of oxygen is too low compared to counterflow of escaping steam (two independent assessments based on molecular diffusion models were examined).
   - Oxygen consumption by the metal walls would further reduce its concentration.
   - Presence of hydrogen from leaking water and diffusion through the upper head results in a reducing environment.
   - Even if the concentration of hydrogen was depleted by local boiling, coupling between low alloy steel and Alloy 600 would keep the electrochemical potential low.
   - Corrosion potential will be close to the Ni/NiO equilibrium, resulting in PWSCC susceptibility similar to normal primary water.

2. The most likely crevice environments are either hydrogenated steam or PWR primary water within normal specifications and both would result in similar, i.e. non-accelerated, susceptibility of the Alloy 600 penetration material to PWSCC.

3. If the boiling interface happens to be close to the topside of the J-groove weld, itself a low probability occurrence, concentration of PWR primary water solutes, lithium hydroxide and boric acid, can in principle occur. Of most concern here would be the accelerating effect of elevated pH on SCC, but calculations and experiments show that any changes are expected to be small, in part because of the buffering effects of precipitates. A factor of 2x on the crack growth rate (CGR) conservatively covers possible acceleration of PWSCC, even up to a high-temperature pH of around 9.

For larger leakage rates, which could lead to local cooling of the head, concentration of boric acid, and development of a sizeable wastage cavity adjacent to the penetration, the above arguments no longer directly apply. However, limited data (Berge et al., 1997) on SCC in concentrated boric acid solutions indicate that:

- Alloy 600 is very resistant to transgranular SCC (material design basis).
- High levels of oxygen and chloride are necessary for intergranular cracking to occur at all.
- The effects are then worse at intermediate temperatures, suggesting that the mechanism is different from PWSCC.

The above considerations show that there is no basis for assuming that any post-leakage, crevice environment in the CRDM housing/RPV head annulus would be significantly more aggressive with regard to SCC of the Alloy 600 penetration material than normal PWR primary water, irrespective of the assumed leakage rate and/or annulus geometry. The current industry model[6], which includes a factor of 2x on CGR to cover residual uncertainty in the composition of the annulus environment, remains valid.

Concern 5: *The presence of boron deposits or residue on the RPV head, due to leakage from mechanical joints, could mask pressure boundary leakage. This raises concerns that a through-wall crack may go undetected for years.*

Response: The experience at Davis-Besse has clearly demonstrated that effective visual inspection for leakage from CRDM nozzle and weld PWSCC requires unobstructed inspection access and that the head surface be free of pre-existing boric acid deposits. This case has already been shown for St. Lucie Unit 2 based on the completed Bulletin 2001-01 bare metal inspection results. Accumulations of debris and boric acid deposits from other sources can interfere with a determination as to the presence or absence of boric acid deposits extruding from the tube-to-head annulus. Therefore, to effectively perform a visual examination of the RPV head outer surface for penetration leakage, such deposits and debris accumulations must be carefully inspected, removed, and the area re-inspected. Evaluation may show that it is necessary to perform a non-visual examination to establish the source of the leakage.

As identified in the response to Bulletin 2002-01, the St. Lucie Unit 1 and 2 CEDM and head vent penetration designs utilize a welded connection above the RPV head. The remaining RPV head instrument penetrations utilize a mechanical connection design, which is not prone to leakage. Therefore, boron deposits from these connections are unlikely.

Accordingly, each inspection at St. Lucie Unit 1 and 2 will be conducted with a questioning attitude and any boric acid deposit on the vessel head will be evaluated to determine its source in accordance with existing industry guidance, supplemented by the most recent industry experience at the time of the inspection. These requirements are incorporated in the visual inspection guidance contained in the MRP Inspection Plan. Implementation of these requirements will preclude the cited condition of a through-wall crack remaining undetected for years.

Concern 6: *The causative conditions surrounding the degradation of the RPV head at Davis-Besse have not been definitively determined. The staff is unaware of any data applicable to the geometries of interest that support accurate predictions of corrosion mechanisms and rates.*

Response: The causes of the Davis-Besse degradation are sufficiently well known to avoid significant wastage. The root cause evaluation performed by the utility[11] clearly identifies the root cause as PWSCC of CRDM nozzles followed by boric acid corrosion. The large extent of degradation has been attributed to failure of the utility to address evidence that had been accumulating over a five year period of time (Figure 26 of Ref. 11).

The industry has provided utilities with guidance for vessel top head visual inspections to ensure that conditions approaching that which existed at Davis-Besse will not occur. Visual inspection guidelines have been provided[5], and a workshop was conducted to thoroughly review industry experience, regulatory requirements, leakage detection, and analytical work performed to understand the causes of high wastage rates[8]. FPL has been active in reviewing this guidance and FPL representatives attended the workshop.

Subsequent to significant wastage being discovered on the Davis-Besse RPV head, the industry has performed analytical work to determine how a small leak such as seen at several plants can progress to the significant amounts of wastage discovered at Davis-Besse. This work is referenced within the basis for the MRP Inspection Plan (Ref. 1, Appendix C) and was previously presented to the NRC[12].

The analytical work shows that the corrosion rate is a strong function of the leakage rate. Finite element thermal analyses show that leak rates must reach approximately 0.1 gpm for there to be sufficient cooling of the RPV top head surface to support concentrated liquid boric acid that will produce high corrosion rates. The leak rate is in turn a strong function of the crack length. The effect of crack length above the J-groove weld on crack opening displacement and area has been confirmed by finite element modeling of nozzles including the effects of welding residual stresses and axial cracks. Leak rates have been calculated using crack opening displacements and areas determined by the finite element analyses and leak rate models based on PWSCC cracks in steam generator tubes.

Cracks that just reach the annulus through the base metal or weld metal will result in small leaks such as those that produced small volumes of boric acid deposits on several vessel heads at locations where the CRDM nozzles penetrate the RPV head outside surface. These leaks are typically on the order of 10^{-6} to 10^{-4} gpm. There is no report of any of these leaks resulting in significant corrosion. A leak rate of 10^{-3} gpm will result in the release of about 500 cubic inches of boric acid deposits in an 18-month operating cycle, which will be detectable by visual inspections.

The time for a crack to grow from a length that will produce a leak rate of 10^{-3} gpm to a leak rate of 0.1 gpm has been estimated by deterministic analyses based on the MRP crack growth models to be 1.7 years for plants with 602°F head temperatures. Probabilistic analyses show that there is less than a 1×10^{-3} probability that corrosion will proceed to the point that the inside surface cladding of the head would be uncovered over a significant area before the wastage would be detected by supplemental visual inspections as required under the MRP Inspection Plan. During the transition from leak rates of 10^{-3} gpm to 0.1 gpm, loss of material will be by relatively slow processes (Ref. 1, Appendix C).

The ability to detect leakage prior to the risk of structural failure is illustrated by Figure 26 of the Davis-Besse root cause analysis report (Ref. 11). There was visual evidence of boric acid deposits on the vessel head for five years prior to the degradation being detected. Guidance provided in the MRP Inspection Plan would not permit these conditions to exist without determining the source of the leak, including nondestructive examinations if necessary.

Therefore, while the exact timing of the event progression at Davis-Besse cannot be definitively established, the probable durations can be predicted with sufficient certainty to conclude that a visual inspection regimen can ensure continued structural integrity of the RCS pressure boundary.

NRC Request 2. *Within 30 days after plant restart following the next inspection of the RPV head and VHP nozzles to identify the presence of any degradation, all PWR addressees are requested to provide:*

A) *The inspection scope and results, including the location, size, extent, and nature of any degradation (e.g., cracking, leakage, and wastage) that was detected; details of the NDE used (i.e., method, number, type, and frequency of transducers or transducer packages, essential variables, equipment, procedure and personnel qualification requirements, including personnel pass/fail criteria); and criteria used to determine whether an indication, "shadow," or "backwall anomaly" is acceptable or rejectable.*

B) *The corrective actions taken and the root cause determinations for any degradation found.*

FPL Response to NRC Request 2.A and B:

FPL will provide this response within 30 days after plant restart following the next inspection at St. Lucie Units 1 and 2. This request is a duplicate of the request from Bulletin 2002-01. Accordingly, FPL will submit a response to the requests from Bulletin 2002-01 and 2002-02.

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1 "PWR Reactor Pressure Vessel (RPV) Upper Head Penetrations Inspection Plan (MRP-75)," Revision 1, EPRI, Palo Alto, CA: 2002. 1007337.

[2] Nuclear Energy Institute (NEI) Letter, "EPRI Technical Report 1007337, PWR Reactor Pressure Vessel (RPV) Upper Head Industry RVHP Inspection Program, (MRP-75), Project Number 689" Alex Marion (NEI) to Brian Sheron (NRC), September 10, 2002.

[3] FPL letter L-2001-198, "St. Lucie Units 1 and 2 and Turkey Point Units 3 and 4, Docket Nos. 50-335, 50-389, 50-250 and 50-251, Response to NRC Bulletin 2001-01, " R. S. Kundalkar to NRC, September 4, 2001.

[4] FPL letter L-2001-247, "St. Lucie Units 1 and 2, Docket Nos. 50-335, 50-389, Supplemental Response to NRC Bulletin 2001-01, " R. S. Kundalkar to NRC, November 1, 2001.

[5] "Visual Examination for Leakage of PWR Reactor Head Penetrations on Top of RPV head: Revision 1 of 1006296, Includes Fall 2001 Results," Electric Power Research Institute (EPRI), Palo Alto, CA: March 2002, 1006899.

[6] EPRI Document MRP-55, "Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Material," July 2002.

[7] NRC Letter, "Flaw Evaluation Criteria," Jack Strosnider, NRC, to Alex Marion, NEI, November 21, 2001.

[8] "Proceedings: EPRI Boric Acid Corrosion Workshop, July 25–26, 2002 (MRP-77)," Electric Power Research Institute (EPRI) Report 1007336, September 2002.

[9] EPRI TR-103696, "PWSCC of Alloy 600 Materials in PWR Primary System Penetrations", July 1994.

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[10] Walton Jensen, NRC, Reactor Systems Branch, Division of Systems Safety and Analysis (DSSA), Sensitivity Study of PWR Reactor Vessel Breaks, memo to Gary Holahan, NRC, DSSA, May 10, 2002.

[11] Davis-Besse Nuclear Power Station Report CR2002-0891, "Root Cause Analysis Report – Significant Degradation of the Reactor Pressure Vessel Head," April 2002.

[12] Glenn White, Chuck Marks and Steve Hunt, Technical Assessment of Davis-Besse Degradation, Presentation to NRC Technical Staff, May 22, 2002.

ATTACHMENT 2

Bulletin 2002-02 Response for Turkey Point Units 3 and 4

On August 9, 2002, the Nuclear Regulatory Commission (NRC) issued Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs." The NRC requested that specific information be provided within 30 days of the date of the Bulletin. Florida Power and Light Company (FPL) hereby responds to the 30-day information request set forth in the Bulletin with respect to Turkey Point Units 3 and 4.

NRC Request 1: *Within 30 days of the date of this bulletin:*

A. *PWR addressees who plan to supplement their inspection programs with non-visual NDE methods are requested to provide a summary discussion of the supplemental inspections to be implemented. The summary discussion should include EDY, methods, scope, coverage, frequencies, qualification requirements, and acceptance criteria.*

FPL Response to NRC Request 1.A:
Turkey Point Units 3 and 4 reactor pressure vessel (RPV) head and RPV head penetration nozzle inspections will combine both visual and non-visual methods at the next refueling outage.

The Electric Power Research Institute (EPRI) Material Reliability Program (MRP) Inspection Plan and supporting technical basis documents[1] have been developed by owners and operators of PWR units and have been transmitted to the NRC[2]. The MRP Inspection Plan presents a technically sound inspection regimen that assures to a high degree of certainty that leaks will be detected at an early stage long before wastage or circumferential cracking can challenge the structural integrity of the RCS pressure boundary. Furthermore, implementation of the MRP Inspection Plan will assure continued compliance with the Regulatory Requirements cited within NRC Bulletin 2002-02, since the MRP Inspection Plan addresses the safety aspects of the six concerns identified in the Bulletin. Therefore, FPL will implement the MRP Inspection Plan and will comply with its requirements, at a minimum, beginning with the next planned refueling outage (RFO).

As requested in the subject bulletin, FPL will supplement the visual inspection with ultrasonic examination of the RPV head penetration base material during the next scheduled RFO for Turkey Point Units 3 and 4. The next RFO for Turkey Point Unit 3 is scheduled to begin March 1, 2003 (PTN3-RFO20), and the next RFO for Turkey Point Unit 4 is scheduled to begin on October 4, 2003 (PTN4-RFO21). Penetrant testing will be used to assist in characterization of any leakage indication not confirmed in the tube material.

FPL is also evaluating its long-term plans for RPV head replacement at Turkey Point Units 3 and 4. Once those plans and schedules are complete, FPL will re-evaluate its commitment with respect to inspection plans. FPL will notify the NRC if its plans result in any changes to the Bulletin 2002-02 response.

The elements (EDY, methods, scope, coverage, frequencies, qualification requirements, and acceptance criteria) of these inspections are provided below:

1. Effective Degradation Years (EDY)

FPL has calculated EDY values for Turkey Point Units 3 and 4 for the next planned RFO according to the methodology described by equation 2.2 of MRP-48 (PWR Materials Reliability Program Response to NRC bulletin 2001-01).

Turkey Point Unit 3 will have approximately 18.3 EDY at the start of its next RFO on March 1, 2003. Turkey Point Unit 4 will have approximately 18.6 EDY at the start of its next RFO on October 4, 2003.

2. Supplemental Inspection Methods, Scope and Coverage

2.a. Ultrasonic Testing (UT) of the RPV Head Penetration Base Material

An ultrasonic (UT) examination of all of the RPV head penetrations including the head vent penetration tube locations will be performed at the next Turkey Point Units 3 and 4 RFOs with the exception of the two locations in each unit that contain a reactor vessel level monitoring system (RVLMS) probe. The exam scope will include the material starting from approximately 2" above the weld down to the bottom end (to the maximum extent possible) of the respective penetration. The UT examination has been demonstrated to detect both axial and circumferential flaws initiating from the inside diameter (ID) or outside diameter (OD) surface of the tube material. Since this UT examination will detect circumferential cracks in the tube, the concern regarding penetration ejection from crack propagation in the tube material is effectively addressed.

2.b. UT "Leak Path" Examination

A UT back reflection monitoring examination of the interference fit region above the weld will be performed to determine if a reactor coolant leak has occurred into the annulus causing corrosion in the interference fit region. This UT technique is referred to as a "leak path" examination. In all previous UT examinations of CRDMs with known leakage performed by Framatome ANP, the FPL contracted vendor, a leak path has been observed with the UT scan that corresponded to the known leakage. The UT "leak path" examination provides additional confirmation of the visual results and also addresses the concern of potential wastage resulting from a leak. Therefore, a complete UT examination for detection of axial and circumferential flaws combined with a "leak path" examination addresses the wastage concern resulting from leakage and the potential for a nozzle ejection resulting from a circumferential crack above the weld.

2.c. Reactor Vessel Head Leak Detection System

Turkey Point Units 3 and 4 have a reactor vessel head leak detection system capable of detecting leakage on top of the RPV head inside the CRDM cooling shroud. Primary side leakage is detectable by the containment area radiation monitors and increasing primary side water make-up, but exact determination of where a leak is located has been difficult. This standby system was installed as an enhancement to the normal on line monitoring of RCS leak rate and containment radiation monitoring. When this system is cycled to the head detection mode, it can provide the capability of determining if the leak is located in the area of the RPV head.

The system, which is designed to withstand the normal containment environment, obtains the samples to be monitored from the reactor head area (CRDM cooler discharge) for comparison with the background containment atmosphere sample. A Beta scintillation detector (Particulate), which provides a signal to a rate meter in a remote display rack in the computer room, analyzes the samples. The detector response to leaks is proportional to the RCS activity level.

This standby system is used as a tool and can be run to diagnose a potential RPV head leak. The system is currently checked for functionality periodically, by procedure, to determine system operability. This system has a rate meter alarm that illuminates, should the radiation level increase above 1 x 10^7 counts per minute as well as a fail alarm that is checked during the periodic operability check. As a standby system, the operability of Turkey Point Units 3 and 4 are not directly determined by output from this leak detection system. When cycled to the head detection mode, this system provides additional assurance that leakage would be detected on the RPV head between periods of inspection before significant degradation could occur. Therefore, this system, when combined with the other supplemental examinations, addresses the concern that through-wall leakage (and wastage) may go undetected for years.

2.d. Bare Metal Visual Examination of RPV Head Penetration to RPV Head Surface
As noted in the FPL response to question 1.D to Bulletin 2002-01[3], both Turkey Point Units 3 and 4 have completed the remote "qualified" bare metal visual examination that was indicated in the FPL response to Bulletin 2001-01[4]. These examinations were performed with all of the insulation removed from both Turkey Point RPV heads and no evidence of leakage or boric acid accumulations were noted. Therefore, visual examination performed at the next RFO for Turkey Point Units 3 and 4 will be a supplemental visual examination on top of the RPV head insulation since a 100% UT examination is planned for the RPV penetration material.

In addition, a bare metal visual examination will be performed at all RPV head penetration locations that the UT examinations identified in 2.a and 2.b above can not be performed, specifically the two locations that contain a RVLMS probe. Also, a bare metal visual examination will be performed at all locations with identified through-wall flaws or "leak path" indications from the UT examinations in 2.a and 2.b above, to determine if leakage or degradation has occurred. Therefore a visual examination with no evidence of boric acid leakage addresses the concern that wastage has not occurred on the top of the head or in the nozzle annulus since any leak would provide visual evidence of boron on the head.

2.e. Dye Penetrant (PT) Testing of the J-Groove Weld Wetted Surface
A dye penetrant (PT) examination will be performed on any RPV head penetration J-groove weld surface to disposition a location that has a relevant external visual indication of leakage that is suspected to originate from the RPV head penetration annulus and can not be confirmed as originating from the tube material by a UT examination.

2.f. Potential interferences: The planned scope of UT examinations at Turkey Point Units 3 and 4 is 100% of the RPV head penetrations with the exception of the two penetrations that contain a RVLMS probe. These two locations contain a welded retainer on the end of the RPV head penetrations to support the RVLMS probes rendering the penetration inaccessible for UT examination. A qualified visual will be performed at these locations. Physical restrictions may also exist for some portion of the Turkey Point Units 3 and 4 UT examinations. Specifically, the CRDM penetrations have guide/thermal sleeves with a funneled end installed inside the CRDM penetration to position the CRDM shaft. This results in an annular gap of approximately 0.125" or less for examination using a thin "gap scanning" UT probe. Each sleeve is centered by centering tabs attached to the sleeve above the weld to contact the CRDM penetration. Examination near these tabs with the gap scanning probe may be limited if the sleeve can not be rotated, and could affect examination in the area of interest. Actual coverage can only be determined after scanning and imaging the nozzle. Where significant limitations exist that preclude a reasonable determination of the integrity of a nozzle to be made, the limitations will be noted and reported as requested by Bulletin 2002-02 request 2.A.

3. Supplemental Inspection Frequencies:
The additional supplemental examinations described above in 2.a, 2.b, 2.d, and 2.e will each be performed during the next scheduled RFOs for Turkey Point Units 3 and 4 (PTN3-RFO20 and PTN4-RFO21). The leak detection system described above in 2.c is a diagnostic tool, which is only available when Turkey Point Units 3 or 4 is in operation at pressure, and will be tested periodically per procedure.

FPL expects that the recommended method of performing supplemental exams, vendor specific examination methods, as well as the examination frequency may change over the next operating cycle based on the availability of additional examination results. FPL will therefore work closely with the NRC, EPRI MRP, and ASME to establish an accepted frequency for performance of these exams during subsequent outages (PTN3-RFO21 and PTN4-RFO22 and beyond).

4. Qualification Requirements:
Currently, a qualification program similar to the ASME Section XI, mandatory Appendix VIII, "Performance Demonstration For Ultrasonic Examination Systems" does not exist for testing of the CRDM nozzle base material and J-groove weld configuration. The FPL selected vendor, Framatome ANP, has participated in a demonstration of the UT examination procedures to be used for detection of axial and circumferentially oriented flaws in the RPV head penetration tube material. These procedures and capabilities were demonstrated in blind testing as part of the EPRI MRP, and have been made available to the NRC. The demonstration has shown the procedures being used will detect both axial and circumferential flaws.

The "leak path" UT technique is a recently developed, Framatome ANP proprietary technology that has no formal industry or ASME qualification program. The basis of the "leak path" UT qualification is from empirical data obtained from UT examination of approximately 270 CRDM/CEDM nozzle penetrations to date. In March 2001, Framatome ANP began consistently scanning the nozzle interference fit region during UT examinations. In all subsequent UT examinations of CRDM's with known bare metal visual leakage, and where the interference fit has been scanned, a UT "leak path" has been observed. The "leak path" UT technique has been presented by Framatome ANP to the NRC on three separate occasions. The first meeting occurred on January 23, 2002 at the White Flint NRC offices as part of a pre-outage presentation for a utility specific examination application (ADAMS ML0202403310). The second disclosure of the "leak path" UT technique occurred on January 24, 2002 at the White Flint NRC offices as part of a pre-outage presentation for another utility specific application (ADAMS ML0203806880). Mr. William Bateman, Mr. Allen Hiser and Mr. Tim Steingass of the NRC were in attendance for both meetings. Subsequent to those meetings the NRC requested another meeting at the Framatome ANP Lynchburg offices to review the "leak path" technique in more detail. That meeting took place on February 12, 2002, which included Mr. Tim Steingass, Mr. Wally Norris, and Dr. Steve Doctor of the NRC.

The technical basis of the technique is described in a Framatome ANP proprietary document titled "Reactor Vessel Head Penetration Leak Path Qualification Report," dated February 6, 2002. Due to the proprietary nature of the document, Framatome ANP is willing to meet with NRC personnel for further discussions on the technique and experience to date and to support any review necessary.

The visual examination personnel and procedures will be qualified in accordance with the vendor's written practice, ASME Section XI, and supplemented by March 2002 EPRI report[5].

Dye penetrant examination personnel and procedures will be qualified in accordance with ASME sections V and XI.

Personnel utilized to perform these supplemental examinations will be certified in accordance with the vendor's written practices. FPL will review and approve all NDE personal certifications and procedures prior to examinations being performed.

5. Acceptance Criteria:

The acceptance of ultrasonic examinations will be determined based on the length, location and depth of an identified indication. FPL anticipates that flaws will be removed or evaluated. If the flaws are evaluated, the approach will be to size the flaw, apply the growth rate identified in MRP-55[6] to the next inspection interval, and evaluate using ASME Section XI flaw tolerance methods and acceptance criteria as modified by the NRC recommendation letter of November 21, 2001[7].

No acceptance criteria have been identified for the reactor vessel head leak detection system beyond the system alarms, since this system is not relied upon for plant operation or safe shutdown. Alarm indications or inoperability of this system that could indicate a potential RPV head leak, will be addressed for correction.

The acceptance criteria for the bare metal visual inspections is no evidence of leakage coming from the RPV head penetration at the intersection of the bare metal head. Typical indications of RPV penetration leakage are identified in the March 2002 EPRI report[5] and will be used as an aid for visual examiners. The acceptance criteria for a supplemental visual inspection at penetrations that have acceptable results from UT examinations identified in 2.a and 2.b above is a minimum detectable condition of any evidence of RCS leakage such as flow emanating from beneath the insulation, bulging insulation, or boric acid accumulation emerging upward through the joints and gaps between adjoining insulation panels from the RPV head surface[1].

The acceptance criteria for any PT examination that is performed as a result of positive indication of a leak, will be no indications.

Justification for the inspection approach above:

In the discussion section of Bulletin 2002-02, the NRC staff noted six specific concerns about the adequacy of current industry RVP head and VHP inspection programs that rely solely on a visual examination as the primary inspection method. FPL has reviewed the NRC's position and has taken steps to supplement examination of the RPV head and RPV head nozzles to address the NRC's concerns. Taken together, the supplemental examinations stated herein and the information provided below from the EPRI MRP-75 report[1] relating to the six NRC concerns ensures that unacceptable wastage or RPV head nozzle ejection will not occur at Turkey Point Units 3 and 4 between refueling outages.

Concern 1: *Circumferential cracking of CRDM nozzles was identified by the presence of relatively small amounts of boric acid deposits. This finding increases the need for more effective visual and non-visual NDE inspection methods to detect the presence of degradation in CRDM nozzles before nozzle integrity is compromised.*

Response: As stated in section 2.a and 2.b above, a UT examination of all of the RPV head penetration nozzles (subject to the limitations identified) will be performed during the next scheduled Turkey Point Units 3 and 4 RFOs. This UT examination has been demonstrated to detect the presence of circumferential cracks in the RPV head penetration tube material, effectively addressing this concern. Where physical limitations exist that prevent this examination the following justification is provided.

Since the initial industry discovery of circumferential cracks above the J-groove weld in 2001, visual inspection techniques and approaches employed have been dramatically improved and a heightened sense of awareness exists for the range in size and appearance of visual indications that must be further investigated. Non-visual techniques similarly have and continue to evolve to more effectively examine the penetration tube and associated welds for evidence of cracks. Recent events at Davis-Besse have not invalidated the fundamental inspection capability requirements previously established as necessary to identify the presence of PWSCC and subsequent associated wastage. The effectiveness of inspection techniques continues to be evaluated and improved.

EPRI MRP has published detailed guidance for performing visual examinations of RPV heads[5]. A utility workshop[8] was recently conducted to discuss this guidance and lessons learned from recent field experience (including Davis-Besse). RPV head bare metal visual examinations at Turkey Point Units 3 and 4 have been and will be performed and documented in accordance with written procedures and acceptance criteria that comply with the guidance of the MRP Inspection Plan. Evaluations and corrective actions will be rigorous and thoroughly documented.

In order for OD circumferential cracks above the J-groove weld to initiate and grow, a leak path must first be established to the CRDM annulus region from the inner wetted surface of the RPV head. If primary water does not leak to the annulus, the environment does not exist to cause circumferential OD cracking. Axial cracks in the CRDM nozzles or cracks in J-groove welds must first initiate and grow through-wall. Experience has shown that through-wall axial cracks will result in observable leakage at the base of the penetration on the outer surface of the vessel, even with interference fits. Alloy 600 steam generator drain pipes at Shearon Harris (1988) and pressurizer instrument nozzles at Nogent 1 and Cattenom 2 (1989) were all roll expanded but still developed leaks during operation (Ref. 1, Appendix B). Plant specific top head gap analyses have been performed for a large number of plants with nozzle initial interference fits ranging from 0 to 0.0034" which bounds the mean interference fit for Turkey Point Units 3 and 4 as identified in FPL's response to Bulletin 2001-01. These analyses have confirmed the presence of a physical leak path in essentially all nozzles under normal operating pressure and temperature conditions (Ref. 1, Appendix B).

The probability of detecting small CRDM leaks by visual inspections alone is high. "Visual inspections of the reactor coolant system pressure boundary have been proven to be an effective method for identifying leakage from primary water stress corrosion cracking (PWSCC) cracks in Alloy 600 base metal and Alloy 82/182 weld metal. Specifically, visual inspections have detected leaks in RPV head CRDM nozzles, RPV head thermocouple nozzles, pressurizer heater sleeves, pressurizer instrument nozzles, hot leg instrument nozzles, steam generator drain lines, a RPV hot leg nozzle weld, a power operated relief valve (PORV) safe end, and a pressurizer manway diaphragm plate[9] ." To date, no leaking (CRDM) nozzles have been discovered by non-visual NDE examinations except for the three nozzles at Davis-Besse where leakage would have been detected visually had there been good access for visual inspections and the head cleaned of pre-existing boric acid deposits from other sources (Ref. 1, Appendix B).

Finally, as described under Concern 3 below, detailed probabilistic fracture mechanics (PFM) analyses have been performed to demonstrate the effectiveness of visual inspections in protecting the CRDM nozzles against failure due to circumferential cracking (Ref. 1, Appendix A). Even though the above discussion illustrates that visual inspections performed in accordance with MRP recommendations have a high probability of detecting through-wall leakage, a very low probability of detection was assumed in the PFM analyses. The PFM analyses assume only a 60% probability that leakage will be detected if a CRDM nozzle is leaking at the time a visual inspection is performed. Furthermore, if a nozzle has been inspected previously, and leakage was missed, subsequent visual inspections are assumed to have only a 12% probability of detecting the leak that was previously missed. Even with these conservative probability of detection assumptions, the PFM analyses show that visual inspection every outage reduces the probability of a nozzle ejection to an acceptable level for plants with 18 or more EDY. Visual inspections of plants with fewer than 18 EDY in accordance with the MRP Inspection Plan will maintain the probability of nozzle ejection for these plants more than an order of magnitude lower than that for the greater than 18 EDY plants.

In summary, the industry has responded to the need to detect small amounts of leakage by increased visual inspection sensitivity, increased inspection frequencies, and improved inspection capabilities. Small amounts of leakage can be detected visually and it has been shown that timely detection by visual examination will ensure the structural integrity of the RPV head penetrations with respect to circumferential cracking.

Concern 2: *Cracking of Alloy 82/182 weld metal has been identified in CRDM nozzle J-groove welds for the first time and can precede cracking of the base metal. This finding raises concerns because examination of weld metal material is more difficult than base material.*

Response: Cracks in the J-groove weld do not pose an increased risk regarding nozzle ejection as compared to penetration base metal cracks. Cracking that is completely within the weld metal, even if 360° around the nozzle, will not lead to ejection since the portion of the weld that remains attached to the outside surface of the nozzle will not be able to pass through the tight annular fit[1]. J-groove weld cracks that initiate and grow through-wall will leak the same as cracks in the penetration base metal. Therefore, weld cracks pose a similar risk as cracks in the base material and are equally detectable by visual examination as well as by the supplemental inspections identified above. Although higher crack growth rates have been observed in laboratory testing of weld metal, the industry model of time-to-leakage includes plants that have had weld metal cracking as well as base metal cracking. The visual examination frequencies from the MRP Inspection Plan have been conservatively established based on the risk informed analyses considering leakage due to both weld metal and base metal cracking. The Turkey Point Units 3 and 4 RPV head leak detection system provides additional assurance that leakage will be detected.

Concern 3: *Through-wall circumferential cracking from the outside diameter of the CRDM nozzle has been identified for the first time. This raises concerns about the potential for failure of CRDM nozzles and control rod ejection, causing a LOCA.*

Response: As stated in section 2.a and 2.b above, a UT examination of all of the RPV head penetration nozzles (subject to the physical limitations identified) will be performed during the next scheduled Turkey Point Units 3 and 4 RFOs. These UT exams have been demonstrated to detect the presence of circumferential cracks in the RPV head penetration tube material, effectively addressing this concern. Where limitations exist that prevent this examination the following justification is provided.

Probabilistic fracture mechanics (PFM) analyses using a Monte-Carlo simulation algorithm were performed to estimate the probability of nozzle failure and control rod ejection due to through-wall circumferential cracking (Ref. 1, Appendix A). The PFM analyses conservatively assume that, once a leak path has extended to the annulus region, an OD circumferential crack develops instantaneously, with a length encompassing 30° of the nozzle circumference. Fracture mechanics crack growth calculations are then performed for this initially assumed crack, using material crack growth rate data from EPRI Report MRP-55[6]. The parameters used in the PFM model were benchmarked against the most severe cracking found to date in the industry (B&W Plants) and produced results that are in agreement with experience to date. The analyses were used to determine probability of nozzle failure versus EFPY for various head operating temperatures. Analyses were then performed to estimate the effect of visual and non-visual (NDE) inspections of the plants in the most critical inspection category, using the conservative assumption discussed above (see Concern #1 response) for probability of leakage detection by visual inspection. These analyses demonstrate that performing visual inspections significantly reduces the probability of nozzle ejection, and that performing such examinations on a regular basis (in accordance with the inspection schedule prescribed in the MRP Inspection Plan) effectively maintains the probability of nozzle ejection at an acceptably low level indefinitely.

In the extremely unlikely event that nozzle failure and rod ejection were to occur due to an undetected circumferential crack, an acceptable margin of safety to the public would still be maintained[10]. The consequences of such an event are similar to that of a small-break LOCA, which is a design-basis event. The probability of core damage given a nozzle failure (assuming that failure leads to ejection of the nozzle from the head) has been estimated by the industry to be 1×10^{-3}. The PFM analyses demonstrate that periodic visual inspections are capable of maintaining the probability of nozzle failure due to circumferential cracking well below 1×10^{-3}. Therefore, the PFM analyses demonstrate that the resulting incremental change in core damage frequency due to CRDM nozzle cracking can be maintained at less than 1×10^{-6} (i.e., 1×10^{-3} times 1×10^{-3} equals 1×10^{-6}) per plant year, through a program of periodic visual examinations performed in accordance with the MRP inspection plan. This result is consistent with NRC Regulatory Guide 1.174 that defines an acceptable change in core damage frequency (1×10^{-6} per plant year) for changes in plant design parameters, technical specifications, etc.

Concern 4: *The environment in the CRDM housing/RPV head annulus will likely be more aggressive after any through-wall leakage because potentially highly concentrated borated primary water may become oxygenated. This raises concerns about the technical basis for current crack growth rate models.*

Response: The MRP panel of international experts on SCC (including representatives from ANL/NRC Research), prior to the Davis-Besse incident, gave extensive consideration to the likely environment in the annulus between a leaking CRDM nozzle and the RPV head and revisited this issue subsequently[6]. When revisited, the relevant arguments remain valid for leak rates that are less than 1 liter/h or 0.004 gpm, which plant experience has shown to be the usual case. The conclusions were:

1. An oxygenated crevice environment is highly unlikely because;

   - Back diffusion of oxygen is too low compared to counterflow of escaping steam (two independent assessments based on molecular diffusion models were examined).
   - Oxygen consumption by the metal walls would further reduce its concentration.
   - Presence of hydrogen from leaking water and diffusion through the upper head results in a reducing environment.
   - Even if the concentration of hydrogen was depleted by local boiling, coupling between low alloy steel and Alloy 600 would keep the electrochemical potential low.
   - Corrosion potential will be close to the Ni/NiO equilibrium, resulting in PWSCC susceptibility similar to normal primary water.

2. The most likely crevice environments are either hydrogenated steam or PWR primary water within normal specifications and both would result in similar, i.e. non-accelerated, susceptibility of the Alloy 600 penetration material to PWSCC.

3. If the boiling interface happens to be close to the topside of the J-groove weld, itself a low probability occurrence, concentration of PWR primary water solutes, lithium hydroxide and boric acid can in principle occur. Of most concern here would be the accelerating effect of elevated pH on SCC, but calculations and experiments show that any changes are expected to be small, in part because of the buffering effects of precipitates. A factor of 2x on the crack growth rate (CGR) conservatively covers possible acceleration of PWSCC, even up to a high-temperature pH of around 9.

For larger leakage rates, which could lead to local cooling of the head, concentration of boric acid, and development of a sizeable wastage cavity adjacent to the penetration, the above arguments no longer directly apply. However, limited data (Berge et al., 1997) on SCC in concentrated boric acid solutions indicate that:

- Alloy 600 is very resistant to transgranular SCC (material design basis).
- High levels of oxygen <u>and</u> chloride are necessary for intergranular cracking to occur at all.
- The effects are then worse at intermediate temperatures, suggesting that the mechanism is different from PWSCC.

The above considerations show that there is no basis for assuming that any post-leakage, crevice environment in the CRDM housing/RPV head annulus would be significantly more aggressive with regard to SCC of the Alloy 600 penetration material than normal PWR primary water, irrespective of the assumed leakage rate and/or annulus geometry. The current industry model[6], which includes a factor of 2x on CGR to cover residual uncertainty in the composition of the annulus environment, remains valid.

Concern 5: *The presence of boron deposits or residue on the RPV head, due to leakage from mechanical joints, could mask pressure boundary leakage. This raises concerns that a through-wall crack may go undetected for years.*

Response: The experience at Davis-Besse has clearly demonstrated that effective visual inspection for leakage from CRDM nozzle and weld PWSCC requires unobstructed inspection access and that the head surface be free of pre-existing boric acid deposits. This case has already been shown for both Turkey Point Units 3 and 4 based on the completed Bulletin 2001-01 bare metal inspection results[3]. Accumulations of debris and boric acid deposits from other sources can interfere with a determination as to the presence or absence of boric acid deposits extruding from the tube-to-head annulus. Therefore, to effectively perform a visual examination of the RPV head outer surface for penetration leakage, such deposits and debris accumulations must be carefully inspected, removed, and the area re-inspected. Evaluation may show that it is necessary to perform a non-visual examination to establish the source of the leakage.

As identified in the response to Bulletin 2002-01[3], the Turkey Point Unit 3 and 4 CRDM and head vent penetration designs utilize a welded connection above the RPV head. The remaining 4 RPV head instrument ports/penetrations per RPV head utilize a mechanical connection design, which is not prone to leakage. Therefore, boron deposits from these connections are unlikely.

Accordingly, each inspection at Turkey Point Unit 3 and 4 will be conducted with a questioning attitude and any boric acid deposit on the vessel head will be evaluated to determine its source in accordance with existing industry guidance, supplemented by the most recent industry experience at the time of the inspection. These requirements are incorporated in the visual inspection guidance contained in the MRP Inspection Plan. Implementation of these requirements will preclude the cited condition of a through-wall crack remaining undetected for years.

Concern 6: *The causative conditions surrounding the degradation of the RPV head at Davis-Besse have not been definitively determined. The staff is unaware of any data applicable to the geometries of interest that support accurate predictions of corrosion mechanisms and rates.*

Response: The causes of the Davis-Besse degradation are sufficiently well known to avoid significant wastage. The root cause evaluation performed by the utility[11] clearly identifies the root cause as PWSCC of CRDM nozzles followed by boric acid corrosion. The large extent of degradation has been attributed to failure of the utility to address evidence that had been accumulating over a five year period of time (Figure 26 of Ref. 11).

The industry has provided utilities with guidance for vessel top head visual inspections to ensure that conditions approaching that which existed at Davis-Besse will not occur. Visual inspection guidelines have been provided[5], and a workshop was conducted to thoroughly review industry experience, regulatory requirements, leakage detection, and analytical work performed to understand the causes of high wastage rates[8]. FPL has been active in reviewing this guidance and FPL representatives attended the workshop.

Subsequent to significant wastage being discovered on the Davis-Besse RPV head, the industry has performed analytical work to determine how a small leak such as seen at several plants can progress to the significant amounts of wastage discovered at Davis-Besse. This work is referenced within the basis for the MRP Inspection Plan (Ref. 1, Appendix C) and was previously presented to the NRC[12].

The analytical work shows that the corrosion rate is a strong function of the leakage rate. Finite element thermal analyses show that leak rates must reach approximately 0.1 gpm for there to be sufficient cooling of the RPV top head surface to support concentrated liquid boric acid that will produce high corrosion rates. The leak rate is in turn a strong function of the crack length. The effect of crack length above the J-groove weld on crack opening displacement and area has been confirmed by finite element modeling of nozzles including the effects of welding residual stresses and axial cracks. Leak rates have been calculated using crack opening displacements and areas determined by the finite element analyses and leak rate models based on PWSCC cracks in steam generator tubes.

Cracks that just reach the annulus through the base metal or weld metal will result in small leaks such as those that produced small volumes of boric acid deposits on several vessel heads at locations where the CRDM nozzles penetrate the RPV head outside surface. These leaks are typically on the order of 10^{-6} to 10^{-4} gpm. There is no report of any of these leaks resulting in significant corrosion. A leak rate of 10^{-3} gpm will result in the release of about 500 cubic inches of boric acid deposits in an 18-month operating cycle, which will be detectable by visual inspections.

The time for a crack to grow from a length that will produce a leak rate of 10^{-3} gpm to a leak rate of 0.1 gpm has been estimated by deterministic analyses based on the MRP crack growth models to be 1.7 years for plants with 602°F head temperatures. Probabilistic analyses show that there is less than a 1×10^{-3} probability that corrosion will proceed to the point that the inside surface cladding of the head would be uncovered over a significant area before the wastage would be detected by supplemental visual inspections as required under the MRP Inspection Plan. During the transition from leak rates of 10^{-3} gpm to 0.1 gpm, loss of material will be by relatively slow processes (Ref. 1, Appendix C).

The ability to detect leakage prior to the risk of structural failure is illustrated by Figure 26 of the Davis-Besse root cause analysis report (Reference 11). There was visual evidence of boric acid deposits on the vessel head for five years prior to the degradation being detected. Guidance provided in the MRP Inspection Plan would not permit these conditions to exist without determining the source of the leak, including nondestructive examinations if necessary.

Therefore, while the exact timing of the event progression at Davis-Besse cannot be definitively established, the probable durations can be predicted with sufficient certainty to conclude that a visual inspection regimen can ensure continued structural integrity of the RCS pressure boundary.

NRC Request 2. *Within 30 days after plant restart following the next inspection of the RPV head and VHP nozzles to identify the presence of any degradation, all PWR addressees are requested to provide:*

A) The inspection scope and results, including the location, size, extent, and nature of any degradation (e.g., cracking, leakage, and wastage) that was detected; details of the NDE used (i.e., method, number, type, and frequency of transducers or transducer packages, essential variables, equipment, procedure and personnel qualification requirements, including personnel pass/fail criteria); and criteria used to determine whether an indication, "shadow," or "backwall anomaly" is acceptable or rejectable.

B) The corrective actions taken and the root cause determinations for any degradation found.

FPL Response to NRC Request 2.A and B:

FPL will provide this response within 30 days after plant restart following the next inspection at Turkey Point Units 3 and 4. This request is a duplicate of the request from Bulletin 2002-01. Accordingly, FPL will submit a response to the requests from Bulletin 2002-01 and 2002-02.

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1 "PWR Reactor Pressure Vessel (RPV) Upper Head Penetrations Inspection Plan (MRP-75), " Revision 1, Electric Power Research Institute (EPRI), Palo Alto, CA: 2002. 1007337.

[2] Nuclear Energy Institute (NEI) Letter, "EPRI Technical Report 1007337, PWR Reactor Pressure Vessel (RPV) Upper Head Industry RVHP Inspection Program, (MRP-75)," Project Number 689" Alex Marion (NEI) to Brian Sheron (NRC), September 10, 2002.

[3] FPL letter L-2002-061, "St. Lucie Units 1 and 2, Docket Nos. 50-335 and 50-389, Turkey Point Units 3 and 4, Docket Nos. 50-250 and 50-251, Response to NRC Bulletin 2002-01, " J. A. Stall to NRC, April 2, 2002.

[4] FPL letter L-2001-198, "St. Lucie Units 1 and 2 and Turkey Point Units 3 and 4, Docket Nos. 50-335, 50-389, 50-250 and 50-251, Response to NRC Bulletin 2001-01, " R. S. Kundalkar to NRC, September 4, 2001.

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[5] "Visual Examination for Leakage of PWR Reactor Head Penetrations on Top of RPV head: Revision 1 of 1006296, Includes Fall 2001 Results," EPRI, Palo Alto, CA: March 2002, 1006899.

[6] EPRI Document MRP-55, "Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Material," July 2002.

[7] NRC Letter, "Flaw Evaluation Criteria," Jack Strosnider, NRC, to Alex Marion, NEI, November 21, 2001.

[8] "Proceedings: EPRI Boric Acid Corrosion Workshop, July 25–26, 2002 (MRP-77)," Electric Power Research Institute (EPRI) Report 1007336, September 2002.

[9] "PWSCC of Alloy 600 Materials in PWR Primary System Penetrations", EPRI TR-103696, July 1994.

[10] Walton Jensen, NRC, Reactor Systems Branch, Division of Systems Safety and Analysis (DSSA), Sensitivity Study of PWR Reactor Vessel Breaks, memo to Gary Holahan, NRC, DSSA, May 10, 2002.

[11] Davis-Besse Nuclear Power Station Report CR2002-0891, "Root Cause Analysis Report – Significant Degradation of the Reactor Pressure Vessel Head," April 2002.

[12] Glenn White, Chuck Marks and Steve Hunt, Technical Assessment of Davis-Besse Degradation, Presentation to NRC Technical Staff, May 22, 2002.