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June 30, 1994

Mr. William T. Russell, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Document Control Desk

Subject: Dresden Nuclear Power Station Units 2 and 3
Quad Cities Nuclear Power Stations Units 1 and 2
Commonwealth Edison's (ComEd) Integrated Evaluation
Report for the Core Shroud Cracking Issue at Dresden and
Quad Cities Stations
NRC Docket Nos. 50-237/249 and 50-254/265

References. See Attached

Dear Mr. Russell:

In April of this year, ComEd informed the NRC staff of observed cracking in the core shrouds at both Dresden Unit 3 and Quad Cities Unit 1. The cracks were discovered by ComEd during visual examinations (VT) of the core shroud during the current refueling outages. The VTs were performed in accordance with the inspection plans discussed in ComEd's March 31, 1994, submittal to the NRC staff. ComEd subsequently corroborated the VT results using both ultrasonic (UT) examination techniques and by analyzing boat samples cut from the affected weldments.

The referenced correspondence shows that ComEd has worked expeditiously and openly with the NRC staff to resolve this issue. NRC staff questions have proved beneficial in determining our conclusion; there exists no risk to the health and safety of the public by the continued operation of Dresden Unit 2 and Quad Cities Unit 2 until their next currently scheduled refueling outages (Spring 1995, for both units). Additionally, there is no adverse risk to the public health and safety by the restart of Dresden Unit 3 and Quad Cities Unit 1 from their current refueling outages. Even with the most appropriate conservatisms applied, operating margins far exceed any potential uncertainties that may exist during the subsequent operation of Dresden Unit 3 and Quad Cities Unit 1 for the next complete operating cycle.

However, ComEd recognizes a need for additional work (technical audits, verification, further analyses, testing, etc.) which can increase or decrease the operating margins. Consequently, ComEd will continuously evaluate future BWR core shroud inspection activity for applicability to Dresden and Quad Cities. ComEd's current plans are summarized as follows:

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- Continue follow-up work and communicate the status of results to the NRC staff by December 15, 1994;
- Quad Cities Unit 1: reinspect and/or repair - Q1R14 (Fall 1995);
- Quad Cities Unit 2: initial inspection and/or repair - Q2R13 (Spring 1995);
- Dresden Unit 2: initial inspection and/or repair - D2R14 (Spring 1995);
- Dresden Unit 3: reinspect and/or repair - D3R14 (Spring 1996).

If ComEd's evaluation activities result in operating margins below acceptable levels, the aforementioned priorities and schedules will be revised as necessary. These revisions will be appropriate to the magnitude of changes in operating margins, including immediate shutdown of the affected units. Any changes to our inspection and/or repair activities will be discussed with the NRC staff prior to their implementation.

Attached is an integrated evaluation of the core shroud cracking issue summarizing our evaluations (as provided to the NRC staff in the referenced correspondence) that support our conclusions. Please direct any questions you may have concerning this response to this office.

Sincerely,

Peter L. Piet
Nuclear Licensing Administrator

Attachment: Commonwealth Edison's Integrated Evaluation Report for the Core Shroud Cracking Issue at Dresden and Quad Cities Stations

cc: J.B. Martin, Regional Administrator - RIII
J. Stang, Project Manager - NRR
C. Patel, Project Manager - NRR
C. Miller, Senior Resident Inspector - Quad Cities
M. Leach, Senior Resident Inspector - Dresden
Office of Nuclear Facility Safety - IDNS

REFERENCES

(a) P.Piet letter to T. Murley, dated March 31, 1994, providing initial screening and acceptance criteria for Dresden and Quad Cities core shroud inspections.

(b) J. Stang letter to D. Farrar, dated May 6, 1994, NRC request for additional information (RAI).

(c) Meeting between ComEd (Lyster, et.al.) and NRC staff (Taylor, Russell, et.al.), dated May 26, 1994.

(d) M. Lyster letter to W. Russell, dated June 6, 1994, ComEd response to NRC RAI.

(e) M. Lyster letter to W. Russell, dated June 13, 1994, ComEd supplemental response to 6/6/94 RAI response.

(f) R. Walsh letter to W. Russell, dated June 13, 1994, Quad Cities Flaw Evaluations.

(g) M. Lyster letter to W. Russell, dated June 13, 1994, Dresden Flaw Evaluations.

(h) J. Williams letter to W. Russell, dated June 14, 1994, UT and Flaw Reports.

(i) Meeting between ComEd (Williams, et.al.) and NRC Staff (Capra, Rubin, et.al.), dated June 21, 1994.

(j) J. Stang letter to D. Farrar, dated June 23, 1994, Second NRC request for additional information (RAI).

(k) M. Lyster letter to W. Russell, dated June 24, 1994, Clarification of UT Methods.

(l) P. Piet letter to W. Russell, dated June 25, 1994, ComEd response to second NRC RAI.

(m) Meeting between ComEd (Williams, et.al.) and NRC Staff (Strosnider, Capra, Hermann, Wickman, et.al.), dated June 27, 1994.

(n) G. Spedl letter to W. Russell, dated June 28, 1994, Dresden/Quad Cities 10 CFR 50.59 safety evaluation summary.

(o) P. Piet letter to W. Russell, dated June 30, 1994, Clarification of Information Related to Commonwealth Edison's (ComEd) Finite Element Analysis Model

COMMONWEALTH EDISON'S
INTEGRATED EVALUATION REPORT FOR THE CORE SHROUD CRACKING ISSUE
AT DRESDEN AND QUAD CITIES STATIONS

1.0 INTRODUCTION AND BACKGROUND

In April 1994, Commonwealth Edison (ComEd) informed the NRC staff of observed cracking in the core shrouds at the H5 weld location for both Dresden Unit 3 and Quad Cities Unit 1. Weld H5 joins the upper side of the core plate support ring to the shroud barrel. The cracks were discovered by ComEd during visual examinations (VT) of the core shroud during the current refueling outages. The VTs were performed by ComEd in accordance with the inspection plans discussed in ComEd's March 31, 1994 submittal to the NRC staff. ComEd's inspection plan was consistent with the recommendations contained in General Electric Company (GE) Rapid Information Communication Service Information Letter (RICSIL) 054, "Core Support Shroud Crack Indications," and SIL 572, Rev. 1.

ComEd's VTs of the Dresden Unit 3 and Quad Cities Unit 1 core shroud revealed circumferential cracking at horizontal weld H5. This was based upon an examination of 100% of all accessible areas on the outside diameter (OD) of the weld's circumference, and determined that the flaw existed in all examined areas. Depth characterization by ultrasonic testing (UT) indicated that the maximum crack depth at the H5 weld was 0.57 inches for Quad Cities Unit 1 and 0.84 inches for Dresden Unit 3. All other welds at both Dresden Unit 3 and Quad Cities Unit 1 (H1, H2, H3, H4, H6 and H7) were examined and found to be structurally acceptable.

To further corroborate the UT testing results at the H5 weld location, ComEd cut boat samples for Dresden Unit 3 and Quad Cities Unit 1. Based upon a comparison of the UT examination findings against the results of the boat samples, the limit of detectability at the near surface and the flaw sizing accuracy predicted for the UT system were not reliably achieved. The boat samples also confirmed the type of cracking to be intergranular stress corrosion cracking (IGSCC) typical of type 304 austenitic stainless steel in the BWR environment.

2.0 METHODS, SCOPE, AND RESULTS OF FLAW INSPECTIONS

In a letter to the NRC staff dated June 6, 1994, ComEd described the methods, scope, and results of inspections performed on the core shrouds at Dresden Station Unit 3 and Quad Cities Unit 1.

The original scope of the core shroud inspections at Dresden Station Unit 3 and Quad Cities Station Unit 1 consisted of a visual examination of the circumferential shroud welds H1 through H7 from the outside diameter (OD) and, where accessible, from the inner diameter (ID). The primary objective of the inspection was to identify sufficient unflawed material at each weld location to positively demonstrate shroud integrity under all design basis events for at least one operating cycle.

ComEd described the core shroud visual inspection results in a letter to the NRC staff dated June 6, 1994 (Table 1 for Dresden Station Unit 3 and Table 2 for Quad Cities Station Unit 1).

Consistent with the primary objective of positively demonstrating shroud integrity under all design basis events for at least one operating cycle, ComEd commissioned General Electric to develop modifications to the existing OD tracker and suction cup ultrasonic examination systems. The purposes of these modifications were to develop an ultrasonic examination system capable of characterizing the visual examination findings at the H5 weld and to corroborate the visual examination findings at the H6 and H7 welds. Ultrasonic examination was also used to corroborate the visual examination findings at the H2 weld since, as in welds H6 and H7, the visual examination was limited to one side only.

ComEd described the core shroud ultrasonic examination results in a letter to the NRC staff dated June 6, 1994, (Table 3 for Dresden Station Unit 3 and Table 4 for Quad Cities Station Unit 1).

2.1 Qualification and Expected Reliability of Visual Examination Testing Methods

ComEd indicated that the visual examinations of the core shroud at Dresden Station Unit 3 and Quad Cities Station Unit 1 were conducted by Level II and Level III certified VT-1 visual examiners from both Commonwealth Edison and General Electric, utilizing underwater video equipment capable of resolving a 0.001 inch wire. Distances from the camera lens to the inspection surface varied somewhat due to accessibility. However, in general, the focal distance from the camera to the inspection surface ranged between 1 inch and 5 inches. At a 1 inch focal distance using a 25 millimeter lens, the effective magnification is approximately 4X and at a 5 inch focal distance it is approximately 2X.

Additionally, all visual examinations were recorded on high resolution videotape and were independently reviewed by a Level II or III certified VT-1 visual examiner in order to substantiate the inspection findings. Based on the above, ComEd concluded that the visual examination performed was of high reliability.

The OD visual examinations below the H2 weld were limited to the areas between the jet pumps. This limitation resulted in a maximum possible inspection area of approximately 40% of the shroud circumference below the

H2 weld when inspecting from the OD. The ID visual examinations were limited to the H3 and H4 welds only due to the proximity of the core spray spargers above the H3 location, and the core plate below the H4 location. The ID examinations at the H3 and H4 locations were only limited by the focal distances achievable through the periphery of the top guide.

2.2 Qualification and Expected Reliability of Ultrasonic Examination Testing Methods

The ultrasonic techniques used by ComEd for the core shroud examinations are a standard 45 degree shear wave, full V-path pulse echo method, and the 60 degree refracted longitudinal wave pitch catch method. The 45 degree shear wave is the primary detection search unit, while the 60 degree RL is used for sizing and confirmation. Original qualifications of these techniques were performed on blocks of 304 stainless steel, with EDM notches machined in both surfaces of the block ranging from 0.0625" to 1.0" in depth. The techniques have also been qualified on actual "as-built" weld configurations (such as the H1, H2, and H3 welds). Scanning was performed from both the OD and ID surfaces of these mock-ups to determine the accuracy from both surfaces. Qualifications were also performed on plate-to-plate blocks with a typical weld in the block. In all cases the 45 degree shear wave was limited in its ability to penetrate the weld material and consequently, is only valid for examination on the same side of the weld from which the sound beam originates. However, the 60 degree RL did reliably penetrate the weld metal to detect and size weld defects on the opposite side of the weld. All ultrasonic qualifications were performed by scanning the qualification block statically and then dynamically. Additionally, all qualification blocks were attached to a qualification fixture and lowered into the General Electric reactor "mockup" in order to qualify the ultrasonic technique at depth.

The qualification process described above was used to generically qualify the UT techniques and procedure for core shroud inspection. However, plant specific UT accuracy must be demonstrated based upon the specific core shroud geometry of the plant being inspected. For the Dresden and Quad Cities examination two special calibration/qualification blocks were manufactured. The first block was for the H5/H6 weld configuration, which was a welded "mock-up" built to match the Dresden Station and Quad Cities Station core shroud configuration. The second calibration/qualification block was for the H7 weld configuration. This block was made of Inconel 600 material with EDM notches installed a fixed distance from a simulated backing ring. Based upon the generic qualification data and the Dresden/Quad Cities specific qualification block data, the following initial conclusions regarding UT detectability and sizing accuracy for the Dresden Station and Quad Cities Station core shroud examinations:

- The 45 degree shear wave search unit can reliably detect a flaw on the same surface (scanning surface), using a full V-path, of 0.100" to 0.125" in depth.

Using a 1/2 V-path, the 45 degree shear wave can reliably detect a flaw on the opposite surface of less than 0.100" in depth.

- The 60 degree RL search unit, which is primarily used for confirmation and sizing, is limited in its ability to detect flaws on the same surface (scanning surface) by the front of the wedge to exit point dimension on the search unit, and the near field affects. The limit of detectability for this search unit, which is focused at 0.800", is approximately 0.200".

- The limiting variable for both the 45 and 60 degree search units is the flaw morphology, which can affect both detectability and sizing accuracy. Not withstanding this, sizing accuracy for flaws that fall within the detectability bounds described above is plus or minus 0.100". This level of accuracy is supported by empirical metallurgical data obtained from several boat samples previously removed from BWR shrouds. These boat samples have shown the actual measured crack depth to be within .060" to .100" of the ultrasonic depth measurement, using the 60 degree RL tip diffraction method of sizing.

2.3 Use of Boat Samples for Validation of Ultrasonic Examination Testing Methods & Exclusion Zone Approach

In order to validate the ultrasonic examinations of the H5 weld, ComEd removed two boat samples from the H5 welds at both Dresden Station Unit 3 and Quad Cities Station Unit 1. The boat samples at Quad Cities Station Unit 1 were removed prior to the UT examination, while the boat samples at Dresden Station Unit 3 were removed after the UT examination. The results of the boat sample validation are described in ComEd's letters to the NRC staff dated June 6, 1994 and June 24, 1994.

Based upon a comparison of the ultrasonic examination findings against the results of the boat samples, ComEd concluded that the limit of detectability at the near surface and the flaw sizing accuracy predicted for the OD Tracker system were not reliably achieved.

The inconsistencies between the depths of flaws determined by UT sizing techniques versus the actual measured depths determined by examination of boat sample cross-sections was discovered at the H5 weld location during the recent ultrasonic examination of the Dresden Unit 3 and Quad Cities Unit 1 shrouds. An alternate approach was developed to establish with a high degree of confidence the depth of uncracked material in the shroud. This alternate approach is identified as the exclusion zone approach.

ComEd's approach is based upon the acquisition of consistent geometry signals when examining the H5 fillet weld with UT. If a flaw were to penetrate the sound path of the transducer during the examination of the inner diameter (ID) of the fillet weld region, recognizable responses would be detected. The exclusion zone approach is similar to that utilized by the EPRI NDE center to detect Intergranular Stress Corrosion Cracking (IGSCC). ComEd's approach is discussed in more detail in the attachment to the June 24, 1994 letter to the NRC staff.

In meetings held with ComEd on June 21 and June 27, 1994, the NRC staff expressed concerns regarding the potential transparency of a flaw using ComEd's approach near a crack tip. It was noted that this phenomenon may have occurred during the qualification of other plants' core shroud UT using refracted L-wave techniques. ComEd's methodology detected shallow crack indications along with the ID fillet weld using 45 degree shear wave UT. These flaws were determined by boat sample evaluation to be IGSCC, demonstrating the detectability of IGSCC with 45 degree shear wave UT. Because the ID fillet weld was observed in each of the more than 2000 stepped transducer scans performed on the H5 weld, it is unlikely that a crack-like defect intersecting the central beam path would remain transparent along the entire inspected length.

The exclusion zone approach requires that no significant cracking be present at the inside surface of the H5 weld lower toe. ComEd did not identify any indications of cracking at the inside surface of the H5 weld lower toe during the UT examinations of the H5 welds at Dresden Unit 3 and Quad Cities Unit 1.

ComEd concludes that the exclusion zone approach is a valid and conservative technique for determining a bounding crack depth for the H5 weld, for the following reasons: the ID fillet weld was consistently identified during the UT examinations; the metallography results show the cracks to be relatively open and exhibit grain encirclement, and the shear wave technique is very sensitive to grain boundaries; the bounding flaw represents the largest flaw that could possibly exist; and flaws shadowing the root is an established flaw detection method.

Due to the geometry of the H5 weld at Dresden Station and Quad Cities Station, the UT examination results can be used to demonstrate that the flaw can not be any greater than 1.24 inches in depth. The H5 weld contains a 1.0 inch reinforcing fillet on the ID of the weld. A signal from the toe of this reinforcing fillet at the shroud cylinder was observed with the 45 degree transducer throughout the entire H5 examination. ComEd determined geometrically that a flaw which started at the sound beam entry surface, and intersected the sound beam at its central axis, would be 1.24 inches in depth. This is conservative because beam spread would actually permit the detection of shallower flaws. A flaw deeper than 1.24 inches would prevent the sound beam from reaching the toe of the reinforcing fillet and the signal from this reflector would be lost. Based upon this information, ComEd has concluded that the bounding depth of the H5 flaws at both Dresden Station Unit 3 and Quad Cities Unit 1 is 1.24 inches.

2.4 Summary of Examination Methods

Based upon the expected reliability of visual examinations; the ultrasonic examination techniques and qualifications (and associated conclusions); and the results of boat samples, ComEd concluded that the postulated bounding crack depth of 1.24 inches is conservative and appropriate.

3.0 FRACTURE MECHANICS EVALUATION

In letters dated June 6, June 13 and June 24, 1994 to the NRC staff, ComEd stated that, based upon the results of automated and manual UT exams of the H5 welds and on the results of boat samples taken from the H5 welds, at Dresden Station Unit 3 and Quad Cities Station Unit 1, no flaws deeper than 1.24 inches were detected in either unit.

In addition, ComEd determined that based upon the UT examinations and boat sample results, the probability of detection of flaws deeper than 1.24 inches on the core plate support ring side of the H5 weld is very high. Backwall reflectors were readily observed during the automated and manual UT examinations, assuring a high probability of detection of any flaws from the surface opposite the scanned surface. No flaws initiating from the opposite (ID) surfaces were detected. ComEd concluded that, based on the use of conservative bounding maximum flaw depth and on the low uncertainty associated with backwall reflector detection, the factor of safety of 1.39 under emergency and faulted conditions imposed by ASME Section XI Appendix C provides sufficient margin to account for UT examination uncertainties when performing limit load analysis of flaws.

3.1 Limit Load Analysis on the H5 Weld

ComEd performed limit load analyses to define structural margins, assuming a maximum 360 degree crack depth of 1.24 inches. ComEd determined that limit load evaluation of austenitic stainless steel shroud flaws using ASME Section III Subsection NG-3200 methodology (with Section XI IWB-3640 and Appendix C for guidance) is appropriate and conservative for evaluating structural margins of the shroud in the H5 weld area.

ComEd determined that limit load analysis is appropriate for evaluating structural margins of the shroud in the H5 weld area, based upon the material

(Type 304 stainless steel) and the low neutron fluence levels. At a neutron fluence level of 3.0E16 n/cm^2 (E > 1 MeV) in the H5 location, the austenitic stainless steel material ductility is comparable to that of fully plastic unirradiated material.

In letters dated June 25 and June 30, 1994 to the NRC staff, ComEd provided justification for the appropriateness of limit load analysis for determining the stress distributions associated with the H5 weld. ComEd concluded that the finite element model shows that the bending stresses in the remaining ligament are minimal and that membrane loading still applies. Since membrane loading applies and the shroud material is fully plastic, limit load analysis is appropriate.

ComEd indicated that faulted loading conditions for this application conservatively include loading from both a design basis earthquake and a main steam line break inside containment, which is the most limiting load combination.

ComEd determined that it was acceptable to consider the 1 inch fillet on the ID of the H5 weld for the purpose of establishing the allowable extent of cracking for crack growth evaluation. This is reasonable, since the cracking appearance observed in boat samples taken from Dresden Station Unit 3 and Quad Cities Station Unit 1 confirms that residual stresses will drive the cracking on a path parallel to the weld fusion line prior to dissipating; end grain effects will also favor cracking in that direction; and cracking is highly unlikely to propagate into the weld metal, which is considered to be resistant to IGSCC as a result of its low carbon and high ferrite content.

ComEd concluded that the results of the limit load analysis show that flaw depths in the location of the H5 weld can be 98% of the shroud thickness at Dresden Station Unit 3 and 96% of the shroud thickness at Quad Cities Station it Unit 1, while still maintaining all ASME Code structural margins. This is based upon a minimum thickness of 3.0 inches that a crack must traverse before reaching through-wall, including the 2.0 inches thickness of the shroud barrel, and the 1.0 inch leg fillet weld on the ID of the H5 weld. ComEd concluded that the minimum required ligament thickness is 0.060 inch for Dresden Station Unit 3 and 0.120 inch for Quad Cities Station Unit 1.

3.2 Crack Growth Rates

ComEd utilized a conservative crack growth rate of 5.0E-5 inch/hour in its analyses. This is an upper bound value that envelopes both intergranular stress corrosion cracking (IGSCC) and irradiation assisted stress corrosion cracking (IASCC). A more realistic best estimate crack growth rate was also developed, which factors in more recent predictions considering plant-specific water chemistry. Due to reduced water conductivities achieved after the first five cycles of operation, recent and future crack growth rates will be much lower than 5.0E-5 inch/hour. Based on the GE PLEDGE predictive model for IGSCC crack growth rates, which accounts for better water chemistry, the best estimated crack growth rate is 1.24E-5 inch/hour at Dresden Station and 1.32E-5 inch/hour at Quad Cities Station.

Based upon the use of a conservative crack growth rate and the additional conservatisms associated with enhanced water chemistry, ComEd concluded that the use of 5E-5 inch/hr is acceptable as a crack growth rate.

3.3 Structural Margin of the H5 Weld

ComEd combined crack growth estimates with the allowable flaw sizes (based on limit load analysis) to determine structural margins for Dresden Station Unit 3 and Quad Cities Station Unit 1. These structural margins were described in ComEd's letters to the NRC staff dated June 6 and June 25, 1994.

For the purposes of showing structural margin, ComEd assumed that the bounding maximum flaw depth was consistent around the entire circumference. ComEd determined this to be conservative, since the limit load analysis can be based upon available structural data, and the actual flaws vary considerably in depth. Actual margins to failure are significantly higher, considering the factors of safety included in ASME Code minimum requirements.

ComEd concluded that a factor of 16 on the ASME Code minimum cross-sectional area will remain after a 24-month operating cycle using the bounding crack depth of 1.24 inches for the H5 weld at Dresden Station Unit 3, and a factor of 9.7 on the ASME Code minimum cross-sectional area will remain after an 18-month operating cycle using the bounding crack depth of 1.24 inches for the H5 weld at Quad Cities Station Unit 1.

3.4 Structural Margin Uncertainty and Compensatory Measures

ComEd determined that, for the H5 welds at Dresden Station Unit 3 and Quad Cities Station Unit 1, structural margin uncertainty is the result of uncertainty in nondestructive testing and crack growth rates. The application of engineering margins by ComEd compensates for these uncertainties.

Even though the shroud is not a primary pressure boundary, ComEd applied Section XI safety factors for primary pressure boundaries to compensate for uncertainties in the nondestructive examinations. In addition, ComEd utilized the upper bound crack growth rate to compensate for uncertainty in crack growth rates. When combined with the maximum depth flaw applied along the entire circumference of the shroud, ComEd concluded that the resulting safety margin factors demonstrate that the observed flaws do not represent an immediate safety concern, and all applicable ASME Code safety margins will be maintained well beyond the end of the next operating cycle for both Dresden Station Unit 3 and Quad Cities Station Unit 1. Based upon the evaluation of structural margin and crack growth rate uncertainties, ComEd concluded that all applicable ASME Code safety margins will be maintained for a minimum of 24 months for Dresden Unit 3 and a minimum of 18 months for Quad Cities Unit 1.

4.0 EVALUATION OF A POSTULATED 360 DEGREE FAILURE OF THE H5 WELD

ComEd evaluated a postulated through-wall failure at the H5 weld location in the core shroud during the following plant conditions: normal operation; anticipated transients; and postulated accident conditions. ComEd's analysis included the evaluation of a design basis loss-of-coolant accident combined with safe-shutdown earthquake loads (LOCA + SSE) to determine: the estimated potential vertical or lateral shroud movement; control rod scram capability; boron injection capability; short and long term core cooling capability (including core spray capability); and ability to maintain 2/3 core coverage with bypass leakage at various elevations.

4.1 Normal Operation

ComEd concluded that, given a 360 degree through-wall crack of the H5 weld during normal operation, the weight of the core shroud above H5 is sufficient to hold the core shroud assembly in place during all normal operating conditions. Assuming a gap of 0.002 inch around the entire circumference. and normal operating pressure drop across the upper shroud (7 psid at Dresden Station , 8 psid at Quad Cities Station) the resulting leakage flow would be approximately 30 gpm at Dresden and 35 gpm at Quad Cities. ComEd determined that these flows would have no significant consequence on plant operation.

4.2 Anticipated Transients

ComEd evaluated the impact of anticipated transients that could increase shroud loads above those experienced during normal operation (transients associated with occurrences that tend to depressurize the reactor vessel or increase core flow). The anticipated transients which ComEd evaluated were: Pressure Regulator Failure - Open; Recirculation Flow Control Failure - Maximum Flow; and, Inadvertent Actuation of ADS.

4.2.1 Pressure Regulator Failure - Open

This postulated event (described in the Safety Analysis Report - SAR) involves a failure in the pressure controls such that the turbine control valves and the turbine bypass valves are opened as far as the Maximum Combined Flow Limiter (MCFL) allows. Steam flow increase, and associated force on the core shroud, would be limited by the MCFL (limited to 105%). ComEd determined that the weight of the core shroud above H5 is sufficiently high to hold the core shroud assembly in place, and no movement will occur. Any leakage postulated may occur through a gap less than 0.002 inch. The postulated leakage flow would be approximately less than 40 gpm at both Dresden Station and Quad Cities Station. ComEd concluded that a leakage flow of this magnitude has no consequence for plant operation.

4.2.2 Recirculation Flow Control Failure

ComEd determined that this postulated event involves a recirculation flow control failure that causes both recirculation loops to increase to maximum flow. In this type of case, the pressure drop could change from a part-load condition to the high/maximum flow condition over a time period of several seconds. However, this should not significantly exceed the pressure drop expected for normal, full-power, high core flow operating conditions (7 psid for Dresden Station and 8 psid for Quad Cities Station). ComEd determined that normal operating procedures are considered sufficient to minimize the consequences of this potential transient. In addition, ComEd concluded that the resulting force from the high flow condition is not high enough to displace the shroud.

4.2.3 Inadvertent Actuation of the Automatic Depressurization System

ComEd determined that the inadvertent actuation of the Automatic Depressurization System (ADS) valves is another postulated event that could put an increased load on the upper shroud. The maximum steam flow and the depressurization rate are significantly smaller than for the postulated main steamline break, causing a short-term increase in steam flow of approximately 30% of rated steam flow. The increase in the shroud dP resulting from the opening of the ADS valves would occur over a period of about one second, spreading the effect of the change in load. ComEd concluded that the increase in the shroud dP is not expected to cause lifting of the shroud. ComEd also determined that inadvertent ADS actuation is also a very low probability event, and is bounded by the ASME Emergency category vessel thermal duty design.

Therefore, ComEd concludes that a postulated 360 degree through-wall crack would have no adverse impact upon the plant or the ability to mitigate the aforementioned transients.

4.3 Postulated Accident Conditions

ComEd determined that the bounding postulated accident condition is the main steamline break inside containment. This accident imposes the largest potential lifting loads on the shroud head. Liquid line breaks, up to and including the recirculation line break, impose lower lifting loads on the shroud head than the main steamline break.

4.3.1 Main Steamline Break

ComEd determined that the main steamline break inside containment is the postulated worst case accident because it results in the largest depressurization rate. During this SAR event, the reactor is rapidly depressurized as a result of a postulated instantaneous, double-ended break of the largest steamline. Thus a larger than normal pressure difference could develop across the shroud as fluid flow is drawn from the core region toward the break. For Dresden, the design basis pressure difference is 12 psid for the guillotine break of a main steam line. The Quad Cities design basis pressure difference across the shroud is 20 psid.

ComEd concluded that, at Dresden Station, the weight of the core shroud above the H5 weld is sufficiently high to hold the core shroud assembly in place during the main steam line break. At Quad Cities, the core shroud could lift momentarily by up to 4 inches during the vessel depressurization resulting from a main steamline break. If the main steamline break occurs simultaneously with the design basis earthquake, an upward displacement (less than 2 inches) of the shroud will result at Dresden. If a safe-shutdown earthquake (SSE) is postulated simultaneously with the main steamline break at Quad Cities, SSE loading could add 4 inches to the projected 4 inch lift. Lateral movement of the shroud at the H5 is limited to less than 2 inches in either case by the clearance between the shroud inner wall and the core support plate.

ComEd evaluated the shroud head pressure drop characteristics calculated for the instantaneous, double-ended steamline break accident. The initial shroud head pressure drop loading is a result of the decompression wave which reduces system pressure overall, but would increase differential pressure across the shroud in the short term. The pressure loading increase is short-lived (less than two seconds) and decreases to below normal steady-state operating loads. If it is postulated that the initial load pulse causes the shroud to separate, the last part of the pressure loading could cause the shroud assembly to lift. The flow path created by any separation reduces the upward lifting forces.

ComEd evaluated the ability of the control rods to insert before or during the postulated accident, given potential reorientation of the fuel bundles prior to control rod insertion. The scram is initiated during the main steamline break (inside containment) accident by the high drywell pressure trip signal. Drywell pressure exceeds the setpoint almost instantaneously, so the only delays in starting rod insertion come from the sensors, the Reactor Protection System, and rod motion. For the main steamline break outside containment, shroud loads are reduced, MSIV closure is initiated by high steam flow, and scram is initiated from the MSIV closure.

ComEd concluded that, for the postulated steamline break scenarios, the insertion of all control rods will occur. Normal CRD alignment from the bottom end of the fuel bundles to the CRD flange will be maintained and no binding within the CRD mechanisms is anticipated during a scram. However, during the design basis earthquake, the shroud assembly could shift laterally up to 2 inches. With the random displacement anticipated during seismic events, the CRD alignment in the core region would undergo intermittent periods of misalignment. Hence, the CRD scram speed would assume an oscillatory velocity profile, such as typically expected under seismic events. ComEd indicated that minimal scram performance degradation is expected. Because CRD scram timing degradation is minimal and safe shutdown is assured, ComEd finds it acceptable.

ComEd concluded that the Standby Liquid Control System function at Dresden Station and Quad Cities Station would not be affected by the H5 weld cracking. Although the shroud assembly may lift during a main steamline break accident (alone at Quad cities or coupled with SSE at Dresden) the effect on boron density will be minimal because the reactor vessel remains intact below the steamline. Because the effects on the Standby Liquid Control System are minimal, ComEd, therefore, finds it acceptable.

ComEd evaluated the impact upon short and long term core cooling capability (including core spray capability); and the ability to maintain 2/3 core coverage with bypass leakage at various elevations. At

Dresden Station, movement of the upper shroud assembly could affect the core spray system if it impacts the core spray line connection. The 2 inch lift can be easily accommodated by a 1.69 inch vertical clearance in the core spray line brackets and the compliance in the core spray line itself. The coolant flow to the two core spray spargers is ensured. Therefore, no change is predicted in the emergency core cooling function. Therefore, ComEd staff finds it acceptable.

At Quad Cities, the upper shroud movement could affect the coolant flow to the core by deflecting the core spray sparger and/or riser. Failure of the sparger or riser would not, however, prevent entry of core spray system water into the vessel. ComEd concluded that, because the reactor vessel remains intact below the steamlines, a floodable volume will be maintained after the main steamline break accident. Because a floodable volume is maintained following this event, ComEd, therefore, finds it acceptable.

4.3.2 Recirculation Line Break

ComEd evaluated the impact of a postulated design basis recirculation line break. During the recirculation line break, the differential pressure across the upper shroud decreases from the initial value as the reactor depressurizes, upward forces are reduced, and thus there is no significant threat to core shroud integrity. Even if the entire circumference is postulated to be cracked, the shroud assembly does not lift, and the lateral loading due to the acoustic phenomena of the event will not significantly move the shroud. The lateral loading is due to an instantaneous break of the recirculation suction line. An asymmetric load would result because the sound wave takes finite time to travel from the broken suction line side to the unbroken suction line side of the annulus. The duration of this load is extremely short (approximately 5 milliseconds) and this limits the lateral motion of the shroud to a very small magnitude. The calculated leakage flow is very small compared to the emergency core cooling system flow capacity, and there is no significant decrease in coolant to the core. Therefore, ComEd concluded that the recirculation line break analysis results are unchanged. Because the recirculation line break analysis results are unchanged, ComEd staff finds it acceptable.

If a recirculation suction line break were to occur in combination with an SSE, the core shroud assembly will not lift and retain substantial downward load even if the entire circumference is postulated to have a through wall crack. Substantial frictional forces exist with the downward load due to the irregular mating surfaces along the crack both in radial and circumferential directions. Therefore the shroud assembly is not likely to move laterally. Any lateral motion near the H5 weld, if postulated, is restricted to less than the thickness of the shroud wall (2 inches) by the limited spacing between the shroud, the weldment, and the core support plate. Since there is no significant threat to core shroud integrity in the vertical direction, shroud integrity will be maintained and a floodable core region is preserved. The resulting leakage flow is small compared to ECCS flow capacity and there is no significant decrease in coolant to the core. In addition, the Standby Liquid Control System function will not be affected by the recirculation line break. The relatively small leakage rates that may occur will not significantly affect boron density in the core or ECCS capability. With an SSE and Recirculation line break occurring simultaneously, the recirculation line break analysis results are unchanged. Because the recirculation line break analysis results in combination with an SSE are unchanged, ComEd, therefore, finds it acceptable.

Therefore, ComEd concludes that a 360 degree through-wall crack at the H5 weld would have no significant adverse impact upon the plant, or the ability to mitigate the aforementioned postulated accidents.

5.0 PROBABILISTIC PERSPECTIVE

During a meeting held with the NRC staff on May 26, 1994, ComEd provided event frequency data for Dresden and Quad Cities Station. For normal loads in conjunction with a Design Basis Earthquake (DBE), the event frequency was determined to be 5E-5/year. For normal loads in conjunction with a LOCA, the event frequency was determined to be 3E-4/year. For a Recirculation Line Break in conjunction with a DBE, the event frequency was determined to be 4.1E-11/year (for Quad Cities, this was determined to be 1.8E-11/year). For the Main Steam Line Break (MSLB) in conjunction with a DBE, the event frequency was determined to be 5.6E-15/year (for Quad Cities, this was determined to be 2.5E-15/year).

In addition, ComEd provided data to the NRC staff in a June 25, 1994 submittal, representing the unavailability of equipment for the following ECCS scenarios: 1 core spray out; 1 LPCI out; both core sprays out; 1 LPCI injection valve unavailable; and the common mode LPCI loop select logic unavailable. ComEd's information (based on 1991 Probabilistic Risk Assessment [PRA] data) is summarized below:

	Dresden	Quad Cities
1 Core Spray OOS	1.4E-2	5.2E-2
1 LPCI OOS	2.6E-3	3.8E-3
Both Core Spray OOS	2.2E-4	6.7E-4
1 LPCI Injection Valve OOS	1.9E-3	1.5E-3

Data was not available for the common mode LPCI loop select logic.

As previously discussed, ComEd has concluded that the MSLB combined with the DBE is the limiting event. Even in the event of a MSLB combined with a DBE, ComEd has determined that control rod insertion is assured, reactor shutdown will be achieved, SBLCS is not significantly impaired, and a 2/3 core height floodable volume is maintained. As previously discussed, although the core spray function may be impaired, the degradation is not significant. Because the event frequencies listed above are of such small magnitude and the consequences are addressed by adequate ECCS availability in the event of a design basis event, ComEd, therefore, finds this acceptable.

6.0 EVALUATION OF DRESDEN UNIT 2 AND QUAD CITIES UNIT 2

6.1 Flaw Tolerance of the Core Shroud

The combination of high ductility, high toughness and low stresses make the core shroud extremely flaw tolerant. Even for the situation of 360 degree circumferential cracking, the observed UT results for Dresden Unit 3 and Quad Cities Unit 1 are acceptable in accordance with ComEd's analyses, which determined a large maximum allowable crack depth that maintains the structural integrity for normal operation and postulated design basis accident conditions, including ASME Code safety factors. The available material considers the extra one inch of ligament provided by the ID fillet weld at the H5 location, in addition to the two inch shroud wall thickness. Due to the inherent toughness and low stresses inherent for the core shrouds and because of the conservative assumptions used to ensure that adequate safety margins remain, ComEd finds this acceptable.

6.2 Plant Water Chemistry Effects

Dresden Units 2 and 3 have been operated at similar mean conductivity levels. As discussed in ComEd's June 6, 1994 submittal to the NRC staff, the mean conductivity level for both units has improved from 0.3 - 0.4 μS/cm during the first five operating cycles to 0.06 - 0.08 μS/cm currently. Unlike Dresden Unit 3, Dresden Unit 2 has been operating with hydrogen injection beginning with operating cycle 9 (1983). Hydrogen injection has ranged from 1.0 - 1.5 ppm at approximately 90% availability.

Quad Cities Units 1 and 2 have been operated at similar mean conductivity levels as Dresden Station. As discussed in ComEd's June 6, 1994 submittal to the NRC staff, the mean conductivity level for both units has improved from 0.6-0.7 μS/cm during the first five operating cycles to 0.15 - 0.2 μS/cm currently. Additionally, both units at Quad Cities Station have been operating with hydrogen injection since November 1990.

The maximum crack depth observed by the UT examinations was approximately 0.57 inches for Quad Cities Unit 1 and 0.84 inches for Dresden Unit 3. The observed UT results for Dresden Unit 3 bound the results for Quad Cities Unit 1. The observed UT results for Dresden Unit 3 are less than ComEd's analyses which determined a large maximum allowable crack depth. Plant water chemistry history indicates that Dresden Unit 2 and Quad Cities Unit 2 is significantly better than Dresden Unit 3 and Quad Cities Unit 1, respectively. Even if there exists cracking in Dresden Unit 2 and Quad Cities Unit 2 that is equivalent to that observed in Dresden Unit 3, the respective core shrouds maintain their structural integrity for normal operation and postulated design basis accident conditions, including the seismic loads. Because Dresden Unit 2 and Quad Cities Unit 2 are bounded by the observed cracking on Dresden Unit 3 and Quad Cities Unit 1, ComEd finds this acceptable.

6.3 Crack Growth Rate

Using the bounding crack growth rate of 5E-5 inch/hr for a BWR with normal water chemistry, ComEd has determined that the allowable crack depth will not be exceeded during the current operating cycles. In addition, no BWR core shroud inspection (including Dresden Unit 3 and Quad Cities Unit 1) has found through-wall cracking. Based upon the fact that assumed crack depths will not exceed maximum bounding flaw depths during the current operating cycles and ComEd's bounding analysis applied appropriate conservatisms in their evaluations, ComEd finds it acceptable.

6.4 Monitoring Indications of Core Shroud Bypass Flow

ComEd determined that the strongest indicator of significant upper shroud leakage would be the resultant power level reduction, causing a power-to-flow anomaly. Site control room operating personnel by procedure record power, core flow, and rod line information at the beginning of each shift and routinely monitor power and core flow conditions during the course of a shift. Existing site procedures which address jet pump and shroud access cover anomalies provide sufficient operator guidance in the event of shroud leakage. Training has been provided to licensed personnel on the symptoms resulting from shroud leakage. Because ComEd has adequately accounted for monitoring and personnel action in the event that shroud bypass leakage is observed, ComEd, therefore, finds it acceptable.

6.5 Operator Actions to Address Core Shroud Failure at the H5 Weld During Design Basis Accident Conditions

The Dresden and Quad Cities Emergency Operating Procedures (EOPs) are symptom based procedures and are capable of addressing a full spectrum of transients and design basis accidents. ComEd determined that the Main Steam Line Break (MSLB) inside containment is the bounding design basis accident and imposes the largest lifting loads on the shroud. Neglecting the presence of any shroud ligament at the H5 weld (360 degree, through-wall crack), ComEd determined that the MSLB could result in the momentary lifting of the shroud assembly and potential lateral movement from the lower shroud. The EOPs provide adequate guidance for reactor power control in the event scram capability function has been impacted (including the appropriate use of the Standby Liquid Control System (SBLCS)) and the level control requirements to ensure core cooling. ComEd determined that for the MSLB, the integrity of the shroud is not required to maintain core coverage or a floodable region. Based upon the above, ComEd finds operator guidance acceptable to address a postulated core shroud failure at the H5 weld in conjunction with an MSLB.

For the design basis Recirculation Line Break event, ComEd determined that the differential pressure across the upper shroud and the lateral loads (on the side of the shroud) will not lift, or significantly laterally shift the shroud. ComEd's evaluations have shown that the bypass leakage would be small as compared to the emergency core cooling system (ECCS) flow capacity resulting in no significant decrease in core cooling. Because of the minor bypass leakage associated with this event, coupled with the conclusion that minimal shroud movement is expected, the current operator procedural guidance to respond to a design basis Recirculation Line Break event is adequate. Therefore, ComEd finds operator guidance acceptable to address a postulated core shroud failure at the H5 weld in conjunction with a Recirculation Line Break event.

In conclusion, the core shroud/core support ring cracking associated with the H5 weld at Dresden Unit 2 and Quad Cities Unit 2, postulated to be similar to that observed at Dresden Unit 3 and Quad Cities Unit 1, which was the most extensively cracked weld area in Dresden Unit 3 and Quad Cities Unit 1, does not represent a threat to the safe operation of Dresden Unit 2 and Quad Cities Unit 2 for the remainder of the current operating cycle.

7.0 CONCLUSION

ComEd performed a detailed examination and evaluation of the core shrouds for Dresden Unit 3 and Quad Cities Unit 1 during their current refueling outages and has identified cracking in the shroud. Although minor flaws were identified in other horizontal welds, a 360 degree flaw was identified in the H5 welds at both plants. ComEd evaluated the structural integrity of the core shroud for both Dresden Unit 3 and Quad Cities Unit 1 in the shroud's current degraded condition. ComEd determined that the flaw at the H5 weld represents the bounding flaw based on existing conditions for the core shroud at both Dresden Unit 3 and Quad Cities Unit 1.

Based upon the structural integrity analyses, ComEd concluded that the flaws associated with the H5 welds will not adversely impact the shroud's structural integrity during the next operating cycle. Due to the aforementioned conservatisms and resulting large safety margins, ComEd has concluded that the existing flaws in the H5 welds at Dresden Unit 3 and Quad Cities Unit 1 are acceptable for continued operation of one refueling cycle or 24 months for Dresden Unit 3 and one refueling cycle or 18 months for Quad Cities Unit 1. A summary of the assumptions is listed in the following table:

Parameters	Best/Realistic Case	Bounding/Limiting Case
Crack Growth Rate	5.2E-6 inch/hr; (0.08 inch, 24 months)	5.0E-5 inch/hr; (0.8 inch, 24 months) *
Fillet Weld (Crack Path) and Membrane	1.0 inch *	0.1 inch
Bounding Flaw Depth	0.69 inch	1.24 inch *
Circumference for Bounding Flaw Depth	50% Dresden; 40% Quad Cities	100% Dresden and Quad Cities *
Factor of Safety on Stresses Assuming Primary Pressure Boundary (ComEd utilized 1.4)	1.0	1.5 - Longitudinal Flaw; 1.4 - Circumferential Flaw in primary pressure boundary *
Load Combinations (ComEd combined LOCA + Seismic)	LOCA or Seismic Limiting Load	LOCA + Seismic Limiting *
RR LOCA Blowdown Load	17 kips at 61.7 inches *	175 kips at 61.7 inches
MSLB	12 psid (Dresden)*	20 psid (Quad Cities) *

* = Current ComEd assumptions.

As discussed in ComEd's letter to the NRC staff dated June 25, 1994, additional work needs to be performed. ComEd will continuously evaluate future BWR core shroud inspection activity for applicability to Dresden and Quad Cities. ComEd's current plans are summarized as follows:

- Continue follow-up work and communicate the status of results to the NRC staff by December 15, 1994;
- Quad Cities Unit 1: reinspect and/or repair - Q1R14 (Fall 1995);
- Quad Cities Unit 2: initial inspection and/or repair - Q2R13 (Spring 1995);
- Dresden Unit 2: initial inspection and/or repair - D2R14 (Spring 1995);
- Dresden Unit 3: reinspect and/or repair - D3R14 (Spring 1996).

If ComEd's evaluation activities result in operating margins below acceptable levels, ComEd will revise the aforementioned priorities and schedules as necessary. These revisions will be appropriate to the magnitude of changes in operating margins including immediate shutdown of the affected units.