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UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
Washington, D.C. 20555

INSPECTION AND ENFORCEMENT MANUAL

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TEMPORARY INSTRUCTION 2515/66

INSPECTION REQUIREMENTS FOR IE BULLETIN 84-03, "REFUELING CAVITY WATER SEALS"

2515/66-01 PURPOSE

To provide guidance for performing near-term inspection followup to the licensee's response to IE Bulletin 84-03, "Refueling Cavity Water Seals," August 24, 1984. This temporary instruction is to be used until permanent criteria for refueling cavity water seals are developed and issued by the Office of Nuclear Reactor Regulation.

2515/66-02 OBJECTIVE

To evaluate the potential for and consequences of a failure of the refueling cavity seal.

2515/66-03 BACKGROUND

On August 21, 1984, the Haddam Neck Plant experienced a failure of the refueling cavity water seal with the refueling cavity flooded in preparation for refueling. The refueling cavity water level (23 feet) decreased to the level of the reactor vessel flange within 20 minutes, which flooded the containment with approximately 200,000 gallons of water. The pneumatic seal assembly was subject to a gross failure that allowed the seal to be significantly displaced. No fuel was being transferred at the time of this seal failure. If, however, fuel had been in transfer at the time, it could have been partially or completely uncovered with possible high radiation levels, fuel cladding failure, and release of radioactivity. In addition, if the fuel transfer tube had been open, the spent fuel pool could have drained to a level that would have uncovered the top of the fuel. IE Bulletin 84-03 was issued as a result of this incident.

Plants with a pneumatic or rubber type seal, such as Haddam Neck, are of the most concern because seal failure or displacement results in a direct, major leak path. Some plants have a metal backing ring over the pneumatic seal; however, the metal ring may not provide a tight seal if the pneumatic seal fails or is displaced. In addition, if the metal seal plate is not bolted in place, it also may be subject to displacement.

The guidance provided in this TI is in excess of the actions requested by the Bulletin. The further guidance was prompted by further difficulties with seals at San Onofre and results of EPRI seal testing. These items are discussed in IE Notice 84-93, "Potential For Loss of Water From The Refueling Cavity," December 17, 1984 (Appendix 1). If reviews against this added guidance result in identification of any backfit concerns by the licensees, the Regional Office should promptly notify IE Headquarters, (E. Rossi).

2515/66-04 BASIC REQUIREMENTS

The first task of the inspection is to determine whether the licensee has identified the worst-credible seal failure. Once this worst-credible failure is identified, it should be determined whether the licensee has properly evaluated the consequences of such a failure. Specifically, it should be determined whether (1) leakage rates are limited to less than makeup capacity and (2) procedures for mitigating the seal failure are properly approved, documented, and implemented before fuel movement. If reactor cavity seal design deficiencies are found to be the result of a design change, the design change process should be reviewed and corrective action taken as appropriate.

The response to IE Bulletin 84-03 from the North Anna Plant (Appendix 2) is an example of a refueling cavity seal that does not appear to have a credible failure mode; it also is an example of the type of response expected for such a seal.

04.01 Failure Mode Review

The potential for seal failure should be based on each identified failure mode that is judged to be credible, up to and including the worst-credible case. The following guidelines are provided as examples for determining credible failure modes:

a. A single failure of any nonmetallic seal component should be considered. For instance, if there are two pneumatic seals in a cavity seal assembly, then one should be assumed to fail unless it is obvious that both would fail if one failed, or unless there is a simple failure which would cause both to fail. This single failure should be assumed to be a complete failure or displacement of that component, unless logical reasoning is presented on why only a portion should be assumed to be failed or displaced. If a seal assembly has one or more gaskets, but no pneumatic seal, then the displacement of a complete gasket should be considered, unless logical reasoning is presented on why only a portion should be assumed to be failed or displaced. For example, if there is a double gasket on either the inside or outside diameter of a metal seal plate, then one of these two gaskets can be assumed to remain in place.

b. When the entire seal assembly is in place, any individual portion of the seal plate or backing plate assemblies not bolted to the cavity floor or reactor vessel flange should be considered to be displaced laterally to the nearest substantial restraint. This failure is in addition to any assumed failure of the pneumatic seals or gaskets.

c. These failure assumptions assume the seal assembly, including backup seal (or a prototype), if provided, has been hydrostatically tested (before initial use) at a hydrostatic pressure equivalent to at least 2 times the maximum head of water on the seal during refueling. If either the primary seal or backup seal does not meet the above requirement, then this part of the seal assembly should be considered to be failed, in addition to the failure assumptions of items 1 and 2 above.

d. The seal assembly should be visually inspected for signs of deterioration (cracking, etc.) before each installation and operationally tested after installation and prior to fuel movement. Any indication of significant deterioration is cause for rejection of the seal.

e. The impact of a fuel assembly on the seal assembly with the refueling cavity filled for refueling should be considered in the failure mode analyses. Flexible, rubber type seals should either be protected from the impact of a dropped fuel assembly in the quadrant(s) over which fuel is moved, or the consequences of a dropped fuel assembly on the unprotected seal should be shown to be acceptable.

04.02 Review of Consequences of Failure

The consequences of a seal assembly failure should be based on the worst-credible seal failure in Section 04.01 above. Additional criteria are included below:

a. The flow area for cavity leakage is based on the clearance between any metal-to-metal sealing joint and/or the gaps formed as a result of pneumatic seal or gasket failure. For example, if a metal backing plate is in place, the clearances between the plate and the cavity floor or reactor vessel flange may be substantial. An equation to approximate the time required for cavity draindown is contained in Section 04.03.

b. The minimum suggested time for the initial operator action following seal failure is 10 minutes after the failure is detected. The time allowed for operator actions should consider the radiation levels at reduced water levels.

c. The effects of cofferdams on the accident scenario should be included as well as the relative elevations of the cavity, transfer canal, transfer tube, and spent fuel pool.

d. The minimum water level (following seal failure) above fuel in the refueling cavity, fuel transfer or spent fuel pool should be based on the largest leak rate, the water makeup capacity available, the minimum initial refueling cavity level, and no operator action for the first 10 minutes after detection of the seal failure. The time to uncover fuel, while the fuel is actually being moved, should be considered. The detection of the seal failure is assumed to be at the lowest level the cavity could reach before actuating a level alarm or radiation alarm. Any fuel uncovery is assumed to be unacceptable. Any operator radiation dose greater than the limits of 10 CFR 20 also is unacceptable.

e. The effect of reduced water levels in the refueling cavity and/or spent fuel pool should be considered in the cooling of the fuel.

f. Any operator procedures used in the analysis of the mitigation of the refueling cavity seal failure should be properly documented and approved. This includes the following areas:

1. seal installation and testing
2. seal leakage monitoring
3. refueling cavity level control
4. emergency activation criteria
5. spent fuel pool isolation
6. fuel movement in cavity and transfer canal
7. water makeup control
8. reactor building evacuation

04.03 Calculation Method for Refueling Cavity Drainage Time

The time required to drain the refueling cavity can be approximated by the following equations:*

$$t = \int_{h_1}^{h_2} \frac{A_c}{Q_{mu} - Q_{Leak}} \, dh$$

t = time to drain down cavity from h_1 to h_2 (sec)

A_c = surface area of refueling cavity (ft^2)

Q_{mu} = makeup capacity (ft^3/sec)

*Standard Handbook For Mechanical Engineers, Baumeister and Marks, Seventh Edition McGraw-Hill, pages 3-55 to 3-73.

h_1 = initial cavity level (ft)

h_2 = drained cavity level (ft)

Q_{leak} = leak rate (ft^3/sec)

$$Q_{leak} = C_D A_{leak} \sqrt{2gh}$$

C_D = leak discharge coefficient $\approx$ 0.8

A_{leak} = cross-sectional area of leak path (ft^2)

g = gravitational constant (ft/sec^2)

h = cavity level (ft)

$$t = \frac{Ac}{3.2A_{leak}} \left[h_1^{1/2} - h_2^{1/2} + \frac{Q_{mu}}{6.4A_{leak}} \ln \left[\frac{Q_{mu}/6.4A_{leak} - h_1^{1/2}}{Q_{mu}/6.4A_{leak} - h_2^{1/2}} \right] \right]$$

If there is no makeup, the equation simplifies considerably. For discontinuities in either the makeup flow or cavity surface area, this equation is solved for each increment of h in which both Q_{mu} and A_c are constant. While the fuel transfer canal and/or spent fuel pool is draining into the cavity, these surface areas are added to cavity surface area.

SSINS No. 6835
IN 84-93

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, DC 20555

December 17, 1984

IE INFORMATION NOTICE NO. 84-93: POTENTIAL FOR LOSS OF WATER FROM THE REFUELING CAVITY

Addressees:

All holders of a nuclear power reactor operating license (OL) or construction permit (CP) except Fort St. Vrain.

Purpose:

This notice is provided to alert licensees and applicants to features in some PWRs and BWRs that may have a significant potential to cause loss of water in the refueling cavity. It is expected that recipients will review the information for applicability to their facilities and consider actions, if appropriate, to preclude similar problems from occurring at their facilities. However, suggestions contained in this information notice do not constitute NRC requirements and, therefore, no specific action or response is required.

Description of Circumstances:

On August 21, 1984, the Haddam Neck plant experienced a failure of the refueling cavity water seal with the refueling cavity flooded in preparation for refueling. The refueling cavity water level (23 feet) decreased to the level of the reactor vessel flange in about 20 minutes, which flooded the containment with approximately 200,000 gallons of water. The leak developed when the pneumatic seal assembly was forced out of the normal position as a result of static water pressure. The pneumatic seal assembly remained intact but was extruded through the gap for about 25 percent of its circumference.

No fuel was being transferred at the time of this seal failure. If fuel had been in transfer at the time, it could have been partially or completely uncovered with possible high radiation levels, fuel cladding failure, and release of radioactivity. In addition, if the fuel transfer tube had been open, the spent fuel pool could have drained to a level that would have uncovered the top of the fuel assemblies stored in the pool. IE Bulletin No. 84-03, "Refueling Cavity Water Seal," was issued on August 24, 1984, as a result of the above incident.

While evaluating the potential for loss of water from refueling cavities at other plants, the NRC staff learned from the Electric Power Research Institute (EPRI) that reactor cavity seal development testing had been previously

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December 17, 1984
Page 2 of 3

performed. This seal testing was sponsored by EPRI as part of a "Refueling Outage Availability Improvement Program." These tests (completed in 1981) initially resulted in a failure mode very similar to that experienced by the Haddam Neck plant. However, this failure mode was not observed in further testing with a modified seal design. This EPRI testing indicates that the performance of pneumatic seals is very sensitive to seal design details and to plant-specific refueling cavity design details, including variations in cavity gap dimensions.

Other potential failure modes of the refueling cavity seal have been identified, since the incident at the Haddam Neck plant, which could cause a rapid loss of water in the refueling cavity at some plants. San Onofre Unit 2 recently experienced several problems while installing the reactor cavity seal in preparation for the unit's first refueling. This unit has redundant (inner and outer) pneumatic seals. The inner pneumatic seal was punctured during installation. The seal was replaced with a spare. The spare seal also failed during testing as a result of a manufacturing defect in the seal wall. Both the above failures were discovered and corrected before flooding the reactor cavity. Failures, like those reported at San Onofre Unit 2, could cause a rapid loss of cavity water (if the cavity were flooded) at plants with nonredundant pneumatic seals. Some pneumatic/flexible seals also may be susceptible to damage from the impact of dropped objects after the cavity is flooded. If the dropped object were radioactive, significant radiation damage to the pneumatic seal also could occur after a period of time.

In addition to the refueling cavity seal, pneumatic seals also are used as hot and cold leg nozzle dams in PWRs and, for some plants, in gates between the spent fuel pool and the fuel transfer canal. The failure modes and concerns expressed above for the pneumatic refueling cavity seal also apply in many cases to these other pneumatic seals. Nozzle dams are of particular concern, when the steam generator primary is open during refueling.

The refueling cavity also can be partially drained (PWR or BWR) by certain misalignments of the residual heat removal system (RHR) valves while in the shutdown cooling mode (assuming that shutdown cooling is in use when the cavity is filled). GE SIL No. 388, "RHR Valve Alignment During Shutdown Cooling Operation For BWR 3/4/5 and 6," dated February 1983, and IE Information Notice 84-81, "Loss of Reactor Pressure Vessel Coolant Inventory in Boiling Water Reactors," dated November 16, 1984, discuss these possibilities in a BWR. Nuclear Safety Analysis Center report, NSAC-52, "Residual Heat Removal Experience Review and Safety Analysis, Pressurized Water Reactors," dated January 1983, discusses these possibilities in a PWR.

Finally, there are numerous ways in which the refueling cavity of a PWR or BWR could be drained at a slower rate through one of the attached drain lines. Adequate emergency procedures and properly calibrated refueling cavity water level instrumentation are considered to be important in the mitigation of any loss-of-cavity-water accident.

No specific action or written response is required by this information notice. If you have any questions about this matter, please contact the Regional Administrator of the appropriate NRC regional office or this office.

Edward L. Jordan, Director
Division of Emergency Preparedness
and Engineering Response
Office of Inspection and Enforcement

Technical Contact: H. A. Bailey, IE
(301) 492-9006

Attachment: List of Recently Issued IE Information Notices

Attachment
IN 84-93
December 17, 1984

LIST OF RECENTLY ISSUED
IE INFORMATION NOTICES

Information Notice No.	Subject	Date of Issue	Issued to
84-92	Cracking of Flywheel on Cummins Fire Pump Diesel Engines	12/17/84	All boiling water reactor facilities holding an OL or CP
84-91	Quality Control Problem of Meteorological Measurements Problems	12/10/84	All boiling water reactor facilities holding an OL or CP
84-90	Main Steam Line Break Effect on Environmental Qualification of Equipment	12/7/84	All boiling water reactor facilities holding an OL or CP
84-89	Stress Corrosion Cracking in Nonsensitized 316 Stainless Steel	12/7/84	All boiling water reactor facilities holding an OL or CP
84-88	Standby Gas Treatment System Problems	12/3/84	All boiling water reactor facilities holding an OL or CP
84-87	Piping Thermal Deflection Induced by Stratified Flow	12/3/84	All boiling water reactor facilities holding an OL or CP
84-86	Isolation Between Signals of the Protection System and Non-Safety-Related Equipment	11/30/84	All boiling water reactor facilities holding an OL or CP
84-85	Molybdenum Breakthrough from Technetium-99m Generators	11/30/84	All NRC licensed medical institutions and radiopharmaceutical suppliers
84-84	Deficiencies In Ferro-Resonant Transformers	11/27/84	All boiling water reactor facilities holding an OL or CP
84-83	Various Battery Problems	11/19/84	All boiling water reactor facilities holding an OL or CP

OL = Operating License
CP = Construction Permit

VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

SEP 7 P2:19

W. L. STEWART
VICE PRESIDENT
NUCLEAR OPERATIONS

August 31, 1984

Mr. James P. O'Reilly
Regional Administrator
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, Suite 2900
Atlanta, Georgia 30323

Serial No. 525
NO/JHL:acm
Docket Nos. 50-338
50-339
License Nos. NPF-4
NPF-7

Dear Mr. O'Reilly:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT NOS. 1 AND 2
RESPONSE TO I.E. BULLETIN 84-03

We have reviewed I.E. Bulletin 84-03, "Refueling Cavity Water Seal", dated August 24, 1984. An evaluation of the potential for and the consequences of a refueling cavity water seal failure is provided in the attachment. Based on the evaluation and the design differences between the seals at North Anna and the failed seals at Haddam Neck, we believe that the refueling cavity water seal being used at North Anna is adequate.

The information contained in the attachment is true and accurate to the best of my knowledge and belief. Should you have any further questions, please contact us.

Very truly yours,

W. L. Stewart

W. L. Stewart

Attachment

cc: U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

Mr. James R. Miller, Chief
Operating Reactors Branch No. 3
Division of Licensing

Mr. M. W. Branch
NRC Resident Inspector
North Anna Power Station

IE11

NORTH ANNA POWER STATION
RESPONSE TO IEB 84-03
REFUELING CAVITY WATER SEAL

North Anna Unit 1 has just completed a refueling outage and is in Mode 5. North Anna Unit 2 is currently in a refueling outage with refueling cavity filling scheduled for September 3, 1984, and fuel transfer scheduled to begin September 5, 1984. Therefore, responses to item 1 and item 2 are provided.

The refueling cavity seal assembly at North Anna Units 1 and 2 consists of a 2 inch thick carbon steel annular plate and neoprene gaskets as shown in Figure 1. The inner edge of the seal ring rests on the reactor vessel flange and is secured by thirty six 0.75 inch diameter bolts torqued to 100±10 ft. lbs. The outer edge rests on the seal ring lower assembly, which is a permanent fixture in the refueling cavity floor, and is secured in the same fashion. Each of these sealing surfaces utilizes redundant neoprene gaskets which are trapezoidal in shape and firmly held in place by a bolted seal spacer. These gaskets are deformed by the hydrostatic load of the water in the refueling cavity and the torqueing of the seal ring bolts to provide for leaktight integrity. This is verified prior to flooding the refueling cavity by the performance of a pressure drop test on each set of gaskets. This test consists of applying an air pressure of 20 psi between each set of gaskets and verifying essentially no pressure drop after 30 minutes.

On Unit 2, the refueling cavity seal gaskets were replaced prior to entering MODE 6.

The refueling cavity seal assembly is designed to retain its integrity under the hydrostatic load imposed by 30 feet of refueling cavity water concurrent with a seismic event.

In a postulated accident consisting of a complete loss of all gaskets, the hydrostatic pressure of the refueling water will force the seal ring against the reactor vessel flange and the seal ring lower assembly. In this event, some leakage from the refueling cavity is expected due to minor seal plate flatness irregularities, however this leakage would be minor and much less then the minimum make up capacity provided by the Chemical and Volume Control System (150 gpm). Additional makeup capacity is provided by the Refueling Purification pumps (400 gpm) and/or Low Head Safety Injection pumps (3000 gpm) taking suction from the Refueling Water Storage Tank. Due to the redundancy of the seal assembly design, a partial gasket failure would only result in minor leakage. A failure of one or several of the 72 bolts, which secure the seal ring, will not result in excessive leakage due to the hydrostatic load of the refueling cavity water. A failure of the annular plate (seal ring) is not considered plausible.

In the event of any type of gasket failure during fuel transfer where the fuel transfer tube is open (i.e., the spent fuel storage pool and the refueling cavity are connected) the fuel assembly in transit could safely reach its destination and the transfer tube could be isolated before a significant drop in level resulted. In addition, the fuel transfer canal is at a significantly lower elevation than the minimum water level which would result from gross

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seal leakage without makeup. Should the transfer tube remain open, and a leak greater than the available makeup capacity occurred, a 15 foot high concrete barrier between the spent fuel storage pool and fuel transfer canal would prevent the spent fuel storage pool level from decreasing below an elevation which is 2 feet 8 inches above the stored spent fuel. Also an alarm would alert the control room operator of a low spent fuel storage pool level when it decreased approximately 7 inches below the normal water level. A decrease in the refueling cavity water level would be detected by the cavity watch operator who is stationed at the refueling cavity whenever it is flooded. A significant decrease in either the spent fuel storage pool or refueling cavity water levels would also result in increased radiation levels detected by Technical Specification required monitors which read out in the Control Room.

A complete failure of the refueling cavity seal ring assembly is not a credible accident at North Anna. Due to the design and redundancy of the refueling cavity seal, any type of failure is unlikely. Even in the event of a credible failure, sufficient time would exist to detect such a leak and take corrective action to prevent damage to spent fuel or fuel in transit.

As a result of this I.E. Bulletin, a new abnormal procedure has been written, approved and is in place for both North Anna Units 1 and 2. This procedure was written to further amplify the corrective actions to be taken on a decreasing refueling cavity water level, including makeup, movement of fuel and isolation of the fuel transfer tube.

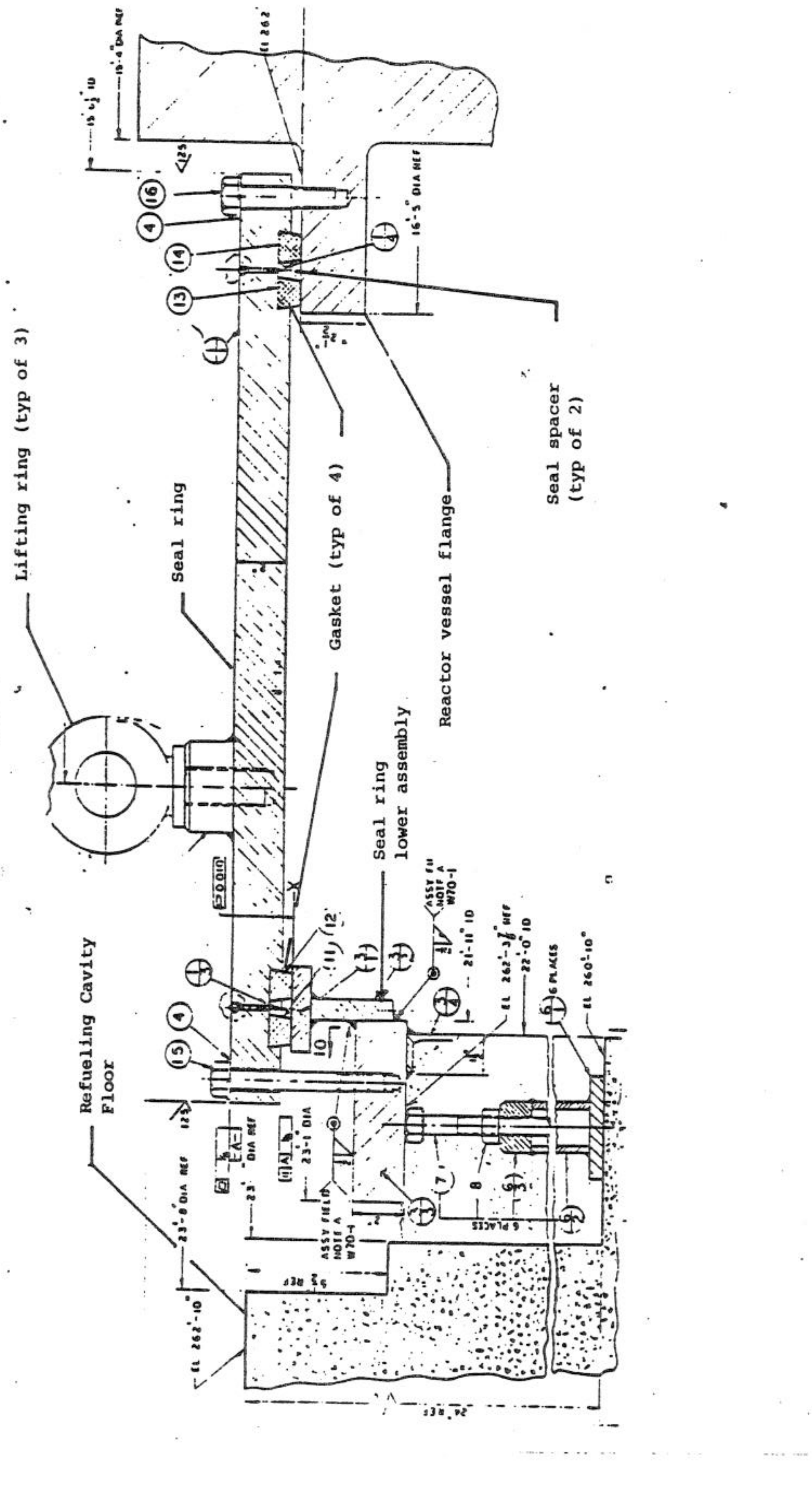

Figure 1. Refueling Cavity - Seal - North Anna Units 1 and 2