Omaha Public Power District

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LIC-01-0095

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

References: 1. Docket No. 50-285
2. NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles"

SUBJECT: Fort Calhoun Station (FCS) Control Element Drive Mechanism (CEDM) Housing Reliability Management

As a result of control rod drive mechanism housing cracks experienced by the nuclear industry, Omaha Public Power District (OPPD) and NRC have had several telephone conferences discussing the reliability of CEDM housings at FCS. In order to support these conferences, FCS has telecopied materials to NRC which describe the programmatic actions being taken by FCS to assure reliability and integrity of the CEDM housings. The purpose of this submittal is to summarize and docket the technical information previously telecopied and presented during the telephone conferences.

The attachment contains only the information and conclusions previously presented during the telephone conferences and does not constitute any new commitments.

FCS technical staff has been in communication with Palisades plant personnel and industry leaders in this field and is participating/leading in Electric Power Research Institute meetings and Combustion Engineering Owner's Group meetings. FCS will continue to use industry experience to stay informed of the developments associated with the control rod drive mechanism housing cracking problems as noted at Palisades and elsewhere in the industry. Lessons learned from the industry experience are being evaluated and appropriately included in the Fort Calhoun CEDM Material Reliability Management Program. OPPD encourages this continuing dialog with the NRC on this important issue.

Please contact me if you have any questions.

A088

Sincerely,

R. L. Phelps 10-15-01

R. L. Phelps
Division Manager
Nuclear Engineering

RLP/RLJ/rlj

Attachment

c: E. W. Merschoff, NRC Regional Administrator, Region IV
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i Executive Summary

During the past ten years the nuclear industry worldwide has focused on addressing stress corrosion cracking in control rod drive mechanism (CRDM) assemblies, and thereby maintaining the material integrity of the reactor coolant system. From a material perspective each CRDM, referred to as Control Element Drive Mechanism (CEDM) assembly at the Fort Calhoun Station (FCS), consists of three separate components: a CEDM seal housing, a CEDM upper housing, and a reactor vessel head nozzle. In the industry, stress corrosion cracking has been found in each of these three material components. In 1990 at FCS, stress corrosion cracking was found in two spare unvented CEDM upper housings. This lack of venting, which produced completely stagnant conditions no longer exists at FCS.

Likewise, FCS's responses to nuclear industry events and experiences have been consistent in developing corrective actions that are focused on safe and event free operations. FCS has demonstrated responsiveness to industry/operation experiences by establishing corrective actions, increasing inspections, developing a program plan, and performing self assessments and independent evaluations using input from other sources in and outside of the nuclear industry. FCS continues to learn from industry (nuclear and non-nuclear) issues in order to provide a reasonable assurance of a low risk probability of rupture and/or excessive leakage in the primary system.

At FCS, a corrosion model has been developed into a program plan for CEDM seal housings. This program plan is a living document that discusses the mechanism of stress corrosion cracking, contains results of non-destructive examinations and gives contingencies for repair and replacement of seal housings. It is the position of FCS that a key element in the cracking of the CEDM seal housings is the stagnant environmental condition that exists in the CEDM seal housings. The CEDM seal housings contain the highest degree of stagnancy, and a chronic, highly oxygenated environment, which makes the seal housings the most susceptible of the three material CEDM components to transgranular stress corrosion cracking (TGSCC). The CEDM seal housings will be the first to crack and act as a precursor to ensuing cracking in the CEDM upper housings and reactor vessel head penetration nozzles. Therefore, by monitoring the condition of the CEDM seal housings with non-destructive examinations, FCS has a predictive tool to anticipate when the cracking in the CEDM upper housings and reactor vessel head penetration nozzles will occur. Based on this approach, FCS has performed non-destructive examinations of the CEDM seal housings in the past two refueling outages, and is continuing to develop a corrosion model by incorporating empirical experimental data.

The FCS CEDM program plan will incorporate, and address any new nuclear industry stress corrosion cracking events. FCS is actively pursuing greater understanding of the corrosion mechanism in the CEDM seal housings. FCS has self-identified the material reliability issue throughout the CEDM housing assemblies, and has instituted corrective actions and contingencies to address the concerns. The management of the material reliability of the FCS CEDM housings is proactive and innovative in assessing the risk, and ensuring the safe material health of each material component of the CEDM assemblies.

In the future, FCS plans to monitor nuclear industry stress corrosion cracking events and to participate in, and when necessary lead nuclear industry activities relating to stress corrosion cracking. During the 2002 refueling outage non-destructive examinations are being planned for the CEDM housings (in accordance with the FCS program plan) and effective visual examinations for the reactor vessel head. It is because of these activities and inspections in conjunction with a comprehensive FCS CEDM program plan that FCS concludes it is effectively managing its risk of stress corrosion cracking and maintaining reactor coolant system integrity by increasing the reliability of the CEDM assemblies

1.0 Introduction

At FCS, a corrosion model has been developed into a program plan for CEDM seal housings. This program plan is a living document that discusses the mechanism of stress corrosion cracking, contains results of non-destructive examinations and gives contingencies for repair and replacement of seal housings. It is the position of FCS that a key element in the cracking of the CEDM seal housings is the stagnant environmental condition that exists in the CEDM seal housings. The CEDM seal housings contain the highest degree of stagnancy, and a chronic, highly oxygenated environment, which makes the seal housings the most susceptible of the three material CEDM components to transgranular stress corrosion cracking (TGSCC). The CEDM seal housings will be the first to crack and act as a precursor to ensuing cracking in the CEDM upper housings and reactor vessel head penetration nozzles. Therefore, by monitoring the condition of the CEDM seal housings with non-destructive examinations, FCS staff and management have a predictive tool to assess the risk of cracking in the CEDM upper housings and reactor vessel head penetration nozzles. Therefore, FCS has self identified the material reliability issue of the CEDM housing and has instituted corrective actions that are described and/or elaborated in the following discussion.

1.1 Self-Identified Material Reliability Issue

In the last decade FCS and the Industry have experienced unscheduled outages, which were directly the result of transgranular stress corrosion cracking (TGSCC). This condition is a challenge to the material reliability for the CEDM housing assemblies. The kind of environment to subject the material condition into an accelerated corrosion attack is present at the FCS CEDM housing assemblies.

1.2 Corrective Actions Taken

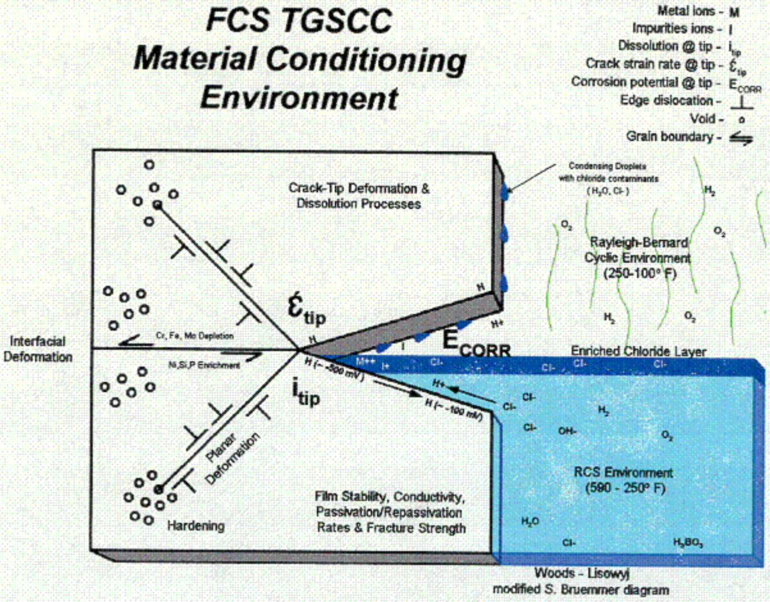
The possibility of TGSCC precipitated development of the Program Plan for FCS CEDM Seal Housings which applies critical self assessment of information, experience and techniques that support the goal of reliable plant material conditions. This program plan presents the basis of the inspection process with a discussion of the environmental conditions in relationship to the two phases of stress corrosion cracking (SCC), which are the incubation and cracking periods. The incubation and/or environmental conditioning period can be described with the industry's most current model diagram as a point of reference. The cracking period is based on the industry's use of

Weibull curves, and both FCS and Palisades data resulting in a prediction of cracked housings during the 1999 refueling outage at Palisades. However, the nuclear industry's prediction model's crack rate has shown to be an unreliable gage in the industry for predicting size and/or locating occurrences. This is due to the material conditioning rate (i.e., incubation period). Material conditioning is affected by many material factors, such as initial fabrication and localized environmental conditions, which make it difficult to quantify. Finally, FCS has a unique opportunity to utilize the information from our previous experience and future non-destructive examination signatures to develop a material conditioning model that will determine TGSCC occurrences for FCS components.

2.0 Program Plan for FCS CEDM Seal Housing Basis and Content

The basis for this program plan has been derived from elements that define TGSCC and the environmental effects that would elevate an early retirement of a component considered resistant to this kind of corrosive condition. These definitions help to define the risk, inspection focus and possible remediation/repair/replacement plan. A systematic inspection plan has been developed in conjunction with support from the Electric Power Research Institute and Westinghouse. In addition, FCS continues to interact with these institutes and other resources to enhance the reliability of this plan.

2.1 TGSCC Root Cause



Crack Model
Figure No. 1

The evolution of TGSCC is started from a process in which an electrochemically oxidizing corrosion environment removes surface metal ions. This chemical reaction attacks the steel's surface structure if not arrested by passivation of material surface (protective film layer). However, repassivation does not occur when the surface is being washed by an acidic solution contaminated by chlorides (leached from: Graphitar, O-ring and Flexitallic gasket). Therefore, this condition tends to deplete iron (Fe), chromium (Cr) and molybdenum (Mo) ions from the crack tip, which in turn are replaced by impurities resulting in a corrosion potential that is referred to as transpassive region (E_{corr}), see Figure No. 1 showing the corrosion mechanism.

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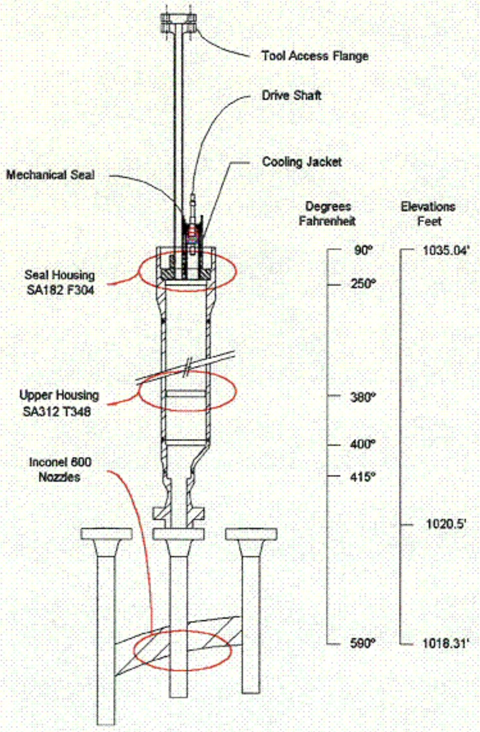
2.2 Environment Condition

The environment conditioning in the CEDM housings is considered to be accelerated by the process that is characterized by the Rayleigh-Bernard cycle. This condition assumes a void develops in a stagnant leg, and a cycle of wetting and drying develops, which removes the film layer and prevents repassivation. This condition would result in an aggressive electrochemical attack of the surface boundary in a corrosive resistant material. This offers a possible explanation for the industry's experience of premature failures of corrosive resistant materials such as stainless steel and Inconel 600 alloys.

2.3 Program Plan's Content Summary

This program plan's content has considered a selection, inspection, evaluation, remediation and repair of the CEDM seal housing assemblies at FCS. This information is based on the most current industry information on the principles, process and techniques for assessing SCC. In addition, the plan also describes in detail the history of gas bubble events that has prompted FCS's concerns for the CEDM housing assemblies material reliability based on TGSCC events of stainless steel material.

3.0 Program Plan's Broader View of Operating Experience



Broader View
Figure No. 2

At FCS as at other plants, the prime areas of concern are the reactor vessel head penetration (RVHP) nozzles. The nuclear industry has labeled these failures as primary water stress corrosion cracking (PWSCC), which has been generalized as a susceptible material under a tensile stress in an environment containing some oxygen and a chloride ion catalyst. A more specific corrosive model developed at FCS depicts the development of a low electrochemical potential (~500 mv) near a cold worked and/or tensile stressed area in contact with the primary system, which can initiate a Transgranular and/or Intergranular Stress Corrosion Crack (TGSCC/IGSCC). In this consideration, the focus of FCS has been to take a broader view of TGSCC versus reacting to single events. This broader view has included the RV head penetration nozzles, CEDM upper and seal housing assemblies (see Figure No. 2). Even though the CEDM upper and seal housing assemblies are made of stainless steel, the environmental conditioning that causes PWSCC is similar to the Inconel 600, head penetration nozzles. Understanding this conditioning or incubation period that is due to stagnancy is paramount to understanding SCC in the CEDM housings and RVHP nozzles.

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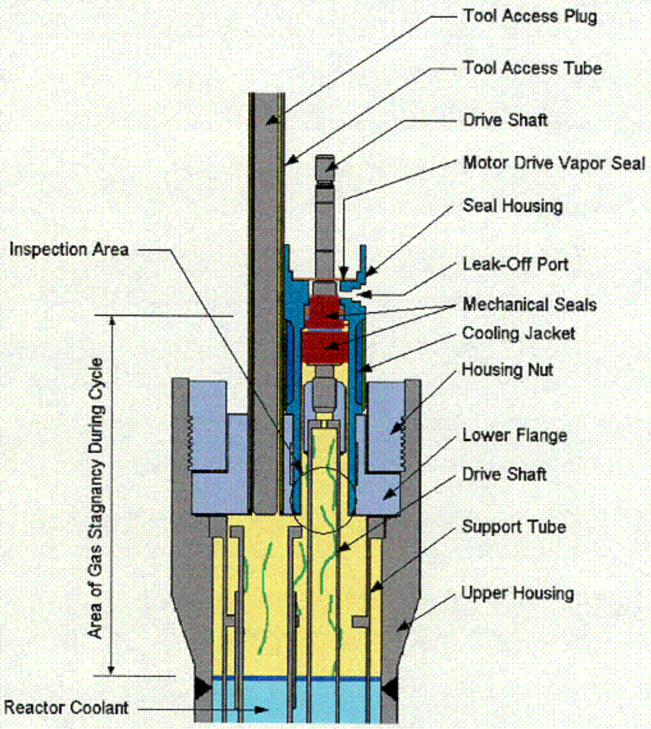
3.1 CEDM Seal Housing Assembly

The CEDM Seal Housing Assembly is made of ASME SA 182 Type F304 material. The assembly consists of three principal elements: the drive housing, the tool access tube and the autoclave flange (see Figure No. 3). The drive housing has an inside diameter (ID) of 2.0625" with a wall thickness of 312 mils and functions as a boundary between the RCS and motor drive. The tool access tube has an ID of 1.240" with wall thickness of 120 mils and provides access for decoupling the control element assembly prior to removal of the reactor head. These two components are sleeve fitted and seal welded to the autoclave flange (outside diameter of 8.825") that is bolted to the upper CEDM housing assembly.



Active Housing Stagnant Area
Figure No. 3

3.1.1 Active Housing Stagnant Area Defined

The stagnant legs of the reactor coolant system have shown signs of localized corrosion in which the metal loss has been exacerbated by the presence of oxygen, chloride and a tensile stress. The industry's and FCS's experiences with TGSCC of CRDM/CEDM assemblies including the seal housings at Palisades (1986 thru 1990, and 1999 events) and the upper assembly spares at FCS (1990 event) suggest similarities in environmental condition. These experiences have demonstrated a significant reduction in the components' life cycle, increased risk for unscheduled outages and reduced reliability of the reactor coolant system's integrity.

3.1.2 Environment/Material Condition Evaluated

The longest stagnant period is at or near the top of the upper housing assembly's autoclave connection to the seal housing assembly (see sketch in section 3.1). The CEDM seal housing is considered as a precursor and/or corrosion history definition for the reactor vessel head CEDM assemblies. It should be noted that each CEDM has a different degree of stagnancy relative to it's length, operational function and mechanical venting efficiency. The FCS staff has assessed the CEDM assemblies by evaluating fabrication and inspection records, re-inspecting, considering operating experience, industry data and inspection results to identify areas of concern. This model is continually being validated by operating experience and FCS investigation activities into the definition of material conditioning for the reactor vessel head assemblies.

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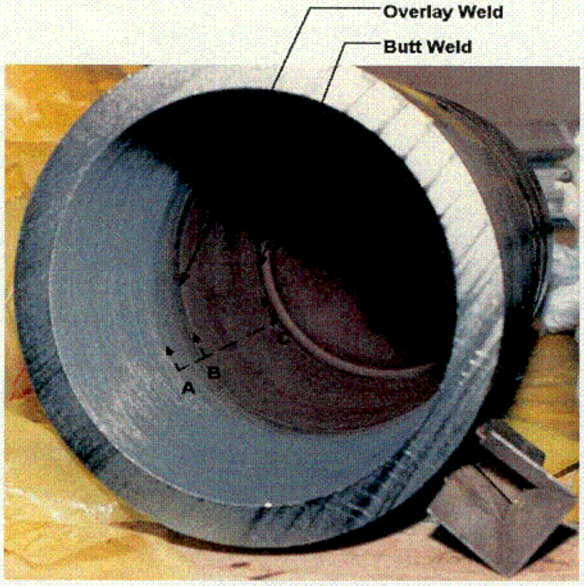
3.1.3 Risk Evaluated/Validated

Finally, the industry's experience on seal housings and upper housing assemblies defines a sequence of events that should be anticipated for the FCS reactor vessel head assemblies. These events should begin at FCS with a through-wall crack near the J-Weld of the CEDM seal housing assembly and about fifteen years later another through-wall crack should develop near the overlay weld for an active CEDM housing assembly. This scenario supports FCS's basis for the Program Plan for FCS CEDM Seal Housing, which has been in continual development since March 4, 1999. The program plan ensures ongoing monitoring of the CEDM seal housings with non-destructive examinations.

3.2 CEDM Upper Housing Assembly

The CEDM Upper Housing Assembly consists of an upper flange, lower flange and a modified eccentric reducer that is made of ASTM SA182 Type F348, and a pipe that is made of ASTM SA312 Type F348 material. This upper flange supports the seal housing assembly and is secured by a housing nut. The lower flange is secured to reactor vessel head penetration nozzle and is sealed by an omega seal. These flanges are attached to a 8", schedule 120 pipe and a 5"x8", schedule 120 eccentric reducer by butt welds and the internals support ring formed from an overlay weld. The assembly consists of five principal internals, which are: the support tube assembly, piston tube guide assembly, rack assembly, drive shaft, and bevel gear housing. The spare CEDM Upper Housing Assemblies were supplied with a spoiler to enhance circulation in these assemblies.



Non-Active Housing Stagnant Area
Figure No. 4

3.2.1 Non-Active Housing Stagnant Area Defined

The through-wall crack event at FCS in 1990 defines the maximum level of stagnancy in non-vented housings (spares). During the destructive examinations, a discoloration on the inside diameter surface was observed just below the overlay weld (Line 'B' on Figure No. 4). The importance of this information is the presentation of an oxygenated, chloride environment in the vicinity of a known tensile field relative to a through-wall TGSCC event. This environmental condition is a classic TGSCC model as presented in the FCS 'Program Plan for FCS CEDM Seal Housings'.

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3.2.2 Vented Versus Non-Vented Housing

The discoloration level (refer to section 3.2.1) is not a definition for an active/vented housing assembly, which will have a varying level of stagnancy that is dependent on operational activities and mechanical seal performance. This event does provide a real life predictive model based on environmental condition and residual stress conditions that induce TGSCC. The information provided by this event has been utilized in implementing a method in assessing material risk and management of the material condition of the reactor vessel head assemblies.

3.3 Reactor Vessel Head Penetration Nozzle

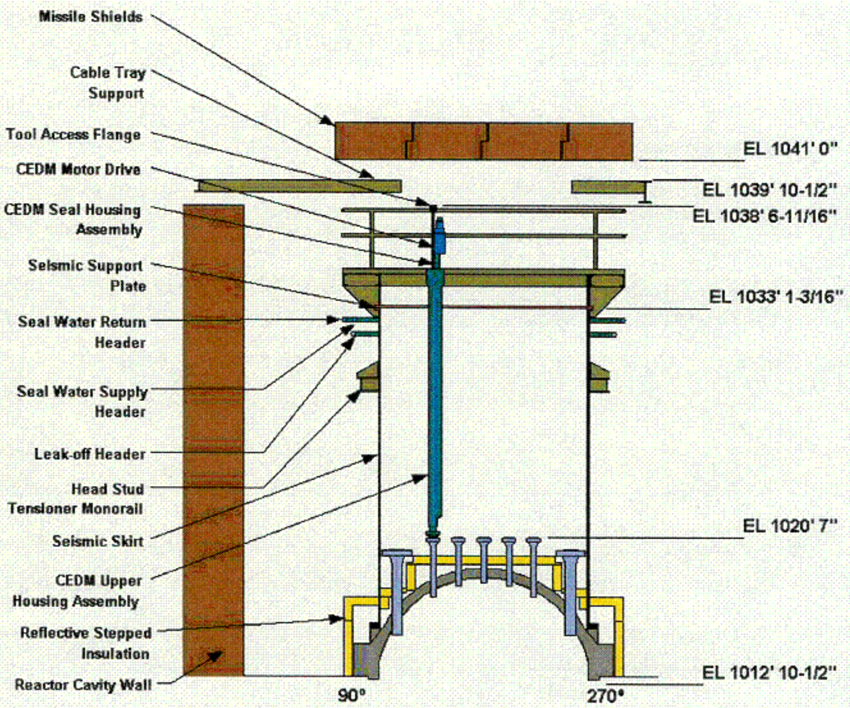
There are 48 RVHP nozzles of which 37 are used for active CEDMs, two of these are spares, two are heated junction thermocouples, six are incore instrumentation and one vent line. The majority of the nozzles are constructed with a stainless steel SA-183 type F316 safe-end and an Inconel SB-167 pipe connected by a full penetration butt weld and attached to the reactor head with partial penetration J-weld.

3.3.1 Industry Concerns

The most recent events that have raised concerns about material reliability for the primary water system occurred at V.C. Summer (NRC Information Notice 2000-17) and Oconee Unit 3 Nuclear Station (NRC Information Notice 2001-5). These two events have challenged the industry's predictability and degree of severity assessment on the effects of PWSCC of Alloy 600 in stagnant areas and/or stratified flows that produce a low corrosive potential. The safety concerns are the numbers, orientation, locations and coalescence of cracks in the areas of the reactor vessel hot/cold legs and CEDM nozzles above and below the interface J-weld. The incidence of circumferential secondary cracking at Oconee Unit No. 3 is a major current industry concern.

3.3.2 FCS Response

The NRC has issued Bulletin 2001-01 on RVHP nozzle cracking on August 3, 2001. The commission has grouped the primary water reactors into four categories based on the initial industry RV head time-at-temperature histogram in which FCS is assessed at 17.9 Effective Full Power Years (EFPY) from Oconee Unit 3 conditions. FCS has responded to this bulletin by demonstrating regulatory compliance, supplying requested information, and planning an effective visual examination of the reactor head surface during the 2002 refueling outage (see Figure No. 5).



RVHP and Associated Equipment
Figure No. 5

4.0 Conclusion

Management of the material reliability issues for the reactor vessel head assemblies has been addressed and actions taken based on the operating experience of the industry. These actions have considered the root cause of TGSCC by defining a crack model in relationship to the environmental and operational conditions that focus on a broader view perspective. In addition, a comprehensive FCS contingency plan is in place for the possible remediation/repair/replacement of the CEDM assemblies based on a theme of safe and reliable operation to reach end of life. Finally, FCS is continuing this effort in reassessing this concern based on the new information from on-going evaluation, inspection results and industry information and/or events. By performing this continuing assessment FCS is effectively managing its risk of TGSCC and increasing the reliability of the reactor vessel head CEDM assemblies.

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