Davis-Besse Reactor Vessel Head Damage

NRC UPDATE

November 2002

This is the third periodic update on the NRC response to the reactor vessel head damage at the Davis-Besse Nuclear Power Station. The updates will be available at public meetings of the NRC Davis-Besse Oversight Panel which is coordinating the agency's activities related to the damage. Each update will include background information to assist the reader in understanding issues associated with the corrosion damage.

Findings of Completed NRC Inspections

These inspections have been completed, and the reports are in preparation. When issued, the reports will be posted on the NRC's web site at: http://www.nrc.gov - select "Davis-Besse" from the list of key issues.

- ***Containment Extent of Condition Inspection***, Part 2, found that plant personnel were properly trained and qualified to identify components and systems inside the containment building that could be affected by boric acid deposits and corrosion. They used adequate tools and followed adequate quality standards and guidance.

  Before the NRC closes this issue, however, FirstEnergy has to complete their analysis of some unresolved items, such as corrective actions for boric acid corrosion of the electrical conduit and the containment air coolers and resolution of the origin of the corrosion staining found on the bottom of the reactor vessel.

  During the first part of the inspection, conducted in September, NRC inspectors found that, in some instances, plant personnel performing these inspections weren't properly trained and certified and found weaknesses in equipment used and quality assurance procedures. After FirstEnergy addressed these problems, NRC inspectors reviewed inspection methods, observed plant personnel performing inspections, and conducted independent examinations of components in containment.

- ***Reactor Vessel Head Replacement Inspection*** found that the old reactor vessel head was safely removed from the containment and stored; the procedures and methods used to open the containment

Ongoing NRC Inspections:

1. ***Management and Human Performance Inspection*** is evaluating FirstEnergy's root cause analysis associated with management, organizational effectiveness and human performance factors that are believed to have led to the degradation of the reactor head. The inspection is also focusing on the licensee's efforts towards creating a more safety-focused environment.

2. ***The Program Effectiveness Inspection*** is reviewing the plant's progress in creating more effective programs for such areas as corrective actions, boric acid corrosion control, modification control and others.

3. ***The two NRC resident inspectors*** continue their inspections of day-to-day activities at the Davis-Besse plant as well as supporting the specific inspections underway.

The NRC Lessons Learned Task Force will present its findings and receive comments in a public meeting at 7 p.m., Wednesday, November 20, in the Auditorium of the Oak Harbor High School.

and close it after the new head was moved into containment were adequate; and plant management used appropriate methods to ensure high quality of work being performed. As part of this inspection, the NRC also reviewed the technical part of Davis-Besse's root cause report for the boric acid corrosion of the reactor vessel head and found that the plant's analysis represented an acceptable scenario for the degradation.

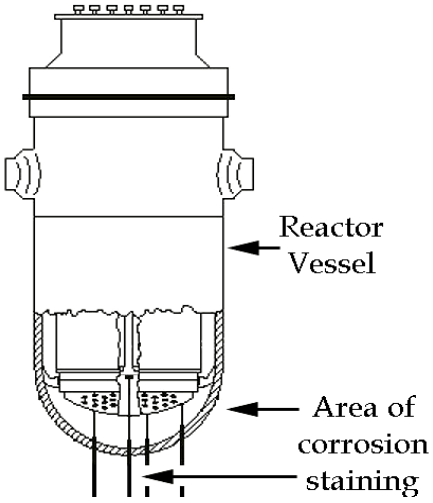
The inspection determined that the replacement head meets the applicable American Society of Mechanical Engineers codes. Inspectors reviewed the material and welds on the head and found that it was an acceptable replacement.

- ***Systems Health Inspection*** is reviewing the plant's assessment of important safety systems. NRC inspectors reviewed FirstEnergy's program for evaluating safety system health, observed and evaluated the implementation of the program by plant personnel, and conducted independent inspections of plant systems. The results of this inspection showed that the licensee's systems health program was effective and that the licensee had identified a significant number of problems requiring resolution.

  NRC inspectors also conducted a design review of three plant systems and found substantive issues requiring further review by FirstEnergy. As a result, the licensee has initiated a "collective significance" review of the NRC's findings and the plant's own inspection results in the system health area to formulate an appropriate plan of action.

- ***The Resident Inspectors' Report 02-10,*** issued October 30, documents inspections of activities such as adverse weather preparation, equipment alignment, plant modifications, and maintenance risk assessment. The findings included one low-level violation for an inadequate procedure dealing with scaffolding placement and several observations regarding implementation of the Return to Service Plan.

Results of Bottom Nozzle Tests Are Inconclusive



FirstEnergy identified rust stains on the bottom of the reactor vessel earlier this year. The stains became visible in June when plant workers removed the insulation from the reactor vessel in order to examine its condition. The licensee believes the stains probably resulted from previous cleaning of the reactor vessel head. A less likely possibility was that the stains resulted from leakage from the penetrations for incore monitoring tubes. There has been no history of such leakage in other U.S. pressurized water reactors. There are 52 tubes, each less than one inch in diameter, which contain incore monitoring devices used to measure conditions in the reactor.

The utility's consultant, Framatome, compared the chemical composition of the corrosion on the top of the reactor vessel head to the stains on the bottom. The testing showed some variation between chemical composition of corrosion products from the top of the reactor and stains on the bottom. The analyses, however, did not provide a conclusive link to the upper vessel head cleaning, nor did they show evidence of leakage from the incore tube penetrations.

Davis-Besse is reviewing its options for definitive testing of the bottom nozzles for leaks. The NRC will review the utility's testing and inspection plans and monitor the tests. The issue will be resolved prior to the NRC considering whether the plant can restart.

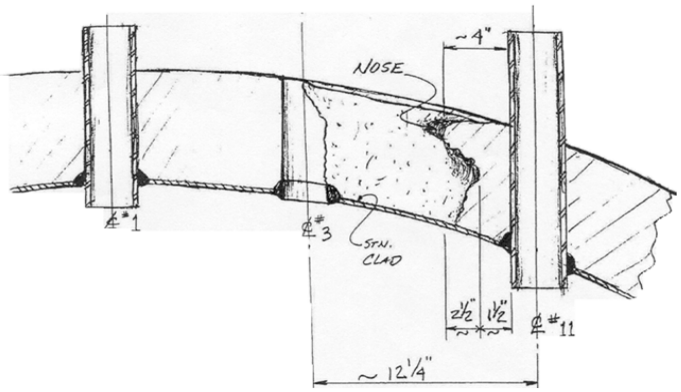
NRC Denies Petition For Independent Review

On October 15, the NRC denied a petition, submitted by several public interest groups under Section 2.206 of the agency's regulations. The groups sought an independent third-party review of all reactor head issues at Davis-Besse. The petition was denied because such a review would unnecessarily duplicate the agency's activities. The NRC is addressing the technical and human performance problems at Davis-Besse raised in the petition through its Oversight Panel activities. Issues regarding the agency's regulatory performance were addressed by the Lessons Learned Task Force. The task force report and recommendations are currently under review by a special management review team which will formulate proposed actions by the agency.

The denial decision and the petition are available for review on the NRC's web site at: http://www.nrc.gov - select "Davis-Besse" under key issues and then select "controlled correspondence."

Sump Screen Improvement

The NRC is reviewing a FirstEnergy initiative to increase the area of the sump strainers in the reactor containment at Davis-Besse. The sump is a collection point for water that would be recirculated for reactor cooling in the event of a loss-of-coolant accident. This sump modification, which was not required by the NRC, has been initiated by FirstEnergy to ensure that the strainers do not get clogged by debris which might collect at the bottom of the containment. The additional surface area of the sump strainers will provide a substantial improvement in the plant's design safety margin.



Sketch provided to NRC by FirstEnergy

Background: What Happened at Davis-Besse

In March 2002 plant workers discovered a cavity in the head or top of the reactor vessel while they were repairing control rod tubes which pass through the head.

The tubes, which pass through the reactor vessel head, are called control rod drive mechanism nozzles. Cracks were detected in 5 of the 69 nozzles. In three of those nozzles, the cracks were all the way through the nozzle, allowing leakage of reactor cooling water, which contains boric acid.

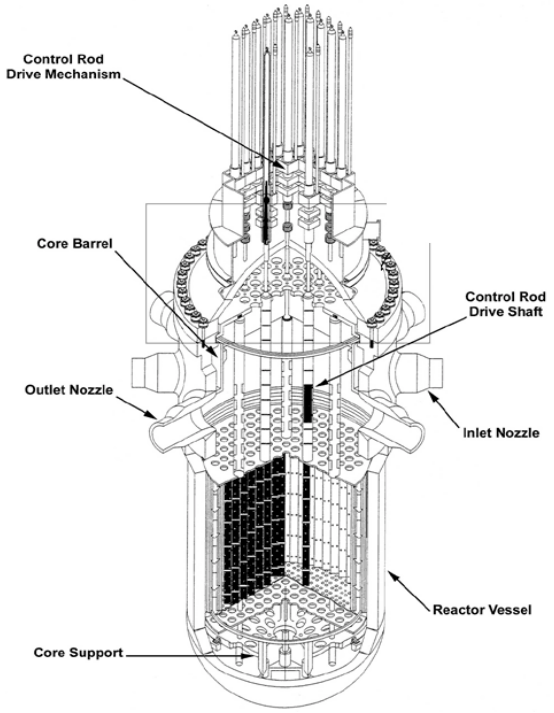
Corrosion, caused by the boric acid, damaged the vessel head next to Nozzle No. 3, creating an irregular cavity about 4 inches by 5 inches and approximately 6 inches deep. The cavity penetrated the carbon steel portion of the vessel head, leaving only the stainless steel lining. The liner thickness varies somewhat with a minimum design thickness of 1/8 inch. Subsequent examination by Framatome, FirstEnergy's contractor, found evidence of a series of cracks in the liner, none of which was entirely through the liner wall.

Earlier indications of the problem: Through-Wall Cracking of Nozzles in France and at the Oconee Nuclear Power Station in South Carolina

In the early 1990's control rod drive mechanism nozzle cracking was discovered at a nuclear plant in France. These cracks penetrated the nozzle wall along the length of the nozzle (referred to as 'axial' cracking). In 1997 the NRC issued Generic Letter 97-01 to gather information on the inspection activities for possible cracking in the control rod drive mechanism nozzles in plants in the United States. Subsequently, through-wall circumferential cracks -- around the nozzle wall -- were discovered in two control rod drive mechanism nozzles at the Oconee Nuclear Power Station, Unit 3, in 2001. While axial cracking had been found at several other plants and repaired, circumferential cracking had not been seen before. Circumferential cracking is more significant because it could lead to complete separation of the nozzle and a resulting loss-of-coolant accident.

After the Oconee discovery, the NRC issued Bulletin 2001-01, requiring all pressurized water reactor (PWR) operators to report to the NRC on structural integrity of the nozzles, including the extent of any nozzle cracking and leakage and their plans to ensure that future inspections would guarantee structural integrity of the reactor vessel boundary. The NRC's Bulletin instructed nuclear power plants with similar operating history to Oconee Unit 3, including Davis-Besse, to inspect their reactor vessel head penetrations by December 31, 2001, or to provide a basis for concluding that there were no cracked and leaking nozzles.

Typical Pressurized Water Reactor



FirstEnergy Nuclear Operating Company requested an extension of the inspection deadline until its refueling outage beginning March 30, 2002, and provided the technical basis for its request. The NRC did not allow the plant to operate until March 30, but agreed to permit operation until February 16, provided that compensatory measures were taken to minimize possible crack growth during the time of operation. The NRC was unaware that nozzle leakage or corrosion had occurred at Davis-Besse when it agreed to the February 16 date.

Boric Acid Corrosion Control Procedure

The water that circulates through a pressurized water reactor to cool the nuclear fuel contains a low concentration of boric acid. This borated water can potentially leak through flanges, pump and valve seals, and other parts of the reactor cooling system and cause corrosion.

The NRC has taken steps to make sure that PWR operators are aware of and pay attention to the corrosion boric acid can cause in certain environments:

- In 1986-89, the NRC issued a series of documents, called "generic communications," informing PWR licensees that boric acid can corrode and damage steel reactor components.

- The NRC's Generic Letter 88-05 requested PWR operators to implement a program to ensure that boric accid corrosion does not lead to degradation of the reactor cooling system components. All nuclear power plants with PWRs, including Davis-Besse, reported to NRC that the Boric Acid Control Procedures had been established and would be implemented.

Barriers Built into Nuclear Plants to Protect Public Health and Safety

The design of every nuclear power plant includes a system of three barriers which separate the highly radioactive reactor fuel from the public and the environment. The Davis-Besse reactor head damage represented a significant reduction in the safety margin of one of these barriers, the reactor coolant system. The reactor coolant system, however, remained intact, as well as the other two barriers, the fuel and the containment.

1. <u>Fuel Pellets and Rods</u>

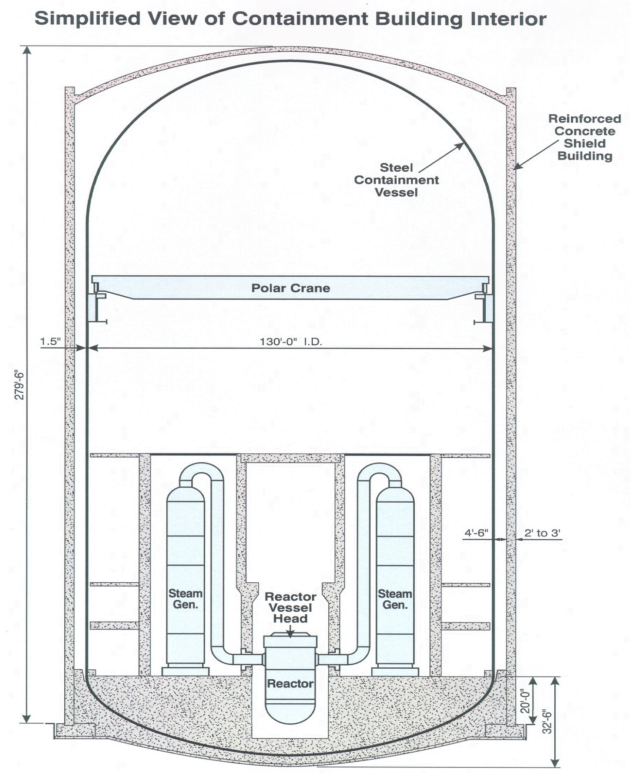
The first barrier is the fuel itself. The fuel consists of strong, temperature-resistant ceramic pellets made of uranium-oxide. The pellets are about the size of a little finger-tip. They retain almost all of the highly radioactive products of the fission process within their structure.

The pellets are stacked in a rod made of a zirconium alloy. At Davis-Besse, each fuel rod is about 13 feet long. The rods are assembled into bundles, with each assembly containing 208 rods. The reactor core

contains 177 fuel assemblies. Any fission products which escape from the pellets are captured inside the cladding of the rod, which is designed to be leak-tight. Small pin hole leaks do occasionally occur, however, and the operating license requires leakage monitoring and contains limits on the maximum allowable leakage of radioactive materials from the fuel rods.

2. Reactor Coolant System

The second barrier is the reactor coolant system pressure boundary. The reactor core is contained inside the reactor pressure vessel, which is a large steel container. Thick steel pipes supply cooling water to the reactor and carry away the heated water after it passes through the reactor core. The pressure vessel, the connected piping, and other connected components make up the reactor coolant system pressure boundary. At Davis-Besse, the reactor coolant system contains about 60,000 gallons of cooling water, circulated by four large pumps at a rate of about 360,000 gallons per minute.



This system is designed to be leak-tight at operating conditions which include a water temperature of 605° F and a water pressure of 2,150 pounds per square inch. The operating license contains limits on the maximum allowable amount of leakage from the system, and it specifies requirements for monitoring any leakage. If a leak is identified as being through any solid wall of the system (reactor vessel, cooling pipes or other components) continued operation of the plant is prohibited, no matter how small the leak rate.

3. Containment Building

The third barrier is the containment building. This is a large cylindrical building which contains the entire reactor coolant system. None of the piping that contains the high-temperature and high-pressure reactor coolant water extends outside the containment building. The containment is a 1 1/2 inch thick steel cylinder, rounded at the top and bottom, which is designed to be leak-tight. This steel structure is surrounded by a reinforced concrete shield building, which is the round building visible from the outside of the plant. Its walls are 2 to 3 feet thick.

NRC's Response to Vessel Head Damage

The NRC responded to the vessel head degradation with a series of actions, some specific to Davis-Besse and others aimed at other PWR plants. The agency began a review of its regulatory activities as well.

Davis-Besse

On March 12, 2002, the NRC initiated an Augmented Inspection Team to examine conditions that led to the head degradation and on March 13, 2002, the NRC issued a Confirmatory Action Letter to Davis-Besse documenting a number of actions the plant needed to implement for the unit to be allowed to restart. On April 29, 2002, the NRC established an Oversight Panel under the Agency's Manual Chapter 0350, to coordinate and oversee NRC activities necessary to address repairs and performance deficiencies at the plant in order to guarantee that it can operate safely. The plant will not restart until the NRC is satisfied that plant operators have met all necessary safety requirements.

Generic

On March 18, 2002, the NRC issued Bulletin 2002-01, instructing PWR licensees to report on the condition of their head, past incidents of boric acid leakage and the basis for concluding that their boric acid inspection programs were effective. All plants sent their responses and indicated that no evidence of extensive corrosion of reactor vessel heads was found at these plants. On August 9, 2002, the NRC issued Bulletin 2002-02 advising PWR operators that more stringent inspection techniques may be necessary to detect head penetration nozzle cracks. Visual examination of reactor vessel heads and nozzles may need to be supplemented with other inspection techniques, such as the use of ultrasound, electric currents and liquid dyes. In October, the agency also requested PWR licensees to provide additional information on their boric acid inspection program with greater detail than initially covered in the responses to Bulletin 2002-01.

NRC Davis-Besse Oversight Panel

An NRC Davis-Besse Oversight Panel was created to make sure that all corrective actions, required to ensure that Davis-Besse can operate safely, are taken before the plant is permitted to restart and that Davis-Besse maintains high safety and security standards if it resumes operations. Should the plant restart, the Oversight Panel will evaluate if Davis-Besse's performance warrants reduction of the NRC's heightened oversight and, if so, recommend to NRC management that the plant return to a regular inspection schedule. The panel was established under the agency's Manual Chapter 0350.

The panel brings together NRC management personnel and staff from the Region III office in Lisle, Illinois, the NRC Headquarters office in Rockville, Maryland and the NRC Resident Inspector Office at the Davis-Besse site. The eight-member panel's chair and co-chair are John Grobe, a senior manager from Region III and William Dean, a senior manager from NRC headquarters.

As part of determining if plant corrective actions are adequate to support restart, the Oversight Panel will evaluate FirstEnergy's return to service plan, which is divided into seven areas of performance that the utility calls "building blocks." A series of NRC inspections are being performed to verify the company is taking proper actions in each of the seven areas. These reviews will include the work by the FirstEnergy staff and, in addition, the NRC staff will perform independent inspections in each of the "building block" areas.

Issues to be resolved in order for Davis-Besse to restart

The NRC Oversight Panel will only consider recommending that Davis-Besse resume operations when the plant has demonstrated its readiness to operate safely. Key elements will include:

- Davis-Besse management and personnel properly understand the technical, organizational, programmatic and human performance problems that led to the extensive degradation of the plant's reactor vessel head.

- Davis-Besse enhances programs for operating the plant safely, detecting and correcting problems, controlling boric acid corrosion, and is fostering a more safety-conscious environment among plant managers and workers.

- Davis-Besse improves the performance standards of its managers and workers, including their "ownership" of the quality of work products and the safety focus of decision-making.

- The replacement of the vessel head is technically sound and all reactor components are inspected, repaired as necessary, and demonstrated to be ready for safe operation.

- Plant safety systems inside and outside containment are inspected, repaired as necessary, and have been confirmed to be ready to resume safe operation of the plant.

- Plant operators demonstrate appropriate safety focus and readiness to restart the plant.
- Any organizational or human performance issues resulting from the ongoing investigation conducted by the NRC's Office of Investigations are addressed.
- All licensing issues that have arisen as a result of the reactor head replacement have been resolved.
- Resolution of radiation protection issues associated with the radiation exposure to workers during steam generator work and the particle contamination found in offsite locations.
- Modification of the strainer system for the containment sump, which would be the source of cooling water for recirculation in the event of a loss-of-coolant accident.

What Happens If the Plant is Allowed to Restart

If the facility is permitted to restart, the NRC Oversight Panel will continue to monitor plant activities and operations until panel members are confident that the root cause(s) of the problem have not recurred. Should FirstEnergy achieve that performance level, the NRC Oversight Panel would recommend to NRC management that responsibility for the plant oversight be transferred back to the Region III line organization for monitoring under the Reactor Oversight Process. The panel would then cease to exist. Should FirstEnergy not demonstrate sustained improved performance, the panel will recommend appropriate regulatory actions.

Public Participation in the Process

The NRC's experience is that members of the public, including public officials and citizens, often raise questions or provide insights that are important to consider. If you have questions or want to provide information or a point of view, please contact us. For feedback on this newsletter, contact Viktoria Mitlyng 630/829-9662 or Jan Strasma 630/829-9663 (toll free 800/522-3025 - ext -9662 or -9663). E-mail: opa3@nrc.gov. Extensive information about the Davis-Besse reactor vessel head damage and the ensuing activities is available on the NRC web site: http://www.nrc.gov - select "Davis-Besse" under the list of key topics.