From: Eric Duncan R3
To: ExponentReportGroup
Date: Fri, May 4, 2007 4:05 PM
Subject: Fwd: Mattson Report

See attached report.

>>> <rritzman@firstenergycorp.com> 05/04/2007 3:56:57 PM >>>

Attached is the Mattson transmittal letter and report. The figures are in black and white - the file is too large to e-mail with color figures.

(See attached file: Mattson Report.pdf)(See attached file: Mattson Report Submittal Letter.pdf)

F-212

Report on Reactor Pressure Vessel Wastage at the Davis-Besse Nuclear Power Plant

December 2006

Roger J. Mattson, Ph.D.

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Attachments

Report on Reactor Pressure Vessel Wastage at the Davis-Besse Nuclear Power Plant

1. Introduction

1.1 Assignment

My name is Roger J. Mattson and my business address is 2511 Fossil Trace Court, Golden, CO 80401. I am self-employed.

I am appearing in this arbitration on behalf of FirstEnergy Nuclear Operating Company (FENOC). (A list of Acronyms is provided in Attachment RJM-1.)

I have been asked by FENOC to perform an independent assessment of the issues identified in the May 9, 2006 "Statement of Defense" provided by Nuclear Electric Insurance Limited (NEIL) insofar as those issues concern the safety regulatory aspects of the operation of the Davis-Besse nuclear power plant in the years leading up to the discovery of wastage of the head of the reactor pressure vessel (RPV) in early March 2002.

First, I have been asked to assess the development and implementation of the Boric Acid Corrosion Control (BACC) program at Davis-Besse and determine whether it was deliberately violated prior to the accident causing the wastage of the reactor vessel head. In making this assessment, I have reviewed and discuss in this report the Nuclear Regulatory Commission's process for overseeing nuclear power plants and the requirements it has established that pertain to Reactor Pressure Vessel (RPV) reliability and boric acid corrosion. In making this assessment, I review, among other things, performance at Davis-Besse in comparison to other nuclear power plants operating in the United States in general terms through the use of performance indicators and in terms specific to its BACC program.

Second, I have reviewed the circumstances surrounding the NRC fine assessed against Davis-Besse and the accompanying Notice of Violation (NOV) and considered whether they are significant indicators of willful misconduct by FENOC with respect to the NRC requirements on boric acid corrosion. In addressing this issue, I have reviewed the various hindsight reports prepared by FENOC, the NRC and others, as well as the comparisons of performance indicators noted above. I have also reviewed data regarding the NRC history of levying fines, again both generally and in regard to BACC.

Third, I have addressed the generic implications of the cracking of the control rod nozzles and the consequent reactor pressure vessel head wastage at Davis-Besse. In doing so, I have reviewed the various technical issuances and generic guidance prepared by the NRC and the industry following the event to assess what these "lessons learned" by the NRC and the industry say about the reasonableness of FENOC's actions before the event.

1.2 Standards

In my analysis I describe and apply two different standards that figure in the Davis-Besse RPV head wastage event. First, there is the standard used by the NRC for the regulation of the safety of nuclear power plants in the United States. That standard derives from the Atomic Energy Act of 1954, as amended, and requires the NRC to provide "reasonable assurance of adequate protection of public health and safety" (Sections 182 and 189) during nuclear power plant operation.

Under this standard, the safety of nuclear power plants is required, as a matter of national policy, to be maintained at very high levels established by the NRC. The NRC has promulgated regulations and other guidance to licensees to define its requirements for assuring adequate protection. At this stage of maturity of the nuclear power industry, the NRC's regulations change only occasionally. However, its safety performance expectations are continually rising through changes in the interpretation of its regulations.

For example, in 2000 the NRC implemented a new Reactor Oversight Process (ROP). The ROP is based on four decades of nuclear power plant operating experience and is designed to take advantage of the maturity of the nuclear industry. It uses insights to safety significance based on risk assessment techniques that were pioneered by the NRC in the mid 1970s and are now widely used in the industry. The NRC implemented the ROP without changing its regulations.

It is important to recognize that the NRC's standard is not a reasonableness standard, i.e., the NRC does not consider whether utility management's actions were reasonable at the time such actions were taken. Rather, the NRC evaluates the results of plant management decisions primarily based on hindsight. The NRC has a policy of continuing to learn from operating experience, and it requires the same from its licensees. The NRC might describe an event as "avoidable", but in doing so, it would take full advantage of knowledge that was gained after the fact. Thus, significant events are studied (including assessments of root causes and extent of condition) to identify lessons learned to help avoid that type of event or more serious events in the future. The NRC takes full advantage of the hindsight bias that is contained in retrospective analyses of operating experience performed by NRC and its licensees. The NRC uses this approach to assure that the safety of nuclear power plants is continually improving. In this way the entire industry is always striving to make plants safer tomorrow than they are today. It has proven to be a good approach but it is different than a reasonableness standard.

The second type of standard that applies to the RPV head wastage event (hereinafter, wastage event or just event) at Davis-Besse is a reasonableness standard. It acknowledges that there is a range of options available to utility management, and it accepts that reasonable utility managers might choose different alternatives from within that range. Also, a negative outcome is not necessarily indicative of an unreasonable decision – sometimes the best we can do with the information we have is to make a choice that in retrospect leads to adverse consequences. Because utility management decisions must be made "in the moment", before their outcome can be known, an evaluation of their reasonableness must occur within the context of the information that was available to the decision makers at the time decisions were made. Hindsight is not used in judging reasonableness. Thus, when performing a reasonableness assessment that depends on reports of retrospective analyses, such as those presented in root cause assessments performed by NRC licensees and inspection and investigation reports of the NRC, one must be careful to remove the hindsight bias that such reports contain.

This is not to say that after-the-fact reports generated by NRC and its licensees, enlightened by hindsight, are useless in reasonableness considerations. Rather, decision makers must be careful in interpreting such reports to separate what a reasonable utility manager should have known at the time a decision was made from what that manager later learned only with the benefit of hindsight.

1.3 Approach

In formulating my opinions in this case I have read a number of documents developed by FENOC (or its predecessor Toledo Edison) and the NRC. The documents that I have relied upon are cited as references in this report by use of endnotes.

I also asked SCIENTECH LLC, the company with which I was formerly affiliated and which has an outstanding capability to retrieve documents and data concerning licensed nuclear facilities, to compile performance statistics for Davis-Besse and other operating nuclear power plants. I have interpreted those statistics as described in Section 3, below. SCIENTECH also provided NRC documents dealing with boric acid controls at plants other than Davis-Besse.

In formulating my opinions I have applied a standard of reasonableness in judging the decisions and actions of FENOC. Where I have relied upon NRC documents to reach my conclusions regarding reasonableness, I have endeavored to separate what NRC knew from hindsight as compared to what FENOC knew or reasonably should have known at the time it made its decisions regarding operations at Davis-Besse. There were also a number of misunderstandings of the nature of boric acid corrosion of the RPV head that were prevalent in the industry before the Davis-Besse event, and I have endeavored to point these out in my report, where appropriate.

1.4 Qualifications

My qualifications are described in detail in my resume in Attachment RJM-2 and summarized here. I am a mechanical engineer and have worked in assuring safety in the nuclear power and nuclear weapons production fields for over 40 years. I received a Ph.D. in mechanical engineering from the University of Michigan in 1972. My Bachelors and Masters Degrees are also in mechanical engineering, from the Universities of Nebraska and New Mexico, respectively. After my first job, a three year stint designing test reactors and irradiation experiments at Sandia National Laboratory in Albuquerque, New Mexico, I served with the headquarters staff of the federal government agencies responsible for regulating the safety of nuclear power plants, the Atomic Energy Commission (AEC) and its successor, the Nuclear Regulatory Commission, for most of the period from 1967 through early 1984. For a brief period in 1980 and 1981, I managed radiation protection and emergency preparedness activities in the Environmental Protection Agency (EPA).

My last seven years at the NRC were spent as Director, in succession, of three Divisions: Systems Safety, Safety Technology, and Systems Integration, in the Office of Nuclear Reactor Regulation (NRR). In those positions, I was responsible for much of the technical review of applications for construction permits, operating licenses, and license amendments for nuclear power plants. People under my supervision reviewed applications for those licensing actions in the following technical areas: reactor systems, containment systems, reactor core performance, fuel design, instrumentation and control systems, power systems, balance of plant systems, spent fuel storage, accident analysis, radiation protection, emergency preparedness, and a variety of engineering disciplines, depending on the time period, including structural design, codes and standards, seismic analysis, fire protection, and equipment qualification. I had signature authority for the technical content of safety evaluations in all of these disciplines for all nuclear power plants under construction or in operation.

In various capacities, I managed development and implementation of the NRC's regulatory requirements for most of the period from 1974 to 1984. I or persons reporting to me have performed safety reviews of all the nuclear power plants now operating in the United States, including Davis-Besse.

I have continued to be involved in assuring the safety of nuclear power plant construction, operation and decommissioning subsequent to my NRC experience. From 1984 to 1987, I worked for International Energy Associates Limited (IEAL). It was a technical services company specializing in nuclear technology with utility and government clients in the United States, Western Europe and Asia. I joined SCIENTECH, Inc. in 1987. While I was there, SCIENTECH provided services in environmental protection; nuclear power plant design, operations, reliability, and maintenance; replacement of obsolete instrumentation and controls for nuclear power plants; reliability of aircraft; information systems; interactive networks; and security systems. I served as the Chief Operating Officer of both IEAL and SCIENTECH. I retired from SCIENTECH in 2002 and have worked as an independent consultant since that time.

Some of the projects in which I have been personally involved since leaving NRC employment, and that keep me apprised of NRC's regulatory approach, are as follows:

- Co-chair of a panel to develop the International Atomic Energy Agency's Safety Principles for nuclear power plants (INSAG-3) after the accident at Chernobyl in the former Soviet Union;
- Reviews of advanced reactors for the Department of Energy (DOE), including advanced light water reactors being developed by Westinghouse and General Electric Companies, the gas-cooled Next Generation Nuclear (Power) Plant, the New Production Reactor and the fast burner reactors recently proposed for the President's Global Nuclear Energy Partnership;
- Reviews sponsored by DOE of commercial projects to develop combined operating license applications for advanced nuclear power plants;
- Assistance in developing nuclear plant life extension and advanced reactor licensing approaches for NRC;
- Studies of safety, cost and schedule effects of NRC regulation on about 20 nuclear construction projects and about 20 operating plants;
- Chair of operational readiness reviews for Limerick 2 nuclear power plant, DOE's Savannah River K Reactor, and DOE's Rocky Flats plutonium facility;
- Studies of environmental, safety, and health vulnerabilities of weapons production reactors and uranium and plutonium processing facilities at Savannah River, Rocky Flats, Livermore, Los Alamos, Hanford and Pantex;
- Member of Nuclear Safety Review Boards for Limerick and Peach Bottom nuclear power stations and for DOE's N-Reactor;
- Vice-chair of Nuclear Safety Review Board for the Rocky Flats Site;
- Vice-chair of Nuclear Safety Review Panel for a project in the Dynamic Experiments Division at Los Alamos National Laboratory;
- Studies for American Nuclear Insurers of regulatory implications of claims of radiation injury at six nuclear facilities (San Onofre, Pilgrim, St. Lucie, Three Mile Island, Apollo, and Parks Township); and
- Safety and management consultant on decommissioning of Maine Yankee and

Connecticut Yankee nuclear power plants.

Also, I have consulted on nuclear safety matters in England, Spain, France, Germany, Ukraine, Russia, Kazakhstan, Egypt, China, Japan, Taiwan, and South Korea.

I have testified as an expert witness or Federal agency representative before committees of the U.S. House of Representatives and Senate, DOE, EPA, NRC, NRC's Advisory Committee on Reactor Safeguards, Defense Nuclear Facilities Safety Board, DOE's Advisory Committee on Nuclear Facility Safety, President's Commission on Three Mile Island, President's Nuclear Safety Oversight Board, licensing and rule-making hearing boards, regional planning commissions, state public service commissions, courts, arbitration panels, and international organizations.

1.5 Summary of Conclusions

Davis-Besse was considered a well-run nuclear power plant prior to the discovery of the wastage of the reactor head. Its BACC program was reasonably developed as measured by contemporaneous NRC inspections both at Davis-Besse and other nuclear power plants. These inspections were conducted by the NRC with knowledge of the accumulation of boric acid on the reactor head and in containment. Prior to the wastage event, at no time did the NRC complain to FENOC about its BACC program at Davis-Besse or the accumulation of boric acid on the reactor head and in containment. Also NRC did not require any corrective actions at Davis-Besse relative to BACC not already identified by the licensee. The contemporaneous record demonstrates that Davis-Besse did not willfully or intentionally violate its BACC program.

Contrary to the views expressed in NEIL's Statement of Defense, the payment of the NRC fine and the accompanying Notice of Violation relating to the reactor vessel head wastage do not substantiate that FENOC engaged in any willful or intentional misconduct at Davis-Besse. The imposition of a fine is the NRC's hindsight response to any significant adverse event at a nuclear power plant and is used to send a signal to the industry that steps must be taken to ensure that such events do not occur in the future. Such a fine is not sufficient to prove willful misconduct. In addition, the fact that FENOC paid the fine without contest is not evidence of any misconduct, nor is it evidence that FENOC agreed that such a fine was justified. NRC fines are nearly always paid without contest because the licensee typically wants to put the event behind it. In this case neither the fine nor the Notice of Violation charged FENOC with willful or intentional misconduct regarding the cracked control rod drive (CRD) nozzle or the consequent damage to the reactor head. Based on its prior inspections of the Davis-Besse, NRC had knowledge of the accumulation of boric acid on the reactor head and in containment. Thus, there is no reasonable basis for concluding the that NRC fine and the Notice of Violation substantiate that FENOC engaged in willful or intentional misconduct leading to the damage to the reactor head.

Finally, based on the NRC actions taken following the discovery of the wastage of the reactor head, it is clear that NRC, FENOC, and the nuclear industry could not have foreseen the accident that occurred at Davis-Besse or the consequent damage to the reactor head.

My detailed conclusions regarding these issues are set forth at the end of this report.

2. NRC Regulation of Nuclear Power Plants

2.1 Organization and Function of NRC Units

The Atomic Energy Commission (AEC) was created by the Atomic Energy Act of 1946. In 1954, the AEC was given responsibility for both promoting and regulating the peaceful uses of atomic energy. These dual roles eventually were perceived to conflict with one another and the United States Congress passed the 1974 Energy Reorganization Act that divided the responsibilities, with the regulatory functions of the old AEC being assigned to the newly-created NRC and the promotional functions being assigned to the new Energy Research and Development Administration, now called the Department of Energy (DOE).

The NRC was established as an independent agency and charged with a primary responsibility of protecting the health and safety of the public and the environment for commercial applications of radioactive materials. The NRC licenses and regulates the ownership, construction, operation and use of nuclear facilities and materials in the public sector. The Commission promulgates regulations and issues other regulatory requirements governing such licenses. In addition, the NRC inspects its licensees to ensure they operate safely and in compliance with their licenses and applicable safety requirements.

A primary purpose of the NRC's regulatory activities is to determine if there is reasonable assurance that the nuclear power plants it licenses are being operated safely and in accordance with the NRC's requirements. A principal focus of the regulatory program is to identify problems, such as operational errors or equipment failures, which could be precursors of more serious events that might threaten the health or safety of workers and the public.

The five members of the Commission are appointed by the President and confirmed by the Senate. The Chairman of the Commission, selected by the President, is the principal executive officer and the official spokesperson of the Commission. The Commission sets regulations and policy relative to safety and licensing of nuclear facilities.

The activities of the NRC's program and support staff are conducted under the direction of the Executive Director for Operations (EDO). The EDO, who reports to the Chairman of the NRC, is also responsible for the development of policy options for Commission consideration. Personnel managed by the EDO are generally referred to as the NRC Staff.

The Office of Nuclear Reactor Regulation is the reactor licensing and inspection branch of the NRC. It oversees nuclear power plants from cradle to grave, including initial permitting, startup, operations, and decommissioning.

The NRC's Office of Research conducts independent research to confirm the technical adequacy of NRC's regulatory requirements and to investigate the significance of emerging safety concerns.

The NRC maintains four regional offices, which are located in or near Philadelphia, Atlanta, Chicago, and Dallas. Davis-Besse is within the jurisdiction of the NRC's Region 3 Office located near Chicago. An important function of the regional offices is the assignment and oversight of resident inspectors for each nuclear power plant. Typically, Davis-Besse has had one resident inspector and one senior resident inspector since the program was established by NRC in the early 1980s.

The NRC's enforcement program is conducted under the direction of the Office of Enforcement. It manages enforcement policy and actions and evaluates regional enforcement activity to assess effectiveness and consistency.

The NRC's Office of Inspector General was established as a statutory entity in 1989 in accordance with the 1988 amendment to the Inspector General Act that became law in 1987. Its missions are to (1) independently and objectively conduct and supervise audits and investigations relating to NRC programs and operations; (2) prevent and detect fraud, waste, and abuse; and (3) promote economy, efficiency, and effectiveness in NRC programs and operations.

The NRC has a technically competent staff (mostly engineers and scientists) of more than 3,000 employees. The NRC's budget for fiscal year 2005 was $669 million. The technical work of the agency is supported by contract assistance from the National Laboratories (Los Alamos, Sandia, Brookhaven, Oak Ridge, etc.) and commercial contractors. The agency's headquarters is located in Rockville, Maryland, while the majority of the NRC inspectors are stationed in the four regional offices and on-site at operating nuclear power plants. The NRC's employees, including license reviewers, inspectors, and enforcement officials, are well trained in the technical disciplines and the regulatory requirements involved in performing their functions. The technical credentials of the NRC regulatory staff are equal to those in the nuclear industry.

2.2 NRC's Methods of Oversight

Nuclear power plants in the United States are closely regulated, starting even before they are constructed. For Davis-Besse, NRC used a two step licensing process. The first step was the construction phase wherein Toledo Edison had to file an application that identified the site features and the design of the reactor and supporting systems. Prior to its approval of any safety-related construction, the NRC reviewed and approved the preliminary plant design and the site. The NRC's staff of technical experts conducted this review. When its review of a construction permit application was affirmative, the NRC staff issued a Safety Evaluation Report, documenting the basis for its approval of the application.

A similar process was followed for Davis-Besse's operating license review. An application for an operating license (OL) was submitted about two and a half years before completion of construction. The NRC staff reviewed this application, and a major feature of the review was consideration of the adequacy of the plant design to accommodate certain postulated accident scenarios. These scenarios included loss of flow, loss of reactivity control, control rod ejection, loss of coolant, loss of power, loss of load, failure to scram on demand, and other challenging upset conditions.

In addition to technical reviews of construction permit and operating license applications, the NRC staff also has conducted hundreds of inspections at Davis-Besse to ensure that permitted activities are performed correctly and that all activities are within the bounds of the permits and licenses. In addition, the NRC's regulations require that FENOC and all other licensees have an independent quality assurance program that the NRC inspects to ensure that quality is provided in design, procurement, manufacturing, construction, operations and maintenance of the plant. The NRC conducts independent technical inspections of records of work already accomplished and work in progress for conformance to NRC requirements.

Since about 1980, the NRC has maintained resident inspectors at all operating nuclear power plants to ensure that their licenses and applicable regulations are being followed. The NRC also has its regional and headquarters specialists conduct focused inspections to assure that licensees maintains their plant within the requirements of their licenses and the regulations. These focused inspections by NRC cover areas such as operations, engineering, maintenance, in-service inspections by third parties (e.g., nuclear insurers and inspectors certified by the American Society of Mechanical Engineers), fire protection, emergency planning, radiation protection, radioactive effluent controls, environmental monitoring, training, safeguards and security. The NRC also requires timely reports by its licensees of any unusual occurrences or violations of regulations.

NRC holds its licensees as primarily responsible for the safety of operating nuclear power plants. However, the definition of how safe is safe enough is made by the NRC and that definition constantly changes, consistent with the national policy of continuous improvement of safety of nuclear operations.

2.3 Policy of Continuous Improvement

The NRC's primary mission is protection of public health and safety. It is uniquely empowered and qualified to establish requirements for nuclear power plants to ensure adequate protection of health and safety. To carry out its mission, the NRC has long maintained a policy of continuous improvement in the safe operations of nuclear power plants. These improvements reflect advancing states of technology and operating experience.

The NRC implements its responsibilities by developing formal requirements published in the Code of Federal Regulations (CFR) and issuing licenses to operate nuclear power plants. In addition to these requirements, the NRC publishes extensive guidance information. This information is contained in numerous documents of the NRC, including Commission policy statements, decision papers also called SECY papers, a Standard Review Plan, Regulatory Guides, Generic Letters, Bulletins and Information Notices.

The NRC's interpretations of its formal requirements have changed over time. These changes often are revealed to licensees after-the-fact through the NRC's inspection and enforcement process.

The NRC implements essentially "around the clock" regulatory oversight through numerous plant inspections. These inspections are performed by the NRC's resident inspectors, by technical specialists stationed at the NRC's regional offices and Headquarters, and by teams of safety specialists. The inspections are designed to identify violations of the NRC's requirements and opportunities for improvement in safety programs. The results of inspections are documented in inspection reports, notices of violation, and civil penalties. These documents reflect the various inspectors' interpretations of the NRC's policy and regulations and their assessments of plant management and personnel performance. Because these documents are primarily intended to identify opportunities for improved licensee performance, they are inherently negative in tone. Even reports that conclude that a licensee's overall performance is superior may contain criticisms and identify weaknesses or opportunities for improvement.

2.4 Tools of Regulation

The NRC uses a range of public issuances to communicate its requirements and expectations to its licensees. These include regulations, regulatory guides, technical reports called NUREGs, bulletins, generic letters, information notices, inspection reports, notices of violations, non-cited violations, performance indicators, civil penalties, confirmatory action letters, a semi-annual publication of a Watch List and associated Trending Letters, orders, confirmatory action letters, and various integrated assessment reports such as SALP

(Systematic Assessment of Licensee Performance) reports and annual assessment letters. The Watch List, Trending Letters and SALP programs were replaced by a new reactor oversight process in 2000. Several of these issuances figured in the Davis-Besse wastage event, including the regulations, generic letters, information notices, and bulletins, as I will explain later in this report. Also, I have relied upon NRC's performance indicator data, Watch List, Trending Letters, and SALP and annual assessment reports in measuring the performance of Davis-Besse in the years leading up to the wastage event, as described more fully below.

NRC also uses a variety of meetings with licensees to communicate its expectations. Most important among these meetings are the exit meetings that occur at then end of each inspection, including quarterly integrated inspection reports by resident inspectors. Some of NRC's meetings with licensees are open to the public, such as meetings to deliver annual assessment reports.

2.5 NRC's Knowledge of Plant Safety Status

NRC is well informed about and influences what goes on in licensed nuclear power plants. Its primary reliance for current status information is placed on resident inspectors who have open, 24-hour access to all of a licensee's documentation and people. In addition to reviews of plant documentation, these inspectors attend any meetings they choose, observe operations in every quarter of the plant, and conduct independent inspections and walkdowns during operations and shutdowns.

Another important way that NRC stays informed of what is going on at licensed plants is through the change control process for the licensing basis of each plant. In a nutshell, that process is required by 10 CFR 50.59 and requires that any significant changes in the safety functions reflected in the Final Safety Analysis Report (FSAR) for the plant must be reviewed and approved in advance by the NRC. Formal reviews are required by 50.59 to be conducted by all licensees to assure that changes in configuration or procedure do not change the licensing basis of their plants. The NRC inspects the record of these determinations by its licensees. If there is a significant change to the licensing basis, then a license amendment is required. License amendment applications are reviewed on the record by technical experts under the control of NRC project managers in the headquarters offices of NRR. There is also a requirement for licensees to bi-annually update their FSARs, which provides a periodic opportunity for NRC to be updated on plant status.

The NRC also has requirements that cause significant conditions or events to be formally reported by licensees in a timely way to NRC. The most important of these reporting requirements are the so-called Licensee Event Reports.

The timelines and accuracy of information supplied to NRC is assured by long-established rules and processes. NRC's enforcement policy provides that a violation of the regulations involving the submittal of incomplete and/or inaccurate information, whether or not considered to be intentional, can result in the full range of enforcement sanctions.

There are various modes of communication within NRC to assure that there is timely sharing of information on plant status among cognizant individuals. These communication opportunities include daily interactions between resident inspectors at the plants and their supervisors in their assigned regional office, weekly conference calls among regional staff, resident inspectors, and NRR project managers and technical staff in NRC headquarters. Also, there are periodic assessments of licensee performance that require input from all quarters of NRC.

The NRC also encourages the sharing of information among licensees about common problems and opportunities for improvement. The NRC stays in touch with the organizations that are set up to address such generic concerns. These organizations involve the owners groups established for each reactor design type (e.g., the former Babcock & Wilcox owners group for the Davis-Besse plant), the Electric Power Research Institute (EPRI), the Institute for Nuclear Power Operations (INPO), the Nuclear Energy Institute (NEI), and others.

It is not an overstatement to say that NRC is aware, day-by-day, of the pending safety issues in the nuclear industry and the reasons why it is safe to continue operations in light of those issues, both on a plant-specific and a generic basis.

3. Davis-Besse Performance Prior to Wastage Event

3.1 Description of Plant

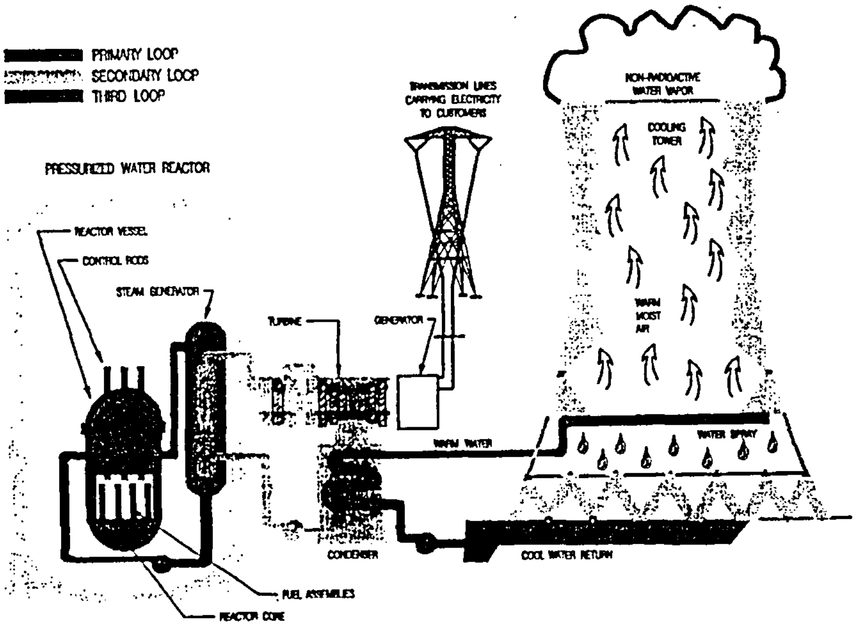
The nuclear steam supply system for the Davis-Besse plant was designed and manufactured by the commercial nuclear division of the Babcock & Wilcox Company (B&W), later owned by Framatome (now called AREVA), a nuclear company based in France. The architect/engineer for Davis-Besse was Bechtel Corporation. The plant is located in northern Ohio, 20 miles East of Toledo. It began operation in August 1977. The original owner and NRC licensee was Toledo Edison. The role of NRC licensee transferred to FirstEnergy Nuclear Operations Company (FENOC) in 1997.

The Davis-Besse plant incorporates a pressurized water reactor (PWR) wherein heat generated in the reactor core is transferred from a liquid primary coolant system to a secondary coolant system via steam generators. Steam produced in the secondary system flows to turbines which spin a generator to produce electricity. Waste heat from the secondary system is transferred to the environment via a tertiary cooling system utilizing a 493 foot tall, natural draft cooling tower and Lake Erie. Feedwater from the condensate system down stream of the turbines is returned by feedwater pumps to the steam generators in a closed cycle.

Davis-Besse is a relatively large nuclear power plant having an electrical output of 940 megawatts and a thermal power of 2772 megawatts. Nominally, the primary coolant system operates at 2155 pounds per square inch gage (psig) with a core outlet water temperature of 608 degrees Fahrenheit (°F). Purified water is the primary coolant. It serves to moderate (slow down) neutrons emitted by fissioning of uranium in the core and to transfer heat from the core to the secondary system. Water in the secondary system is nominally around 910 psi. As required by NRC, pursuant to a defense-in-depth approach to safety, Davis-Besse has three levels of confinement of fission products: fuel cladding, reactor coolant system, and a containment building. When it was shut down for refueling outage number 13 (RFO13), the plant had accumulated 15.78 effective full power years.[1]

The reactor coolant system (RCS), also known as the primary coolant system (PCS), consists of the reactor vessel, piping, pressurizer, primary side of the four steam generators, and four reactor coolant pumps. The reactor vessel is 15 feet in diameter, 39 feet tall, and 6 to 8 inches thick. It is made of carbon steel and has a 3/8 inch stainless steel liner.

Davis-Besse Nuclear Power Station



The reactor vessel, also called the reactor pressure vessel (RPV), weighs more than 800,000 pounds. Numerous penetrations (called nozzles) penetrate the RPV to allow entry of instrumentation to monitor the reactor conditions and control rod drives to raise and lower the power level of the reactor by controlling the reactivity of the uranium-fueled core.

Typical of all pressurized water reactors, boric acid is dissolved and modulated in primary coolant water as part of the reactivity control system at Davis-Besse. Its concentration ranges between 0 ppm at the end of a fuel cycle and about 1500 ppm at the start, with an average of about 750 ppm.[2]

3.2 Performance

This section discusses the performance of Davis-Besse, both the operational performance and the regulatory performance. Operational performance denotes the performance of the people and equipment involved in generating electric power and assuring safety.

Regulatory performance denotes the performance of FENOC in meeting the rules, regulations, and other expectations of the NRC.

3.2.1 Operational Performance

The NRC established a Performance Indicators Program in 1986 to provide data for early indication of declining trends in plant performance. Based on experience with its use, the first performance indicator program was discontinued in 1999 and replaced in 2000 by a new Reactor Oversight Process that included another set of performance indicators. NRC has used performance indicators from 1986 to today to help identify issues or circumstances that the NRC should examine further, i.e., where to apply its inspection resources.

The NRC has always published its Performance Indicator data for review by its licensees and the public. The data were originally published and distributed quarterly, but in September 1995, the NRC changed to an annual publication consistent with the Federal government's fiscal year. Since implementation of the new ROP in 2000, the Performance Indicator data for each plant are updated quarterly on the NRC website.

I used data from the NRC performance indicator programs for this review of Davis-Besse's performance. To accomplish this task I designed and oversaw a project by SCIENTECH to compile a variety of performance indicator data for Davis-Besse and the industry, using Monthly Operating Reports.

The charts provided in Attachment RJM-3 graphically depict Davis-Besse's performance for each of the performance indicators chosen for this analysis, i.e., those that bear on the reliability and safety of operations. The years 1996 to 2001 were selected for these comparisons. This length of time is reasonable for purposes of avoiding misimpressions that can be created by looking at narrow time periods of unusually high or low performance.

In the attachment there is a definition and a chart for each of the indicators. Each chart shows by year the average performance of Davis-Besse and other plants appropriate for comparisons for that indicator. It is important to remember as one looks at these charts that at any given point in time, say 1998, the NRC and the managers of Davis-Besse would have only been able to utilize this information in hindsight.

In sum, there are 19 performance indicators depicted in Attachment RJM-3, some treating similar variables over the two periods, 1995 to 1999 (old indicators) and 2000 to 2001 (new indicators). The indicator data show that the average performance of Davis-Besse met or exceeded the average performance of the comparison groups for 14 of the 19 indicators. A twentieth area, the hours of NRC oversight received each year, is also included in the attachment. This last graph shows that Davis-Besse was subject to only the normal level of NRC oversight during the six years depicted.

The performance indicators show that Davis-Besse was performing at a level exceeding the average for the industry and its peers, i.e., it was a superior plant, in the years leading up to the discovery of RPV head wastage.

3.2.2 Regulatory Performance

From 1980 to 1999 the summary assessment process used by NRC for all of its nuclear power plant licensees was called the SALP process. The process was replaced in 2000 by NRC's new reactor oversight process. The SALP report for Davis-Besse of March 7, 1997 covered the period from January 22, 1995 to early 1997. In that report, NRC accorded Davis-Besse the best possible score (category 1, superior performance) in Maintenance, Engineering and Plant Support, while Operations was assessed a SALP category 2 (good performance). Few plants ever received all category 1 scores in an assessment period. Davis-Besse did not receive a SALP report in 1999 because NRC was in transition to its new reactor oversight process (ROP).

In the period 1999 to 2001, NRC provided semiannual and annual assessments of the regulatory performance of Davis-Besse, pursuant to the new ROP, as follows:

- March 31, 1999: Transition to ROP Assessment: Performance acceptable since January 1997.
- March 31, 2000: Performance Review: Two white performance indicators since February 1, 1999 (safety system functional failure due to component cooling water pump failure and emergency drill failure to meet 15 minute reporting rule).
- November 29, 2000: Mid-Cycle Performance Review: All green findings and performance indicators, performance in licensee response column (no augmented NRC oversight) since April 2, 2000.

- May 31, 2001: First ROP Annual Assessment; met all cornerstone objectives with all green findings; performance in licensee response column since April 2, 2000.
- March 4, 2002: ROP Annual Assessment; Met all cornerstone objectives with all green findings; performance in licensee response column since April 1, 2001.

Under the new ROP, inspection findings are assigned a color commensurate with their safety significance. A green finding is one of very low safety significance, while white indicates low to moderate safety significance, yellow indicates substantial safety significance, and red indicates high safety significance.[3] A plant cannot rate much better with NRC than Davis-Besse's performance in this period, except for the two, short-lived, white performance indicators in 1999.

Other indicators of NRC's assessment of Davis-Besse in the period of interest are the following:

- Davis-Besse was not on the NRC Watch List (augmented NRC oversight) and did not receive a Trending Letter (trending towards augmented NRC oversight) between 1996 and 1999 when these regulatory programs were eliminated by NRC.
- Between 1996 and 2001, Davis-Besse received one Confirmatory Order (NRC direction to do a particular thing) and no Corrective Action Letters or CALs (NRC confirmation of agreements reached with a licensee on actions to be taken in response to a significant event). The Order was issued June 22, 1998 and concerned a commitment to complete implementation of Thermo-Lag 330-1 fire barriers by December 31, 1998.

The NRC inspection reports (noted in the industry for their generally negative tone) for the period 1996 through 2001 contain examples of Davis-Besse's favorable standing with NRC at the time. They include the following:

- 1996: "We noted during the inspection that, overall, activities at Davis-Besse continue to be conducted in a controlled, conservative manner. Performance during the recently completed tenth refueling outage was generally satisfactory."[4]
- 1997: "Good overall performance was noted in all functional areas. The excellent material condition of the plant minimized the challenges and burdens to operators. Additionally, plant performance during an emergency diesel generator outage was very good."[5]
- 1998: "The inspection mainly reviewed activities conducted during the eleventh refueling outage. Generally, these activities were well planned and executed, and shutdown risk controls for evolutions were effective. During the reactor shutdown for the outage, the operators effectively responded to an unexpected failure of a

purification demineralizer. Engineering, maintenance, and health physics support was also effective during the outage."[6]

- 1999: "During the inspection period, the plant was operated in a conservative, risk-informed manner."[7]
- 2000: "During this period, the plant was operated safely and in a conservative manner."[8] "Based on the Results of this inspection [covering refueling outage 12], the NRC identified two issues which were categorized as being of very low risk significance (Green)...One of these issues was determined to involve a violation..."[9]
- 2001: "Overall, Davis-Besse operated in a manner that preserved public health and safety and fully met all cornerstone objectives. Plant performance for the most recent quarter was within the Licensee Response Column of the NRC's Action Matrix, based on all inspection findings being classified as having very low safety significance (Green) and all PIs [performance indicators] indicating performance at a level requiring no additional NRC oversight (Green). Therefore, we plan to conduct only baseline inspections at your facility through May 31, 2002.[10]

The issuance of civil penalties is also an indication of a plant's regulatory performance. From 1996 to 2001 there were 129 civil penalties issued by NRC to the approximately 105 nuclear power plants licensed to operate. The total amount of civil penalties in that time period was $15,193,000. In that period Davis-Besse received one civil penalty in 1996 for $50,000 for fire safety violations.[11]

3.3 Summary of Davis-Besse's Performance

In the years leading up the RPV head wastage event (1996-2001), Davis-Besse was a high-performing plant as demonstrated by comparison of its performance indicators to the rest of the industry, by the treatment it received from NRC, and by the electricity it produced for its customers. Its regulatory performance was typical of plants that fulfill their regulatory obligations.

4. Requirements and Practices for Assuring Reactor Pressure Vessel Integrity

4.1 NRC's Development of Requirements

Early in its development of the commercial nuclear power program, the AEC undertook extensive research aimed at high assurance of RPV integrity. In addition, in mid-1965 the AEC's statutory Advisory Committee on Reactor Safeguards (ACRS) raised the possibility of reactor accidents resulting from failure of the reactor vessel, despite the care that had gone into the manufacture of the vessels that had been approved for the demonstration and test reactors that were built prior to that time. The growing size of commercial power reactors and the population densities near some proposed sites heightened the committee's concerns.

After several years of debate involving the AEC commissioners, the AEC Regulatory Staff, the ACRS and the nuclear industry, a revision of the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code was developed. It was stringent enough to give the AEC and the ACRS adequate assurance that vessel failures could be ruled to be beyond the design basis of nuclear power plants, i.e., reactor vessel failures were considered to be incredible because of the measures undertaken to prevent them. The features of the Code that gave this assurance included selection of materials, design methods, required margins, fabrication methods, quality assurance, third-party inspections, pre-operational testing, and in-service testing and surveillance. The issue was formally resolved in about 1968 with the granting of construction permits for the Zion plants located near Chicago. Zion and all subsequent nuclear power plants were required to meet the ASME Code.[12] For more than 30 years, there were no serious challenges to the adequacy of this decision.

Another safety feature underlying the policy of excluding failures of the reactor vessel from reactor accident analyses also was adopted early in the history of safety regulation. It is the idea of "leak before break." That is, steps are taken to assure that small leaks can be detected before they turn into large leaks in the reactor coolant system, thus allowing the reactor to be shut down and cooled before the core is endangered. Leak detection systems and associated specifications and procedures are required features of the overall system to preclude reactor vessel failure.

The possible failure of the reactor vessel is the only failure of a safety component that is ruled out of accident analyses for nuclear power plants. All other postulated accidents are required to have both prevention and mitigation features. Potential reactor vessel failures that have only prevention features are those that could occur below the level of the core and prevent refilling of the vessel by the emergency core cooling system (ECCS). Vessel failures above the level of the core, as long as their discharge area is not larger than the equivalent of twice the cross-sectional area of largest reactor coolant pipe, are within the capability of the ECCS.

4.2 Davis-Besse Requirements

The reactor vessel design, construction, operation, testing, inspection, surveillance and leak detection features required by NRC are included in the Davis-Besse Updated Final Safety Analysis Report (UFSAR). The UFSAR is a document that was reviewed and approved by NRC when Davis-Besse was licensed to operate and when it was periodically updated. The following table shows where these features are addressed in the UFSAR.

UFSAR Section	Topic
5.1	Reactor Coolant System Summary Description
5.2	Integrity of Reactor Coolant Pressure Boundary (RCPB)
5.2.1	RCPB Design Criteria, Methods, Procedures
5.2.2	RCPB Overpressure Protection
5.2.3	RCPB Material Considerations
5.2.4	RCPB Leak Detection System
5.2.5	Inservice Testing and Inspection Program
5.2.6	Loose Parts Monitoring
5.3	Thermal Hydraulic System Design
5.4	Reactor Vessel and Appurtenances
5.5	Component and Subsystem Design (Primary and Secondary System)
Table 5.2-1	Reactor Coolant System Codes and Classifications
Table 5.2-2	Code Case Interpretations
Table 5.2-14	Fabrication Inspections
Table 5.2-15	Properties of Reactor Vessel Materials and...Beltline Region Materials

4.3 Operating Experience Revealed Alloy 600 Cracking

Alloy 600 is used for a number of components that penetrate the reactor pressure boundary in PWRs, including control rode drive mechanisms (CRDMs), instrument ports, and pressurizer heater sleeves. Alloy 600 and associated weld materials were originally proposed by industry and approved by NRC because of their expected resistance to service-induced cracking. As plants have aged, however, parts fabricated from these materials have demonstrated a susceptibility to primary water stress corrosion cracking (PWSCC).

In the U.S., PWSCC of Alloy 600 was first noticed in a leaking pressurizer heater at the Calvert Cliffs plant in 1989. Other instances of leakage in pressurizer instrument nozzles then were identified in both domestic and foreign PWRs. The first observation of an Alloy 600 crack in a penetration in the upper head of a RPV occurred at the French Bugey reactor in 1991. The cracking was found to be due to PWSCC.

The principal concern of NRC and the industry in the ensuing years, as more Alloy 600 cracking occurred, was not the possibility of boric acid corrosion resulting from CRDM cracking. Rather, it was the possibility of circumferential cracking leading to a LOCA or control rod ejection accident.

The incidence of cracking in Alloy 600 CRDM nozzles accelerated in late 2000 and through 2001 with the discovery of leaks at all three Oconee units, and similar PWSCC events were experienced at five other PWRs that same year.[13] The heightened concern created by these events occurred after RFO12 had been completed at Davis-Besse. At that time, Davis-Besse was considered by the B&W Owners group, NRC and FENOC to be less susceptible to CRDM nozzle cracking than many other B&W plants because its effective full power days of operation were among the least.[14]

4.4 Operating Experience Revealed Boric Acid Corrosion

Because bolted flanges and other connections often leak a little, the potential for boric acid corrosion had been recognized since Pressurized Water Reactors with boron controls were first designed. Later, the incidence of corrosion events due to such leakage increased as the plants aged. The NRC issued several documents that chronicled what was being learned.[15] [16] [17] [18] [19] The fundamental idea that was being learned by the PWR owners was that boric acid at normal concentrations in the primary coolant system would not cause significant corrosion, but, when coolant leaks out of the reactor and loses a substantial volume of water by evaporation, the concentration of the acid rises and its corrosive potential increases.

On March 17, 1988 NRC issued Generic Letter 88-05[20] that referred to previous Information Notice 86-108 and supplements, described other examples of boric acid corrosion, and required all PWR licensees to submit a program for control of boric acid corrosion of the reactor coolant pressure boundary. It read, in part, "...the NRC believes that boric acid leakage potentially affecting the integrity of the reactor coolant pressure boundary should be procedurally controlled to ensure continued compliance with the licensing basis. We therefore request that you provide assurances that a program has been implemented consisting of systematic measures to ensure that boric acid corrosion does not lead to degradation of the assurance that the reactor coolant pressure boundary will have an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture." The Letter went on to describe the elements of such a program, including (1) identification of small leaks below the technical specification limit that could degrade the primary coolant boundary by boric acid corrosion, (2) procedures for locating such small leaks, (3) methods to examine the impact on the reactor coolant pressure boundary of such leaks, and (4) corrective actions to prevent recurrence of such leaks. The Letter contained some estimates of corrosion rates for boric acid at high concentrations (25 times higher than normally found in the reactor coolant system) and some NRC advice that even the boric acid crystals that remain after the water is all evaporated could be corrosive, although much less so, i.e., "...at a temperature of 500 °F, corrosion rates of 0.8 to 1.6 mils/month were obtained" in the Westinghouse tests referenced in the Generic Letter.

The Letter also reported that at Turkey Point Unit 4 "...more than 500 pounds of boric acid crystals were found on the reactor vessel head. After these crystals were removed, corrosion of various components on the reactor vessel head was observed...The maximum depth of corrosion was 0.25 inches." Thus, the Letter described how one could experience substantial accumulation of dry boric acid crystals on the hot upper head of a pressurized water reactor without suffering significant operational or regulatory consequences.

5. Boric Acid Corrosion Control at Davis-Besse

5.1 NRC Approved the BACC Program at Davis-Besse

Toledo Edison developed a boric acid corrosion control (BACC) program in response to Generic Letter 88-05. The initial Toledo Edison response to the Generic Letter was provided on May 27, 1988.[21] It cited several already existing programs and procedures as adequate to address the issues in the Generic Letter. On June 26, 1989, Toledo Edison amended its initial response to clarify that the preventive maintenance program for control rod drive flanges was yet to be implemented but would become a refueling outage preventive maintenance procedure. [22] On February 8, 1990, the NRC approved Toledo Edison's response to GL 88-05.[23]

The NRC approval of the BACC program at Davis-Besse was based on a trip report documenting an onsite audit conducted from September 11 to 13, 1989, by two subject matter experts from NRC headquarters and an expert consultant from Brookhaven National Laboratory. The trip report noted that a Nuclear Group Procedure NG-EN-00324, "Boric Acid Corrosion Control," dated September 8, 1989, Revision 0, was written to "additionally enhance the Davis-Besse Boric Acid Corrosion Control Program." The trip report went on to note that this was the "administrative (overall) procedure" and that "various implementing procedures had not been written" at that time but were due to be completed in 90 days. The trip report also noted the need for training and formal documentation of inspection results. The auditors reviewed three instances of boric acid leakage and evaluation that occurred at Davis-Besse in the past and concluded, "For all three items the utility appeared to do a thorough and professional investigation and corrective-action follow-up."

5.2 Implementation of The BACC

The BACC program at Davis-Besse was controlled by Administrative Procedure NG-EN-00324. After it was first approved by NRC in 1989, there were two revisions of this procedure before the RPV head wastage event.[24] [25] Revision 1 became effective on February 22, 1994, and occurred as a result of lessons learned in application of the original procedure. Revision 2 became effective on October 1, 1999, following the RC-2 carbon nut corrosion event in September 1998 when FENOC incorporated lessons learned from industry benchmarking. Thus, Revision 1 was in effect at the time of RFO11 in 1998 and Revision 2 was in effect at the time of RFO12 in 2000 and RFO13 in 2002.

In Revision 1, the responsibility for overall coordination of the Program fell to the Plant Engineering Department in general, without a requirement to name a lead person. In Revision 2, a Boric Acid Corrosion Control Coordinator was required by the Procedure to be assigned in the Plant Engineering Department to provide planning and oversight to the program. Both revisions refer to a number of other plant procedures that governed when inspections for leaks were conducted, e.g., ASME Section XI Pressure Tests and walkdowns during heat up to and cool down from power operation.

Both revisions list the places to look for small leaks before they could turn into large leaks, e.g., bolted flanges. Neither revision specifically listed the reactor pressure vessel head as a place to look for leaks, but other documents indicate that the reactor vessel head was to be inspected at each outage pursuant to the BACC Program.[26] Both revisions of the procedure discuss how inspections for leakage were to be performed, how leaks were to be reported, and the roles of various organizations in following up on such reports. Revision 2 contains checklists for such reporting. Both revisions required that the discovery of leakage be controlled by the plant's corrective action program, either through Potential Conditions Adverse to Quality Reports (PCAQRs), Condition Reports (CRs) or work orders, and that photographs be used to record the findings. It appears that CR 2000-0782 with its attached photographs of rust-colored boric acid deposits was written in accord with the BACC Program, Revision 2.

Various people were assigned by plant management to activities that implemented, supported, or interfaced with the BACC Program at Davis-Besse. Some oversaw the implementation of the program, some conducted walkdowns of the systems inside containment, others reviewed the consequences of leakage that was found, others designed remedies (e.g., correction of CRDM flange leakage and cleaning of the RPV head of boric acid residues), some wrote or reviewed PCAQRs, others represented the company on industry efforts to deal with Alloy 600 cracking issues (EPRI, NEI, B&W Owners' Group Materials Committee, and B&W/Framatome), and still others served at various times as Systems Engineers for the reactor coolant system. A wide range of plant management and staff interacted with the people charged with implementing the BACC program, such as the review board for PCAQRs, engineering managers and staff, plant support managers and staff, maintenance managers and staff, outage managers, operations managers and staff, and the Company Nuclear Review Board (CNRB).

Various condition reports prepared by Davis-Besse describe BACC Program activities. Examples include the following:

- PCAQR 96-551[27] was written after an inspection conducted pursuant to the BACC Program during RFO10. It noted that the videotape of CRDM nozzles showed patches of boric acid, and one nozzle (#67) showed rust or brown-stained boron at the bottom of the nozzle where it meets the reactor vessel head.
- CR 1998-0026[28] documents the results of an independent review of the management issues associated with the failure of nuts on the RC-2 valve due to boric acid corrosion. Followup to this event was governed by the BACC Program and is described in more detail, below.

The Babcock & Wilcox Company was the original supplier of the nuclear steam supply system for Davis-Besse and its peer plants. The B&W Nuclear Technologies Division responsible for the design of nuclear power plants was later purchased by Framatome. Framatome provided the technicians who photographed the boric acid residue from the reactor head in refueling outages 10, 11 and 12 and provided video tapes showing the cleaning of the head. Framatome personnel also assisted Davis-Besse personnel in addressing corrective actions for boric acid deposits that were observed, as shown by the following corrective action documents.

- PCAQR 1998-0767[29] was written after an inspection conducted pursuant to the BACC Program during RFO11. The report noted that video inspections of the reactor vessel head found clumps of boric acid but no pitting of the head surface. Citation was made to a B&W document that showed almost no corrosion occurred at temperatures greater than 550°F, less than the head temperature during normal operations.
- CR 2000-1037[30] documents the results of an inspection of the reactor vessel head performed pursuant to the BACC Program during RFO12. It noted the observation of boron in the area of the CRDM nozzle penetrations and on the top of the thermal insulation under the CRD flanges. Framatome performed the video inspections of the control rod drives, consulted with Davis-Besse personnel in

examining the results of the inspection, and collaborated in the formulation of corrective actions for leaking CRD flange gaskets.

- CR 2000-0781[31] discusses the fact that boric acid residue from the CRDs blocked visual examination of the reactor vessel head studs, and its removal before visual exams could be completed and videoed by Framatome required a different type of ASME examination.
- CR 2000-0782[32] discusses and provides photographs of the "red-brown" boric acid leakage from weep holes found during inspections conducted during RFO12 and notes that Framatome completed the visual inspection of the vessel head and examined the results of the inspection.

An independent review of the CNRB was conducted in August 2002 to determine if the Board had missed opportunities to intercept the vessel head wastage.[33] The CNRB is comprised of FENOC managers and outside consultants and is required to function in accord with specifications in the plant's Updated Final Safety Analysis Report. The minutes of CNRB meetings reveal occasions from 1999 through 2000 that the Board was made aware of the observations (boric acid accumulation in containment air coolers, clogging of radiation monitors with rust, and unidentified leakage from the reactor coolant system) that were later interpreted with hindsight to indicate when vessel head wastage was underway.

Other changes were made in programs and procedures at Davis-Besse in response to documents that were issued by industry groups to chronicle the growing understanding of boric acid corrosion associated with the PWSCC of Alloy 600 penetrations. A summary of the documents issued, along with descriptions of the responsive actions taken at Davis-Besse, is provided in Table 7 of the August 27, 2002, Root Cause Analysis Report for the Davis-Besse event.[34]

One example of such a document is the May 1993 report BAW-10190P[35] that was sponsored by the B&W Owners' Group Materials Committee, of which Toledo Edison was a member. It presented stress analyses of CRDM nozzles in B&W reactors. It also contained information on crack growth rates and the associated buildup of boric acid crystals and concluded (p. ii) that "...safe operation of the B&W-design plants will not be affected for at least six years, and that within this time, the leak will be detected. Thus, the potential for cracking does not present a near-term safety concern." The report also contained an assessment (p. 19-25) of "... the potential damage that can occur to the reactor vessel head as a result of a leaking CRDM nozzle. Two areas of concern are considered in the discussion:

1. General corrosion damage to the reactor vessel head as a result of existing boric acid crystals and borated steam condensing on the head insulation from a through-wall crack in the CRDM nozzle.
2. Corrosion damage both within and in the vicinity of the reactor vessel head penetration due to boric acid corrosion resulting from a through-wall crack in the CRDM nozzle."

Several important conclusions were reached in this report about the second type of corrosion, namely:

- This wastage analysis [condition 2, above] shows that safe operation of a B&W-design plant will not be affected for a minimum of 6 years based on a maximum wastage rate of 1.07 in^3/yr. (p. 24)
- Therefore, in the six years minimum required for a through-wall crack to grow to 2 inches in length....the accumulation of boric acid crystals would begin slowly...but would eventually attain an accumulation rate of 93.9 ft^3/yr...It is very unlikely that this type of accumulation would continue undetected with regular walkdown inspections of the RV head area... (p. 25)

Based upon this report, it would have been reasonable for management of Davis-Besse to expect that the BACC Program already in place and approved by the NRC would be sufficient to protect the plant against this type of damage.

There also were operating experiences at Davis-Besse that led to changes in its BACC program. For example, on September 18, 1998, FENOC discovered that three of eight carbon steel body-to-bonnet nuts on pressurizer spray valve RC-2 were damaged by boric acid corrosion. The station had incorrectly assumed that all of the valve bonnet materials were made of stainless steel and did not earlier remove known boric acid deposits caused by a small leak in the valve. The event led to major changes in the BACC Program, an indication that station personnel were paying attention to the program at that time.

Davis-Besse had also experienced repetitive leaks and boric acid accumulation on the RPV head from defective CRDM flanges located above the insulation over the RPV head. This was a common, well-known problem for all B&W plants, but Davis-Besse's flanges continued to leak after it implemented new gaskets and bolting materials that cured the problem for other B&W plants.[36]

Toledo Edison issued Condition Reports concerning the BACC Program at Davis-Besse. The NRC resident inspectors typically would be aware of such Condition Reports. Condition Reports are resolved through a licensee's Corrective Action Program.

5.3 NRC Oversight of BACC Program

The NRC maintained cognizance of the BACC Program at Davis-Besse after the Program was first approved pursuant to Generic Letter 88-05. This section reviews information concerning that NRC oversight and refers to periodic NEIL inspections that bore on RPV integrity.

In reviewing the information provided in this section it is important to bear in mind that Condition Reports and PCAQRs issued pursuant to the corrective action program at Davis-Besse were typically reviewed by NRC inspectors, either by reading them or attending the meetings of plant managers in which the reports are discussed. It is not possible to say that the inspectors read all these reports, but they had the opportunity to do so and inspectors typically review most of them at all plants.

No NRC-issued violations have been found for the BACC Program at Davis-Besse prior to the RPV head wastage event in 2002. NRC issued two violations for the pressurizer spray valve degradation associated with boric acid corrosion that was discovered by FENOC in 1998. See the information for 1998, below.

Following are excerpts from NRC reports showing its level of cognizance of the BACC Program at Davis-Besse from 1996 through 2001.

<u>1996</u>

None of the NRC inspection reports in 1996 mention boric acid. The integrated inspection report covering the period of refueling outage ten (RFO10) noted NRC observation of implementation of the Inservice Inspection (ISI) program and other containment walkdowns, CRDM modifications and outage radiological controls.[37]

1997

The NRC inspection reports in 1997 do not mention boric acid, corrosion, or leaking control rod drive flanges.

The Nuclear Mutual Limited evaluation of June 1997 referred to FENOC's ASME Section XI ISI Program and awarded maximum credit points for major pressure vessels.[38]

1998

The NRC inspection report covering RFO11 includes a description of NRC inspectors touring "the containment building to review housekeeping and general material condition of the building."[39] The only anomaly noted during these tours by the inspectors was peeling paint and the effect it might have on the containment sump in the event of a loss of coolant accident.

The NRC inspection report covering the ISI activities conducted during RFO11 included the following statements:

> This routine inspection focused on the ***conduct of the inservice inspection (ISI) activities*** at Davis-Besse. ***The inspection included*** aspects of licensee Code repairs of the main steam isolation valve and ***nondestructive examination of control rod drive housing***, main steam nozzle and decay heat system welds, ***as well as the reactor vessel head***, reactor coolant pump flywheels and steam generator. The following specific observations were made:...In general, licensee personnel and contracted personnel [Framatome] involved in the FAC [flow assisted corrosion] and ISI efforts appeared knowledgeable, well trained and competent....Consistent with the components importance to safety, the licensee demonstrated an aggressive assessment of vendor code repair and ISI contractor supplied procedures to assure the applicable ASME and regulatory requirements were met....The following is a sample of the ***work activities that were observed by the [NRC] inspectors: Framatome personnel performing Dye Penetrant examinations (PT) of control rod drive housing weld No. B14.010.0716 for CRD Housing and Penetration No. B53-53....Davis-Besse personnel performing a Visual Examination (VT) of the reactor vessel head bolt holes.*** (emphasis added)

Another inspection report documented NRC inspectors' oversight of the replacement of two carbon steel nuts that had wasted away due to boric acid corrosion of the RC-2 pressurizer spray isolation valve.[40] The first missing nut had been discovered on September 1, 1999 by FENOC personnel during a walkdown of containment during operations following RFO11. NRC conducted a special inspection of this incident. The report of that inspection[41] stated

> Once the licensee determined that BAC was the most likely cause for the missing nuts on RC-2, ***a thorough evaluation of the situation was conducted and extensive, effective corrective actions were developed. The inspectors noted a much greater sensitivity to the effects of BAC on plant equipment and a recognition that some plant maintenance practices required improvement, more oversight, and more assessment.*** The engineering plan to address the extent of condition for the two missing body-to-bonnet nuts on Pressurizer Spray Valve RC-2 was comprehensive and detailed. ***The licensee effectively completed the extent of condition review during the recently completed mid-cycle outage. Additionally, the licensee demonstrated a heightened sensitivity to boric acid corrosion effects***....The inspectors determined that for the most part, procedure NG-EN-00324 incorporated the GL 88-05 recommendations either explicitly or by referencing other plant procedures. However, procedure NG-EN-00324 did not provide detailed information on the methods for conducting examinations and performing engineering evaluations to establish the impact on the reactor coolant pressure boundary when leakage was located. Specifically, the procedure did not require that the materials subject to boric acid be verified to be corrosion resistant in the field. Consequently, engineering personnel assumed that the RC-2 BTB [body-to-bonnet] nuts were made of boric acid corrosion resistant stainless steel, as per plant specifications, instead of verifying that the materials were actually as specified. ***The licensee indicated that a review of this procedure was ongoing and that the procedure would be revised as necessary to address weaknesses in the boric acid corrosion control program identified during the evaluation of this event.*** (emphasis added)

Later, in deciding not to issue a civil penalty for the Level III violation it associated with the RC-2 valve incident, NRC told FENOC [42]

> You were given credit for initiating effective corrective actions once you identified the root cause of the degradation. Your corrective actions included: (1) training sessions with maintenance personnel to enhance knowledge of the effects of boric acid on materials; (2) a review of boric acid corrosion procedures which resulted in program enhancements; (3) the inspection of pressure retaining bolted connections with a potential for

> the instillation of fasteners of nonconforming material; and (4) resolution of the pressurizer spray valve packing problems.

The NEIL evaluation of September 1998 referred to FENOC's ASME Section XI ISI Program.[43] The report notes that "During the Spring 1998 RFO limited inspections were performed on the Reactor vessel to meet the Section XI Program. Documentation was reviewed for the work performed during this last RFO and no major problems noted." NEIL awarded maximum credit points for the reactor pressure vessel.

1999

Inspection Reports for 1999 show that NRC was aware of the developing situation involving boric acid occurrences in containment. For example,

> February 25, 1999: Since November 1998, the licensee made periodic **containment entries (approximately every 10 days) to clean boric acid deposited onto the fan coolers from a leaking overhead pressurizer isolation valve.** The licensee planned to repair the valve during the scheduled mid-cycle outage in May 1999, and to continue the at power entries in the interim. As of February 4, 1999, collective worker dose from these entries was about 1.1 rem. On February 5, 1999, an inspector observed a work crew cleaning these coolers inside containment.[44]
>
> June 7, 1999: Operation of the plant was characterized by conservative decision making. Of particular note was the initiative taken to plan a mid-cycle outage and then to ***start the outage 2 weeks early to address an upward trend in reactor coolant system (RCS) leakage...***By the time of plant shutdown on April 24, the unidentified leak rate was at .82 gpm. During the outage, station personnel replaced ***the pressurizer code safety valves*** and had the old ones tested to determine their leak rate. Test results indicated that the combined leak rate of the two valves was around .75 gpm which nearly matched the leak rate observed prior to shutting the plant down. ***The inspectors walked down the accessible portions of the...***Reactor Coolant System Relief systems in containment... [and] Portions of ***Reactor Coolant System Boundary in Containment.***[45]
>
> July 20, 1999: During the inspection period, the plant was operated in a conservative, risk-informed manner. The unidentified reactor coolant system leak rate approached the Technical Specification limit of 1 gallon per minute prior to the recently completed maintenance outage. ***Your efforts to reduce the leak rate during the outage were effective.*** Subsequent to the end of the outage, ***low flow rates have been routinely occurring in the containment atmosphere particulate and gaseous radiation monitoring system.*** While your staff has been aggressive in attempting to identify the reasons for this phenomenon, the frequent filter changes required to address the low flow conditions have been a

> distraction to plant personnel...***The RCS leakage [before the mid-cycle outage] caused containment atmosphere boric acid particulate concentrations to increase as evidenced by the accumulation of boric acid on the containment air coolers which required their periodic cleaning****....*The major contributor to the leakage was determined to be two leaking pressurizer code safety valves....Station personnel conducted several containment walkdowns to identify leakage...Engineering personnel used portable acoustic instruments to identify any high pressure leak acoustic signatures [plus 8 other things credited by the inspector as aggressive action by plant staff to find the remaining leakage]... ***Subsequent to the outage, particulates in the containment air have caused the filters on the [radiation monitoring] skids to clog on nearly a daily basis.***[46]
>
> <u>August 20, 1999</u>: The plant was operated in a conservative manner throughout the inspection period....The inspectors reviewed the licensee's efforts to resolve ***frequent low flow alarms on the containment atmospheric particulate and gaseous radiation monitoring system.*** Engineering and maintenance personnel did extensive testing of the system, but did not identify any functional problems with the system. The licensee noted that ***system filters had accumulated a dark colored particulate (along with white colored boric acid residue) and independent testing determined the particulate was primarily iron oxide (a corrosion product)****....*The licensee postulated that the corrosion product was the cause of the low flow alarms.[47]
>
> <u>October 8, 1999</u>: Overall, your facility was operated in a conservative and conscientious manner....The inspectors reviewed the licensee's continuing efforts to address suspended corrosion product particulates in the containment atmosphere that periodically affected the operation of the reactor coolant system leak detection system (RCSLDS)....To address the situation, portable filtration units were placed into containment to clean up the air, which resulted in decreasing the frequency of RCSLDS degradations...***However, the source of the corrosion product particulates was still unknown.*** The license planned to perform thorough inspections of the containment during the next refueling outage to detect the source."[48] (emphasis added)

All of the inspection reports quoted immediately above were signed by the Chief of Reactor Projects Branch 4 in NRC Region III. The distribution of these reports included managers at several levels in FENOC and three departments of the State of Ohio. In addition, the reports were placed in the NRC public document room and had an internal distribution in NRC that included the NRR Project Manager, the two Division Managers in the Regional Office, the Regional Administrator and the Deputy Regional Administrator. Thus, counting the senior resident and the resident inspector at Davis-

Besse and their Branch Chief in the Regional Office who signed the inspection reports, at least 8 NRC people saw information in real time that later would come to be viewed as early indicators of the wastage event.

The NRR Project Manager for Davis-Besse, located in the Rockville, MD headquarters of NRC, was informed of boric acid crystals and iron oxide impeding radiation monitors in containment in 1999. A Technical Specification amendment was requested by FENOC on July 26, 1999, designed, in part, to relax the number of radiation monitors required to be operable. The NRR Project Manager for Davis-Besse was informed by Davis-Besse's Licensing Manager of the boron conditions in containment. The Project Manager was also aware of the radiation monitoring issue and the fouling of containment air coolers through his daily telephone conversations with the senior resident inspector and the latter's Region III branch chief. The NRR Project Manager also said the NRC senior resident inspector told him the problem was related to leaking code safety valves and had been corrected. Typically, the results of the NRC's morning meetings were communicated daily to all managers in the Region, up to and including the Regional Administrator. There were 38 instances documented by the Region III Branch Chief between April 1999 and April 2000 when unidentified leakage and/or boron precipitation in containment were discussed in morning meetings.[49]

The NEIL evaluation of July 1999 referred to FENOC's ASME Section XI ISI Program.[50] The report notes that "During the Spring 1998 RFO limited inspections were performed on the Reactor vessel to meet the Section XI Program. Documentation was reviewed for the work performed during this last RFO and no major problems noted." NEIL awarded maximum credit points for the reactor pressure vessel.

2000

The NRC Inspection Report of April 27, 2000[51] records an evaluation of

> "...the implementation of your inservice inspection program for monitoring degradation of the reactor coolant system boundary, risk significant piping system boundaries, and the containment boundary...Specifically, the inspector observed three types of nondestructive examination activities, and reviewed three modification packages including radiography... The inspector reviewed nine condition reports to verify the identification of ISI problems at an appropriate threshold. The inspector also verified that the corrective actions were appropriate

> ...[The inspector observed] Reactor Closure Head to Flange Weld Ultrasonic Examination [and] Reactor Closure Head to Flange Weld Magnetic Particle Examination...[The inspector] reviewed 1998 Inservice Inspection Final Report for Toledo Edison Company Davis-Besse Unit 1, Refueling Outage 11...[and] Davis-Besse Condition Report No. 2000-0781 [that referenced CR 2000-0782 and its attached photos of boric acid accumulation on the RPV head]."

The NRC Inspection Report of May 16, 2000[52] records a radiation safety inspection performed during RFO12 that included observation of work activities on the refueling floor. Since RPV head cleaning was underway for most days during that outage it is likely that the NRC radiation safety inspector observed the condition of the upper head and certainly would have been aware of the boric acid crystals that reportedly existed on surfaces throughout containment. Also, the report notes that the station exceeded its worker exposure goal for the outage and reports, "The inspectors also performed surveys within the radiologically controlled area to verify the accuracy of the licensee's records/surveys of identified hot spots and to identify any other significant unidentified sources of radiation exposure."

The NRC Inspection Report of June 16, 2000[53] documents the activities undertaken by inspectors during RFO12, including various activities inside containment in the vicinity of the reactor coolant system, e.g., " conducted a containment inspection prior to startup to ensure that material in containment would not degrade the ability of the emergency sump to perform its design function."

Other inspection reports for 2000 do not contain information that bears on CRD nozzle leakage or boric acid corrosion. Because of the new reactor oversight process implemented in the spring of 2000, much of the detail that was contained in earlier reports was eliminated from inspection reports beginning in 2000.

The NRC resident inspector was provided a copy of Davis-Besse Condition Report 2000-0782 (and the color photos it contained of boric acid on the RPV head) shortly after it was written in early April 2000.

> The service water systems engineer told OIG that during the same morning he wrote CR 2000-0782, he discussed with the Davis-Besse Resident Inspector his discovery of the boric acid on the RPV head. He stated that he described the accumulation of boric acid on the RPV head to the Resident Inspector as "molten, lava-like, rust-colored boric acid debris." The engineer said that as he described the condition of the RPV head to the Resident Inspector, he printed a copy of the Condition Report

> along with color copies of the photographs which depicted the boric acid accumulation and gave them to the Resident Inspector.
>
> The Davis-Besse engineer told OIG he recalled that the Resident Inspector read CR 2000-0782 and reviewed the color photographs in his presence. He also recalled that the Resident Inspector expressed surprise upon reading the condition Report and viewing the color photographs.[54]

Other NRC people became aware of the boric acid on the RPV head in the course of RFO12, as follows:[55]

- A Region III Inservice Inspection (ISI) inspector conducted an announced routine ISI at Davis-Besse from April 17-21 2001, during RFO12 and reviewed condition reports, including 2000-0781 that referred to 2000-0782. He observed in-progress nondestructive examinations by the licensee for welds on the RPV head flange. He said he spoke to the Senior NRC Resident Inspector about the boric acid he observed and was told there had been leakage from safety relief valves and CRDM flanges.
- The Senior Resident Inspector said that he did not recall CR 2000-0782, that thousands of activities were performed during the outage and he focused on other areas, and that he believed the source of boric acid on the RPV head owed to CRDM flange leakage.
- The Resident Inspector did not recall seeing CR 2000-0782 and said he was new to the station and not sufficiently trained to recognize the significance of boric acid on the RPV head.
- The Chief of Reactor Projects Branch 4 in Region III knew the licensee had a long-term problem with unidentified leakage, boric acid accumulation on containment air coolers, and fouling of radiation monitors. He was aware that the licensee attributed the boric acid to CRDM flange leakage.
- The Division of Reactor Safety Director in Region III denied knowledge of the boric acid at Davis-Besse, said he was not aware of any inspection of the BACC program at that plant and said that NRR had not followed up on Generic Letter 88-05 so it was not incorporated into the routine inspection program. These statements are at variance with the distribution list of the inspection reports that document the presence of boric acid at Davis-Besse and with the NRC inspections of the BACC Program at Davis-Besse that are described above.
- The Administrator of NRC Region III said that with hindsight his Reactor Projects Branch Chief and Senior Resident Inspector at Davis-Besse had been wrong in their assessments of the cause of boric acid corrosion, that had CR 2000-0782 been raised to Regional managers they would have understood its significance, and that after the 1990 NRC review of BACC programs to ensure compliance with Generic Letter 88-05, NRC decided not to proactively inspect the implementation of such programs.

- The former Director of Licensing Project Management in NRR headquarters said that Region III had a lot of information to show that a BACC Program inspection should have been implemented at Davis-Besse. He knew that Davis-Besse was experiencing fouling of its containment radiation monitors prior to RFO12.

One NRC Commissioner summarized the foregoing list of NRC's communication missteps that contributed to the Davis-Besse event. He said

> I believe the [NRC] cross-communication lapses associated with Davis-Besse were a failure of our organization and not an individual....the signs were all there...we failed to integrate all of this information. There were missed opportunities that left the citizens of Ohio and Members of Congress questioning NRC's oversight activities and capabilities...the Commission will devote the time and effort necessary to ensure that the communications and inspection process gaps that contributed to the unidentified multi-year degradation of the vessel head at Davis-Besse are thoroughly evaluated and corrected in a timely manner. As with most industries, there will always be new technical issues that may surface and need to be addressed. [56]

The NEIL evaluation of June 2000 referred to FENOC's ASME Section XI ISI Program.[57] The report notes in reference to the ISI Program that, "These inspections were performed during the April 2000 Refueling Outage. Vessel circumferential welds, nozzle to shell welds, nozzle to pipe welds and nozzle to safe-end welds were inspected. Several indications were found during these inspections and were evaluated as acceptable to the ASME acceptance standards...Documentation was reviewed for the work performed during the April 2000 RFO and no items of concern to NEIL were noted." NEIL awarded maximum credit points for the reactor pressure vessel.

2001

There is little information in the 2001 inspection reports because NRC's new reactor oversight process implemented in the spring of 2000 required inspectors to record only information concerning their observed findings and violations. The inspection reports for 2001 contain no mention of boric acid corrosion, CRDMs or the BACC Program. There is indication in one of the reports that NRC inspectors were inside containment where they could have observed indications of boric acid corrosion, as follows:

> The inspector reviewed activities conducted under the following RWPs [radiation work permits] in order to evaluate the effectiveness of the

> licensee's ALARA controls for the last refueling outage (12RFO), and the containment entry conducted during the current inspection:...2000-5110: Reactor Head Work...2001-2001: Cleaning Containment Air Coolers... No findings of significance were identified,"[58]

The NRC issued Bulletin 2001-01[59] in August 2001 seeking information from all PWR licensees regarding the structural integrity of reactor pressure vessel head penetrations. The focus of this Bulletin was the possibility of circumferential cracking in VHP nozzles. The NRC's concern at the time was that such cracks could lead to the sudden ejection of a control rod from the reactor or a loss of coolant accident. Because of the time frame involved in the development of a circumferential crack that could be subject to nozzle ejection, visual inspections of the RPV head outer surface, where the nozzle intersected the RPV head, were considered at that point to be an adequate inspection. FENOC submitted the same generic information regarding the likelihood of cracks as the other B&W owners.

In the fall of 2001, Framatome's videos of head cleaning efforts in RFO 10, 11 and 12 were provided to the NRC headquarters staff.

The NEIL evaluation of July 13, 2001 referred to FENOC's ASME Section XI ISI Program.[60] The report notes in reference to the ISI Program that "These inspections were performed during the April 2000 Refueling Outage. Vessel circumferential welds, nozzle to shell welds, nozzle to pipe welds and nozzle to safe-end welds were inspected. Several indications were found during these inspections and were evaluated as acceptable to the ASME acceptance standards...Documentation was reviewed for the work performed during the April 2000 RFO and no items of concern to NEIL were noted." NEIL awarded maximum credit points for the reactor pressure vessel.

6. Comparison of Davis-Besse's Boric Acid Controls with Others

This section compares the boric acid corrosion controls at Davis-Besse with those at other NRC licensees to gain insight on whether those controls were reasonable.

In August 1991, three years after it issued Generic Letter 88-05, NRC issued an inspection procedure for use by its Regions to determine if the Generic Letter had been appropriately implemented.[61] This inspection procedure was deleted by NRC on

September 17, 2001[62] and boric-acid-related inspection activity is now covered in the following inspection procedures: 71111.08 Inservice Inspection Activities, 71111.20 Refueling and Outage Activities, 71152 Identification and Resolution of Problems.

Document research by SCIENTECH, LLC for this case provided 19 reports by NRC of inspections that it performed of BACC programs at 27 operating units during the years 1991 to 1998, i.e., more than one-third of the 71 operating PWRs. Only one of these inspections was conducted in NRC Region III, at the Kewaunee plant. Judging by the search tools used by SCIENTECH, these are probably most if not all of the BACC inspections that NRC performed from the time Generic Letter 88-05 was issued in 1988 to the discovery of the Davis-Besse RPV head wastage event in 2002. These inspection reports identified strengths and weaknesses of the BACC programs that were inspected. Only six low-level violations were identified in these 19 NRC inspection reports, even though some of the weaknesses identified included multiple failures to identify and correct primary system leaks resulting in boric acid deposits inside containment. The February 1990 NRC "audit trip report" for Davis-Besse[63] reads much like the inspection reports issued by NRC for the 18 plants that were inspected. For example, the NRC inspectors at Davis-Besse looked at how the specific requirements in Generic Letter 88-05 had been implemented in procedures and training, they looked at documents describing how the procedures were being implemented, and they made their own walkdowns to look for leaks and traces of boric acid that the licensee might have missed. Thus, Davis-Besse had NRC oversight of its BACC program that was similar to the NRC oversight received by other plants. Unlike several of the other plants, NRC found that leaks at Davis-Besse had been receiving adequate investigation and correction and no violation was issued. From this review of NRC inspection reports, and in view of the NRC-reviewed changes that were made in the BACC Program after the RC-2 event in 1998, and the original NRC approval of the BACC program, all of which were publicly available, it would have been reasonable for managers at Davis-Besse to conclude that they had a reasonable BACC Program.[64]

The implementation of the BACC program at Davis-Besse also can be compared to other plants by reviewing information in inspection reports that deal in some way with boric acid corrosion and that were issued after the wastage event at Davis-Besse. SCIENTECH has identified the NRC inspection reports for the period 2002 through mid 2006 that contain boric-acid-related findings. There were 25 such reports concerning 15 licensees and 22 units. Although essentially all of these findings were violations, all were either level IV (green) or noncited, i.e., NRC judged that none of them had any more than low safety significance. The violations covered a range of noncompliances, including inadequate BACC program, inadequate implementation of BACC program, and inadequate corrective action. In a number of cases the NRC inspectors found boric acid indicators of reactor coolant system leaks that had not been found or dispositioned by the licensees. These inspection reports, and those directed at the BACC programs in the years before the Davis-Besse event that are summarized above, demonstrate that the emphasis of these programs and NRC inspections was on small leaks from welded and bolted connections, not on potential wastage in the solid pressure-retaining portions of the reactor coolant system (i.e., vessel and pipe walls).[65]

Although Davis-Besse was the only plant to report significant RPV head wastage as a consequence of CRDM nozzle cracking, it was not the only plant to experience accumulation of boric acid crystals on the RPV head. It has been estimated that Davis-Besse had about 900 pounds of boric on its RPV head[66] Others with reportable accumulations include the following:

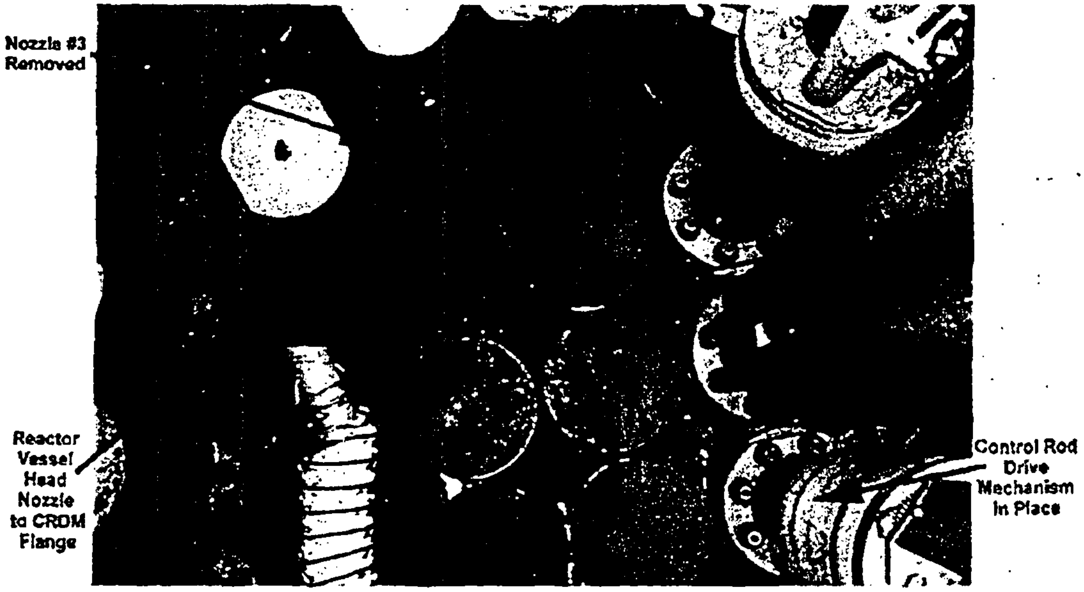
- Turkey Point Unit 4 experienced a leaking instrument tube seal resulting in 500 pounds of boric acid crystals accumulating on the RPV head and limited boric acid wastage.[67]
- Oconee Unit 3 experienced cracks in nine CRDM nozzles in February 2001. In total there were 14 leaking CRDM nozzles and a large amount of boric acid on RPV head prior to 2000.[68]
- Arkansas Nuclear One Unit 1 experienced 1 leaking CRDM nozzle and some boric acid on the RPV head.[69] (ANO Inspection Report 2001-02 has no details.)
- Three Mile Island Unit 1 experienced severe corrosion on 14 of 24 carbon steel flange bolts on the 1C rector coolant pump, as reported in March 2001.[70] TMI-1 also had 5 leaking CRDM nozzles and some boric acid on RPV head.[71]

- Crystal River Unit 3 had one leaking CRDM nozzle and some boric acid on the RPV head.[72]

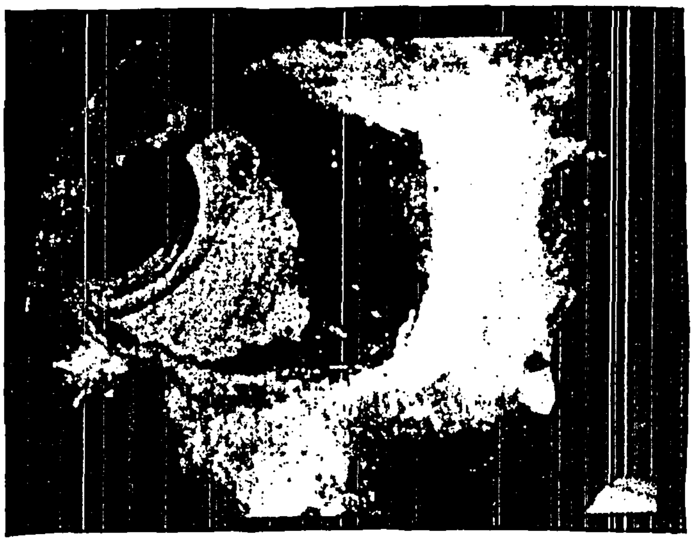
7. FENOC's Response to Discovery of RPV Head Wastage

Refueling outage 13 began on February 16, 2002. FENOC planned to perform a visual inspection of the outer surface of the RPV head looking for signs of boron deposits, and ultrasonic inspection of all CRDM nozzles. The ultrasonic inspection identified five nozzles with indications of cracking, including three with through-wall cracks, and the licensee decided to repair all five nozzles. The crowded work space in which these operations were conducted is illustrated by the following figure.

Davis Besse - Reactor Vessel Head Insulation
Top View - Nozzle #3 Removed



On March 6, during machining to facilitate repair of nozzle 3, the equipment rotated and was removed from the head. Upon removal, it was found that the nozzle had tipped, with the CRDM flange contacting the flange of an adjacent CRDM. The surface of the RPV head was cleaned and a cavity was found adjacent to nozzle 3. Subsequent investigation revealed an additional smaller degraded area near nozzle 2. The cavity beside nozzle 3 was about 5 in. by 5 in. by 6 in. The wastage was completely through the carbon steel vessel, leaving only the 3/8 in. stainless steel liner that had deformed somewhat into the wastage area. The following photo shows the wastage area adjacent to nozzle 3.



FENOC undertook a number of actions in response to the event. The primary investigation of the cause of the RPV head wastage was a root cause analysis led by a FENOC employee from the Beaver Valley nuclear power plant.[73] FENOC made a decision to replace rather than repair the damaged head of the reactor. Extent of condition reviews were conducted for equipment inside containment exposed to boric acid. Emerging issues during the outage were addressed to NRC's satisfaction and the plant resumed operation in March 2004.[74]

FENOC concluded from its internal reviews that no one person or group was solely responsible for the RPV head wastage. Rather, FENOC concluded that the Davis-Besse organization must bear collective responsibility for missed opportunities to prevent or detect earlier the RPV head wastage. FENOC concluded that no one engaged in any deliberate or willful misconduct. Personnel actions were taken against 18 individuals during the week of September 16, 2002. People who were significantly involved in RPV head cleaning in two previous outages and individuals and senior management significantly involved in preparing responses to Bulletin 2001-01 were removed from the company. Others were demoted or removed from management positions or received unsatisfactory performance ratings.[75]

On April 21, 2005, NRC issued a Notice of Violation and Civil Penalty to FENOC for matters related to the RPV head wastage event. The $5,450,000 Civil Penalty was the largest ever issued by the NRC. FENOC replied to but did not appeal the Notice of Violation and Civil Penalty.[76] In replying, FENOC said

> In furtherance of reconciliation, in an effort to close the RPV head matter and in accordance with [NRC Regulations], we are paying the proposed civil penalty...in full....FENOC has accepted full responsibility for those performance deficiencies, and, as set forth more fully in its enclosed response, admits many of the violations cited by the NRC...Nonetheless, we are not addressing the allegations of willfulness contained in the April 21, 2005, transmittal letter because the NOV itself does not cite willfulness and a specific response to those allegations is not required.

My review of the record provides no evidence that people willfully violated the BACC program at Davis-Besse.

The FENOC decision to not appeal the Notice of Violation and Civil Penalty is not unusual. Most licensees do not appeal civil penalties because it creates the impression that the licensee is not listening to its regulator. From 1980 through 2005, NRC issued 794 civil penalties for more than $70,000,000 to the approximately 105 operating nuclear power plants in the United States. Of the 794 penalties, 6 were denied by the licensees; of the 6 denials, only two penalties of $110,000 each were formally appealed by the licensees. Both appeals resulted in a reduction but not elimination of the civil penalty.

Although there are many self-criticisms contained in self assessments and root cause assessments performed by FENOC in the aftermath of the wastage event, these statements do not amount to admissions of misconduct. First, such assessments are retrospective in nature, i.e., they are fully informed of the consequences of the preceding actions. Second, such assessments, as is the norm in the nuclear industry, are designed to discover what could have been done, not necessarily what should have been done in real time as events unfolded. Third, such assessments are affected by hindsight bias, a psychological phenomenon that has been observed in accident and other retrospective examinations in many technological endeavors. For example in writing of hind sight bias as applied to the medical profession, one investigator writes

> There are a variety of factors that block or inhibit the learning processes central to a high reliability culture. One is the hindsight bias (Fischhoff,

> 1975; Woods et al., 1994; Woods and Cook, 1999). The hindsight bias is one of the most reproduced research findings relevant to accident analysis and reactions to failure. Knowledge of outcome biases our judgment about the processes that led up to that outcome.
>
> In the typical study, two groups of judges are asked to evaluate the performance of an individual or team. Both groups are shown the same behavior; the only difference is that one group of judges are told the episode ended in a poor outcome; while other groups of judges are told that the outcome was successful or neutral. Judges in the group told of the negative outcome consistently assess the performance of humans in the story as being flawed in contrast with the group told that the outcome was successful. Surprisingly, this hindsight bias is present even if the judges are told beforehand that the outcome knowledge may influence their judgment.[77]

The NRC's licensees do not correct their retrospective analyses, such as root cause assessments, for hindsight bias because they are required by NRC to learn what could have been done in the past so they can do it in the future to provide continuous improvement in reactor safety. In using NRC and licensee documents of such retrospective analyses in determining what was reasonable to do, one must correct for the hindsight bias that such documents contain.

There are specific claims in the NEIL Statement of Defense[78] that derive from FENOC self-assessments or NRC analyses that contain hindsight bias, including the following:

- The NRC concluded that, "had [FENOC] properly implemented its [BACC program], it would have...prevented the significant corrosion." (Statement of Defense, p. 4). Although it is incontrovertible that there was a level of implementation of the BACC program that could have prevented the wastage event, this conclusion by NRC is not sufficient to judge whether it was unreasonable, given the specific circumstances that had occurred at Davis-Besse (e.g., NRC had specifically approved the upgraded BACC Program after the RC-2 event in 1998 and there was a long record of CRDM flange leakage that was the worst in the B&W fleet, that was beyond FENOC's control, and that contributed a significant fraction of the total boric acid deposited on the RPV head at Davis-Besse), to have not prevented the wastage event.
- The Statement of Defense (p. 14, 15) cites NRC and FENOC documents to argue that the wastage event could have been anticipated. The arguments fail to make the case that the information available at the time was sufficient to convince a reasonable person, qualified in their position, that significant corrosion of the RPV head could have occurred without

> detection in a plant that was so successfully operating in conformance with its safety requirements.

8. NRC's Response to Davis-Besse Head Wastage

8.1 NRC's Augmented Inspection Team

After being advised by FENOC during the period March 6 to 10, 2003 of the identification of the cavity in the reactor vessel head, the NRC dispatched an Augmented Inspection Team (AIT) to the site on March 12 and issued a Confirmatory Action Letter (CAL) on March 13.[79] The AIT was comprised of an engineering Branch Chief and three inspectors from Region III and a materials engineer from NRC's Office of Research. The AIT conducted its work over the period March 12 to April 5 and issued its report on May 3, 2002.[80] The AIT conducted its inspection in accord with NRC procedure 93800. It was chartered to determine the facts and circumstances related to the degradation of the reactor vessel head and to determine any precursor events to this condition. It developed a sequence of events, interviewed plant personnel, collected and analyzed factual information and conducted visual inspections. The AIT did not address compliance with NRC rules and regulations or make a determination of the risk significance of the wastage in the RPV head. The transmittal letter for the AIT report states the following:

> The AIT concluded that the cavity in head was caused by boric acid corrosion from leaks through the control rod drive nozzles in the reactor vessel. These leaks were caused by primary water stress corrosion cracking of the nozzle material leading to a through-wall crack and corrosion of low alloy steel that went undetected for an extended period of time. The boric acid corrosion control program at the site included both cleaning and inspection requirements, but was not effectively implemented to detect the leakage and prevent the significant corrosion of the reactor vessel head over a period of years. Similarly on several occasions, maintenance and corrective action activities failed to detect and address the indications in the containment that the significant corrosion of the reactor vessel head was occurring. The NRC views these as missed opportunities to identify and correct this significant degradation to the reactor pressure vessel head.

As is typical of NRC inspection reports, the AIT report made no distinction between what could have been done and what was reasonable to have been done based on the information that was available at the time. That is, it provided no judgment about what it was reasonable for FENOC to have done in the circumstances leading up to the discovery of the wastage event.

On October 2, 2002, the NRC staff issued a follow-up report on the AIT inspection.[81] It reported on a special inspection begun on May 15, 2005 focused on compliance with NRC rules and regulations as they related to the facts and circumstances associated with the wastage event. The report identified ten findings, some that were apparent violations with multiple examples. At the time of that report, the findings were characterized as unresolved items.

8.2 NRC's Lessons Learned Task Force

On September 30, 2002, The NRC's Task Force on Lessons Learned from Davis-Besse issued its report.[82] The nine members of the task force came from NRC headquarters and regional offices. They were charged to conduct an independent evaluation of the NRC's regulatory processes related to assuring reactor vessel head integrity and to recommend areas of improvement applicable to the NRC and the industry. The Observations and Conclusions of the Task force included the following:

> About 10 years ago, the NRC and industry recognized the potential for an event such as the one that occurred at DBNPS. In spite of the wealth of information, which includes extensive foreign and domestic PWR plant operating experience, as well as research activities involving tests and engineering analyses, the DBNPS event occurred... In 1993, the industry and NRC specifically addressed the possibility of extensive RPV head wastage stemming from undetected VHP nozzle leaks involving axial cracking caused by PWSCC. ***The industry and the NRC concluded that the likelihood of such an event was low*** because VHP nozzle leaks would be detected before significant RPV head degradation could occur.
>
> ***The task force concluded that DBNPS VHP nozzle leakage and RPV head degradation event was preventable...The task force concluded that the event was not prevented because: (1) the NRC, DBNPS, and the nuclear industry failed to adequately review, assess, and followup on relevant operating experience; (2) DBNPS failed to assure that plant safety issues would receive appropriate attention; and (3) the NRC failed to integrate known or available information into its assessments of DBNPS's safety performance.***
>
> ***Because the NRC and nuclear industry concluded that Alloy 600 VHP nozzle cracking was not an immediate safety concern, the NRC and the industry's efforts to further evaluate this issue became protracted. Also, the NRC and industry continued to rely on visual inspections of VHP nozzles. These inspections are incapable of characterizing the extent of nozzle cracking and damage.*** While the industry initiated actions to

improve non-visual inspection capabilities, the requirements governing inspections remained unchanged.

...Rather than adopt an approach of leakage prevention, the NRC focused on measures intended to enhance licensee capabilities to detect small VHP nozzle leaks. ...Leakage detection would serve as a means of providing defense-in-depth to account for any potential ***uncertainties in the industry analysis that boric acid corrosion walkdown inspections would be an effective means of detecting VHP nozzle leaks before significant degradation could occur.*** However, PWR plant licensees have not installed enhanced leakage detection systems designed to detect VHP nozzle leaks.

The licensee for DBNPS, as well as the NRC, failed to learn a key lesson from boric acid leakage and corrosion operating experience. Specifically, predictions regarding boric acid-induced corrosion rates, for in-plant boric acid leaks, have not been reliable in all cases...

The NRC and the industry regarded boric acid deposits on the RPV head as an issue that required attention; however, the ***NRC and industry did not regard the presence of the boric acid deposits on the RPV head as a significant safety concern because they expected that boric acid crystals would form from flashing steam and such crystals would not cause significant corrosion of RPV heads.*** For example, the NRC and industry were concerned that the presence of boric acid deposits, from CRDM flange leakage in the case of B&W PWR plants, could obscure the indications of VHP nozzle leakage. ***While dry boric acid crystals would not be expected to result in significant corrosion rates, representative testing of nozzle leakage indicated that corrosion rates from boric acid solutions could be in the range of 4 inches per year.*** These rates of corrosion could occur at primary system leakage rates that are significantly lower than the typical PWR plant technical specification limit, namely, at a rate too small to directly measure with the current leakage detection systems. ***Even at somewhat lower rates of corrosion, properly implemented boric acid corrosion control programs may not lead licensees to detect VHP nozzle leaks before significant RPV head degradation could occur. The results of these tests, while known within the NRC, were not widely recognized by the NRC staff.***

The recurring nature of boric acid leakage and corrosion events generally indicates a lack of effectiveness of industry corrective actions in these areas. This event also indicates that DBNPS failed to effectively implement its operating experience review program. Also, the NRC failed to adequately review, assess, and followup on relevant operating experience to bring about the necessary industry and plant specific actions to prevent this event... The NRC accepted industry positions regarding the nature and significance of VHP nozzle cracking ***without having***

> ***independently verified a number of key assumptions, including the implementation effectiveness of boric acid corrosion control programs*** and enhanced visual inspections of RPV heads...The task force identified multiple DBNPS performance problems..
>
> ***For a number of years, the NRC was aware of the symptoms and indications of active RCS leakage.*** The NRC even reviewed some of these individual symptoms during routine inspections; however, ***the NRC failed to integrate this information into its assessments of DBNPS's safety performance.*** As a result, the NRC failed to perform focused inspections of these symptoms. If focused inspections had been performed, then the NRC may have ultimately discovered the VHP nozzle leaks and RPV head degradation. ***The former senior resident inspector became aware of boric acid deposits on the RPV head at the onset of the spring 2000 refueling outage; however, he did not inform his supervisor and did not perform inspection followup.*** There were other licensee performance data that were available for review, in the context of the NRC's inspection program, but the NRC did not review or assess this information. Actual and perceived weaknesses with inspection, enforcement, and assessment guidance, as well as inadequate VHP nozzle and RPV head inspection requirements, contributed to the NRC's failure to identify the problem. (emphasis added)

Implementation of the recommendations of the Davis-Besse Lessons Learned Task Force received continuous oversight by the Commissioners themselves from the time they were first reviewed and approved by senior NRC management until November 14, 2005 at which time the Commission relinquished control, to the NRC staff, of the still-ongoing implementation of the corrective actions found to be required within NRC.[83]

This report demonstrates several things. First, the NRC and the nuclear industry in general shared many of the same misconceptions regarding the ability to detect damage to nozzles and the reactor head due to boric acid. Second, the NRC and the industry continued to believe that boric acid on the reactor head did not represent a significant safety concern. Third, the NRC and the industry did not believe that nozzle cracking itself was an immediate safety concern. And, finally, this report is a good example of the NRC's use of hindsight to ensure that adverse events do not occur in the future. Nowhere in this report does the NRC attempt to consider the reasonableness of its own actions or the actions of Davis-Besse or the industry based on the information available prior to and at the time these events were occurring.

8.3 NRC Inspector General's Review

The NRC Inspector General issued a report on the Davis-Besse wastage event on October 17, 2003.[84] It addressed the NRC's oversight of operations at Davis-Besse pertaining to boric acid leakage and corrosion and was initiated in response to a request from Congress. The Congressional request was specific to the circumstances surrounding the NRC's receipt of FENOC Condition Report 2000-0782 and the photos and description it contained of red-brown boric acid deposits. The IG report concluded in part that "This outage [RFO 12] provided the NRC staff a good opportunity to evaluate the licensee's handling of boric acid leakage and corrosion prior to the actual discovery of reactor vessel head degradation..." The findings of the IG report faulted NRC headquarters for failing to emphasize the importance of boric acid corrosion controls to the NRC regional offices. It also faulted Region III managers and individuals for failing to adequately inspect Davis-Besse and to communicate and follow-up on information gained by the inspectors about the continuing problem with boric acid at the plant, including Condition Report 2000-0782.

Like the report of the NRC Lessons Learned Task Force, the Inspector General's report shows that NRC's technical judgment about the hazards of CRD nozzle cracking and indications of RCS leakage were consistent with those of FENOC before the discovery of the RPV wastage. That is, any wastage that might occur would be relatively slow, giving plenty of time for detection. Only with hindsight were FENOC and NRC able to see the rapid progression of events that actually occurred at Davis-Besse and understand the safety implications. In addition, NRC came to understand that the methods for leak detection in use prior to the event were not adequate to provide the assurances of RPV integrity that are necessary.

8.4 Government Accountability Office Review of NRC

The Government Accountability Office (GAO) issued a report in May 2004 after conducting a review of the David-Besse event to determine why NRC did not prevent it, whether the processes NRC used in delaying the shutdown of the plant for inspection of the RPV head was credible, and whether NRC was taking sufficient action after the event to prevent similar problems.[85] The GAO noted that the NRC and the operators of nuclear power plants share the responsibility for ensuring that nuclear reactors are operated safely (page 1). GAO also reported that

> NRC should have but did not identify or prevent corrosion at Davis-Besse because both its inspectors at the plant and its assessments of the operator's performance yielded inaccurate and incomplete information on plant safety conditions....***NRC resident inspectors had information revealing potential problems,*** such as boric acid deposits on the vessel head and air monitors clogged with boric acid deposits, but this information did not raise alarms about the plant's safety. ***NRC inspectors did not know that these indications could signal a potentially significant problem*** and therefore did not fully communicate their observations to the ***other NRC staff,*** some of whom ***might have recognized the significance of the problem....resident inspectors did not know*** that boric acid, rust, and unidentified leaking indicated that the reactor vessel might be degrading....these inspectors thought they understood the cause for the indications, based on licensee actions to address them. Therefore, ***resident inspectors, as well as regional and headquarters officials, did not fully communicate information*** on the indications or decide how to address them, and therefore took no action....Because the leakage rates were below NRC limits, ***NRC's inspection reports following the implementation of the NRC's new oversight process (in the spring of 2000) did not identify any discussion of these problems at the plant....***a FirstEnergy official said he showed one of the two resident inspectors a report that included photographs of rust-colored boric acid on the vessel head." (emphasis added)

Like the NRC's Lessons Learned and Inspector General reports, this GAO report shows that the NRC staff's technical judgments about the hazards of CRD cracking and indications of RCS leakage were consistent with those of FENOC before the discovery of RPV wastage. Only with hindsight was it possible to see the actual progression of events and the importance of other indicators, such as rust and clogged filters, and to understand the risk portended by corrosion occurring between the CRDM nozzle and the ferritic steel, hidden below the upper surface of the RPV head.

The GAO report also reviews the NRC actions being taken at that time to prevent boric acid from corroding RPV heads at other plants. Those actions go beyond the requirements for such prevention measures before the event, as is shown below, thus indicating NRC's overriding conclusion that, in hindsight, the industry-wide programs before the Davis-Besse RPV head wastage event were not sufficient to prevent this type of event.

8.5 NRC's Notice of Violation and Civil Penalty

The Notice of Violation and Civil Penalty connected with the wastage event was transmitted to Davis-Besse on April 21, 2005.[86] The violations for which NRC assessed a penalty were as follows:

1. Exceedance of technical specification on pressure boundary leakage ($5,000,000);
2. Failure to provide accurate information in plant documents ($110,000),
3. Ineffective corrective actions ($110,000);
4. Failure to comply with procedures and remove obstructions to viewing the RPV head at the end of RFO12 ($110,000); and
5. Failure to supply complete and accurate information to the NRC in response to Bulletin 2001-01 ($120,000).

The first of these violations concerned the long term leakage of coolant from the reactor coolant pressure boundary. Such leakage is prohibited by the plant's technical specifications but was only known by NRC and FENOC with the benefit of hindsight. The second violation concerned the accuracy of documents internal to the Davis-Besse plant that were prepared by an individual after 12RFO and such inaccuracy was known to others only with hindsight. The third violation could only be seen with hindsight since the corrective action program was viewed favorably by NRC before the discovery of the wastage event, as evidenced by inspection reports in the years leading up to the event. The fifth violation had to do with the accuracy and the supply of information to the NRC and is not germane to this proceeding. The fourth violation had to do with not removing all of the boric acid residue on the RPV head by the end of RFO12. Even if this violation had not occurred, that is, if the boric acid had been entirely removed from the head by the end of RFO12, there may not have been indication that the wastage of the head was underway because the wastage started in the space between the CRDM nozzle and the ferritic steel, below the upper surface of the RPV head where it was out of sight, and because even when cleaned of all boric acid, the upper head was very difficult to observe by accepted inspection techniques due to congestion of the CRDMs and thermal insulation above the head.

The transmittal of the NOV and Civil Penalty contained several references to the alleged willfulness of FENOC's alleged failures. The violations themselves contained no mention or citations to evidence of willfulness. Criticisms of implementation of the BACC Program at Davis-Besse contained in the violation are similar to criticisms NRC voiced of BACC Programs at other plants both before and after the RPV wastage was discovered at Davis-Besse, as discussed in Section 6, above.

Although the civil penalty was the largest ever issued by NRC, a civil penalty, by itself, does not demonstrate unreasonable performance. The opposite may be true since, on various occasions in the past, NRC has, by its own admission, issued civil penalties to one licensee in order to send a message to all licensees about NRC's rising standards of performance. In this case, the NRC issued the civil penalty at the time it was reversing previous trends in the industry for dealing with Alloy 600 cracking, e.g., by requiring application of more capable inspection techniques and by encouraging more and earlier RPV head replacements.

8.6 NRC's Generic Issuances and Other Statements

The NRC Issued Information Notice 2002-11 on March 12, 2002.[87] This was NRC's first notice to the industry concerning the Davis-Besse event. It contained no requirements but provided information available at the time and said "It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems." The NRC discussion of the event describes how leakage from the CRDM flanges flowed downward leaving boric acid crystals in its wake and masking indication of leakage from the CRDM nozzles. It also describes previous instances of corrosion of ferritic steel and parameters that affect the rate of general corrosion.

The NRC issued Bulletin 2002-01 on March 18, 2002.[88] The purpose of this Bulletin was to assess licensee inspections and other information that could provide a basis for conclusions on the condition of the RPV head. The Bulletin also addressed boric acid corrosion of other parts of the reactor coolant system. Responses to this Bulletin indicated that

> While licensee programs and procedures are consistent with technical specification requirements that prohibit operating with through-wall cracking in the reactor coolant pressure boundary, ***most licensees do not perform inspections of these materials beyond those required by the***

> ***ASME Code to identify potential cracking and leakage of components susceptible to primary water stress corrosion cracking. Such inspections are generally performed without removing insulation and are not capable, in many cases, of detecting through-wall leakage....***In the implementation of boric acid corrosion control programs, some licensees are relying solely on visual examinations in the course of walkdowns during refueling outages to look for evidence of leakage, such as rust stains or boric acid crystals...***the staff considers that the identification of small leaks by this process of visual examination may not be sufficient in all cases to ensure pressure boundary integrity, even using bare metal visual techniques...The staff has identified a number of weaknesses in BACC and ASME Code inspection programs*** related to the identification of pressure boundary through-wall cracking and leakage.... the staff determined that many plants have not taken steps to identify locations that are susceptible to cracking...***The nuclear industry has become increasingly aware that boric acid leakage can become airborne and that crystals can form in locations other than in the vicinity of the leak, such as in containment ventilation filters.*** Thus, the exact location or the magnitude of leaks may not be detected simply by looking for boric acid crystals on leaking components or their nearby targets..." [89] (emphasis added)

These hindsight-aided conclusions further demonstrate that the practices at Davis-Besse prior to the discovery of RPV wastage were typical of those elsewhere in the industry and that the methods used by the industry in general probably were not sufficient to prevent the RPV head wastage that occurred at Davis-Besse.

The NRC issued Bulletin 2002-02 in August 2002.[90] Since the first occurrence of circumferential cracking at Oconee Unit 3 in 2001, the nuclear industry had been developing inspection recommendations for other plants but did not have a proposal available for NRC's consideration by the summer of 2002, so this Bulletin was issued. It directed operators of PWRs to increase the frequency and thoroughness of inspections of reactor vessel heads as their susceptibility to degradation increased with age. It described an inspection program that included a combination of visual and non-visual examinations on a graded approach consistent with a correlation of plant susceptibilities to PWSCC. The approach involved a parameter referred to as effective degradation years to characterize plant susceptibility to PWSCC. Calculation of this parameter requires information on the RPV head operating temperature(s) and the operating time (i.e., effective full power years) at each operating temperature. The NRC created a grading chart, ranking each reactor head's susceptibility to degradation. As of April 2003, 27 PWRs were in the high susceptibility category, three already had new vessel heads, and the owners of 21 others had publicly stated plans to replace their vessel heads.[91] Clearly, the NRC and the industry's perception of the threat of boric acid corrosion of the RPV head and the timing of that threat had remarkably changed in less than a year when prompted by the insights afforded by the Davis-Besse event.

On October 29, 2002, in yet another indication that NRC, like FENOC and the rest of the industry, did not appreciate prior to 2002 the failure mode that developed at Davis-Besse and thus did not understand the early indicators of possible head wastage, NRC Chairman Dr. Richard Meserve told a Nuclear Safety Research Conference in Washington, DC,[92]

> Let me close my comments this morning with a cautionary note. To gain the full benefits of research, the knowledge that is gained must be carefully and thoughtfully applied. ***Our recent experience with the degradation of the reactor pressure vessel head at the Davis-Besse Nuclear Power Station illustrates what can happen when information is not properly integrated. We understood boric acid corrosion of carbon steel. We understood primary water stress corrosion cracking of reactor pressure vessel head penetrations. Unfortunately, we did not fully integrate the two together and appreciate the resulting safety significance.*** So let me stress the need not only to perform research, but also to internalize its findings. Henri Poincare once wrote, "Science is built upon facts, as a house is built of stones; but an accumulation of facts is no more a science that a heap of stones is a house." We must ensure that our research efforts result in facts and knowledge that are applied in a manner which strengthens our capacity to ensure safety and security. (emphasis added)

The NRC issued Order EA-03-009 on February 11, 2003[93] to provide specific RPV inspection requirements for all PWR licensees. The Order required that plants evaluate their susceptibility to PWSCC using a formula for effective degradation years. It then provided specific inspection requirements based upon that parameter for each plant. High susceptibility plants were required to perform a bare metal visual examination and a non-visual examination every refueling outage. Moderate susceptibility plants were required to perform either bare metal visual or non-visual examination every outage, alternating the two methods with each refueling. Low susceptibility plants were required to perform a bare metal visual examination by their second refueling outage after issuance of the Order and every third refueling outage or five years thereafter. In addition, low susceptibility plants were required to perform non-visual examination by February 11, 2008, and then repeat every fourth refueling outage or seven years thereafter. The non-visual examinations described in the Order were ultrasonic examination or surface examination. In explaining the order, a senior NRC staffer said, "The NRC staff was not comfortable with the visual inspections alone. The reason is that we did not and still don't have a good understanding of the corrosion issue..."[94] This is another indication that even if the boric acid residue had been completely cleaned from the Davis-Besse head during RFO12, it is unlikely that the wastage underway below the surface of the head would have been discovered by the visual inspection techniques alone. A revised Order EA-03-009 Rev. 01 was issued on February 13, 2004.

Westinghouse issued WCAP-15988-NP[95] in March 2003 to provide guidance on effective BACC programs for all three PWR owners groups. The report acknowledges that "A sample review of the current GL 88-05 inspection programs and licensee 60-day responses to Bulletin 2001-01 suggested that significant variations exist in the inspection procedures, ownership and responsibility, personnel qualification and training, as well as in the detection and evaluation methods for boric acid corrosion." This 85-page document contains detailed information and relevant summaries of regulatory documents to assist licensees in correcting deficiencies in their BACC programs. Some of those deficiencies at other plants were similar to the ones found in the Davis-Besse BACC Program after the RPV head wastage event. Thus, as with Davis-Besse, NRC was using hindsight afforded by knowledge of the outcome to make improvements in BACC.

The NRC issued Bulletin 2003-02[96] on August 21, 2003 to all holders of operating licenses for pressurized-water nuclear power reactors with penetrations in the lower head of the RPV. The NRC issued this bulletin to advise licensees that current methods of inspecting the RPV lower heads (e.g., bare-metal visual inspections) may need to be supplemented with additional measures to detect reactor coolant pressure boundary leakage and to request licensees to provide the NRC with information related to inspections that have been or will be performed to verify the integrity of the RPV lower head penetrations. This Bulletin is further indication that hindsight afforded by the Davis-Besse event taught the nuclear industry that insufficient methods were being used prior to the event for assuring the integrity of aging reactor pressure vessels.

On October 21, 2003, NRC Commissioner Jeffrey Merrifield stated a similar conclusion when he told the Nuclear Safety Research Conference in Washington, DC that no one expected the failure mode that occurred at Davis-Besse,[97]

> [T]he NRC has maintained an active research effort for many years that is on the management of age-related degradation in nuclear power plants. However, the effectiveness of this program has been recently challenged...materials degradation issues have been pushed to the forefront of the nuclear industry in the past few years. None is more prominent than the reactor pressure vessel head degradation at Davis-Besse. It is nearly 20 months since the discovery of the pineapple-sized cavity in the vessel head at Davis-Besse. What is disturbing to me, is how this was missed. ***Our attention was focused on the potential for cracks propagating, turning circumferentially and thus leading to an ejection of a control rod. No one expected the significant erosion of the vessel head itself.*** Since this discovery, the NRC and industry have spent a considerable amount of resources reflecting on this event and pondering how it happened. Some in industry believe it is merely one data point and not a reflection of the entire industry. Others question the NRC's oversight and understanding of materials degradation issues, and our ability to effectively manage them. As many of you are aware, the NRC formed a nine-person, lessons-learned task force that spent more than 7000 hours reviewing the NRC's regulatory processes and activities, and provided specific recommendations to the Commission for areas of improvement. Action plans to address these recommendations have been initiated, including recommendations to evaluate plant experience with stress corrosion cracking and boric acid corrosion in order to enhance our inspection requirements and guidelines. In addition, the industry through the EPRI Materials Reliability Project (MRP) is leading the industry's actions to respond to materials degradation issues. (emphasis added)

The NRC issued NUREG-1823 in April 2005.[98] This technical report was prepared by the NRC Office of Research. It includes a summary of foreign and domestic Alloy 600 cracking experience, an analysis of the Alloy 600 cracking susceptibility model for vessel head penetration nozzles, and information on corrosion of pressure boundary materials in boric acid solutions. As it reports on page A-9, Davis-Besse was not the only plant in which incompletely removed boric acid residue masked indications of leaking in CRDM nozzles. Although this observation at Oconee occurred more than a year after the Davis-Besse RPV head wastage was discovered, it related to incomplete cleaning of the Oconee RPV head that preceded the Davis-Besse event.

Oconee Unit 3 (Event Notification Report 39821 and LER 287-2003-

> 001) entered its scheduled end-of-cycle 20 refueling outage on April 20, 2003. During a visual inspection of the reactor vessel head on May 2, 2003, evidence of possible through-wall leakage was observed on two vessel head penetrations. The locations of these penetrations are Nozzles #4 and 7. Nozzle #4 contained a very thin white coating while nozzle #7 appeared to have a small accumulation of boron on the head adjacent to the annulus region. ***Approximately 6 to 8 additional nozzle-to-head penetrations were masked by deposits from a component cooling system leak above the RV head and were unable to be inspected. Prior refueling outage RVH inspection videotapes showed that the Nozzle #7 deposits were not associated with a new leak but rather were remnants from a prior outage leak and repair where the boron residue had not been removed.*** The Nozzle #4 boron deposits were similar to previous reactor vessel head leaks. The apparent root cause of the nozzle leak was PWSCC. The head was replaced during this refueling outage. (emphasis added)

Duke Power Company was not cited by the NRC for the situation described above.

The matters described in this section support the conclusion that, in hindsight, the industry-wide programs before the Davis-Besse RPV head wastage event were not sufficient to prevent this type of event and that Davis-Besse was not unique n the conditions it experienced with boric acid buildup on the reactor pressure vessel.

9. Conclusions

Based on the information reviewed in the foregoing sections of this report a number of conclusions have been reached and are described below.

NRC sets and interprets the rules governing the safety of nuclear power plants in the United States. Although the licensees are primarily responsible for safety, NRC and the licensees share the responsibility for ensuring that nuclear reactors are operated safely. The nuclear industry is very closely regulated. The NRC knows what is going on in the plants it regulates.

The NRC relies on hindsight in gleaning lessons from operating experience so as to prevent very low probability events in the future. It uses hindsight in its reports or those provided by its licensees that describe retrospective analyses of operating events, such as root cause assessments.

Hindsight is appropriate to use in judging the reasonableness of performance because what could have been done, with foreknowledge of the outcome, is not a reasonable standard of performance.

Davis-Besse was a superior performing plant in the years leading up to the discovery of wastage in the reactor vessel head.

The NRC licensing staff approved and its inspectors were aware of the implementation of the boric acid control program at Davis-Besse, as evidenced by inspection records before the RPV head wastage was found and by testimony to investigators after the fact.

Implementation of the boric acid corrosion control program at Davis-Besse was similar to the implementation of such programs at other plants as evidenced by NRC inspection records before and after RPV wastage was discovered at Davis-Besse and by generic issuances of the NRC after the event.

A number of NRC personnel at the plant, in the region and at headquarters and some FENOC contractors, including Framatome support personnel, received the same early indications of corrosion products in containment (boric acid accumulation on the RPV head, in containment and on air coolers; iron in the radiation filters; etc.) that FENOC had and made similar conclusions about their lack of significance, thus confirming the reasonableness of FENOC's conclusions.

The Violations and Civil Penalty issued by NRC for the RPV wastage were not for willful violation of the BACC Program. My review also found no indication of willful violation of the BACC.

Like other Civil Penalties issued by NRC, the size of the penalty issued to FENOC was meant in part to send a message to the rest of industry.

The RPV wastage at Davis-Besse could not have reasonably been predicted because of the state of knowledge at the time about boric acid corrosion throughout the industry and at Davis-Besse. The following are examples of misconceptions that have been eliminated with the benefit of hindsight applied to the Davis-Besse event:

- Reactor pressure vessel failures are incredible because of assurances provided based on an approach developed nearly 4 decades ago;

- If boric acid is dry and at high temperature there will be no corrosion (this ignores intermediate states of boric acid);
- The relatively high temperature of the Davis-Besse RPV head inhibited corrosion;
- The peripheral nozzles in the RPV head are more vulnerable to cracking than central nozzles because of higher stresses on the periphery;
- The most serious consequence of longitudinal cracks in CRD nozzles is that they lead to circumferential cracks;
- Rod ejection and loss of coolant accidents are the most serious things that can happen with CRD nozzle cracking;
- Longitudinal nozzle cracks are not as dangerous because they leak before they break and are readily observable on walk downs;
- One gallon per minute of unidentified leakage from a nuclear reactor is acceptable;
- Old boric acid deposits are brown (dark);
- Boric acid deposits on the reactor head inhibit corrosion of the head by preventing exposure to oxygen;
- Boric acid deposits are usually flaky; and
- Leaking nozzles only cause popcorn-like boric acid deposits.

As a result of these misconceptions, NRC, FENOC and the entire nuclear industry shared a cognitive dissonance (mindset) on the improbability of significant vessel head wastage by boric acid.

There were alternative interpretations of the indications of the onset of RPV wastage:

- Other sources of iron on radiation filters were plausible.
- SWRI said the iron on the filters came from a high location in containment.
- There had been chronic leakage from the CRD flanges above the insulation on the RPV head.
- Other sources of leakage (e.g., CRD flanges) had caused contamination of containment air coolers in the past.
- Leaking control rod drive flanges produced lots of boron deposits, while cracked control rod drive nozzles were understood to lead to very small deposits of boron.
- Special inspections by FENOC to locate unidentified reactor leakage found other sources that appeared to account for nearly all the leakage.
- As events unfolded in real time, the possibility that the corrosion products seen in containment were associated with unidentified RCS leakage and possible RPV head wastage did not occur to anyone, not FENOC and its contractors, including Framatome, not NEIL, not the CNRB, and not the NRC.

- This is the first time significant material wastage has ever been reported below the top of the RPV head. There were no precedents for its occurrence. Framatome's risk assessment concluded this type of failure would take a long time to occur and would be detected before it progressed significantly.

Boron deposits on the vessel head did not damage the head. Rather, RPV head wastage occurred in the annulus between the Alloy 600 CRD nozzle and the carbon steel RPV head, below the top of the head. The cause of the wastage was through-wall leakage via longitudinal cracks in the CRD nozzles, which industry and NRC considered in the past and dismissed as being observable before damage occurred.

Since the Davis-Besse event, the NRC is saying that bare metal visual observation is not sufficient to find nozzle cracks. Licensees are required to use ultrasonic testing or other approaches that require access through the bottom of the vessel head while it is removed during refuelings. This new NRC approach tends to confirm that the wastage at Davis-Besse probably was not discernable even if the RPV head had been completely cleaned of boric acid residue at the end of RFO12.

The recriminations of individuals and organizations at Davis-Besse after the event have to be taken with cognizance of hindsight, as do those of the NRC. Organizations so challenged will always find missed opportunities to have done better because of the psychological phenomenon called hindsight bias.

Report prepared by

Roger J. Mattson

Roger J. Mattson, Ph.D.

Attachment RJM-1 Acronyms

ACRS	Advisory Committee on Reactor Safeguards
AEC	Atomic Energy Commission
AIT	Augmented Inspection Team (from NRC)
ASME	American Society of Mechanical Engineers
B&W	Babcock & Wilcox Company
B&WOG	Babcock & Wilcox Owners Group
BACC	Boric Acid Corrosion Control
CAP	Corrective Action Program
CFR	Code of Federal Regulations
CNRB	Company Nuclear Review Board
CR	Condition Report
CRD	Control Rod Drive
CRDM	Control Rod Drive Mechanism
DOE	Department of Energy
ECCS	Emergency Core Cooling System
EDO	Executive Director for Operations
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FENOC	FirstEnergy Nuclear Operating Company
FSAR	Final Safety Analysis Report
GAO	Government Accountability Office
IEAL	International Energy Associates Limited
IG	Inspector General
INPO	Institute of Nuclear Power Operations
LOCA	Loss of Coolant Accident
NCV	Non Cited Violation
NOV	Notice of Violation
NEI	Nuclear Energy Institute
NEIL	Nuclear Electric Insurance Limited
NRC	Nuclear Regulatory Commission
NRR	NRC's Office of Nuclear Reactor Regulation
PCAQR	Potential Condition Adverse to Quality Report
PCS	Primary Coolant System
PWR	Pressurized Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
RCS	Reactor Coolant System
RFO	Refueling Outage (as in RFO12 or refueling outage 12)
ROP	Reactor Oversight Process (of the NRC)
RPV	Reactor Pressure Vessel
SALP	Systematic Assessment of Licensee Performance
UFSAR	Updated Final Safety Analysis Report
VHP	Vessel Head Penetration

Attachment RJM-2 Resume of Roger J. Mattson

Summary
Forty-two years in nuclear safety and related fields
Thirty-nine years in nuclear facility licensing
Expert in nuclear safety, licensing and risk management

Education
Ph.D., Mechanical Engineering, University of Michigan, 1972
M.S., Mechanical Engineering, University of New Mexico, 1966
B.S., Mechanical Engineering, University of Nebraska, 1964, cum laude

Qualifications

Reactor Licensing – Dr. Mattson participated in the licensing programs of the U.S. government for 17 years, the last 7 directing the technical review of applications to construct and operate nuclear power plants and to amend their operating licenses. The scope of his responsibilities included reactor systems, nuclear fuel and core design, balance of plant, associated structures, and electrical, mechanical, and fluid systems; radiation protection and emergency preparedness; and geology, seismology, and meteorology. He introduced probabilistic risk assessment and TMI requirements into the licensing process. He has participated in technical safety reviews of every U.S. nuclear power plant. Since leaving government service, he has helped NRC licensees implement regulatory requirements and assisted NRC with new rules for advanced reactors and life extension/license renewal. He assisted DOE in designing a system of safety criteria for tritium production reactors that met or exceeded requirements of NRC. In 2006 he assisted DOE in an independent review of two advanced, commercial nuclear power plant designs that are to be submitted to the NRC for combined construction permits and operating licenses. In 2005 and 2006, he assisted Idaho National Laboratory in upgrading the Advanced Test Reactor in comparison to commercial reactor safety standards, in a review of safety and licensing aspects of the Next Generation Nuclear Plant that utilizes high temperature gas technology, and in a review of the development plan for the Global Nuclear Energy Partnership.

Non Reactor Nuclear Facility Licensing – In addition to reactor licensing experience Dr. Mattson has experience with licensing projects for non reactor facilities, including the setting of NRC licensing standards for safety, radiation protection, and environmental protection of fuel cycle facilities, including waste management facilities; representation of NRC in EPA's rulemaking for uranium fuel cycle standards; assistance to nuclear power plants in utilization of dry cask storage for spent nuclear fuel destined for shipment to DOE's Yucca Mountain facility; independent analysis of the licensing history of decommissioned uranium and mixed oxide fuel fabrication plants; and independent review of the test phase plan for the Waste Isolation Pilot Plant at Carlsbad.

Nuclear Safety – Dr. Mattson conducted safety reviews for AEC and NRC for 17 years covering more than 110 nuclear power plants and other radiological facilities. His nuclear safety review experience includes all types of safety systems. He assisted the International Atomic Energy Agency by co-chairing the development of safety principles for nuclear power plants after the accident at Chernobyl (INSAG-3, updated to INSAG-12) that were promulgated to all member nations for implementation. He developed NRC's new requirements after the accident at Three Mile Island in 1979. He has served as a consultant to DOE and its operating contractors in overseeing safety of nuclear facilities, including Rocky Flats, Savannah River Plant, Los Alamos National Laboratory, Pantex Plant, Mound Laboratory, Idaho National Laboratory and Livermore

National Laboratory. He has served on nuclear safety review boards for five operating nuclear power plants, the N Reactor at Hanford, the Rocky Flats Environmental Technology Site and the DynEx Program at Los Alamos. He oversaw two environmental radiochemistry labs involved in radioactive waste management. He assisted in streamlining the safety authorization basis for decommissioning of Rocky Flats.

Safety Analysis – Dr. Mattson developed and applied safety analysis techniques for nuclear facilities, including plant dynamic analysis, systems interaction studies, probabilistic safety (risk) assessment, reliability analysis, hazards analysis, technical safety appraisals, operational readiness reviews, independent design reviews, fire protection reviews, and management reviews. He pioneered use of independent analyses by nuclear safety oversight groups in the United States and abroad. He assisted in NRC analysis of the TMI accident in 1979 and the Chernobyl accident in 1986, including plant failure modes and effects analysis. He has reviewed Hazards Analysis Reports and Safety Analysis Reports and developed Safety Evaluation Reports for a range of private and government facilities.

System Safety Appraisals – Dr. Mattson participated in safety analysis and field reviews of nearly 150 nuclear facilities in the United States, Europe, the former Soviet Union, China, Taiwan and Korea. Such reviews included licensing reviews, hazard assessments, inspections of construction progress, incident response, preparation for litigation, independent design reviews, safety system functional inspections, safety and security vulnerability assessments, and operational readiness assessments.

Regulatory Policy – Dr. Mattson developed and applied regulatory policies of AEC, NRC, EPA, and DOE. He has conducted policy studies in nuclear safety, radiation protection, environmental monitoring, worker protection, standardized design, independent commissions, and security of nuclear facilities and materials. He assisted DOE and its operating contractors with order compliance for advanced and operating reactors, plutonium manufacturing plants, and nuclear weapons facilities. He participated in the Nuclear Utility Safety Standards program of the International Atomic Energy Agency and assisted development of regulatory policy for nuclear facilities in China, Taiwan, Japan, Korea, Spain, Russia, Ukraine, Kazakhstan, and Egypt.

Operational Readiness Reviews - In 1980 Dr. Mattson organized the transfer of operational readiness review (ORR) practices from NASA and DOD to the NRC for general application in the nuclear industry. He has reviewed the results of ORRs on a number of commercial and government facilities and has led ORRs at Limerick 2 nuclear power plant, the plutonium chemistry facility at Rocky Flats Plant, and K-Reactor at Savannah River Plant. He was the senior advisor to DOE managers in their first application of ORR techniques in 1990, developing the first Criteria and Review Approach Document and assisted later in the drafting of predecessor requirements to DOE Order 425.1A. He assisted a review of Kaiser-Hill's ORR program at Rocky Flats.

Decommissioning – Dr. Mattson oversaw the decommissioning of two licensed radiochemistry laboratories in the private sector. He advised the Department of Energy on approaches for decommissioning of plutonium contaminated ductwork at Rocky Flats Production Plant and Hanford Plutonium Finishing Plant. He assisted in streamlining the safety authorization basis for facilities undergoing decommissioning at Rocky Flats Environmental Technology Site and served as Vice Chairman of the Nuclear Safety Review Board for the Rocky Flats decommissioning project. He has reviewed decommissioning activities for NUMEC/B&W uranium and mixed oxide fuel fabrication facilities in preparation for litigation. He led an independent oversight team in selection of the decommissioning approach for Maine Yankee nuclear power plant and assisted the President of Maine Yankee and Connecticut Yankee in management of decommissioning activities. He participated in a study of alternative decommissioning approaches for Millstone 1 nuclear power plant.

Emergency Preparedness – Dr. Mattson assisted in response to the accident at Three Mile Island and several other nuclear incidents. He directed the NRC's radiation protective measures team in the headquarters emergency response organization. He coordinated EPA's national radiation emergency response network. He has participated in emergency response exercises for commercial and government-owned radiological facilities in a number of states. He developed federal regulations for radiological emergency preparedness and directed their implementation. He helped to establish the earliest interagency coordination program for response to clandestine fission explosives.

Criticality Safety – Dr. Mattson participated as senior safety expert in criticality safety assessments of DOE's plutonium facilities at Hanford, Rocky Flats and Los Alamos. He assisted in a root cause review of an intentional violation of criticality limits at Rocky Flats. He conducted independent reviews of the criticality safety program at Rocky Flats and has reviewed the criticality safety programs at other nuclear materials processing facilities.

Radiation Protection – Dr. Mattson has managed radiation protection activities as an employee of the AEC, NRC and EPA and has assisted DOE, NRC, and private companies in implementing radiation protection measures for workers and the public. He chaired the radiation protection committee of a radiochemistry laboratory, led the development of Federal radiation guidelines for all licensed radiological facilities in the U.S., including those related to 10 CFR Parts 20, 50, and 70, and 40 CFR Part 190. He managed the review of radiation protection measures for U.S. nuclear power plants. He reviewed radiation protection programs for DOE and commercial nuclear facilities.

Environmental Protection – Dr. Mattson wrote environmental impact statements and developed federal guidelines to implement Clean Air, Clean Water, Safe Drinking Water, and National Environmental Policy Acts. He has managed consulting and laboratory services in environmental risk management. He developed and implemented environmental standards for ionizing and nonionizing radiation. He led historical reconstructions of radioactive source terms for several nuclear facilities following guidelines of the National Academy of Sciences.

Quality Assurance – Dr. Mattson implemented federal regulations governing nuclear quality assurance by reviewing license applications for nuclear power plants and assisting oversight of QA programs at nuclear plants under construction and in operation. He assisted Dupont Corporation in the application of nuclear QA techniques to the Savannah River Plant. He assisted DOE and its prime contractors in implementing nuclear QA programs for nuclear facilities. He has performed independent analysis of the effects of QA requirements on safety and cost of nuclear facilities.

Expert Testimony – Dr. Mattson has testified on the effects of regulation on safety and costs of nuclear facilities before the United States Congress, several Presidential Commissions, the Nuclear Regulatory Commission, the Defense Nuclear Facilities Safety Board, the Advisory Committee on Nuclear Facility Safety, the Advisory Committee on Reactor Safeguards, Federal and State Courts, panels of the American Arbitration Association, and State Public Utility Commissions.

Security – Dr. Mattson developed NRC's security standards for the commercial nuclear industry in the mid 1970s and managed security-consulting services in the 1980s. He has written threat definitions and participated in security response for nuclear facilities and materials. From 1987 to 2002 he oversaw security equipment research by SCIENTECH for a range of U.S. government clients.

Site-Related Disciplines – Dr. Mattson led the siting standards development effort for NRC and assisted the International Atomic Energy Agency in its development of siting standards for nuclear power plants. The standards addressed site safety, geology, meteorology, hydrology, demographics and environmental protection.

Employment

Independent Consultant, 2002 to present time, Risk Management, Licensing, Safety, Quality, Security, and Management Assessments

SCIENTECH, Inc., Senior Vice President, 1987-2002, Safety Analysis and Appraisals, Operational Readiness Reviews, Nuclear Safety and Licensing, Strategic Planning, Decommissioning, Security

International Energy Associates Limited, Engineer then President, 1984 -1987, Nuclear Safety and Licensing, Management, Litigation Support, Security

U.S. Nuclear Regulatory Commission, Director of Systems Integration, Nuclear Reactor Regulation, 1981-1984, Nuclear Safety and Licensing, Regulatory Policy, Emergency Preparedness, QA, Radiological Protection

U.S. Environmental Protection Agency, Director, Radiation Surveillance, Radiation Programs Office, 1980-1981, Radiological Protection, Emergency Preparedness, Management

U.S. Nuclear Regulatory Commission, Director of Systems Safety, Nuclear Reactor Regulation, 1977-1980, Nuclear Safety Regulation, TMI Response

U.S. Nuclear Regulatory Commission, Director of Site, Health, Safeguards Standards, 1975-1977, Environmental and Radiological Protection, Emergency Preparedness, Site Related Disciplines, Security

U.S. Atomic Energy Commission, Engineer then Supervisor, 1967-1975, Safety Analysis, Nuclear Design, Assistant to Commissioner, Security of Nuclear Materials and Facilities

Sandia Corporation, Engineer, 1964 -1967, Hardware Design, Safety Analysis, Thermal-Hydraulic Analysis

Honors

NRC Distinguished Service Award, 1980, for work on TMI accident
NRC Meritorious Service Award, 1976, for leadership in standards development
NRC and AEC letters of commendation for performance on various task forces
National Science Foundation Research Assistantship, 1971
Sigma Xi (Science Honorary Society)
Pi Tau Sigma (Mechanical Engineering Honorary Society)
Pi Mu Epsilon (Mathematics Honorary Society)
Sigma Tau (Engineering Honorary Society)

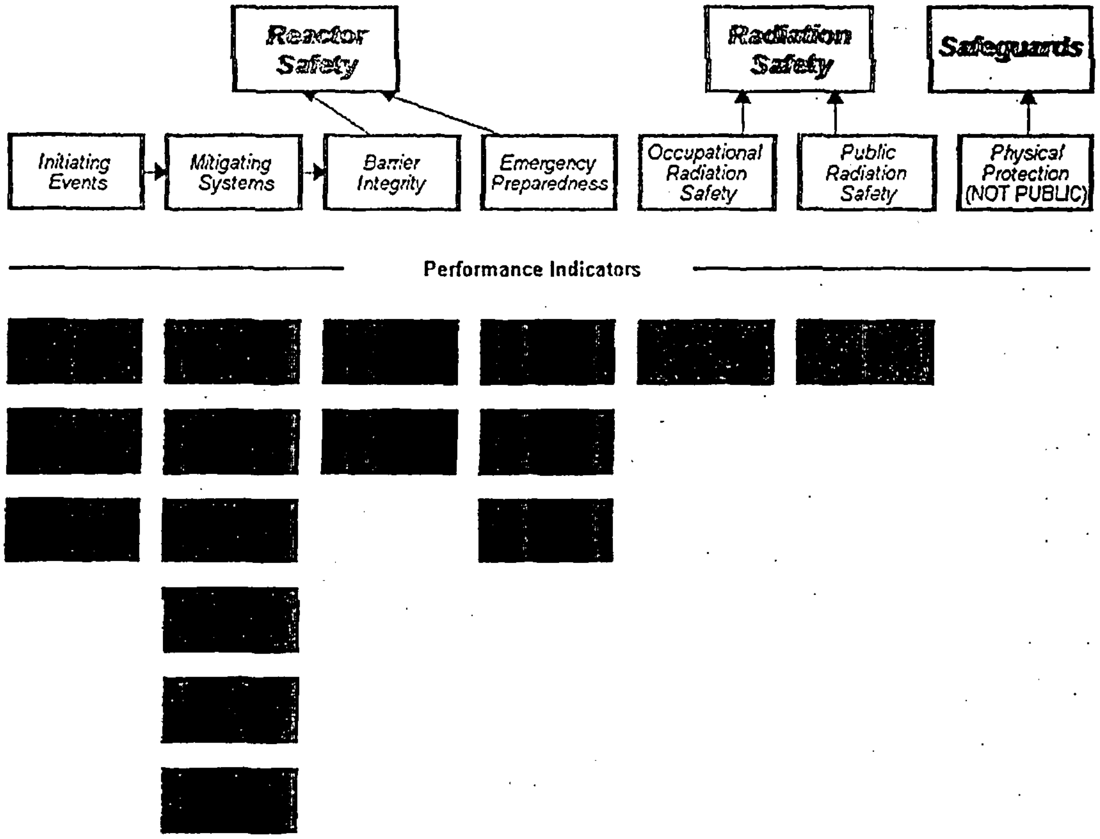
Attachment RJM-3 Performance Indicator Data

The NRC established a Performance Indicators Program in 1986 to provide data for early indication of declining trends in plant performance. Based on experience with its use, the first performance indicator program was discontinued in 1999 and replaced in 2000 by a new Reactor Oversight Process that included another set of performance indicators. NRC has used performance indicators from 1986 to today to help identify issues or circumstances that the NRC should examine further, i.e., where to apply its inspection resources.

The first NRC Performance Indicator Program monitored plant performance in the following areas: automatic scrams while critical, safety system actuations, significant events, safety system failures, forced outage rate, and equipment forced outages per 1,000 critical hours, collective radiation exposure and the causes of Licensee Event Reports (LERs). The new performance indicators are arrayed in seven cornerstones of safety namely, Initiating Events, Mitigating Systems, Barrier Integrity, Emergency Preparedness, Occupational Radiation Safety, Public Radiation Safety, and Physical Protection.

Under the Reactor Oversight Process, color-coded summaries of performance indicators and inspection findings are provided quarterly for each plant in what NRC calls action matrices. The action matrix for a particular plant determines NRC's regulatory response to current circumstances. If the findings in a matrix are all green or if there are no findings, then the NRC applies its baseline inspection program. If the findings in the matrix are not all green but include some white, yellow or red cornerstones, then the NRC applies additional inspection resources. The NRC's Performance Indicator Action Matrix for Davis-Besse for the last quarter of 2001 was all green, just as it was for the second quarter of 2006, shown below.

Performance indicators can be compared among plants of similar vintage and design that the NRC has grouped into "peer groups." The performance indicators for particular plants can also be compared to their generic design type (pressurized water reactors or PWRs in the case of Davis-Besse) and to the entire industry. Such comparisons aid the assessment of Davis-Besse's performance against industry performance norms. Davis-Besse's peer group is comprised of Oconee Units 1-3, Three Mile Island Unit 1, Arkansas Nuclear One Unit 1, and Crystal River Unit 1.



Last Modified: August 2, 2006

NRC's Performance Indicator Action Matrix for Davis-Besse, 2nd Quarter 2006

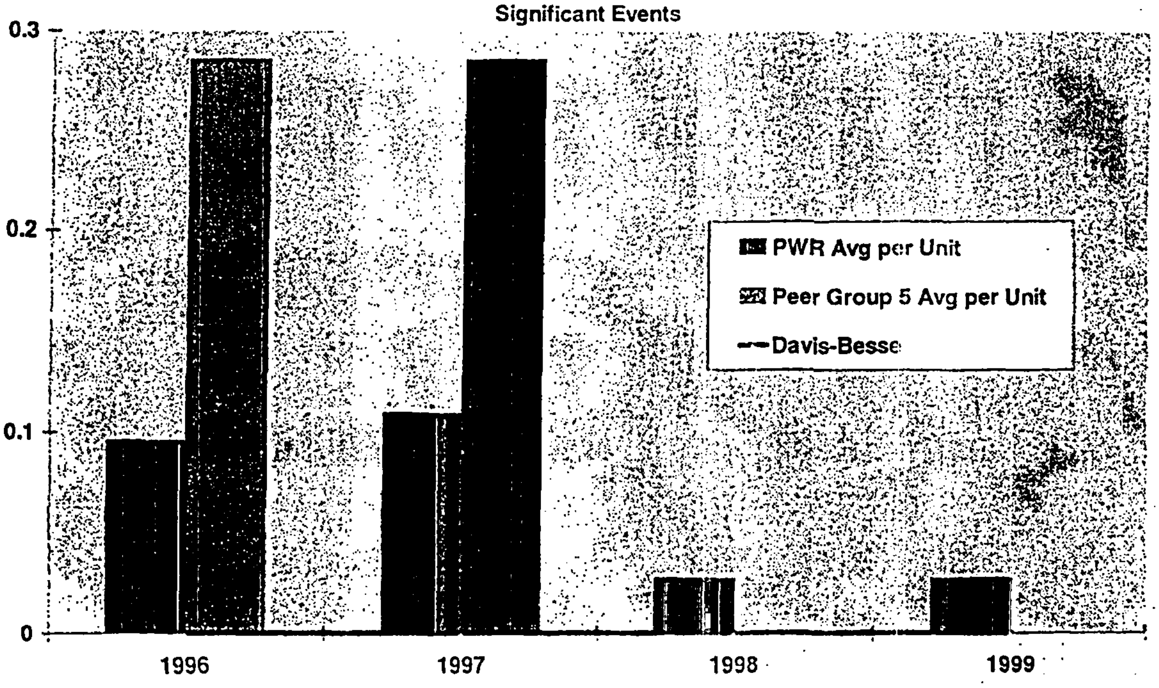
The charts provided below graphically depict Davis-Besse's performance for each of the performance indicators chosen for this analysis, i.e., those that bear on the reliability and safety of operations. Indicators relating to emergency preparedness and security were not included because they have no bearing on the issues in this case. The time period from 1996 to 2001 was chosen as sufficiently long as to avoid misimpressions that can be created by looking at narrow time periods of unusually high or low performance.

A definition and a chart is provided for each of the indicators. Each chart shows by year the performance of Davis-Besse and the performance of other plants appropriate for comparisons for that indicator. It is important to remember as one looks at these charts that at any given point in time, say 1998, the NRC and the managers of Davis-Besse would have only been able to utilize this information in hindsight.

In sum, 19 indicators were used, some treating similar variables over the two periods, 1995 to 1999 and 2000 to 2001. The performance of Davis-Besse met or exceeded the average performance of the comparison groups for 14 of these 19 indicators. The performance in each of these 19 areas is described in the following numbered paragraphs. A twentieth area, the hours of NRC oversight received each year, is also included.

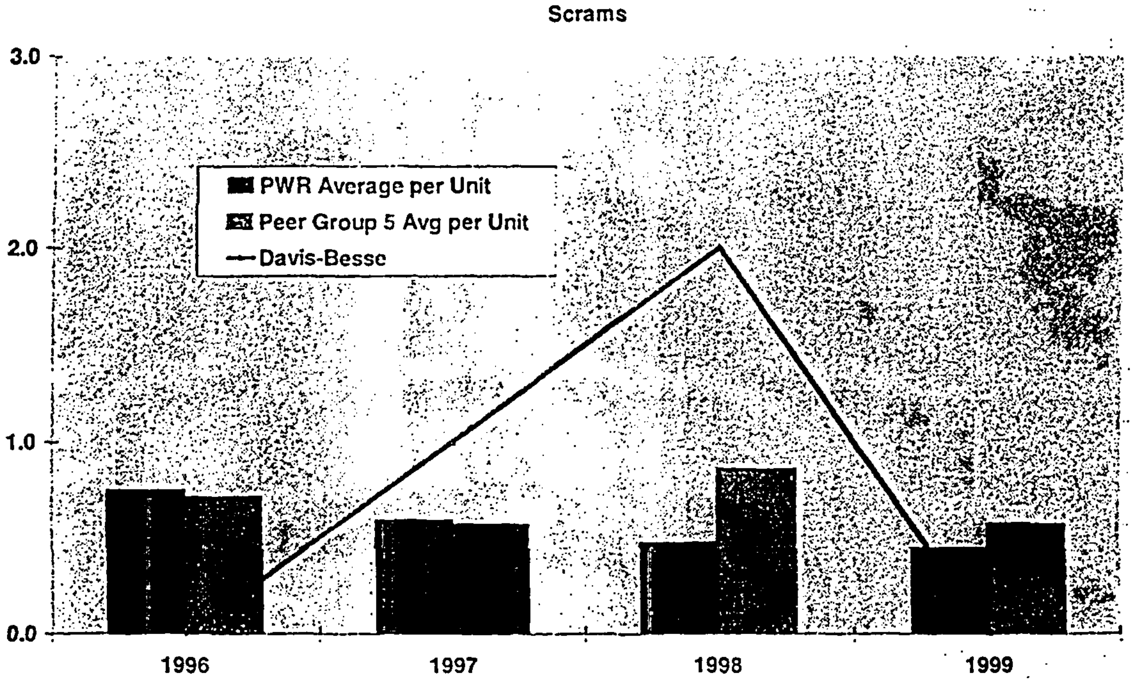
1. Significant Events

This indicator is the total number of events during the year that directly challenged the safety of the unit, such as degradation of important safety equipment, unexpected plant response to a transient, degradation of fuel integrity or the primary pressure boundary, or reactor scram with complications. On average, between 1996 and 1999, U.S. nuclear units experienced one significant event approximately every 10 to 20 years. Davis-Besse experienced none of these events in that time period, performing better in this category than their peer group and the other PWRs, as illustrated by the following chart. NRC eliminated this indicator when the new ROP came into being in 2000.



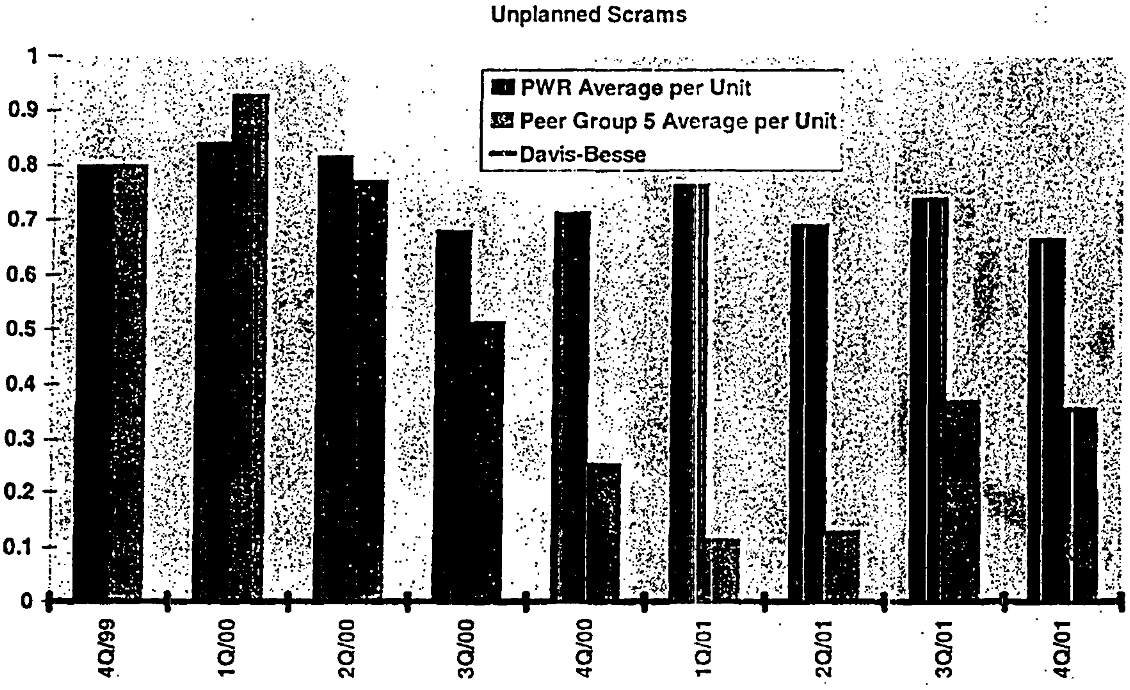
2. Automatic Scrams While Critical

This indicator is the total number of unplanned automatic reactor scrams that occur while the reactor is critical and that automatically and promptly shut the reactor down. Such scrams require the reactor operators and the plant equipment to perform in a stressful and off normal manner, thus providing a challenge to plant safety. The reactor is said to be critical when it is being started up and when it is in power operation. This indicator is one way to track how often plant safety is challenged by unanticipated events. Davis-Besse had fewer scrams than both its peer group and the other PWRs for two years and more than the others in two of the four years from 1996 to 1999, a slightly worse than average performance, as shown in the following graph. This indicator was dropped in 2000 with the advent of the new ROP and replaced by another indicator called Unplanned Scrams.



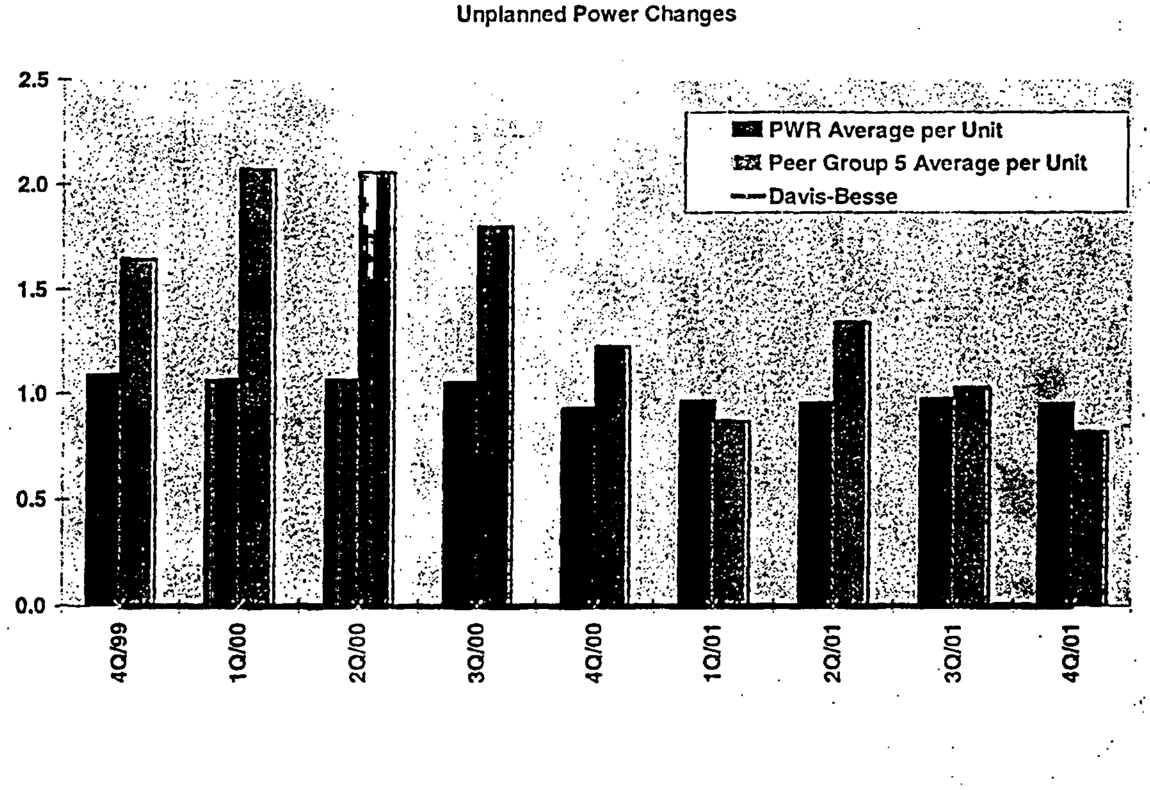
3. Unplanned Scrams

This indicator was adopted by NRC in 2000 and is an input to the Initiating Events Cornerstone of the Reactor Oversight Process. It is similar to the automatic scrams while critical indicator described above, but includes unplanned manual scrams. The indicator is equal to the number of unplanned scrams while the reactor was critical in the previous 4 quarters, times 7000 hours, divided by the number of hours critical in the previous 4 quarters. As shown in the following chart Davis-Besse had no unplanned scrams over the period 2000 to 2001.



4. Unplanned Power Changes per 7,000 Critical Hours

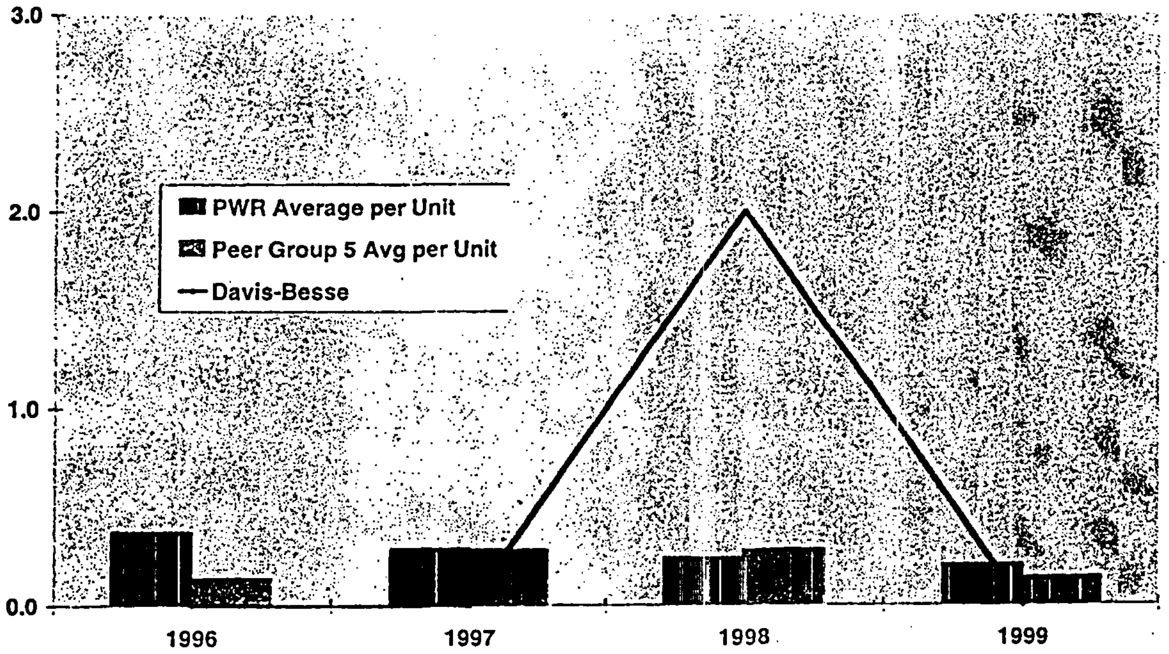
This indicator was created at the time the ROP was initiated. It monitors the number of unplanned power changes (excluding scrams) that could have, under other plant conditions, challenged safety functions. It is equal to the number of unplanned power changes in reactor power greater than 20% of full power over the previous 4 quarters, times 7,000 hours, and divided by the total number of hours critical in the previous 4 quarters. As shown in the following graph, Davis-Besse had no unplanned power changes in 2000 and 2001.



5. Safety System Actuations

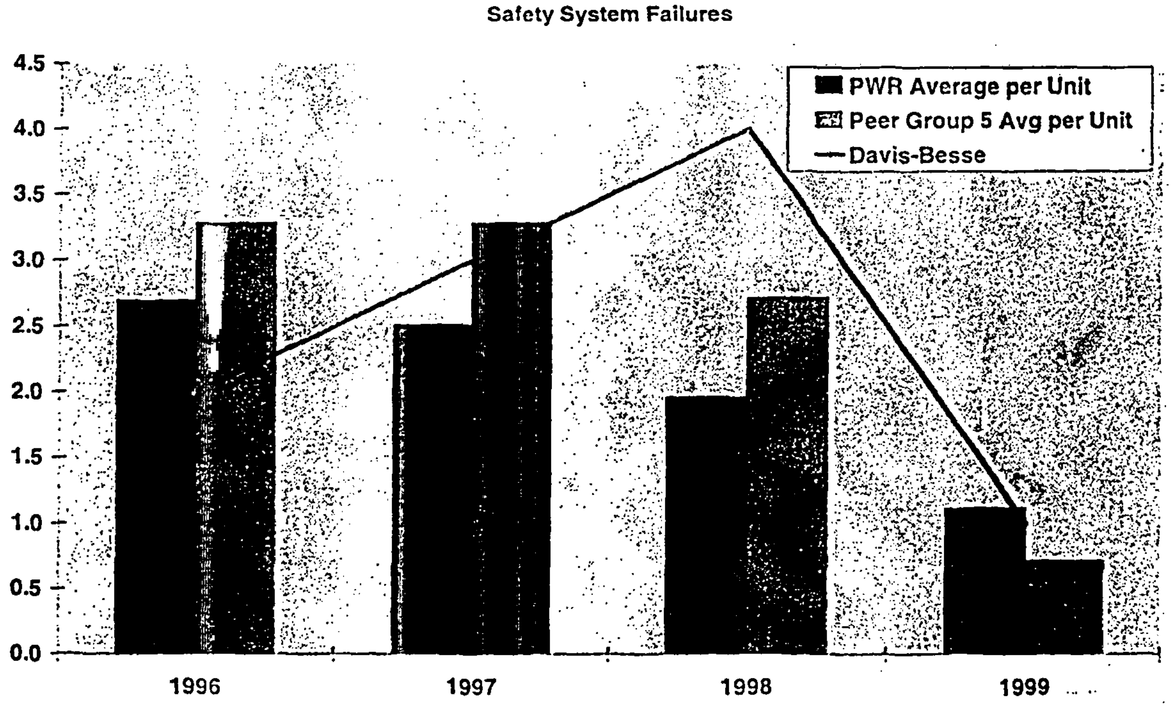
This indicator combines manual and automatic actuations of the logic or equipment of either certain Emergency Core Cooling Systems or the Emergency AC Power System. It includes both faulty and authentic actuations. It is a measure of how frequently safety systems are being challenged – the more frequent the challenge, the greater the likelihood of eventual failure. Davis-Besse had fewer safety system actuations (better performance) than its peer group and other PWRs for three of the four years from 1996 to 1999 but its average number of such events was slightly higher than both of these groups for that period, as shown in the following graph. The NRC eliminated this indicator when the new ROP was initiated in 2000.

Safety System Actuations



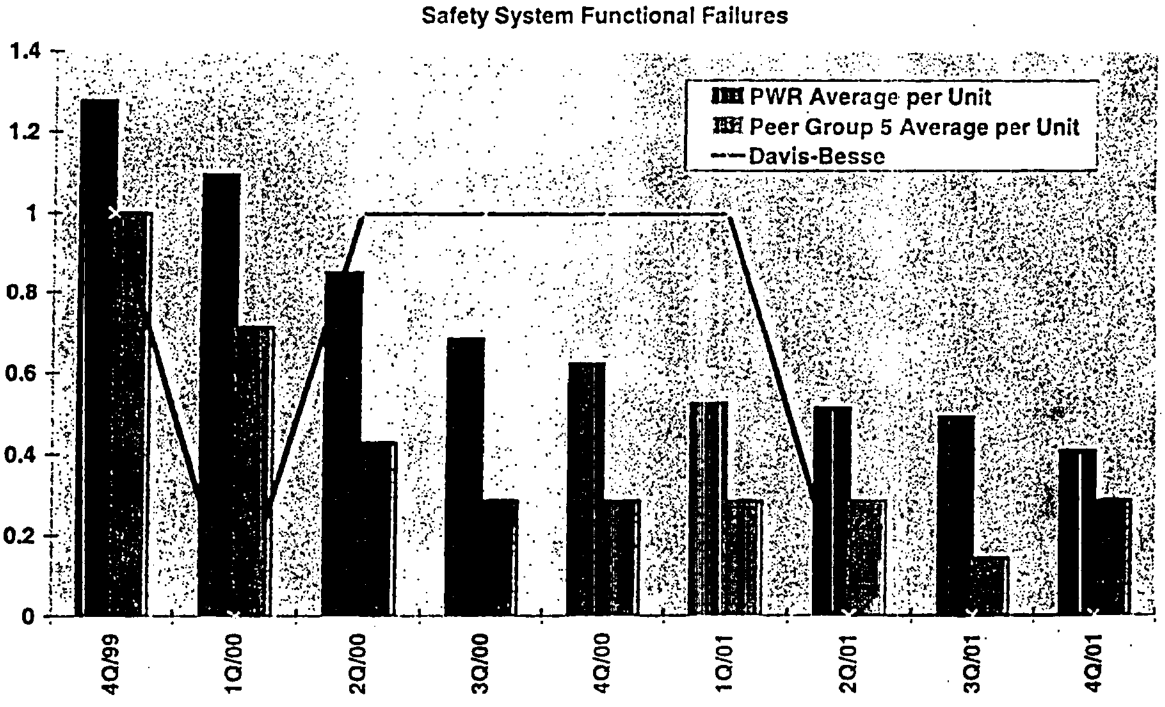
6. Safety System Failures

These are events or conditions that could prevent the fulfillment of the safety function of structures, systems or components related to safety. This indicator includes failures on demand and failures during testing. It is a measure of how well the safety equipment in a plant is designed and maintained. As shown in the following graph, Davis-Besse averaged 2.5 safety system failures over the four year period from 1996 to 1999 which was slightly worse than the average for PWRs over this period (2.1) and the average for the peer group (2.48). In 2000, with the advent of the ROP, an indicator called Safety System Functional Failures replaced this indicator, as discussed next.



7. Safety System Functional Failures

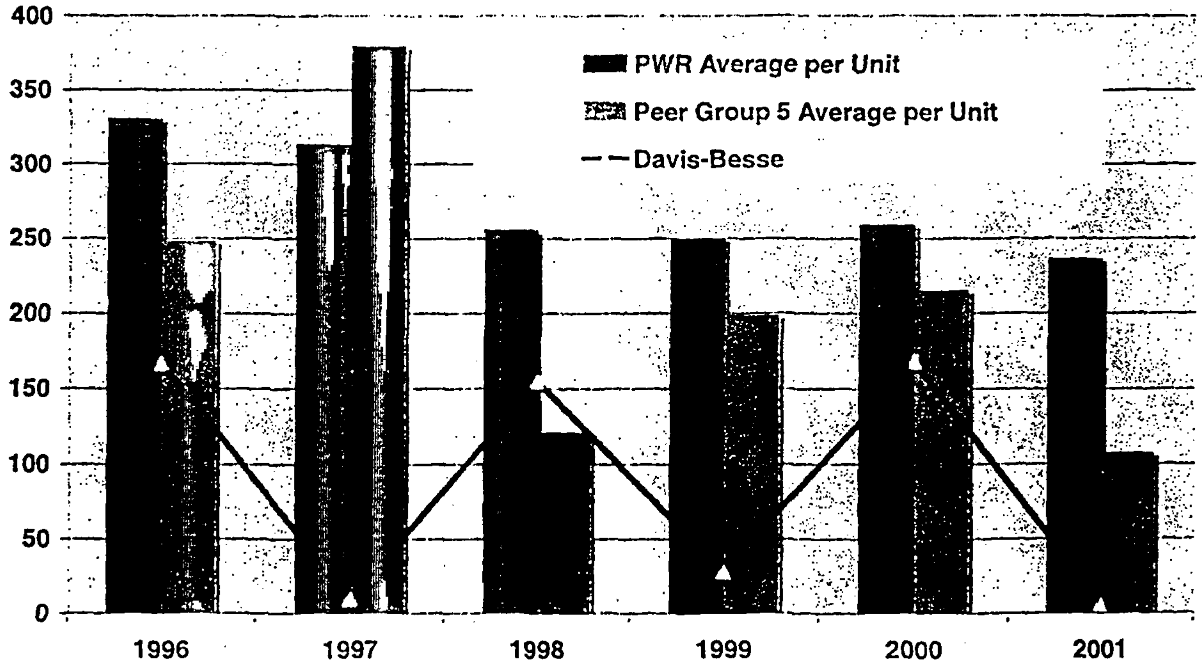
This indicator is an input to the Mitigating Systems Cornerstone in the NRC's Reactor Oversight Process. It is equal to the number of events or conditions in the previous 4 quarters that prevented or could have prevented the fulfillment of the safety functions of reactor shutdown, removal of residual heat, control of radioactivity releases, and mitigation of accident consequences. Davis-Besse met or outperformed the record of other PWRs and its peer group 5 of the 9 quarters that this indicator was used between its inception and the end of 2001, as shown in the following graph. The graph also illustrates the fact that once a unit has one failure of this type, the indicator stays high for four quarters. The average performance of Davis-Besse over the 9 quarters of data was 0.4, a value that exceeded the average for PWRs and equaled that of the peer group over the same 9-quarter period.



8. Collective Radiation Exposure

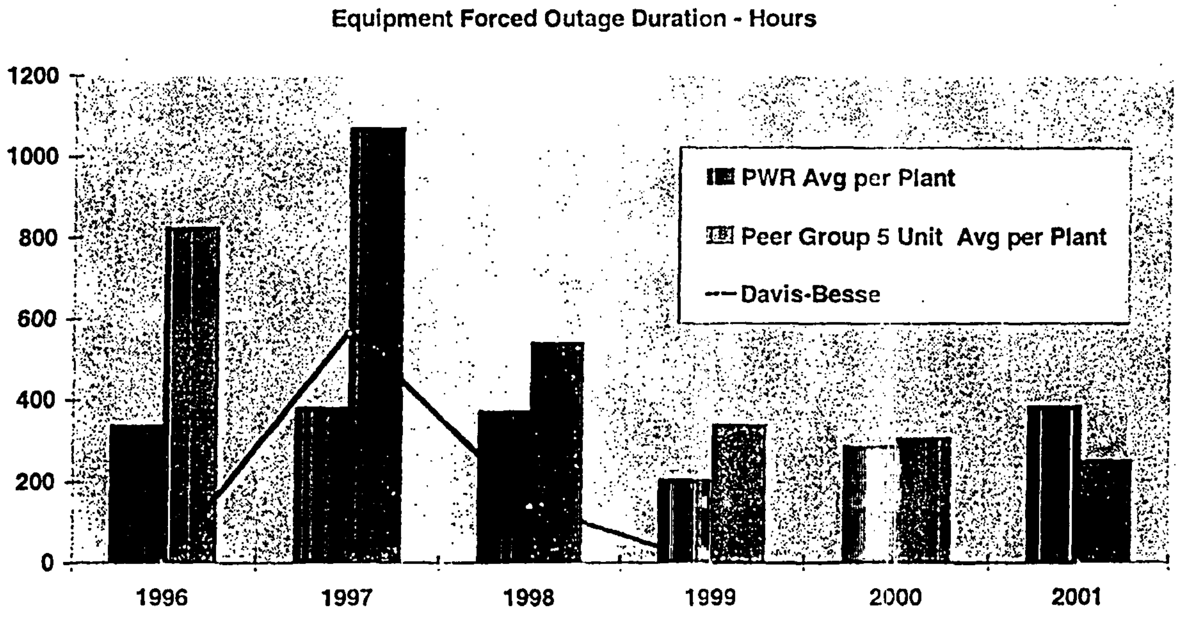
This indicator is the total radiation dose accumulated by plant personnel in a year. It indicates the effectiveness in planning and performing work in a manner that minimizes exposure of workers to radiation. It also is an indicator of how well the physical condition of a unit is maintained as it ages. For the period 1996 to 2001, the average collective exposure for Davis-Besse was much better (less) than the per-unit averages for other PWRs and the peer group, as shown in the following graph. The up and down nature of the Davis-Besse plot owes to the bi-annual refueling outages. Exposures are always higher during refueling years at all plants, but the ups and downs get averaged out over the population of plants in the PWR and peer groupings.

Collective Radiation Exposure, mrem



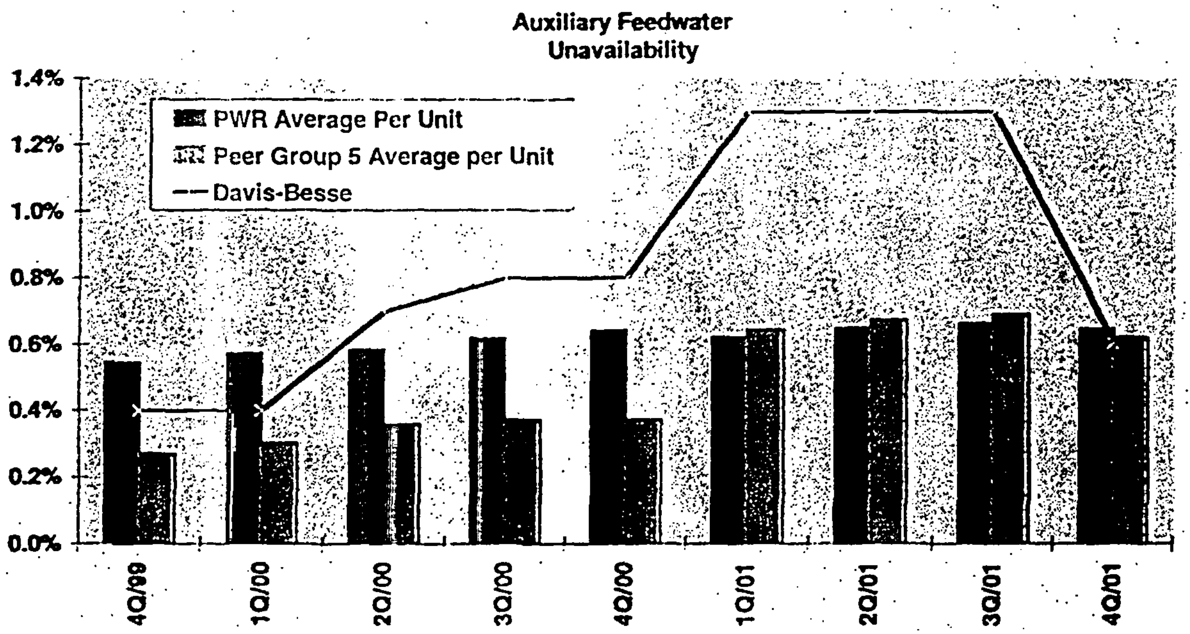
9. Equipment Forced Outage Duration

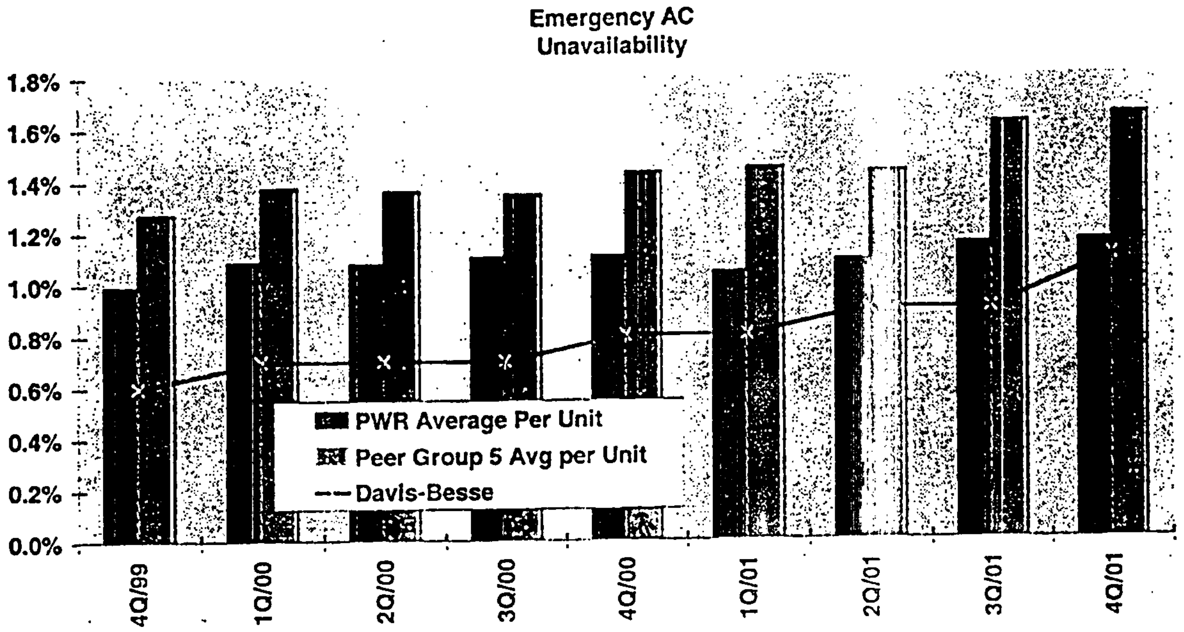
Equipment Forced Outage Duration is the number of hours of forced outage of safety equipment per year. For the period 1996-2001, Davis-Besse had average equipment forced outage durations that were much better than its peers and the other PWRs, as shown in the following graph. This performance indicator was eliminated in 2000 with the advent of the ROP.



10. Safety System Unavailability

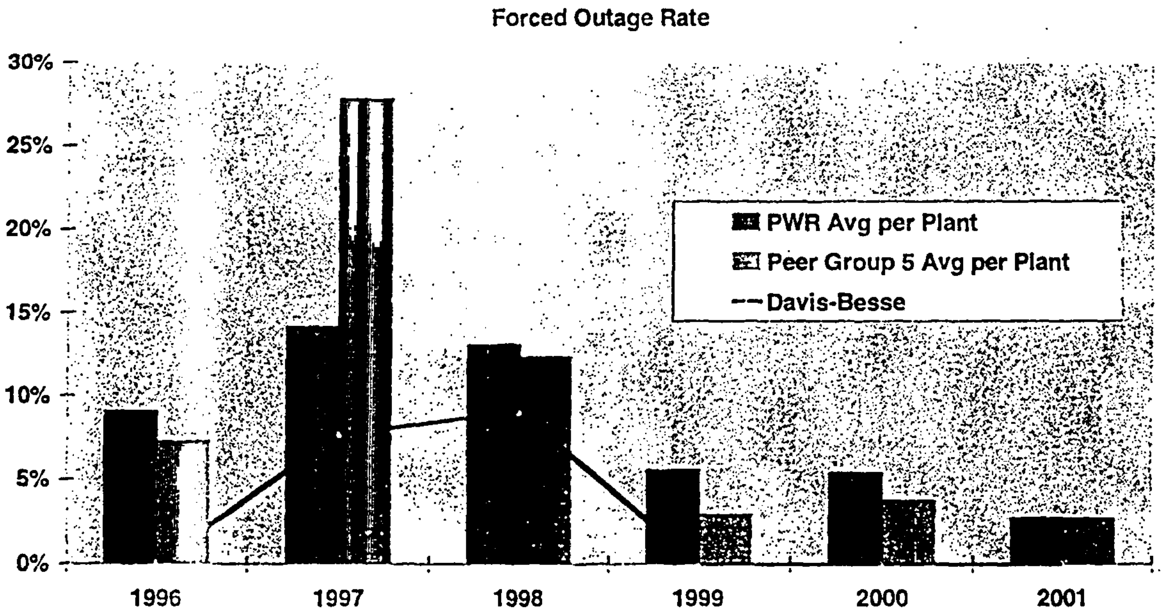
In 2000 with the advent of the ROP the Equipment Forced Outage indicators of the NRC were replaced by indicators of the unavailability of four key safety systems, namely, auxiliary feedwater, residual heat removal, high pressure safety injection, and emergency AC power. These four indicators provide important input to the Mitigating Systems Cornerstone concerned with the ability to prevent or reduce the consequences of accidents. As shown in the four graphs that follow, Davis-Besse on the average performed about as well as its peers and other PWRs when considering all four safety systems. Auxiliary Feedwater was somewhat worse than average while Emergency AC power was somewhat better.




Emergency AC
Unavailability
1.8%
1.6%
1.4%
1.2%
1.0%
0.8%
0.6%
0.4%
0.2%
0.0%
PWR Average Per Unit
Peer Group 5 Avg per Unit
Davis-Besse
4Q/99
1Q/00
2Q/00
3Q/00
4Q/00
1Q/01
2Q/01
3Q/01
4Q/01

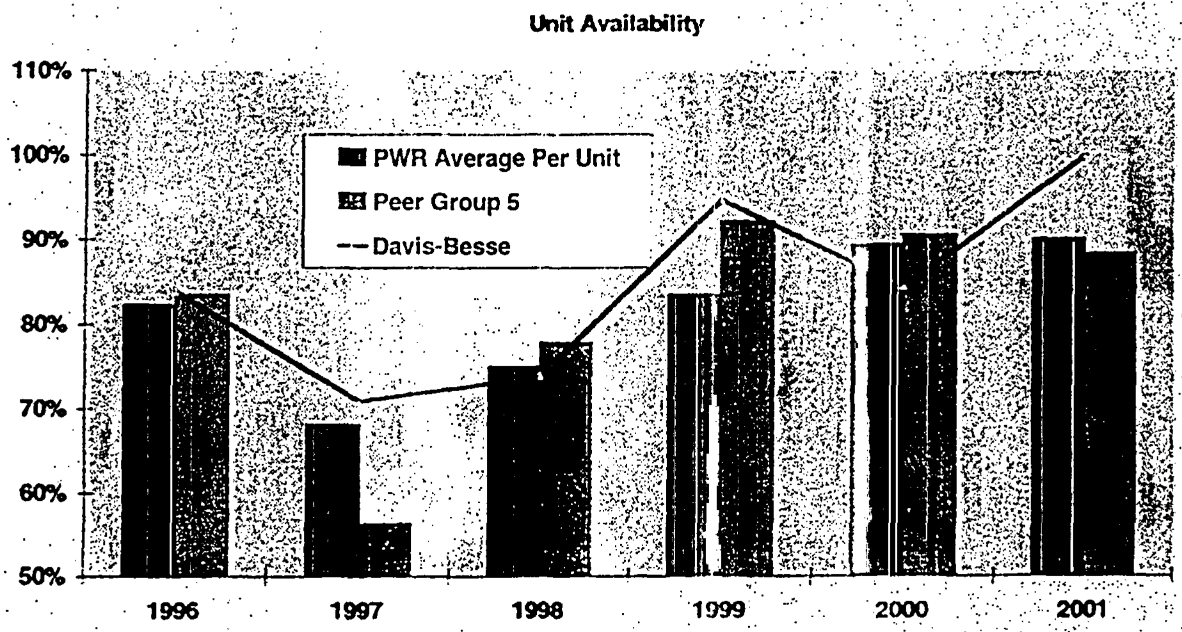
11. Forced Outage Rate

This indicator consists of the number of forced outage hours, multiplied by 100, divided by the sum of the unit service hours and forced outage hours. It is a measure of how long unanticipated conditions require a unit to be shut down relative to the total time it otherwise would have been available to produce power. For the period 1996 – 2001, Davis-Besse on the average achieved a forced outage rate that was much better than its peer group and other PWRs, as shown in the following graph.



12. Yearly Average Availability

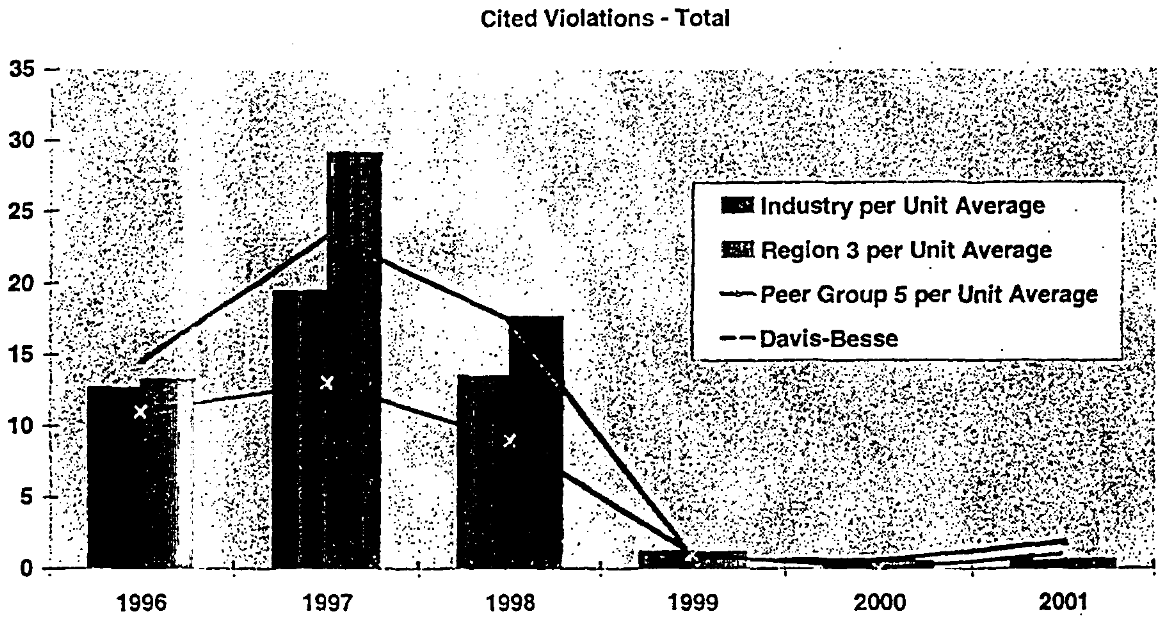
This indicator is a measure of the performance of the plant in producing power. It is computed by dividing the actual yearly power output in megawatt hours by the theoretical maximum output (100% power times the number of hours in a year). The low average availability in the industry in 1997 was caused by extended outages at a number of plants. The availability of Davis-Besse was generally better (higher) than its peer group and other PWRs over the period 1996 – 2001, as shown in the following graph.



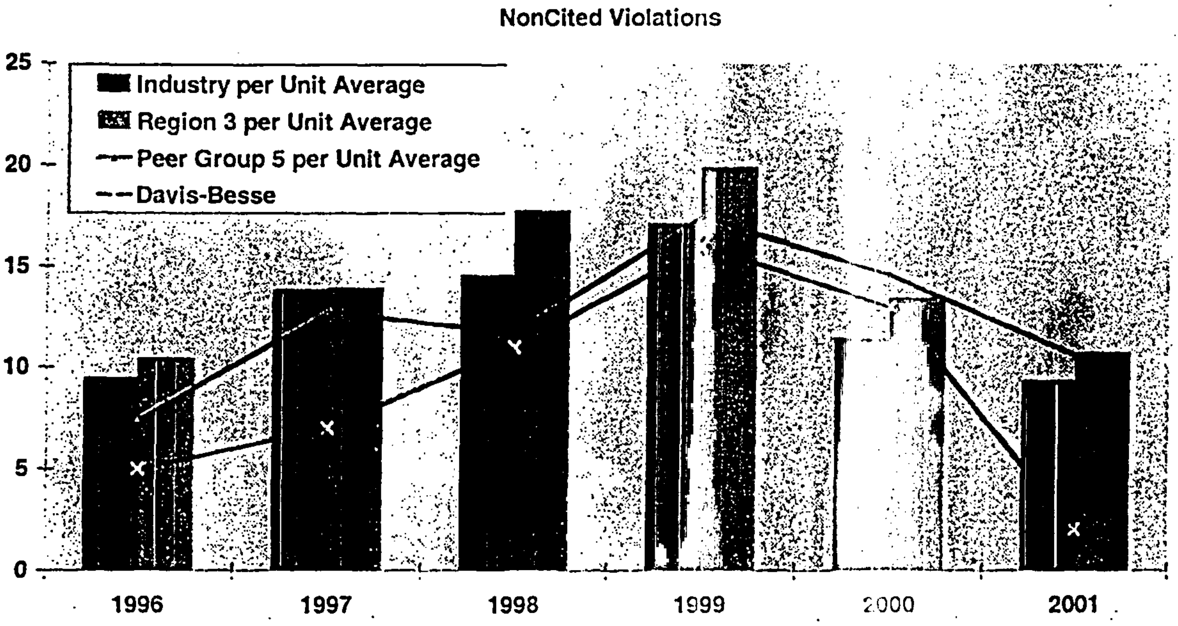
13. Violations of NRC Requirements

Comparisons of the numbers of violations cited against licensees over time provide a sense of how a particular licensee is fairing relative to others in the receipt of negative NRC feedback. As described above, NRC issues both cited and non-cited violations, and the relative number of the two changed with the advent of the ROP in 2000 (in fact, the number of cited violations took a precipitous drop in 1999 as the new ROP was being discussed internally to the NRC and prepared for implementation in 2000).

Davis-Besse had good performance in terms of the number of cited violations leading up to the RPV wastage event. During the period 1996 through 2001, Davis-Besse averaged fewer notices of violation than the industry average (BWRs and PWRs), fewer than the average for their NRC-defined peer group, and fewer than the other units in Region 3, as shown in the following graph.

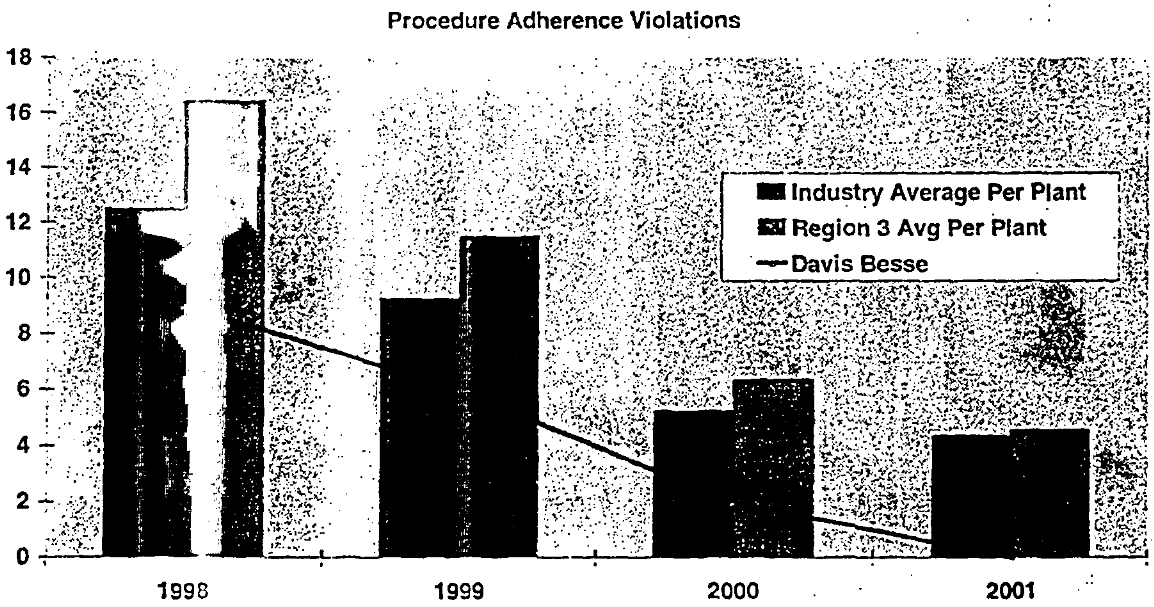


As shown in the following chart of non-cited violations, Davis-Besse also averaged better than its peers, other units in Region 3 and other units in the industry (BWRs and PWRs) for the period from 1996 to 2001.



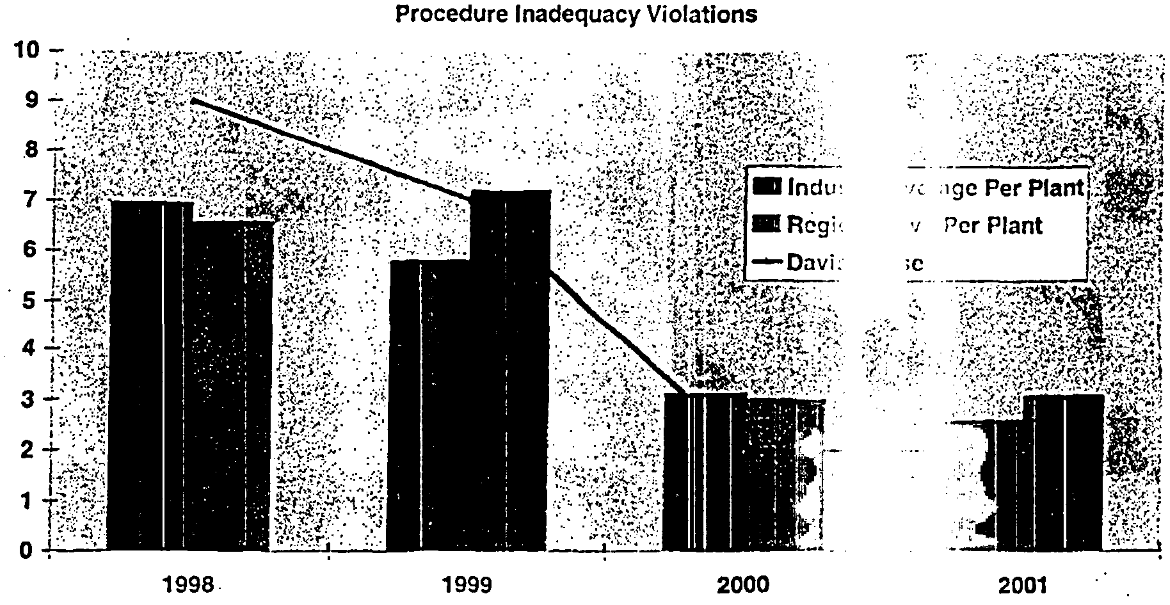
14. Procedure Adherence Violations

A measure of how well a plant adheres to its procedures is provided by the number of NRC violations it experiences for failure to adhere. NRC has only tracked this parameter since 1998. The following graph shows that Davis-Besse out performed the average of all the nuclear plants in the Unites States and those in NRC Region 3 throughout the period 1998 to 2001. I have made the comparison in this case to all plants (BWRs and BWRs) on a national and regional basis because NRC does not distinguish between design types in judging procedural adherence and because there is variation among NRC regions in the number and type of violations that are issued.



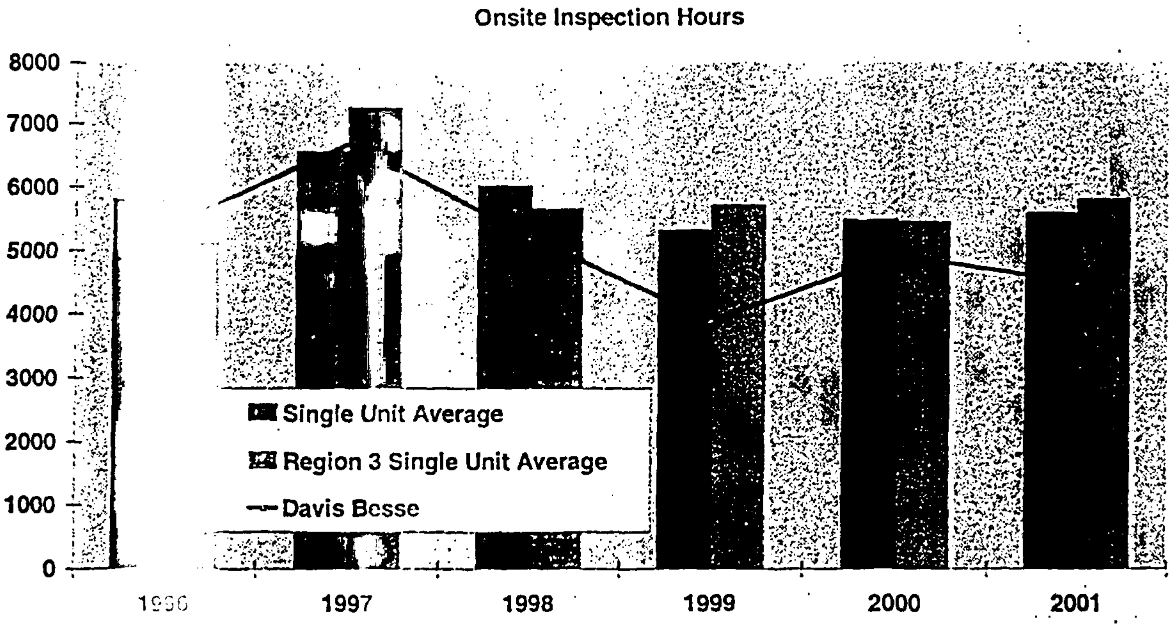
15. Procedure Inadequacy Violations

A measure of how well a plant prepares its procedures is provided b number of NRC violations it experiences for noncompliant procedures. NRC has only ked this parameter since 1998. The following graph shows that Davis-Besse p d about average or better than the average when compared to all the nuclear p the United States and those in NRC Region 3 for three of the four years during t riod 1998 to 2001. I have made the comparison in this case to all plants (BWRs an VRs) on a national and regional basis because NRC does not distinguish betwee sign types in judging procedure adequacy and because there is variation among NR ns in the number and type of violations that are issued.



16. Onsite Inspection Hours

This parameter reflects the level of NRC scrutiny applied to a particular site each year. It shows that NRC averaged about 6000 hours per year at single-unit sites for the period 1996 to 2001. During this period, Davis-Besse received average or less oversight than the other single-unit sites in the nation and those in NRC Region 3. Such oversight reflects NRC's judgment that the plant's performance is adequate and not trending downwards.



Attachment RJM-4 References

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[1] August 27, 2002, "Root Cause Analysis Report: Significant Degradation actor Pressure Vessel Head," CR 2002-0891, Revision 1, FirstEnergy, Davis-Be ar Power Station, p. 2..

[2] BAW-10190P, May, 1993, "Safety Evaluation for B&W Design Reactor ead Control Rod Drive Nozzle Cracking," p. 24.

[3] NRC Directive 8.13, "Reactor Oversight Process," Revised, June 1 . 20

[4] NRC Inspection Report 96003, "NRC Integrated Inspection Report. Noti Violation," July 30, 1996, cover letter.

[5] NRC Inspection Report, November 21, 1997, cover letter.

[6] NRC Inspection Report 98005 and Notice of Violation, June 11, 1998, c r.

[7] NRC Inspection Report 990008, July 20, 1999, cover letter.

[8] NRC Inspection Report 2000001, May 1, 2001, cover letter.

[9] NRC Inspection Report, June 16, 2000, cover letter.

[10] NRC Annual Assessment Letter, May 31, 2001, p. 1.

[11] NRC Enforcement Action EA-96-304, October 22, 1996

[12] <u>Containing the Atom: Nuclear Regulation in a Changing Environment 1</u> , J. Samuel Walker, NRC Historian, University of California Press, 199 . p. 1

[13] Davis-Besse Condition Report 2002-0891, Rev. 1, August 27, 2002, "R Analysis Report: Significant Degradation of the Reactor Pressure Vessel H 12-13.

[14] July 1997, BAW-2301, "B&WOG Integrated Response to Generic Letter 9 Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel C ead Penetrations," p. 2-3.

[15] NRC Information Notice 80-27: Fort Calhoun had seven reactor coolant uds reduced by boric acid corrosion from 3.5 inch diameter to between 1 and 1. diameter.

[16] NRC Information Notice 86-108: Arkansas Nuclear One Unit 1 had high p e injection nozzle leak and corrosion penetrated 67% of pressure boundary.

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[17] NRC Inf Notice 86-108, Supplement 1: "Degradation of Reactor coolant System Pr ndary Resulting from Boric Acid Corrosion" Turkey Point Unit 4 had corrosi us components on reactor vessel including three reactor vessel bolts, to de 5 inch.

[18] NRC Inf otice 86-108, Supplement 2: "Degradation of Reactor coolant System Pr dary Resulting from Boric Acid Corrosion" Salem Unit 2 had leaking co. e reactor vessel head to depth of 0.36 inch. San Onofre Unit 2 shutdown em isolation valve bolts corroded, failed, leaked 18,000 gallons of primary co containment.

[19] NRC Inf Notice 86-108, Supplement 3: "Degradation of Reactor coolant System Pres ndary Resulting from Boric Acid Corrosion"

[20] Generic 5, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary s in PWR Plants," March 17, 1988.

[21] May 27, do Edison response to NRC Generic Letter 88-05.

[22] June 26, do Edison amended response to NRC Generic Letter 88-05.

[23] February NRC approval of Toledo Edison's response to GL 88-05.

[24] Davis-B nistrative Procedure NG EN 00324/R1, "Boric Acid Corrosion Control," 1994, 18 pages.

[25] Davis-B nistrative Procedure NG-EN-00324 R02, "Boric Acid Corrosion Control," 1999, 24 pages.

[26] Davis-Be tial Condition Adverse to Quality Report (PCAQR) 96-551, "Boric Acid on RX essel Head," P. K. Goyal, April 21, 1996, p. 3.

[27] Davis-Be tial Condition Adverse to Quality Report (PCAQR) 96-551, "Boric Acid on RX ead," P. K. Goyal, April 21, 1996.

[28] Davis-B ion Report (CR) 1998-0026, regarding Independent Management Review of ociated with Valve RC-2, Dennis Schreiner, December 17, 1998.

[29] Davis-Be Pot tial Condition Adverse to Quality Report (PCAQR) 1998-0767, "Reactor Ve el he d Inspection Results," Peter J. Mainhardt, April 25, 1998.

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License Number NPF-3

Serial Number 3342

May 4, 2007

United States Nuclear Regulatory Commission
Document Control Desk
Washington, D.C 20555-0001

Subject: **Submittal of Expert Witness Report Prepared by F attson**

Ladies and Gentlemen:

Pursuant to a request by the Nuclear Regulatory Commission (Energy
Nuclear Operating Company (FENOC) is enclosing a copy of a ness
report, prepared by Roger J. Mattson, Ph.D., "Report on React
Vessel Wastage at the Davis-Besse Nuclear Power Plant," dat r .
2006.

The report was developed for FENOC by a former senior NRC dress
certain defenses raised by Nuclear Electrical Insurance Limited ng the
course of FENOC's claim for coverage associated with property nd
accidental outage coverage at the Davis-Besse Nuclear Power NPS).
Dr. Mattson's report is unrelated to the technical analysis of the th
rates and reactor pressure vessel head wastage performed by ailure
Analysis Associates and Altran Solutions Corporation (Expone tson's
report contains an overall assessment of the performance of D to the
discovery of the wastage, the implementation of the Boric Acid Control
Program at DBNPS, and the response to the discovery of the v

This report was provided to NEIL on December 18, 2006, on th as the
Exponent Report, and was obliquely referred to in a February 2 er
from NEIL. In this letter, NEIL implied that the Exponent Repor 57
pages. In fact, the Exponent report is 661 pages while Dr. Mat is 96
pages for a total of 757 pages. Since both of the reports were NEIL
on December 18, 2006, FENOC surmises that NEIL inadverte d that
Dr. Mattson's Report was part of the Exponent Report.

It shou [illegible] ue to a software compatibility issue, the photographs associat [illegible] 3 and 43 of the Mattson Report failed to print in the copies t [illegible] d to NEIL. Those photographs are properly reproduced in the En [illegible] herewith.

This rep [illegible] nitted at the request of the NRC for information only, and not as p [illegible] or licensing basis for DBNPS. While FENOC will continue [illegible] mation required by NRC regulations and as part of the station's [illegible] ions, FENOC does not plan to routinely docket corresp [illegible] to this insurance arbitration.

The atta [illegible] tter identifies that there are no commitments contained in this re [illegible] are any questions, or if additional information is required, [illegible] Mr. David Jenkins, Senior Attorney, at (330) 384-5037.

Sincerel

Danny L.
Senior V [illegible] nt, eet Engineering

Enclosu [illegible] Reactor Pressure Vessel Wastage at the Davis-Besse [illegible] wer Plant

Attachm [illegible] nt List

cc: N [illegible] ager – Davis-Besse Nuclear Power Station
N [illegible] spector – Davis-Besse Nuclear Power Station
N [illegible] ministrator – Region III
U [illegible] l Safety Board

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3342
1 of 1

Commitment List

The following list identifies those actions committed to by First ar
Operating Company (FENOC) for the Davis-Besse Nuclear Po Unit
No. 1. Any other actions discussed in the submittal represent
planned actions by FENOC. They are described only as infor not
regulatory commitments. Please notify contact Mr. David Jen
Attorney, at (330) 384-5037 of any questions regarding this do
associated regulatory commitments.

Commitment	D
None	[illegible]