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FOR: The Commissioners

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SUBJECT: STATUS REPORT ON ACCIDENT SEQUENCE PRECURSOR PROGRAM AND RELATED INITIATIVES

PURPOSE:

To inform the Commission of the status of the Accident Sequence Precursor (ASP) Program and related initiatives.

SUMMARY

In an April 24, 1992, memorandum to the Chairman, the staff committed to report periodically to the Commission on the status of efforts to improve the ASP Program. In SECY-94-268, dated October 31, 1994, two changes were made to the report. First, the staff committed to provide the report annually. The second change introduced a yearly update of annual quantitative ASP results at the request of a commissioner.

Since the last status report, SECY-99-289, dated December 20, 1999, the staff has:

- Evaluated Fiscal Years (FYs) 1999 and 2000 events for precursors.
- Evaluated trends in the precursor data.

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- Evaluated the risk significance of 141 “as found” deficiencies identified at both D.C. Cook units and published the results of the evaluation.

- Used the results and insights of ASP analyses to support risk-informed regulatory activities.

- Started implementing improvements in the ASP Program to expedite the completion of preliminary analyses and awarded a commercial contract to support ASP analysis.

- Continued developing the Standardized Plant Analysis Risk (SPAR) models.

BACKGROUND:

The discussion below provides a brief background of the ASP program and it’s uses.

Established by the NRC in 1979 in response to the Risk Assessment Review Group report (Ref. 1), the primary objective of the Accident Sequence Precursor (ASP) Program is to systematically evaluate U.S. nuclear plant operating experience to identify, document, and rank operating events most likely to lead to inadequate core cooling and core damage (precursors). In addition, the secondary objectives of the ASP Program are (1) to categorize the precursors by their plant-specific and generic implications, (2) to provide a measure for trending nuclear plant core damage risk, and (3) to provide a partial check on probabilistic risk assessment (PRA)-predicted dominant core damage scenarios.

The program is also used to monitor the agency’s performance against the following Strategic Plan goals for maintaining safety (Ref. 2):

> No more than one event per year which is a significant precursor (i.e., CCDP $\geq$ 1×10^{-3}) of a nuclear reactor accident.
>
> No statistically significant adverse industry trends in safety performance.

Since its inception, the ASP Program has published 17 reports documenting the results of its review of operational experience for precursors covering the years 1969–1998. These reports have been issued yearly since 1986.

Accident sequences of interest to the ASP Program are those that would have resulted in inadequate core cooling and severe core damage if additional failures had occurred. Events and conditions from licensee event reports, inspection reports, and special requests from NRC staff are reviewed for potential precursors. These potential precursors are analyzed, and a conditional core damage probability (CCDP) is calculated by mapping failures observed during the event onto accident sequences in risk models. An event with a CCDP or a condition with an
importance (i.e., ?CDP) greater than or equal to 1.0×10^{-6} is considered a precursor in the ASP Program.

The NRC staff uses the ASP methodology and models, and results of ASP analyses to do the following:

(1) Promptly assess the risk significance of operational events to support regulatory decisions by senior management.

(2) In Phase 3 of the significance determination process (SDP), evaluate the significance of inspection findings as part of the agency's reactor oversight process.

(3) Evaluate the change in risk associated with licensing amendments submitted by licensees requesting changes in surveillance frequencies or allowed outage times.

(4) Determine the need for generic communications (such as information notices).

(5) Systematically screen, review, and analyze operational experience data for accident sequence precursors.

(6) Evaluate the generic implications of precursors, trend industry performance, and check against PRAs.

(7) Perform regulatory analyses to resolve generic issues.

(8) Evaluate the risk associated with a specific technical issue identified at a specific plant.

(9) Establish plant-specific performance thresholds and performance baselines to support the development of risk-based performance indicators.

DISCUSSION:

This section provides a summary of: the results of the trends and insights evaluation, ASP support of risk-informed regulatory activities; ASP program improvements; intra-agency coordination of ASP program efforts; and ASP model and methods development.

Historical Trends and Insights

A review of the ASP analyses for FYs 1999 and 2000 and a comparison with analyses from previous years for insights and trends are summarized in Attachment 1. The ASP results used to monitor the agency's performance against the two Strategic Plan goals are as follows:

Trends. The occurrence rate of precursors has exhibited a decreasing trend that is statistically significant during the 1993–1999 period (see Figure 1 of Attachment 1). The number of precursors has decreased over the period by a factor of 2 to 3.

Significant precursors. In the Strategic Plan goal, "No more than one event per year identified as a *significant precursor* of a nuclear accident," a *significant precursor* is defined in the Strategic Plan as an event that has a 1/1000 (10^{-3}) or greater probability of leading to a reactor accident.

No potential precursors were identified during FYs 1999 and 2000 with a CCDP$1.0×10^{-3}. Precursors with CCDP$1.0×10^{-3} have occurred, on the average, about once every 4 years. The events in this group appear to involve no common failure modes, causes, or systems.

ASP Support to Risk-Informed Regulatory Activities

Results and insights from ASP analyses are used to support various risk-informed activities within the agency. For example, the results of the ASP analysis of plant deficiencies at D.C. Cook (summarized in Attachment 1) was used to identify the risk-important deficiencies in support of the Agency's inspection program during the Cook restart. Other examples are provided in Attachment 2.

ASP Program Improvements

Several actions to expedite the completion of preliminary analyses have been initiated. Staff from the Operating Experience Risk Analysis Branch (OERAB/RES) will perform about 50% of the precursor analyses, concentrating on the more risk-significant events to support activities, such as incident response decision-making and special inspections. A commercial contractor (contract awarded on September 25, 2000) will screen and review licensee event reports (LERs) for potential precursors, and perform the remaining half of the precursor analyses during the next 4 years.

A procedure to expedite the screening of potential precursors for detailed analysis is being developed by staff. Currently, a search algorithm is used to screen LERs in the Sequence Coding and Search System (SCSS). An extended 60-day LER reporting period took effect in January 2001. The staff is exploring other means to identify potential precursors that occur at the end of the fiscal year.

ASP Program Coordination

The coordination of model development efforts that support the ASP Program is the responsibility of the SPAR Model Users Group (SMUG), which comprises representatives from each of the organizations within the agency's program and regional offices that use risk models in regulatory activities.

During the past year, the SMUG met on a regular basis. It prepared the Integrated SPAR Model Development Plan, which conforms to the modeling needs identified by the SMUG members and their management for performing risk-informed regulatory activities. The following models are addressed in this plan:

- Level 1: internal events during full power operation
- Level 1: internal events during low-power and shutdown operations
- Level 1: external events (including fires, floods, seismic events)
- Level 2/large early release frequency (LERF)

The plan was approved by management in each user organization in September 2000.

ASP Model and Methods Development

In the last year, the staff has completed the following activities in model and methods development:

Level 1: internal events during full power operation

- Maintained Revision 2QA SPAR models. These models are currently used by staff to perform risk-informed regulatory activities.

- Completed 20 Revision 3i SPAR models during FY 2000 (the *i* stands for interim; most of these models have not undergone an onsite QA review against the licensee's risk model). To date, 30 Revision 3i SPAR models out of a total of 70 have been completed.

- Completed the detailed onsite QA review of two Revision 3i SPAR models.

- Completed limited onsite QA reviews of five Revision 3i SPAR models in conjunction with the review of the SDP Phase 2 Notebooks.

Level 1: internal events during low-power and shutdown operations

- Completed a BWR low-power/shutdown model based on the Grand Gulf Shutdown PRA.

- Updated the low-power/shutdown model based on the Surry shutdown PRA.

FUTURE STATUS REPORTS:

The 1999 Precursor Report, "Precursors to Severe Core Damage Accidents: 1999—A Status Report," NUREG/CR-4674, Volume 28, is scheduled to be issued by June 2001. However, each ASP analysis is made public as it is completed. The next SECY paper on the status of the ASP Program will be made in March 2002. Future reports and SECY papers will be coordinated with NRR to factor ASP Program results into the Agency's evaluation of industry trends.

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Risk Assessment Review Group Report," NUREG/CR-0400, Washington, D.C., September 1978.

2. U.S. Nuclear Regulatory Commission, “Strategic Plan, Fiscal Year 2000 - Fiscal Year 2005,” NUREG-1614, Vol. 2, Part 1, Washington, D.C., February 2000.

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Attachments: 1. Summary of Results, Trends, and Insights From the ASP Program
2. ASP Program Support of Risk-Informed Regulatory Activities

Summary of Results, Trends, and Insights From the ASP Program

This status report differs from previous reports in two respects. First, the results are reported on a fiscal year basis. Previous status reports were based on the calendar year. This change makes the report consistent with the annual performance report to Congress, which is based on the fiscal year.

Second, this status update reports the preliminary results of potential precursors from FY 2000 (at the time of this writing). This report includes most of the FY 2000 potential precursors; however, as discussed in the Improvements section in the main report, a plan is being implemented this year to expedite the completion of preliminary analyses of the current fiscal year's potential precursors. This addition will provide current results for inclusion in next year's and future status reports.

FY 1999 and FY 2000 ASP Event Analysis

The screening, review, and preliminary analysis of events in FYs 1999 and 2000 are nearing completion. The preliminary analyses identified 13 potential precursors for FYs 1999 and 2000. The final analyses of seven precursors are complete; six potential precursors are undergoing peer and licensee review. In addition to the 13 potential precursors, the preliminary analyses of five other FY 2000 events are nearing completion. Final precursor analyses for FY 1999 will be completed in Summer 2001; FY 2000 analyses will be completed in Fall 2001.

The results of final and preliminary ASP analyses for FYs 1999 and 2000 are presented in Tables 1 through 4.

Historical Trends and Insights

The 1993–1999 data are trended. FY 2000 data was not included in the trending analysis because, as stated above, preliminary analysis of the remaining five events for FY 2000 are nearing completion. However, the insights include preliminary analyses of FY 2000 potential precursors that were completed as of January 31, 2001.

- The occurrence rate of precursors has exhibited a decreasing trend that is statistically significant during the 1993–1999 period (Figure 1). The number of precursors has decreased over the period by a factor of 2 to 3.

- The occurrence rate for the potential precursors in FY 1999 is consistent with the end point of this trend, as shown in Figure 1.

- Nine potential precursors in FYs 1999 and 2000 involved the unavailability of equipment, four involved initiating events. These preliminary results are also consistent with the 1993–1998 results, in which conditional unavailability events (63%) outnumbered initiating events (37%).

Important precursors. Precursors with a CCDP or importance 1.0×10^{-4} are considered important with respect to risk significance. There was one potential important precursor in

FY1999 and there were four in FY 2000. These preliminary results are consistent with the period 1993–1998, when the average number of important precursors per year was two. Three of the potential precursors in FYs 1999 and 2000 involved conditions that could render safety systems inoperable during postulated high-energy line breaks at both units of D.C. Cook and at Oconee 1. The two other potential precursors were an extended loss of offsite power at Diablo Canyon 1 and a steam generator tube failure at Indian Point 2.

Significant precursors. The ASP Program is used to monitor the agency's performance against the following Strategic Plan goal: "No more than one event per year identified as a significant precursor of a nuclear accident." A "significant precursor" is defined in the Strategic Plan as an event that has a 1/1000 (10^{-3}) or greater probability of leading to a reactor accident (Ref. 1).

No potential precursors were identified during FYs 1999 and 2000 with a CCDP$1.0×$10^{-3}$. Precursors with CCDP$1.0×10^{-3} have occurred, on the average, about once every 4 years. The events in this group appear to involve no common failure modes, causes, or systems.

Two precursors with a CCDP$1.0×$10^{-3}$ have occurred since 1991—the Wolf Creek reactor coolant system blowdown to the refueling water storage tank during hot shutdown (1994) and the Catawba 2 extended plant-centered loss of offsite power with an emergency diesel generator out of service for maintenance (1996).

BWR vs PWR. Historically, six times as many precursors have occurred at pressurized-water reactors (PWRs) as at boiling-water reactors (BWRs). Since about two-thirds of the power reactors are PWRs, a precursor is twice as likely to occur at a PWR, than at a BWR. None of the potential precursors in FYs 1999 and 2000 occurred at a BWR; there has been only one since 1996. According to the staff's review of individual plant examinations (NUREG-1560, Ref. 2), the core damage frequencies estimated in the IPEs were generally lower for BWRs than for PWRs. NUREG-1560 attributed the difference to the larger number of injection systems in the BWR design along with the ability to rapidly depressurize to allow the use of low-pressure injection systems. This may explain, in part, the lower number of precursors at BWRs.

LOOP-related precursors. Two potential precursors involving loss of offsite power (LOOP) initiating events occurred during the FY 1999–2000 period—a plant-centered LOOP to safety-related buses following a reactor trip at Indian Point 2 (1999) and an extended plant-centered LOOP to safety-related buses following a reactor trip at Diablo Canyon 1 (2000). The preliminary analysis and review of the ASP data reveal the following:

- The preliminary results for FYs 1999 and 2000 are consistent with the period 1993–1998, when the average number of potential precursors involving a LOOP initiator was about two a year.

- None of the precursors since 1989 have involved a grid-related LOOP event.

- The occurrence rate of LOOP-related precursors has exhibited a decreasing trend during the 1993–2000 period. The number of LOOP-related precursors has decreased over the period by about a factor of 4. The decreasing trend is comparable

with the results provided in NUREG/CR-5496, “Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980–1996" (Ref. 3).

Precursors caused by unavailability of safety-related equipment. Most precursors involve the unavailability of safety-related equipment. These events occur during periods of extended unavailability of equipment without a reactor trip. A review of the ASP data during the 1993–2000 time period produced the following insights about the unavailability of safety-related equipment.

- *Emergency core cooling systems (ECCS).* The unavailability of safety-related high- and low-pressure injection trains was associated with 40% of all precursors. These unavailabilities were caused by failures in the ECCS (44%), electric power distribution (27%), and the cooling water system (8%).

- *Auxiliary/emergency feedwater systems.* The unavailability of auxiliary/emergency feedwater (AFW/EFW) trains contributed to 23% of all precursors in PWRs. These unavailabilities were caused by failures in the AFW/EFW system (65%), electric power distribution (29%), and the cooling water system (6%).

- *Emergency power sources.* The unavailability of emergency power sources, such as an emergency diesel generator (EDG) and hydroelectric generators at Oconee, contributed to 23% of all precursors. A simultaneous EDG unavailability and a LOOP were also involved in three of the LOOP-related precursors. Each of the precursors involving a LOOP event and EDG unavailability had a CCDP1.0×10^{-4}.

Evaluation of Risk Trends in Precursor Data

The staff reviewed ASP results to obtain insights about industry risk. In its review the staff analyzed trends in the occurrence of precursors, compared an Annual ASP Index with core damage frequencies (CDFs) from individual plant examinations (IPEs), and compared the modes and causes of precursors from the ASP data with modes and causes modeled in probabilistic risk assessments (PRAs) and IPEs.

Trends. A chart showing CCDP “probability bins” for ASP results from FYs 1993 through 1999, including partial results for FY 2000, is given in Figure 2. As reported above, the occurrence rate of all precursors has exhibited a decreasing trend that is statistically significant during the 1993-1999 period (Figure 1).

Annual ASP Index. Using CCDPs from ASP results to estimate CDF is difficult because (1) the mathematical relationship requires a great level of detail, (2) statistics for frequency of occurrence of specific precursor events are sparse, and (3) events that did not occur also need to be accounted for in the assessment. The ASP models and process do not explicitly cover all core damage frequency scenarios, such as fires, flooding, and external events, and are therefore incomplete for estimating total core damage frequency.[1] Also, using CCDP to

[1] Although the ASP models and process do not *explicitly* cover all core damage frequency scenarios that are typically found in IPEs, ASP analyses of actual events and conditions include the adaptation of ASP models or the creation of simplified models that are used to analyze any scenario of interest.

estimate CDF can overestimate the frequency because of double counting. Because of these and other limitations, the CCDPs have been used primarily as a relative trending indication. Despite these limitations, ASP results can be linked to CDF by using an Annual ASP Index based on the sum of the CCDPs divided by the number of calendar years (CYs) of operating reactors. This index can be used for order of magnitude comparisons with industry average CDF estimates derived from PRAs and IPEs. For the last 7 fiscal years, the index is as follows:

Fiscal Year	Annual ASP Index (per CY)
1993	1.2×10^{-5}
1994	3.1×10^{-5}
1995	2.1×10^{-6}
1996	2.3×10^{-5}
1997	4.5×10^{-7}
1998	5.8×10^{-6}
1999[a]	7.0×10^{-6}
Average[a]	1.1×10^{-5}

a. Preliminary results

The estimated CDFs in the IPEs range from 1.2×10^{-6}/CY to 3.7×10^{-4}/CY, with an average value of 6.2×10^{-5}/CY. The IPEs give incomplete estimates of total CDF, but IPEs are reasonably similar in scope to the current ASP Program. On an order of magnitude basis, the ASP Index over the last 7 fiscal years is consistent with the order of magnitude of estimates of CDFs from the IPEs. However, because of the limitations discussed above, the ASP results are not sufficient to verify the IPE CDF results.

Consistency with PRAs/IPEs. A review of final and preliminary precursor results for the period 1994–2000 shows that several precursors involved event initiators or conditions not typically modeled in PRAs or IPEs. These events make up approximately 20 percent of the precursors for this period. Almost half of these events involved conditions that could render safety-related equipment inoperable during a postulated high-energy line break.

Evaluation of Risk Associated with Issues at D.C. Cook Nuclear Plant, Units 1 and 2

NUREG-1728, "Assessment of Risk Significance Associated with Issues Identified at D.C. Cook Nuclear Power Plant," was issued in October 2000. This report documents the assessment of the risk significance of 141 "as found" conditions identified at D.C. Cook 1 and 2 from August 1997 through December 1999. The licensee completed numerous plant-specific modifications, upgrades in procedures, operator training, and other corrective actions to address the key issues identified in the report. The report does not address changes in risk associated with the corrective actions taken by the licensee.

Of the 141 issues analyzed, four issues had estimated changes to the baseline core damage frequencies (?CDF) greater than 1.0×10^{-6}/year, which qualified them as accident sequence precursors. Each of the four precursors involved conditions that existed since Cook 1 and 2 received their operating licenses. The cumulative ?CDF resulting from all issues identified at Cook 1 and 2 was estimated to be approximately 5.1×10^{-4}/year for each of the units. High-energy line break issues, degraded capability of some equipment to withstand seismic events, and potential pressure-locking conditions in two motor-operated valves were the dominant contributors to the CDF increase. The combined risk significance of the containment-related issues was small.

References

1. U.S. Nuclear Regulatory Commission, "Strategic Plan, Fiscal Year 2000 - Fiscal Year 2005," NUREG-1614, Vol. 2, Part 1, Washington, D.C., February 2000.

2. U.S. Nuclear Regulatory Commission, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance, Summary Report," NUREG-1560, Vol. 1, Part 1, Washington, D.C., October 1996.

3. U.S. Nuclear Regulatory Commission, "Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980–1996," NUREG/CR-5496, Washington, D.C., November 1998.

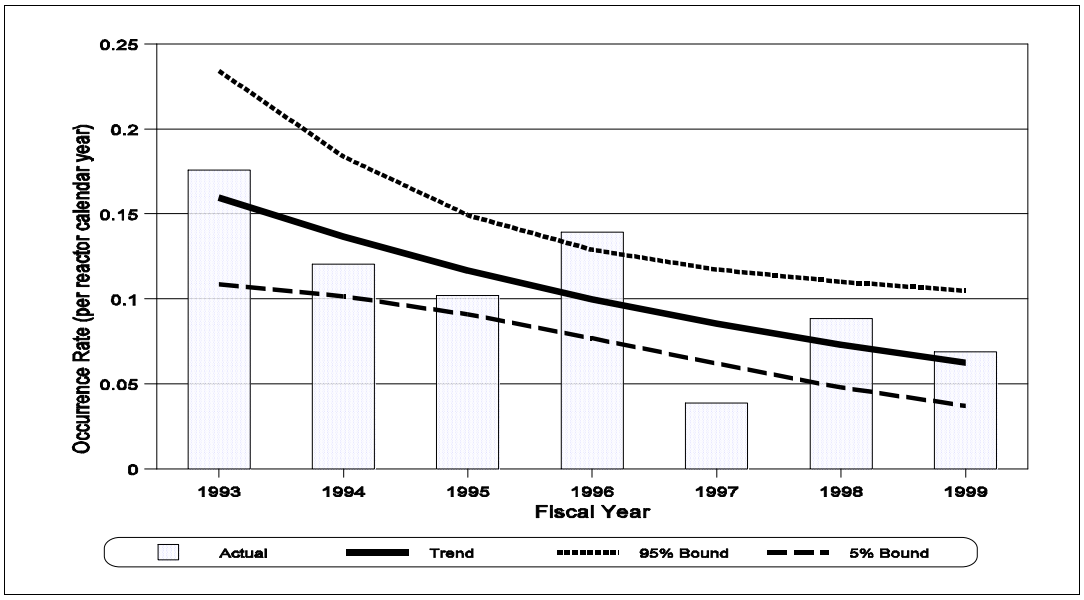

Figure 1. Precursor occurrence rate for 1993-1999 plotted against fiscal year. The trend is statistically significant (p-value = 0.0068). The result for 1999 is preliminary.

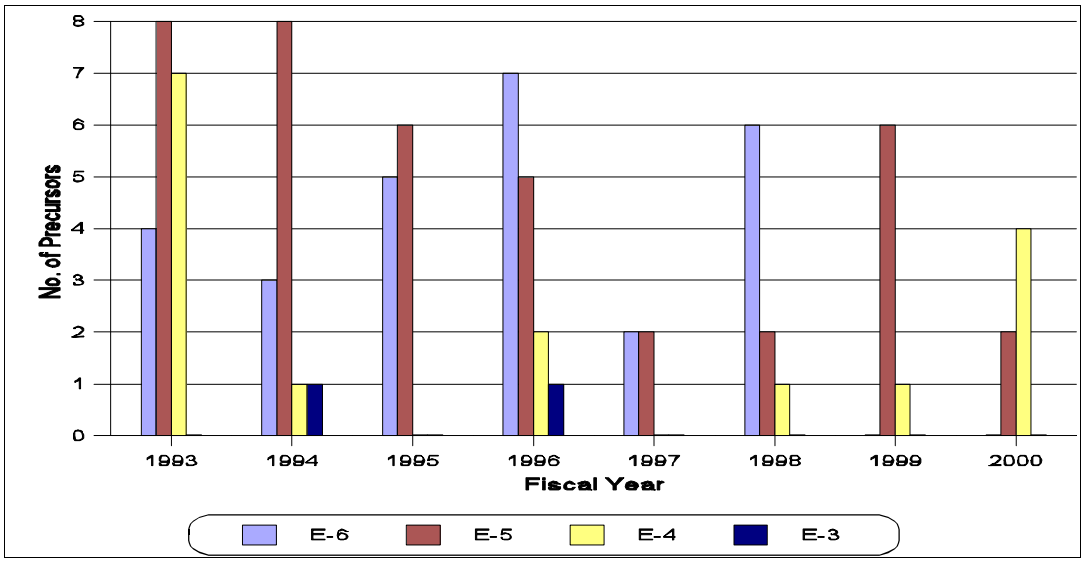

Figure 2. Conditional core damage probability results from ASP Program (1993-2000) for each of the CCDP bins (*E-3*: $\geq$ 1 x 10^{-3}; *E-4*: 9.9 x10^{-4} to 1.0 x10^{-4}; *E-5*: 9.9 x10^{-5} to 1.0 x10^{-5}; *E-6*: 9.9 x10^{-6} to 1.0 x10^{-6}). Results for FYs 1999 and 2000 are preliminary.

Table 1. FY 2000 At-Power Precursors Involving Initiating Events

Plant	Description/Event identifier	Plant type	Event date	CCDP	Event type
Indian Point 2	Manual reactor trip following a steam generator tube failure (LER 247/00-001)	PWR	2/15/00	1.1×10^{-4} (preliminary)	Steam generator tube rupture
Diablo Canyon 1	Reactor trip and extended plant-centered loss of offsite power (LER 275/00-004)	PWR	5/15/00	3.1×10^{-4} (preliminary)	Loss of offsite power

Table 2. FY 2000 At-Power Precursors Involving Unavailabilities

Plant	Description/Event identifier	Plant type	Event date	CCDP	Importance (CCDP – CDP)	Event type
Cook 1 and 2	Potential high-energy line break conditions affecting the operability of mitigating systems (LER 315/99-026)	PWR	10/22/99	4.5×10^{-4}	4.3×10^{-4}	Unavail-ability
Cook 1 and 2	Valves required to operate post-accident could fail to open due to pressure-locking/thermal binding (LER 315/99-031)	PWR	12/30/99	5.7×10^{-5}	3.7×10^{-5}	Unavail-ability

Table 3. FY 1999 At-Power Precursors Involving Initiating Events

Plant	Description/Event Identifier	Plant type	Event date	CCDP	Event type
Davis Besse	Manual reactor trip while recovering from a component cooling system leak and deenergization of safety-related bus D1 and nonsafety bus D2 (LER 346/98-011)	PWR	10/14/98	1.4×10^{-5}	Transient
Indian Point 2	Loss of offsite power to safety-related buses following a reactor trip and a emergency diesel output breaker trip (LER 247/99-015)	PWR	08/31/99	6.3×10^{-5} (preliminary)	Loss of offsite power

Table 4. FY 1999 At-Power Precursors Involving Unavailabilities

Plant	Description/Event identifier	Plant type	Event date	CCDP	Importance (CCDP – CDP)	Event type
Oconee 1	Postulated high-energy line leaks or breaks in turbine building leading to failure of safety-related 4 kV switchgear (LER 269-99-001)	PWR	2/24/99	3.1×10^{-4} (preliminary)	2.9×10^{-4} (preliminary)	Unavail-ability
Oconee 2	Postulated high-energy line leaks or breaks in turbine building leading to failure of safety-related 4 kV switchgear (LER 269-99-001)	PWR	2/24/99	1.0×10^{-4} (preliminary)	7.9×10^{-5} (preliminary)	Unavail-ability
Oconee 3	Postulated high-energy line leaks or breaks in turbine building leading to failure of safety-related 4 kV switchgear (LER 269-99-001)	PWR	2/24/99	1.0×10^{-4} (preliminary)	7.5×10^{-5} (preliminary)	Unavail-ability
Cook 1 and 2	Lack of capability to operate emergency service water following a seismic event (Inspection reports 50-315/316/97-024 and 50-315/316/99-010)	PWR	6/11/99	5.2×10^{-5}	3.2×10^{-5}	Unavail-ability

ASP Program Support of Risk-Informed Regulatory Activities

Results and insights from ASP analyses are used to support various risk-informed activities within the agency. For example, the results of the ASP analysis of plant deficiencies at D.C. Cook (summarized above) was used to identify the risk-important deficiencies in support of the Agency's inspection program during the Cook restart. Other recent examples include the following:

! Incident response

Independent assessment of risk associated with actual events were used to support senior management decisions to dispatch augmented and special inspection teams.

Recent events include the following:

- Hatch 1 reactor trip with complications in January 2000,
- Indian Point 2 steam generator tube failure in February 2000,
- Arkansas Nuclear One 1 common-mode failure of both low-pressure injection pumps during decay heat removal in February 2000, and
- Diablo Canyon 1 loss of offsite power in May 2000.

! Generic communications

The discovery of several high-energy line break concerns about failure of redundant safety-related equipment at Cook 1 and 2 resulted in the issuance of Information Notice 2000-20, "Potential Loss of Redundant Safety-Related Equipment Because of the Lack of High-Energy Line Break Barriers," December 11, 2000.

! Strategic Goal Performance Measure

Precursor results and trends are used to monitor the agency's performance against the following Strategic Plan goals for maintaining nuclear reactor safety:

> No more than one event per year which is a significant precursor (i.e., CCDP $\geq$ 1 x 10^{-3}) of a nuclear reactor accident.
>
> No statistically significant adverse industry trends in safety performance.

! Generic safety issue resolution

Insights from the detailed ASP analysis of the sump debris issue at D.C. Cook are being used by staff to develop risk assessment methods for resolving of Generic Safety Issue (GSI) 191, "Assessment of Debris Accumulation on PWR Sump Performance."

! Regulatory effectiveness

ASP precursor results were used in staff's studies to determine the safety significance of potential regulatory issues. These studies provide insights to support ongoing NRC and industry efforts to make NRC's regulatory framework and oversight process more risk-informed and performance-based and to reduce unnecessary regulatory burden.

Recent studies include the following:

- SECY-99-129, "Effects of Electric Power Industry Deregulation on Electric Grid Reliability and Reactor Safety;"

- NUREG-1275, Vol.14, "Causes and Significance of Design-Basis Issues at U.S. Nuclear Power Plants;"

- NUREG-1275, Vol. 13, "Evaluation of Air-Operated Valves at U.S. Light-Water Reactors;"

- NUREG/CR-6654, "A Study of Air-Operated Valves in U.S. Nuclear Power Plants;" and

- NUREG/CR-6582, "Assessment of Pressurized Water Reactor Primary System Leaks."