December 22, 1998

FOR: The Commissioners

FROM: William D. Travers /s/
Executive Director for Operations

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

PURPOSE:

To inform the Commission of the staff's activities and progress with respect to the Accident Sequence Precursor (ASP) Program and related initiatives. .

DISCUSSION:

Since the last status report, SECY-97-296, dated December 23, 1997, the staff has made progress in the following areas: (1) 1997 and 1998 ASP event analysis, (2) evaluation of ASP results and trending, (3) model and methods development, and (4) ASP Program coordination.

1997 ASP Event Analysis

The screening, review, and analysis of 1997 operational events have been completed. A total of five precursors affecting five units were identified for 1997. This is the lowest number of precursors for any year since 1970. Several factors may have contributed to this result. There has been a significant reduction in the number of transients and challenges to safety systems across the industry over the last 10 years. Reducing the number of transients and safety system challenges directly affects the number of precursors. Implementation of Generic Letter 88-20, which requested that each licensee perform an Individual Plant Examination (IPE), influenced the number of precursors. Completing an IPE enabled licensees to identify and address the most risk-significant vulnerabilities associated with their specific plants, thereby reducing plant risk. Furthermore, modeling improvements and refinements in the ASP Program's review and analysis process (e.g., including licensee review/comment on each precursor analysis) may have contributed to a reduction in the number of events identified as precursors. The effect of the modeling improvements and refinements has not been quantified due to the resources required to rebaseline previous analyses. The staff does not intend to pursue rebaselining nor does the staff believe that significant changes to our current understanding of ASP performance would be realized from such effort.

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Three of the 1997 precursors involved the unavailability of equipment; two involved initiators. This result differs from 1996, but is consistent with each of the previous 4 years (1992-95), in which conditional unavailability events outnumbered initiators.

Historically, the percentage of precursors occurring at boiling water reactors (BWRs) has been less than the percentage of BWRs in the operating reactor population. None of the 1997 precursors occurred at a BWR. This marks the first time in the history of the ASP Program that no precursor occurred at a BWR. Results from the staff's review of IPEs (NUREG-1560) indicate that the BWR core damage frequencies estimated in the IPEs generally were less than those for pressurized water reactors (PWRs). NUREG-1560 attributed the difference to the larger number of injection systems in the BWR design and the capability of the BWR to more easily depressurize to allow use of low pressure injection systems. Since the ASP Program uses conditional core damage probability (CCDP) as the screening criterion for precursors, the observed BWR precursor percentages are consistent with expectations relating to core damage frequency (CDF) from the body of BWR risk assessments.

Precursors involving degradations or failures in the auxiliary/emergency feedwater (AFW/EFW) systems at PWRs have typically been contributors to the number of precursors in a given year. Between 1984 and 1996, the number of precursors involving AFW/EFW system degradations ranged from one to ten per year, with an average of about 4 per year. However, none of the 1997 precursors involved problems with AFW/EFW systems. This is the first year since the ASP Program was established in which there were no precursors with AFW/EFW system problems. An analysis documented in the 1997 Precursor Report (NUREG/CR-4674, Volume 26) of the number of precursors involving failures or degradations of the AFW/EFW system over the period 1984-1997 revealed a statistically significant, decreasing trend. The observed decrease is attributed in part to the decrease in the number of unexpected AFW/EFW system demands and a slight reduction in the number of failures per demand.

One of the 1997 precursors involved problems with electrical equipment [loss of offsite power (LOOP) at Three Mile Island, Unit 1 (TMI-1) - See Attachment 1]. Although this result is consistent with the relative contribution of electrical equipment problems in the 1996 results, it differs from the previous 5-year period (1990-95), when about 60 percent of the precursor events each year involved electric power issues. Of the four LOOP events that occurred in 1997, it was the only one classified as a precursor. The ASP program also classifies certain operational experiences as "interesting events" when they involve unusual scenarios or failure modes, but do not result in a CCDP$\geq$1.0 10^{-6}. The LOOP event (at Pilgrim in March 1997) was classified as an "interesting event" because the plant was in an unusually vulnerable electrical configuration when the LOOP occurred. However, the CCDP associated with this event was less than the precursor threshold because: (1) the plant was in a cold shutdown condition; (2) very little decay heat was contained in the fuel; (3) the duration of the LOOP was only about 3 hours; (4) the plant's Technical Specifications prevented the plant from starting up, since the main transformer was out of service - thus the event could not have occurred at power, (5) the emergency diesel-generators had been started and were loaded, and (6) the station blackout diesel-generator was also started and placed in a standby condition. The other two LOOP events (at Browns Ferry 3 in March, and at Indian Point 3 in June) were both of relatively short duration, and offsite power was readily restored in each case without any complications. As a result, the CCDPs associated with these events were lower than the precursor threshold, and they did not meet the

criteria for an "interesting event".

Loss-of-coolant-accident (LOCA) - related issues were significant contributors to four of the five 1997 precursors. These involved (1) an unisolable leak in piping between the high pressure injection system and the injection nozzle safe end, (2) damage to two high pressure injection system pumps because of a low water level in the letdown storage tank, (3) potential pressure locking of reactor coolant system hot-leg recirculation valves because of post-LOCA thermal expansion of the trapped water, and (4) potential failure of the post-LOCA recirculation mode of emergency core cooling system operation because of a non-conservative recirculation actuation signal set point.

The ASP Program considers precursors with CCDP$\geq$1.0 10^{-4} important with respect to risk significance. There were no precursors identified for 1997 that had CCDPs$\geq$1.0 10^{-4}. This is the first year in the history of the ASP Program in which no precursor with CCDP$\geq$1.0 10^{-4} was identified. Over the last ten years, approximately 25% of the precursors have had a CCDP$\geq$1.0 10^{-4}. The number of these precursors varied from 1-13 per year, with an average of 5 per year.

The 1997 precursor results are presented in Attachment 1. Detailed discussion of the analysis results and the insights summarized above may be found in the 1997 Precursor Report ("Precursors to Severe Core Damage Accidents: 1997 A Status Report," NUREG/CR-4674, Volume 26). This report is in printing and should be issued by the middle of December.

Evaluation of ASP CCDP Results and Trending

The ASP results were reviewed to obtain insights about industry risk. This review consisted of analysis of trends in the occurrence of precursors, comparison of an annual ASP index with core damage frequencies (CDFs) from IPEs (the ASP index for a given year is defined as the sum of the CCDPs divided by the number of reactor operating years), and comparison of the modes and causes of precursors from the ASP data with those modeled in probabilistic risk assessments (PRAs) and IPEs. An updated chart showing CCDP "probability bins" for ASP results from 1984 through 1997 is contained in Attachment 2.

A recent staff technical paper(1) reported the detailed results of a statistical analysis of trends in the occurrence rate of precursors identified by the ASP Program between 1984 and 1994. In preparing this status report, the above analysis was updated with the three most recent years of data. Statistically significant decreasing trends were found for all of the ASP CCDP bins, except for precursors with CCDP$\geq$1.0 10^{-3}. Precursors with CCDP$\geq 10^{-3}$ occur, on the average, about once every two years. The events in this group appear to exhibit no common (generic) characteristics with respect to the nature, modes, causes, and systems affected by the events. The last precursor with CCDP$\geq$1.0 10^{-3} was the loss-of-offsite power event with an emergency diesel-generator out of service for maintenance at Catawba 2 in February 1996.

As noted in last year's ASP Program status report, SECY-97-296, we compared the annual ASP index with CDF estimates from IPEs. Using CCDPs from ASP results to estimate CDF is difficult because: (1) the actual 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 and are therefore incomplete for estimating total core damage frequency. Also, using CCDP to estimate CDF can overestimate the frequency due to double counting(2). Due to these and other limitations, the CCDPs have been used primarily as a relative trending indication.

The estimated CDFs in the IPEs range from $1.2\text{x}10^{-6}$/reactor-year (RY) to $3.7\text{x}10^{-4}$/RY, with an average value of $6.2\text{x}10^{-5}$/RY. They also provide 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 six years is consistent with the order of magnitude of estimates of CDFs from the IPEs. On an industry-wide level, the ASP results do not provide indication that the IPEs have underestimated their core damage frequencies. However, due to the limitations discussed above, the ASP results are not sufficient to verify the IPE CDF results.

The above limitations notwithstanding, a link between ASP results and CDF can be made using the Annual ASP Index. For the last six years, the ASP index is:

	Year	Annual ASP Index
	1997	6.2 10^{-7}/RY
	1996	$2.4\text{x}10^{-5}$/RY
	1995	$2.2\text{x}10^{-6}$/RY
	1994	$3.0\text{x}10^{-5}$/RY
	1993	$8.9\text{x}10^{-6}$/RY
	1992	$1.5\text{x}10^{-5}$/RY

		$1.3x10^{-5}$/RY Average

Since very little change occurred in the average ASP index with the addition of the 1997 precursor data, the average ASP index remains consistent with an industry average CDF in the range of about 10^{-5}/RY to 10^{-4}/RY.

One of the objectives of the ASP Program is to provide a check with PRAs by comparing ASP data and insights with expectations based on PRAs and IPEs. The results can be used to identify modeling deficiencies or areas with completeness problems, thereby providing a feedback mechanism for improving the analysis process. In last year's report, we presented the results of a review of precursor results for the period 1994-1996 and showed that a number of these events involved event initiators or conditions that are not included specifically in the IPEs. These events comprise approximately 15 percent of the precursors for this period and indicate that, while CDF implications from the ASP Program are in general agreement with overall estimates of CDF from the IPEs, occasionally contributors to these results may be somewhat different from those identified in PRAs. Of the five precursors for 1997, the three involving unavailabilities included the following specific failure mechanisms that are not explicitly considered in the IPEs:

- potential failure of the recirculation mode of emergency core cooling system (ECCS) operation because of reactor coolant system hot-leg recirculation valves being subject to pressure locking in a post-LOCA environment
- high pressure injection (HPI) pumps damaged because of low water level in the letdown storage tank
- potential failure of the recirculation mode of ECCS operation because of a non-conservative recirculation actuation system (RAS) setpoint.

These results are presented to increase the analyst's awareness of such mechanisms for consideration in updating PRAs.

1998 ASP Event Analysis

The ASP screening, review, and analysis of 1998 operational events began in May 1998. Of the more than 900 licensee event reports (LERs) received to date, 399 LERs received engineering review as potential precursors. Of these, 27 individual events have been identified for detailed analysis to determine if they are potential precursors. Out of the 17 analyses of 1998 events that have been completed to date, no precursors have been identified.

Model and Methods Development

Progress in model and methods development by the Office of Nuclear Regulatory Research (RES) included the completion of the systematic quality assurance (QA) review of the Revision 2 standardized plant analysis risk (SPAR) models, which produced the Revision 2QA SPAR models. RES also completed development work and checkout testing on the Windows version of the Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) suite of probabilistic risk assessment (PRA) codes, which is now being used by staff analysts. In addition, RES began work on Revision 3 of the SPAR models, which will improve the Revision 2QA SPAR models by adding more initiating events, support systems, other dependencies, and methodology changes for common cause failures, human performance during recovery, and explicit treatment of data uncertainty. RES also initiated development of large early release frequency (LERF) models with the goal of providing the capability to calculate an estimated LERF for events occurring at operating nuclear power plants. The development of Level 2/3 models has been superceded by the LERF model development effort.

The construction of a data link with Idaho National Engineering and Environmental Laboratory was completed, resulting in easier accessibility to the PRA codes and the SPAR and detailed PRA plant models for staff analysts.

Last year's report identified two projects for which development activities had previously been suspended due to funding and resource limitations. These two projects [(1) models to analyze internal fires, flooding, and seismic events, and (2) models to analyze events occurring during low power/shutdown operation and flooding events occurring during full power operation] have received funding for FY 1999, and plans have been made to resume work on them by the end of January 1999. The current long range goal is to have initial development of Item (1) completed by September 1999, and Item (2) by September 2000.

ASP Program Coordination

The interoffice [Office for Analysis and Evaluation of Operational Data (AEOD), Office of Nuclear Reactor Regulation (NRR), and RES] ASP Technical Coordination Group continued to meet regularly to discuss experiences with the analysis of operational events. The group also provided guidance regarding the technical direction of several other efforts, which have been discussed above. These include: (1) systematic quality assurance and review of the Revision 2 SPAR models used in ASP analyses, (2) development of the Revision 3 SPAR models, and (3) development of LERF analysis capability. In addition, the group produced the annual update (Revision 4) of the Integrated ASP Program Plan for the ASP-related activities conducted by each office.

FUTURE STATUS REPORT:

The next report to the Commission on the status of the ASP Program will be provided in December 1999.

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Attachments:
1. ASP Program Precursors for 1997
2. Conditional Core Damage Probability Results from ASP Program (Chart)

ATTACHMENT 1

1997 At-Power Precursors Involving Initiating Events Sorted by Conditional Core Damage Probability

CCDP	Plant	Plant Type	Event Identifier	Description	Event Date
2.2×10^{-5}	Oconee 2	PWR	LER 270/97-001	Unisolable reactor coolant system (RCS) leak	4/21/97
9.6×10^{-6}	TMI-1	PWR	LER 289/97-007, -008, and 010	Failure of both generator output breakers causes a loss of offiste power (LOOP)	6/21/97

1997 At-Power Precursors Involving Unavailabilities Sorted by Increase in Core Damage Probability

△ CDP	Plant	Plant Type	Event Identifier	Description	Event Date
1.3×10^{-5}	Maine Yankee	PWR	LER 309/97-004	RCS hot-leg recirculation valves subject to pressure locking because of post-loss-of-coolant accident (LOCA) thermal expansion of the trapped water	1/22/97
4.3×10^{-6}	Oconee 3	PWR	LER 287/97-003	Two high pressure injection (HPI) pumps were damaged because of a low water level in the letdown storage tank (LDST)	5/3/97
1.7×10^{-6}	St. Lucie 1	PWR	LER 335/97-011	Non-conservative recirculation actuation system (RAS) set point	11/2/97

1. "Analysis of Annual Accident Sequence Precursor Occurrence Rates for 1984-1994," P.D. O'Reilly and D.M. Rasmuson, PSA'96 Proceedings, Park City, UT, 1996, pp. 1645-1652.

2. Double counting is explained in the following papers: "The US NRC's Accident Sequence Precursor Program: An Overview and Development of a Bayesian Approach to Estimate Core Damage Frequency Using Precursor Information," James W. Johnson and Dale M. Rasmuson, Reliability Engineering and System Safety, 53, 1996, pp. 205-216, and "Core Damage Frequency Estimation Using Accident Sequence Precursor Data 1990-1993," Harry F. Martz, Proceedings of the 4th International Conference on Probabilistic Safety Assessment and Management, 13-18 September 1998, New York City, USA, pp. 2344-2349.