

December 23, 1997

SECY-97-296

FOR: The Commissioners

FROM: L. Joseph Callan /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 and to present (1) the results of the final ASP analyses of 1996 operational events, (2) the results of the preliminary analyses of 1997 operational events completed to date, and (3) an update of the staff's progress in ASP-related methods and model development efforts. This paper also responds to a request from a former Commissioner (Rogers) to present a yearly update of annual quantitative ASP results.

SUMMARY:

Since the last status report, SECY-96-241, dated November 26, 1996, the staff has made progress in the following areas: (1) ASP Program coordination, (2) 1996 and 1997 ASP event analysis, (3) 1982 and 1983 ASP event analysis, (4) evaluation of ASP results and trending, (5) improvements to existing models, and (6) development of new models. Budget redirections have dictated that completion of improved ASP models be postponed until November 2001. Other deferrals or cancellations may be necessary; decisions will be made in the near future.

DISCUSSION:

The Office for Analysis and Evaluation of Operational Data (AEOD), the Office of Nuclear Reactor Regulation (NRR), and the Office of Nuclear Regulatory Research (RES) have continued to make progress in a number of areas, which are discussed below.

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### ASP Program Coordination

The interoffice (AEOD, 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. These include (1) systematic quality assurance and review of the Revision 2 simplified plant analysis risk (SPAR) models used in ASP analyses, (2) development of improved (Revision 3) SPAR models, and (3) development of Level 2/3 analysis capability. In addition, the group produced the annual update (Revision 3) of the Integrated ASP Program Plan for the ASP-related activities conducted by each office.

### 1996 ASP Event Analysis

The screening, review, and analysis of 1996 operational events have been completed. A total of 11 precursors affecting 14 units were identified for 1996. Eight of the 1996 precursors involved initiators; six involved the unavailability of equipment. This result differs from each of the past 4 years, in which conditional unavailability events greatly outnumbered initiators. Five of the 1996 precursors (~36 percent) involved problems with electrical equipment. This result differs from the previous 5-year period (1990–95), when about 60 percent of the precursor events each year involved electric power issues. Besides electrical problems, the 1996 precursors involved problems with auxiliary feedwater, design problems, and human performance issues. The 1996 precursor results are presented in Attachment 1.

The following three 1996 precursor events had conditional core damage probabilities (CCDP)  $\geq 1.0 \times 10^{-4}$ .

- a loss of offsite power (LOOP) with emergency diesel generator B unavailable at Catawba 2 on February 6, 1996 (The estimated CCDP for this event was  $2.1 \times 10^{-3}$ , which was the highest CCDP for any of the 1996 precursor events.);
- a reactor trip with loss of train A of essential service water due to frazil ice formation and loss of the turbine-driven auxiliary feedwater pump at Wolf Creek on January 30, 1996 (The estimated CCDP for this event was  $2.1 \times 10^{-4}$ .); and
- a condition that was discovered at the Haddam Neck plant on August 8, 1996, involving potentially inadequate reactor heat removal system pump net positive suction head following a postulated large- or medium-break loss-of-coolant accident. (This event had an estimated CCDP of  $1.1 \times 10^{-4}$ .)

### 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 ASP events, comparison of an Annual ASP Index based on the past 5 years of ASP events with core damage frequencies (CDF) from individual plant examinations (IPE), and comparison of the modes and causes of ASP events with those modeled in probabilistic risk assessments (PRA) and IPEs. An updated chart showing CCDP "probability bins" for ASP results from 1984 through 1996 is contained in Attachment 2.

A paper was presented by the staff at the "PSA '96" conference in Park City, Utah, in October 1996, reporting the results of a statistical analysis of trends in the occurrence rate of precursors identified by the ASP Program between 1984 and 1994. Statistically significant decreasing trends were found for all of the ASP CCDP bins except the events with  $\text{CCDP} \geq 1 \times 10^{-3}$ . There was no statistically discernible trend in the occurrence rate of this group of precursors. The occurrence rate of precursors with  $\text{CCDP} \geq 1.0 \times 10^{-3}$  based on this data is approximately one event every 2 years, although there have been years in which two such events occurred. The Catawba 2 LOOP in February 1996 occurred 2 years after the previous  $10^{-3}$  precursor (the blowdown of the reactor coolant system to the refueling water storage tank during hot shutdown at Wolf Creek in 1994), and it is consistent with previous experience with the occurrence of  $10^{-3}$  precursors. A review of the nature, modes, causes, and systems affected by the precursors with  $\text{CCDP} \geq 10^{-3}$  revealed that the events in this group appear to exhibit no common (generic) characteristics.

The following provides an indication of industry-wide CDF risk implications based on operating experience from the ASP Program. 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. In addition, using CCDP to estimate CDF can overestimate the frequency due to double counting. Due to these and other limitations, the CCDPs have been used primarily as a relative trending indication.

The above limitations notwithstanding, a link between ASP results and CDF can be made using an Annual ASP Index based on the sum of the CCDPs divided by the number of reactor operating years (RY). For the last 5 years, the index is the following:

<u>Year</u>	<u>Annual ASP Index</u>
1996	$2.4 \times 10^{-5}/\text{RY}$
1995	$2.2 \times 10^{-6}/\text{RY}$
1994	$3.0 \times 10^{-5}/\text{RY}$
1993	$8.9 \times 10^{-6}/\text{RY}$
1992	$1.5 \times 10^{-5}/\text{RY}$
	$1.6 \times 10^{-5}/\text{RY}$ Average

This average index is consistent with an industry average CDF in the range of about  $10^{-5}/\text{RY}$  to  $10^{-4}/\text{RY}$ .

The estimated CDFs in the IPEs range from  $1.2 \times 10^{-6}/\text{RY}$  to  $3.7 \times 10^{-4}/\text{RY}$ , with an average value of  $6.2 \times 10^{-5}/\text{RY}$ . They also provide incomplete estimates of total CDF, but IPEs are reasonably similar in scope to the current ASP Program. It is observed that the order of magnitude of the index over the last five 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 plants' core damage frequencies. However, due to the limitations discussed above, the ASP results are not sufficient to verify the IPE CDF results.

In addition, a review of the precursor events for the period 1994-1996 revealed that a number of these events involved event initiators or conditions that are not included in the IPEs. These include the following:

- blowdown of the reactor coolant system to the refueling water storage tank during hot shutdown,
- a reactor trip with loss of one train of essential service water due to frazil ice formation and the unavailability of the turbine-driven auxiliary feedwater pump, and
- discovery of the potential for inadequate reactor heat removal pump net positive suction head following a large-break or medium-break loss of coolant accident.

Other precursor events included specific failure causes that could have led to failure probabilities that are higher than are typically assumed, either explicitly or implicitly, in the IPE models. Examples include the following:

- the failure of a safety-relief valve to close and failure of a suppression pool strainer and
- the fouling of cooling water systems due to concrete sealant injection.

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, occasionally key contributors to these results may be somewhat different from those identified in PRAs.

#### 1997 ASP Event Analysis

The ASP screening, review, and analysis of 1997 operational events began in May 1997. Of the more than 1,000 licensee event reports (LER) received to date, 377 LERs received engineering review as potential precursors. Of these, 23 individual events have been identified for detailed analysis to determine if they are potential precursors. The preliminary analyses of two events have been completed, and the results have been transmitted to the respective licensees and to the NRC staff for review and comment.

#### 1982-1983 ASP Event Analysis

The review and analysis of 1982-1983 LERs to obtain the 2 years of precursor data which had previously been missing from the ASP results were completed during the first quarter of 1997. The 1982-1983 Precursor Report was published in April 1997 as NUREG/CR-4674, Volume 24. In this effort, over 2,100 LERs were reviewed for precursors. Detailed analyses were performed on 435 LER with 109 precursors identified — 54 for 1982 and 55 for 1983. There were no new issues identified as a result of this effort. Fifteen of the 109 events had CCDPs  $\geq 1.0 \times 10^{-4}$ . There was one event with a CCDP  $\geq 1.0 \times 10^{-3}$  (a reactor trip with failure of automatic reactor trip capability at Salem 1 in February 1983). Other important precursors for 1982-1983 include (1) a reactor trip with a degraded auxiliary feedwater system and an inoperable pressurizer power-operated relief valve at Robinson 2 in April 1983, (2) a steam generator tube rupture with one power-operated relief valve failed open at Ginna in January 1982, and (3) a scram with loss of both residual heat removal service water loops for 8 hours due to common cause failure at Brunswick 2 in February 1982. Most of the boiling-water reactor precursors involved the loss of long-term decay heat removal capability. The pressurized-water reactor precursors were dominated by LOOP events (emergency diesel-generator and other electrical problems) and reactor trips with a degraded auxiliary feedwater system.

#### Model and Methods Development

Progress in model and methods development by RES included the continuation of work on the initial Windows version of the SAPHIRE (SAPHIRE 6.0) suite of PRA codes. Specific members of the ASP Technical Coordination Group were selected to form a beta testing group for the hardware and software required to run SAPHIRE 6.0. A workshop on the composition and use of SAPHIRE 6.0 was held for staff analysts in January 1997. Additionally, initial steps in the construction of a data link with Idaho National Engineering and Environmental Laboratory were completed, and staff analysts were tied in to the data link for checkout purposes. This data link will result in easier accessibility to the PRA codes and the Simplified Plant Analysis-Risk (SPAR) and detailed PRA plant models for staff analysts.

The systematic quality assurance (QA) review of the 73 Revision 2 SPAR models continued, with completion of this effort scheduled for the end of calendar year 1997. In order to provide technical support for some of the modeling approaches, thermal-hydraulic calculations were performed using RELAP5 with human performance data input obtained from the results of runs performed on the reactor simulators at the NRC's Technical Training Center.

The ASP Technical Coordination Group reviewed the results from the QA of the Revision 2 SPAR models and the original scope for the Revision 3 SPAR models to identify those issues which should be addressed during the development of the 73 Revision 3 models. The Group determined that better models were necessary for certain systems (e.g. support systems) and that more detailed QA is required. RES revised the scope of the Revision 3 model development effort accordingly. The revised work scope and funding limitations have resulted in the preliminary schedule for completion of the Revision 3 models (including QA and checkout) extending to November 2001, instead of August 1998, as projected in the November 1996 ASP Program Plan. RES is investigating options to accelerate completion of the models.

Due to funding and staff limitations, the status of two key projects sponsored by RES that support the ASP Program is currently under review. These two projects are (1) development of models to analyze events occurring during low power/shutdown operation and flooding events occurring during full power operation and (2) models to analyze internal fires, flooding, and seismic events. A decision on the future direction of these projects will be made by RES in January 1998.

FUTURE STATUS REPORT:

The 1996 Precursor Report is scheduled to be published by December 31, 1997. The next report to the Commission on the status of the ASP Program will be provided in November 1998.

L. Joseph Callan  
Executive Director  
for Operations

Attachments:

1. ASP Program Precursors for 1996
2. Conditional Core Damage Probability Results from ASP Program (Chart)

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**\*See previous concurrence \*See previous concurrence\***

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1996 At-Power Precursors Involving Initiating Events Sorted by Conditional Core Damage Probability

CCDP	Plant	Plant Type	Event Identifier	Description	Event Date
$2.1 \times 10^{-3}$	Catawba 2	PWR	LER 414/96-001	Loss of Offsite Power with Emergency Diesel-Generator B Unavailable	2/6/96
$2.1 \times 10^{-4}$	Wolf Creek	PWR	LER 482/96-001, -002	Reactor Trip with Loss of Train A of Essential Service Water and the Turbine-Driven Auxiliary Feedwater Pump Unavailable	1/30/96
$5.3 \times 10^{-5}$	Prairie Island 1 and 2	PWR	LER 282/96-012	Loss of Power to Safeguards Buses on Both Units	7/29/96
$7.0 \times 10^{-6}$	LaSalle 1 and 2	BWR	LER 373/96-007, -008	Concrete Sealant Fouls Cooling Water Systems	6/28/96
$*1.1 \times 10^{-5}$	Arkansas Nuclear One, Unit 1	PWR	LER 313/96-005	Reactor Trip and Subsequent Steam Generator Dryout	5/19/96

\*Preliminary results, Final results under review.

1996 At-Power Precursors Involving Unavailabilities Sorted by Increase in Core Damage Probability

ACDP	Plant	Plant Type	Event Identifier	Description	Event Date
$1.1 \times 10^{-4}$	Haddam Neck	PWR	LER 213/96-016	Potentially Inadequate RHR Pump NPSH Following a Large- or Medium-Break LOCA	8/1/96
$4.6 \times 10^{-5}$	Seabrook	PWR	LER 443/96-003	Turbine-Driven Emergency Feedwater Pump Unavailable Because of a Mechanical Seal Failure	5/21/96
$5.8 \times 10^{-6}$	Salem 1	PWR	LER 272/96-002	Charging Pump Suction Valves from the RWST Potentially Unavailable Because of Pressure Locking	1/10/96
$2.9 \times 10^{-6}$	Haddam Neck	PWR	LER 213/96-024	After a Residual Heat Removal Pump Seized, It Was Determined to Be Susceptible to Failure Since Being Overhauled in 1987	9/1/96
$1.8 \times 10^{-6}$	McGuire 2	PWR	LER 370/96-002	2B Emergency Diesel Generator Inoperable Due to Slow Instrumentation Response	3/6/96

1996 Shutdown Precursors Involving Initiating Events Sorted by Conditional Core Damage Probability

CCDP	Plant	Plant Type	Event Identifier	Description	Event Date
$1.7 \times 10^{-5}$	Byron 1	PWR	454/96-007	Transformer Bus Fault Causes a LOOP	5/23/96



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