Results, Trends, and Insights of the Accident Sequence Precursor Program

1.0 Introduction

This enclosure discusses the results of accident sequence precursor (ASP) analyses conducted by the staff as they relate to events that occurred during fiscal years (FYs) 2012 and 2013. Based on those results, this document also discusses the staff's analysis of historical ASP trends and the evaluation of the related insights.

2.0 Background

The U.S. Nuclear Regulatory Commission (NRC) established the ASP Program in 1979 in response to recommendations made in NUREG/CR-0400, "Risk Assessment Review Group Report," issued September 1978. The ASP Program systematically evaluates U.S. nuclear power plant (NPP) operating experience to identify, document, and rank the operating events most likely to lead to inadequate core cooling and severe core damage (i.e., precursors).

To identify potential precursors, the staff reviews plant events, including the impact of external events (e.g., fires, floods, and seismic events) from licensee event reports (LERs) and inspection reports (IRs) on a unit basis (i.e., a single event that affects a multiunit site is counted as a precursor for each unit). The staff then analyzes any identified potential precursors by calculating the probability of an event leading to a core damage state. A plant event can be one of two types—either (1) an occurrence of an initiating event, such as a reactor trip or a loss of offsite power (LOOP), with or without any subsequent equipment unavailability or degradation, or (2) a degraded plant condition depicted by the unavailability or degradation of equipment without the occurrence of an initiating event.

For the first type, the staff calculates a conditional core damage probability (CCDP). This metric represents a conditional probability that a core damage state is reached given an occurrence of an initiating event (and any subsequent equipment failure or degradation).

For the second type, the staff calculates an increase in core damage probability (ΔCDP). This metric represents the increase in core damage probability for a time period that a component or multiple components are deemed unavailable or degraded.

The ASP Program considers an event with a CCDP or a ΔCDP greater than or equal to 1×10^{-6} to be a precursor.[1] The ASP Program defines a *significant* precursor as an event with a CCDP or ΔCDP greater than or equal to 1×10^{-3}.

Figure 1 provides a flowchart showing the complete ASP analysis process.

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1 For initiating event analyses, the precursor threshold is a CCDP greater than or equal to 1×10^{-6} or the plant-specific CCDP for a non-recoverable loss of balance-of-plant systems, whichever is greater. This initiating event precursor threshold prevents reactor trips, with no losses of safety system equipment, from being precursors.

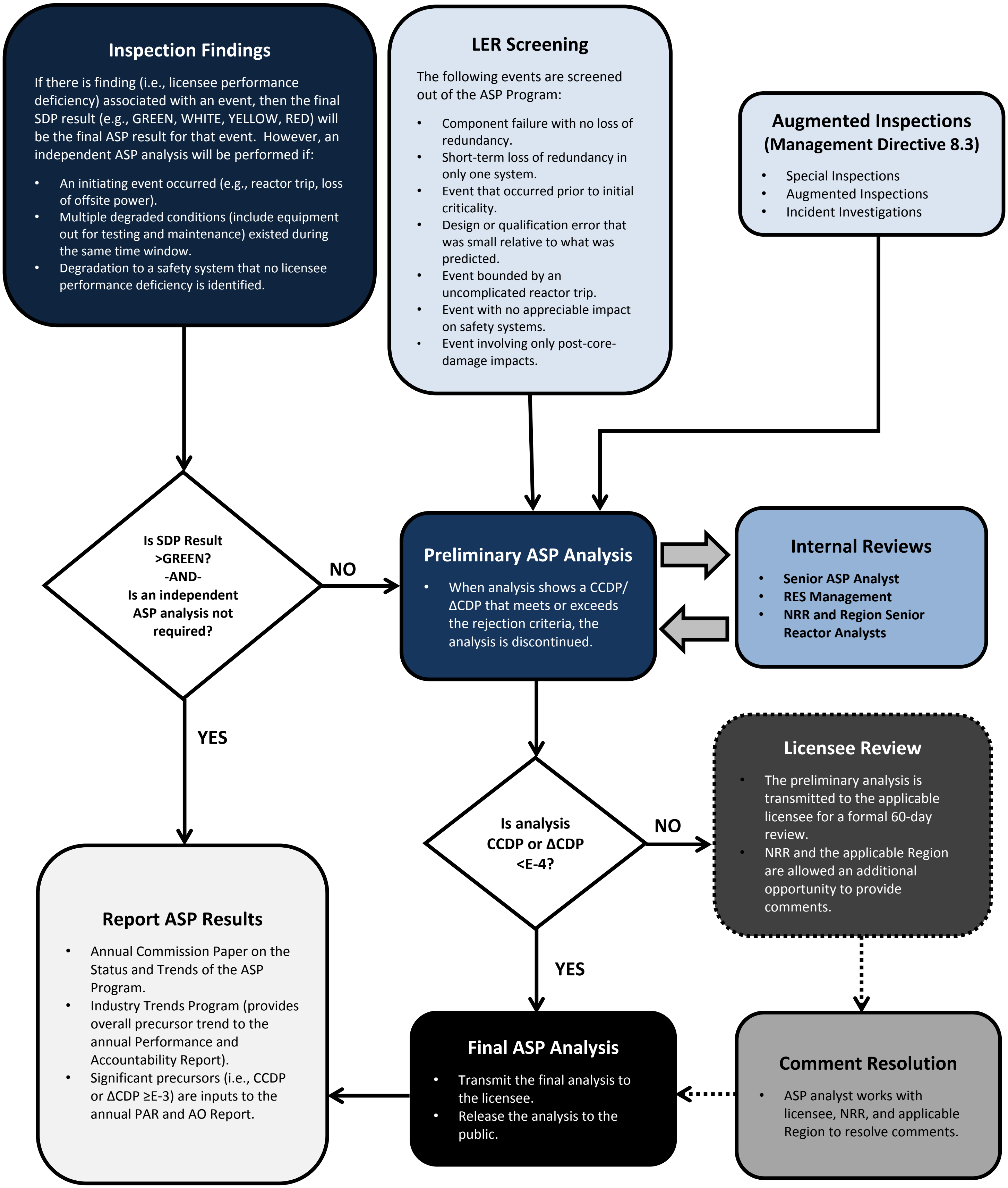

Figure 1. ASP process diagram

Program Objectives. The ASP Program has the following objectives:

- Provide a comprehensive, risk-informed view of NPP operating experience and a measure for trending core damage risk.
- Provide a partial validation of the current state of practice in risk assessment.
- Provide feedback to regulatory activities.

The NRC also uses the ASP Program as a means to monitor performance against the safety measures established in the agency's Congressional Budget Justification (Ref. 1), which was formulated to support the agency's safety and security strategic goals and objectives.[2] Specifically, the program provides input to the following safety measures:

- Zero events per year identified as a *significant* precursor of a nuclear reactor accident.
- No more than one significant adverse trend in industry safety performance (determination principally made from the Industry Trends Program (ITP) but partially supported by ASP results).

Program Scope. The ASP Program is one of three agency programs that assess the risk significance of events. The other two programs are the Significance Determination Process (SDP) and the event response evaluation process, as defined in Management Directive (MD) 8.3, "NRC Incident Investigation Program" or Inspection Manual Chapter (IMC) 309, "Reactive Inspection Decision Basis for Reactors." The SDP evaluates the risk significance of licensee performance deficiencies, while assessments performed under MD 8.3 or IMC 309 are used to determine the appropriate level of reactive inspection in response to a significant event. Compared to the other two programs, the ASP Program assesses an additional scope of operating experience at U.S. NPPs. For example, the ASP Program analyzes initiating events as well as degraded conditions where no identified deficiency occurred in the licensee's performance. The ASP Program scope also includes events with concurrent, multiple degraded conditions.

3.0 ASP Program Status

The following subsections summarize the status and results of the ASP Program as of September 30, 2013.

FY 2012 Analyses. The ASP analyses for FY 2012 identified eight precursors (six initiating events and two degraded conditions). All eight precursors occurred while the plants were at power. For two of the eight precursors, the performance deficiency identified under the Reactor Oversight Process (ROP) fully captured the risk-significant aspects of the event. In these cases, the SDP significance category (i.e., the "color" of the finding) is reported in the ASP Program. For the remaining six events an independent ASP analysis was performed to gain an accurate understanding of the increase in risk during the event. In these events it may be that there was no performance deficiency identified, or that there were multiple performance deficiencies that contributed to the overall significance of the event.

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2 The performance measures involving precursor data (i.e., number of *significant* precursors and trend of all precursors) are the same for FYs 2005–2013.

The CCDP for three FY 2012 ASP analyses exceeded 1×10^{-4} (Wolf Creek precursor event that occurred on January 13, 2012; Byron, Unit 2, precursor event that occurred on January 30, 2012; and River Bend precursor event that occurred on May 24, 2012); therefore, the analyses were sent for a formal 60-day review to the licensees, Regions IV, III, and IV, respectively, and the Office of Nuclear Reactor Regulation (NRR).[3] All of the other ASP analyses were issued as final after completion of internal reviews in accordance with the ASP review process (see Ref. 2 and Figure 1).

Table 1 presents the results of the staff's ASP analyses for FY 2012 precursors that involved initiating events. Table 2 presents the analysis results for FY 2012 precursors that involved degraded conditions.

Table 1. FY 2012 Precursors Involving Initiating Events

Event Date	Plant	Description	CCDP
1/13/12	Wolf Creek	Multiple switchyard faults cause reactor trip and subsequent loss of offsite power. ***LER 482/12-001***	5×10^{-4}
1/30/12	Byron 2	Transformer and breaker failures cause loss of offsite power, reactor trip, and de-energized safety buses. ***LER 454/12-001***	1×10^{-4}
4/4/12	Catawba 1	Reactor trip caused by faulted reactor coolant pump cable and an error in protective relay. ***LER 413/12-001***	9×10^{-6}
5/22/12	Browns Ferry 3	Reactor trip and subsequent loss of offsite power caused by failure of unit station system transformer differential relay. ***LER 296/12-003***	2×10^{-5}
5/24/12	River Bend	Loss of normal service water, circulating water, and feedwater caused by electrical fault. ***LER 458/12-003***	3×10^{-4}
7/23/12	Oyster Creek	Turbine-generator trip and reactor scram following a transmission line trip causing a loss of offsite power. ***LER 219/12-001***	5×10^{-5}

Table 2. FY 2012 Precursors Involving Degraded Conditions

Condition Duration	Plant	Description	ΔCDP/ SDP Color
6 months	San Onofre 3	Steam generator tube integrity. ***Enforcement Action (EA)-13-083***	WHITE[4]
194 days	Point Beach	Inadequate maintenance leads to failure of turbine-driven auxiliary feedwater pump. ***EA-12-220***	WHITE

FY 2013 Analyses. The staff immediately performs an initial review of events to determine if they have the potential to be *significant* precursors. Specifically, the staff reviews a combination of LERs (per Title 10 of the *Code of Federal Regulations* (10 CFR) 50.73, "Licensee Event Report System," and daily event notification reports (per 10 CFR 50.72, "Immediate Notification Requirements for Operating Nuclear Power Reactors") to identify potential *significant* precursors. The staff has completed the initial review of FY 2013 events and identified no potentially *significant* precursors. The staff will inform the Commission if *significant* precursors are identified during the more detailed evaluations of events. The staff will perform full ASP

[3] The preliminary ASP analysis for River Bend is currently undergoing the 60-day review by the licensee, NRR, and Region IV. The analysis results may change prior to the analysis being finalized.

[4] A WHITE finding corresponds to a licensee performance deficiency of low-to-moderate safety significance and has an increase in core damage frequency in the range of greater than 10^{-6} to 10^{-5} per reactor year.

analyses of applicable events after the licensee and the NRC complete their follow-up actions, such as inspection and condition reporting.

4.0 Industry Trends

This section discusses the results of trending analyses for all precursors and *significant* precursors.

Statistically Significant Trend. Statistically significant is defined in terms of the "p-value." A p-value is a probability indicating whether to accept or reject the null hypothesis that no trend exists in the data. P-values of less than or equal to 0.05 indicate that there is 95 percent confidence that a trend exists in the data (i.e., reject the null hypothesis of no trend).

Data Coverage. The data period for the ASP trending analyses is a rolling 10-year period in alignment with the ITP. The following caution applies to the data coverage of *significant* precursors.

- The data for *significant* precursors includes events that occurred during FY 2013. The results for FY 2013 are based on the staff's screening and review of a combination of LERs and daily event notification reports (as of September 30, 2013). The staff analyzes all potential *significant* precursors immediately.
- The ITP monitors a significant events indicator, which includes precursors with CCDP or ΔCDP greater than or equal to $1{\times}10^{-5}$. The ITP and ASP Program are not two independent indicators of industry performance, but are two separate programs that make use of some of the same data.

4.1 Occurrence Rate of All Precursors

The NRC's ITP provides the basis for addressing the agency's safety-performance measure on the "number of statistically significant adverse trends in industry safety performance" (one measure associated with the safety goal established in the NRC's Strategic Plan). The mean occurrence rate of all precursors identified by the ASP Program is one indicator used by the ITP to assess industry performance.[5]

Results. A review of the data for the rolling 10-year period reveals the following insights:

- The mean occurrence rate of all precursors does not exhibit a trend that is statistically significant (p-value = 0.32) for the period from FY 2003–2012 (see Figure 2).

[5] The occurrence rate is calculated by dividing the number of precursors by the number of reactor years.

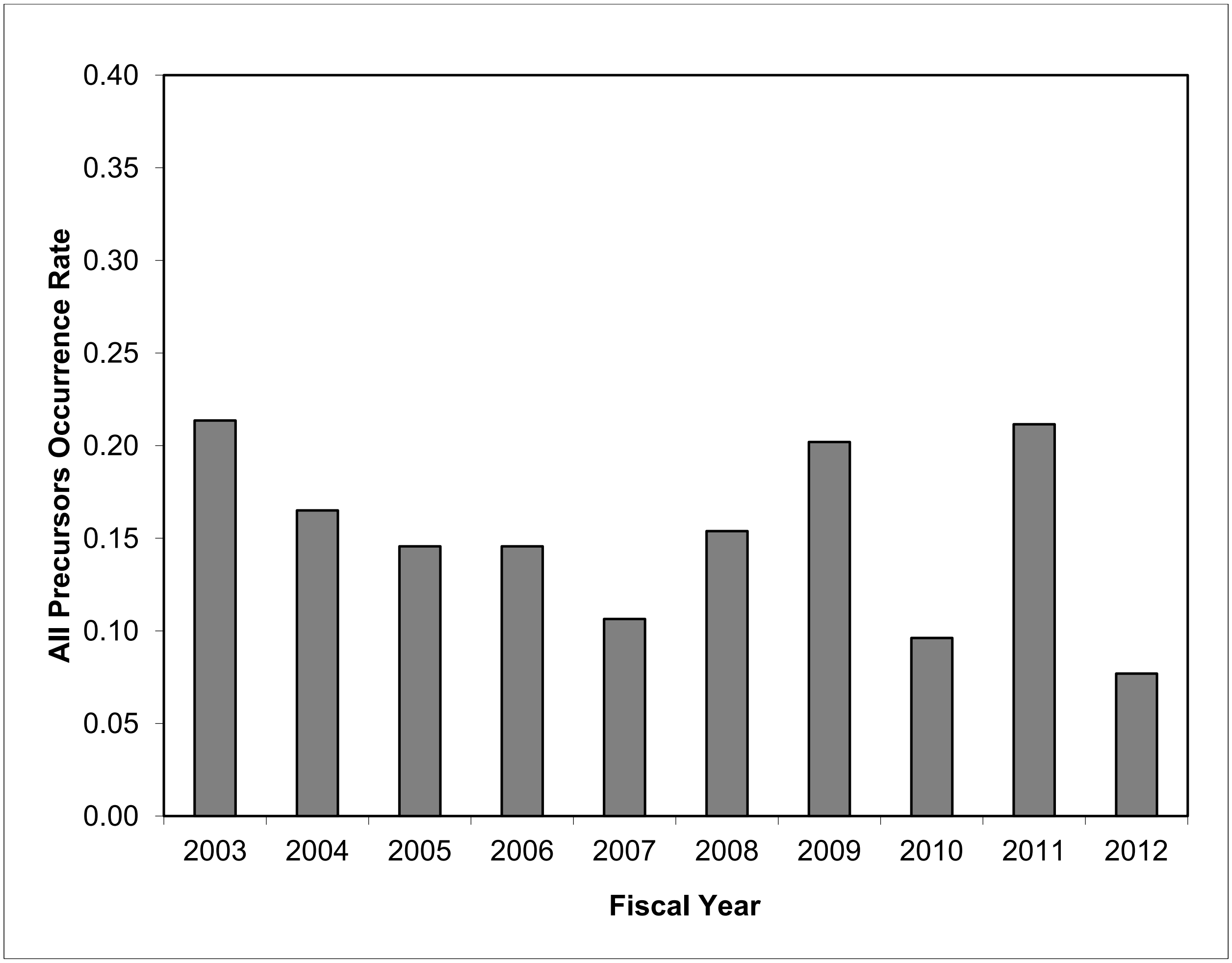

Figure 2. Total precursors

4.2 *Significant* Precursors

The ASP Program provides the basis for the safety measure of zero "number of significant accident sequence precursors of a nuclear reactor accident" (one measure associated with the safety goal established in the NRC's Congressional Budget Justification (Ref. 1)).

Results. A review of the data for the rolling 10-year period reveals the following insights:

- No *significant* precursors have been identified in the last 10 years.

- The last *significant* precursor was identified in FY 2002. The staff identified a *significant* precursor involving concurrent, multiple-degraded conditions at Davis-Besse.[6]

[6] Ref. 3 provides a complete list of all *significant* precursors from 1969–2012.

5.0 Insights and Other Trends

The following sections provide additional ASP trends and insights for the period from FY 2003–2012.

5.1 Occurrence Rate of Precursors with a CCDP or ΔCDP ≥ 1×10^{-4}

Precursors with a CCDP or ΔCDP ≥ 1×10^{-4} are considered important in the ASP Program because they generally have a CCDP higher than the annual core damage probability (CDP) estimated by most plant-specific probabilistic risk assessments (PRAs).

The staff identified three such precursors that occurred during FY 2012. Over the past 10-year period (FY 2003 to FY 2012), a total of eight precursors with CCDP or ΔCDP ≥ 1×10^{-4} occurred. Table 3 summarizes these *important* precursors over the last three years. The staff issued a total of five information notices and one bulletin for four of these events. In addition, the staff issued four greater than GREEN SDP findings (in addition to the two RED findings) as a result of these events.

Table 3. FY 2010–2012 *Important* Precursors (i.e., CCDP or ΔCDP ≥ 1×10^{-4})

Date	Plant (Risk Measure)	Event or Condition	Risk Insights
3/28/10	H. B. Robinson **CCDP = 4×10^{-4}**	Fire causes loss of non-vital busses along with a partial loss of offsite power with reactor coolant pump seal cooling challenges. ***LER 261/10-002***	Neither the fire nor the minor equipment failures individually should have led to a high risk event. However, poor operator performance created a much higher risk scenario. Risk was dominated by transient-induced reactor coolant pump seal loss of coolant accidents (LOCAs). The SDP assessment resulted in two WHITE findings.
10/23/10	Browns Ferry 1 **RED Finding[7] (7×10^{-4})**	Failure to establish adequate design control and perform adequate maintenance causes valve failure that led to a residual heat removal loop being unavailable. ***EA-11-018***	A valve failure coupled with a hypothetical fire that required execution of self-induced station blackout (SBO) procedures would have led to an unrecoverable situation. The self-induced SBO procedures added one to two orders of magnitude to the risk of this event. Risk was dominated by fire-initiated scenarios.
6/7/11	Fort Calhoun **RED Finding (4×10^{-4})**	Fire in safety-related 480-volt electrical breaker because of deficient design controls during breaker modifications. Eight other breakers were susceptible to similar fires. ***EA-12-023***	The plant operated with a poorly designed modification to nine breakers, all of which had a potential for a fire, especially in a relatively minor seismic event. Risk comes from a very wide variety of sequences.

[7] A RED finding corresponds to a licensee performance deficiency of high safety significance and has an increase in core damage frequency greater than 10^{-4}.

Date	Plant (Risk Measure)	Event or Condition	Risk Insights
8/23/11	North Anna, Unit 1 **CCDP = 3×10^{-4}**	Dual unit loss of offsite power caused by earthquake that coincided with the Unit 1 turbine-driven auxiliary feedwater (AFW) pump being out-of-service because of testing and the subsequent failure of a Unit 2 emergency diesel generator (EDG). ***LER 338/11-003***	Earthquake coupled with routine maintenance on the AFW pump and an unrelated failure of an EDG. Risk was dominated by SBO sequences. The SDP assessment resulted in a WHITE finding.
1/13/12	Wolf Creek **CCDP = 5×10^{-4}**	Multiple switchyard faults cause reactor trip and subsequent loss of offsite power. ***LER 482/12-001***	A moderate length LOOP (two to three hours) caused by equipment failures in the switchyard. Risk was dominated by SBO sequences. ASP looked at the LOOP initiating event while the SDP analysis performed a condition assessment on the loss of the startup transformer resulting in a YELLOW finding.
1/30/12	Byron, Unit 2 **CCDP = 1×10^{-4}**	Transformer and breaker failures cause loss of offsite power, reactor trip, and de-energized safety buses. ***LER 454/12-001***	The key issue for this event is the potential for operators to fail to recognize this scenario. Operator errors could lead to SBO-like sequences.
5/24/12	River Bend **CCDP = 3×10^{-4}**	Loss of normal service water, circulating water, and feedwater due to electrical fault. ***LER 458/12-003***	Initiating event coupled with postulated loss of safety-related service water would lead to complete loss of heat sink.

Results. A review of the data for FY 2003–2012 reveals the following insights:

- The mean occurrence rate of precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4} exhibited a statistically significant (p-value = 0.0042) trend during this same period (see Figure 3).

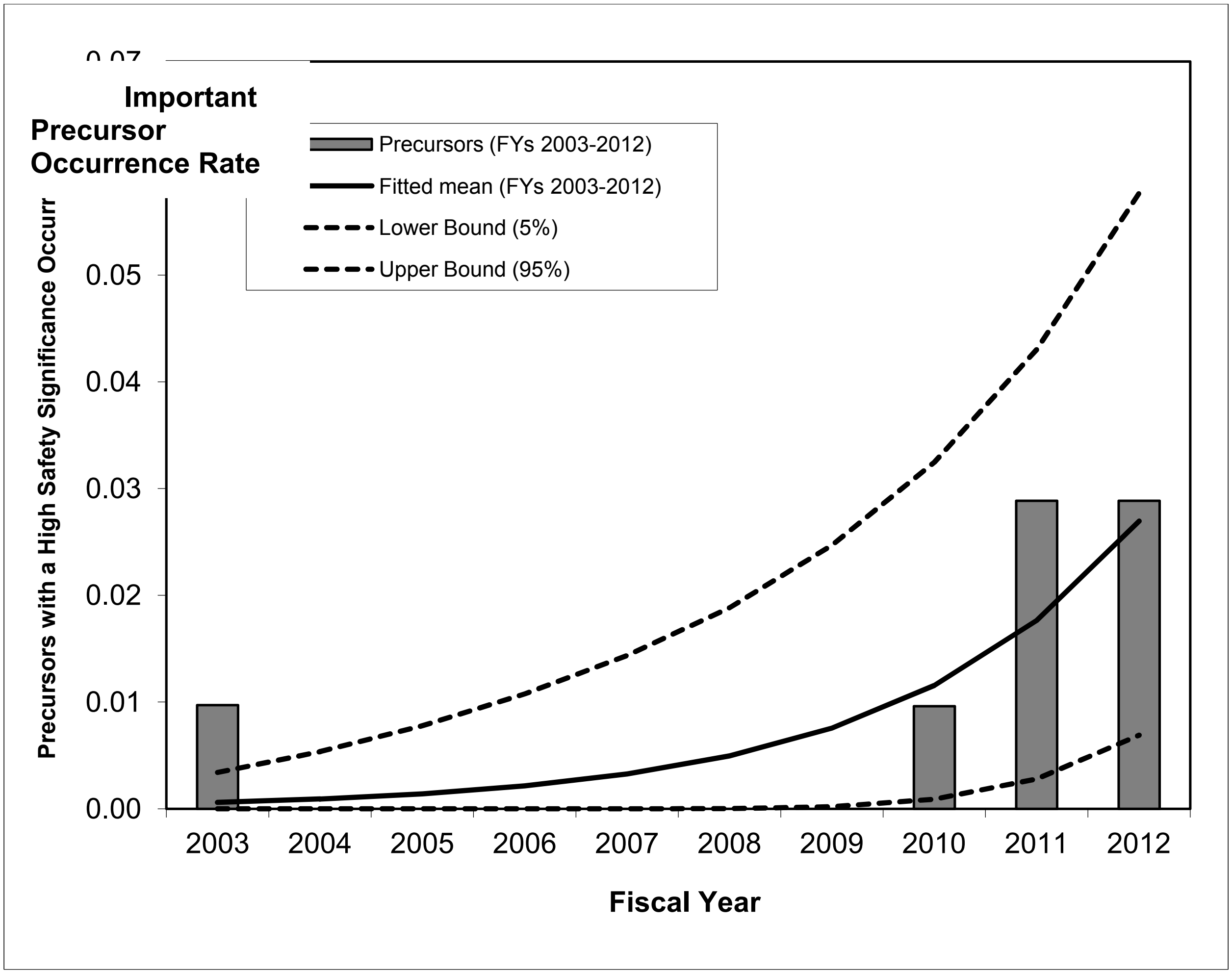

Figure 3. ***Important*** **Precursors (10 year)**

- Figure 3 shows that one precursor with a CCDP or ΔCDP greater than or equal to 1×10^{-4} occurred between 2003 and 2009 and seven such precursors have occurred since 2010.
  - Historically, 28 *important* precursors occurred over the last 20 years (Figure 3A). Thus, historic occurrence rates were somewhat higher.
  - Of these 28 *important* precursors, 36 percent involved a LOOP initiating event. This is generally consistent with recent experience.

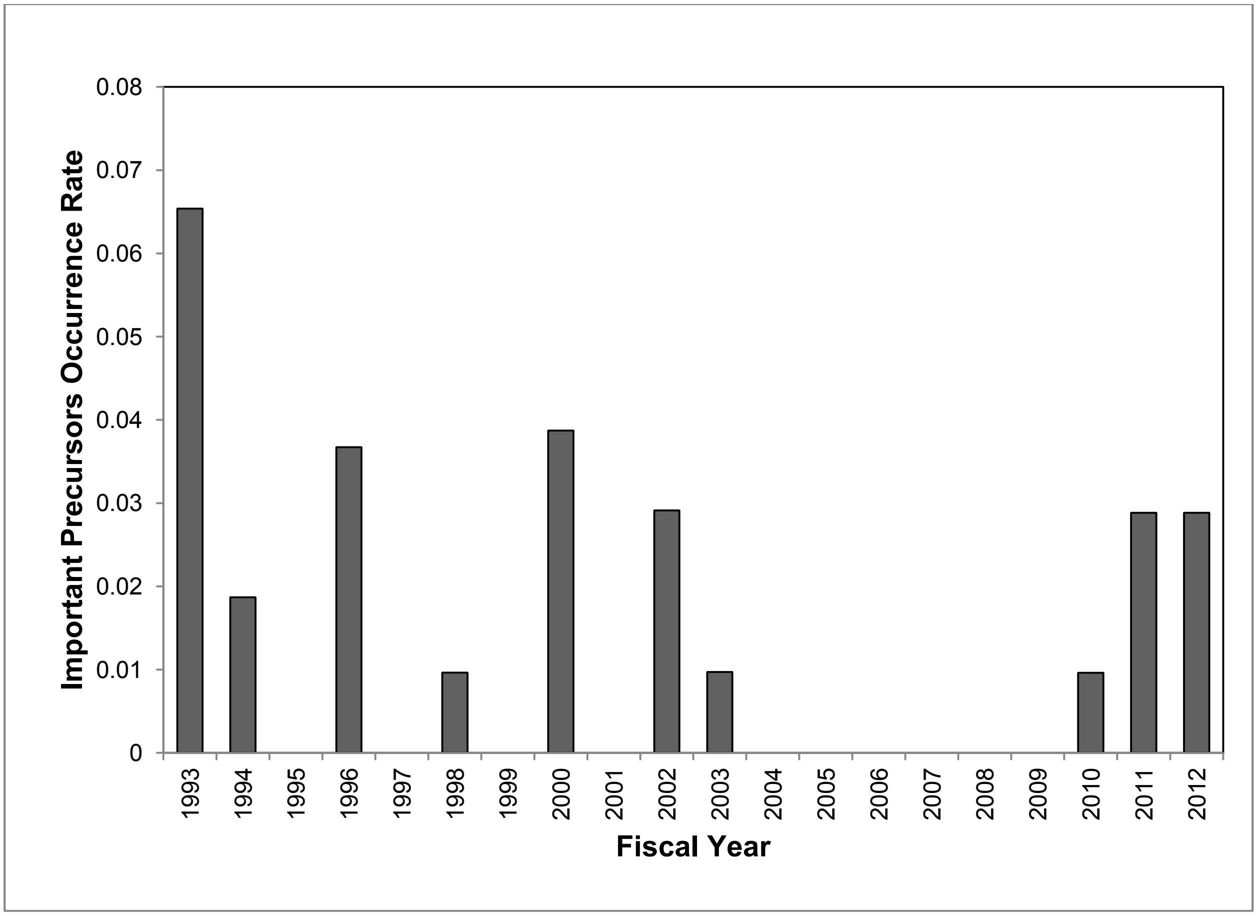

Figure 3A. ***Important*** **Precursors (20 year)**

- The events in this group over the last 10 years involve differing reactor types, causes, systems, and components.

A review of the *important* precursors in Table 3 reveals the following:

- Six of the seven precursors involved electrical-related events in electrical distribution systems. Five of the electrical-related events resulted in reactor trips, of which three were associated with LOOP initiating events. Fort Calhoun was in cold shutdown during the sixth electrical-related non-trip event.

- LOOP initiating events with no complications are not usually *important* precursors. However, the three LOOP events reviewed here involved one or more additional failures and/or test/maintenance unavailabilities of standby safety equipment that resulted in higher CCDPs (North Anna, Byron, and Wolf Creek). The LOOP at Byron was unique in that operator action was required to establish emergency power to the safety buses because of a design vulnerability associated with a single-phase open circuit condition.[8]

- Two precursors involved fires of electrical components caused by electrical faults (Robinson and Fort Calhoun). In the case of Robinson, multiple electrical fires occurred during the initial fault, and a second fire was caused during plant restoration (i.e., the

[8] See NRC Bulletin 2012-01, “Design Vulnerabilities in Electric Power System,” (Ref. 6).

operating crew attempted to reset an electrical distribution system control relay before isolating the fault, which re-initiated the electrical fault and caused a second fire). The fires at Robinson were extinguished by plant personnel using dry chemical fire extinguishers. The electrical fire in a switchgear room at Fort Calhoun was extinguished by the automatic fire suppression system.

- Four of the five precursors involving reactor trips had failures that were recoverable. In fact, the recovery actions were successfully implemented by the operators during each of these actual events.[9] These recovery actions were credited in the ASP analysis and contributed to risk reductions in these four events.

- Two of the seven precursors did not result in a reactor trip, but involved conditions resulting in the unavailability of safety components for some period of time. These components were not recoverable in the time necessary to mitigate a hypothetical initiating event.

- Three precursors involved failures and initiators that contributed to rarely seen accident sequences.
  - The Robinson electrical fault with subsequent reactor trip resulted in a complete loss of reactor coolant pump (RCP) cooling and a partial loss of seal injection for 39 minutes. In PRA models, including the standardized plant analysis risk (SPAR) models, loss of RCP seal injection and cooling significantly increases the likelihood of a RCP seal loss-of-coolant accident (LOCA) within 13 minutes of the loss of seal injection and cooling. The operators restarted the charging pumps within one minute; however, an open valve in the charging system diverted flow away from the RCP seals. The operators recovered seal cooling at 13 minutes. Recovery of seal injection was not credited in the ASP analysis and recovery of seal cooling within 13 minutes was assigned a very high failure probability (0.8), which contributed to the high risk result.
  - The Bryon Unit 2 LOOP and design vulnerability resulted in the complete loss of useful electrical power to the safety buses. The operators were able to diagnose the problem and restore power from the emergency diesel generators (EDGs) to the safety buses in eight minutes. Offsite power was restored to both safety buses approximately 34 hours after the LOOP occurred. Recovery of emergency power to the safety bus prior to station battery depletion was modeled in the ASP analysis.
  - The beyond design basis earthquake at North Anna induced a LOOP event and subsequent reactor trips in both units. During the LOOP event, one of four EDGs onsite failed, and the Unit 1 turbine-driven auxiliary feedwater (AFW) pump was out of service for surveillance testing. The station blackout diesel generator was manually aligned to the safety bus in 49 minutes. The turbine-driven AFW pump was placed back into service in 33 minutes. Offsite power was restored to all four safety buses approximately nine hours after the LOOP occurred. These recovery actions were modeled in the ASP analysis.

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9 Even though recovery actions were successfully accomplished during the actual events, the ASP Program does not take complete credit for these successful human actions. Human Reliability Analysis (HRA) is performed for each recovery action to calculate the probability of failure to recover. HRA considers complications in human performance that were observed during the actual event and impacts on human performance, both negative and positive, that would be experienced during each postulated accident sequence.

5.2 Initiating Event and Degraded Condition Precursor Subgroup Trends

A review of the data for FY 2003–2012 yields insights described below.

Initiating Events

- The mean occurrence rate of precursors involving initiating events does not exhibit a trend that is statistically significant (p-value = 0.37) for the period from FY 2003–2012, as shown in Figure 4.

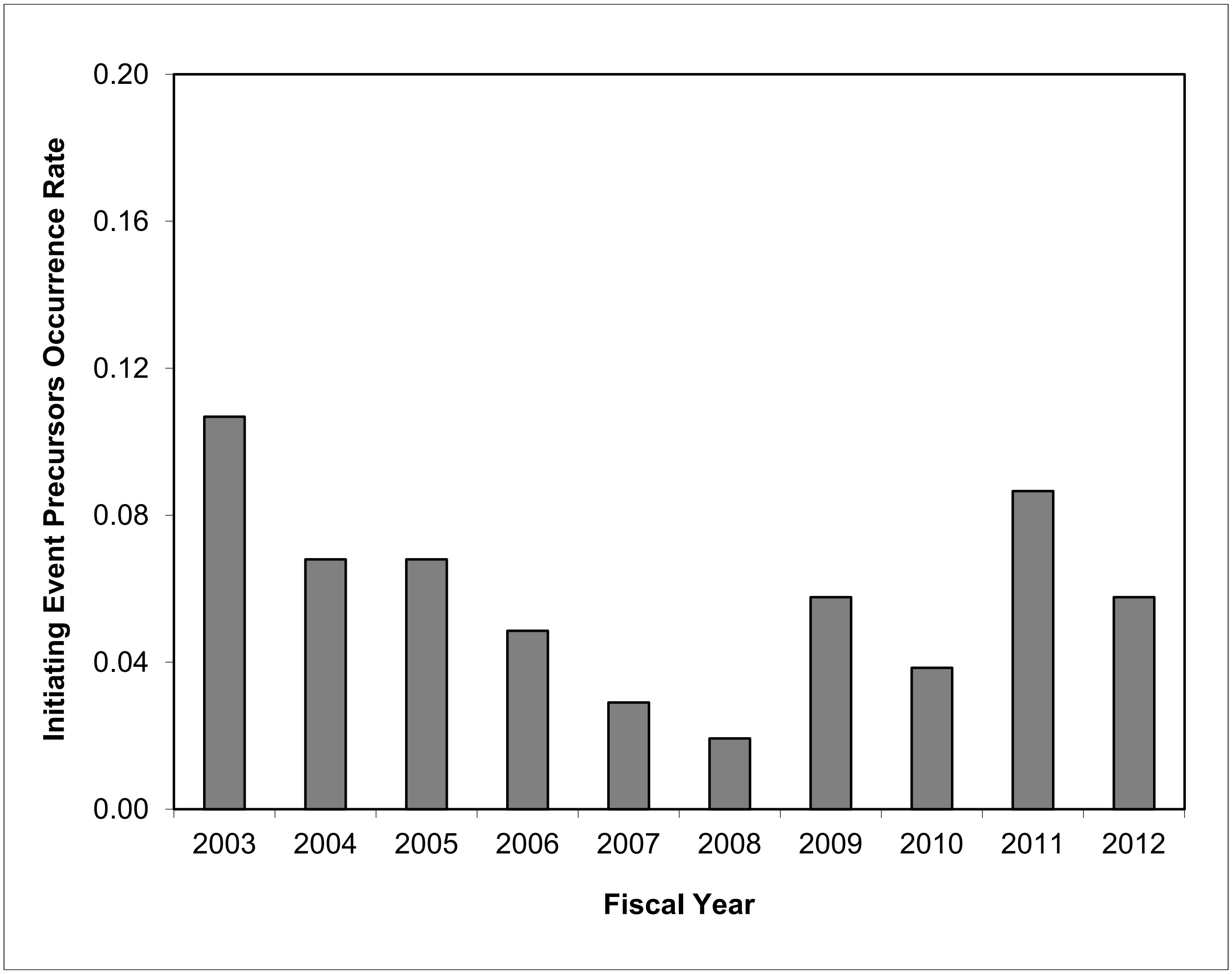

Figure 4. Precursors involving initiating events

- Of the 60 precursors involving initiating events during FY 2003–2012, 60 percent were LOOP events. This is expected because uncomplicated transients typically do not exceed the ASP threshold (10^{-6}), while essentially all LOOPs do exceed the threshold. While the frequency of complicated transients is about the same as the frequency of LOOPs, the risk estimates for LOOPs are somewhat higher.

Degraded Conditions

- The mean occurrence rate of precursors involving degraded conditions does not exhibit a trend that is statistically significant (p-value = 0.52) during FY 2003–2012, as shown in Figure 5.

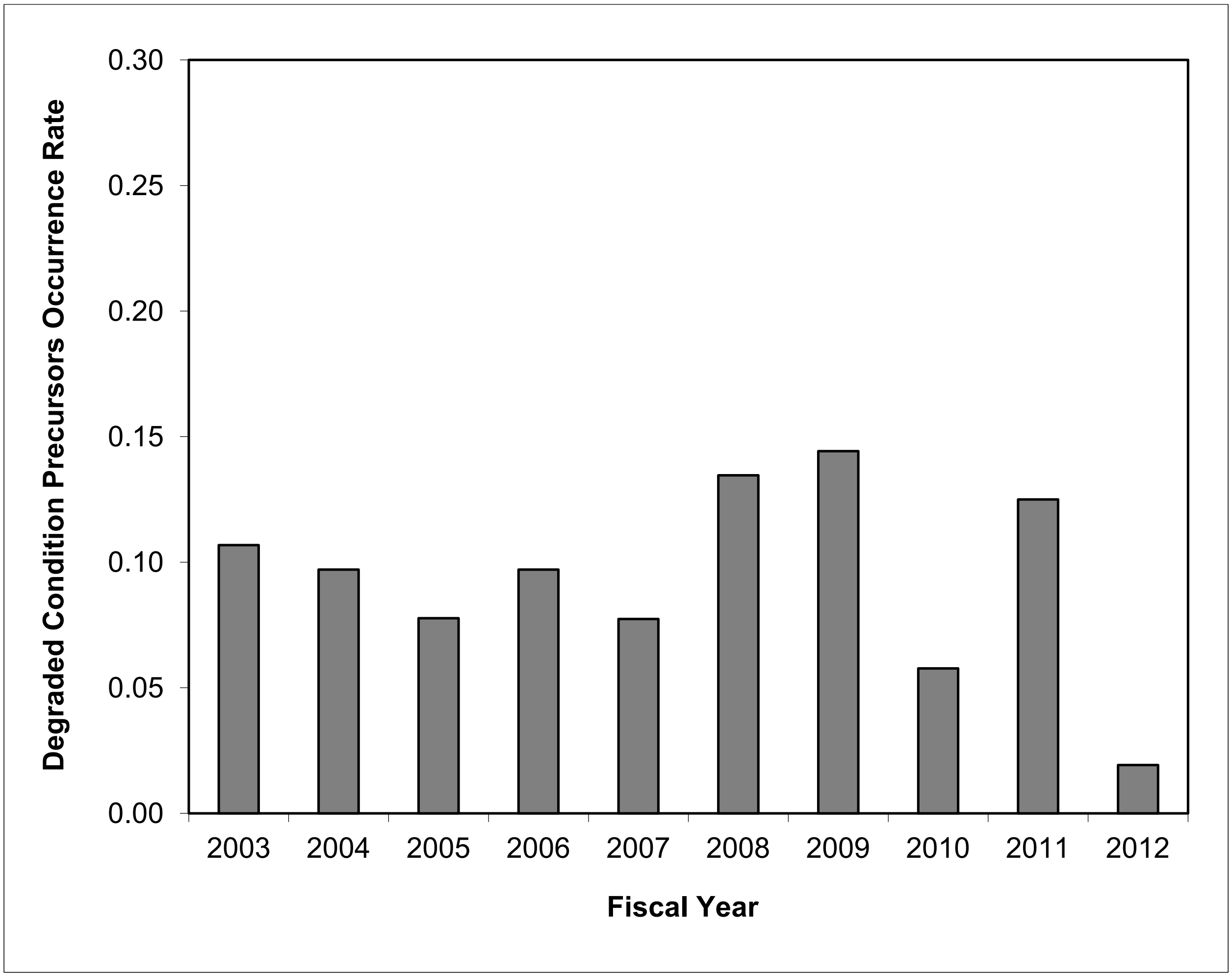

Figure 5. Precursors involving degraded conditions

- Over the past 10 years, precursors involving degraded conditions outnumbered initiating events by 60 percent.

- From FY 2003–2012, 27 percent of precursors involved degraded conditions existing for a decade or longer.[10] Of these precursors, 42 percent involved degraded conditions dating back to initial plant construction.

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[10] Note that although these degraded conditions lasted for many years, ASP analyses limit the exposure period to 1 year.

5.3 Precursors Involving a Complete Loss of Offsite Power Initiating Events

In FY 2012, five precursors resulted from a complete LOOP initiating event. Typically, all complete LOOP events meet the precursor threshold.

Results. A review of the data for FY 2003–2012 leads to the following insights:

- The mean occurrence rate of precursors resulting from a LOOP does not exhibit a trend that is statistically significant (p-value = 0.45) for the period from FY 2003–2012, as shown in Figure 6.

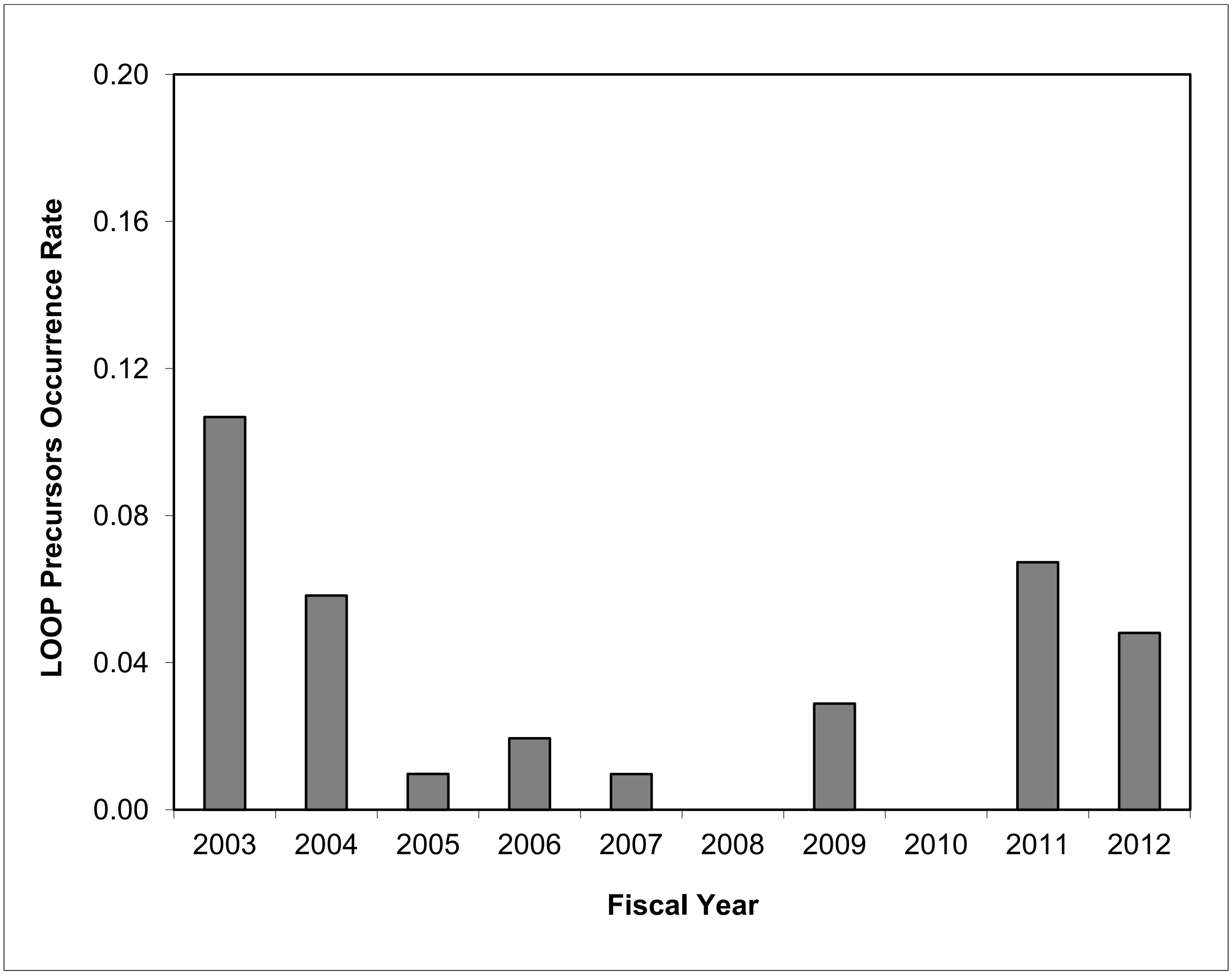

Figure 6. Precursors involving LOOP events

- Of the 36 LOOP precursors that occurred during FY 2003–2012, 33 percent resulted from external events and 33 percent resulted from a degraded electrical grid outside of the NPP boundary.
  - Eight of the 12 grid-related LOOP precursors were the result of the 2003 Northeast Blackout.
  - Seven of the 12 LOOP precursors that were caused by external events occurred in FY 2011. This is unusual and unprecedented, but there is no indication of a trend of these events.

- Four of the 36 LOOP precursor events during FY 2003–2012 involved a simultaneous unavailability of an emergency power system train.

5.4 Precursors at BWRs and PWRs Subgroup Trends

A review of the data for FY 2003–2012 reveals the results for boiling-water reactors (BWRs) and pressurized-water reactors (PWRs) described below.

BWRs

- The mean occurrence rate of precursors that occurred at BWRs does not exhibit a trend that is statistically significant (p-value = 0.71) for FY 2003–2012, as shown in Figure 7.

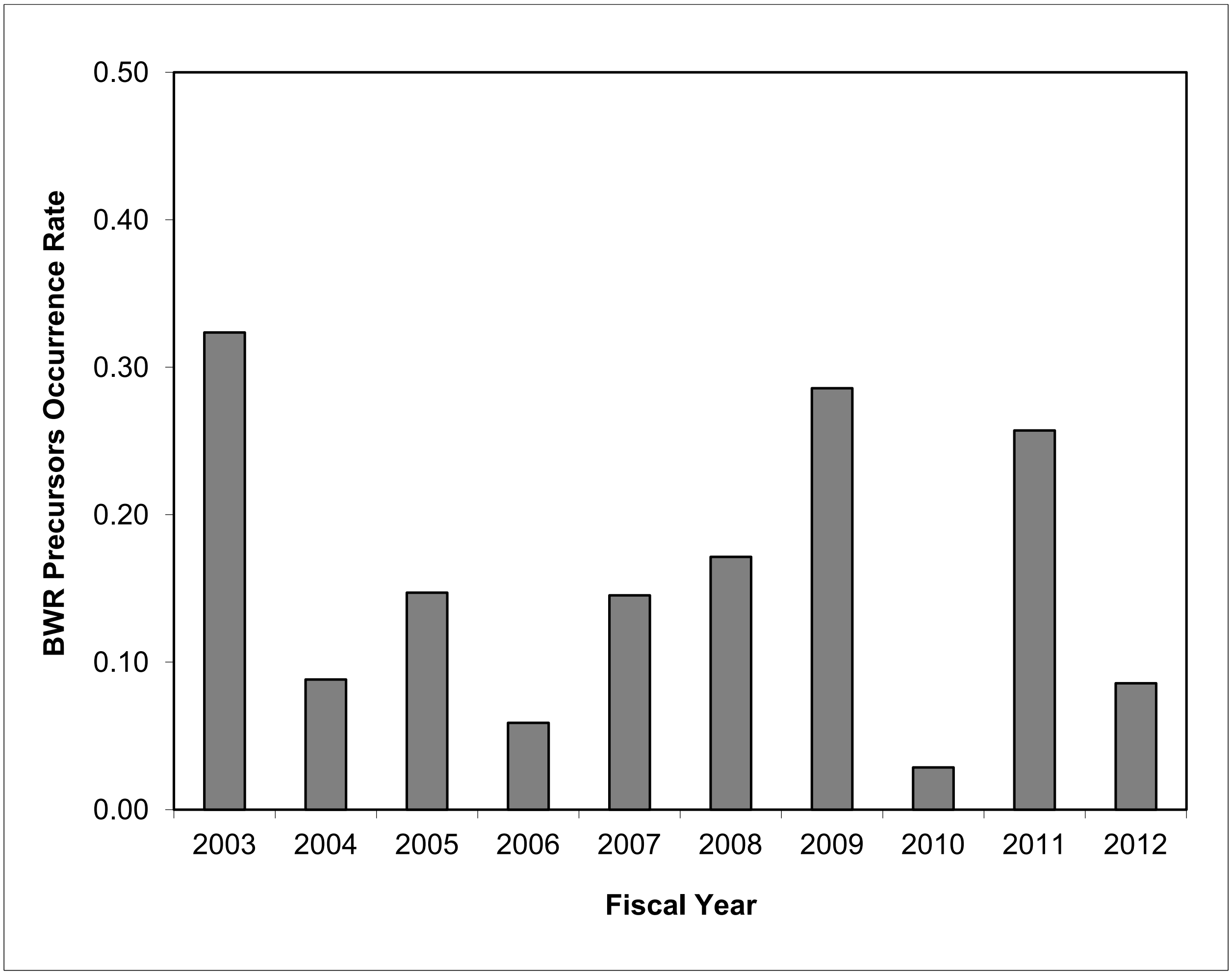

Figure 7. Precursors involving BWRs

- LOOP events contributed to 63 percent of precursors involving initiating events at BWRs.

- Of the 31 precursors involving the unavailability of safety-related equipment that occurred at BWRs during FY 2003–2012, most were caused by failures in the emergency power system (35 percent), emergency core cooling systems (23 percent), safety-related cooling water systems (13 percent), or electrical distribution system (10 percent).

PWRs

- The mean occurrence rate of precursors that occurred at PWRs does not exhibit a trend that is statistically significant (p-value = 0.20) for FY 2003–2012, as shown in Figure 8.

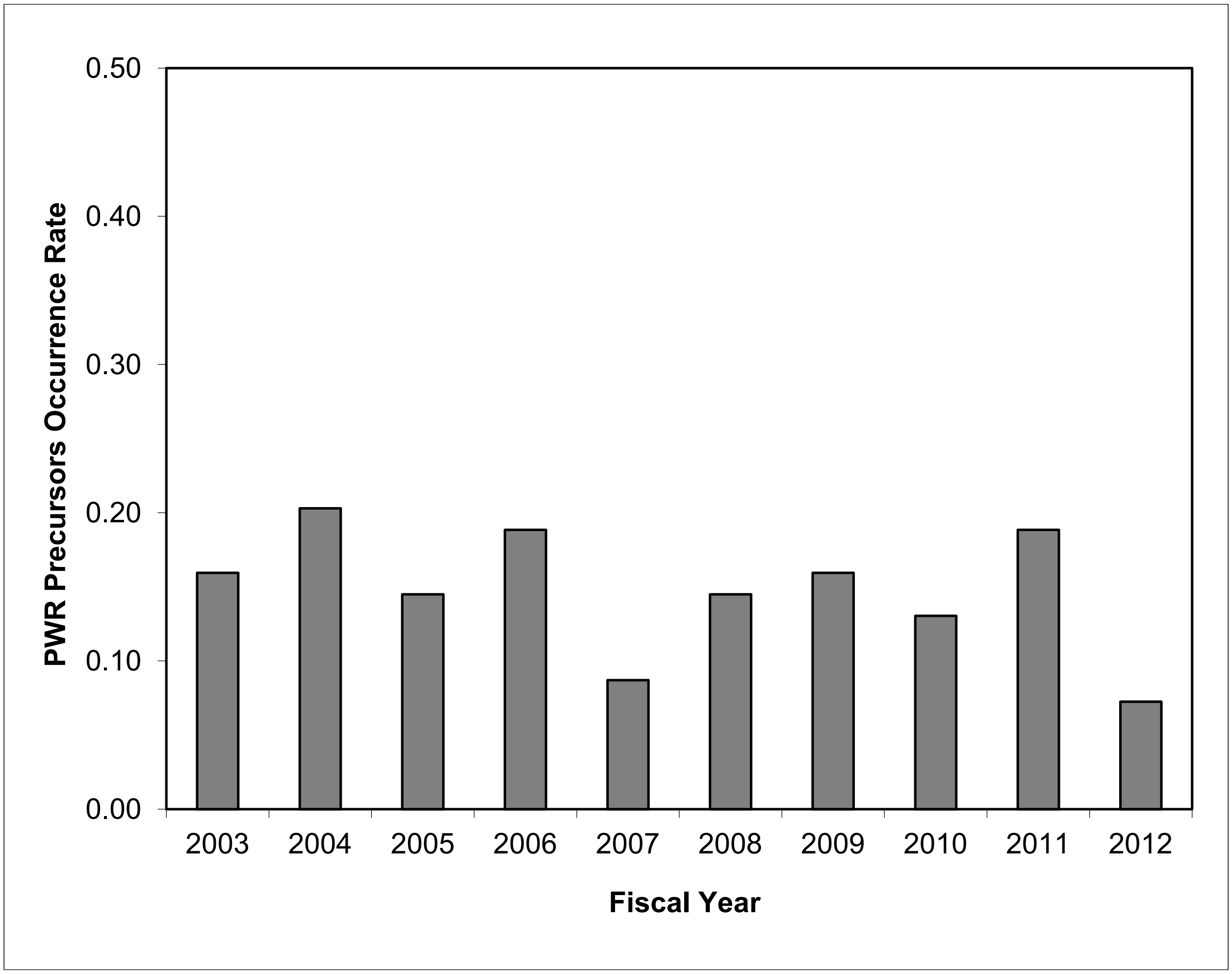

Figure 8. Precursors involving PWRs

- LOOP events contribute 58 percent of precursors involving initiating events at PWRs.

- Of the 66 precursors involving the unavailability of safety-related equipment that occurred at PWRs during FY 2003–2012, most were caused by failures in the emergency power system (27 percent), emergency core cooling systems (14 percent), auxiliary feedwater system (18 percent), safety-related cooling water systems (14 percent), or electrical distribution system (14 percent).
  - Of the 9 precursors involving failures in the emergency core cooling systems, 7 precursors (78 percent) were because of conditions affecting sump recirculation during postulated LOCAs of varying break sizes. Design errors caused most of these precursors (71 percent).

- Of the 12 precursors involving failures of the auxiliary feedwater system, random hardware failures (58 percent) and design errors (42 percent) were the largest failure contributors. Eleven of the 12 precursors (92 percent) involved the unavailability of the turbine-driven auxiliary feedwater pump train.
- Of the 18 precursors involving failures of the emergency power system, 15 precursors (83 percent) were from hardware failures.
- Design errors contributed 41 percent of all precursors involving the unavailability of safety-related equipment that occurred at PWRs during FY 2003–2012.

5.5 Integrated ASP Index

The staff derives the integrated ASP index for order-of-magnitude comparisons with industry-average core damage frequency (CDF) estimates derived from probabilistic risk assessments (PRAs) and the NRC's standardized plant analysis risk (SPAR) models. The index or CDF from precursors for a given fiscal year is the sum of CCDPs and ΔCDPs in the fiscal year divided by the number of reactor-operating years in the fiscal year.

The integrated ASP index includes the risk contribution of a precursor for the entire duration of the degraded condition (i.e., the risk contribution is included in each fiscal year that the condition exists). The risk contributions from precursors involving initiating events are included in the fiscal year that the event occurred.

Examples. A precursor involving a degraded condition is identified in FY 2011 and has a ΔCDP of 5×10^{-6}. A review of the LER reveals that the degraded condition has existed since a design modification that was performed in FY 2007. In the integrated ASP index, the ΔCDP of 5×10^{-6} is included in FY 2007, 2008, 2009, 2010, and 2011 and is not prorated for any portion of the year that this condition existed but rather implemented for the entire year, which conservatively estimates the risk contribution during the first and last year. For an initiating event occurring in FY 2011, only FY 2011 includes the CCDP from this precursor.

Results. Figure 9 depicts the integrated ASP indices for FY 2003–2012. A review of the ASP indices leads to the following insights:

- Based on the order of magnitude (10^{-5}), the average integrated ASP index for the period from FY 2003–2012 is consistent with the CDF estimates from the SPAR models and industry PRAs.

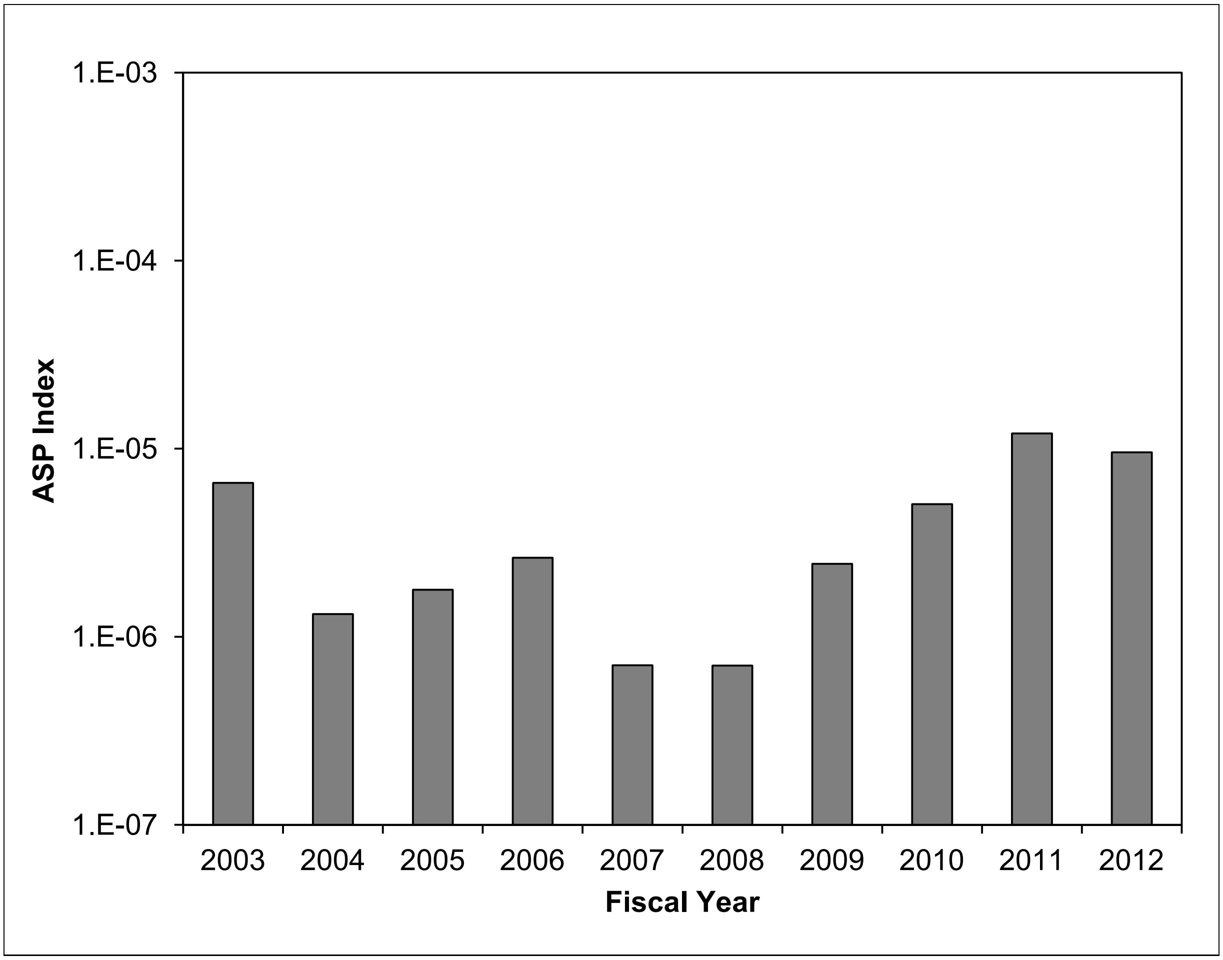

Figure 9. Integrated ASP index

- Precursors over the FY 2003–2012 period made the following contributions to the average integrated ASP index:
  - The average integrated ASP index resulted from contributions from the 157 precursors.
  - The number of precursors was a little higher than typical in FY 2011 and a little lower than typical in FY 2012. However, the value of this index is relatively high in both FY 2011 and FY 2012 because of the increase in precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4}, which tends to drive the indicator much more than the number of precursors. From a broad industry perspective, this increase is not viewed to be significant.

Limitations. Using CCDPs and ΔCDPs from ASP results to estimate CDF is difficult because (1) the mathematical relationship between CCDPs, ΔCDPs, and CDF requires a significant level of detail, (2) statistics for frequency of occurrence of specific precursor events are sparse, and (3) the assessment must also account for events and conditions that did not meet the ASP precursor criteria.

The integrated ASP index provides the contribution of risk (per fiscal year) resulting from precursors and cannot be used for direct trending purposes because the discovery of precursors involving longer-term degraded conditions in future years may change the cumulative risk from the previous year(s).

5.6 Operating Experience Insights Feedback for PRA Standards and Guidance

A secondary objective of the ASP Program is to provide insights into the current state of practice in risk assessment. ASP events from this fiscal year were reviewed against the approaches to PRA described in the American Society of Mechanical Engineers (ASME)/ American Nuclear Society (ANS) RA-S-2008, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," (Ref. 4), as endorsed in Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," (Ref. 5). This review sought to identify aspects of the events for which the risk-significant ASME/ANS PRA Standard did not provide guidance. None of the events indicated an inadequacy in the state of PRA practice as described in ASME/ANS RA-Sa-2009.

6.0 Summary

This section summarizes the ASP results, trends, and insights:

- ***Significant Precursors.*** The staff identified no *significant* precursors (i.e., CCDP or ΔCDP greater than or equal to 1×10^{-3}) in FY 2012. The staff identified no potentially *significant* precursors in FY 2013. The ASP Program provides the basis for the safety-performance measure goal of zero "number of *significant* accident sequence precursors of a nuclear reactor accident." The final results will be provided in the FY 2013 NRC Performance and Accountability Report (NUREG-1542).

- ***Occurrence Rate of All Precursors.*** The occurrence rate of all precursors does not exhibit a trend that is statistically significant during FY 2003–2012. The trend of all precursors is one input into the ITP to assess industry performance and is part of the input into the adverse trends safety measure. These results will be provided in the FY 2013 NRC Performance and Accountability Report.

- ***Additional Trend Results.*** During the same period, a statistically significant increasing trend was observed in precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4}. There is an increase of precursors in this subgroup the past three years after no events were identified in the previous six years.

As documented in SECY-13-0038, "Fiscal Year 2012 Results of the Industry Trends Program for Operating Power Reactors," the long-term trend for the significant events indicator did not show a statistically significant adverse trend. However, the paper did note that final analysis of FY 2011 events by the ASP program had pushed the number of significant events in FY 2011 above the short-term prediction limit.

SECY-13-0038 also notes that the Office of Nuclear Reactor Regulation is reviewing significant events from the past 5 years as documented in the FY 2012 Industry Trends annual report, including the seven events noted in this paper as *important* precursors, to determine if there is any trend of concern that the Nuclear Regulatory Commission will need to address. This evaluation found that loss of offsite power was a significant contributor to risk in some of the *important* precursors from the past three years. Rulemaking actions already underway to address station blackout as part of the follow-up to the Fukushima Task Force recommendations should have an impact on the risk significance posed by future loss of offsite power events. The evaluation also found that the risk in many of the most significant events was being driven by equipment failures and human errors that compounded the significance of expected initiators, and that weaknesses in licensee corrective action programs were a contributing factor in all of the events listed in Table 3 above. The staff is considering the conclusions and recommendations from this review as part of the ongoing ROP Enhancement Project effort discussed in the SECY-13-0037, "Reactor Oversight Process Self-Assessment for Calendar Year 2012."

7.0 References

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