POLICY ISSUE
(Information)

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FOR: The Commissioners

FROM: William D. Travers
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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.

BACKGROUND:

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 those operating events that were most significant in terms of the potential for inadequate core cooling and core damage (precursors). In addition, the ASP Program has the following secondary objectives: (1) to categorize the precursors for plant-specific and generic implications, (2) to provide a measure that can be used to trend nuclear plant core damage risk, and (3) to provide a partial check on PRA-predicted dominant core damage scenarios. The program is also used to monitor the agency's performance against the following Strategic Plan goal for maintaining safety: "No more than one event per year which is a significant precursor of a nuclear reactor accident." Since its inception, the ASP Program has published sixteen reports documenting the results of its review of operational experience for precursors covering the years 1969-1997. These reports have been issued on a yearly basis since 1986.

Accident sequences of interest to the ASP Program are those that would have resulted in inadequate core cooling that could have caused severe core damage, if additional failures had occurred. Events or conditions considered to be 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.

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The NRC staff uses the ASP methodology and models as follows:

(1) To make prompt assessments of the risk significance of operational events to support regulatory decisions by senior management.

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

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

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

(5) In the systematic screening, review, and analysis of operational experience data for accident sequence precursors.

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

(7) In regulatory analyses performed in association with the resolution of generic issues.

(8) To evaluate the risk associated with a specific technical issue identified at an individual plant.

Important points and key findings in the discussion below are identified in bold. The numbers in brackets associated with each point or finding explicitly link it to the appropriate use(s) listed above.

DISCUSSION:

Since the last status report, SECY-98-298, dated December 22, 1998, the staff has:

- Per the Commission's direction given in response to COMSECY-98-031, transferred functional responsibility for the ASP Program to the Office of Nuclear Regulatory Research.
- Evaluated 1998 events for precursors and published the results of the analyses.
- Evaluated and assessed trends in the precursor data.
- Evaluated the risk significance of issues regarding the D. C. Cook plant.
- Evaluated 1999 events for precursors and published the results of the analyses.
- Redirected the coordination of the ASP Program.

- Continued the development of the Standardized Plant Analysis Risk Models (SPAR).

Transfer of ASP Program Functional Responsibilities to RES

In January 1999, the Office for Analysis and Evaluation of Operational Data (AEOD) was abolished and many of its functions were transferred to the Office of Nuclear Regulatory Research (RES). Effective March 29, 1999, RES was reorganized, and, in concert with its charter to apply risk insights to the evaluation of operational experience data, the Operating Experience Risk Analysis Branch (OERAB) in the Division of Risk Analysis and Applications (DRAA) assumed responsibility for management of the ASP Program. In addition, OERAB became responsible for the development of the models and methods that support the ASP Program and other regulatory activities.

Responsibility for development of the computer codes [e.g., the agency's suite of PRA codes (SAPHIRE) and the GEM analysis tool] that support the ASP Program remained with the Probabilistic Risk Analysis Branch (PRAB) in DRAA.

1998 ASP Event Analysis

The screening, review, and preliminary analysis of 1998 operational events are complete. The preliminary analyses identified 11 potential precursors affecting ten different units for 1998. Peer and licensee review of the 11 analyses is complete, and preparation of responses to comments and final analysis of the last four 1998 potential precursors are in progress. The review of licensee comments on one event led to a reanalysis of the event that yielded a conditional core damage probability (CCDP) which was below the ASP Program threshold ($CCDP=1.0\times10^{-6}$). As a result, ten operational events affecting nine different units are under consideration as precursors for 1998. **Although this is an increase in the number of precursors over 1997 (when there were 5 precursors), the 1998 results are consistent with the period 1993-96, when the average number of precursors per year was 12. [6]**

Eight of the 1998 precursors involved the unavailability of equipment; two involved initiators. **This result is consistent with 1993-1997 results (with the exception of 1996), in which conditional unavailability events outnumbered initiators. [6]**

Historically, the percentage of precursors occurring at BWRs has been less than the percentage of BWRs in the operating reactor population. One of the 1998 precursors occurred at a BWR; there were none in 1997. 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 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, this result is 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) at PWRs typically have been contributors to the number of precursors in a given year. As in 1997, none of the 1998 precursors involved problems with AFW/EFW systems. **An update of the analysis first presented last year 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 1998 data were consistent with this trend. [6] 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.

Three of the 1998 precursors involved problems with electrical equipment (two at Davis-Besse and one at Byron 1 - See Attachment 1). **Although this result is consistent with the relative contribution of electrical equipment problems in the 1996 and 1997 results, it differs from the previous 5-year period (1990–95), when about 60 percent of the precursors each year involved electric power issues. [6]** One 1998 precursor also involved a loss of offsite power (LOOP) - the tornado-caused LOOP at Davis-Besse in June.

Four of the ten 1998 precursors involved loss-of-coolant-accident (LOCA)-related issues, but none involved an actual loss of reactor coolant. Three of these involved calibration and calculational errors in emergency sump and borated water storage tank level instrumentation which compromised the capability to transfer the emergency core cooling system from the injection mode to the recirculation mode of operation. These three precursors involved conditions at the three reactors at the Oconee site.

Precursors with CCDP$\geq 1.0\times10^{-4}$ are considered important with respect to risk significance. There was one precursor identified for 1998 that had a conditional core damage probability (CCDP)$\geq 1.0\times10^{-4}$ - the tornado-caused LOOP at Davis-Besse. Over the last eleven years, approximately 25% of the precursors have had a CCDP$\geq 1.0\times10^{-4}$. **Since 1984, the occurrence rate for this group of precursors has exhibited a statistically significant decreasing trend. [6]**

The 1998 precursor results are presented in Attachment 1. Detailed discussion of the analysis results and the insights summarized above is found in the 1998 Precursor Report (NUREG/CR-4674, Volume 27, which is scheduled to be issued in January 2000).

Evaluation of Risk Trends in Precursor Data

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 individual plant examinations (IPEs), 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 1998 is provided as Attachment 2. Precursor results represent but one indication of the overall risk of the industry.

A recent staff technical paper (Ref.2) reported the results of a statistical analysis of trends in the occurrence rate of precursors between 1984 and 1994. This paper updates that analysis with four more years of data (Attachment 3). **Statistically significant decreasing trends were found for all of the ASP CCDP bins, except for precursors with CCDP$\geq 1.0\times10^{-3}$. Although, there is a decreasing trend for this bin, it is not statistically significant. Absent a precursor with CCDP$\geq 1.0\times10^{-3}$ in 1999, the trend identified will become**

statistically significant. [6] Precursors with CCDP≥1.0×10^{-3} have occurred, on the average, about once every 2-3 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≥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.

The following presents an update of the 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. Also, 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. This index can be used for order of magnitude comparisons with industry average CDF estimates derived from PRAs and IPEs. For the last seven years, the index is:

Year	Annual ASP Index
1998	5.8×10^{-6}/RY
1997	4.6×10^{-7}/RY
1996	2.4×10^{-5}/RY
1995	2.2×10^{-6}/RY
1994	3.0×10^{-5}/RY
1993	8.9×10^{-6}/RY
1992	1.5×10^{-5}/RY
	1.2×10^{-5}/RY Average

The estimated CDFs in the IPEs range from 1.2×10^{-6}/RY to 3.7×10^{-4}/RY, with an average value of 6.2×10^{-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. [6]** However, due to the limitations discussed above, the ASP results are not sufficient to verify the IPE CDF results.

In last year's report, we presented the results of a review of precursor results for the period 1994-1997 and showed that a number of these events involved event initiators or conditions that are not included in the IPEs. These events comprise approximately 15 percent of the precursors for this period. While CDF implications from the ASP Program are in general agreement with overall estimates of CDF, occasionally key contributors to precursors differ from those identified in PRAs. **Of the ten precursors currently under consideration for 1998, the following conditions occurred that are not typically considered in the IPEs:**

- **Potential failure of the recirculation mode of ECCS operation because of calibration and calculational errors in emergency sump and borated storage tank**

level instrumentation. This specific condition was cited in Information Notice 98-40. [4,6]

- **Potential failure of all component cooling water pumps due to steam intrusion resulting from a postulated high energy line break. This preliminary result is still undergoing technical review, and issuance of an information notice will be considered based on the results of the review. [4,6]**

Evaluation of Risk Associated with Issues at D. C. Cook Plant

As a result of the large number of potential safety issues identified at D. C. Cook Units 1 and 2 (Cook) and the increased regulatory activities since August 1997, RES conducted an analysis of the risk significance of the issues using the Accident Sequence Precursor (ASP) Program methodology. **To date, we have completed the analysis of 94 out of 117 individual issues. Preliminary results indicate that one of these is risk-significant (potential ASP precursor). [4,5,8]** A draft report detailing the results of the analyses of the individual issues and the integrated analysis of all issues will be issued for review and comment in December. The final report will be prepared after all comments on the draft report have been resolved. Issuance of the final report is currently scheduled for April 2000.

The one issue at Cook that has been identified as a potential precursor involves the potential failure of all component cooling water pumps due to steam intrusion resulting from a postulated high energy line break identified above. The results of the preliminary analysis of this issue were sent to the Cook licensee for review and comment. When all comments on the preliminary analysis have been resolved, the final analysis will be prepared and issued.

1999 ASP Event Analysis

The ASP screening, review, and analysis of 1999 operational events began in May 1999. We have received 628 1999 LERs, which represents about 40% of the total number of LERs (1500) anticipated for the whole year. We selected 240 of these for engineering review as potential precursors. Our review identified 23 individual events for detailed analysis to determine if they are precursors. We completed eleven preliminary analyses and identified one event as a potential precursor. This event is currently receiving peer review by the licensee and the staff.

Redirected ASP Program Coordination

Recent developments in the nuclear regulatory arena have resulted in new or different agency activities:

- The NRC's transition to a risk-informed regulatory framework.
- Development and implementation of the improved reactor oversight process and the associated significance determination process.
- Approval and implementation of Regulatory Guide 1.174.

These developments necessitated a reevaluation of the coordination of the ASP Program and its associated methods and model development efforts. In addition, the efforts involving

development of SPAR models and other analytical tools which had been initiated before these activities were undertaken are being reassessed to make sure that they meet current and future needs of agency users.

In an effort to ensure continuation of user input to the development efforts that support the ASP Program, OERAB formed the SPAR Models Users Group (SMUG). This group consists of representatives from each of the organizations within the agency's program offices that use risk models in the performance of their regulatory activities. This group includes a senior reactor analyst (SRA) from each regional office, staff from each branch within RES and NRR that is involved with PRA applications, and staff from each branch involved in the implementation of the agency's new reactor oversight process. The SMUG was formed to provide the coordination of activities that the former ASP Program Technical Coordination Group (ASPPTCG) was not designed to handle. The SMUG has met three times - on September 29, 1999, on October 21, 1999, and on November 17, 1999 - to agree on the objectives and charter for the group, review the current status of the development of methods and model capability in each of the major areas identified above, and to identify the methods and model needs of each of the participating organizations in SMUG along with their associated priorities.

One of the functions of the former ASPPTCG had been the preparation of the annual update of the ASP Program Plan (originally issued as Enclosure 1 to SECY-94-076 in March 1994; the most recent update, Revision 4, was issued in December 1998). Scheduling and tracking of SPAR model development are now part of the RES Operating Plan. This eliminates the need for a separate ASP Program Plan.

Model and Methods Development

As mentioned above, OERAB is now responsible for development of methods and models that support the ASP Program and other regulatory activities. The staff currently uses 72 simplified, plant-specific, Level 1 models [the Revision 2QA standardized plant analysis risk (SPAR) models] in analyses performed during its risk-informed regulatory activities. Ongoing development activities include:

- The Level 1 SPAR models.
- Low power/shutdown models.
- Capability to perform Level 2/3 precursor analysis of events.
- Capability to estimate the large early release frequency (LERF) associated with operational events.
- Capability to estimate the relative risk associated with external events.

Since last year, the following accomplishments were achieved in these areas:

Standardized Plant Analysis Risk (SPAR) Models

- Continued maintenance of the existing Revision 2QA SPAR models.

- Developed a preliminary on-site review process for the Revision 3 SPAR models. The Revision 3 SPAR models have been developed from the Revision 2QA models by adding:

  - The modeling of support systems (e.g., electrical power systems, component cooling water, service water).

  - A recovery model that includes an improved human performance analysis method.

  - An improved method for treating common cause failures.

  - A method for treating the parameter uncertainty associated with each basic event in the models.

  - Models for additional initiating events (e.g., large LOCA, medium LOCA).

- Completed the on-site review (using the preliminary process) and generated three draft Revision 3 SPAR models (Calvert Cliffs, Duane Arnold and Millstone 2).

Large Early Release Frequency (LERF) Models

- Completed the initial draft of 6 PWR and 2 BWR LERF models and containment parameter databases for the remaining plants.

- Completed containment phenomenology scoping which identified the phenomenology to be updated based on recent research/studies.

- Completed code changes for the decomposition of LERF model results to identify the contribution from the Level 1 portion of the plant model.

FUTURE STATUS REPORT:

The 1998 Precursor Report, "Precursors to Severe Core Damage Accidents: 1998 A Status Report," NUREG/CR-4674, Volume 27, is scheduled to be issued by mid-January 2000. The next report to the Commission on the status of the ASP Program will be provided in December 2000.

REFERENCES:

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

2. Dale M. Rasmuson and Patrick D. O'Reilly, "Analysis of Annual Accident Sequence Precursor Occurrence Rates for 1984-94," Proceedings of the International Topical

Meeting on Probabilistic Safety Assessment, Park City, Utah, September 29 - October 3, 1996, Volume III, pp.1645 -1652.

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Attachments:
1. ASP Program Precursors for 1998
2. Conditional Core Damage Probability Results from ASP Program (Chart)
3. Update of Statistical Analysis of Trends in Precursor Occurrence Rate (Four Charts)

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1998 At-Power Precursors Involving Initiating Events Sorted by Conditional Core Damage Probability

CCDP	Plant	Plant Type	Event Identifier	Description	Event Date
5.6×10^{-4}	Davis-Besse	PWR	LER 346/98-006	A Tornado Touchdown Causes a Complete Loss of Offsite Power	6/24/98
$*1.5 \times 10^{-5}$	Davis-Besse	PWR	LER 346/98-011	Manual Reactor Trip Due to Component Cooling System Leak and the De-Energizing of Safety-Related Bus D1 and Non-Safety-Related Bus D2	10/14/98

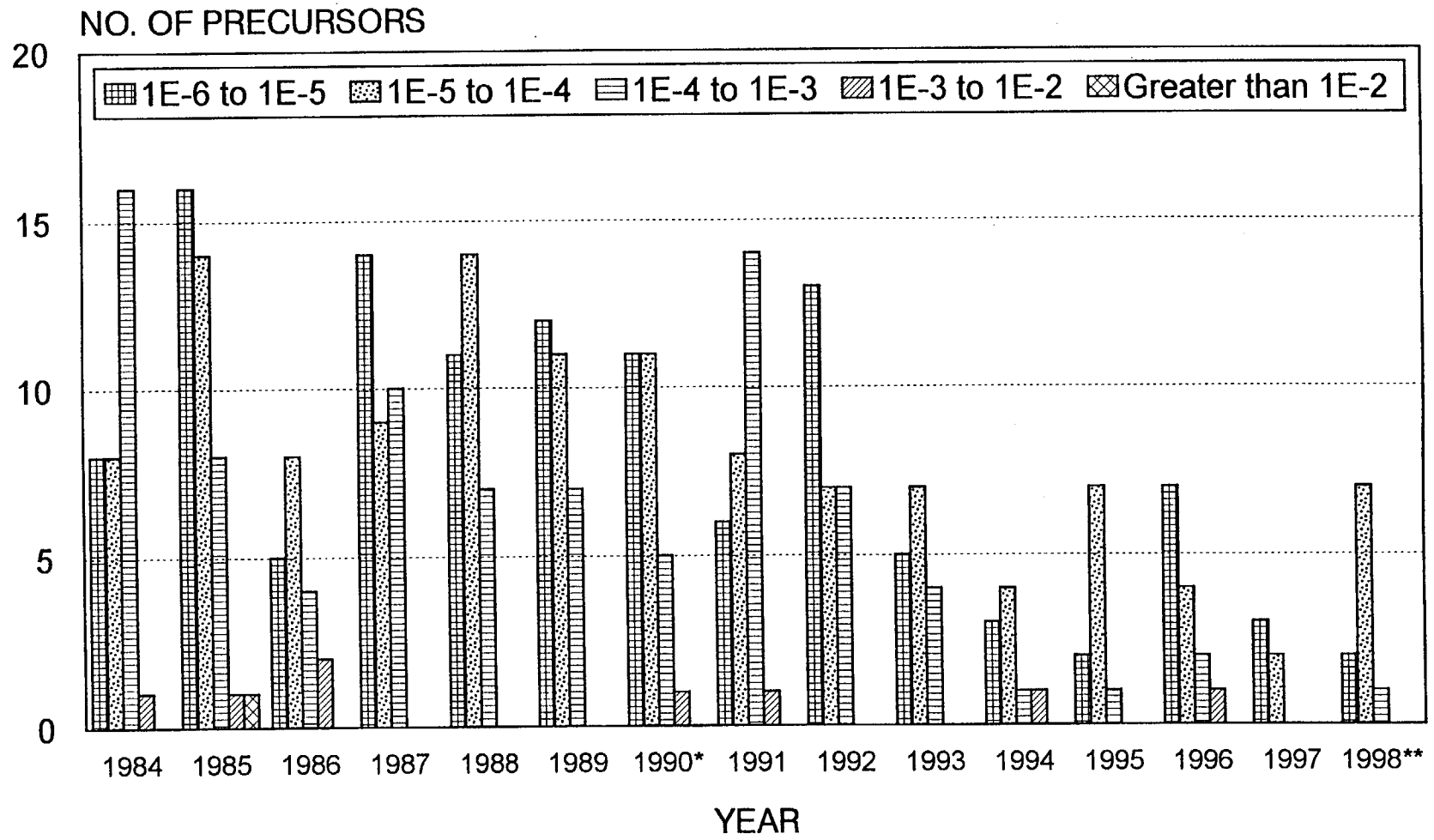
* Preliminary results. Final analysis review in progress.

1998 At-Power Precursors Involving Unavailabilities Sorted by Increase in Core Damage Probability

ΔCDP	Plant	Plant Type	Event Identifier	Description	Event Date
$*2.2 \times 10^{-5}$	D. C. Cook 1 and 2	PWR	LER 316/98-005	Potential for High Energy Line Break to Degrade Component Cooling Water System	7/15/98
1.1×10^{-5}	Big Rock Point	PWR	LER 155/98-001	Long-Term Unavailability of Liquid Poison Control System	3/27/98
7.2×10^{-6}	San Onofre 2	PWR	LER 361/98-003	Inoperable Sump Recirculation Valve	2/5/98
5.6×10^{-6}	Byron 1	PWR	LER 454/98-018	Long-Term Unavailability of an Emergency Diesel-Generator	9/12/98
1.7×10^{-6} (Units 1, 2) 1.4×10^{-6} (Unit 3)	Oconee 1, 2, and 3	PWR	LER 269/98-004	Calibration and Calculational Errors Compromise Emergency Core Cooling System Transfer to Emergency Sump	2/12/98

* Preliminary results. Final analysis review in progress.

CONDITIONAL CORE DAMAGE PROBABILITY RESULTS FROM ASP PROGRAM



* THE 3/20/90 VOGTLE EVENT HAS BEEN ROUNDED UP FROM 9.7E-4 AND PLOTTED AS 1.0E-3.
** PRELIMINARY RESULTS.

Attachment 2

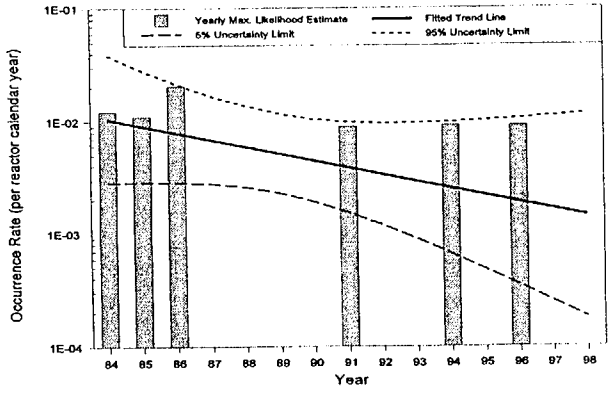


Figure 1. Trend for events with exponent = -3. Trend is not statistically significant (p-value = 0.1307)

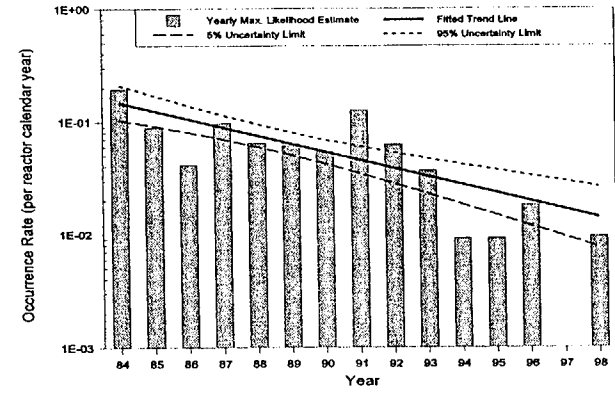


Figure 2. Trend for events with exponent = -4. Trend is statistically significant (p-value = 0.0001)

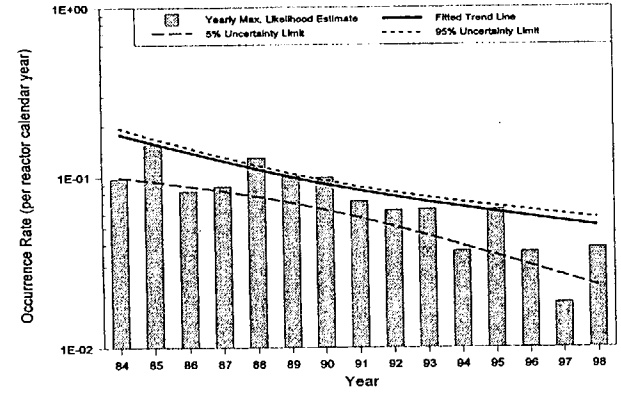


Figure 3. Trend for events with exponent = -5. Trend is statistically significant (p-value = 0.0001)

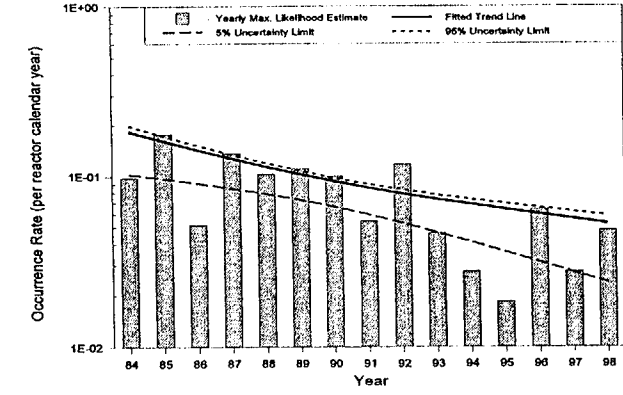


Figure 4. Trend for events with exponent = -6. Trend is statistically significant (p-value = 0.0001)

Attachment 3