JAERI-Tech
97-067

TRENDING ANALYSIS OF PRECURSOR EVENTS

January 1998

Norio WATANABE

日本原子力研究所
Japan Atomic Energy Research Institute

本レポートは，日本原子力研究所が不定期に公刊している研究報告書です。
入手の問合わせは，日本原子力研究所研究情報部研究情報課（〒319－1195 茨城県那珂郡東海村）あて，お申し越しください。なお，このほかに財団法人原子力弘済会資料センター（〒319－1195 茨城県那珂郡東海村日本原子力研究所内）で複写による実費頒布をおこなっております。

This report is issued irregularly.
Inquiries about availability of the reports should be addressed to Research Information Division, Department of Intellectual Resources, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 〒319－1195, Japan.

編集兼発行　日本原子力研究所
印　　刷　日立高速印刷株式会社

Trending Analysis of Precursor Events

Norio WATANABE

Department of Reactor Safety Research
Nuclear Safety Research Center
Tokai Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken, JAPAN

(Received December 2, 1997)

The Accident Sequence Precursor (ASP) Program of United States Nuclear Regulatory Commission (U.S.NRC) identifies and categorizes operational events at nuclear power plants in terms of the potential for core damage. The ASP analysis has been performed on yearly basis and the results have been published in the annual reports.

This paper describes the trends in initiating events and dominant sequences for 459 precursors identified in the ASP Program during the 1969-94 period and also discusses a comparison with dominant sequences predicted in the past PRA studies. These trends were examined for three time periods, 1969-81, 1984-87 and 1988-94. Although the different models had been used in the ASP analyses for these three periods, the distribution of precursors by dominant sequences show similar trends to each other. For example, the sequences involving loss of both main and auxiliary feedwater were identified in many PWR events and those involving loss of both high and low coolant injection were found in many BWR events. Also, it was found that these dominant sequences were comparable to those determined to be dominant in the predictions by the past PRAs.

As well, a list of the 459 precursors identified are provided in Appendix, indicating initiating event types, unavailable systems, dominant sequences, conditional core damage probabilities, and so on.

Keywords : Accident Sequence Precursor (ASP), Dominant Core Damage Sequences,

Trending Analysis, PRA

前兆事象に対する傾向分析

日本原子力研究所東海研究所安全性試験研究センター原子炉安全工学部
渡邉　憲夫

(1997年12月２日受理)

米国原子力規制委員会（ＵＳＮＲＣ）の前兆事象評価（ＡＳＰ）プログラムは、原子力発電所における運転時の事象を、炉心損傷に至る可能性の観点から評価し分類するためのものである。ＡＳＰ評価は、年単位で行われており、その結果は年報形式で公開されている。本報告書では、1969年から1994年の事象に対するＵＳＮＲＣのＡＳＰ評価により同定された459件の前兆事象について、炉心損傷の起因事象及びドミナントシーケンスの傾向を分析すると共に、過去の確率論的安全評価（ＰＳＡ）の結果との比較を行った。傾向分析は、ＡＳＰ評価に用いられたモデルの相違から、３つの期間（1969-1981年、1984-1987年及び1988-1994年）に分けて行った。その結果、各期間共に類似の傾向を示すことが判明した。例えば、ＰＷＲでは主給水・補助給水喪失を伴うシーケンスが、ＢＷＲでは高圧・低圧注入失敗を伴うシーケンスが多くの事象でドミナントとなっている。また、これらのシーケンスは過去のＰＳＡでもドミナントと識別されており、ＡＳＰとＰＳＡの結果に類似性のあることが分かった。

また、本報告書の付録には、459件の前兆事象について、起因事象の種類、故障あるいは不作動系統、ドミナントシーケンス、条件付き炉心損傷確率等を一覧形式にまとめている。

東海研究所：〒319－1195　茨城県那珂郡東海村白方白根２－４

Contents

目　　次

1. Introduction

The Accident Sequence Precursor (ASP) Program systematically reviews and evaluates operating events that have occurred at light water reactors. The ASP program uses probabilistic risk assessment (PRA) techniques to identify and categorize operating events that have a safety significance in terms of the potential for core damage. The events evaluated in the program include core damage initiators such as loss-of-coolant accident (LOCA), degradation of plant conditions that was not predicted or that proceeded differently from the plant design basis, and safety equipment failures that could have affected the course of postulated core damage initiators. The significance of a precursor is evaluated by calculating the probability of postulated core damage accident sequences given the failed equipment associated with the particular event. This probability is called a conditional core damage probability (CCDP).

The ASP Program was established in 1979 by the United States Nuclear Regulatory Commission (U.S.NRC) and the first report was issued in 1982. To date, thirteen reports describing precursors during the period from 1969 through 1994, excluding 1982 and 1983, have been published in the program[1-13]. These reports identified 459 precursors with their respective CCDPs of 10^{-6} or higher. With the precursor events being accumulated, nowadays, trending analysis of the results from the ASP Program has been recognized one indication of industry risk. Actually, the U.S.NRC determined whether any trends existed in the annual occurrence rates of precursors that occurred during 1984 though 1994 and indicated that the trends for relatively lower CCDP bins were decreasing[14]. The present study focused on the other points of view, that is, initiating events and dominant core damage sequences identified for the precursors, and examined their trends to characterize risk insights. The thirteen ASP analysis reports were surveyed to pick over the initiating events and the dominant sequences. As stated in Ref. 14, on the other hand, the ASP models used in the program have been improved several times since 1982 to provide as realistic an evaluation of the event significance as possible. These improvements have resulted in the application of different models to the ASP analyses over the years, which precludes a direct year-to-year comparison of their results. However, the basic concepts incorporated into development of the models have not been changed, and standardized or generic event tree models have always been used in the analyses. Therefore, the trending analysis results described here may indicate limited observations but provide generic implications on dominant sequences for precursors, which could be useful for characterizing risk insights to identify plant vulnerabilities and checking the dominant core damage scenarios predicted in the PRAs. As well, these trends are considered more realistic indications of significant core damage sequences than expectations by PRAs because the ASP analyses account for all actual and potential concurrent failures, degradations, and/or outages of safety systems.

2. History of Development of Accident Sequence Precursor Models

The ASP Program has used an event tree analysis method since the program was initiated in 1979. However, the event tree models had been improved several times to reflect state of the art in PRA techniques and/or plant design differences.

The first phase analysis for 1969-79 events and 1980-81 events used simplified, standardized event trees to model potential core damage sequences. One set of event trees was used for PWRs and a separate set was used for BWRs. These event trees were developed for four initiating events : loss of feedwater (LOFW), loss of offsite power (LOOP), small break LOCA, and main steam line break (MSLB). They were functional event trees, where mitigation systems were functionally represented. However, success criteria for the mitigation systems varied from plant to plant. This difference was addressed in the probabilities assigned to branches in the event trees.

In 1985, the ASP event tree models were improved to reflect the design differences among commercial nuclear power plants in the United States. This improvement incorporated eight plant classes, five PWR plant classes and three BWR plant classes. At that time, event trees were reconstructed for three initiating events - a nonspecific reactor trip including LOFW (TRIP), LOOP and small break LOCA - for each plant class. These were systemic event trees where safety-related systems were individually represented. The differences in plant system configuration were reflected in the process of quantifying event trees by assigning their respective unavailabilities for different systems to the appropriate branches. These systemic event trees were used in the ASP analyses of 1984-87 events. In these models, a core vulnerability end state was assigned to sequences in which core protection was expected to be provided, but for which no specific analytical basis was generally available or which involved non-proceduralized operator actions.

In 1989, two modeling changes were made to the ASP event trees : reassignment of core vulnerability sequences in the 1984-87 analyses as success or core damage sequences, and explicit representation of electric power recovery and reactor coolant pump (RCP) seal LOCA in the LOOP event trees for PWRs. Two other changes were also made to simplify the BWR event trees : elimination of the top event for standby liquid control (SLC), resulting in assignment of reactor trip failure to the anticipated transient without scram (ATWS) end state, and consideration of the condensate system (COND) as a recovery action instead of low pressure systems. Although the revised event tree models were used in the ASP analyses of 1988-93 events, supplemental and plant-specific mitigation systems and/or actions beyond those included in the basic models were considered in the analyses of 1992 and 1993 events.

In 1995, the ASP models were significantly changed by applying the fault tree linking technique to the modeling of safety-related systems on the event trees. In addition, an event tree for steam generator tube rupture (SGTR) was developed for each PWR plant class. An ATWS event tree was also developed and a transfer was provided from its corresponding nonspecific trip event tree. The event trees for the other initiating events were basically the same as those used in the analyses of 1988-93 events. These simplified, plant-specific ASP models were used in the analysis of 1994 events.

3. Trends in Initiating Events or Unavailable Systems

The precursors identified can be divided into two general categories in terms of initiating events : one is called a precursor involving initiators where an initiating event actually occurred and the other is called a precursor involving unavailabilities where safety-related system(s) had been rendered unavailable or experienced degraded conditions with no occurrence of any initiating event.

In the present study, precursors involving initiators were further categorized into the following five initiating event types : TRIP, LOOP, LOCA, MSLB and SGTR. The first four initiating event types are common to PWRs and BWRs, but the last type is specific to PWRs only. For precursors involving unavailabilities, the event categorization was carried out focusing on the failed or degraded safety-related systems or safety functions which were represented as top events in the ASP event tree models. The systems/functions focused on are as follows : emergency power system (EPS), emergency coolant injection (ECI), decay heat removal (DHR), reactor protection system (RPS) and pressurizer power-operated relief valve (PORV). A typical example of the EPS is the emergency diesel generators (EDGs). ECI includes high/low pressure coolant injection systems (HPI/LPI in PWRs and HPCI/LPCI in BWRs), high/low pressure core spray (HPCS/LPCS), automatic depressurization system (ADS) and reactor core isolation cooling/isolation condenser (RCIC/IC) in BWRs. DHR includes auxiliary feedwater system (AFW), high/low pressure coolant recirculation (HPR/LPR) and containment spray recirculation (CSR) in PWRs, power conversion system (PCS), and residual heat removal system (RHR) in PWRs and BWRs. RPS includes scram logic circuits and control rod drive mechanism (CRDM).

As described previously, three different event tree models were used in the ASP analyses of 1969-81 events, 1984-87 events and 1988-94 events, respectively. In this chapter, therefore, the trends on initiating events or unavailable systems are discussed for these three periods, separately.

3.1 Trends for 1969-81 Precursors

For the events occurring during the years 1969-81, two separate sets of ASP analyses were performed - one covered 1969-79 events and the other considered 1980-81 events. Figures 1(a) and 1(b) display the distributions of PWR and BWR precursors by initiator types and unavailable systems/functions for these two periods, respectively. As shown in these figures, for the two periods, the relative contributions of precursors by initiator types are similar at PWRs while those for BWRs are somewhat different. At PWRs, LOOP-initiated precursors represented the largest contributor to the distributions for both periods. Approximately 40% (27 events) of the 69 precursors in the 1969-79 period were initiated by a LOOP and approximately 35% (10 events) of the 28 precursors in the 1980-81 period involved LOOPs. There were seven LOCA-initiated precursors during the 1969-79 period (approximately 10%) and six precursors during the 1980-81 period (approximately 20%). Ten of them (six in 1969-79 and four in 1980-81) were caused by inadvertent opening of a pressurizer PORV. As for the precursors involving unavailabilities, different trends are observed for both periods. During the 1969-79 period, there were twelve precursors involving DHR unavailability, seven involving EPS unavailability and five involving ECI unavailability. Four of the six 1980-81 precursors involving unavailabilities were associated with ECI unavailability and the others were with DHR unavailability. Eight of the 1969-79 precursors in the DHR unavailability category involved the unavailability of AFW. One of them was caused by problems in the DC power system and the other four involved the unavailability of HPR/LPR, one of which was due to failure of the service water system (SWS). Both of the precursors associated with DHR unavailability in 1980-81 involved the unavailability of AFW. For BWRs, as can be seen from Figure 1 (b), the distribution of precursors by initiator types is different for the two periods - sixteen of the 50 precursors in 1969-79 were initiated by a LOOP and four of the 14 precursors in 1980-81 had LOCA initiators. For the 1969-79 period, there were eight LOCA-initiated precursors and seven TRIP-initiated precursors. Ten of the twelve LOCA-initiated precursors (six of eight in 1969-79 and all of four in 1980-81) were caused by inadvertent opening of safety relief valves (SRVs). Out of the precursors involving unavailabilities, ECI unavailability was the largest contributor for both periods. Five of nine such precursors in 1969-79 and two of three in 1980-81 involved the unavailability of high pressure systems such as RCIC and HPCI and the others were due to problems with ADS. Two of the six precursors involving EPS unavailability in 1969-79 and one such precursor in 1980-81 were caused by failure of CCW/SWS. As well, all of the four precursors involving DHR unavailability (three in 1969-79 and one in 1980-81) were due to failure of SWS. All three precursors involving RPS unavailability during the years 1969-81 stemmed from problems with the scram discharge volume (SDV). In addition, three precursors were related to shutdown events at PWRs (one in 1969-79 and two in 1980-81) and one 1969-79 precursor was associated with vulnerabilities to an earthquake at a BWR.

Figures 2(a) and 2(b) display the distributions of PWR and BWR precursors, respectively, as a function of CCDP for the two periods. It can be seen from these figures that for the two periods, the distributions of PWR precursors are different while those of BWR precursors are quite similar. For PWRs, about one-half of the 1969-79 precursors had CCDPs in the range of 1.0×10^{-4} - 1.0×10^{-3}. Included in this range were eighteen of the 27 LOOP-initiated precursors and five of the seven LOCA-initiated precursors for 1969-79. Three of the five TRIP-initiated precursors were found to have CCDPs of 1.0×10^{-3} or higher. About a half of the precursors involving unavailabilities had CCDPs that were higher than 1.0×10^{-4}. In particular, six of the twelve precursors involving DHR unavailability had CCDPs of 1.0×10^{-3} or higher. However, five of the seven precursors involving EPS unavailability were in the range of 1.0×10^{-6} - 1.0×10^{-5}. On the other hand, for 1980-81, about two-thirds of precursors had CCDPs that were lower than 1.0×10^{-4}. These included eight of the ten LOOP-initiated precursors and four of the six LOCA-initiated precursors. Also, five of the six precursors involving unavailabilities were found in these ranges. Three of four precursors in the range of 1.0×10^{-3} - 1.0×10^{-2} were TRIP-initiated precursors. For BWRs, about a half of precursors in each of the two periods had CCDPs in the range of 1.0×10^{-5} - 1.0×10^{-4}. In 1969-

79, thirteen of the sixteen LOOP-initiated precursors had CCDPs in this range. However, the CCDPs for five of the eight LOCA-initiated precursors and four of the seven TRIP-initiated precursors were in the ranges of 1.0×10^{-4} - 1.0×10^{-3} and higher than 1.0×10^{-3}, respectively. All the precursors involving unavailabilities had CCDPs that were 1.0×10^{-3} or lower. In particular, all of the six precursors involving EPS unavailability fell in the range of 1.0×10^{-6} - 1.0×10^{-5}. In 1980-81, all the precursors involving initiators were distributed over the range of two probability bins : 1.0×10^{-5} - 1.0×10^{-3}. Three of the four LOCA-initiated precursors and one TRIP-initiated precursor had CCDPs in the range of 1.0×10^{-4} - 1.0×10^{-3}.

In summary, for both PWRs and BWRs, it was found that TRIP-initiated precursors had relatively higher CCDPs than either LOOP-initiated precursors or LOCA-initiated precursors as can be seen from Figures 3(a) and 3(b). In addition, the CCDPs for precursors involving unavailabilities were distributed over relatively lower ranges. This tendency is remarkably observed in the case of the precursors involving EPS unavailability ; five of the seven at PWRs and all of the seven at BWRs had CCDPs in the range of 10^{-5} or lower.

3.2 Trends for 1984-87 Precursors

During the 1984-87 period, a total of 125 precursors were identified (73 at PWRs and 52 at BWRs). For the individual calendar years except for 1986, thirty to forty precursors were identified and, as shown in Figures 4(a) and 4(b), more than 70% of these precursors involved an actual initiator. Especially, the initiator type, TRIP, was found to be a major contributor at both PWRs and BWRs for these years. The contributions from LOOP-initiated precursors to the overall total number were approximately 10-20% in each of these years. Four LOCA-initiated precursors occurred at BWRs. Three of them were caused by inadvertent opening of SRVs and the other (in 1984) was due to leakage from an LPCS valve which could have led to an interfacing system LOCA. On the other hand, the ASP analysis for events in 1986 identified 19 precursors, 14 of which occurred at PWRs and 5 at BWRs. Although TRIP was found to be a major initiator type, for PWRs, its contribution was smaller than that for other

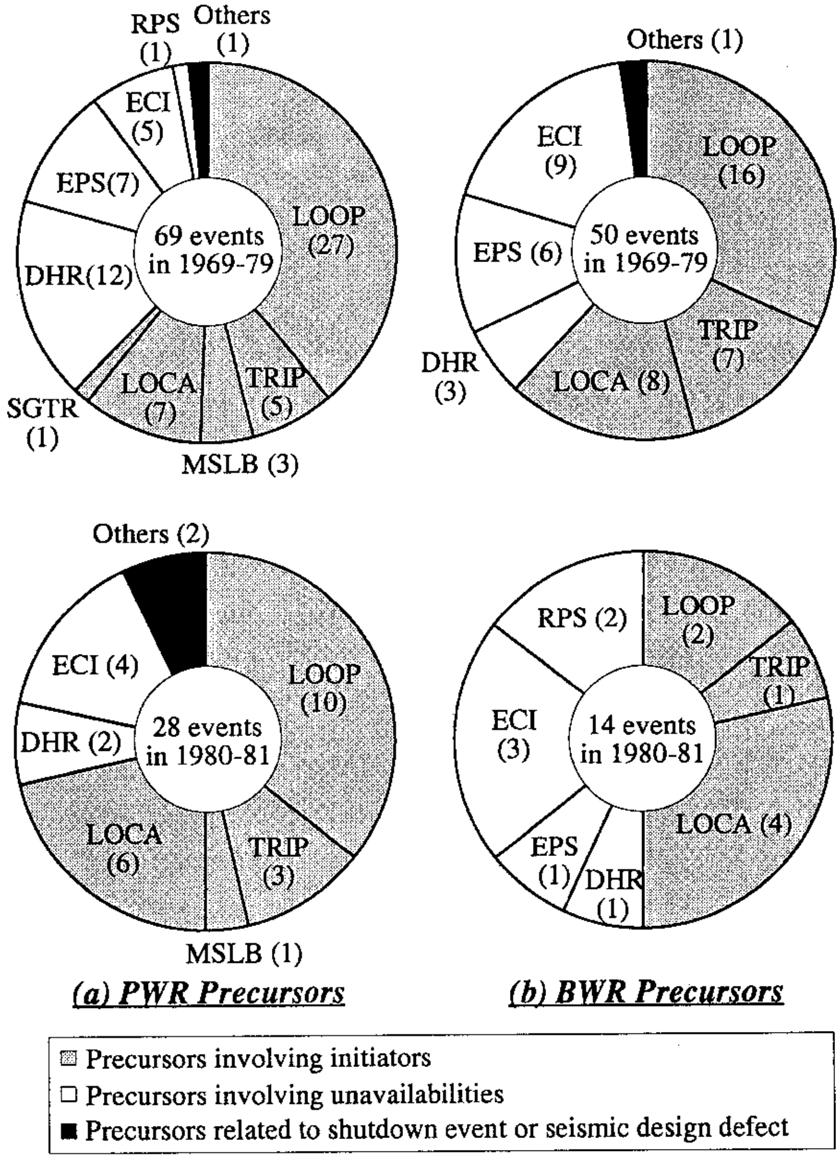
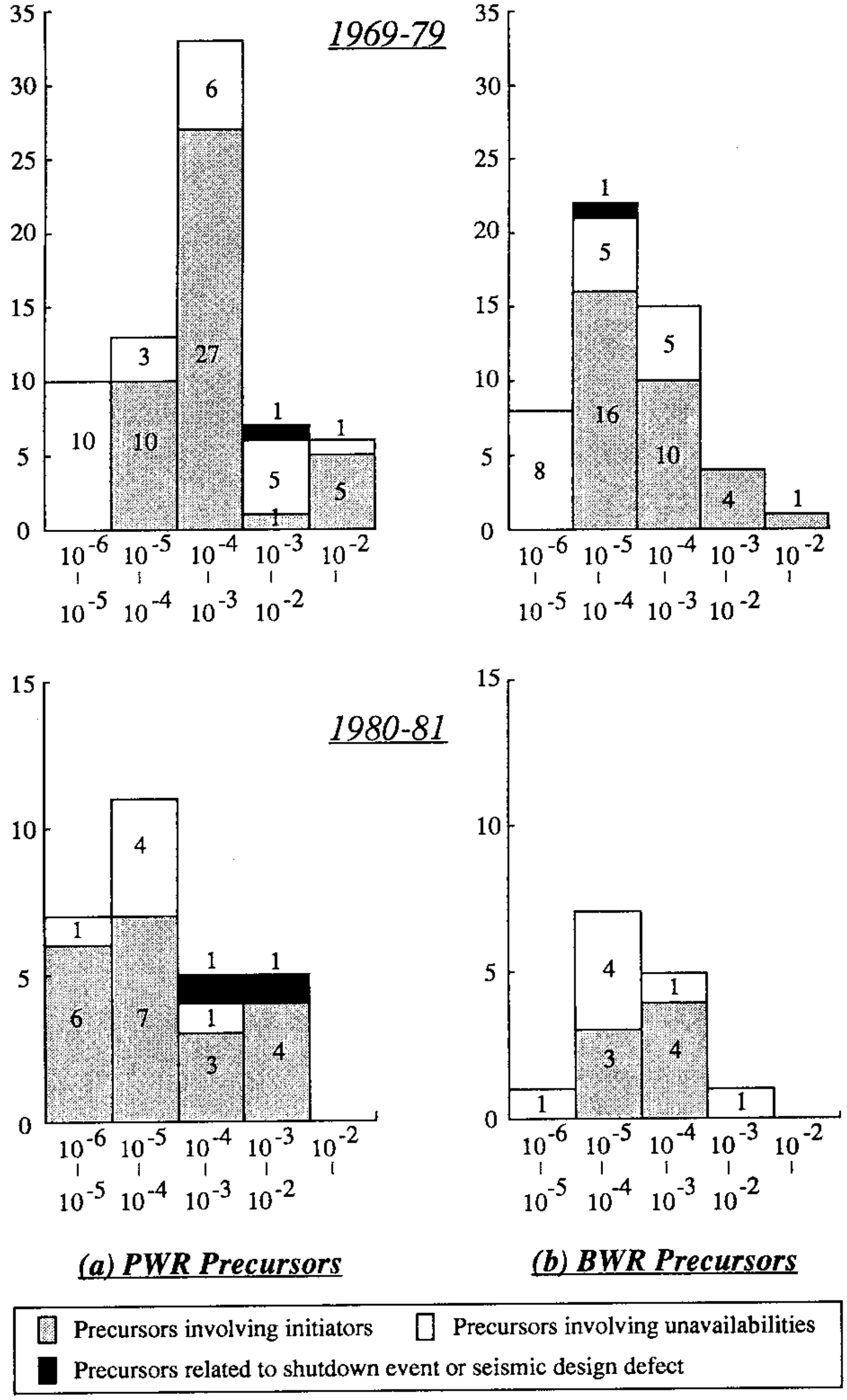


Figure 1 Distribution of 1969-81 Precursors by Initiators/Unavailable Systems



(Ordinates stand for the number of precursors and Abscissas stand for the range of CCDPs)

Figure 2 Distributions of 1969-81 Precursors by CCDPs

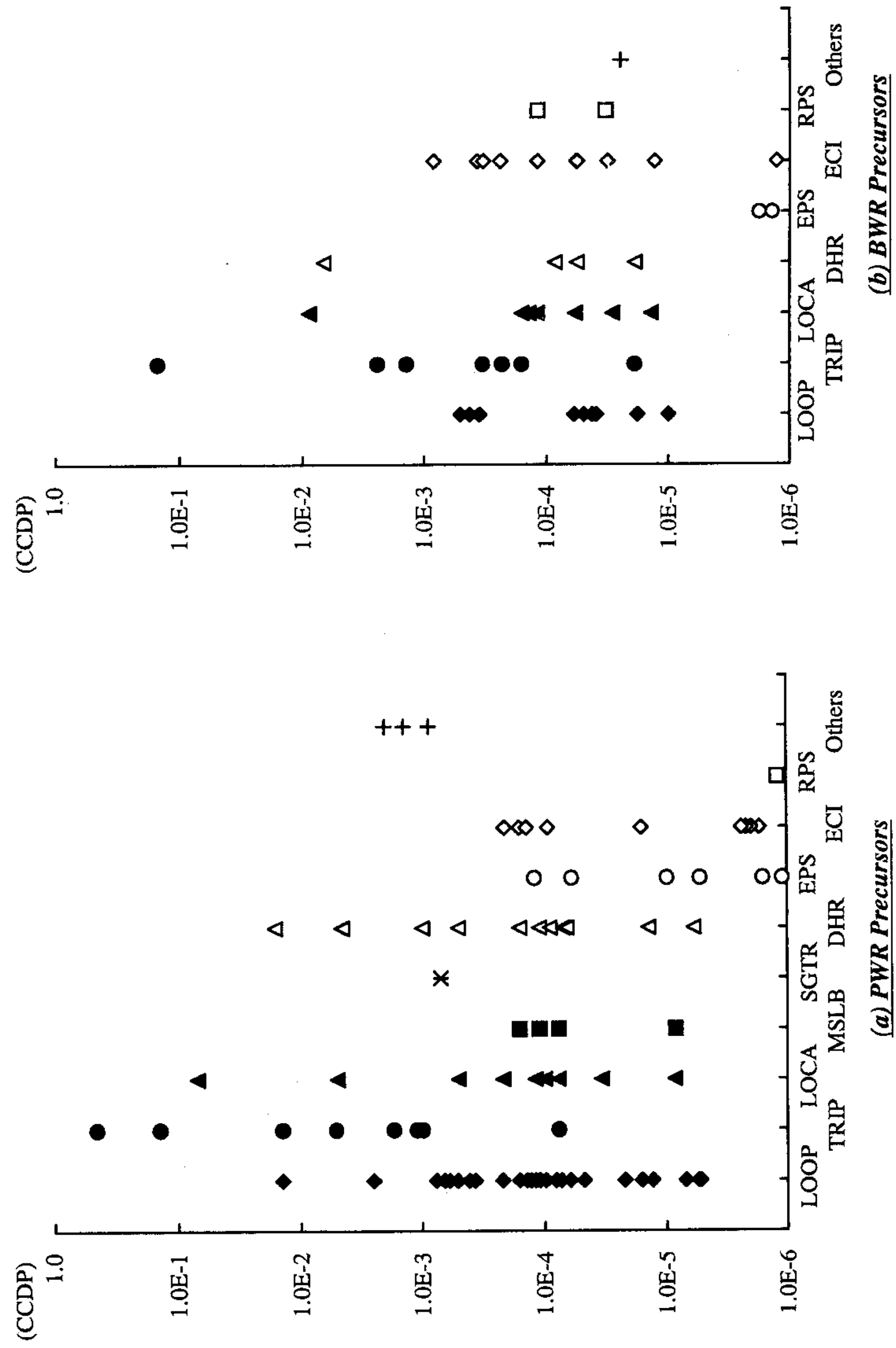


Figure 3 Distributions of CCDPs for 1969-81 Precursors by Initiators/Unavailable Systems

years as seen from Figure 4(a). One LOCA-initiated precursor resulted from leakage in the chemical volume and control system (CVCS). For BWRs, as shown in Figure 4(b), LOOP-initiated precursor was the largest contributor in 1986. As for precursors involving unavailabilities, their contributions were relatively small in each calendar year. During this period, there were eleven precursors involving EPS unavailability, nine precursors involving DHR unavailability and six precursors involving ECI unavailability. Seven of the precursors involving EPS unavailability occurred in 1987. One of such precursors at a PWR in 1987 and one at a BWR in 1985 were caused by the failure of CCW. Out of six precursors involving DHR unavailability at PWRs, five events were associated with the unavailability of AFW, four of which occurred in 1986, and the other involved the unavailability of HPR due to problems with CCW. One precursor involving ECI unavailability at a PWR in 1984 resulted from the failure of CCW and one precursor at a BWR in 1986 involved failure of both high and low pressure coolant injection systems.

Figures 5(a) and 5(b) indicate that trends in the distributions of PWR precursors during the 1984-87 period are different from those of BWR precursors. Except for 1986, the distributions of PWR precursors are similar over this period, but those of BWR precursors are quite different year by year. For PWRs, except for 1986, a large number of precursors were distributed in the range of two probability bins : 1.0×10^{-6} - 1.0×10^{-4}. Out of the precursors involving initiators, twenty-seven of the 34 TRIP-initiated precursors (five in 1984, eleven in 1985, and eleven in 1987) and seven of the twelve LOOP-initiated precursors (one in 1984, five in 1985, and one in 1987) had CCDPs in this range. Precursors involving unavailabilities, excluding two precursors with EPS unavailable in 1987, were also distributed in this range. In 1986, on the other hand, precursors involving initiators except for three TRIP-initiated precursors had CCDPs that were higher than 1.0×10^{-4} but all the precursors involving DHR (AFW) unavailability had CCDPs in the range of 1.0×10^{-5} - 1.0×10^{-4}. For BWRs, precursors involving initiators were distributed differently for each year. For example, eight of the eleven TRIP-initiated precursors in 1984 had CCDPs in the range of 1.0×10^{-4} - 1.0×10^{-3}, eight of nine such precursors in 1985 were distributed evenly in the range of two probability bins $1.0x10^{-5}$ - $1.0x10^{-3}$, and four of seven such precursors in 1987 had CCDPs of $1.0x10^{-5}$ or lower. As well, precursors involving unavailabilities were found in different CCDP ranges year by year. While all of three precursors involving ECI unavailability had CCDPs in the range of $1.0x10^{-6}$ - $1.0x10^{-5}$, four precursors involving EPS unavailability were distributed evenly in the two probability bins of 1.0×10^{-6} - 1.0×10^{-5} and 1.0×10^{-4} - 1.0×10^{-3}.

It can be summarized that, during this period, BWR precursors had higher CCDPs than PWR precursors. A lot of TRIP-initiated precursors at PWRs had CCDPs in the range of two probability bins $1.0x10^{-6}$ - $1.0x10^{-4}$, as shown in Figure 6(a), in particular nineteen of the 39 TRIP-initiated precursors (two in 1984, nine in 1985, two in 1986, and six in 1987) at PWRs were distributed in the range of $1.0x10^{-6}$ - $1.0x10^{-5}$. On the other hand, as indicated in Figure 6(b), there were most of TRIP-initiated precursors at BWRs in higher two CCDP bins $1.0x10^{-5}$ - $1.0x10^{-3}$, in particular thirteen of the 28 such precursors (eight in 1984, four in 1985 and one in 1987) at BWRs were included in the CCDP range of $1.0x10^{-4}$ - $1.0x10^{-3}$. This difference mainly contributed to the differences in the distributions of PWR and BWR precursors. More than a half of the precursors involving unavailabilities (14 events) had CCDPs of lower than $1.0x10^{-5}$: five of the six precursors involving ECI unavailability (two at PWRs and three at BWRs), five of the eleven precursors involving EPS unavailability and four of the nine precursors involving DHR unavailability.

3.3 Trends for 1988-94 Precursors

During the 1988-94 period, the ASP Program identified 173 precursors : 128 precursors occurred at PWRs and 45 precursors occurred at BWRs. There were approximately 30 precursors identified in each calendar year except for 1993 and 1994 where less than twenty precursors were identified. For the years, 1988 and 1991-93, PWR precursors can be roughly evenly divided between precursors involving initiators and those involving unavailabilities as shown in Figure 7(a). While, for the years 1990 and 1994, about two-

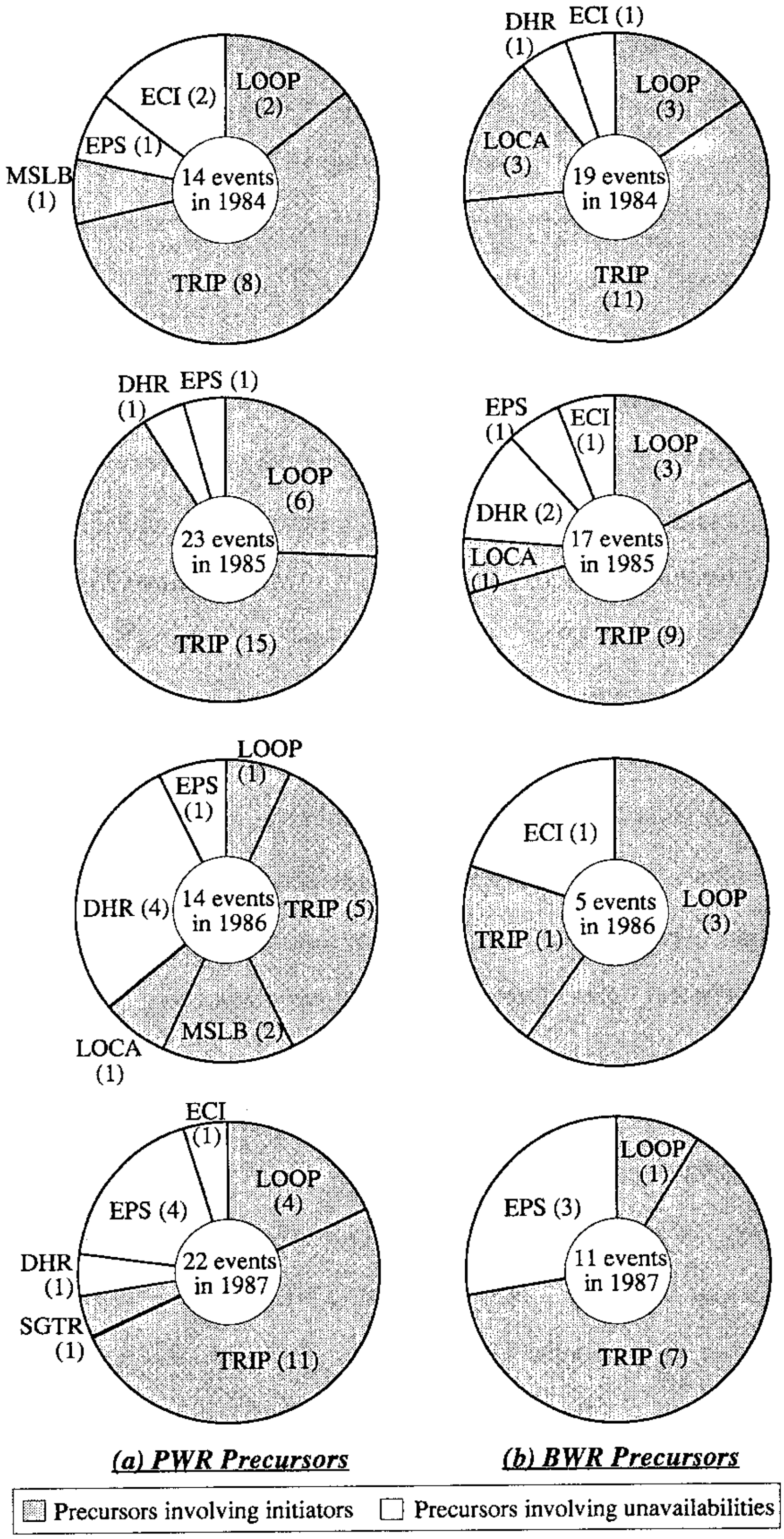
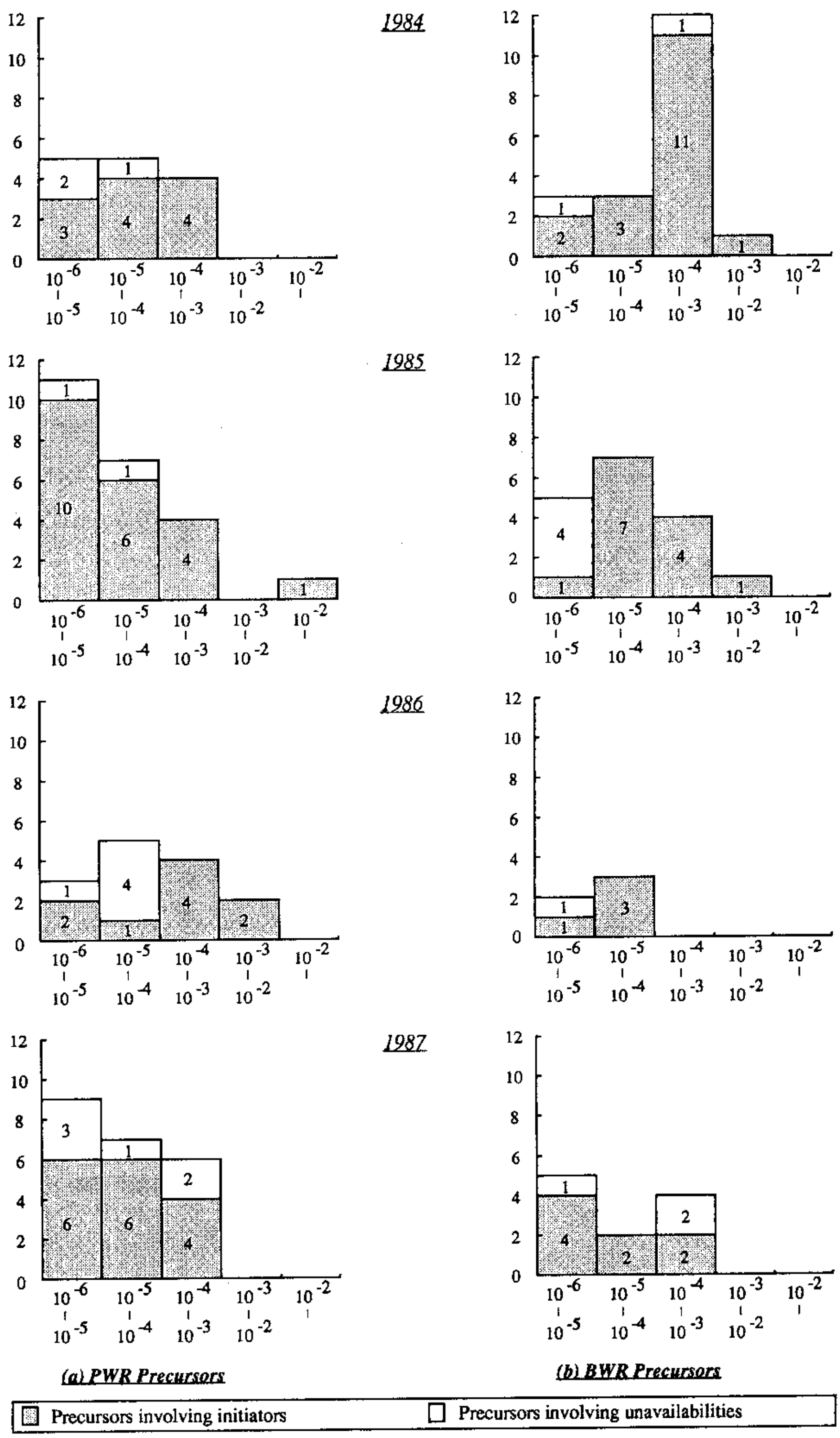
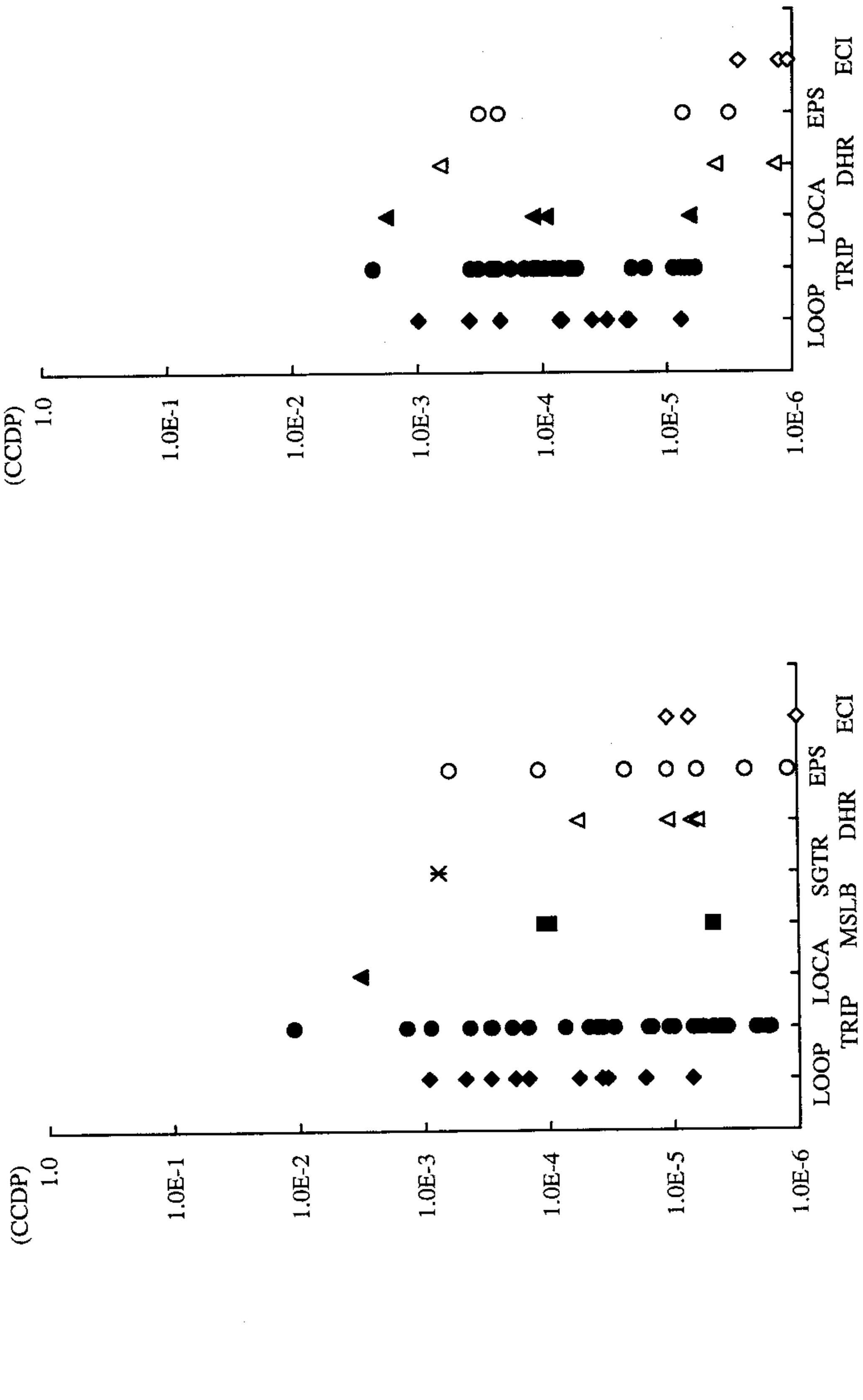


Figure 4 Distributions of 1984-87 Precursors by Initiators/Unavailable Systems



(Ordinates stand for the number of precursors and Abscissas stand for the range of CCDPs)

Figure 5 Distributions of 1984-87 Precursors by CCDPs



(a) PWR Precursors

(b) BWR Precursors

Figure 6 Distributions of CCDPs for 1984-87 Precursors by Initiators/Unavailable Systems

thirds were occupied by precursor involving unavailabilities, for the year 1989, two-thirds were the precursors involving initiators. In contrast, except for 1994, BWR precursors are dominated by precursors involving initiators for the individual years as shown in Figure 7(b). From the standpoint of initiating event category, TRIP was found to be a major contributor at both PWRs and BWRs. This was, especially, remarkable for BWRs, where more than 40% of the precursors for individual years except for 1994 were initiated by a TRIP. Three LOCA-initiated precursors were identified during this period, all of which were caused by inadvertent opening of a PORV or an SRV. For the case of precursors involving unavailabilities, different trends can be observed for PWRs and BWRs. Such precursors occurring at PWRs can be roughly divided into three types, precursors involving DHR unavailability, those involving EPS unavailability and those involving ECI unavailability, but their contributions vary from year to year. Only one of precursors involving DHR unavailability in 1990 was caused by the failure of AFW and the other sixteen precursors involved the unavailability of HPR/LPR, four of which were due to SWS problems. Two out of the 25 precursors involving EPS unavailability and two out of the 19 precursors involving ECI unavailability were caused by CCW/SWS problems. On the other hand, on an individual year basis, BWR precursors involving unavailabilities are dominated by those involving EPS unavailability and/or those involving ECI unavailability. Three of the seven precursors involving EPS unavailability were caused by SWS failure. Six precursors involving ECI unavailability consisted of three HPI unavailabilities, two ADS unavailabilities due to instrument air problem and signal logic circuit failure, and one LPCI/LPCS unavailability. It should be noted that no precursor involving DHR unavailability was identified during this period. Additionally, there were three precursors related to shutdown events : two at PWRs in 1990 and 1994 and the other at a BWR in 1990.

As indicated in Figure 8(a) and 8(b), different trends can be seen in the distributions of PWR and BWR precursors as a function of CCDP for calendar years during this period. While PWR precursors were roughly evenly distributed in the range of three probability bins that were lower than $1.0x10^{-3}$ for each year, most of BWR precursors were in the range of two probability bins that were lower than $1.0x10^{-4}$ except for 1991 and 1993. For PWRs, twenty-one of the 34 TRIP-initiated precursors (three in 1988, five in 1989, five in 1990, two in 1991, four in 1992 and two in 1993) had CCDPs in the range of $1.0x10^{-6}$ - $1.0x10^{-5}$ but thirteen of the 20 LOOP-initiated precursors (two in 1988, two in 1989, three in 1991 and six in 1992) were included in the CCDP range of $1.0x10^{-4}$ - $1.0x10^{-3}$. Precursors involving unavailabilities were distributed roughly evenly in the range of three probability bins $1.0x10^{-6}$ - $1.0x10^{-3}$. For BWRs, twelve of the 21 TRIP-initiated precursors (two in 1988, three in 1989, three in 1990, three in 1991, and one in 1994) were included in the range of $1.0x10^{-5}$ - $1.0x10^{-4}$ but the eight LOOP-initiated precursors were distributed evenly in the range of three probability bins that were lower than $1.0x10^{-3}$. Most of the precursors involving unavailabilities were found in the range of probability bins that were lower than $1.0x10^{-4}$.

In summary, as can be seen from Figure 9(a) and 9(b), the TRIP-initiated precursors for both PWRs and BWRs had relatively lower CCDPs. Especially, this tendency is quite noticeable for the case of PWR precursors. Furthermore, many LOOP-initiated precursors at PWRs had CCDPs in the higher probability bins. For both PWRs and BWRs, precursors involving unavailabilities were widely distributed in the range of three probability bins $1.0x10^{-6}$ - $1.0x10^{-3}$.

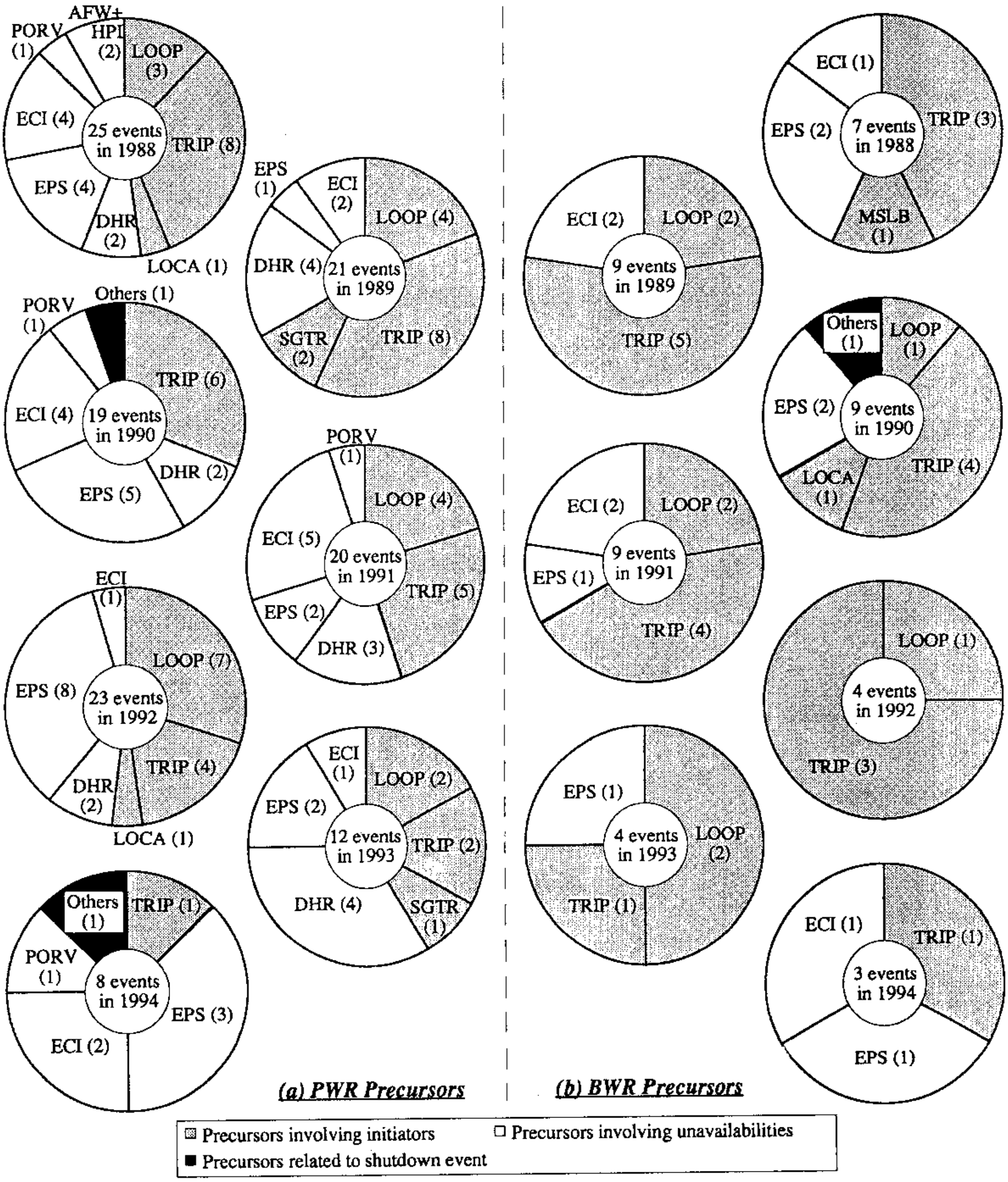
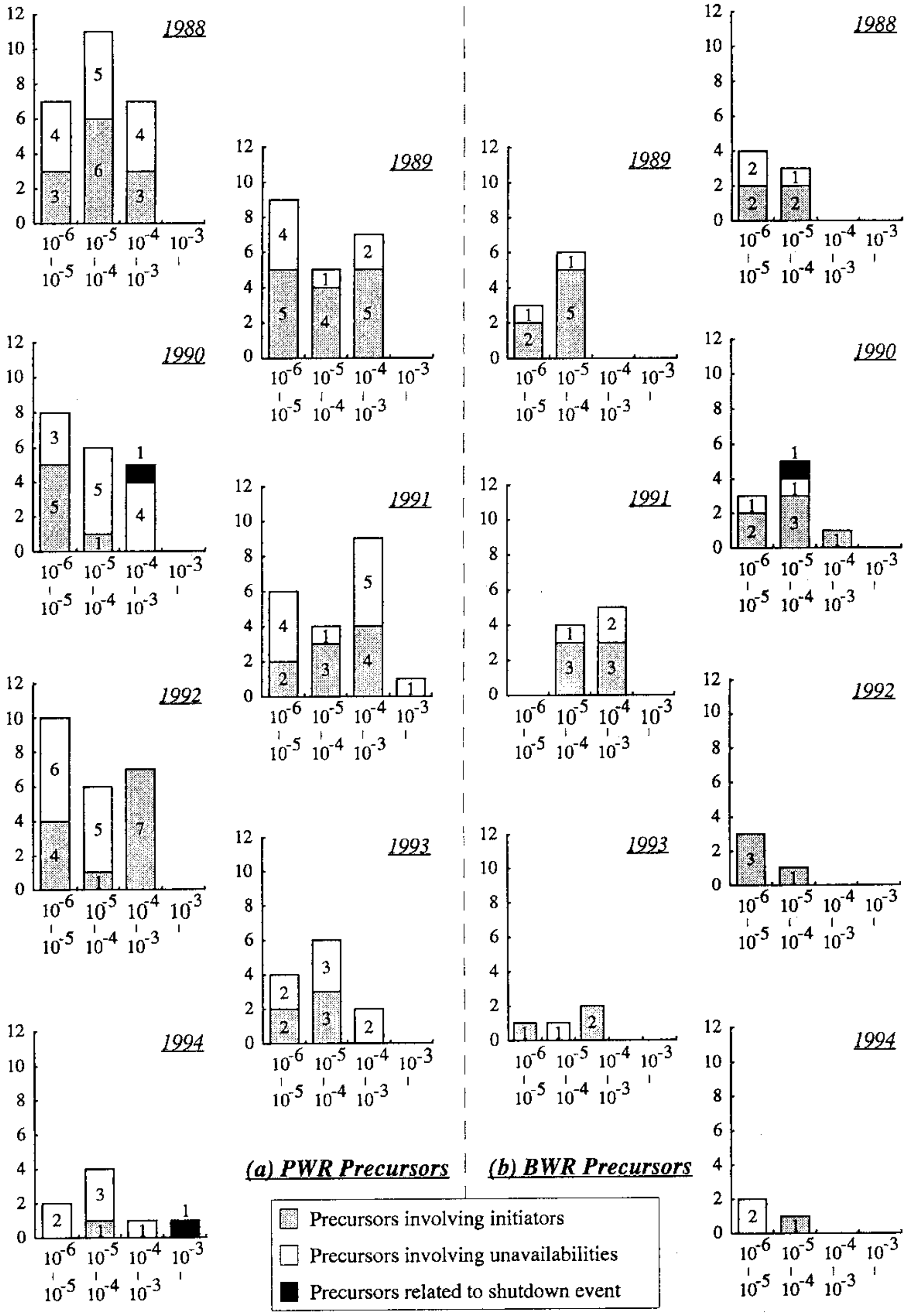
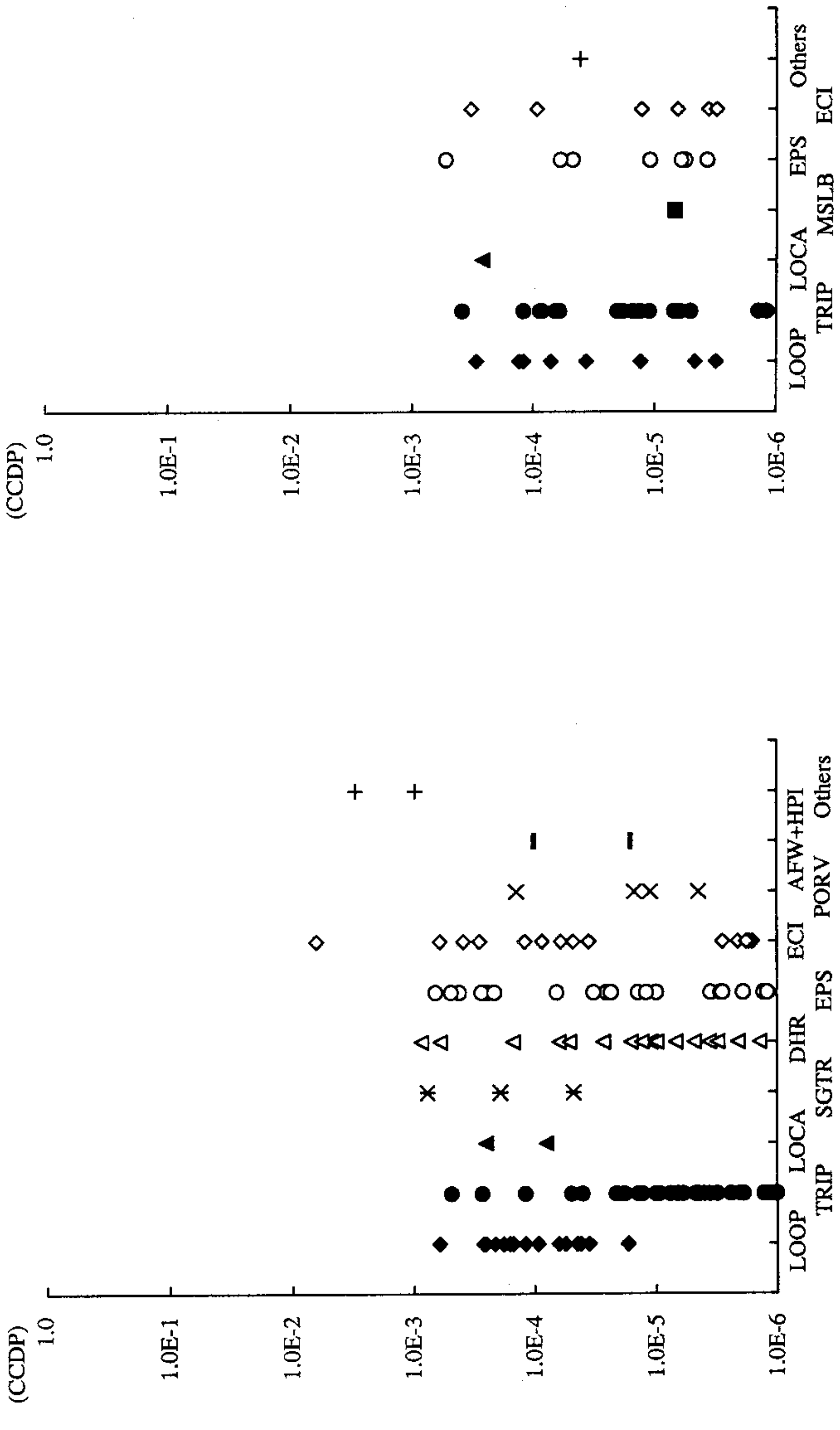


Figure 7 Distribution of 1988-94 Precursors by Initiators/Unavailable Systems



(Ordinates stand for the number of precursors and Abscissas stand for the range of CCDPs)

Figure 8 Distributions of 1988-94 Precursors by CCDPs



(a) PWR Precursors

(b) BWR Precursors

Figure 9 Distributions of CCDPs for 1988-94 Precursors by Initiators/Unavailable Systems

4. Trends in Dominant Core Damage Sequences Identified

In the present study, the dominant core damage sequence is defined as one which contributes more than 50% to the CCDP estimated for a precursor. However, in some events, the CCDP was dominated by two or more sequences. This chapter describes the trends in dominant sequences for 459 precursors identified for the 1969-94 period. As well as the trends in initiating events, the trends in dominant sequences are discussed for the same three time periods as considered above, excluding the precursors related to shutdown events and potential seismic design defects because of the event-specific models used. In the followings, the discussions about the dominant sequences are divided between PWRs and BWRs.

Tables 1, 2 and 3 show the dominant sequences contributing to the precursors for PWRs and BWRs during each of the three periods. The sequence identifiers used in the present study basically follow the symbols defined in WASH-1400[15] and are listed along with their descriptions in Table 4. The discussions as below are based on these tables.

4.1 Trends for 1969-81 Precursors

(1) PWR Precursors

As can be seen in Table 1(a), for the 1969-79 precursors, four major dominant sequences were identified : two transient sequences, TML/TMLD and TMLB, and two small break LOCA sequences, S2D and S2H. Thirty-six of the 68 precursors were dominated by TML/TMLD, approximately 80% of which (28 events) involved an actual initiator. Especially, twenty-two of these 28 precursors were initiated by a LOOP. All of eight precursors involving unavailabilities were associated with the unavailability of AFW. There were also nineteen precursors dominated by TMLB, including seven precursors also contributed by TML/TMLD. Out of them, twelve precursors were initiated by a LOOP and the other seven involved EPS unavailability. As for LOCA sequences, four precursors were dominated by S2D, four precursors were dominated by S2H, and seven precursors were dominated by both sequences. All the S2D-dominated precursors involved the unavailability of HPI, two of which were caused by human errors, one was due to pump failure, and one was due to valve failure. The S2H-dominated precursors were associated with HPR failure, three of which were caused by sump valve malfunctions and the other resulted from SWS problem. All of the precursors dominated by both S2D and S2H sequences were LOCA-initiated events, six of which were caused by inadvertent opening of PORVs and the other was due to RCP seal failure.

For 1980-81 precursors, there were three major dominant sequences : TML/TMLD, TMLB and S2D. Among the 26 precursors, there were ten precursors dominated by TML/TMLD, consisting of four LOOP-initiated precursors, three TRIP-initiated precursors, one MSLB-initiated precursor, one precursor involving AFW unavailability and one precursor involving HPI unavailability caused by SWS failure. The MSLB-initiated precursor was also contributed by an ATWS sequence, TK. Six of seven precursors dominated by TMLB were initiated by a LOOP and the other involved AFW unavailability caused by SWS problem. Five of seven precursors dominated by S2D were initiated by a LOCA. Three of them were due to inadvertent opening of a PORV, one was caused by leakage from a CVCS valve and one was due to RCP seal failure. The other two precursors involved HPI unavailability - one was caused by the pipe blokage due to boric acid precipitate and the other was caused by inadvertent closure of supply valve. It should be noted that there was one precursor involving unavailabilities dominated by a large break LOCA sequence, AD, which was caused by potential failure of ECCS injection valves in closed position.

(2) BWR Precursors

As shown in Table 1(b), during the period 1969-79, four major dominant sequences contributed to the BWR precursors : three transient sequences, TQUX/TQUV, TB/TBU, and TW, and one small break LOCA sequence, S2UX/S2UV. Twenty-five of the 49 precursors were dominated by the TQUX/TQUV sequences, nine of which were also dominated by other sequences, TBU and/or TW. Out of the 25 precursors, there were 17 precursors involving initiators - seven TRIP-initiated precursors and ten LOOP-initiated precursors. All of the precursors dominated by more than two sequences were initiated by a LOOP. Eight precursors involving unavailabilities consisted of four involving unavailabilities of high pressure systems, three involving failure of ADS valve(s) to open and one involving RHR unavailability due to SWS failure. Fourteen precursors were dominated by the TB/TBU sequences, including four precursors contributed by other sequences. These 14 precursors can be divided into six precursors initiated by a LOOP, six involving EPS unavailability, and two involving IC unavailability. Two of the precursors involving EPS unavailability were caused by CCW/SWS problems. Out of thirteen precursors dominated by the TW sequence, eleven were LOOP-initiated precursors and the others involved RHR unavailability due to SWS failure. As for LOCA sequences, seven precursors were dominated by the S2UX/S2UV sequences and five of them were caused by inadvertent opening of an SRV. It should be noted that there was one precursor dominated by a large break LOCA sequence, AE, which was initiated by inadvertent opening of all ADS valves due to human errors.

For 1980-81 events, TQUX/TQUV and S2UX/S2UV were identified as major dominant sequences. Two of five precursors with dominant sequences TQUX/TQUV involved an actual initiator, one initiated by a TRIP and one initiated by a LOOP. The others were associated with ECI unavailability, two with high pressure systems and one with ADS. Four precursors were dominated by the S2UX/S2UV sequences, all of which were initiated by inadvertent opening of an SRV. Two precursors were dominated by the ATWS sequence, TC, both of which were caused by problems in the SDV.

4.2 Trends for 1984-87 Precursors

(1) PWR Precursors

As shown in Table 2(a), during this period, on a year by year basis, trends in the dominant sequences are different from each other. For events in 1984, one-half of the precursors were found to be dominated by the TMLD sequence, all of which were initiated by a TRIP. Out of the 23 precursors in 1985, also, TMLD was identified as a dominant sequence in fourteen precursors, most of which were initiated by a TRIP. However, eleven of them were also contributed by another transient sequence, TMLH. In addition, there were five precursors dominated by the transient sequence, TQH, all of which were initiated by a TRIP. A review of precursors in 1986 identified two major dominant sequences, TMLB and TQH. The five precursors dominated by the TMLB sequence consisted of one LOOP-initiated precursor, three precursors involving AFW unavailability and one involving EPS unavailability. All of the five TQH-dominated precursors were initiated by TRIP. There were three precursors in 1986 dominated by TMLD, one of which was initiated by a TRIP, one by an MSLB and one involving AFW unavailability. For the precursors in 1987, TMLD and TMLB were the major dominant sequences : twelve precursors were dominated by TMLD and eight were dominated by TMLB. Eleven of the TMLD-dominated precursors were initiated by a TRIP and the other involved AFW unavailability. Four of the TMLB-dominated precursors were initiated by a LOOP and the other four involved EPS unavailability, one of which was caused by problems in the instrument air system.

There were five precursors associated with LOCA during the period 1984-87. These can be divided into three events dominated by the S2D sequence, which involved HPI unavailability due to maintenance or testing errors, and two dominated by the S2H sequence, one of which was initiated by a small break LOCA due to leakage from a CVCS valve and the other involved HPR/LPR unavailability was due to failure of CCW.

(2) BWR Precursors

As shown in Table 2(b), it should be noted that TW was identified as one of the major dominant sequences for BWR precursors in each of calendar years during this period. The TW sequence was dominant in six precursors in 1984 and 1985, and in three precursors in 1986 and 1987. Thirteen of these precursors were initiated by a TRIP (five in 1984, four in 1985, one in 1986 and three in 1987), two precursors in 1986 were initiated by a LOOP and the other three involved DHR unavailability. On the other hand, the other major dominant sequences for this period are slightly different year by year. Eight of the 19 precursors in 1984 were dominated by the transient sequence, TPQUX, six of which were initiated by a TRIP, one was initiated by a LOOP and one involved HPI unavailability. As well, three precursors in this year were dominated by LOCA sequences : two by S2UX and one by AE. While both S2UX-dominated precursors occurred due to inadvertent opening of an SRV, the AE-dominated precursor was caused by leakage from an LPCS valve, which could lead to an interfacing system LOCA. For the precursors in 1985, instead of TPQUX, TQUX was identified as a major dominant sequence. Four of the seven TQUX-dominated precursors were initiated by a TRIP, two were initiated by a LOOP and one involved HPI unavailability. In 1986, in addition to three TW-dominated precursors, there was one precursor dominated by the TQUX sequence initiated by a LOOP and one dominated by the TPQUX sequence involving HPI unavailability. Different from the previous years, in 1987, TPQUX and TB/TBU were identified as major dominant sequences in addition to the TW sequence. Although all of the four TPQUX-dominated precursors were initiated by a TRIP, three of the four TB/TBU-dominated precursors involved EPS unavailability and one was initiated by a LOOP.

4.3 Trends for 1988-94 Precursors

(1) PWR Precursors

Table 3(a) indicates that trends in dominant sequences contributing to precursors are similar for each calendar year during the period 1988-94. Two transient sequences, TMLD and TMLB, and two LOCA sequences, S2D and S2H, were the major dominant sequences in each year. However, the respective percentages of the precursor population dominated by these sequences vary from year to year. It should be noted that the definition of TMLB is slightly different from that for the previous periods because of consideration of a possibility of RCP seal LOCA resulting from station blackout. That is, TMLB in this period includes sequences with and without RCP seal LOCA. In 1988, about a half of the precursors (12 events) were dominated by TMLD, eight of which were initiated by a TRIP. There were seven TMLB-dominated precursors, three of which were initiated by a LOOP and three involved EPS unavailability. Four of the five S2D-dominated precursors involved HPI unavailability. It should be noted that one precursor contributed by the above three sequences involved the unavailability of DGs and HPI due to CCW failure. Out of the 21 precursors in 1989, there were nine precursors dominated by TMLD, seven of which were initiated by a TRIP, and five dominated by TMLB, three of which initiated by a LOOP. All of four precursors dominated by LOCA sequences, S2D, S2H and S1H, involved unavailabilities of HPI, HPR and LPR, respectively. For precursors in 1990, there were seven TMLD-dominated precursors and six TMLB-dominated precursors. Four of the TMLD-dominated precursors were initiated by a TRIP and the other three involved unavailabilities of AFW, HPI and PORV, respectively. Five of the TMLB-dominated precursors involved EPS unavailability, one of which was caused by CCW failure. Out of three precursors dominated by LOCA sequences, one dominated by S2D and S2H was caused by CCW failure. In 1991, there were six precursors dominated by TMLB, five by TMLD, five by S2D, and four by S2H. While most of the precursors dominated by transient sequences involved an actual initiator (four LOOP-initiated precursors and three TRIP-initiated precursors), most of the precursors dominated by LOCA sequences involved unavailability of system(s) (three involving HPR/LPR unavailability and five involving HPI unavailability). Of the precursors in 1992, about two-thirds (16 events) were dominated by the TMLB sequence. These precursors can be divided into those initiated by a LOOP (7 events) and those involving EPS unavailability (8 events). There were also four TMLD-dominated precursors, which were initiated by a TRIP. Similar to 1992, one-third of the precursors in 1993 were dominated by the TMLB sequence. Two of them were initiated by a LOOP and the other two involved EPS unavailability. Two TMLD-dominated precursors were initiated by a TRIP, two TMLH-dominated precursors involved HPR/LPR unavailability due to SWS failure and two S2H-dominated precursors involved HPR unavailability. For the precursors in 1994, there were three TMLD-dominated precursors. All of them involved EPS unavailability, one of which also involved AFW unavailability. Two precursors were dominated by the AD sequence, but it should be noted that these occurred at a two-units site due to load sequencer problems.

(2) BWR Precursors

As shown in Table 3(b), quite similar trends can be observed in dominant sequences for each of the calendar years in this period. The following three transient sequences were identified as major dominant sequences for this period : TPQUX, TB/TBU and TW. Nine of the thirteen TPQUX-dominated precursors were initiated by a TRIP, two were initiated by a LOOP and two involved HPI unavailability. As for the TB/TBU-dominated precursors, about one-half (6 events) were LOOP-initiated precursors and the others consisted of seven involving EPS unavailability, two of which were caused by CCW/SWS failure, and one involving ECI unavailability due to IC problems. Nine of the eleven TW-dominated precursors were initiated by a TRIP, one was initiated by an MSLB and one involved RHR (LPCI) failure due to pressure locking which was also dominated by a small break LOCA sequence, S2UV. In addition, there were three TQUX-dominated precursors and two S2UX-dominated precursors. The TQUX-dominated precursors were initiated by a TRIP and the S2UX-dominated precursors consisted of one involving inadvertent opening of an SRV and one involving ADS unavailability due to control wiring damage. It should be noted that one out of the precursors in 1994 was dominated by a medium break LOCA sequence, S1UX, which involved long-term unavailability of HPI due to valve failure.

4.4 Summary of Trends in Dominant Sequences for All Precursors

As previously described, although slight differences were observed in trends in dominant sequences, the results can be summarized as follows.

Overall, for PWR precursors, two transient sequences, TML/TMLD and TMLB, were identified as major dominant ones. While more than 80% of the TML/TMLD-dominated precursors were initiated by a TRIP or LOOP, about one-half of the TMLB-dominated precursors were associated with system unavailability, most of which involved EPS unavailability. In addition, approximately 20% of the PWR precursors were dominated by LOCA sequences such as S2D and S2H. More than two-thirds of them involved unavailability of systems such as HPI and HPR. This tendency was especially observed more remarkably for the precursors during the 1984-94 period.

In the case of BWR precursors, in general, three transient sequences, TQUX/TPQUX, TB/TBU and TW, were found to be major dominant ones. Although an LOCA sequence, S2UX, was identified as dominant in more than ten precursors during the 1969-81 period, TPQUX, not S2UX, appeared as a major dominant sequence for the other two periods considered. A possible reason of this difference may be that the number of LOCA-initiated precursors, in particular those involving inadvertent opening of an SRV, decreased. At about this time, failure of an open SRV to reclose was incorporated into the ASP event tree models explicitly and hence was no longer an initiator, resulting in the increase of the number of TPQUX-dominated precursors.

Table 1 Number of 1969-81 Precursors by Dominant Sequences

(a) PWR Precursors

Dominant Sequences	1969-1979	1980-1981	Total
TMLB	12 (5, 7)[a]	7 (6, 1)	19 (11, 8)
TMLB, TML/TMLD	7 (7, 0)		7 (7, 0)
TML/TMLD	27 (19, 8)	9 (7, 2)	36 (26, 10)
TML/TMLD, TQD	1 (1, 0)		1 (1, 0)
TML/TMLD, ISOL	1 (1, 0)		1 (1, 0)
TML/TMLD, TK		1 (1, 0)	1 (1, 0)
TK	1 (0, 1)		1 (0, 1)
ISOL	2 (2, 0)		2 (2, 0)
S2D	4 (0, 4)	7 (5, 2)	11 (5, 6)
S2H	4 (0, 4)	1 (1, 0)	5 (1, 4)
S2D, S2H	7 (7, 0)		7 (7, 0)
AD		1 (0, 1)	1 (0, 1)
SGTR	1 (1, 0)		1 (1, 0)
not identified	1 (0, 1)		1 (0, 1)
Total [b]	68 (43, 25)	26 (20, 6)	94 (63, 31)

(b) BWR Precursors

Dominant Sequences	1969-1979	1980-1981	Total
TQUX/TQUV	16 (8, 8)[a]	5 (2, 3)	21 (10, 11)
TQUX, TBU	2 (2, 0)		2 (2, 0)
TQUX, TW	5 (5, 0)		5 (5, 0)
TQUX, TBU, TW	2 (2, 0)		2 (2, 0)
TB/TBU	10 (2, 8)	1 (0, 1)	11 (2, 9)
TW	6 (4, 2)	1 (1, 0)	7 (5, 2)
TC		2 (0, 2)	3 (0, 3)
S2UX/S2UV	5 (5, 0)	4 (4, 0)	10 (10, 0)
S2W		1 (0, 1)	1 (0, 1)
S2W, S2UX	2 (2, 0)		2 (2, 0)
AE	1 (1, 0)		1 (1, 0)
Total [b]	49 (31, 18)	14 (7, 7)	63 (38, 25)

[a] (m, n), (number of precursors involving initiators, number of precursors involving unavailabilities)

[b] The total number excludes three PWR precursors related to shutdown event (one in 1969-79 and two in 1980-81) and one BWR precursor related to seismic design defect in 1969-79.

Table 2 Number of 1984-87 Precursors by Dominant Sequences

(a) PWR Precursors

Dominant Sequences	1984	1985	1986	1987	Total
TMLB	3 (2, 1)[a]	2 (1, 1)	5 (1, 4)	8 (4, 4)	18 (8, 10)
TMLD	6 (6, 0)	3 (3, 0)	2 (1, 1)	12 (11, 1)	23 (21, 2)
TMLD, TMLH	1 (1, 0)	11 (11, 0)	1 (1, 0)		13 (13, 0)
TMLH, TMLF		1 (1, 0)			1 (1, 0)
TQH	2 (2, 0)	5 (5, 0)	5 (5, 0)		12 (12, 0)
S2D	2 (0, 2)			1 (0, 1)	3 (0, 3)
S2H		1 (0, 1)	1 (1, 0)		2 (1, 1)
SGTR				1 (1, 0)	1 (1, 0)
Total	14 (11, 3)	23 (21, 2)	14 (9, 5)	22 (16, 6)	73 (57, 16)

(b) BWR Precursors

Dominant Sequences	1984	1985	1986	1987	Total
TQUX	1 (1, 0)	6 (5, 1)	1 (1, 0)		8 (7, 1)
TQUX, TPQUX	1 (1, 0)	1 (1, 0)			2 (2, 0)
TPQUX	7 (6, 1)	3 (2, 1)	1 (0, 1)	4 (4, 0)	15 (12, 3)
TB/TBU				4 (1, 3)	4 (1, 3)
TBPU	1 (1, 0)				1 (1, 0)
TW	6 (5, 1)	6 (4, 2)	3 (3, 0)	3 (3, 0)	18 (15, 3)
S2UX	3 (3, 0)	1 (1, 0)			4 (4, 0)
AE	1 (1, 0)				1 (1, 0)
Total	19 (17, 2)	17 (13, 4)	5 (4, 1)	11 (8, 3)	52 (42, 10)

[a] (m, n), (number of precursors involving initiators, number of precursors involving unavailabilities)

Table 3 Number of 1988-94 Precursors by Dominant Sequences
(a) PWR Precursors

Dominant Sequences	1988	1989	1990	1991	1992	1993	1994	Total
TMLB	6 (3, 3)[a]	5 (4, 1)	3 (0, 3)	5 (3, 2)	15 (7, 8)	4 (2, 2)	3 (0, 3)	41 (19, 22)
TMLB, TMLD			1 (0, 1)	1 (1, 0)				2 (1, 1)
TMLB, S2D, TMLD	1 (0, 1)							1 (0, 1)
TMLB, TQD			2 (0, 2)					2 (0, 2)
TMLB, S2H					1 (0, 1)			1 (0, 1)
TML/TMLD	11 (8, 3)	9 (8, 1)	6 (4, 2)	4 (3, 1)	4 (4, 0)	2 (2, 0)	1 (0, 1)	37 (29, 8)
TMLD, TQD			1 (1, 0)					1 (1, 0)
TMLH, TMLF	1 (0, 1)					2 (0, 2)		3 (0, 3)
TQH		1 (0, 1)						1 (0, 1)
TQD			1 (1, 0)					1 (1, 0)
TK				1 (1, 0)				1 (1, 0)
S2D	4 (0, 4)	1 (0, 1)	1 (0, 1)	5 (0, 5)	2 (1, 1)	1 (0, 1)	1 (1, 0)	15 (2, 13)
S2H	2 (1, 1)	2 (0, 2)	1 (0, 1)	4 (1, 3)	1 (0, 1)	2 (0, 2)		12 (2, 10)
S2D, S2H			1 (0, 1)					1 (0, 1)
S1H		1 (0, 1)						1 (0, 1)
AD							2 (0, 2)	2 (0, 2)
SGTR		2 (2, 0)				1 (1, 0)		3 (3, 0)
not identified			1 (0, 1)					1 (0, 1)
Total[b]	25 (12, 13)	21 (14, 7)	18 (6, 12)	20 (9, 11)	23 (12, 11)	12 (5, 7)	7 (1, 6)	126 (59, 67)

[a] (m, n), (number of precursors involving initiators, number of precursors involving unavailabilities)

[b] The total number excludes two PWR precursors related to shutdown event in 1990 and 1994.

Table 3 Number of 1988-94 Precursors by Dominant Sequences
(b) BWR Precursors

Dominant Sequences	1988	1989	1990	1991	1992	1993	1994	Total
TQUX			1 (1, 0)[a]	1 (1, 0)			1 (1, 0)	3 (3, 0)
TPQUX	3 (3, 0)	6 (4, 2)	2 (2, 0)	1 (1, 0)	1 (1, 0)			13 (11, 2)
TB/TBU	3 (0, 3)	1 (1, 0)	2 (0, 2)	3 (2, 1)	1 (1, 0)	3 (2, 1)	1 (0, 1)	14 (6, 8)
TW	1 (1, 0)	2 (2, 0)	2 (2, 0)	2 (2, 0)	2 (2, 0)	1 (1, 0)		10 (10, 0)
S2UX			1 (1, 0)	1 (0, 1)				2 (1, 1)
S2UV, TW				1 (0, 1)				1 (0, 1)
S1UX							1 (0, 1)	1 (0, 1)
Total [b]	7 (4, 3)	9 (7, 2)	8 (6, 2)	9 (6, 3)	4 (4, 0)	4 (3, 1)	3 (1, 2)	44 (31, 13)

[a] (m, n), (number of precursors involving initiators, number of precursors involving unavailabilities)

[b] The total number excludes one BWR precursors related to shutdown event in 1990.

Table 4 Description of Sequence Identifiers

PWR

Sequence Identifiers	Sequence Description
TK	transient followed by failure of reactor scram
TML	transient with PCS unavailable followed by failure of AFW
TMLB	station blackout
TMLD	transient with PCS unavailable followed by failure of AFW and failure of primary feed-and-bleed operation
TMLF	transient with PCS unavailable followed by failure of AFW and failure of CSR
TMLH	transient with PCS unavailable followed by failure of AFW and failure of HPR/LPR
TQD	transient with PORV stuck open followed by failure of HPI
TQH	transient with PORV stuck open followed by failure of HPR/LPR
S2D	small-break LOCA followed by failure of HPI
S2H	small-break LOCA followed by failure of HPR/LPR
S1H	medium-break LOCA followed by failure of HPR/LPR
AD	large-break LOCA followed by failure of ECCS
ISOL	steam line break followed by failure of SG isolation
SGTR	steam generator tube rupture

BWR

Sequence Identifiers	Sequence Description
TB	station blackout
TBU	station blackout followed by failure of HPCI/RCIC
TBPU	station blackout with SRV stuck open followed by failure of HPCI/RCIC
TC	transient followed by failure of reactor scram
TPQUX	transient with SRV stuck open followed by failure of feedwater system, failure of HPCI/RCIC, and failure of manual depressurization
TQUV	transient followed by failure of feedwater system, failure of HPCI/RCIC, and failure of low pressure ECCS
TQUX	transient followed by failure of feedwater system, failure of HPCI/RCIC, and failure of manual depressurization
TW	transient followed by loss of decay heat removal
S2UV	small-break LOCA followed by failure of HPCI/RCIC and failure of low pressure ECCS
S2UX	small-break LOCA followed by failure of HPCI/RCIC and failure of manual depressurization
S2W	small-break LOCA followed by loss of decay heat removal
S1UX	medium-break LOCA followed by failure of HPCI and failure of manual depressurization
AE	large-break LOCA followed by failure of ECCS

AFW: auxiliary feedwater system, CSR: containment spray recirculation, HPCI: high pressure coolant injection, HPI: high pressure injection, HPR/LPR: high/low pressure recirculation, PCS: power conversion system, PORV: power-operated relief valve, RCIC: reactor core isolation cooling, SRV: safety relief valve

5. Comparison with PRA Results

This chapter describes a comparison of dominant sequences identified in the ASP analyses with those identified in past PRAs such as WASH-1400 and NUREG-1150[16].

5.1 PWR Dominant Sequences

In WASH-1400, two small break LOCA sequences (S2D and S2H) and two transient sequences (TML and TMLB) were major contributors to the core damage frequency (CDF) for the PWR (Surry). The most dominant sequence, S2D, contributed approximately 20% of the CDF.

On the other hand, in NUREG-1150, the dominant sequences identified for three PWRs (Surry, Sequoyah, Zion) were different from each other. For Surry, station blackout sequences, TMLB with or without RCP seal LOCA, contributed more than 60% of the CDF from internal events. The estimated contribution from LOCA sequences was approximately 15%. The S1H sequence was the largest contributor among LOCA sequences with a contribution of approximately 4%. For Sequoyah, the LOCA sequences involving recirculation failure contributed more than 60% of the CDF from internal events. Also, station blackout sequences, TMLB with or without RCP seal LOCA, were found to be major contributors with a contribution of approximately 25% of the CDF. For Zion, transient sequences such as TMLD with potential RCP seal LOCA contributed more than 70% of the CDF from internal events. The contributions from LOCA sequences and station blackout sequences were relatively small, that is, approximately 3% and 2%, respectively.

As described previously, approximately 95% of the 1969-81 precursors (88 events) were dominated by TML/TMLD, TMLB, S2D or S2H, each of which had been identified as a dominant sequence in WASH-1400 : TML/TMLD and/or TMLB were dominant in 65 events and S2D/S2H were dominant in 23 events. In other words, it can be said that the trends in dominant sequences identified in the ASP analyses of 1969-81 events were consistent with the predictions by WASH-1400. As well, approximately 75% of 1984-87 precursors were found to be dominated by the following two sequences : TMLD dominated in 36 events and TMLB dominated in 18 events. However, instead of the LOCA sequences, two other transient sequences, TQH and TMLH, were also identified as dominant in twelve and fourteen events, respectively. These sequences did not appear as major contributors in either WASH-1400 or NUREG-1150. In spite of such differences, the trends in dominant sequences for 1984-87 precursors were relatively consistent with the predictions from PRAs. For 1988-94 precursors, four sequences similar to those for 1969-81 precursors, TMLB, TMLD, S2D and S2H, were identified as dominant. One-third of the PWR precursors (47 events) were dominated by TMLB, one-third (41 events) by TMLD, sixteen precursors were dominated by S2D and thirteen precursors were dominated by S2H. Out of these sequences, as mentioned above, TMLB and S2H were determined to be the major contributors in both WASH-1400 and NUREG-1150. Especially, the TMLB sequence with RCP seal LOCA, which was the largest contributor to the CDF for Surry in NUREG-1150, was dominant in many precursors (24 events). In summary, although the ASP models have evolved, dominant sequences identified for PWRs in the ASP analyses are comparable to those predicted by WASH-1400 and NUREG-1150.

5.2 BWR Dominant Sequences

WASH-1400 indicated that two transient sequences, TW and TC, were the major contributors to the CDF for a BWR (Peach Bottom). The contributions of TW and TC to the CDF were approximately 55% and 40%, respectively. On the other hand, in NUREG-1150, the station blackout sequence, TB, dominated the CDFs for Peach Bottom and Grand Gulf. Its contribution was approximately 50% of the CDF for Peach Bottom and more than 90% for Grand Gulf. For Peach Bottom, there was another dominant sequence, TC, which contributed approximately 40%. The WASH-1400 and NUREG-1150 results show that for the BWRs, the LOCA sequences were found to be extremely small contributors to the CDF.

The review of BWR precursors indicated that three sequences, TQUX/TPQUX, TW and

TB/TBU, were identified as the dominant sequences. In particular, the TQUX/TPQUX sequence dominated more than 40% of BWR precursors : 28 events during 1969-81, 25 events during 1984-87 and 16 events during 1988-94. Although this sequence was not identified as dominant in either WASH-1400 or NUREG-1150, the RMIEP study for LaSalle indicated that the TQUX sequence was the largest contributor (approximately 30%) to the CDF[17]. The TW sequence was determined to be the major contributor in RMIEP as well as in WASH-1400 but not included in the dominant sequences in NUREG-1150. On the contrary, the dominant sequence, TB, was found in NUREG-1150 but not in WASH-1400 and RMIEP. It can be summarized that the trends in dominant sequences from the review of BWR precursors were relatively consistent with those predicted by the PRA studies.

6. Conclusion

This paper described the trends in initiating events and dominant sequences identified in the ASP analyses through the review of precursors during the 1969-94 period and also discussed a comparison with dominant sequences predicted in past PRA studies. These trends were examined for three time periods, 1969-81, 1984-87 and 1988-94, because the respective analysis models were employed by the ASP Program were different. The distributions of precursors by dominant sequences for these periods showed similar trends.

For PWRs, the following four major dominant sequences were identified : TML/TMLD, TMLB, S2D, and S2H. Although the first and third sequences, TML/TMLD and S2D, have been determined to be the major contributors to the CDF in WASH-1400 but not in NUREG-1150, the other two sequences, TMLB and S2H, were dominant in both of these PRA studies. As for BWRs, major dominant sequences identified were as follows : TQUX/TPQUX, TW, and TB/TBU. These sequences have been determined to have the largest contribution to CDF for BWRs in RMIEP, WASH-1400, and NUREG-1150, respectively.

Although major changes had been made in the ASP models and different event tree models had been used in the ASP analyses for three time periods, similar dominant sequences were identified for many precursors at both PWRs and BWRs. These sequences were also determined to be dominant in predictions by past PRAs. It should be noted that the present study provides a limited comparison of dominant sequences with PRA results because dominant sequences generally depend on the plant system configuration.

Acknowledgments

The author wishes to thank Drs. Patrick D. O'Reilly and Dale M. Rasmuson, Office for Analysis and Evaluation of Operational Data, United States Nuclear Regulatory Commission, for their reviews and valuable comments.

6. Conclusion

This paper described the trends in initiating events and dominant sequences identified in the ASP analyses through the review of precursors during the 1969-94 period and also discussed a comparison with dominant sequences predicted in past PRA studies. These trends were examined for three time periods, 1969-81, 1984-87 and 1988-94, because the respective analysis models were employed by the ASP Program were different. The distributions of precursors by dominant sequences for these periods showed similar trends.

For PWRs, the following four major dominant sequences were identified : TML/TMLD, TMLB, S2D, and S2H. Although the first and third sequences, TML/TMLD and S2D, have been determined to be the major contributors to the CDF in WASH-1400 but not in NUREG-1150, the other two sequences, TMLB and S2H, were dominant in both of these PRA studies. As for BWRs, major dominant sequences identified were as follows : TQUX/TPQUX, TW, and TB/TBU. These sequences have been determined to have the largest contribution to CDF for BWRs in RMIEP, WASH-1400, and NUREG-1150, respectively.

Although major changes had been made in the ASP models and different event tree models had been used in the ASP analyses for three time periods, similar dominant sequences were identified for many precursors at both PWRs and BWRs. These sequences were also determined to be dominant in predictions by past PRAs. It should be noted that the present study provides a limited comparison of dominant sequences with PRA results because dominant sequences generally depend on the plant system configuration.

Acknowledgments

The author wishes to thank Drs. Patrick D. O'Reilly and Dale M. Rasmuson, Office for Analysis and Evaluation of Operational Data, United States Nuclear Regulatory Commission, for their reviews and valuable comments.

References

[1] J. W. Minarick and C. A. Kukielka, Precursors to Potential Severe Core Damage Accidents: 1969-1979, NUREG/CR-2497, June 1982.

[2] W. B. Cottrell et al., Precursors to Potential Severe Core Damage Accidents: 1980-1981, NUREG/CR-3591, Vols. 1 and 2, July 1984.

[3] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1985, NUREG/CR-4674, Vols. 1 and 2, December 1986.

[4] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1984, NUREG/CR-4674, Vols. 3 and 4, May 1987.

[5] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1986, NUREG/CR-4674, Vols. 5 and 6, May 1988.

[6] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1987, NUREG/CR-4674, Vols. 7 and 8, July 1989.

[7] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1988, NUREG/CR-4674, Vols. 9 and 10, February 1990.

[8] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1989, NUREG/CR-4674, Vols. 11 and 12, August 1990.

[9] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1990, NUREG/CR-4674, Vols. 13 and 14, August 1991.

[10] J. W. Minarick et al., Precursors to Potential Severe Core Damage Accidents: 1991, NUREG/CR-4674, Vols. 15 and 16, September 1992.

[11] D. A. Copinger et al., Precursors to Potential Severe Core Damage Accidents: 1992, NUREG/CR-4674, Vols. 17 and 18, December 1993.

[12] L. N. Vanden Heuvel et al., Precursors to Potential Severe Core Damage Accidents: 1993, NUREG/CR-4674, Vols. 19 and 20, September 1994.

[13] R. J. Bells, et al., Precursors to Potential Severe Core Damage Accidents: 1994, NUREG/CR-4674, Vols. 21 and 22, December 1995.

[14] D. M. Rasmuson and P. D. O'Reilly, Analysis of Annual Accident Sequence Precursor Occurrence Rates for 1984-1994, Proc. of PSA'96, September 1996.

[15] U. S. Nuclear Regulatory Commission, Reactor Safety Study: An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants, WASH-1400, October 1975.

[16] U. S. Nuclear Regulatory Commission, Severe Accident Risks: An Assessment of Five U. S. Commercial Nuclear Power Plants, NUREG-1150, June 1989.

[17] A. C. Payne, Jr., et al., Analysis of the LaSalle Unit 2 Nuclear Power Plant: Risk Methods Integration and Evaluation Program (RMIEP), NUREG/CR-4832, Vol. 3, August 1992.

Appendix : List of Precursors

This appendix provides a list of all precursors identified for the years 1969 through 1994, which indicates the report numbers (Docket/LER No.), event date, CCDP, initiating event type (IE), plant, reactor type (Type), unavailable systems (Unav. System), dominant sequences and short description for each precursor.

PWR Precursors

Docket/LER No	Event Date	CCDP	IE	Plant	Type	Unav. System	Dominant Sequence
213/69-LTR	1969/07/15	2.20E-04	LOOP	HADDAM NECK	PWR-B	RCP seal leak	(TMLB), TML/TMLD
003/70-LTR	1970/12/26	1.40E-04	LOOP	INDIAN POINT 1	PWR		TMLB
255/71-LTR-2	1971/09/08	1.00E-04	LOCA	PALISADES	PWR-G	PORV-FO	S2H, S2D
255/71-LTR-1	1971/09/02	7.70E-04	LOOP	PALISADES	PWR-G	EDG	(TML/TMLD), TMLB
266/71-053	1971/02/05	1.10E-04	LOOP	POINT BEACH 1	PWR-B		TMLB, TML/TMLD
266/71-LTR-1	1971/01/12	1.00E-03	Unav	POINT BEACH 1	PWR-B	HPR, LPR	S2H
261/71-057	1971/03/08	1.20E-04	Unav	ROBINSON 2	PWR-B	EDG	TMLB
266/71-LTR-2	1971/04/16	1.10E-04	Unav	POINT BEACH 1	PWR-B	HPR, LPR	S2H
003/72-LTR	1972/07/20	1.40E-04	LOOP	INDIAN POINT 1	PWR		TMLB
255/72-086	1972/05/17	1.10E-04	LOOP	PALISADES	PWR-G		TML/TMLD, (TMLB)
244/73-010	1973/10/21	1.30E-04	LOOP	GINNA	PWR-B		TMLB, (TML/TMLD)
250/73-005	1973/07/04	1.30E-05	LOOP	TURKEY POINT 3	PWR-B		TML/TMLD
280/73-005	1973/11/30	7.60E-05	TRIP	SURRY 1	PWR-A	RCP	TML
251/73-007	1973/06/18	5.00E-04	Unav	TURKEY POINT 4	PWR-B	AFW	TML/TMLD
309/73-001	1973/02/02	2.10E-04	Unav	MAINE YANKEE	PWR-B	HPI	S2D
213/74-003	1974/01/19	2.20E-04	LOOP	HADDAM NECK	PWR-B	EDG(SWS)	TMLB, (TML/TMLD)
251/74-LTR	1974/04/25	1.10E-04	LOOP	TURKEY POINT 4	PWR-B	MSRV	TML/TMLD
255/74-LTR	1974/10/17	8.10E-05	LOOP	PALISADES	PWR-G		TML/TMLD
250/74-LTR	1974/05/08	1.60E-02	Unav	TURKEY POINT 3	PWR-B	AFW	TML/TMLD
266/74-LTR	1974/04/07	4.60E-03	Unav	POINT BEACH 1	PWR-B	AFW	TML/TMLD
304/74-LTR-1	1974/02/17	1.40E-05	Unav	ZION 2	PWR-B	EDG, AFW	TML/TMLD
304/74-LTR-2	1974/10/22	1.70E-06	Unav	ZION 2	PWR-B	HPI	not identified
313/74-013	1974/11/24	1.20E-06	Unav	ARKANSAS 1	PWR-D	RPS	TK
261/75-009	1975/05/01	5.00E-04	LOCA	ROBINSON 2	PWR-B	RCP seal leak	S2D, S2H
287/75-007	1975/06/13	1.00E-04	LOCA	OCONEE 3	PWR-D	PORV-FTC	S2D, S2H
305/75-020	1975/11/05	4.50E-03	Unav	KEWAUNEE	PWR-B	AFW	TML/TMLD
251/75-LTR	1975/05/25	5.90E-05	Unav	TURKEY POINT 4	PWR-B	EDG	TMLB
336/76-042	1976/07/20	1.40E-02	LOOP	MILLSTONE 2	PWR-G	EPS	TMLB
213/76-014	1976/06/26	1.60E-04	LOOP	HADDAM NECK	PWR-B		TMLB
336/76-049	1976/08/10	9.80E-05	LOOP	MILLSTONE 2	PWR-G		TML/TMLD, (TMLB)
312/76-015	1976/11/11	1.60E-04	Unav	RANCHO SECO	PWR-D	HPR, LPR	S2H
346/77-016	1977/09/24	7.00E-02	LOCA	DAVIS-BESSE 1	PWR-D	PORV-FO	S2D, S2H
346/77-098	1977/11/29	4.10E-04	LOOP	DAVIS-BESSE 1	PWR-D	EDG	TML/TMLD
348/77-012	1977/09/16	1.10E-04	LOOP	FARLEY 1	PWR-B		TML/TMLD
255/77-058	1977/12/11	1.10E-04	LOOP	PALISADES	PWR-G		TML/TMLD
255/77-055	1977/11/25	1.10E-04	LOOP	PALISADES	PWR-G		TML/TMLD
255/77-047	1977/09/24	1.10E-04	LOOP	PALISADES	PWR-G		TML/TMLD
285/77-021	1977/08/22	9.80E-05	LOOP	FORT CALHOUN 1	PWR-G		TML/TMLD
286/77-003	1977/07/13	8.10E-05	LOOP	INDIAN POINT 3	PWR-B		TML/TMLD
335/77-026	1977/05/16	7.30E-05	LOOP	ST LUCIE 1	PWR-G		TML/TMLD
315/77-030	1977/09/01	2.20E-05	LOOP	COOK 1	PWR-B		TML/TMLD
304/77-044	1977/07/12	2.00E-03	SD	ZION 2	PWR-B		Shutdown Event
302/77-020	1977/03/03	1.60E-04	SLB	CRYSTAL RIVER 3	PWR-D	ADV-FO	SLB*SGISOL, (TML/TMLD)
346/77-110	1977/12/11	4.60E-03	Unav	DAVIS-BESSE 1	PWR-D	AFW	TML/TMLD
312/77-002	1977/02/18	9.00E-05	Unav	RANCHO SECO	PWR-D	AFW	TML/TMLD
336/77-020	1977/05/15	9.80E-06	Unav	MILLSTONE 2	PWR-G	EDG(fuel supply)	TMLB
261/77-029	1977/11/23	2.20E-06	Unav	ROBINSON 2	PWR-B	HPI	S2D
272/77-034	1977/05/06	2.00E-06	Unav	SALEM 1	PWR-B	HPI	S2D
320/78-LTR	1978/03/29	2.20E-04	LOCA	THREE MILE ISL 2	PWR-D	PORV-FO	S2D, S2H
285/78-045	1978/12/20	7.70E-05	LOCA	FORT CALHOUN 1	PWR-G	PORV-FO	S2D, S2H
317/78-020	1978/04/13	2.50E-03	LOOP	CALVERT CLIFFS 1	PWR-G	EDG	TML/TMLD
335/78-017	1978/05/14	6.60E-04	LOOP	ST LUCIE 1	PWR-G	EDG	TML/TMLD
334/78-043	1978/07/28	5.10E-04	LOOP	BEAVER VALLEY 1	PWR-A	EDG	TML/TMLD
320/78-033	1978/04/23	1.10E-04	SLB	THREE MILE ISL 2	PWR-D	MSRV-FTC	SLB*SGISOL
312/78-001	1978/03/20	1.40E-01	TRIP	RANCHO SECO	PWR-D	AFW	TML/TMLD
272/78-073	1978/11/27	1.40E-02	TRIP	SALEM 1	PWR-B	AFW, EDG, HPI, RHR	TML/TMLD
348/78-021	1978/03/25	4.60E-03	Unav	FARLEY 1	PWR-B	AFW	TML/TMLD
312/78-016	1978/10/24	1.10E-06	Unav	RANCHO SECO	PWR-D	EDG	TMLB
213/79-010	1979/08/13	1.00E-04	LOCA	HADDAM NECK	PWR-B	PORV-FO	S2D, S2H
346/79-096	1979/10/15	1.20E-04	LOOP	DAVIS-BESSE 1	PWR-D	EDG	TMLB
282/79-027	1979/10/02	7.00E-04	SGTR	PRAIRIE ISLAND 1	PWR-B		SGTR*SI (T7D)
334/79-005	1979/01/18	7.60E-05	SLB	BEAVER VALLEY 1	PWR-A	SDV-FO	SLB*SGISOL
320/79-012	1979/03/28	4.60E-01	TRIP	THREE MILE ISL 2	PWR-D	PORV-FO, HPI	TQD, TML/TMLD
346/79-009	1979/01/12	9.90E-04	TRIP	DAVIS-BESSE 1	PWR-D		TML
272/79-068	1979/11/28	1.60E-04	Unav	SALEM 1	PWR-B	HPI	S2D
270/79-007	1979/10/24	5.90E-06	Unav	OCONEE 2	PWR-D	LPR(SWS)	S2H
348/79-013	1979/02/22	5.20E-06	Unav	FARLEY 1	PWR-B	EDG	TMLB
270/79-LTR	1979/09/26	1.60E-06	Unav	OCONEE 2	PWR-D	EPS	TMLB
269/79-LTR	1979/09/26	1.60E-06	Unav	OCONEE 1	PWR-D	EPS	TMLB

PWR Precursors

Short Description
Reactor trip with LOOP. Error fails 115KV line. Transformers trip. RCP seal leak.
Loss of offsite power from 1 substation. Transformer tripped due to inadvertent relay operation.
Open electromatic relief valve. Errors de-energize RPS & ECCS A. PORVs open/block valve closed.
Failure of DG to load. 345KV line trip. Relay failure causes LOOP. DG2 starts & fails to load.
Loss of offsite power in ice storm. Spurious opening of breakers causes LOOP.
Sump isolation valves closed. Install error & air bind make sump isolate valves inoperable.
During testing, both DGs fail to start due to failure of lube oil switches (trapped air/water).
Failure of containment sump isolation valves due to install error & air bind.
Loss of offsite power due to grid disturbance. Trip. Low bus voltage.
Loss of offsite power due to design relay error in testing of SIS from spurious signal.
LOOP. Excessive RCS cooldown. Safety injection & failure of vital instrument bus.
Reactor/turbine trip during test due to false signal in maintenance. Steam line sensors cause SIS injection. LOOP.
RCP shaft fails at 92% power. RCP seal fails during shutdown for investigating seal flow oscillations. LOCA.
Failure of AFW pumps to autostart in test due to failure to install DC power fuses. Turbine control valve opens.
CHP valve fails to open during testing. Ice freezes RWST valve to HPI pump. 2nd HPIP valve fails also.
Lightening arrestor fault causes a line failure. 2nd line fails due to improper relay operation. LOOP. SWS pump fails.
Reactor trip with loss of offsite power. U4 test/sneak circuit causes LOOP. U3 affected. MSRV fails open.
Loss of offsite power during SIS testing. Relay design failure causes LOOP.
Failure of 3 AFW pumps to start in test due to overtightened packings/turbine reg. valve malfunction.
Inoperable AFW pumps during shutdown. U1 AFW strainers plug. U2 had only the TDAFW line plug.
Failure of DG to start & load. 2 AFW pumps out of service. Test error fails DG. Breaker fails. 2 AFW pump found inoperable.
BIT auto injection failure. RCP manual trip/Scram. ECCS A fails due to loss of power. ECCS B BIT valve fails to open.
Failure of RPS for monitoring RCP trips due to wrong relay adjustment. RPS fails to trip plant when two RCPs trip off.
RCP seal fails/LOCA. Trip. RCP seal valve closed. 103500 gal to sump.
Stuck open PORV. Error cause MFW transient. PORV fails open. Scram. Block valve closed.
inoperable AFW pumps during startup. Resin leak from demineralizer to CST. All AFW strainers plug.
Breaker and relay failure during test. DG 3&4 trip in test. Breakers fail to load (relay failures).
LOOP from grid disturbance. Errors in DG loading fail ECCS due to blown fuses in undervoltage trip logic.
Loss of offsite power during refueling. 115KV line maintenance error trips CBs. Bad relay installation.
Hurricane causes switchyard failures from salt buildup, resulting in LOOP.
Valves fail to open for delay heat system. Both sump isolation valves fail to open in test. Wrong switch setting.
Stuck open PORV. False SFRCS/MWFP trip. Operator not see PORV fails open. PORV closed in 25 min.
Loss of offsite power. Bad procedure opens breakers. DG 2 fails due to improper setting of limit switch.
Lightening causes 2 yard breaker open/LOOP (all 4160V buses are deenergized).
Reactor trip with loss of offsite power. Spurious signal deenergizes bus and causes LOOP.
Reactor trip with loss of offsite power. R bus deenergized. Condenser trip. Turbine trip.
Reactor trip due to loss of offsite power dueing electrical storm. R bus deenergized. Condenser trip. Turbine trip.
Momentary loss of offsite power. Relay fails 161KV line. Transfer to 22KV transformer fails.
Loss of offsite power. Reactor trip. Electrical storm causes a LOOP.
Grid disturbance force plant trip/LOOP. 1 1/2 hours later 2nd LOOP.
Reactor trip & loss of offsite power due to lightening. Transfer breaker opens. 2nd strike/scram. Loss of power.
Dummy signals installed on instrumentation. Error fails pressurizer level sensor high/CP off. Reactor water level drop.
Atmospheric dump valves open (50%). Inverter/bus fails. ICS fails. Scram. ASDV fails open. LOFW.
AFW pumps inoperable during test. AFWP 1-1 fails test (governor problem). AFWP 1-2 fails test (blown fuse).
Both AFW pumps unavailable. AFWP P318 made unavailable due to human error. AFWP P319 not yet in use.
An inspection found both DG fuel valves to be closed (reason unknown).
HPI pump breakers not racked in. Test procedure error. HPI unavailable.
Failure to clear overpressure during heatup. Operators' error fails SI pumps & charging pump during startup.
Stuck open PORV. During breaker test, fuses fail/vital bus fails. PORVs open/LOCA.
Two stuck open PORVs during cold shutdown. Error opens both PORV in maintenance. They were quickly closed.
Loss of offsite power while shutdown. Switchyard breakers open. DG 11 fails.
Loss of offsite power during refueling. Switch errors cause LOOP. DG 1 in maintenance at the time.
Loss of offsite power & DG failure. Fault in transformer/Scram. Error causes LOOP. DG 2 fails to run.
Multiple stuck open relief valves. False trip signal. 4 MSRV on SG 1 & 1 MSRV on SG 2 fail open.
Failure of NNI & SG dryout. Error shorts NNI-Y. ICS fails. LOFW. AFW valves fail closed.
Loss of vital bus and scram. 2AFW, 1DG, 1CP, 1RHR fail due to loss of vaital bus.
Low-low water level in one SG trip/scram. TD AFWP fails. Open recirc. valves fail MD AFWP.
Loss of one DG while 2nd out of service. DG A fails in test when control power fuses fail.
Open PORV + isolation valve. Pressure controller fails, causing PORV to open. RCS blows down.
Reactor trip with LOOP. ICS fails/opens TBS. Generator breaker fails. DG 2 fails due to output breaker linkage rod failure.
SG tube break. Plant shutdown. No safety system failures.
Stuck open steam dump valves. Cond. valve air dampers set wrong. MSLB.
LOFW and PORV fails open. Major errors in operation of AFW & HPI. Core meltdown.
Loss of vital bus due to blown fuse while at power, AFWP 1-2 in test. ICS wrong signal. SFRCS trip/scram/LOFW.
One PMP pump fails & one degraded in cold SD. HPI pump (loose parts) and 2nd HP same.
Fail to properly position SWS valves after test. Procedure error. Misalign low pressure recirc. system valves.
Unavailability of two DGs. DG 1B in maintenance. Later DG 2A sequencer found failed from bad switch.
Loss of standby power during power operation. Both Keowee units in maintenance. Lee Station gas turbine, EPS backup fails.
Loss of standby power during power operation. Both Keowee units in maintenance. Lee Station gas turbine, EPS backup fails.

PWR Precursors

302/80-010	1980/02/26	5.00E-03	LOCA	CRYSTAL RIVER 3	PWR-D	PORV-FO	S2H
313/80-015	1980/05/10	5.00E-04	LOCA	ARKANSAS 1	PWR-D	RCP seal LOCA	S2D
213/80-004	1980/02/04	3.40E-05	LOCA	HADDAM NECK	PWR-B	PORV-FO	S2D
368/80-018	1980/04/07	6.00E-04	LOOP	ARKANSAS 2	PWR-G	AFW	TMLD
206/80-038	1980/11/22	6.10E-05	LOOP	SAN ONOFRE 1	PWR-H		TMLB
306/80-020	1980/07/15	4.70E-05	LOOP	PRAIRIE ISLAND 2	PWR-B		TMLD
368/80-042	1980/06/24	1.60E-05	LOOP	ARKANSAS 2	PWR-G		TMLD
247/80-006	1980/06/03	1.30E-05	LOOP	INDIAN POINT 2	PWR-B		TMLD
313/80-022	1980/06/24	5.40E-06	LOOP	ARKANSAS 1	PWR-D		TMLB
313/80-013	1980/04/07	5.40E-06	LOOP	ARKANSAS 1	PWR-D	HPI	TMLB
346/80-029	1980/04/19	1.40E-03	SD	DAVIS-BESSE 1	PWR-D		Shutdown Event
335/80-029	1980/06/11	1.10E-03	TRIP	ST LUCIE 1	PWR-G	RCP seal LOCA(CCW)	TMLD
317/80-027	1980/05/20	7.00E-05	Unav	CALVERT CLIFFS 1	PWR-G	AFW, DG(SWS)	TMLB
206/80-006	1980/03/10	1.60E-05	Unav	SAN ONOFRE 1	PWR-H	HPI/RHR(CCW)	TML
335/81-056	1981/12/19	7.70E-05	LOCA	ST LUCIE 1	PWR-G	PORV-FO	S2D
213/81-003	1981/04/03	3.40E-05	LOCA	HADDAM NECK	PWR-B	PORV-FO	S2D
261/81-005	1981/01/29	8.60E-06	LOCA	ROBINSON 2	PWR-B	Letdown line leak	S2D
302/81-033	1981/06/16	3.70E-04	LOOP	CRYSTAL RIVER 3	PWR-D	DG	TMLB
312/81-039	1981/08/07	6.90E-06	LOOP	RANCHO SECO	PWR-D		TMLB
312/81-034	1981/06/19	5.20E-06	LOOP	RANCHO SECO	PWR-D		TMLB
327/81-021	1981/02/11	8.70E-04	SD	SEQUOYAH 1	PWR-B		Shutdown Event
339/81-076	1981/10/03	8.40E-06	SLB	NORTH ANNA 2	PWR-A	Dump Valve	TK, TMLD
336/81-005	1981/01/02	5.10E-03	TRIP	MILLSTONE PT 2	PWR-G	DG(SWS)	TML
346/81-037	1981/06/24	1.70E-03	TRIP	DAVIS-BESSE 1	PWR-D	AFW	TML/TMLD
206/81-020	1981/09/03	1.40E-04	Unav	SAN ONOFRE 1	PWR-H	HPI	AD
251/81-011	1981/10/21	9.30E-05	Unav	TURKEY POINT 4	PWR-B	HPI	S2D
304/81-033	1981/12/11	6.50E-05	Unav	ZION 2	PWR-B	AFW	TMLD
334/81-047	1981/06/06	2.40E-06	Unav	BEAVER VALLEY 1	PWR-A	HPI	S2D
286/84-015	1984/11/16	1.90E-04	LOOP	INDIAN POINT 3	PWR-B	DG	TMLB
369/84-024	1984/08/21	1.70E-05	LOOP	MCGUIRE 1	PWR-B		TMLB
327/84-033	1984/05/11	4.80E-06	SLB	SEQUOYAH 1	PWR-B	ADV-FO	TQH
389/84-011	1984/11/21	2.00E-04	TRIP	ST LUCIE 2	PWR-G	AFW	TMLD
389/84-004	1984/02/09	2.00E-04	TRIP	ST LUCIE 2	PWR-G	AFW, SRV-FO	TMLD
346/84-003	1984/03/28	1.50E-04	TRIP	DAVIS-BESSE 1	PWR-D	AFW, ADV-FO	TMLD, TMLH
336/84-012	1984/11/28	3.00E-05	TRIP	MILLSTONE PT 2	PWR-G	AFW	TMLD
344/84-017	1984/09/26	1.10E-05	TRIP	TROJAN	PWR-B	SRV-FO	TMLD
338/84-019	1984/11/14	1.00E-05	TRIP	NORTH ANNA 1	PWR-A	AFW	TMLD
346/84-013	1984/09/11	4.10E-06	TRIP	DAVIS-BESSE 1	PWR-D	ADV-FO	TMLD
312/84-015	1984/03/19	2.20E-06	TRIP	RANCHO SECO	PWR-D		TQH
280/84-011	1984/05/18	1.10E-05	Unav	SURRY 1	PWR-A	HPI(CCW)	S2D
272/84-017	1984/07/16	7.30E-06	Unav	SALEM 1	PWR-B	HPI	S2D
339/84-013	1984/12/09	1.20E-06	Unav	NORTH ANNA 2	PWR-A	DG	TMLB
206/85-017	1985/11/21	9.40E-04	LOOP	SAN ONOFRE 1	PWR-H	AFW	TMLB
247/85-016	1985/12/12	5.80E-05	LOOP	INDIAN POINT 2	PWR-B	AFW	TMLD, TMLH
251/85-011	1985/05/17	3.80E-05	LOOP	TURKEY POINT 4	PWR-B		TMLD, TMLH
528/85-076	1985/10/07	3.40E-05	LOOP	PALO VERDE 1	PWR-H		TMLD
528/85-058	1985/10/03	3.40E-05	LOOP	PALO VERDE 1	PWR-H	DG	TMLD
287/85-002	1985/08/28	7.10E-06	LOOP	OCONEE 3	PWR-D		TMLH, TMLF
346/85-013	1985/06/09	1.10E-02	TRIP	DAVIS-BESSE 1	PWR-D	AFW, PORV-FTO	TMLD, TMLH
250/85-021	1985/07/21	9.00E-04	TRIP	TURKEY POINT 3	PWR-B	AFW	TMLD, TMLH
344/85-009	1985/07/20	4.40E-04	TRIP	TROJAN	PWR-B	AFW	TMLD, TMLH
346/85-002	1985/01/15	3.00E-04	TRIP	DAVIS-BESSE 1	PWR-D	AFW	TMLD, TMLH
344/85-002	1985/03/09	1.60E-05	TRIP	TROJAN	PWR-B		TMLD, TMLH
312/85-025	1985/12/26	1.60E-05	TRIP	RANCHO SECO	PWR-D	HPI, ADV-FO	TQH
413/85-043	1985/06/22	6.70E-06	TRIP	CATAWBA 1	PWR-B	SRV-FTO	TMLD, TMLH
413/85-041	1985/06/17	6.70E-06	TRIP	CATAWBA 1	PWR-B	SRV-FTO	TMLD, TMLH
369/85-004	1985/01/28	4.80E-06	TRIP	MCGUIRE 1	PWR-B	AFW, SRV-FO	TQH
364/85-010	1985/07/15	4.70E-06	TRIP	FARLEY 2	PWR-B		TMLD, TMLH
482/85-041	1985/06/09	4.20E-06	TRIP	WOLF CREEK 1	PWR-B	AFW	TMLD, TMLH
269/85-007	1985/04/25	2.10E-06	TRIP	OCONEE 1	PWR-D	SRV-FO	TQH
318/85-001	1985/04/25	1.80E-06	TRIP	CALVERT CLIFFS 2	PWR-G	ADV, CCW	TMLD
269/85-005	1985/04/11	1.70E-06	TRIP	OCONEE 1	PWR-D	SRV-FO, HPI	TQH
269/85-002	1985/01/22	1.70E-06	TRIP	OCONEE 1	PWR-D	SRV-FO	TQH
413/85-022	1985/03/14	1.10E-05	Unav	CATAWBA 1	PWR-B	DG	TMLB
311/85-018	1985/08/27	7.10E-06	Unav	SALEM 2	PWR-B	HPR/LPR(CCW)	S2H
413/86-031	1986/06/13	3.30E-03	LOCA	CATAWBA 1	PWR-B	Leak from CVCS	S2H
261/86-005	1986/01/28	3.00E-04	LOOP	ROBINSON 2	PWR-B	DG	TMLB
414/86-028	1986/06/27	1.10E-04	SLB	CATAWBA 2	PWR-B	HPI, SRV-FO	TMLD
247/86-017	1986/05/28	1.00E-04	SLB	INDIAN POINT 2	PWR-B	HPI, TBV-FO	TQH
250/86-039	1986/12/27	1.40E-03	TRIP	TURKEY POINT 3	PWR-B	PORV-FO	TQH

PWR Precursors

The 24VDC to non-nuclear instrumentation lost, causing PORV to stay open. Turbine and plant trips.
RCP seal fails, resulting in excessive RCS leakage to containment.
PORV opens. False signal causs the pressurizer PORV and its block valve to open.
Cavitation of EFW pumps. ADV isolates from vibrate. Tornado fails 4 power lines, resulting in LOOP.
LOOP and degraded load shed ability. Operator opens bus breaker instead of aux. transformer breaker.
Electrical storm causes spurious reactor trip. LOOP. Diesel generators start and provide power.
Ground fault on grid causes trip. Transmission lines fail from fault/overload. Transfer lockout from fault.
Lightning strikes transmission tower. 345KV/138KV tower fault. 4 lines out. LOOP. DGs start.
Ground fault on grid causes trip & transmission line failure. Transfer fails from relay fault, resulting in LOOP.
LOOP due to tornado and HPI isolation valve fails to open. 4 offsite lines fail.
Loss of 2 essential buses. Head detensioned. Breaker trip/lost 2 essential buses. Loss of RHR.
CCW lost to RCP seals. Spray causes CCW to isolate. Manual plant trip. Steam bubble in RCS.
Air line leak fails SWS. Operator valve realignment error fails AFW.
Loss of service water system. Salt water pump fails. 2nd pump valve fails closed. 3rd pump low flow.
MSIV closure & safety valve lift. Low instrument air & high steam flow cause MSIV to close/SRVs open.
Pressurizer PORV & block valve open. Loose controller connector.
Letdown RV leak in a LOFW. Drain valve cap blown off. 3000 gal in sump.
LOOP and one DG fails. Lightning strike to the 230KV feeder line. DG B fails to start due to maladjusted relay.
Switchyard voltage is too low. High electrical demand results in reduction in switchyard voltage.
Low switchyard voltages occur due to excessive load demand.
Loss of RHRS & RCS blowdown occurs. Error opens 3 valve. Spray initiation and draining of RCS occurs.
Steam dump valves (all 8 SDVs) open. Turbine/reactor trip. Steam dump switch to auto.
Loss of DC power and one DG fails due to SWS leak. Error opens breaker. Loss of control room annunciator.
Loss of vital bus. Man bumps non-essential breaker. AFW inoperable due to maladjusted clutch/bent pin.
SIS valves fail due to high differential pressure in LOFW, power supply fails. SI unavailable.
BIT flow path to RCS obstructed. BIT pipes blocked by boric acid precipitate. Missing insulation. Low temp.
Aux feed pumps fail to auto start. 1AFW pump in maintenance. 2AFWP trip from faulty low suction indication.
SIS supply valve found closed. Normally open emergency water supply valve to SIS unlocked & closed.
DG 31 in maintenance. Breaker fault causes LOOP. DG 32 breaker fails.
Computer repair error/unit 1 LOOP. U1 giving steam to U2 MFWP.
Spurious trip. SG ADS valve fails open from broken linkage.
Loss of load trip. AFWP C trips off due to steam leakage.
Bad pump design/LOFW/scram. AFWP 2C fails/MSRV fails open.
SFRCS trip/scram. MSRV fails open. SG2 AFW valve isolates.
FW-HX tube leak. MFW problem. AFW flow leaks thru a failed check valve. Manual trip.
MFWP instrument fails (runback). Operator misses temperature change & SRV fails open.
Inverter fails/scram. MFW B valves fail close. AFW B fails autostart.
Error trips turbine trip/scram. SFRCS trip. 1 atmospheric vent valve fails open.
MCC trip. TG hydrogen explosion. TBV/ADSV fails open. NNIX fails.
CCW/SW isolates from the HPI seal coolers on two occasions by error.
HPIP fails test (resin particles/metal filings). All HPIP affected.
DG 2H in maintenance. DG 2J trip in test due to tech spec error.
Ground fails transformer, LOOP. Manual trip. AFW flows thru failed check valve to MFW.
Trip on instr. failures. LOOP due to human err(bump relay). AFW 23 trips by open coil.
Multiple high volt faults cause LOOP. Transformer 3C fails.
Multiplexer failure during maintenance causes LOOP.
Multiplexer failure results in LOOP. DG B trips due to error(not reset lockout).
Startup transfer relay actuates (lockout). Main buses deenergized.
LOFW/scram/false SFRCS trip. Error causes AFW/PORV to fail to open.
Lightning causes scram. AFW A,C fail because of failed valves due to moisture in IA.
Transformer trip. Scram by error. AFWPs trip due to logic problems.
ICS failure/SFRCS trip/LOFW. 1 AFWP fails (operator error).
LOFW. Waterhammer/rupture heater drain line.
ICS failure/trip. SRV/ADV/TBV fail open. Errors. HPI suction valve fails closed.
LOFW. Cond. vacuum lost by error. SG A&B SRVs fail to open.
RCS leak. MFW problems/trip/scram. 3 SG-SRVs fail to open.
False signal/MFWP trip/scram. SG-SRV sticks open & AFWP valve fails to close.
Lightning/scram. TG breakers open relay/LOP 4160V non-safety buses.
MFWP B shutdown. MFWP A trips twice. TD AFWP trips on overspeed.
Two inverter fail. LOFW/scram. MSRV fails open and close at 900 psi.
RCP seal/SWCS/CCWS fail. Scram/LOFW. ADV fails open.
Turbine intercept valves trip/scram. 2 MSRV stick open. HPI valve fails to open.
Six intercept valves fail close. 2 MSRV fail open and close at 875 psi.
DG 1A & B are disable from problems (clogged fuel filters) over several days.
#21 CCWHX in maint. #22 CCWHX outlet valve fails closed.
CVCS leak (130gpm) from CCW/CVCS HX joint. SBLOCA and plant trip.
DG unavailable due to maintenance. Bus failure. Switchyard failure/LOOP.
Control room/shutdown panel test. Errors cause SG-SRV to open. HPI potentially fails.
Steam dump controller opens 12 dump valves. Trip. HPI train B fails.
Manual trip. PORV sticks open.

PWR Precursors

247/86-035	1986/10/20	2.90E-04	TRIP	INDIAN POINT 2	PWR-B	AFW	TMLD, TMLH
285/86-001	1986/07/02	4.10E-05	TRIP	FORT CALHOUN 1	PWR-G	ADV-FTO	TQH
269/86-001	1986/01/31	2.10E-06	TRIP	OCONEE 1	PWR-D	SRV-FO	TQH
318/86-006	1986/09/05	1.80E-06	TRIP	CALVERT CLIFFS 2	PWR-G	ADV-FO	TQH
250/86-038	1986/12/04	5.80E-05	Unav	TURKEY POINT 3	PWR-B	AFW	TMLD
287/86-011	1986/10/01	1.10E-05	Unav	OCONEE 3	PWR-D	AFW(CCW)	TMLB
270/86-011	1986/10/01	1.10E-05	Unav	OCONEE 2	PWR-D	AFW(CCW)	TMLB
269/86-011	1986/10/01	1.10E-05	Unav	OCONEE 1	PWR-D	AFW(CCW)	TMLB
389/86-011	1986/07/09	2.60E-06	Unav	ST LUCIE 2	PWR-G	DG	TMLB
317/87-012	1987/07/23	4.80E-04	LOOP	CALVERT CLIFFS 1	PWR-G	AFW	TMLB
255/87-024	1987/07/14	4.30E-04	LOOP	PALISADES	PWR-G		TMLB
455/87-019	1987/10/02	1.50E-04	LOOP	BYRON 2	PWR-B		TMLB
412/87-036	1987/11/17	1.70E-05	LOOP	BEAVER VALLEY 2	PWR-A		TMLB
338/87-017	1987/07/15	7.70E-04	SGTR	NORTH ANNA 1	PWR-A		T7X, T7D
389/87-003	1987/04/09	7.50E-05	TRIP	ST LUCIE 2	PWR-G	AFW, SRV-FO	TML
344/87-037	1987/12/06	4.80E-05	TRIP	TROJAN	PWR-B	AFW	TMLD
455/87-007	1987/05/04	3.70E-05	TRIP	BYRON 2	PWR-B	AFW	TMLD
413/87-026	1987/07/06	3.70E-05	TRIP	CATAWBA 1	PWR-B	AFW	TMLD
382/87-020	1987/07/31	1.50E-05	TRIP	WATERFORD 3	PWR-H	AFW	TMLD
370/87-016	1987/09/06	7.00E-06	TRIP	MCGUIRE 2	PWR-B	PORV-FTO, LPR/HPR	TMLD
346/87-011	1987/09/06	5.80E-06	TRIP	DAVIS-BESSE 1	PWR-D	RHR(SWS)	TMLD
251/87-001	1987/01/06	3.70E-06	TRIP	TURKEY POINT 4	PWR-B	AFW	TMLD
414/87-029	1987/11/03	1.70E-06	TRIP	CATAWBA 2	PWR-B	AFW	TMLD
400/87-035	1987/06/17	1.70E-06	TRIP	HARRIS 1	PWR-B	AFW	TMLD
400/87-008	1987/02/27	1.70E-06	TRIP	HARRIS 1	PWR-B	HPI/LPI(RWST valve)	TMLD
285/87-025	1987/07/06	6.20E-04	Unav	FORT CALHOUN 1	PWR-G	DG(IA)	TMLB
482/87-015	1987/12/11	1.20E-04	Unav	WOLF CREEK 1	PWR-B	DG	TMLB
369/87-030	1987/09/08	2.40E-05	Unav	MCGUIRE 1	PWR-B	DG	TMLB
312/87-022	1987/07/29	6.30E-06	Unav	RANCHO SECO	PWR-D	DG	TMLB
424/87-036	1987/06/03	6.30E-06	Unav	VOGTLE 1	PWR-B	AFW	TMLD
287/87-006	1987/09/10	1.00E-06	Unav	OCONEE 3	PWR-D	HPI	S2D
424/88-016	1988/06/03	8.00E-05	LOCA	VOGTLE 1	PWR-B	PORV-FO	S2H
456/88-022	1988/10/16	1.80E-04	LOOP	BRAIDWOOD 1	PWR-B		TMLB
309/88-006	1988/08/13	1.20E-04	LOOP	MAINE YANKEE	PWR-B		TMLB
323/88-008	1988/07/17	4.10E-05	LOOP	DIABLO CANYON 2	PWR-B		TMLB
414/88-012	1988/03/09	2.70E-04	TRIP	CATAWBA 2	PWR-B	AFW	TMLD, TML
455/88-008	1988/07/14	4.00E-05	TRIP	BYRON 2	PWR-B	AFW	TMLD, TML
338/88-002	1988/01/08	1.40E-05	TRIP	NORTH ANNA 1	PWR-A	AFW	TMLD, TML
328/88-023	1988/05/19	1.30E-05	TRIP	SEQUOYAH 2	PWR-B	AFW, HPI	TMLD
286/88-002	1988/03/31	1.00E-05	TRIP	INDIAN POINT 3	PWR-B	AFW	TMLD
328/88-027	1988/06/06	4.50E-06	TRIP	SEQUOYAH 2	PWR-B	AFW	TMLD
344/88-028	1988/09/16	1.90E-06	TRIP	TROJAN	PWR-B	HPI	TMLD
369/88-007	1988/04/16	1.00E-06	TRIP	MCGUIRE 1	PWR-B	AFW	TMLD
400/88-006	1988/02/08	4.80E-04	Unav	HARRIS 1	PWR-B	DG, SWS	TMLB, S2D, TMLD
275/88-014	1988/05/05	4.10E-04	Unav	DIABLO CANYON 1	PWR-B	DG	TMLB
328/88-005	1988/02/12	3.80E-04	Unav	SEQUOYAH 2	PWR-B	HPI	S2D
295/88-019	1988/10/25	1.00E-04	Unav	ZION 1	PWR-B	AFW, HPI(CCW)	TMLD
344/88-029	1988/09/16	8.60E-05	Unav	TROJAN	PWR-B	HPI, DG	S2D
255/88-021	1988/11/04	2.70E-05	Unav	PALISADES	PWR-G	CSR(SWS)	TMLF, TMLH
339/88-004	1988/05/20	2.50E-05	Unav	NORTH ANNA 2	PWR-A	DG	TMLB
251/88-003	1988/02/07	1.60E-05	Unav	TURKEY POINT 4	PWR-B	AFW, HPI	S2D
280/88-011	1988/04/15	1.50E-05	Unav	SURRY 1	PWR-A	PORV-FTO	TMLD
250/88-011	1988/05/29	9.90E-06	Unav	TURKEY POINT 3	PWR-B	DG	TMLB
247/88-020	1988/12/11	6.90E-06	Unav	INDIAN POINT 2	PWR-B	HPR/LPR	S2H
344/88-027	1988/09/15	2.80E-06	Unav	TROJAN	PWR-B	HPI	S2D
346/88-007	1988/03/04	1.60E-06	Unav	DAVIS-BESSE 1	PWR-D	HPI(CCW)	TMLD
301/89-002	1989/03/29	2.50E-04	LOOP	POINT BEACH 2	PWR-B		TMLB
395/89-012	1989/07/11	1.50E-04	LOOP	SUMMER 1	PWR-B		TMLB
302/89-025	1989/06/29	6.30E-05	LOOP	CRYSTAL RIVER 3	PWR-D	DG, AFW	TMLB
302/89-023	1989/06/16	3.50E-05	LOOP	CRYSTAL RIVER 3	PWR-D	AFW	TMLD
369/89-004	1989/03/07	7.70E-04	SGTR	MCGUIRE 1	PWR-B		T7X, T7D, SGISOL
338/89-005	1989/02/25	1.90E-04	SGTR	NORTH ANNA 1	PWR-A	RHR	SGISOL
368/89-006	1989/04/18	1.20E-04	TRIP	ARKANSAS 2	PWR-G	AFW	TML/TMLD
530/89-001	1989/03/03	4.90E-05	TRIP	PALO VERDE 3	PWR-H	EPS, ADV	TML
400/89-001	1989/01/16	1.30E-05	TRIP	HARRIS 1	PWR-B	AFW	TML/TMLD
316/89-014	1989/08/14	9.40E-06	TRIP	COOK 2	PWR-B	EPS	TMLB
400/89-017	1989/10/09	4.40E-06	TRIP	HARRIS 1	PWR-B	AFW	TML/TMLD
400/89-006	1989/03/14	4.40E-06	TRIP	HARRIS 1	PWR-B	AFW	TML/TMLD
483/89-008	1989/06/23	1.20E-06	TRIP	CALLAWAY	PWR-B	DG	TMLD
348/89-007	1989/11/12	1.10E-06	TRIP	FARLEY 1	PWR-B	AFW	TML/TMLD

PWR Precursors

RPS breaker opens/trip(loose wires). MDAFW trips, TDAFW unav. due to open relief valve.
Inverter fails. Trip. ADV/TBV fail to open from inverter loss.
Error closes breaker. 230KV breakers open. LOFW. MSRV sticks open.
RCP trip/reactor trip. ADV fails open for 22 min.
AFWP B trips on overspeed. AFWP C steam valve fails to open.
Load shed test, LPSW/CCW/ECCW fail from abnormally low lake level. AFW affected.
Load shed test, LPSW/CCW/ECCW fail from abnormally low lake level. AFW affected.
Load shed test, LPSW/CCW/ECCW fail from abnormally low lake level. AFW affected.
DG 2A fails its test. DG 2B then fails its test. EPS unavailable.
"C" phase to ground fault on 500KV line causes LOOP. TDAFW fails on high vibration.
Operator error during maintenance causes ground fault, resulting in LOOP (7.5hrs).
Trip + LOOP due to wrong transformer disconnection.
Trip, LOFW, and LOOP.
SG-C tube rupture during operations.
Error in ESFAS repair causes LOFW/scram. MSRV fails open. AFW trips on overspeed.
TG EHC switch fails causing manual trip. AFW fails due to loose electrical connection.
Inverter failure fails bus. RPS false trip. LOFW. AFW fails due to loss of power.
MFW control fails (runback). Manual trip/LOFW. AFW fails due to valve misalignment.
Trip. AFW trips on overspeed.
Trip due to overcurrent in compressor. SWS out of service, PORVs inoperable by loss of power.
Trip with unavailable essential bus, SWS, RHR.
Spurious RPS signal causes trip while 'C' AFW out of service for maintenance.
Trip, LOFW, TDAFW fails on overspeed due to incorrect governor adjustment.
Relay bumped, trips bus 1C. Scram/LOFW. TDAFW trips on overspeed.
Error causes MFW trip/LOFW. RWST valve failure causes HPI/LPI unavailable.
Water intrusion into instrument air causes DG air system to fail. HPI failure expected.
Both DGs out in 9 days due to governor/fuse problems.
Personnel label DG fuel valves wrong. Later isolate wrong valve.
DG-A cooling water leaks in test. DG-B out of service for maintenance.
AFW unavailable twice due to incorrect fuses.
BIT isolated during plant shutdown by error. HPI not available.
Leak into control room causes spurious PORV to lift.
Loss of offsite power for approximately 2 hrs.
Loss of offsite power. SWS pump trips due to control device fault.
Loss of offsite power (24 hr) with safety injection.
Asiatic clams cause potential loss of AFW.
LOFW and 1 train of AFW trips on false overspeed signal caused by loose terminals.
Trip with failure of one AFW train due to regulator valve failure.
Trip with one HPI and AFW train unavailable due to surveillance/maintenance.
Plant trips and one of 3 AFW pumps fails due to damaged flow controller.
Trip from steam/feedwater flow mismatch. TDAFW unavailable due to flow control valve failure.
Trip with one SI pump out for maintenance.
Trip and the TDAFW train failure to start due to steam supply valve problem.
SWS pump seal water unavailable due to debris accumulation.
Degraded diesel generator due to clogged filter.
High head injection system unavailable due to fault in pump speed increaser.
Potential for AFW and CCW pump auto-start failure due to breaker design deficiency.
Both trains of SI due to clam debris & out of service and one EDG inoperable (out of service).
Potential loss of service water pumps.
Both emergency diesel inoperable - output breaker failure & preventive maintenance.
Reactor shutdown due to battery chargers, causing LPI/HPI and AFW unavailable.
Inoperable PORVs (failure to operate), causing feed & bleed inoperable.
Emergency power unavailable (16 hr) due to fuel tank isolation valve failure.
RWST level indication inoperable, rendering HPR/LPR unavailable.
Loss of VCT isolation capability, resulting in potentially unavailable charging pumps.
Component cooling valves drift close on loss of air.
LOOP due to inadvertent fire deluge system actuation.
Trip causes LOOP due to operator error.
LOOP with 1 DG unavailable (out of service). Degraded EFW due to faulty relays.
LOOP with degraded emergency feedwater due to faulty relays.
SG tube rupture results in radioactive release.
SG tube leak and RHR suction valve failure.
Trip with unavail of 1 train of AFW due to speed control circuit fault.
ADVs, non-safety related buses unavail after trip.
Reactor trip and loss of one train of AFW (trip on overspeed).
Trip due to CRID-IV failure, resulting in degraded EPS.
Reactor trip and trip of the TDAFW pump on spurious overspeed signal.
Reactor trip with one AFW pump out of service for maintenance.
Trip, 1 EDG out of service, and loss of ESF bus.
MDAFW pumps fail to start due to mispositioned switch under manual control.

PWR Precursors

313/89-028	1989/10/12	2.80E-04	Unav	ARKANSAS 1	PWR-D	HPI/LPI(SWS)	TMLD
289/89-002	1989/11/14	2.40E-04	Unav	THREE MILE ISL 1	PWR-D	DG	TMLB
370/89-010	1989/09/05	1.60E-05	Unav	MCGUIRE 2	PWR-B	LPR/RHR	S1H
327/89-033	1989/12/16	4.80E-06	Unav	SEQUOYAH 1	PWR-B	HPR, RHR	S2H
328/89-033	1989/12/16	3.60E-06	Unav	SEQUOYAH 2	PWR-B	HPR, RHR	S2H
344/89-021	1989/10/30	2.10E-06	Unav	TROJAN	PWR-B	HPI	S2D
317/89-005	1989/03/14	1.40E-06	Unav	CALVERT CLIFFS 1	PWR-G	HPR(SWS)	TQH
424/90-006	1990/03/20	9.70E-04	LSDC	VOGTLE 1	PWR-B		Shutdown Event
456/90-018	1990/09/29	2.10E-05	TRIP	BRAIDWOOD 1	PWR-B	AFW	TML/TMLD
206/90-011	1990/05/15	7.60E-06	TRIP	SAN ONOFRE 1	PWR-H	AFW	TML/TMLD
389/90-001	1990/01/14	4.70E-06	TRIP	ST LUCIE 2	PWR-G	AFW	TML/TMLD
244/90-017	1990/12/12	2.00E-06	TRIP	GINNA	PWR-B	HPI(ESFAS)	TQD
311/90-005	1990/01/17	1.30E-06	TRIP	SALEM 2	PWR-B	HPI	TQD, TMLD
423/90-011	1990/03/30	1.10E-06	TRIP	MILLSTONE PT 3	PWR-A	CSR	TML/TMLD
328/90-012	1990/08/22	6.00E-04	Unav	SEQUOYAH 2	PWR-B	HPR	S2H
285/90-020	1990/09/13	6.50E-04	Unav	FORT CALHOUN 1	PWR-G	DG	TMLB
213/90-008	1990/07/09	6.00E-04	Unav	HADDAM NECK	PWR-B	HPI	not identified
369/90-017	1990/06/26	2.70E-04	Unav	MCGUIRE 1	PWR-B	DG	TMLB
206/90-006	1990/02/20	6.00E-05	Unav	SAN ONOFRE 1	PWR-H	HPI	TMLB, TMLD
482/90-025	1990/12/23	4.70E-05	Unav	WOLF CREEK 1	PWR-B	HPI	S2D
295/90-023	1990/11/06	1.40E-05	Unav	ZION 1	PWR-B	DG	TMLB, TQD
285/90-009	1990/03/16	1.10E-05	Unav	FORT CALHOUN 1	PWR-G	AFW	TMLD
317/90-011	1990/03/30	1.10E-05	Unav	CALVERT CLIFFS 1	PWR-G	PORV-FTO	TML/TMLD
286/90-005	1990/08/09	3.50E-06	Unav	INDIAN POINT 3	PWR-B	DG	TMLB
285/90-025	1990/09/29	1.70E-06	Unav	FORT CALHOUN 1	PWR-G	HPI/LPI/RCP seal	S2H, S2D
311/90-042	1990/12/20	1.30E-06	Unav	SALEM 2	PWR-B	DG/SI(CCW/SWS)	TMLB, TQD
029/91-002	1991/06/15	6.10E-04	LOOP	YANKEE ROWE	PWR		TMLB, TML/TMLD
369/91-001	1991/02/11	2.60E-04	LOOP	MCGUIRE 1	PWR-B		TMLB
304/91-002	1991/03/21	2.10E-04	LOOP	ZION 2	PWR-B	DG	TMLB
443/91-008	1991/06/27	4.40E-05	LOOP	SEABROOK 1	PWR-B		TMLB
368/91-012	1991/05/15	4.80E-04	TRIP	ARKANSAS 2	PWR-G	HPR/RHR(SWS)	S2H
287/91-007	1991/07/03	1.80E-05	TRIP	OCONEE 3	PWR-D	AFW	TMLD
304/91-004	1991/06/11	1.00E-05	TRIP	ZION 2	PWR-B	AFW	TML/TMLD
400/91-010	1991/06/03	6.60E-06	TRIP	HARRIS 1	PWR-B	RPS	TK
247/91-001	1991/01/07	2.00E-06	TRIP	INDIAN POINT 2	PWR-B	AFW	TML/TMLD
400/91-008	1991/04/03	6.30E-03	Unav	HARRIS 1	PWR-B	HPI	S2D
423/91-011	1991/04/10	8.60E-04	Unav	MILLSTONE PT 3	PWR-A	HPR	S2H
336/91-009	1991/08/21	2.10E-04	Unav	MILLSTONE PT 2	PWR-G	DG	TMLB
269/91-010	1991/09/19	1.20E-04	Unav	OCONEE 1	PWR-D	HPI	S2D
269/91-010	1991/09/19	1.20E-04	Unav	OCONEE 2	PWR-D	HPI	S2D
269/91-010	1991/09/19	1.20E-04	Unav	OCONEE 3	PWR-D	HPI	S2D
445/91-012	1991/03/26	6.20E-05	Unav	COMANCHE PEAK 1	PWR-B	HPR	S2H
272/91-030	1991/09/20	4.40E-06	Unav	SALEM 1	PWR-B	PORV-FTO	TML/TMLD
280/91-017	1991/07/15	2.90E-06	Unav	SURRY 1	PWR-A	DG	TMLB
323/91-003	1991/09/01	2.10E-06	Unav	DIABLO CANYON 2	PWR-B	RHR/HPR	S2H
206/91-014	1991/08/07	2.10E-06	Unav	SAN ONOFRE 1	PWR-H	HPI	S2D
285/92-023	1992/07/03	2.50E-04	LOCA	FORT CALHOUN 1	PWR-G	PORV-FO	S2D
270/92-004	1992/10/19	2.10E-04	LOOP	OCONEE 2	PWR-D	EPS	TMLB
261/92-017	1992/08/22	2.10E-04	LOOP	ROBINSON 2	PWR-B		TMLB
327/92-027	1992/12/31	1.80E-04	LOOP	SEQUOYAH 1	PWR-B		TMLB
327/92-027	1992/12/31	1.80E-04	LOOP	SEQUOYAH 2	PWR-B		TMLB
251/92-S01	1992/08/24	1.60E-04	LOOP	TURKEY POINT 4	PWR-B		TMLB
250/92-S01	1992/08/24	1.60E-04	LOOP	TURKEY POINT 3	PWR-B		TMLB
302/92-001	1992/03/27	1.70E-05	LOOP	CRYSTAL RIVER 3	PWR-D	DG	TMLB
344/92-020	1992/07/22	5.90E-06	TRIP	TROJAN	PWR-B	AFW	TMLD
269/92-004	1992/05/08	4.00E-06	TRIP	OCONEE 1	PWR-D	AFW	TMLD
247/92-007	1992/04/13	3.60E-06	TRIP	INDIAN POINT 2	PWR-B	AFW	TML/TMLD
251/92-007	1992/09/29	3.10E-06	TRIP	TURKEY POINT 4	PWR-B	AFW	TMLD
261/92-013	1992/07/10	3.50E-05	Unav	ROBINSON 2	PWR-B	HPI	S2D
269/92-018	1992/12/02	3.20E-05	Unav	OCONEE 1	PWR-D	EPS	TMLB
269/92-018	1992/12/02	3.20E-05	Unav	OCONEE 2	PWR-D	EPS	TMLB
269/92-018	1992/12/02	3.20E-05	Unav	OCONEE 3	PWR-D	EPS	TMLB
483/92-011	1992/10/17	1.30E-05	Unav	CALLAWAY	PWR-B	HPI/HPR	TMLB, S2H
301/92-003	1992/09/18	9.90E-06	Unav	POINT BEACH 2	PWR-B	HPR/CSS	S2H
269/92-008	1992/07/17	2.80E-06	Unav	OCONEE 1	PWR-D	EPS	TMLB
269/92-008	1992/07/17	2.80E-06	Unav	OCONEE 2	PWR-D	EPS	TMLB
269/92-008	1992/07/17	2.80E-06	Unav	OCONEE 3	PWR-D	EPS	TMLB
328/92-010	1992/07/17	1.90E-06	Unav	SEQUOYAH 2	PWR-B	DG, RHR/HPR	TMLB
286/92-011	1992/07/06	1.20E-06	Unav	INDIAN POINT 3	PWR-B	DG	TMLB
370/93-008	1993/12/27	9.30E-05	LOOP	MCGUIRE 2	PWR-B		TMLB

PWR Precursors

Two service water pump circuits inhibit auto-start due to wiring error.
Oil sludge renders emergency diesels inoperable.
Containment spray heat exchanger gasket failure.
RWST level and other instrument transmitters inoperable   Potentially unavailable HPR/RHR.
RWST level and other instrument transmitters inoperable   Potentially unavailable HPR/RHR.
HHSI inoperable due to unavail. of VCT isol. during testing.
Failure of instrument air boundary check valves results in unavailability of SWS.
LOOP & both EDGs inoperable [shutdown event].   Loss of shutdown cooling.
SSPS B trips reactor, AFW pump A trips on low suction pressure.
Trip with one AFW train autostart disabled, resulting from inadevertently short circuit.
Loss of feedwater with one AFW train unavailable (trip on overspeed).
Trip with manual & auto safeguards init disabled due to procedural error.
HPI inoperable due to leaking weld.
Trip and one containment spray recirc pump unavailable due to high bearing oil level.
Hydrogen accumulation in charging/HPI pump suction.
EDG failure due to voltage regulator overheating. Similar condition with other EDG.
Wrong SOV installation could cause gas-binding of charging system.
Both EDGs inoperable caused by fuel pump binding due to inadequate painting.
Wrong failure mode for a CVCS valve causes charging pump failure.
Safety injection pumps mini-flow return line frozen.
Two of three diesel generators inoperable due to bad switch contact/leaking air start valve.
Unavailability of AFW due to high differential pressure at valve following postulated MSLB.
Inoperable pressurizer PORV for 19 months.
All diesel generators potentially inoperable due to relay failure/insuf jacket water cooling.
Component cooling water would fail on loss of IA. HPI/LPI affected. RCP seal challenged.
SI and one train of emergency power inoperable due to CCW pipe leak.
Loss of offsite power due to lightning strike.
Switchyard breaker test results in loss of offsite power.
Loss of offsite power with one diesel generator out of service for maintenance.
Loss of offsite power due to breaker trip.
Both normal service water trains fouled by debris.   RHR/HPR/LPR affected.
Reactor trip due to LOFW plus degraded EFW due to flow control valve failure.
Main feedwater pump trip with one AFW pump failed (unspecified reason).
Reactor trip breaker fails to open on trip (SSPS A fails).
Reactor trip and auxiliary feedwater pump failure due to miscalbration of pump trip device.
HPI unavailability for one refueling cycle because of inoperable alternate mini-flow lines.
Both trains of HPSI inoperable due to relief valve failure (open).
Both diesel generators unavailable due to erratic load control and unit shutdown.
Potential for hydrogen entrainment in HPI pumps.
Potential for hydrogen entrainment in HPI pumps.
Potential for hydrogen entrainment in HPI pumps.
Potential charging pump unavailability due to hydrogen voids.
Both PORVs fail due to leaking actuators.
Both EDGs for unit 2 inoperable for 13 hrs due to inadequate post-maintenace testing.
Containment sump isolation valves and containment spray pumps deenergized. RHR affected.
Inoperable volume control tank level transmitters (17 hr).   HPI affected.
Reactor trip with faulty pressurizer safety valve (leaking PORV).
LOOP with failed EPS due to operator error/breaker failure at Keowee station.
LOOP (loss of startup transformer)
LOOP due to switchyard breaker fault in testing.
LOOP due to switchyard breaker fault in testing.
LOOP due to Hurricane Andrew.
LOOP due to Hurricane Andrew.
LOOP with inoperable vital bus inverter. EDG inoperable due to jacket water leak.
Reactor trip and AFW pump fails to start (trip on overspeed due to controller failure).
Reactor trip with one EFW train inoperable due to control valve failure.
Reactor trip and AFW pump problems due to low suction pressure.
MFW pump trip with one AFW pump out of service for post-maintenance testing.
SI pump out of service because plastic sheeting material obstructs the pump line.
Both Keowee units (EPS source) potentially unavailable.
Both Keowee units (EPS source) potentially unavailable.
Both Keowee units (EPS source) potentially unavailable.
Loss of main control room annunciators due to blown fuses. Potentially unavailable HPR/PORV.
Plugged SI pump suction by foreign material (foam rubber plug).
Both keowee units (EPS source) unavailable.
Both keowee units (EPS source) unavailable.
Both keowee units (EPS source) unavailable.
EDG out of service & RHR pump inoperable due to mini-flow valve failure (HPR affected).
Multiple EDGs inoperable due to loose wire/out of service for maintenance.
Loss of offsite power and failure of MSIV to close.

PWR Precursors

334/93-013	1993/10/12	5.50E-05	LOOP	BEAVER VALLEY 1	PWR-A		TMLB
529/93-001	1993/03/14	4.70E-05	SGTR	PALO VERDE 2	PWR-H		HPI*DEPRESS
316/93-007	1993/08/02	2.40E-06	TRIP	COOK 2	PWR-B	AFW	TML/TMLD
339/93-002	1993/04/16	1.10E-06	TRIP	NORTH ANNA 2	PWR-A	AFW	TML/TMLD
413/93-002	1993/02/25	1.50E-04	Unav	CATAWBA 1	PWR-B	HPR/LPR/RCP seal	TMLH
413/93-002	1993/02/25	1.50E-04	Unav	CATAWBA 2	PWR-B	HPR/LPR/RCP seal	TMLH
213/93-S01	1993/06/27	6.50E-05	Unav	HADDAM NECK	PWR-B	DG, PORV-FTO	TMLB
313/93-003	1993/09/30	5.10E-05	Unav	ARKANSAS 1	PWR-D	HPR/RHR	S2H
498/93-005	1993/12/29	1.20E-05	Unav	SOUTH TEXAS 1	PWR-B	DG, AFW	TMLB
289/93-002	1993/01/29	3.10E-06	Unav	THREE MILE ISL 1	PWR-D	HPR	S2H
412/93-012	1993/10/04	2.10E-06	Unav	BEAVER VALLEY 2	PWR-A	HPI(ESFAS)	S2D
482/94-018	1994/09/17	3.00E-03	ISLOCA	WOLF CREEK 1	PWR-B	RHR	Shutdown Event
318/94-001	1994/01/12	1.30E-05	TRIP	CALVERT CLIFFS 2	PWR-G	HPI	S2D
213/94-004,005	1994/02/16	1.40E-04	Unav	HADDAM NECK	PWR-B	PORV-FTO, EPS	TMLD
304/94-002	1994/03/07	2.30E-05	Unav	ZION 2	PWR-B	DG, AFW	TMLB
266/94-002	1994/02/08	1.20E-05	Unav	POINT BEACH 1	PWR-B	DG	TMLB
266/94-002	1994/02/08	1.20E-05	Unav	POINT BEACH 2	PWR-B	DG	TMLB
250/94-005	1994/11/03	1.80E-06	Unav	TURKEY POINT 3	PWR-B	HPI/LPI(ESFAS)	AD
250/94-005	1994/11/03	1.80E-06	Unav	TURKEY POINT 4	PWR-B	HPI/LPI(ESFAS)	AD

PWR Precursors

Dual unit loss of offsite power due to feeder breaker trip.
Steam generator tube rupture.
Reactor trip with degraded AFW due to flow switch problem.
AFW disabled due to mispositioned control switch after reactor trip.
Essential service water potentially unavailable. Loss of RCP seal cooling. HPR/LPR affected.
Essential service water potentially unavailable. Loss of RCP seal cooling. HPR/LPR affected.
Degradation of MCC-5, pressurizer PORV (due to air leak), & both EDGs (due to insuf. cooling).
Both trains of recirculation inoperable for 14 hrs due to improper coupling of pump & motor.
EDG unavailable due to fuel pump problem and TDAFW unavailable due to water intrusion into turbine.
Both RHR heat exchangers unavailable due to valve misalignment.
Failure of both EDG load sequences. SI signal logic affected (loss of ESFAS)
RCS blows down to RWST due to inappropriate alignment of RHR during hot shutdown.
Trip. Loss of 13.8-kV bus and short-term saltwater cooling system unavailable. HPI affected.
Power-operated relief valves and vital 480-V AC bus degraded. EPS affected.
Unavailability of TDAFW pump (trip on overspeed) and EDG (due to insuf cooling).
Both EDGs inoperable (out of service for maintenance & due to fuel pump failure).
Both EDGs inoperable (out of service for maintenance & due to fuel pump failure).
Load sequencers periodically inoperable. ESFAS affected.
Load sequencers periodically inoperable. ESFAS affected.

BWR Precursors

Docket/LER No	Event Date	CCDP	IE	Plant	Type	Unav. System	Dominant Sequence
237/70-LTR	1970/06/05	1.60E-04	LOCA	DRESDEN 2	BWR-B	SRV-FO, TCV/TBV	S2UX/S2UV
133/70-LTR	1970/07/17	4.20E-04	LOOP	HUMBOLT BAY	BWR	IC (valve)	TQUX/TQUV, (TBU)
010/70-LTR	1970/04/27	1.20E-04	Unav	DRESDEN 1	BWR-B	ECI (sensors)	TQUX/TQUV
249/71-LTR	1971/12/08	1.60E-04	LOCA	DRESDEN 3	BWR-B	SRV-FO	S2UX/S2UV
245/71-099	1971/10/10	1.40E-04	LOCA	MILLSTONE 1	BWR-A	SRV-FO	S2UX/S2UV
409/71-LTR-2	1971/03/24	4.20E-05	LOOP	LACROSSE	BWR	TBV, RCIC	TQUX/TQUV, (TBU)
409/71-LTR-1	1971/01/20	4.20E-05	LOOP	LACROSSE	BWR		TW, (TQUX/TQUV)
220/71-LTR	1971/12/31	1.60E-04	TRIP	NINE MILE PT 1	BWR-A	FWCI	TQUX/TQUV
219/72-LTR	1972/12/29	1.40E-04	LOCA	OYSTER CREEK	BWR-A	SRV-FO, MSIV, IC	S2W, S2UX/S2UV
271/72-012	1972/12/01	5.90E-05	LOOP	VERMONT YANKEE	BWR-C	HPCI, SRV-FTO	TBU, (TW, TQUX/TQUV)
155/72-LTR	1972/01/25	4.90E-05	LOOP	BIG ROCK POINT	BWR-A		TW, (TQUX)
409/72-014	1972/08/17	4.20E-05	LOOP	LACROSSE	BWR		TW, TQUX/TQUV
254/72-004	1972/06/10	8.50E-05	Unav	QUAD CITIES 1	BWR-C	RHR(SWS), EDG(CCW)	TW
259/73-LTR-1	1973/11/19	5.00E-04	LOOP	BROWNS FERRY 1	BWR-C	RCIC, HPCI	TBU
220/73-LTR	1973/11/21	4.90E-05	LOOP	NINE MILE PT 1	BWR-A		TW, TQUX/TQUV
219/73-LTR	1973/09/08	3.90E-05	LOOP	OYSTER CREEK	BWR-A	EDG	TBU, (TW, TQUX/TQUV)
259/73-LTR-2	1973/11/19	1.20E-04	Unav	BROWNS FERRY 1	BWR-C	RCIC, HPCI	TQUX
260/74-LTR	1974/08/23	5.70E-05	Unav	BROWNS FERRY 2	BWR-C	HPCI, RCIC	TQUX
321/74-LTR	1974/12/08	1.40E-06	Unav	HATCH 1	BWR-C	EDG	TBU
324/75-013	1975/04/29	8.90E-03	LOCA	BRUNSWICK 2	BWR-C	RCIC, RHR, SRV-FO	S2W, S2UX
321/75-062	1975/07/29	5.80E-05	LOCA	HATCH 1	BWR-C	ADS-FO, HPCI	AE
265/75-031	1975/08/17	2.90E-05	LOCA	QUAD CITIES 2	BWR-C	FW line valve	S2UX/S2UV
324/75-005	1975/03/20	4.90E-05	LOOP	BRUNSWICK 2	BWR-C		TW, TQUX/TQUV
293/75-034	1975/09/13	4.90E-05	LOOP	PILGRAM 1	BWR-C	SRV-FO	TQUX/TQUV
133/75-LTR	1975/06/27	2.50E-05	QUAKE	HUMBOLT BAY	BWR		Seismic Event
259/75-006	1975/03/22	1.50E-01	TRIP	BROWNS FERRY 1	BWR-C	ECCS(control)	TQUX
333/75-024	1975/02/25	3.70E-04	Unav	FITZPATRICK	BWR-C	ECCS(ESFAS)	TQUX
265/75-035	1975/09/09	5.70E-05	Unav	QUAD CITIES 2	BWR-C	HPCI, RCIC	TQUX
245/76-029	1976/08/10	3.50E-04	LOOP	MILLSTONE 1	BWR-A	Gas Turbine(EPS)	TBU
271/76-020	1976/07/06	3.30E-04	Unav	VERMONT YANKEE	BWR-C	ADS-FTO	TQUX
321/76-088	1976/11/11	5.60E-05	Unav	HATCH 1	BWR-C	RHR (SW strainer)	TW
245/76-012	1976/03/15	1.30E-06	Unav	MILLSTONE 1	BWR-A	IC, FWCI(Gas Turb)	TBU
245/76-010	1976/03/08	1.30E-06	Unav	MILLSTONE 1	BWR-A	IC, FWCI(Gas Turb)	TBU
324/77-054	1977/07/15	1.40E-04	LOCA	BRUNSWICK 2	BWR-C	SRV-FO	S2UX/S2UV
298/77-040	1977/08/31	1.40E-03	TRIP	COOPER STATION	BWR-C	RCIC, HPCI	TQUX
325/77-001	1977/01/04	1.40E-06	Unav	BRUNSWICK 1	BWR-C	EDG	TBU
277/77-037	1977/08/28	1.40E-06	Unav	PEACH BOTTOM 2	BWR-C	EDG	TBU
249/77-054	1977/11/29	1.40E-06	Unav	DRESDEN 3	BWR-B	EDG	TBU
331/77-026	1977/04/08	2.40E-04	Unav	DUANE ARNOLD	BWR-C	ADS-FTO	TQUX
293/78-035	1978/08/06	4.90E-05	LOOP	PILGRAM 1	BWR-C		TW
293/78-003	1978/02/06	4.90E-05	LOOP	PILGRAM 1	BWR-C		TW
293/79-033	1979/08/28	4.90E-05	LOOP	PILGRAM 1	BWR-C		TW
293/79-027	1979/07/27	4.90E-05	LOOP	PILGRAM 1	BWR-C		TW
219/79-014	1979/05/02	2.40E-03	TRIP	OYSTER CREEK	BWR-A	IC	TQUX
366/79-045	1979/06/03	1.40E-03	TRIP	HATCH 2	BWR-C	HPCI, RCIC	TQUX
325/79-089	1979/11/20	2.30E-04	TRIP	BRUNSWICK 1	BWR-C	HPCI, RCIC	TQUX
366/79-059	1979/06/28	4.80E-05	TRIP	HATCH 2	BWR-C	HPCI, RCIC	TQUX
324/79-050	1979/06/03	1.90E-05	Unav	BRUNSWICK 2	BWR-C	RHR	TQUX
331/79-005	1979/03/21	1.40E-06	Unav	DUANE ARNOLD	BWR-C	EDG/RHR/HPCI/RCIC	TBU
237/79-034	1979/06/12	1.40E-06	Unav	DRESDEN 2	BWR-B	EDG	TBU
293/80-080	1980/10/31	1.40E-04	LOCA	PILGRAM 1	BWR-C	SRV-FO	S2UX
293/80-079	1980/10/01	1.40E-04	LOCA	PILGRAM 1	BWR-C	SRV-FO	S2UX
293/80-069	1980/10/07	1.40E-04	LOCA	PILGRAM 1	BWR-C	SRV-FO	S2UX
331/80-054	1980/01/11	1.40E-05	LOCA	DUANE ARNOLD	BWR-C	SRV-FO	S2UX
321/80-069	1980/06/26	3.30E-04	TRIP	HATCH 1	BWR-C	HPCI, RCIC	TQUX
296/80-024	1980/06/28	9.80E-04	Unav	BROWNS FERRY 3	BWR-C	CRD	TC
249/80-031	1980/07/19	3.30E-05	Unav	DRESDEN 3	BWR-B	CRD	TC
265/80-032, 77	1980/11/16	3.20E-05	Unav	QUAD CITIES 2	BWR-C	HPCI, RCIC	TQUX
249/80-021	1980/04/25	1.30E-05	Unav	DRESDEN 3	BWR-B	ADS-FTO	TQUX
263/81-009	1981/04/27	1.80E-05	LOOP	MONTICELLO	BWR-C		TW
409/81-002	1981/02/01	1.00E-05	LOOP	LACROSSE	BWR		TQUX
325/81-032	1981/04/19	6.70E-03	Unav	BRUNSWICK 1	BWR-C	RHR(SWS)	S2W
324/81-039	1981/04/10	5.60E-05	Unav	BRUNSWICK 2	BWR-C	HPCI, RCIC	TQUX
249/81-037	1981/10/23	1.80E-06	Unav	DRESDEN 3	BWR-B	EDG	TBU
331/84-001	1984/06/07	1.20E-04	LOCA	DUANE ARNOLD	BWR-C	SRV-FO	S2UX
259/84-027	1984/06/27	9.50E-05	LOCA	BROWNS FERRY 1	BWR-C	SRV-FO	S2UX
259/84-032	1984/08/14	6.60E-06	LOCA	BROWNS FERRY 1	BWR-C	LPCS	AE
409/84-011	1984/07/16	9.90E-04	LOOP	LACROSSE	BWR	HPCS(DG)	TQUX/TQUV
388/84-013	1984/07/26	2.20E-04	LOOP	SUSQUEHANNA 2	BWR-C	DG	TBPU

BWR Precursors

Short Description
Depressurization incident. False signal. TBS/TBC valves open. Scram. Level sensor fail.
Loss of offsite power. IC fails due to Switching error. Substation relay trip.
Steam drum sensors fail (3 of 4)
Safety valve operation after LOFW. Cond booster pump fail. MFWP start. FW regulating valve locked out. SRV opens.
Transient and blowdown. Scram. Turbine bypass valve fails to close. LOCA due to an open SRV. SRV closes at 263psig.
Loss of offsite power due to yard fire. Cond. pumps/turbine bypass valve fail. LPSW fails. Shutdown Condenser (IC) fails.
Loss of offsite power due to maintenance work.
High coolant level.
Malfunction of several valves. Scram by error. SRV/MSIV fail, resulting in LOCA. IC valve fails open.
Loss of normal station power due to startup trans fault (LOOP). HPCI fails autostart. 1SRV chatters.
Loss of offsite power. Breakers open. Backup lines fail. LOOP for 20 min.
Loss of load caused by transformer maintenance error.
Flooding of turbine building. SWS valve shuts. Waterhammer/pipe failure. Flood 4 RHRSWP & CCWP for 2 DGs.
Loss of AC power causes HPCI/RCIC to fail. RCIC/HPCI could not be started.
Worker bumps relay, causing LOOP.
Loss of offsite power due to human error on transformer. DG 1 fails.
RCIC/HPCI fails during testing: RCIC steam valve fails to open. HPCI tripped when started.
HPCI injection valve fails to open in test. RCIC fails to show speed indication in test.
Two DGs malfunction: DG 1A fails in test. DG 1B trips. Governor booster had rusted. Water found in day tank.
Multiple valve failures and RCIC inoperable. RCIC down/SRV open/RHR fails due to SW supply valve failure.
All ADS valves open inadvertently. HPCI inoperable. Error causes ADS valves to open during test.
MFW low flow FW line severed at 6x4 reducer. MFW trip/LOFW. Scram. 12500gal water spill.
Loss of offsite power. Error fails 230KV buses. Ground fault trips relays, causing LOOP (4 min).
Loss of offsite power and such open SRV. Turbine trip. Breakers open. SRV fails open.
Minor earthquake. No damage done. Potential Event only.
Cable tray fire causes extensive damage, test error. Big fire. Wiring errors. ECCS fails.
All drywell high pressure switches isolated. Drywell HP instrument root valves found closed. ECCS affected.
HPCI found inoperable. RCIC out for repairs. HPCI fails in test (broken lube oil line).
Gas turbine fails during plant trip due to LOOP.
Improper insulation found. SRV fails test. 2 SRVs fail 2nd test. Air operator fails (excess heating).
Plant SWS strainers plug in 2 divisions (motor failure). Cooling systems affected.
Gas turbine for FWCI fails to achieve rated speed. IC inoperable.
Gas turbine inoperable. IC inoperable.
SRV fails to reseat. 1 SRV fails open because of grounded solenoid assembly.
Loss of no-break-power and feedwater control. Power panel fail. MFW/RCIC degraded. Trip. HPCI degraded.
Two DGs trip in LOOP test. DG 3&4 trip/restart. 8hrs later, DG 2,3&4 trip (setpoint drift).
Two DGs fail to start in LOOP test. DG E1 fails (known problem). DG E4 fails in test (install error).
DG trips during testing. DG 2/3 trip in test (due to failed cooling pump). DG 3 starts but trips in 30 min.
Six MS relief valves fail to lift. 4 SRV fail lift test at design point. 2 SRV lift at high pressure.
Loss of offsite power. ILghtning causes fault in offsite line relays. LOOP for 0.5 hr.
Loss of offsite power. Winter storm (high winds and ice) causes LOOP (takes out transmission lines).
Loss of offsite power. Lightning causes switchyard fault. SRV opened/closed.
Loss of offsite power. Lightning strike causes a ground fault.
Loss of feedwater flow.
HPCI fails to start given LOFW, trip. RCIC is out of service. HPCI fails to start. Operator error.
RCIC trip with HPCI unavailable, reactor trip (reason unspecified). HPCI in maintenance.
MSIV fast close test. HPCI/RCIC isolates after the trip.
Both RHR SW pumps not operable. Error disable SWS pump 2A. Pump 2B inoperable.
Both emergency SW systems out, strainers in ESW LOOP plug. Multi system impacts.
Failure of two DGs: Unit 2 DG fails in test. Test DG 2/3 fails. U2 has no DGs available.
Relief valve stuck open due to high nitrogen pressure at valve operator. IORV
Scram from main steam line high radiation. SRV sticks open. IORV.
Relief valve stuck open due to high nitrogen pressure at valve operator. IORV.
Stuck open relief valve. Valve cycled for better seating.
RCIC fails to start due to a faulty limit switch. HPCI fails to inject due to miscalib. of turbine speed controller.
Control rods (76) fail to insert, manual trip. 1 SDV had excess water.
Failure of SDV vent check valve: 1 of 2 SDV fails to drain. SDV level indication was in error.
RCIC discharge isolation valve fails to open. HPCI fails from turbine valve oil leak.
ADS valves fail to operate (4 SRVs fail). SRVs unavailable for 41 days.
Loss of 4.16KV bus. Error racks out Live 4.16KV breaker, causing momentary LOOP.
Operator error fails AC power. Operator opens wrong switch. All offsite power was lost.
RHR heat exchanger damaged. Oysters in SWS pipe dislodge and accumulate in B RHR HX.
Loss of RCIC and HPCI systems by valve operator and turbine governor failure.
Degraded cooling of DGs. DG water Hi temperature causes EPS to be unavailable. DG cooling pumps trip.
Operator error causes LOFW. SRV opens from operator error.
RCS leaks due to inadvertent SRV opening found during startup.
Valve install error. LPCS relief valve fails open in full power test. ISLOCA.
LOOP. 1 DG & HPCS fail due to DG output breaker fault.
LOOP test. DGs fail due to procedure/labelling error. Station blackout.

BWR Precursors

331/84-028	1984/07/14	7.30E-05	LOOP	DUANE ARNOLD	BWR-C	HPCI	TPQUX
373/84-054	1984/09/21	2.30E-03	TRIP	LASALLE 1	BWR-C	RCIC, RHR	TW
374/84-017	1984/05/17	3.80E-04	TRIP	LASALLE 2	BWR-C	HPCS	TPQUX
388/84-006	1984/05/27	3.30E-04	TRIP	SUSQUEHANNA 2	BWR-C	LPCI/RHR	TW
325/84-006	1984/03/31	2.60E-04	TRIP	BRUNSWICK 1	BWR-C	HPCI	TPQUX
387/84-010	1984/02/22	1.40E-04	TRIP	SUSQUEHANNA 1	BWR-C	SRV-FO	TPQUX
324/84-014	1984/11/27	1.40E-04	TRIP	BRUNSWICK 2	BWR-C	RCIC, LPCI/RHR	TW
325/84-014	1984/08/01	1.20E-04	TRIP	BRUNSWICK 1	BWR-C	HPCI	TPQUX
296/84-012	1984/11/20	1.20E-04	TRIP	BROWNS FERRY 3	BWR-C	HPCI	TPQUX
296/84-015	1984/12/09	1.10E-04	TRIP	BROWNS FERRY 3	BWR-C	COND, CRD	TQUX, TPQUX
416/84-030	1984/05/25	5.80E-05	TRIP	GRAND GULF 1	BWR-C	RCIC	TW
265/84-010	1984/10/25	8.90E-06	TRIP	QUAD CITIES 2	BWR-C	RCIC	TW
254/84-014	1984/08/08	6.70E-04	Unav	QUAD CITIES 1	BWR-C	LPCI/RHR	TW
333/84-003	1984/02/07	1.30E-06	Unav	FITZPATRICK	BWR-C	HPCI, RCIC	TPQUX
321/85-018	1985/05/15	1.80E-03	LOCA	HATCH 1	BWR-C	SRV-FO, HPCI, RCIC	S2UX
237/85-034	1985/08/16	4.00E-05	LOOP	DRESDEN 2	BWR-B	IC	TQUX, TPQUX
245/85-018	1985/11/21	3.00E-05	LOOP	MILLSTONE PT 1	BWR-A	IC	TPQUX
409/85-017	1985/04/12	2.05E-05	LOOP	LACROSSE	BWR		TQUX/TQUV
321/85-010	1985/01/06	2.30E-04	TRIP	HATCH 1	BWR-C	HPCI, RCIC	TQUX
219/85-012	1985/06/12	2.30E-04	TRIP	OYSTER CREEK	BWR-A	CRD, IC	TQUX
416/85-050	1985/12/03	1.80E-04	TRIP	GRAND GULF 1	BWR-C	HPCS	TPQUX
366/85-030	1985/11/05	1.20E-04	TRIP	HATCH 2	BWR-C	RCIC	TQUX
259/85-016	1985/06/16	9.50E-05	TRIP	BROWNS FERRY 1	BWR-C	RCIC	TW
373/85-045	1985/03/31	7.20E-05	TRIP	LASALLE 1	BWR-C	RHR(CCW)	TW
325/85-059	1985/11/02	6.00E-05	TRIP	BRUNSWICK 1	BWR-C	DG, LPCI/RHR, RCIC	TW
373/85-017	1985/02/08	5.30E-05	TRIP	LASALLE 1	BWR-C	RCIC	TW
220/85-021	1985/11/01	7.20E-06	TRIP	NINE MILE PT 1	BWR-A	FWCI, ADS	TQUX
237/85-044	1985/12/13	3.20E-06	Unav	DRESDEN 2	BWR-B	DG(CCW)	TQUX
277/85-003	1985/06/03	4.10E-06	Unav	PEACH BOTTOM 2	BWR-C	LPCI/RHR	TW
293/85-027	1985/09/19	1.40E-06	Unav	PILGRAM 1	BWR-C	LPCI/RHR	TW
333/85-025	1985/01/29	1.10E-06	Unav	FITZPATRICK	BWR-C	HPCI, RCIC	TPQUX
458/86-002	1986/01/01	7.00E-05	LOOP	RIVER BEND 1	BWR-C		TW
409/86-023	1986/07/10	2.00E-05	LOOP	LACROSSE	BWR		TQUX/TQUV
293/86-027	1986/11/19	7.70E-06	LOOP	PILGRAM 1	BWR-C		TW
277/86-003	1986/01/24	8.10E-05	TRIP	PEACH BOTTOM 2	BWR-C	DG	TW
249/86-013	1986/08/27	2.70E-06	Unav	DRESDEN 3	BWR-B	HPCI, CSS, LPCI	TPQUX
293/87-014	1987/11/12	3.90E-04	LOOP	PILGRAM 1	BWR-C	DG	TB
324/87-001	1987/01/05	2.40E-04	TRIP	BRUNSWICK 2	BWR-C	HPCI, RCIC	TPQUX
324/87-004	1987/03/11	1.90E-05	TRIP	BRUNSWICK 2	BWR-C	HPCI	TPQUX
354/87-047	1987/10/10	1.50E-05	TRIP	HOPE CREEK 1	BWR-C	SRV-FO	TPQUX
321/87-011	1987/07/23	7.70E-06	TRIP	HATCH 1	BWR-C	RCIC	TPQUX
440/87-012	1987/03/02	6.60E-06	TRIP	PERRY 1	BWR-C	RCIC	TW
397/87-002	1987/03/22	6.50E-06	TRIP	WASHINGTON NP 2	BWR-C	RCIC	TW
458/87-032	1987/12/19	5.90E-06	TRIP	RIVER BEND 1	BWR-C	CRDI, COND	TW
331/87-009	1987/05/27	3.30E-04	Unav	DUANE ARNOLD	BWR-C	EDG	TB
440/87-009	1987/02/27	2.30E-04	Unav	PERRY 1	BWR-C	EDG	TB
387/87-003	1987/01/27	7.50E-06	Unav	SUSQUEHANNA 1	BWR-C	EDG	TB
416/88-005	1988/01/11	6.90E-06	SLB	GRAND GULF 1	BWR-C	TBV-FO	TW
366/88-017	1988/05/27	2.00E-05	TRIP	HATCH 2	BWR-C	RCIC	TPQUX
321/88-018	1988/12/17	1.50E-05	TRIP	HATCH 1	BWR-C	RCIC	TPQUX
219/88-022	1988/10/02	5.00E-06	TRIP	OYSTER CREEK	BWR-A	EDG	TPQUX
410/88-036	1988/07/21	1.10E-05	Unav	NINE MILE PT 2	BWR-C	EDG	TB
397/88-018	1988/05/22	5.60E-06	Unav	WASHINGTON NP 2	BWR-C	EDG	TB
219/88-019	1988/09/02	3.60E-06	Unav	OYSTER CREEK	BWR-A	IC	TBU
324/89-009	1989/06/17	3.60E-05	LOOP	BRUNSWICK 2	BWR-C	RHR	TB
249/89-001	1989/03/25	1.30E-05	LOOP	DRESDEN 3	BWR-B	HPCI, LPCI	TPQUX
353/89-013	1989/12/11	1.50E-05	TRIP	LIMERICK 2	BWR-C	HPCI	TPQUX
333/89-023	1989/11/12	1.30E-05	TRIP	FITZPATRICK	BWR-C	HPCI	TPQUX
333/89-020	1989/11/05	1.30E-05	TRIP	FITZPATRICK	BWR-C	HPCI	TPQUX
331/89-003	1989/03/04	6.50E-06	TRIP	DUANE ARNOLD	BWR-C	RCIC	TW
416/89-016	1989/12/06	1.20E-06	TRIP	GRAND GULF 1	BWR-C	RCIC	TW
458/89-022	1989/05/02	1.30E-05	Unav	RIVER BEND 1	BWR-C	ADS	TPQUX
333/89-003	1989/03/06	6.50E-06	Unav	FITZPATRICK	BWR-C	SRV-FTC, HPCI	TPQUX
237/90-006	1990/08/02	2.60E-04	LOCA	DRESDEN 2	BWR-B	SRV-FO	S2UX
237/90-002	1990/01/16	3.10E-06	LOOP	DRESDEN 2	BWR-B	RHR	TPQUX
387/90-005	1990/02/03	4.10E-05	SD	SUSQUEHANNA 1	BWR-C		Shutdown Event
219/90-005	1990/04/21	8.80E-05	TRIP	OYSTER CREEK	BWR-A	IC, CRD	TQUX
293/90-013	1990/09/02	8.40E-05	TRIP	PILGRAM 1	BWR-C	RCIC, HPCI, RHR	TW
366/90-001	1990/01/12	6.00E-05	TRIP	HATCH 2	BWR-C	HPCI	TPQUX
440/90-001	1990/01/07	1.40E-06	TRIP	PERRY 1	BWR-C	RCIC	TW

BWR Precursors

LOOP when substation degrades power. HPCI isolates from loss of power.
Error causes scram. RCIC fails. RHR valve fails to open.
MFW trip (plug strainer)/Reactor trip. LOFW. HPCS fails due to pump breaker failure.
LPCI fails. Turbine bypass valve fails open. Manual scram.
Maintenance error causes trip/LOFW. HPCI trips. HPCI manually restarted.
SRV fails open in test (solenoid valve failure). Manual scram.
Turbine trip/scram. RCIC/LPCI/RHR B in maintenance. RHR A waterhammer.
Spurious scram. HPCI out of service for test. 1 MSIV fails to close.
Poor procedure causes scram. HPCI outboard FCV fails to open.
Cond. pump failure. Coil & panel power loss. Scram. CRD pump failure.
Broken valve/MFW trip/LOFW. RCIC trips on overspeed.
RCIC trip. CRDS valve found closed (1rod fails to fully insert).
Undetected design error. LPCI inject valves fail to open.
HPCI in maintenance. Operator error disables RCIC.
HVAC water shorts panel. SRV fails open. RCIC out of service. HPCI fails.
U1 & U2 RAT fail, leading to U2 LOOP. IC valve fails.
LOOP due to hurricane. IC cond. return valve remote operation causes IC unavailable.
LOOP due to operator bumping trip lever.
Vital DC power fails. LOFW/trip. RCIC/HPCI fail due to valve failures.
MSIVs isolate. SDV fails to isolate due to installation error.
Hotwell level alarm error causes LOFW/scram. HPCS inject valve fails to open.
Cond. booster pump trip/MFW trip/scram. RCIC trip on overspeed.
MFW pump trips (turbine steam isolates). RCIC fails on overspeed.
CWS/SWS pumps fail (expand joint). Scram. RHR affected.
Containment isolation leads to scram. LOFW. RCIC & LPCI/RHR fail. DG4 trip.
Maint error/instrument valve causes MFW pump trip. Scram. RCIC trips on overspeed.
Instrument air fails MFW FCV. 1 ADS valve not open. FWCI fails due to failed trip switch.
Workers damage unit 2 DG 2/3 cable. U2 DG 3 fails due to failed bearing/bent shaft.
RHR/LPCI A inject valve fails to open in test twice.
LPCI/RHR train B inject valve fails to open. Rest of LPCI out of service.
Steam supply valve motor operator failure disable HPCI. RCIC out of service.
Trip. Transformer A&C trip. Hand-held radio trips transformer B&D/LOOP.
Uncomplicated LOOP due to lightning strike at coal-fired unit.
High volt line arcs in winter storm result in LOOP (3hr).
DG fails in loss of power test. Loss of power to buses. 2MSIV close.
In test, HPCI, LPCS B, LPCI min. flow valve & DG 2/3 fail.
LOOP & 1 DG out of service for inspection.
Grid fluctuation causes scram. HPCI/RCIC fail due to valve failures.
HPI unavailable due to loss of power to discharge valve.
MFW and TG trips. SRV opens.
LOFW & RCIC trips on overspeed.
LOFW. RCIC fails due to valve failure to open.
Trip. MS line flooding leads to potential RCIC failure.
Error leaves CST isolated. No CRD flow. Cond line leaks.
EPS is unavailable due to incorrectly set overcurrent relays.
Two DGs unavailable due to failed solenoid valves.
DG-B out for maintenance. DG-A trips in test due to control failure.
Effective SLB due to failed open TBS valves.
Reactor trip and failure of RCIC pumps due to limit switch failure.
Trip with degraded RCIC (trip on overspeed).
Trip with one safety-related bus unavailable due to ground fault, preventing DG from auto-start.
Both DGs unavailable for 42 hrs - failed contact & out of service for maintenance.
Both EDGs unavailable - misposition of indication switch & out of service.
Both trains of IC inoperable due to mechanical problems and procedural deficiency.
Reactor manual scram cause LOOP. RHR inoperable due to stuck-closed injection valve.
LOFW with unavailable LPCI (due to breaker failure). Degraded HPCI and CCW (loss of lub oil cooling).
Reactor scram with degraded HPCI due to valve failure.
Scram with HPCI system inoperable due to speed control circuit fault while testing SRVs.
Reactor scram with HPCI system inoperable due to speed control circuit fault.
Reactor scram and isolation with RCIC out of service.
Scram with RCIC unavailable caused by valve closure for testing.
IA SOVs were installed backward, impacting ADS operability.
Inadvertent SRV actuation with HPCI inoperable due to turbine stop valve problem.
Stuck open safety relief valve followed by scram.
Reactor scram followed by loss of offsite power (12.5 hr). RHR unavailable due to valve failure.
Fault on RPS bus causes loss of shutdown cooling [Shutdown Event].
B ESF 480V feeder and isolation condenser & CRD injection failure due to loss of DC power.
Scram with RCIC failure, FW, HPCI, & RHR problems.
Reactor scram with HPCI inoperable due to valve control logic fault.
RCIC isolation due to equipment room high temperature following reactor scram.

BWR Precursors

461/90-011	1990/05/14	4.70E-05	Unav	CLINTON 1	BWR-C	EDG(SWS)	TB
254/90-003	1990/02/13	3.70E-06	Unav	QUAD CITIES 1	BWR-C	EDG	TB
271/91-009	1991/04/23	2.90E-04	LOOP	VERMONT YANKEE	BWR-C		TB
293/91-024	1991/10/30	1.20E-04	LOOP	PILGRAM 1	BWR-C	RCIC	TB
410/91-017	1991/08/13	3.80E-04	TRIP	NINE MILE PT 2	BWR-C	RHR(DC)	TW
325/91-018	1991/07/18	6.00E-05	TRIP	BRUNSWICK 1	BWR-C	HPCI	TPQUX
333/91-006	1991/05/07	2.00E-05	TRIP	FITZPATRICK	BWR-C	RHR/LPCI	TW
321/91-001	1991/01/18	1.10E-05	TRIP	HATCH 1	BWR-C	HPCI, RCIC	TQUX
440/91-009	1991/03/14	5.30E-04	Unav	PERRY 1	BWR-C	EDG	TB
278/91-017	1991/09/24	3.30E-04	Unav	PEACH BOTTOM 3	BWR-C	ADS	S2UX
333/91-014	1991/08/05	9.50E-05	Unav	FITZPATRICK	BWR-C	LPCS, RHR	S2UV, TW
219/92-005	1992/05/03	7.10E-05	LOOP	OYSTER CREEK	BWR-A		TB
254/92-004	1992/02/06	6.90E-06	TRIP	QUAD CITIES 1	BWR-C	HPI, ADS	TPQUX
388/92-001	1992/03/18	6.60E-06	TRIP	SUSQUEHANNA 2	BWR-C	EDG	TW
374/92-012	1992/08/27	6.10E-06	TRIP	LASALLE 2	BWR-C	RCIC	TW
373/93-015	1993/09/14	1.30E-04	LOOP	LASALLE 1	BWR-C		TB
293/93-004	1993/03/13	4.60E-06	LOOP	PILGRAM 1	BWR-C		TB
440/93-011	1993/03/26	1.20E-04	TRIP	PERRY 1	BWR-C	RHR(SWS)	TW
265/93-010	1993/04/22	6.00E-05	Unav	QUAD CITIES 2	BWR-C	EDG(CCW)	TB
458/94-023	1994/09/08	1.80E-05	TRIP	RIVER BEND 1	BWR-C	RCIC, CRD	TQUX
237/94-018	1994/06/08	6.10E-06	Unav	DRESDEN 2	BWR-B	EPS	TB
237/94-021	1994/08/04	3.10E-06	Unav	DRESDEN 2	BWR-B	HPCI	S1UX

BWR Precursors

Division I & II emergency diesels inoperable due to incorrect SWS valve operation.
One EDG out of service for scheduled maintenance and one EDG fails test on overspeed.
Extended loss of offsite power (13 hr).
Loss of offsite power and RCIC trip on overspeed due to discharge valve problem.
Loss of five non-safety uninterruptible power supplies. RHR affected.
Loss of feedwater with degraded HPCI due to turbine oil leak.
Trip with both LPCI trains inoperable due to valve failure.
LOFW with HPCI degraded due to overspeed and RCIC failure due to isolation valve failure.
Two EDGs inoperable (28 days, 15 days) due to field contact failure & failure to synchronize.
Control wiring for ADS/relief valves found damaged.
Hydraulic pressure locking of two low-pressure ECCS injection valves.
LOOP due to forest fire.
Reactor trip with HPCI out of service for maintenance and one SRV unavailable (failure to open).
Reactor trip with EDG unavailable due to loss of field & vital bus unavailable.
Reactor trip with degraded RCIC (trip on high exhaust pressure due to water intrusion).
Scram and loss of offsite power (transformer fault).
Weather-induced (coastal storm) LOOP. Vessel pressure/temperature limits violated.
Clogged suppression pool strainers and service water flood. RHR affected.
Degradation of both emergency diesel generators due to loss of CCW.
Scram. Turbine-generator fails to trip. RCIC trip on overspeed & CRD unavailable due to blown fuse.
Motor control center trips due to improper breaker settings. EDG affected.
Long-term unavailability of high pressure coolant injection due to failed check valve.