LER SCREENING ALGORITHM FOR IDENTIFICATION OF POTENTIAL ACCIDENT SEQUENCE PRECURSOR EVENTS*

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ABSTRACT

A computer algorithm has been developed and implemented to search the Sequence Coding and Search System (SCSS) Licensee Event Report (LER) database for failures or conditions common to Accident Sequence Precursor (ASP) events. The use of the algorithm has greatly improved the efficiency and timeliness in identifying potential ASP events and, by focusing attention on the most likely precursor events, has reduced the likelihood that these events will be overlooked in manual screening.

I. GENERIC ASP EVENT DESCRIPTION

Operational events are selected as precursors if they are core damage initiators or if they impact systems or functions which provide protection against core damage given an initiator. These initiators (or transients) and adverse plant conditions of interest are described in more detail in *Precursors to Potential Core Damage Accidents: 1994, A Status Report*, NUREG/CR-4674, Vols. 21 and 22.[1]

Operational events are designated potential precursors if they include:

1. a core damage sequence initiator such as a loss of offsite power (LOOP), a steam line break, or a loss of coolant accident (LOCA); or

2. a failure of a system (or multiple trains of a multitrain system); or

3. failures or degradations in more than one system; or

4. a transient concurrent with a failed or degraded system, and

5. the conditional probability of subsequent core damage is greater than or equal to a cutoff value of 1.0×10^{-6}.

II. SEQUENCE CODING AND SEARCH SYSTEM DATABASE (SCSS)

The Sequence Coding and Search System[a] was developed by the Nuclear Regulatory Commission's (NRC's) Office for Analysis and Evaluation of Operational Data (AEOD) and the Oak Ridge National Laboratory (ORNL) to capture detailed analyses of event sequences reported in LERs in a database available to NRC staff and contractors.[2] The analyses of the events reduce the LER descriptive text to coded, searchable sequences. The steps in the sequences describing the information reported in the LER fall into four basic types. These are:

1. Equipment Failures. The type and number of component failures (e.g., two flow control valves); the system to which the components belong (e.g., feedwater system); the cause and failure mode (e.g., erosion resulting in a failure to open); vendor and model number data, if stated; and links to later steps describing system failures or unit effects.

2. Personnel Errors. The personnel activity under way (e.g., maintenance, design, etc.), the type of personnel involved (e.g., licensed operator), and the cause and effect of the error are all noted in steps in the event sequence.

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[a]Access to the SCSS database is available on-line to NRC staff and NRC contractors, or the SCSS staff at ORNL can perform searches and send the results directly to the user. Searches are performed on a cost-recovery basis for non-NRC users.

DISCLAIMER

3. System and Train Level Performance. The system involved (e.g., feedwater system, high pressure coolant injection system), the number of trains involved (if applicable), the cause and mode of failure, and the timing of the failure (e.g., pre-existing, potential, or actual failure) are all captured.

4. Effect on the Unit or Environment. The effect on the unit includes reactor trips or shutdowns, power reductions, engineered safety feature actuations, actuation parameters, types of actuations, and initial plant conditions. The effect on the environment includes radiological releases or personnel radiation exposures.

Each LER sequence will consist of one or more of each of these basic step types which are linked together in a searchable, time-ordered sequence or sequences to form the entire event. As of mid-1996, the database contains approximately 43,000 LERs with event dates from 1980 to within about 60 days of the current date—LERs are added to the database within about two weeks of when they are received at ORNL.

The database supports simple and broad searches, such as identifying LERs at selected plants that involve certain component types. It also supports far more detailed and complex searches, such as identifying events where a design error in the feedwater control system led to a steam generator low level trip and where one or more trains of AFW failed subsequent to the trip due to a procedure-related operator error. Many different types of these conditions may be combined with Boolean operators to further define searches. The ASP algorithm is one of the more complex SCSS search applications.

III. ASP MANUAL SCREENING

ASP screening has been performed by experienced analysts who often review numerous events consecutively. Events with elements typical of precursors are set aside for detailed analysis and quantification. Manual screening is normally very effective for a small number of LERs, but it becomes less effective as the number of events increases. The events must be carefully studied to catch incidental remarks, especially concerning unexpected system responses or equipment unavailabilities. To ensure that no potential precursors were missed, each LER was reviewed by two engineers. Approximately 1,200–1,500 LERs are reported each year, therefore, a considerable amount of effort was expended to review the events with recognition that effectiveness in identifying the events drops as more have to be reviewed.

IV. SCSS COMPUTERIZED SEARCH STRATEGY

An SCSS screening algorithm was developed to address the intensive review activity deemed necessary to identify all potential precursors over a yearly period. The purpose of the algorithm was to reduce significantly the number of LERs subject to detailed review by ASP project staff yet still identify all potential precursors reported in LERs.

The algorithm capitalizes on the intensive LER review and encoding already used for SCSS and utilizes SCSS' extensive search capabilities. The algorithm was constructed in a manner analogous to the ASP manual screening. The algorithm requires that (1) one complete train of two or more safety systems or (2) one entire safety system is faulted or unavailable. It also includes the occurrences of initiating events such as LOCAs or LOOPs or reactor trips with one or more trains or an entire safety system unavailable. Several search groups based upon the conditions above are then saved. Set algebra is then performed on the groups in order to prioritize the groups having the highest likelihood of containing precursor events. The groups are:

1. potential LOOPs and LOCAs;

2. reactor scrams plus faults in at least two safety system trains (e.g., a scram and a fault in one train of two different safety systems or a scram and one entire safety system faulted);

3. faults in the refueling water storage tank involving multiple instrument faults, multiple heat tracing faults, leakage from the RWST, interfaces with the residual or decay heat removal (RHR) or chemical and volume control (CVCS) systems;

4. reactor scrams plus a fault in one entire safety system;

5. faults in trains from at least two different safety systems or two entire safety systems faulted;

6. faults of the entire emergency power system; and

7. other safety systems faults (not including the emergency power system).

V. RESULTS

The algorithm was executed on the SCSS database and compared to results from past manual ASP reviews for eight years. Several significant benefits were realized. First, the algorithm provided a reduction of approximately 75% in the number of LERs that were required to be reviewed and identified about 98% of the precursors during the years of

interest. Table 1 summarizes the results of applying the algorithm to the several years' worth of data.

Table 1. Success of Algorithm in Finding Precursors

Year	Reduction %	Precursors Found	Accuracy %
1980	86	30/30	100
1981	79	27/27	100
1984	73	49/51	96
1985	74	56/59	95
1986	72	28/28	100
1987	69	47/47	100
1988	71	32/32	100
1989	68	30/31	97
All years	75	299/305	98

A second benefit was that the LER screening process could be accomplished is a more timely manner. The execution of the algorithm on the SCSS database and the processing of the results for ASP staff use takes less than one hour.

An important additional benefit is that the detailed review of approximately 750–1,000 LERs per year is obviated—over ½ person-year of effort per year.

All told, the algorithm was successful in screening the 15,000 LERs during this time period to approximately 3,000. The number of precursors in the remaining group is 299 out of a total of 305 identified during manual review—a success rate of 98%.

The six precursors that the algorithm did not find were carefully reviewed. Three of these events would not be labeled as precursors under present precursor screening criteria. Two of these three events involved failures of one train of low pressure coolant injection. Failures of a single train of a safety system alone are no longer selected as potential precursor events. One of the three events was a trip and subsequent feedwater isolation. Again, these conditions alone are not now sufficient for an event to be labeled as a potential precursor event.

The other three events were not found by the algorithm due to incomplete coding. One event involved a reactor trip, a loss of a feedwater pump and a start of auxiliary feedwater. A leaky check valve diverted AFW flow away from the steam generator. SCSS did not indicate that AFW flow did not reach the steam generator. The algorithm was modified to give special consideration to transient conditions such as reactor trips to reflect the importance of these events.

One event involved a main steam isolation valve closure followed by a reactor trip and subsequent failure of the scram discharge volume to completely isolate. The screening algorithm did not search for failures of the scram discharge volume. The modification to the algorithm to account for transient conditions also addressed the conditions of this event. The third event involved a 10,000 gallon leak from a containment spray heat exchanger gasket to the auxiliary building via the primary coolant system, residual heat removal system, and refueling water storage tank—the concern being failure of low-pressure recirculation as a result of the loss of containment sump inventory. Various valve configuration problems were coded, but a low refueling water storage tank level (which would have triggered the algorithm) was not coded due to only a 2% reduction in tank volume.

VI. SUCCESS OF THE SEARCH ALGORITHM FOR DIFFERENT PRECURSOR TYPES

The algorithm was found to have the highest success in identifying those precursors involving actual or potential loss of coolant accidents and loss of offsite power events and those events reporting actual or potential loss of the emergency power system. As Table 2 shows, approximately 15% of the events grouped in this category were actual precursor events. The percentage of precursor events in groups for trips and safety system faults was less, typically 2–10%. This is because SCSS does not distinguish long-term train or system unavailabilities (or those that may be of higher significance) from unavailabilities that are less significant or more easily recoverable.

VII. SUMMARY

The development and implementation of a computer algorithm to screen the SCSS LER database for potential accident sequence precursor events has been demonstrated to significantly reduce intensive manual review efforts formerly required to screen LERs. The number of events now requiring a detailed review has been reduced by about 75%. At least 98% of the precursors are expected to be found in the remaining 25% of the LERs. This results in both cost savings and improvements in the timeliness of LER screening.

The algorithm demonstrates the effectiveness of the SCSS encoding and utilization capabilities to quickly and efficiently search for both significant events readily identifiable as potential precursors and those events with far more subtle

implications. These capabilities may be applicable to other operational experience-related program or problem areas.

Table 2. Algorithm Success by Search Topic

Search Topic	No. LERs Identified	No. Precursors in Group	% Precursors in Group
LOCA or LOOP	387	65	16.8%
Trip + Two Safety System Faults	787	74	9.4%
Refueling Water Storage Tank Fault	47	1	2.1%
Emergency Power System Fault	126	19	15.1%
Trip + One Safety System Fault	696	38	5.5%
Two Safety System Faults	1,683	66	3.9%
One Entire Safety System Faulted	2,220	36	1.6%
All Groups Combined	5,946	299	5.0%
Total Number of LERs: 23,557		Total Number of Precursors: 305	

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