B.4 LER No. 316/98-005

Event Description: A postulated break in a Unit 2 main steam line could degrade the ability of the adjacent CCW pumps to perform their function

Date of Event: July 14, 1998

Plant: Donald C. Cook Nuclear Plant, Unit 2

B.4.1 Event Summary

On July 15, 1998, with Donald C. Cook Nuclear Plant, Units 1 and 2 (Cook 1 and 2) in cold shutdown, it was determined that a postulated crack in a Unit 2 main steam line could degrade the ability of the adjacent component cooling water (CCW) pumps to perform their design function.[1] The CCW pumps for both units are adjacent to one another in a semi-enclosed area in the Auxiliary Building. Next to the area where the pumps are located is a pipe chase enclosing two Unit 2 main steam lines and a main feedwater (MFW) line. This pipe chase can be accessed through any one of three doors. Although the pipe chase walls provide a qualified high energy line break (HELB) barrier, these doors are not designed to be watertight or pressure-retaining. The CCW pump motors and other equipment are not qualified for a high temperature/high humidity environment. As a result, if the postulated HELB were to occur, the potential would exist for one or both units to suffer a total loss of CCW.

The estimated increase in the core damage probability (i.e., importance) associated with this issue for a one-year period at Cook 2 is 3.0×10^{-6}. The importance associated with this issue at Cook 1 is $< 10^{-6}$.

B.4.2 Event Description

On July 15, 1998, with both units in Operating Mode 5, cold shutdown, the licensee determined that a postulated crack in a Unit 2 main steam line could degrade the ability of adjacent CCW pumps for both units to perform their design function. The condition was reported on August 14, 1998, as an unanalyzed condition in Interim LER 316/98-005, Rev. 0, (Ref. 1).

The CCW pumps for both units are adjacent to one another in a semi-enclosed area in the Auxiliary Building. Next to the area where the CCW pumps are located is a pipe chase enclosing two Unit 2 main steam lines and a MFW line, which can be accessed through any one of three access doors. Although the walls of the pipe chase provide a qualified HELB barrier, these doors are not designed to be watertight or pressure-retaining. The CCW pump motors and other equipment are not qualified for the high temperature/high humidity environment that would exist following an HELB.

There are five CCW pumps for the two units. Each unit has two dedicated, 100% capacity, redundant, CCW pumps and associated systems. The fifth pump is available to supply either unit and can be powered from any safety-related electrical bus. For fire protection considerations, the fifth pump is grouped with the Unit 1 pumps. The Unit 2 pumps are separated from the Unit 1 pumps and the spare pump by a three-hour fire barrier. This barrier is approximately seven feet tall, while the room containing the CCW pumps (CCW Pump Room) is

~4.3 m (14 ft) tall. The barrier, which extends from the CCW Pump Room wall to beyond the location of the pumps, is ~9.1 m (30 ft) long. In the place where a sixth CCW pump could have been located, outside of the CCW Pump Room, is a small area where the Unit 2 main steam (two lines) and MFW (one line) lines pass the CCW Pump Room. These pipes are oriented in the vertical direction as they pass the CCW Pump Room. These lines are isolated from the CCW Pump Room by concrete walls. Access is provided to these lines from the CCW Pump Room through three industrial style personnel doors [~0.9 × 2 m (3 ft × 7 ft)]. These doors are not designed to be watertight or pressure-retaining.

B.4.3 Additional Event-Related Information

As stated above, there are two main steam lines and one MFW line running through the pipe chase of interest. This pipe chase contains only large bore main steam and MFW piping. There are no small bore high energy branch lines in this area. The licensee's investigations found that there are no high stress pipe segments in this area which are vulnerable to cracks or breaks. There are three access doors between the pipe chase and the CCW Pump Room, which open into the CCW Pump Room. The length of piping adjacent to each of the doors is about 6.1–9.1 m (20–30 ft), which means that about 18–27 m (60–90 ft) of piping are situated near the doors.[2]

References 2 and 3 provide the following information: The pipe chase in question communicates with a steam tunnel, which is a large area. A postulated failure of the high energy piping in this large area could send steam into the pipe chase adjoining the CCW Pump Room. If the pressure increase due to the postulated piping failure were high enough, then the doors from the pipe chase to the CCW Pump Room could open, and allow steam to enter that room. However, based on Refs. 2 and 3, it is known that one end of the steam tunnel is open to the turbine building. Therefore, the turbine building provides a large potential escape path for steam generated by postulated piping breaks in the steam tunnel. The other end of the steam tunnel is also open to a very large, potential steam escape volume.

B.4.4 Modeling Assumptions

The data and approach used to estimate piping failure frequencies are as follows:

Type of piping failure (crack, leak, or rupture)

Reference 4 [*Reliability of Piping System Component, Framework for Estimating Failure Parameters from Service Data, SKI (Swedish Nuclear Power Inspectorate (SKI) Report 97: 26)*] classifies pipe failures as cracks, leaks, and ruptures. For the scenario considered for the analysis of the condition at the Cook plant, according to Ref. 5 (*Expert Judgement on Capability of Non-EQ CCW Pumps at DC Cook*), only pipe ruptures are capable of creating a pressure increase that is capable of failing the doors to the pipe chase. Cracks and leaks are not capable of generating pressures that are large enough to fail the doors open. Steam flow around closed doors (i.e., gaps under the door) is not capable of failing the CCW pumps, since steam will tend to enter the large open areas at the ends of the pipe chase rather than flow into the CCW Pump Room around the doors. Even if some steam enters the CCW Pump Room through gaps around the doors, due to the buoyant forces, the steam will rise toward the ceiling rather than move toward the CCW pumps. Therefore only feedwater or steam line ruptures, rather than cracks or leaks, were considered in the frequency estimation.

Location of piping ruptures capable of causing CCW pump failure

This analysis assumed that only the breaks at piping elbows which are located in the immediate vicinity of the CCW Pump Room doors would be capable of generating a pressure that could cause the doors to fail open. The basis for this conclusion is summarized as follows. If an HELB were to occur at or near an elbow in the immediate vicinity of the pipe chase, there could be a local pressure spike that could open one or more doors. However, the capability of breaks at elbows away from the pipe chase was not considered, since the large open areas at the ends of the pipe chase would result in low pressure spikes at the doors. Reference 5 provides details on the basis for this assumption.

Selection of data sources (plant-specific versus U.S. and International)

Piping failures at nuclear plants are rare events. Therefore, the use of plant-specific information and the Bayesian approach with a non-informative prior (zero failures in main steam lines and MFW lines in approximately 50 calendar years for Cook 1 and Cook 2) would lead to an overly conservative piping failure frequency of 0.01/calendar-year (½/51). The licensee's individual plant examination (IPE)[10] uses a value of 3.4×10^{-4}/year for the combined frequency of main steam line breaks and feedwater line breaks. However, no basis could be found for this value. Therefore, several sources of U.S. and international operating experience data were used to select appropriate data for a realistic estimate of pipe failure frequency.[4,6,7,8,9] Since the frequency calculations use data from other nuclear plants to estimate the frequencies for Cook, the conditions of the main steam or MFW piping or conditions pertaining to failure events might not be identical to conditions found at Cook. However, randomness and the use of a significantly larger population of data would result in a more realistic estimate than using Cook operating experience only. Reference 4 refers to the most up-to-date and comprehensive data source, with 2356 pipe failure records of U.S. and international events. Therefore, insights provided in Ref. 4 were used to screen the U. S. data. References 6, 7, and 8 were used to identify data for calculating the rupture frequency. These three references include only U.S. operating experience. These references were chosen over Ref. 4, since this report does not provide details on events and the database itself is not available.

Piping reliability attributes

Piping reliability (or the failure frequency) depends on a large number of attributes. For example, the segments of the main steam and MFW lines in the pipe chase at the Cook plant consist of carbon steel piping with large diameters. The MFW piping in the pipe chase is 51-cm (20-in) Schedule 80 piping, whose normal operating temperature is 216°C (421°F) and the normal operating pressure is 7.07 Mpa (1025 psig). Such variations in design and operating characteristics which influence the piping reliability need to be factored into the piping frequency calculation, to the extent practical (e.g., availability of data breakdowns by reliability influence factors). Table 4-2 of Ref. 4 identifies piping reliability attributes as:

- Pipe diameter, wall thickness, and ratio;
- Piping system type which implicitly accounts for process medium (e.g, feedwater, steam);
- Piping material (e.g., stainless steel, carbon steel);

- Process parameters (e.g., temperatures, pressures); and
- Design/construction/installation (e.g., welding techniques).

Data tabulated in Ref. 4 showed a significant difference in the number of ruptures between those that occurred in large-bore [> 25 cm (~10 in.) in diameter] stainless steel pipes (zero failures) and those that occurred in all balance-of-plant, large-bore piping, which is typically made of carbon-steel (33 failures). The above attributes, which have a propensity to affect the piping failure frequency and cause, were examined for the specific case of the piping in the Unit 2 pipe chase. For these reasons, only carbon steel large diameter piping carrying single-phase feedwater (for feedwater pipes) or high-quality main steam (for main steam pipes) was considered in selecting failure events and operating experience.

Failure experience for the main steam line break frequency estimation was limited to pipes carrying high-quality steam since: (a) operating experience indicates that main steam pipes carrying high-quality steam have similar (lower) failure rates , and (b) one of the significant contributing failure mechanisms (erosion/corrosion) is highly unlikely to occur in piping for steam that does not carry water droplets. The use of operating experience data for feedwater lines was limited to piping that carries single-phase flow, since experience has shown a significant difference between the failure rate of piping carrying single-phase flow and piping carrying two-phase flow. According to Tables B.5-5 and Tables B.6-5 of Ref. 4, all ruptures in condensate and feedwater lines whose diameter was greater than ~10 cm (4 in) were caused by erosion and corrosion. However, rather than selecting experience involving piping with diameters greater than 10 cm (4 in), experience pertaining to piping whose diameter exceeded 25 cm (10 in) was used. This was justified since process media, systems, and the process parameters are more closely related to the large bore piping in the Unit 2 pipe chase.

Pooling PWR and BWR operating experience data

The balance-of-plant (BOP) of pressurized water reactors (PWRs) and the reactor coolant pressure boundary of boiling water reactors (BWRs) contain carbon steel piping. The operating experience data (failures and root causes of those failures), as well as process parameters (temperatures and pressures) were considered to determine whether the large bore piping experience of the BWR and PWR populations could be pooled. In U.S. commercial reactor operational history, there has been one MFW pipe rupture in a large bore pipe (Quad Cities 2 – 8/75) in approximately 550 critical-years of BWR operation, and three MFW ruptures (Indian Point 2 – 11/73, Maine Yankee – 01/83, and Surry – 12/86) in approximately 1100 critical-years of PWR operation. No main steam line failures have occurred in large-bore carbon steel piping. Based on the above, it was concluded that there is no statistically significant difference in failure probabilities between PWR and BWR piping. In terms of the attributes that contribute to failures, both BWRs and PWRs have large-bore carbon-steel piping that carry single-phase flow (for MFW) and high-quality steam (for main steam). Therefore, PWR and BWR data were pooled to perform rupture frequency estimations.

Total operating experience

For both PWRs and BWRs, based on Ref. 6 (NUREG/CR-5750) and Ref. 17 (NUREG-1272), the total operating experience is approximately 1600 critical-years.

Piping Failures

Piping reliability attributes discussed earlier in this document were used to identify the pipe ruptures that were used in the frequency calculations. Zero failures in main steam lines and two failures in MFW lines were used in the pipe failure frequency estimates. The basis for these values is as follows:

References 4, 6, and 7 report many failures in main steam lines. However, there were no main steam line ruptures in carbon steel large-bore piping that carry high-quality steam in U.S. reactors during the period covered by Ref.s 4, 6, and 7 (1970–1998).

Between 1970 and 1998, there were two MFW pipe failures in large-bore piping in U.S. nuclear power plants. Each of these failures was reviewed to determine whether there were any associated unique factors that would make them inapplicable to the potential for breaks at the welds, elbows, or straight piping in the vicinity of the pipe chase.

At Surry, the feedwater pipe rupture occurred at a carbon steel elbow in the 46-cm (18-in) suction pipe to the “A” main feed pump. The ruptured feedwater piping was attributed to pipe wall thinning due to an erosion/corrosion phenomenon. When the reliability attributes stated earlier were used, there was no basis to conclude that this failure was not applicable to Cook (Refs. 11 and 12).

In the Indian Point 2 event, a feedwater line rupture occurred in an 46-cm (18-in) diameter pipe with 2.54-cm (1-in) wall thickness at a fillet weld between the feedwater line and the end plate, which was welded into the penetration sleeve in the containment. The rupture was attributed to water hammer. The LER for this event identified several mechanisms (sudden closure of regulating valves, check valve malfunction, water-steam interaction in the line segment adjacent to the steam generator). Just like Indian Point 2 , the MFW lines at Cook could experience one or more of these transients during a random event. During a water hammer event, breaks could occur at locations such as welds and bends. Therefore, it was concluded that this type of occurrence was applicable to Cook. Since this MFW line break occurred in 1973, in consideration of changes to pipe break prevention programs instituted since 1973 (e.g., erosion/corrosion programs), it was necessary to consider the appropriateness of this 1973 failure in frequency calculations. Based on Ref. 18, the database and the knowledge base on pipe failures were too limited for drawing conclusions relating to trends in pipe rupture frequency, therefore it was appropriate to include this failure in the frequency estimation.

Frequency of MFW and main steam piping ruptures

Based on the above information regarding the number of failure events and operating years for large bore [> 25 cm (10 in) diameter] carbon steel piping which is not connected to small bore piping, but is carrying single-phase feedwater or high-quality steam, the estimated pipe rupture frequencies used in this analysis were 1.6×10^{-3}/critical-year (2.5/1600) for MFW piping and 3.1×10^{-4}/ critical-year (0.5/1600) for main steam piping. A Jefferey’s non-informative prior was used in this Bayesian update.

Adjusting the frequency by the criticality factor

The criticality factor for Cook 2 is 0.68 (Ref. 6). The criticality factor for Unit 2 was used in this analysis to calculate the initiating event frequency rather than the factor for Unit 1 because the piping in the pipe chase of concern was associated with Unit 2. As a result, the estimated frequencies were 2.1×10^{-4} per year ($0.68 \times 3.1 \times 10^{-4}$) for steam line breaks/leaks, and 1.0×10^{-3} per year ($0.68 \times 1.6 \times 10^{-3}$) for feedwater line breaks/leaks.

Length of MFW piping and main steam piping at Cook

Based on input provided by the licensee,[13] the length of MFW piping whose diameter exceeds 25 cm (10 in) was estimated to be ~396 m (1300 ft). This 396 m (1300 ft) included feedwater piping that starts at the MFW pumps and ends at the steam generators. However, since the pipe rupture at Surry occurred in condensate piping (suction side of the MFW pumps), the length of condensate piping that met the reliability attributes identified earlier was also added to the total piping length. Based on the UFSAR, this total was estimated to be ~366 m (1200 ft). [Note: In order to be consistent with the reliability attributes (e.g. process parameters such as pressure and temperature), condensate piping from feedwater heaters 1A, 1B, and 1C to the MFW pumps was included in this estimate]. Therefore, the estimated total length of feedwater and condensate piping considered was 762 m (2500 ft).

According to Ref. 13, the total length of large bore main steam piping is ~1463 m (4800 ft). However, whether the 1463 m (4800 ft) of piping carries high-quality main steam could not be ascertained. Therefore, information provided in the UFSAR[3] was used to estimate the length of large bore [>25-cm (10-in) diameter] main steam piping—approximately 610 m (2000 ft).

Frequency of HELB in the vicinity of the pipe chase (HELB-PC)

It was necessary to adjust the estimated frequency of the pipe breaks for the total plant to account for the limited amount of piping in the pipe chase and its vicinity whose rupture would be capable of causing the CCW Pump Room doors to fail open. As stated before, steam from a pipe break anywhere in the tunnel could potentially enter the pipe chase. However, due to the large potential escape paths, based on expert judgement provided in Ref. 5, it was assumed that only breaks which occurred in the piping in the vicinity of the doors to the CCW Pump Room would be capable of opening any one of the three doors. The length of piping adjacent to each of the doors is about 6.1–9.1 m (20–30 ft), which means a total of about 18–27 m (60–90 ft) is situated near the doors.[2] Therefore, the length of the pipes in the pipe chase was assumed to be 7.6 m (25 ft) for the single MFW line and 15 m (50 ft) for the main steam lines. Considering past operating experience, it was assumed that breaks could occur at welds and bends. Even though ruptures are less likely in straight pipe runs free of connections to smaller diameter pipes and welds, they could occur at locations downstream of straight runs and downstream of bends and welds. Therefore, in this analysis, the ratio of pipe lengths was used as an indicator to ratio the pipe break frequencies. The ratio for MFW was 0.01 (25/2500) and that for main steam piping was 0.025 (50/2000). Therefore, the estimated frequency of a MFW rupture in the vicinity of the CCW doors was 1.0×10^{-5} ($0.01 \times 1.0 \times 10^{-3}$). The estimated frequency of a main steam line break in this area was 5.3×10^{-6} ($0.025 \times 2.1 \times 10^{-4}$). The total HELB frequency in this area due to a MFW line break (HELB-PC) or a main steam line break was estimated to be 1.5×10^{-5}/year.

Probability of CCW pump failure when exposed to harsh environment (CCS-COOL)

As stated in Ref. 1, the CCW pump motors and associated equipment are not qualified for the high temperature/high humidity environment that could occur as a result of a postulated HELB. Operating experience was reviewed to investigate the response of pumps that were not qualified for high humidity to events that imposed those environmental conditions on such pumps. First, approximately 80 LERs that reported water spray, cascade, flood, or high humidity problems affecting pumps were identified using the NRC's Sequence Coding and Search System (SCSS) database. Of these, a sample of approximately 50% was screened, resulting in four LERs being identified for detailed review, since they contained information on pumps impacted by steam environments. The purpose of the review was to identify whether the pumps failed when subjected to a high humidity or temperature environment. If a failure did occur, the nature of the failure was examined to determine the recoverability. Some observations from this review are as follows. In two of the four events that were reviewed in detail (LER Nos. 302/91-003 and 251/90-008), pumps failed when exposed to a steam environment due to moisture intrusion of the motor winding. These did not appear to be recoverable. There was one event where the pumps continuously ran, even when water had collected in the lower motor bearings (LER No. 285/92-031). The fourth event (LER No. 272/90-033) appeared to be a recoverable pump failure. Therefore, during three of the four events, the pumps failed (two non-recoverable failures and one potentially recoverable failure). As a result of this review, it was concluded that there is a high likelihood that the CCW pumps would fail when exposed to a harsh environment (CCS-COOL). This failure probability was assumed to be 1.0 for the following reasons:

- An accurate count of failures and demands could not be used to estimate a failure probability due to biases in reporting failed versus successful operation of pumps exposed to moisture;
- As pump motors age, the likelihood that the motor will develop a crack in the winding insulation increases. The CCW pumps at Cook have been in operation for approximately 25 years.
- Periodic testing of CCW pumps would not reveal any pre-existing cracks in the motor windings.

Reference 5 provides additional bases to support this conclusion.

Potential impact on Unit 1 versus Unit 2 CCW pumps (NSS-CSS-RM)

It was determined that the steam that enters the CCW room during pipe rupture in the pipe chase would most likely fail the CCW pumps supporting Unit 2. However, this event would not be expected to fail the two CCW pumps that support Unit 1 or the spare CCW pump. Reference 5 provides the detailed basis for this conclusion. In summary, this is attributed to a three-hour fire barrier, buoyancy of steam, and the large open spaces connecting to the pipe chase.

As discussed previously, the Unit 2 CCW pumps are separated from the Unit 1 CCW pumps and the spare CCW pump by a three-hour fire barrier, which is ~2.1 m (7 ft) tall. The CCW Pump Room is ~4.3 m (14 ft) tall. The barrier extends from the CCW Pump Room wall to beyond the location of the pumps, ~9.1 m (30 ft) long. There will be more resistance to steam flow through the CCW Pump Room than out of the pipe chase (i.e., into the turbine building). Thus the pressure differential driving the steam flow would favor entering the turbine building instead of toward the CCW Pump Room. The velocity of the steam entering the CCW Pump Room would be low and the natural buoyant forces would cause the steam to rise to the ceiling of the room. Given the low horizontal velocity and considering the protection afforded by the fire wall surrounding the Unit 1 CCW pumps and the spare CCW pump, it was assumed that only the Unit 2 CCW pumps were likely to be exposed to a harsh steam environment (NSS-CSS-RM).

Recovery credit for the spare CCW pump

As discussed above, the spare CCW pump may remain functional in the aftermath of an HELB in the pipe chase. The spare CCW pump can be aligned to support either of the units. Therefore, whether the operators have the capability to align the spare pump in about 1.5 h [prior to reactor coolant pump (RCP) failure due to lack of seal or lubricating oil cooling[16] was investigated. Based on Ref. 14, it was concluded that the actions necessary to swap the pump from Unit 1 to Unit 2 are scheduled to take 8 h, and generally take about 16 h. In the event of an emergency, due to the high priority that would be assigned to this activity, the actions might be completed in 4–5 h. Therefore, it was concluded that no recovery credit could be given for the spare CCW pump to support Unit 2 prior to reactor coolant pump (RCP) seal failure.

Recovery credit for the CVCS cross-tie

If the Unit 2 CCW pumps were lost, seal injection from the charging pumps would be adversely affected. It would be possible to provide cooling to the Unit 2 reactor coolant pump (RCP) seals using a cross-tie from the Unit 1 chemical and volume control system (CVCS).

However, the CVCS cross-tie was not credited in this analysis due to the following uncertainties about its availability:

- *Guidance on re-initiation of seal injection.* The Westinghouse emergency response guidelines caution against re-initiation of seal injection if the RCP seals have heated up. Consistent with this guidance, the licensee's procedure[20] would not reinitiate seal injection if the RCP Seal 1 Outlet Temperature alarms were LIT. Given that the thermal barrier would be lost immediately after the break, and seal injection would be degraded, these alarms might light before the actual RCP seal failure. As a result, even if the CVCS cross-tie were established, the operators might opt to starve the Unit 2 RCP seals.

- *Procedural Guidance.* Reference 20 provides guidance on how to establish the CVCS cross-tie in the event of a loss of CCW. After an HELB, the time at which the procedure on loss of CCW would be entered is unknown. Whether this procedure can be implemented prior to RCP seal outlet temperature alarms activating is unknown. (According to Ref. 16, seal failure would start at about 1 h.)

Material condition of the CVCS cross-tie. Inspection Report 50-315/99-004 (Ref. 19) indicated that small particulate foreign material was found inside the cross-tie header. The exact amount of particulate was unknown and could be insufficient to fail the seal cooling. However, in combination with other factors mentioned above, the presence of particulate represents a new failure mode.

Impact of actuation of fire suppression systems due to steam in the CCW room

There have been operating events in the past in which fire suppression systems have actuated as a result of steam (e.g., LER 281/86-020, Surry feedwater line break event). Therefore, whether the Unit 1 CCW pumps might fail as a result of fire suppression spray actuation was investigated. Based on information provided by the licensee,[15] it was concluded that this was not a credible scenario. The CCW area has fire suppression sprays for the general area, as well as sprays dedicated to suppress fires in the CCW motors. If main steam entered the CCW area, it might actuate the sprays in the general area. However, the pumps are equipped with shields to allow them to continue to operate.

Consequences of CCW pump failure (CCS-PMP-REC)

If the CCW pumps failed due to the postulated steam environment, cooling to the RCP seals would be lost. Even though the RCP seals can also be cooled by seal injection, since the charging pumps require CCW for charging pump seal cooling, the seal injection function would also be lost. With no seal cooling, the Westinghouse type RCP seals would degrade rapidly. The D.C. Cook Nuclear Plant IPE[10] assumes that the RCP seals will fail with a probability of 1.0 if seal cooling is unavailable for 1-h. This assumption is conservative since all eight RCPs at Units 1 and 2 have newer high temperature seals. Based on the RCP seal failure models suggested by NUREG/CR-4550 (Ref. 16) for new high temperature seals, the seal failure probability (CCS-PMP-REC) when seal cooling is lost for an extended period is 0.19.

If an RCP seal LOCA were to occur, according to the modeling discussed in the Cook IPE, [10] and based on actual RCP seal LOCA events, high-pressure injection (high pressure, low volume) is needed to mitigate the accident. However, all four high-pressure injection (HPI) pumps at the D.C. Cook plant are cooled by CCW, so a loss of CCW could lead to a loss of HPI. According to the D.C. Cook UFSAR,[3] all HPI pumps at Cook are highly dependent on CCW. The seal and lube oil heat exchangers of the two safety injection pumps are cooled by CCW. In addition, the pump gear, lube oil, and seal exchangers of the centrifugal charging pumps are also cooled by CCW. Even if the HPI pumps could inject for a short duration to terminate the RCP seal LOCA and stabilize the reactor coolant system (RCS), the RCS must be cooled down and depressurized. With CCW unavailable, the operator would be expected to trip the RCPs. Therefore, forced circulation would be unavailable. With only natural circulation in the RCS, there is no basis to conclude that the RCS would be stabilized before the HPI pump seals would be damaged due to loss of cooling. Therefore, the probability of failure of all HPI pumps, given CCW unavailable, was assumed to be 1.0.

B.4.5 Analysis Results

Figure B.4.1 shows the accident sequence that leads to core damage. This sequence consists of the following:

- An HELB occurs in the high energy pipe chase in the vicinity of one of the three doors leading to the CCW Pump Room ($f = 1.5 \times 10^{-5}$/year).
- Access doors fail to prevent steam from entering CCW pump room (p = 0.0 for Unit 1, 1.0 for Unit 2).

- Failure of the running and standby CCW pumps and the spare CCW pump due to high humidity and high temperature environment (p = 1.0).
- Failure of RCP seals given failure to recover any CCW pump and restore seal cooling to the RCPs (p = 0.19).
- Failure to recover HPI pumps prior to core uncovery (p = 1.0).

Since failure of the CCW pumps would cause an RCP seal LOCA and would also fail the mitigating capability (i.e., the HPI pumps), a steam line break or a MFW line break in the vicinity of these doors could lead to core damage. Thus the conditional core damage frequency (CCDF - conditional frequency of subsequent core damage given the failures observed during an operational event) associated with this condition is 3.0×10^{-6}.

B.4.6 References

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19. U.S. Nuclear Regulatory Commission, Inspection Report No. 50-315/99004(DRP); 50-316/99004 (DRP), May 14, 1999.

20. American Electric Power Cook Plant Procedure O2-OHP 4022.015.004, "Loss of Component Cooling Water," Rev. 5, Change 2.

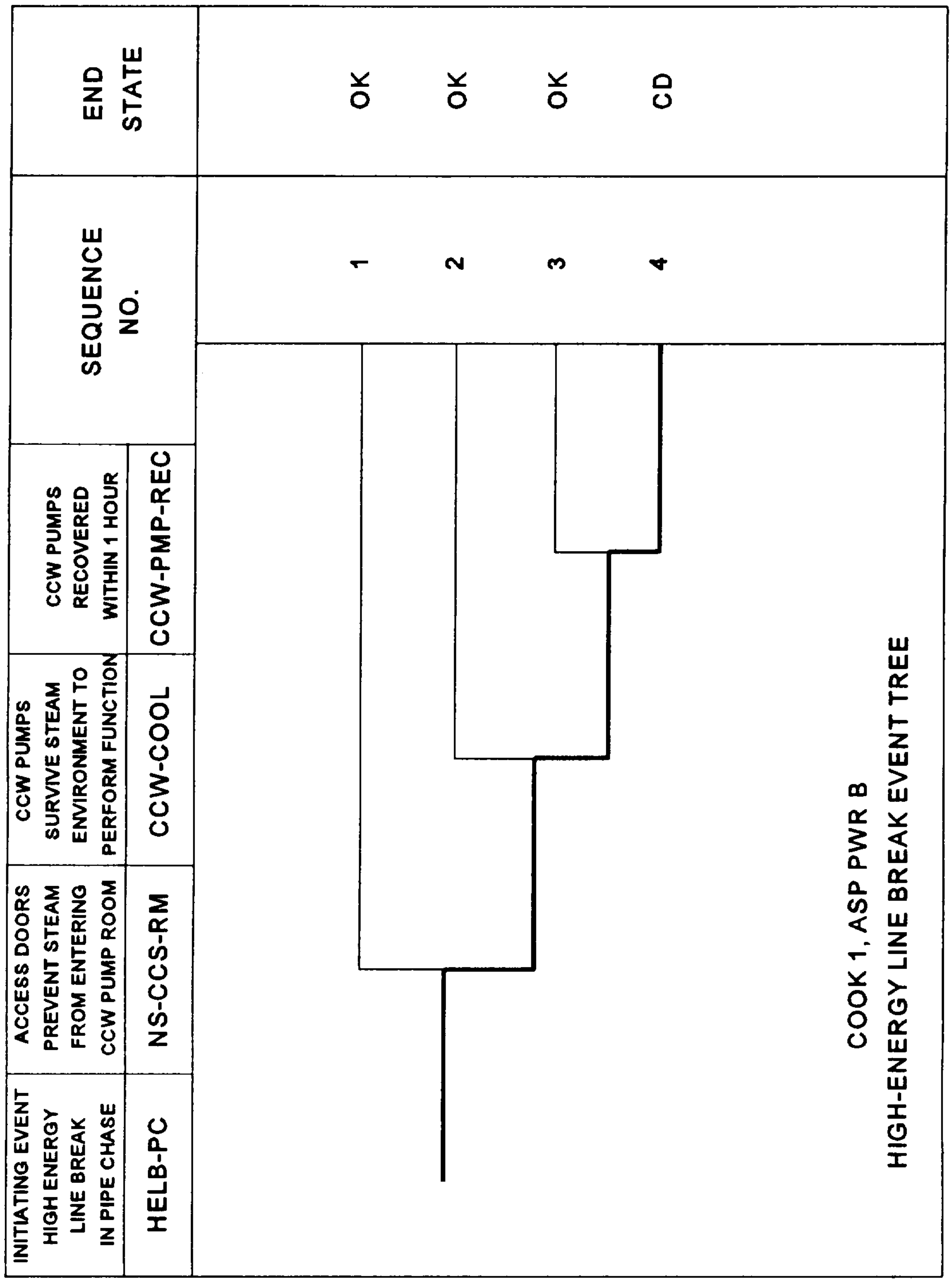

Fig. B.4.1 Dominant core damage sequence for LER No. 316/98-005. (CCW is component cooling water)