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Review of the Arkansas Nuclear One Generating Station Unit No. 1 Emergency Feedwater System Reliability Analysis

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ABSTRACT

The purposes of this report are: (1) to review the Emergency Feedwater System Upgrade Reliability Analysis for the Arkansas Nuclear One Nuclear Generating Station Unit No. 1, and (2) to estimate the probability that the Emergency Feedwater System will not perform its mission for each of three different initiators: (1) loss of main feedwater with offsite power available, (2) loss of offsite power, (3) loss of all 4160 VAC power. The scope, methodology, and failure data are prescribed by NUREG-0611, Appendix III.

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SUMMARY

The probability of failure of the Arkansas Nuclear One Nuclear Generating Station Unit No. 1 Emergency Feedwater System[1] on demand, under different loss of main feedwater conditions and different success criteria, has been evaluated using methodology and data put forth in NUREG-0611[2]. The results are as follows:

Initiator	Probability of Failure to: Avoid Dryout	Supply EFW within 20 minutes
1. Loss of Main Feedwater(LMFW)	$8x10^{-4}$	$6.3x10^{-4}$
2. Loss of Offsite Power(LOOP)	$1.6x10^{-3}$	$1.5x10^{-3}$
3. Loss of all AC(LOAC)	$2.8x10^{-2}$	$2.7x10^{-2}$

The column "Avoid Dryout" gives the probability per demand of failure to prevent dryout, given each of the three initiators. These results have been obtained under the assumption that there is no time for any recovery action; thus, the calculations do not include any credit for operator action to recover from malfunctions or maintenance errors. The column "Supply EFW within 20 minutes" gives the probability of failure to deliver emergency feedwater within 20 minutes, given each of the initiators. This mission success requirement is less restrictive as far as the available time for recovery is concerned and, therefore, credit has been given for operator actions.

1. INTRODUCTION

The purposes of this study are: 1) to review and evaluate a Reliability Analysis[1] of the Emergency Feedwater System (EFW) of the Arkansas Nuclear One Nuclear Generating Station Unit No. 1 (ANO-1) prepared by Babcock & Wilcox (B&W) for Arkansas Power & Light (AP&L) and submitted to the Nuclear Regulatory Commission (NRC); and 2) to perform an independent reliability analysis of the EFW system using methodology and data put forth in NUREG-0611[2].

After the accident at Three Mile Island, a study was performed of the Auxiliary Feedwater Systems (AFWS) of all then-operating plants. The results obtained for operating Westinghouse-designed plants were presented in NUREG-0611[2]. At that time, the objective was to compare Auxiliary Feedwater System (AFWS) designs; accordingly, generic failure probabilities were used in the analysis, rather than plant-specific data. Some of these generic data were presented in NUREG-0611. The probability that the AFWS would fail to perform its mission on demand was estimated for three initiating events: LMFW, LOOP, and LOAC.

Since then, each applicant for an operating license has been required[3] to submit a reliability analysis of the plant's AFWS, carried out in a manner similar to that employed in the NUREG-0611 study. In addition, some operating plants have also submitted reliability analyses of upgraded Auxiliary Feedwater Systems. Recently, a quantitative criterion for AFWS reliability has been defined by NRC[4] in the New Standard Review Plan (SRP).

> "...An acceptable AFWS should have an unreliability in the range of 10^{-4} to 10^{-5} per demand based on an analysis using methods and data presented in NUREG-0611 and NUREG-0635. Compensating factors such as other methods of accomplishing the safety functions of the AFWS or other reliable methods for cooling the reactor core during abnormal conditions may be considered to justify a larger unavailability of the AFWS."

The objective of the present study is, therefore, to analyze the reliability of the ANO-1 EFWS, using methodology and data presented in NUREG-0611, in order to facilitate and supplement the qualitative review of the system design.

The report is organized as follows: Section 2 presents the scope of the present study. Section 3 discusses the mission success criteria for the EFWS and highlights the important differences between the definition of EFWS success for B & W plants and Westinghouse plants. The latter were the subject of the analysis in NUREG-0611. Section 4 describes the basic configuration and characteristics of the EFWS. Section 5 discusses the qualitative aspects of the reliability of the system and presents the dominant contribution to the unavailability. Section 6 presents the quantitative analysis and compares the results and approaches used in the AP&L study with those of this study. Finally, Section 7 summarizes the results.

The original draft of the present report was based on Reference 1. After the original draft of the present report was completed, substantial design changes were made. These are summarized here in Appendix B, which contains AP&L responses to BNL questions. No new analysis was submitted to BNL for review. In keeping with the original objective of reviewing Ref.1, Sections 2 through 6 of this report continue to reflect the design of Ref.1; in Appendix A of this report, the effect of the changes on the analysis is presented, and in the Summary of this report (Section 7), results are presented for both the old and new designs.

2. SCOPE

The scope of the reliability analysis of the AFWS is defined in APPENDIX III of NUREG-0611[1].

In the present study, the probability that the EFWS will not perform its mission on demand is calculated for two mission definitions and three types of demands. The two mission success definitions were necessary because of the substantial differences between the B & W plants and the Westinghouse plants. The success criteria stipulated by NUREG-0611 were based on the Westinghouse design. For the B & W plants the following two success criteria are considered:

1) Avoid dryout of the steam generators; and

2) Supply the steam generators with EFW within 20 minutes of the demand.

The failure to supply water to make up for a loss of main feedwater is estimated for different conditions, namely,

1) Loss of Main Feedwater without Loss of Offsite Power (LMFW).

2) Loss of Main Feedwater associated with Loss of Offsite Power (LOOP).

3) Loss of Main Feedwater associated with Loss of Offsite and Onsite AC (LOAC).

Since one purpose of this analysis is to assess the important characteristics of the EFWS design configuration, detailed modeling of such support systems as electrical power (both AC and DC), service water, instrument air etc. was not performed. Such an undertaking is beyond the stated scope of the BNL reviews. The goal is a rudimentary understanding of the properties of the design of the EFWS. To this end, standardized data are used wherever they are available (emergency AC is schematically represented by the diesel generators) or assumed to be available (e.g., DC power is assumed available), although in some cases where such a system is seen to introduce a common cause mechanism, this is pointed out. Moreover, such phenomena as earthquakes, fires, and floods are excluded, along with high energy line breaks. The emphasis in NUREG-0611 is on independent hardware failures within the AFWS itself; dependent failures are analyzed if they arise from shared hardware. Depth and resolution of the studies are set by NUREG-0611.

The quantity calculated here is the unavailability of the EFW system due to fluid system failures, maintenance acts, human errors, and failure to initiate, with mission success defined below (Section 3). "Unavailability" means (as in NUREG-0611) "the probability per demand that the system will fail to perform its mission". The AP&L report deals with a number of additional failure modes, including steam generator overfill due to EFW control failures, spurious isolation of the steam generators, etc. These failures lie beyond the scope of NUREG-0611 and, therefore, are beyond the scope of this report.

3. SYSTEM MISSION

3.1 Mission and Success Criteria

In the AP&L reliability study(1), mission success is defined as attainment of adequate flow from at least one pump to at least one steam generator. In reference 11, minimum acceptable flow is given as 500 gpm at a SG pressure of 1050 psig, and the maximum acceptable time for achievement of this flow is given as 50 seconds from the time an initiation signal is given.

There are two time scales to consider. One is a 20-minute deadline for EFWS initiation, which refers to a point up to which EFWS initiation can prevent core damage. According to NUREG-0667(5), "For plants with reactors designed by B&W, analyses prepared by B&W concluded that a period of approximately 20 minutes is available after loss of all feedwater for the operator to either (1) restore feedwater (either auxiliary or main), or (2) start the HPI pumps and enter into a "feed-and-bleed" method of core cooling. This available time is consistent with independent staff analyses". [page 5-32 of Ref. 5]

On the other hand, it is acknowledged that "...B&W-designed 177-FA plants show some unique levels of sensitivity in their response and recovery from anticipated transients involving overcooling and undercooling events as well as small-break loss of coolant accidents. The recovery from such events has often led to undesirable challenges to engineered safety features (ESF) systems. This sensitivity stems mainly from the small heat sink resulting from the operation of the once-through steam generator (OTSG), which is an inherent design feature of the B&W reactor plants ... [page 2-1 of Ref. 5] ... B&W plants place a premium on the reliability with which the auxiliary feedwater starts are properly timed. The penalty for late starts is an increased likelihood of transient-induced LOCA". [p. 7-8]

Therefore, for each initiator (LMFW, LOOP, and LOAC), failure probabilities are calculated for each of two mission success criteria:

1) Failure to deliver flow from at least one pump to at least one steam generator, with no credit for operator action;
2) Failure to deliver flow from at least one pump to at least one steam generator within 20 minutes, allowing credit for some operator actions within this time.

The top event for NUREG-0611 purposes is steam generator dryout. It is considered that dryout occurs on a sufficiently short time scale that no credit for operator actions is warranted. Thus, for NUREG-0611 purposes, mission criterion (1) above is applied.

Loss of main feedwater is assumed by the utility to lead occasionally to momentary loss of SG level, i. e., the SG level becomes zero although EFW flow is entering from the top of each SG and being vaporized. This is discussed in the response to Comment 1.b in Enclosure 2 of a transmittal from D. C. Trimble

(AP&L) to R. W. Reid (NRC) dated March 12, 1981[6]. Since heat is being carried away, it is clearly inappropriate to consider this in the same category as a boil-dry resulting from no EFW flow. For purposes of this analysis, then, this has been considered a success state of the system, since this is its design basis.

The utility's report raises the question of whether excessive recirculation capacity can degrade the flow of one pump sufficiently that such an event should be considered system failure. In Ref. 6, it is stated that the EFW pumps are sized for a decay heat load corresponding to approximately 3 1/2% of full power. If degradation of the specified flow (500gpm) by the amount corresponding to excessive recirculation (78 gpm) can be interpreted as reducing the capacity to correspond to 3% of full power, which is the naive conclusion suggested by comparison of the flow rates, then the time elapsed after trip before decay heat drops below pump capacity is almost doubled, going from approximately 5 minutes to approximately 9 minutes. It is not immediately clear whether this leads to a PORV challenge, which (cf. p. III-10 of NUREG-0611) for purposes of this analysis is considered to imply the top event. Comments on this scenario are given in Section 5.2.1.

4. SYSTEM DESCRIPTION

Summarized below is pertinent information contained in Refs. (1), (6), and (7).

4.1 Pumps

There are two pumps, one steam turbine driven (STD) and one electric motor driven (EMD). Each is capable of providing the minimum required flow of 500 gpm at 1050 psig within 50 seconds (see Figure 1).

4.2 Support Systems

Apart from power, neither pump directly requires support systems. Both pumps and the turbine are lubricated by slinging oil from reservoirs near the bearings. Cooling is accomplished by the transfer of heat to the surroundings; the character of the surroundings is not spelled out in the report, so that it is not clear whether a hostile environment is likely to occur.

4.3 Suction

The two pumps take suction from the condensate storage tank through a common line in which there are a locked open manual valve (CS-19) and two check valves (CS-98 and CS-99), all in series. The tank is required by Technical Specifications to contain 107,000 gallons for EFWS use. The backup source is nuclear service water; each pump can be connected to one train of service water by manual action. Low suction pressure on the common header is alarmed; the operator then operates MOVs to switch suction for each pump. The valves that control suction of the STD pump are DC powered from battery-backed busses.

4.4 Discharge Paths

Each pump is connected to each steam generator by an independent path. The paths branch immediately beyond a check valve downstream of each pump. There is no pump isolation valve between the pump and the branch point, so that isolating the pump requires isolating both paths. Each path contains two MOVs and a check valve; one MOV provides flow control, while the other is associated with the logic that isolates a faulted steam generator. The valves that control flow from the STD pump are powered by DC from battery-backed busses. The valves that control flow from the EMD pump require AC.

4.5 Actuation and Control Logic

The EFWS is initiated by the "Initiate Logic" portion of the "Emergency Feedwater Initiation and Control" (EFIC) system when any of the following occurs: a) all 4 RC pumps are tripped, b) both main feedwater pumps trip, c) low level occurs in either SG, d) low pressure occurs in either SG, e) flux to feedwater trip is present.

There are two channels of initiate logic (A and B). At ANO-1, both channels are connected to both pumps. (The system diagram shows only channel

A connected to the EMD pump, but the fault tree shows both channels connected to both pumps. It is assumed here that the fault tree is correct.) Thus, failure of one channel of logic alone has no effect on the system; the other channel actuates both pumps. This contributes to system reliability in this analysis (the possibility of interaction degrading both channels is beyond the scope of this report). Failure of both channels fails automatic initiation of both pumps; this event is listed separately from contributors to Q1 and Q2 (Table 6.3).

4.6 Steam Supply to the STD Pump Turbine

Steam passes from both SG's through check valves and normally-open MOV's into a common line. Either of two normally-closed MOV's (CVY-1 and CVY-2) in parallel can open to admit steam to the turbine. These MOV's are each connected to one of the two channels of EFIC actuation logic. Steam then passes through a pressure reducing station consisting of two pressure reducing valves in parallel (CVY-3 and CVY-4). Downstream of this station, there are relief valves to protect the turbine in the event of failure of a pressure reducing valve in the open position.

The fault tree assumes that failure of a pressure reducing valve will not fail the system unless one of the relief valves subsequently sticks open. This is equivalent to assuming that the relief valves can open and close in a manner that operates the turbine successfully without either leading to an overspeed trip or a lack of steam. It appears that this is a highly non-conservative assumption. Here, failure of either pressure reducing valve is assumed to lead to failure of the STD pump. This is not given a very high probability, however, since the closest comparable component tabulated in NUREG-0611 is an air-operated valve (3×10^{-4}/D). Miscalibration of the pressure would be given a 10^{-3} probability by NUREG-0611, and it is probably appropriate to include in this figure the effects of diaphragm degradation.

The redundancy of the steam admission system leads to low probability of failure but a relatively high probability of maintenance, at least on the assumptions used here. There is also considerable scope for maintenance errors. Events have occurred at ANO-1 in which the STD pump failed for reasons apparently associated with the buildup of condensate in the steam line because of errors in isolating the condensate traps.

4.7 Recirculation and Test Lines

For each pump, there is a full flow test line which is normally closed and a minimum flow line which is normally open (15 gpm). In addition, there is a common recirculation path which is closed under conditions of high flow to the SG's and open under conditions of low flow to the SG's (78 gpm). This is discussed more fully under "Degraded Failure" (Sec. 5.2.1).

A total loss of pump recirculation flow could be caused by blockage of either FW14, FW15, or the three-way valve immediately upstream of these. If total loss of recirculation can fail both pumps, then these are single failure

points of the system. It is not clear that these will be conditions under which minimum flow requirements will not be satisfied by system demand; but from the given description of EFIC control logic, such an event is at least a strong possibility. Actual data on the time dependence of auxiliary feedwater demand are sparse; but the event at TMI-2, which is documented in some detail, is suggestive. EFW control valves did not open for some 35 seconds after trip, because this was the elapsed interval before the SG level setpoint was reached. The block valves, of course, remained closed for some extra time, which also would certainly contribute to a need for minimum flow protection. A delay on the order of minutes before EFW flow is demanded would appear to be credible, and minimum flow protection would appear to be necessary for such conditions. 10^{-4} has therefore been assessed for each of the three single-point recirculation-blockage events. This valve is probably conservative for the manual valve and the three-way valve, but not for the check valve.

Flow diversion through open test lines is considered to be a contributor to pump failure. Flow diversion through the spurious opening of the extra-capacity recirculation lines is considered in Section 5.2.1.

5. QUALITATIVE RELIABILITY ANALYSIS

There are two trains in the EFWS (see Figure 1). Each train consists of one pump and a pair of discharge paths, one to each steam generator. Mission success is defined as adequate flow from one pump to one steam generator within the appropriate time (see Section 3). Therefore, failure of the EFWS is:

$$\text{Failure of both trains} = (Q_1 + A_1B_2) * (Q_2 + A_2B_1)$$
$$= Q_1Q_2 + Q_1A_2B_1 + Q_2A_1B_2 + A_1A_2\ B_1B_2$$

where Q_1 = inadequate flow out of FW-10B (STD train)

Q_2 = inadequate flow out of FW-10A (EMD train)

A_1 = flow path from FW-10B to SGA blocked

A_2 = flow path from FW-10B to SGB blocked

B_1 = flow path from FW-10A to SGA blocked

B_2 = flow path from FW-10A to SGB blocked

The dominant system cut sets are contained in Q_1Q_2. Most of these events are double failures, products of large single contributors to Q_1 multiplying large single contributors to Q_2. These will be discussed in Section 6.

5.1 Single Point Failures

Event Q_1Q_2 contains single failures: blockage of the valves in the lines to and from the CST. These valves are implicitly tested every time either of the pumps is tested (bi-weekly). Nevertheless, 10^{-4} per demand is assessed for blockage. For some of these valves, this is arguably a conservatism; on the other hand, were these not single failure points, their blockage would not be an important issue.

The valves on the suction side that are considered single failure points are CS98, CS99, and CS19. On the recirculation side, FW14, FW15, and the upstream three-way valve have been quantified as single-failure points assuming that loss of recirculation can fail the system. See Section 4.7 for a fuller discussion of this.

5.2 Common Cause Failures

Event $A_1A_2B_1B_2$ contains at least one double event; both paths entering SGA converge at a single check valve, and similarly for SGB, so that a double check valve blockage fails the system. In the absence of common interaction, this is not a significant contributor. Apart from this, the seeming redundancy of the flowpaths suggests that they contribute only to higher-order cut sets (3 or more failures, e.g., $Q_1A_2B_1$). This is true

only if there are no commonalities. There are examples in the LER files of events which bear on this question. At Arkansas Nuclear One, a maintenance error disabled two flowpaths on one occasion (4/6/80), and on another occasion (5/22/79) the unexplained lifting of cable leads disabled two paths. Thus, system failures involving flow paths may not be wholly negligible, especially those involving coupled maintenance errors. However, these errors are unlikely to dominate the other failures assessed here.

In a broader review, it would be appropriate to inquire whether common cause failures (e.g., miscalibrations) in the control logic itself could cause the loss of multiple flow paths. This is considered to be beyond the scope of the present reviews.

The four control valves depend on electric power (DC or AC), and fail as is. Loss of DC is beyond the scope of this report. Loss of AC fails the EMD pump, so that its valve positions do not matter except insofar as these influence the "degraded failure" (Sec. 5.2.1).

5.2.1 Degraded Failures

A minimum flow line is always open from each pump, allowing 15 gpm to recirculate back to the condensate storage tank. When no flow is called for by the control system, an additional recirculation path opens up. This is controlled by valves CV2815 and CV2816, which are DC operated MOVs. These valves respond to the prevailing conditions on the four discharge paths: either the states of valves CVX-1, CVX-2, CVX-3, CVX-4, CV2620, CV2626, CV2627, and CV2670, if the system diagram is correct, or low flow in these lines as sensed by the flow elements upstream of CVX-1, CVX-2, CVX-3, and CVX-4, if the system description is correct (page D-3). The concern expressed in the report is that given loss of AC, CVX-2 and CVX-3 will not open; the system, thinking that the EMD pump needs more recirculation capacity, will open CV2815 and CV2816; this will degrade flow from the STD pump, which is the only pump operating given LOAC. There is some question whether this should be considered to lead to the top event (e.g., a PORV challenge). The report states that the matter should be investigated further.

Deciding whether this event implies the top event is beyond the scope of this report. However, comments are offered below on its probability, which is considered separately from the probability of the other (unambiguous) failures.

As indicated above, there is ambiguity concerning which physical parameter controls the operation of CV2815 and CV2816. Let us assume at first that flow is the controlling parameter. Then no flow through either discharge line of a given pump causes recirculation to open up. This means that, in the language introduced in section 5, the event leading to this degraded failure is Q1 + Q2 + A1A2 + B1B2 . Maintenance on P7B, for example, degrades the flow from P7A, and vice versa.

If valve positions are the controlling parameter, the conclusion changes somewhat. Failure of P7A does not automatically cause recirculation to open

up if P7A's discharge paths are open. However, maintenance on P7A will still presumably cause the problem, because the discharge paths are presumably isolated for maintenance.

If flow is the controlling parameter, then from Tables 6.1-6.2, one arrives at the conclusion that the probability of a degraded failure is 7×10^{-2} per LMFW. If valve positions are the controlling parameter, then the probability of a degraded failure is a factor of two to three less.

5.2.2 Common Cause Maintenance Errors

If it were necessary to isolate CV2802 for maintenance, P7B would probably be deprived of its normal suction source. In such an event, P7B would need to be aligned to service water. An error in performing this alignment would leave the entire system unavailable for the duration of the maintenance act. Depending on the details of the procedure, the probability of leaving P7B without suction for any of several reasons could well be of order 10^{-2}; if maintenance on CV2802 is 2×10^{-3}, then the contribution to system unavailability would be of order 2×10^{-5}. Such contributions would be regarded as significant; however, they have not been included here because the information available does not support their inclusion. Moreover, the figure being used for valve maintenance is probably conservative (see Table 6.1a).

Similar remarks apply to leaving the wrong pair of flow paths disabled for pump maintenance. Depending on the actual procedures and on the actual plant layout, such an event could contribute, but more information would be required to justify its assessment.

An event qualitatively resembling the above occurred at Connecticut Yankee on 6/16/81. While one pump was out for maintenance, an attempt was made to isolate it by closing a valve on the recirculation line of the other pump.

6. QUANTITATIVE RELIABILITY ANALYSIS

6.1 Limitations of the Reliability Analysis

The significance of the point estimates obtained in this review is best illuminated by the following quotation from NUREG-0611 (page III-19):

> "The data was applied to the various identified faults in the fault logic structure and a point value estimate was determined for the top fault event (i.e., AFW System unavailability). Such an approach is considered adequate to gain those engineering and reliability based insights sought for this AFW System reassessment. As noted, no attempt was made to introduce the somewhat time consuming, calculational elegance, associated with the process of error propagation into this assessment (e.g., Monte Carlo). Prior experience with such a calculational process has revealed a somewhat predictable outcome that, even with the very redundant systems, could be slightly higher than the point value solution (e.g., factor of approximately three times higher than the point value and usually less). Should there exist a clearly overwhelming fault in a systems design, then the process of error propagation would be expected to be merely one of higher elegance and it would yield no important change to the quantitative solution".

Clear cut dependencies or commonalities have been sought in the analysis, but parametric modeling of common cause failures (e.g., beta factor treatments) has been considered to be beyond the scope of this report.

6.2 Approach of the AP&L Study vs. Approach of the BNL Review

Data Base: The AP&L study does not give details of basic event probabilities. According to Paragraph 2.3 of the study, generic data were obtained and then made plant-specific to ANO-1 by incorporating ANO-1 experience. The approach taken in the present analysis is to use data provided in NUREG-0611 and WASH-1400[7] wherever these exist, and supplement them as necessary from IEEE sources (9).

Unavailability for Different Initiators: The FPC study does not present unavailability given LMFW, unavailability given LOOP, and unavailability given LOAC; it presents unavailability averaged over the initiators. In this review, unavailability is calculated for the three different initiators.

Level of Detail in the Fault Tree: The AP&L fault trees go into considerable detail in treating the actuation and control logic. NUREG-0611, on the other hand, simply assigns 7×10^{-3} as the failure probability of each channel. Although some qualitative information is provided about the details of the actuation and control logic, its relative newness and our lack of

information concerning its details prevent us from offering a meaningful independent estimate of its failure probability within the scope of this review. Accordingly, we adopt the 7×10^{-3} figure given in NUREG-0611.

Mission Success Criterion: The AP&L study provides conclusions for unavailability given no operator intervention for 20 minutes, and unavailability given credit for operator intervention. This is a useful distinction, which will be observed here (see Section 3).

Failure of normal suction: Failure of locked open manual valve CS-19 to remain open does not appear on the AP&L fault tree. Flow blockage of check valves CS-98 and CS-99 does appear on the AP&L fault tree. All three events are included here.

6.3 Assumptions

Valve Maintenance: NUREG-0611 indicates that valve maintenance should be assessed. In some studies, this has been done (notably the RSSMAP study(10) of Oconee). WASH-1400 indicates (Page III-40) that maintenance on valves should be assessed, but the only important contributor showing up in Table II 5-9 of WASH-1400 is maintenance on the steam admission valve. WASH-1400 acknowledges that maintenance is performed on the MOV's in the AFWS, but in that system the multiplicity of flow paths is such that these contributions to system unavailability are negligible. Here, the difficulty of isolating certain valves causes valve maintenance to contribute in spite of the seeming redundancy of flowpaths. Consider maintenance on CVX-1 (see Figure 1). In order to isolate this valve from the high-pressure discharge of P7A, it is necessary to disable P7A. From an unavailability point of view, then, maintenance on CVX-1 is logically equivalent to maintenance on P7A. A similar remark applies to CVX-4 for P7A, and CVX-3, CVX-2 for P7B. These contributions are tabulated in Q1M and Q2M (Table 6.1).

Maintenance on the MOVs controlling suction to each pump entails disabling one pump, and possibly realigning the other pump to service water. If these acts occur, they give rise to cut sets in which one train is out for maintenance and the other train is inadvertently disabled (e.g., incorrectly aligned to its alternate source). These somewhat hypothetical events are discussed separately in Section 5.2.2.

Fault Duration of Maintenance Errors: Since testing is performed monthly while maintenance is performed every 4.5 months, it can be asked whether a given maintenance error (e.g., leaving a valve unrestored after maintenance) should be assumed to persist over the entire period between maintenance acts. For example, if leaving a certain valve unrestored after maintenance may be assigned a probability of 5×10^{-3}, but this error is discovered at the next monthly test, then the average unavailability of the flow path due to this error is $5 \times 10^{-3}/4.5$. However, the argument becomes complicated if maintenance of other components is factored in: e.g., pump maintenance might occasion a given error in January, May, etc., while maintenance on an associated downstream valve might occasion the same error in February, June, etc. In other words, uncorrelated maintenance acts on different components tend to wash out the effect of recovery, by decreasing the period between op

portunities to commit the error. As more such opportunities are factored in, the unavailability due to the error approaches the value obtained with no credit for recovery at all. Here, the basic error rate is used with no credit for discovery by subsequent testing. A guaranteed operability test after every maintenance act would have a substantial impact in reducing some errors, but in this system, the benefits of testing are limited by the fact that the operating configuration is substantially different from that used for testing.

6.4 Dominant Failure Modes

Singles: For scenarios in which no operator intervention is considered, the failure of CS-19 to remain open (1×10^{-4}) is a dominant failure. This does not appear on the AP&L fault tree. The value of 10^{-4} is dictated by NUREG-0611. Some would consider this conservative; on the other hand, were this not a single failure point, it would not contribute much to the system unavailability. The point is that suction switchover is manual and relatively involved, and failure to diagnose loss of suction can quickly lead to damage of the pumps. Similar remarks apply to CS98 and CS99. An analogous situation is created by blockages of the recirculation path. These are discussed in Section 4.7.

In Table 6.3, single failures contribute 6×10^{-4}, which is 10^{-4} each for CS-19,CS-98, and CS-99, FW14, FW15, and the upstream three-way valve (see Section 4.7).

Doubles: The important doubles are contributions to Q1 multiplying contributions to Q2, where

Q1 = unavailability of the EMD train from CV2800 to FW-10A, inclusive,
and
Q2 = unavailability of the STD train from CV2802 to FW-10B, inclusive.

(There may be doubles arising from commonalities between pairs of flow paths which are isolable by a given logic channel.)

Contributions to Q1 and Q2 are given in Table 6.1.

6.5 Comments on Failure Probabilities Used in the BNL Review

The data used by AP&L were not made available to BNL. Evidently, they were plant-specific data. The data used here have been derived from NUREG-0611 wherever practicable.

Maintenance and Test Unavailability: NUREG-0611 effectively prescribes these numbers for pumps and valves. They have been assessed here wherever they can be assessed consistently with reasonable operating practice. An effort has been made to account for components whose states are altered by maintenance acts on other components (e.g., valve closures or disablings performed to isolate the component being maintained).

Human Error Probabilities: NUREG-0611 gives substantial credit for valve position indication in the control room, which ANO-1 has for many of the valves in the EFWS. Thus, the probability of leaving a suction valve in the wrong position after maintenance is 5×10^{-4} from Table III-2 of NUREG-0611.

There is no pump isolation valve downstream of the pumps. Thus, during maintenance, pumps must be isolated from the steam generators by closure of the flow control valves. The error of leaving a block valve closed in another plant corresponds here to leaving the flow control valves in the discharge paths closed and disabled.

Failure to restore operability of steam to the turbine after maintenance was also included here . An event apparently of this type occurred at Farley on 3/25/78. It would appear that this failure should be considered on a par with failure of suction valve restoration. Since the steam admission valves are normally closed anyhow, credit for their position indication is superfluous; the value adopted here is that corresponding to failure to restore a suction valve without position indication.

This is not a substitute for a detailed human error analysis; it is simply an attempt to be consistent with the scope and methodology of the rest of the analysis without ignoring previously untabulated failure modes. It is not clear that this is a conservatism; several failures of the turbine pump have occurred at Arkansas Nuclear One which, though not precisely of this type, involve degradation of the steam supply because of maintenance errors.

Recovery Factors: Where recovery of a failure is practicable within 20 minutes, substantial credit for such recovery effectively removes that failure from the list of contributors. Example: 5×10^{-4} for an unrestored discharge valve drops to the 10^{-6} to 10^{-5} range when 20-minute recovery is taken into account, which makes it relatively insignificant compared with other contributors to Q_{1H} and Q_{2H}, which are of order 10^{-2}. Substantial credit for recovery is appropriate on a 20-minute time scale. However, some events must be recovered much more quickly. For example, the pumps do not trip on loss of suction, and pump damage is expected within a few minutes if suction is lost. Restoration of suction at 19 minutes is therefore superfluous (the pumps are presumed damaged).

It should be borne in mind that the recovery factor being considered is not simply "failure to diagnose within 2 minutes and promptly correct a closed suction valve"; rather, it is this failure given that the other train of the EFWS has also failed, and that the initiating event might have been, for example, a loss of offsite power. In other words, there are many claims on the operator's attention. Swain and Guttmann (NUREG/CR-1278, page 17-24)[11] suggest that for the first 5 minutes into a transient, it should be assumed that the operator is alone in the control room. Finally, given all this, stress is understandably moderate to high, so that even if the operator gets around to this particular problem, his error rate is somewhat elevated.

Recovery of flow from the EFW turbine-driven pump after dryout is dubious, because it is not known whether there is enough steam in the system to

operate the turbine long enough to generate more steam [Cf. NUREG-0611, §III.4.3., bottom of p.III-10] There is an argument for disallowing recovery of the turbine-driven train, and this conservatism is adopted here.

Actuation Logic: NUREG-0611 prescribes $7x10^{-3}$ per channel for actuation logic failure probability. One should ask whether the assessment of $7x10^{-3}$ per channel is reasonable. In Westinghouse plants, this value tends not to dominate the system unavailability, because NUREG-0611 prescribes substantial credit for operator actuation within the "available" time. Here, for some purposes, we (and AP&L) are giving no credit for operator actions within the first few minutes, so that the conclusions are correspondingly sensitive to this parameter. For example, system failure by failure of both actuation channels without operator backup is $(7x10^{-3})^2 = 4.9x10^{-5}$, which virtually exhausts the unavailability contemplated by the new SRP for auxiliary feedwater systems. B&W plants arguably need, and may have, actuation systems which are more reliable than this. But AP&L has not explicitly documented this by providing failure data, and in any case, this level of detail is beyond the scope of this analysis.

While a more complete analysis might substantiate a lower actuation failure probability, this would be partially offset by the inclusion of failures of automatic control, which have not been addressed here.

Evidently, it is possible to place one channel of the Emergency Feedwater Initiation and Control Logic (EFIC) in "maintenance bypass". Since failure of a single logic channel has no effect, this has been neglected here; its probability is dominated by the failure probability prescribed by NUREG-0611. There are other bypasses associated with startup, which automatically remove themselves, and still others associated with shut down. These latter bypasses do not enter this analysis.

Steam Supply to STD Pump: Although not mentioned in NUREG-0611, the probability of blowing down both steam generators through stuck-open relief valves has been included here. The value adopted was used by Florida Power in their analysis of the CR-3 EFWS (12). This is a small contributor to the unavailability of this train; it is included for reasons of completeness and consistency with other analyses.

7. SUMMARY AND CONCLUSIONS

Since work on the main body of this report was completed, design changes have been made by AP&L. The main body of the report (Sections 2 through 6) continues to reflect properties of the old design. The new design is discussed in Appendix A, which provides details of the impacts of the changes on the system unavailability. Table 7.1 provides a comparison of results calculated here for both the old and new designs, and AP&L results for the old design, which are obtained from Appendix B. It should be noted that the figure supplied in the AP&L submittal states that "comparison with NUREG-0611 results is inappropriate." AP&L results for the new design are not available.

Major contributors to the BNL results include the following:

1. Single valves in the common lines to and from the CST.

2. Maintenance on valves, calculated using NUREG-0611 assumptions. This is a major contributor because isolating the valve under maintenance loses more than the flowpath actually being maintained.

3. Actuation logic failure, calculated according to NUREG-0611 assumptions. This is a large contributor because NUREG-0611 mandates 7×10^{-3} per train, and it is assumed here that operator corrective action cannot recover this in time to prevent dryout. At least some of the time, corrective action takes place outside the control room, and some time is necessary for diagnosis.

4. Maintenance errors. These have been assessed by analogy with failure of valve restoration, which is quantified in NUREG-0611.

REFERENCES

1. "Emergency Feedwater System Upgrade Reliability Analysis for the Arkansas Nuclear One Nuclear Generating Station Unit No. 1", prepared by B&W Plant Performance Engineering, submitted to NRC by AP&L in October 1981; herein called "The AP&L report."

2. "Generic Evaluation of Feedwater Transient and Small Break Loss-of-Coolant Accidents in Westinghouse-Designed Operating Plants", NUREG-0611, U. S. Nuclear Regulatory Commission (January 1980).

3. Letter from D. F. Ross, Jr. (NRC) to "All Pending Operating License Applicants of Nuclear Steam Supply Systems Designed by Westinghouse and Combution Engineering", dated March 10, 1980.

4. USNRC Standard Review Plan, Sec. 10.4.9 (NUREG-0800), Revised July 1981.

5. "Transient Response of Babcock & Wilcox-Designed Reactors", NUREG-0667, U. S. Nuclear Regulatory Commission (May 1980).

6. "Request For Information, Arkansas Nuclear One, Unit 1, Auxiliary Feedwater System (AFWS) Requirements, Docket No. 50-313", submitted to NRC by letter from D. C. Trimble to R. W. Reid dated March 12, 1981.

7. "ANO-1 Emergency Feedwater Upgrade Preliminary Design", submitted to NRC by letter from D.C. Trimble to R. W. Reid (NRC) dated October 15, 1980.

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9. "IEEE Nuclear Reliability Data Manual", IEEE STD 500 (1977).

10. "Reactor Safety Study Methodology Applications Program: Oconee #3 PWR Power Plant", NUREG/CR-1659, U. S. Nuclear Regulatory Commission (January 1981), (Rev. May 1981).

11. "Handbook of Human Reliability Analysis With Emphasis on Nuclear Power Plant Applications", NUREG/CR-1278, U. S. Nuclear Regulatory Commission (October 1980).

12. See "Review of the Crystal River Nuclear Generating Station Unit No. 3 Emergency Feedwater System Reliability Analysis", NUREG/CR...., U.S. Nuclear Regulatory Commission.

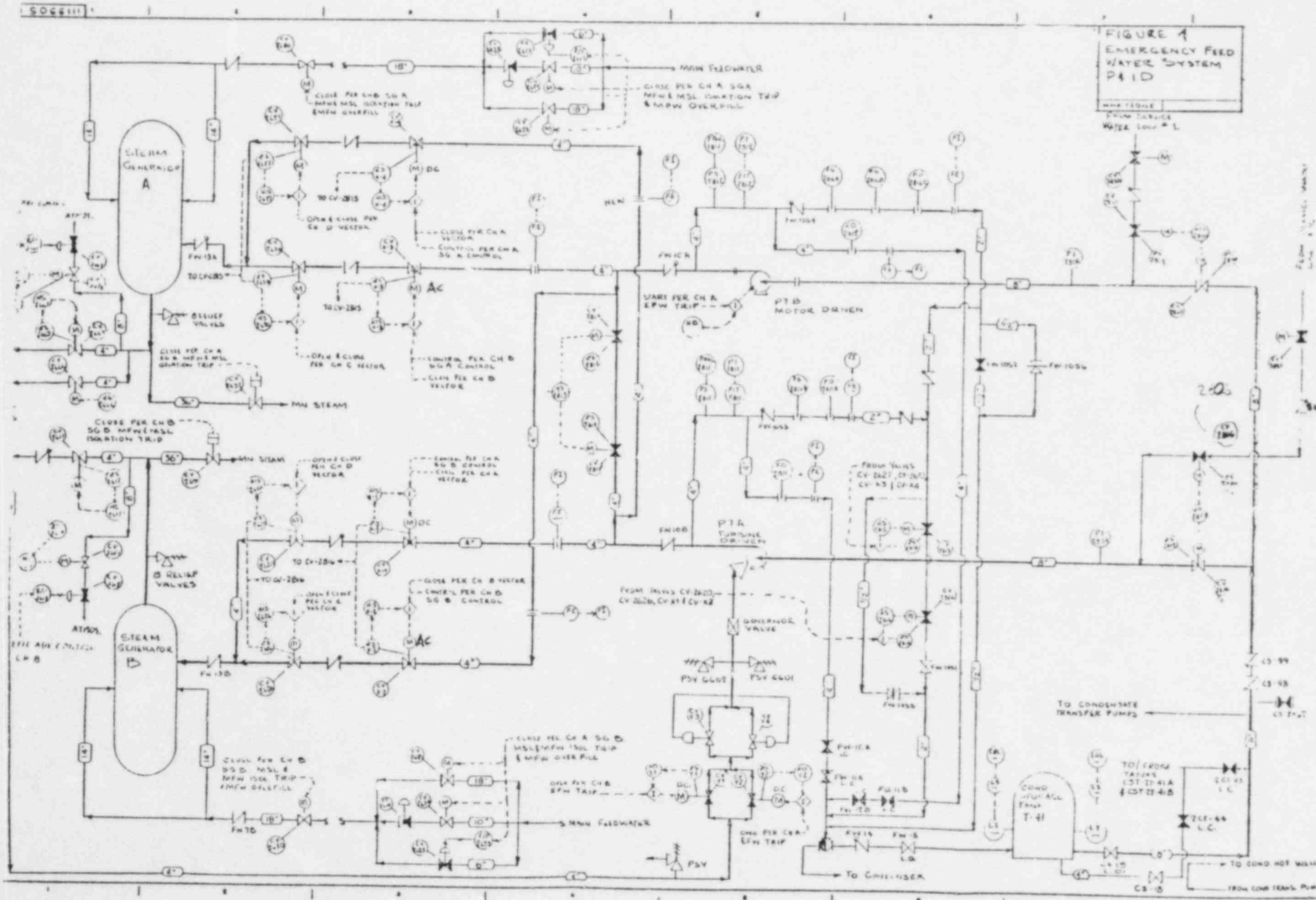
FIGURE 1
EMERGENCY FEED WATER SYSTEM P&ID
STEAM GENERATOR A
STEAM GENERATOR B
MAIN FEEDWATER
MN STEAM
P7B MOTOR DRIVEN
P7A TURBINE DRIVEN
GOVERNOR VALVE
PSV 6607
PSV 6601
PSV
B RELIEF VALVES
A RELIEF VALVES
COND STORAGE TANK T-41
TO CONDENSATE TRANSFER PUMPS
TO CONDENSER
TO COND HOT WELL
ATMOS.
DC
AC

Table 6.1a

Contributors to Q_{1H} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Description of Event
$1x10^{-3}$	Failure of P7A to start
$2.4x10^{-4}$	Failure of P7A to run
$5.1x10^{-5}$	Failure of Steam Admission: either CVY-1 and CVY-2 Fail to open $((3x10^{-3})^2)$, or failure of one channel of actuation logic coupled with failure of one valve to operate $(2x7x10^{-3} \times 3x10^{-3})$
$1.6x10^{-3}$	Either of the two pressure reducing valves (CVY-3 and CVY-4) failing high ($3x10^{-4}$ each), or miscalibration of their settings (10^{-3})
$5x10^{-3}$	CVY-1 and CVY-2 left disabled after pump maintenance (these are normally closed, so position indication is superfluous)
$5x10^{-4}$	CV2667, CV2666, CV2617 left closed after maintenance (control room indication)
$1x10^{-4}$	FW-10B Flow Blockage
$1x10^{-4}$	CV2802 Flow Blockage
$4.4x10^{-5}$	CV2802 Spurious Closure: $\lambda=1.24x10^{-7}$/hr, 1/2 T = 1/2 month (Ref. 8)
$5x10^{-4}$	CV2802 left closed
$5x10^{-3}$	Test line inadvertently left open
$5x10^{-4}$	CVX-1 and CVX-4 left closed and disabled after maintenance
$3.4x10^{-4}$	Relief valve failure on both steam generators (Loss of steam to turbine)

$\sum = 1.5x10^{-2} = Q_{1H}$(LMFW), NO OPERATOR CREDIT

$\sum = 1.5x10^{-2} = Q_{1H}$(LMFW), Failure to initiate within 20 min.
OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

Table 6.1a (cont.)

ADDITIONAL CONTRIBUTORS TO Q_{1H}

GIVEN LOOP:

None.

$\sum = 1.5x10^{-2} = Q_{1H}(LOOP)$, NO OPERATOR CREDIT

$\sum = 1.5x10^{-2} = Q_{1H}(LOOP)$, Failure to initiate within 20 min.
OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

ADDITIONAL CONTIRBUTORS TO Q_{1H}

GIVEN LOAC:

None.

$\sum = 1.5x10^{-2} = Q_{1H}(LOAC)$, NO OPERATOR CREDIT

$\sum = 1.5x10^{-2} = Q_{1H}(LOAC)$, Failure to initiate within 20 min.
OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

Table 6.1a (cont.)

Contributors to Q_{1M} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Description of Event
2.1×10^{-3}	Pump maintenance (24-hour outage allowed)
2×10^{-3}	Pump testing
2.1×10^{-3}	CVY-1 maintenance
2.1×10^{-3}	CVY-2 maintenance
2.1×10^{-3}	CVY-3 maintenance
2.1×10^{-3}	CVY-4 maintenance
2.1×10^{-3}	CVX-1 maintenance
2.1×10^{-3}	CVX-4 maintenance
2.1×10^{-3}	CV2802 maintenance
2.1×10^{-3}	CV2806 maintenance

$\sum = 2.1\times10^{-2}$ Q_{1M}(LMFW), NO OPERATOR CREDIT

$\sum = 2.1\times10^{-2}$ Q_{1M}(LMFW), Failure to initiate within 20 min. OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

ADDITIONAL CONTRIBUTORS TO Q_{1M} GIVEN LOOP:
None

$\sum = 2.1\times10^{-2}$ Q_{1M}(LOOP), NO OPERATOR CREDIT

$\sum = 2.1\times10^{-2}$ Q_{1M}(LOOP), Failure to initiate within 20 min. OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

ADDITIONAL CONTRIBUTORS TO Q_{1M} GIVEN LOAC:
None

$\sum = 2.1\times10^{-2}$ Q_{1M}(LOAC), NO OPERATOR CREDIT

$\sum = 2.1\times10^{-2}$ Q_{1M}(LOAC), Failure to initiate within 20 min. OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

Table 6.1b

Contributors to Q_{2H} (LMFW)

Note: $\epsilon \ll 10^{-4}$

Value	Description of Event
5×10^{-3}	Failure of P7B: 1×10^{-3} pump, 4×10^{-3} control circuit
2.4×10^{-4}	Failure of P7B to run: 3×10^{-5}/hr. x 8 hrs.
5×10^{-3}	Control circuit left disabled after maintenance
or	or
ϵ	Control circuit left disabled after maintenance and failure to recover
1×10^{-4}	FW10A Flow Blockage
1×10^{-4}	CV2800 Flow Blockage
5×10^{-4}	CV2800 Left closed
4.4×10^{-5}	CV2800 Spurious Closure: $\lambda = 1.2 \times 10^{-7}$/hr, 1/2 T=1/2 month (Ref. 8)
5×10^{-3}	Test line inadvertently left open
or	or
ϵ	Test line inadvertently left open and operator fails to recover
5×10^{-4}	CVX-2 and CVX-3 left closed and disabled after maintenance
or	or
ϵ	CVX-2 and CVX-3 left closed and disabled and failure to recover in 20 min.

$\sum = 1.6 \times 10^{-2}$ Q_{2H}(LMFW), NO OPERATOR CREDIT

$\sum = 5.9 \times 10^{-3}$ Q_{2H}(LMFW), Failure to initiate within 20 min.

Table 6.1b (cont.)

Additional Contributors to Q_{2H} given LOOP

3.6×10^{-2}	Diesel Generator Unavailability
$\sum = 5.2\times10^{-2}$	Q_{2H}(LOOP), No Operator Credit
$\sum = 4.2\times10^{-2}$	Q_{2H}(LOOP), Failure to initiate within 20 min.

THE EMD TRAIN IS UNAVAILABLE GIVEN LOAC

$\sum = 1.0$	Q_{2H}(LOAC), with or without operator credit

Table 6.1b (cont.)

Contributors to Q_{2M} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Description of Event
$2.1x10^{-3}$	Pump maintenance (24-hour outage allowed)
$2x10^{-3}$	Pump testing
or	or
ϵ	Pump testing and operator fails to realign
$2.1x10^{-3}$	CV2800 maintenance
$2.1x10^{-3}$	CV2803 maintenance
$2.1x10^{-3}$	CV-X2 maintenance
$2.1x10^{-3}$	CV-X3 maintenance

$\sum = 1.3x10^{-2}$ Q_{2M}(LMFW), no operator credit

$\sum = 1.1x10^{-2}$ Q_{2M}(LMFW), Failure to initiate in 20 min.

ADDITIONAL CONTRIBUTORS TO Q_{2M}

GIVEN LOOP:

None (Diesel maintenance included in Q_{2H})

$\sum = 1.3x10^{-2}$ Q_{2M}(LOOP), no operator credit

$\sum = 1.1x10^{-2}$ Q_{2M}(LOOP), Failure to initiate in 20 min.

ADDITIONAL CONTRIBUTORS TO Q_{2M}

GIVEN LOAC:

THIS TRAIN IS UNAVAILABLE GIVEN LOAC

$Q_{2M}(LOAC) = 0.$

TABLE 6.2

RESULTS FOR Q_1 AND Q_2

	Q_{1H}	Q_{1M}	Q_{2H}	Q_{2M}
LMFW, operator credit	1.5×10^{-2}	2.1×10^{-2}	5.9×10^{-3}	1.1×10^{-2}
LMFW, no operator credit	1.5×10^{-2}	2.1×10^{-2}	1.6×10^{-2}	1.3×10^{-2}
LOOP, operator credit	1.5×10^{-2}	2.1×10^{-2}	4.2×10^{-2}	1.1×10^{-2}
LOOP, no operator credit	1.5×10^{-2}	2.1×10^{-2}	5.2×10^{-2}	1.3×10^{-2}
LOAC, operator credit	1.5×10^{-2}	2.1×10^{-2}	1	0
LOAC, no operator credit	1.5×10^{-2}	2.1×10^{-2}	1	0

Table 6.3

Single Point & Common Failures

Note: $\epsilon << 10^{-4}$

Value	Description of Event
$1x10^{-4}$	Failure of CS-98 to remain open
$1x10^{-4}$	Failure of CS-99 to remain open
$1x10^{-4}$	Failure of CS-19 to remain open
$1x10^{-4}$	Failure of FW14 to remain open
$1x10^{-4}$	Failure of FW15 to remain open
$1x10^{-4}$	Failure of three-way valve to remain open
$4.9x10^{-5}$ or ϵ	Failure of both chanels of initiate logic $(7x10^{-3})^2$ or Failure of both logic channels and failure to initiate manually
$\sum = 6.5x10^{-4}$	Other, no operator credit
$\sum = 6x10^{-4}$	Other, failure to initiate in 20 minutes

Table 7.1

EFWS Unavailability

Values given here are calculated from
$Q = Q_{1H} Q_{2H} + Q_{1H} Q_{2M} + Q_{1M} Q_{2H} + \text{Other}$,
where

Q_1H = Hardware failures associated with P7A
Q_2H = Hardware failures associated with P7B
Q_1M = Maintenance unavailability associated with P7A
Q_2M = Maintenance unavailability associated with P7B

For the old design, contributions to Q_1H, Q_2H, Q_1M, and Q_2M are given in Table 6.2 and summarized in Table 6.3. Contributions to "other" are given in Table 6.3.

Changes to the tables resulting from the design changes are detailed in Appendix A, where new tables are provided.

In the summary at the beginning of the present report, the results quoted are "New Design, This Work."

	Old Design, This Work	Old Design, AP&L Report	New Design, This Work
LMFW, Operator Credit	9.8×10^{-4}	1.4×10^{-5}	6.3×10^{-4}
LMFW, No Operator Credit(Dryout)	1.4×10^{-3}	3.6×10^{-4}	8×10^{-4}
LOOP, Operator Credit	2.3×10^{-3}	9.1×10^{-5}	1.5×10^{-3}
LOOP, No Operator Credit(Dryout)	2.7×10^{-3}	5.2×10^{-4}	1.6×10^{-3}
LOAC, Operator Credit	3.6×10^{-2}	5.7×10^{-3}	2.7×10^{-2}
LOAC, No Operator Credit(Dryout)	3.6×10^{-2}	1.4×10^{-2}	2.8×10^{-2}

APPENDIX A: IMPACT OF DESIGN CHANGES ON SYSTEM AVAILABILITY

After work on the main body of this report was completed, new information was received from AP&L by way of NRC, which is enclosed here as Appendix B. This is in the form of responses to written questions. Since those questions were raised, significant design changes have been made, which are covered in the AP&L responses. This appendix summarizes important changes and describes their impact on system availability. AP&L has not provided a revised estimate of system unavailability reflecting the impact of the changes.

A.1 Revisions in Suction

Formerly, the line from the CST had one manual valve (CS19) and two check valves (CS98 and CS99) in series, any one of which could block flow to both pumps. Now, there are redundant check valves in paralled with CS98 and CS99; these markedly reduce the probability of blockage due to check valves. However, manual valve CS19 can still block flow to both pumps. NUREG-0611 prescribes 10^{-4} for this; considered as a hardware failure, this is a conservatism (by comparison with LER rates), but on the other hand, the scope for inadvertent manipulation is unknown (see Table A.3 for effect of these changes).

A.2 Revisions in Steam Supply to Turbine Driven Pump

Previously, the STD pump required a pressure reducing station, and was equipped with overpressure relief valves (upstream of the governor valve) which could fail open. In the new design, there are no valves between the steam admission valves and the governor valve, so there are fewer things which can fail (see Table A.1a for the effect of these changes).

A.3 Changes in Pump Recirculation Control

Previously, there was a minimum flow path common to both pumps whose capacity was varied by control signals which depended on pump flow. This arrangement left the system vulnerable to certain common cause failures, which were discussed in the AP&L report and are reviewed in the main body of the present report. In the new design, minimum flow is controlled independently for each pump, so that common cause flow diversion has been eliminated as a failure mode. The recirculation path back to the CST still contains a check valve and a manual valve in series; if total loss of recirculation can still fail the system (e.g., in periods of low flow demand), then these are still single failure points.

Minimum flow control is accomplished by a mechanical device which opens up the main flowpath or the minimum flowpath depending on flow demand. At one point, this is called "interlocking check valves" in the AP&L response. There are also devices called "recirculation valves," which may be the same thing. It is not clear what failure probability to assign to this arrangement (e.g., for the probability of its sticking in position to block flow to the SGs).

The result of the calculation is sensitive to this only if it is much worse (say, ten times) than a check valve failure probability. Here, a check valve failure probability is used, in the expectation that this device is unlikely to fail more often than the pumps unless there is something fundamentally wrong with its design. Design problems with new devices are not within the scope of this report.

The modification reduces unavailability due to pump testing. When a test is performed, a downstream MOV is commanded closed by the operator. In this configuration, with the pump running, the recirculation valve automatically provides minimum flow. In the event of a system demand during a pump test, the logic automatically opens the downstream MOV, and the recirculation valve will automatically direct flow to the SGs. No operator action is necessary.

Previously, the pumps were tested at high flow rates, sufficient to constitute flow diversion. The new testing flowrate is not known. (The present analysis is insensitive to this, in any case.) Leaving test lines open is no longer a contributor.

Tables A.1a and A.1b show the effects of these changes in several places. The common cause flow diversion was not originally reflected in these tables.

Table A.1a

Changes to Table 6.1a in New Design

Contributors to Q_{1H} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Deleted by Design Change	Description of Event
$1x10^{-3}$		Failure of P7A to start
$2.4x10^{-4}$		Failure of P7A to run
$5.1x10^{-5}$		Failure of Steam Admission: either CVY-1 and CVY-2 Fail to open ($(3x10^{-3})^2$), or failure of one channel of actuation logic coupled with failure of one valve to operate ($2x7x10^{-3}$ x $3x10^{-3}$)
$1.6x10^{-3}$	***	Either of the two pressure reducing valves (CVY-3 and CVY-4) failing high ($3x10^{-4}$ each), or miscalibration of their settings (10^{-3})
$5x10^{-3}$		CVY-1 and CVY-2 left disabled after pump maintenance (these are normally closed, so position indication is superfluous)
$5x10^{-4}$		CV2667, CV2666, CV2617 left closed after maintenance (control room indication)
$1x10^{-4}$		FW-10B Flow Blockage (now a recirculation valve)
$1x10^{-4}$		CV2802 Flow Blockage
$4.4x10^{-5}$		CV2802 Spurious Closure: $\lambda=1.24x10^{-7}$/hr, 1/2 T = 1/2 month (Ref. 8)
$5x10^{-4}$		CV2802 left closed
$5x10^{-3}$	***	Test line inadvertently left open
$5x10^{-4}$		CVX-1 and CVX-4 left closed and disabled after maintenance
$3.4x10^{-4}$		Relief valve failure on both steam generators (Loss of steam to turbine)

$\sum = 1.5x10^{-2}$ = Q_{1H}(LMFW), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum = 1.5x10^{-2}$ = Q_{1H}(LMFW), Failure to initiate within 20 min., BEFORE DESIGN CHANGE. OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

$\sum = 8.4x10^{-3}$ = Q_{1H}(LMFW), CREDIT FOR DESIGN CHANGES

(Asterisks denote failure modes removed by design change.)

Table A.1a (cont.)

ADDITIONAL CONTRIBUTORS TO Q_{1H}

GIVEN LOOP:

None.

$\sum =$ 1.5×10^{-2} = Q_{1H}(LOOP), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum =$ 1.5×10^{-2} = Q_{1H}(LOOP), Failure to initiate within 20 min., BEFORE DESIGN CHANGE. OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

$\sum =$ 8.4×10^{-3} = Q_{1H}(LOOP), CREDIT FOR DESIGN CHANGE

ADDITIONAL CONTIRBUTORS TO Q_{1H}

GIVEN LOAC:

None.

$\sum =$ 1.5×10^{-2} = Q_{1H}(LOAC), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum =$ 1.5×10^{-2} = Q_{1H}(LOAC), Failure to initiate within 20 min., BEFORE DESIGN CHANGE. OPERATOR CREDIT NOT GIVEN PAST DRYOUT FOR RECOVERY OF STD Train

$\sum =$ 8.4×10^{-3} = Q_{1H} (LOAC), CREDIT FOR DESIGN CHANGE

Table A.1a (cont.)

Contributors to Q_{1M} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Deleted by Design Change	Description of Event
2.1×10^{-3}		Pump maintenance (24-hour outage allowed)
2×10^{-3}	***	Pump testing
2.1×10^{-3}		CVY-1 maintenance
2.1×10^{-3}		CVY-2 maintenance
2.1×10^{-3}	***	CVY-3 maintenance
2.1×10^{-3}	***	CVY-4 maintenance
2.1×10^{-3}		CVX-1 maintenance
2.1×10^{-3}		CVX-4 maintenance
2.1×10^{-3}		CV2802 maintenance
2.1×10^{-3}		CV2806 maintenance

$\sum = 2.1\times10^{-2}$ Q_{1M}(LMFW), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum = 2.1\times10^{-2}$ Q_{1M}(LMFW), Failure to initiate within 20 min., BEFORE DESIGN CHANGE. OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

$\sum = 1.5\times10^{-2} = Q_{1M}$(LMFW), CRDEIT FOR DESIGN CHANGE

(Asterisks denote failure modes removed by design change.)

Table A.1a (cont.)

Contributors to Q_{1M}

ADDITIONAL CONTRIBUTORS TO Q_{1M} GIVEN LOOP:

None

$\sum = 2.1x10^{-2}$ Q_{1M}(LOOP), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum = 2.1x10^{-2}$ Q_{1M}(LOOP), Failure to initiate within 20 min., BEFORE DESIGN CHANGE OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

$\sum = 1.5x10^{-2} = Q_{1M}$(LOOP), CREDIT FOR DESIGN

ADDITIONAL CONTRIBUTORS TO Q_{1M} GIVEN LOAC:

None

$\sum = 2.1x10^{-2}$ Q_{1M}(LOAC), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum = 2.1x10^{-2}$ Q_{1M}(LOAC), Failure to initiate within 20 min., BEFORE DESIGN CHANGE OPERATOR CREDIT NOT GIVEN FOR RECOVERY OF STD TRAIN AFTER DRYOUT

$\sum = 1.5x10^{-2} = Q_{1M}$ (LOAC), CREDIT FOR DESIGN CHANGE

Table A.1b

Changes to Table 6.1b in New Design

Contributors to Q_{2H} (LMFW)

Note: $\epsilon \ll 10^{-4}$

Value	Deleted by Design Change	Description of Event
5×10^{-3}		Failure of P7B: 1×10^{-3} pump, 4×10^{-3} control circuit
2.4×10^{-4}		Failure of P7B to run: 3×10^{-5}/hr. x 8 hrs.
5×10^{-3} or ϵ		Control circuit left disabled after maintenance or Control circuit left disabled after maintenance and failure to recover
1×10^{-4}		FW10A Flow Blockage (Now a recirculation valve)
1×10^{-4}		CV2800 Flow Blockage
5×10^{-4}		CV2800 Left closed
4.4×10^{-5}		CV2800 Spurious Closure: $\lambda=1.2\times10^{-7}$/hr, 1/2 T=1/2 month (Ref. 8)
5×10^{-3} or ϵ	***	Test line inadvertently left open or Test line inadvertently left open and operator fails to recover
5×10^{-4} or ϵ		CVX-2 and CVX-3 left closed and disabled after maintenance or CVX-2 and CVX-3 left closed and disabled and failure to recover in 20 min.

$\sum = 1.6\times10^{-2}$ Q_{2H}(LMFW), NO OPERATOR CREDIT, BEFORE DESIGN CHANGE

$\sum = 5.9\times10^{-3}$ Q_{2H}(LMFW), Failure to initiate within 20 min., BEFORE DESIGN CHANGE

$\sum = 1.2\times10^{-2} = Q_{2H}$(LMFW), NO OPERATOR CREDIT, CREDIT FOR DESIGN CHANGE

$\sum = 5.9\times10^{-3} = Q_{2H}$(LMFW), Failure to initiate within 20 min., CREDIT FOR DESIGN CHANGE

(Asterisks denote failure modes deleted by design change.)

Table A.1b (cont.)

Additional Contributors to Q_{2H} given LOOP

3.6×10^{-2}	Diesel Generator Unavailability
$\sum = 5.2 \times 10^{-2}$	Q_{2H}(LOOP), No Operator Credit, Before Design Change
$\sum = 4.2 \times 10^{-2}$	Q_{2H}(LOOP), Failure to initiate within 20 min., Before Design Change
$\sum = 4.8 \times 10^{-2}$	Q_{2H}(LOOP), No operator credit, credit for design change
$\sum = 4.2 \times 10^{-2}$	Q_{2H}(LOOP), failure to initiate within 20 min., credit for design change

Table A.1b (cont.)

Contributors to Q_{2M} (LMFW)

Note: $\epsilon << 10^{-4}$

Value	Deleted by Design Change	Description of Event
2.1×10^{-3}		Pump maintenance (24-hour outage allowed)
2×10^{-3}	***	Pump testing
or		or
ϵ	***	Pump testing and operator fails to realign
2.1×10^{-3}		CV2800 maintenance
2.1×10^{-3}		CV2803 maintenance
2.1×10^{-3}		CV-X2 maintenance
2.1×10^{-3}		CV-X3 maintenance

$\sum = 1.3 \times 10^{-2}$ Q_{2M}(LMFW), no operator credit

$\sum = 1.1 \times 10^{-2}$ Q_{2M}(LMFW), Failure to initiate in 20 min.

$\sum = 1.1 \times 10^{-2}$ Q_{2M}(LMFW), CREDIT FOR DESIGN CHANGE

ADDITIONAL CONTRIBUTORS TO Q_{2M}

GIVEN LOOP:

None (Diesel maintenance included in Q_{2H})

$\sum = 1.3 \times 10^{-2}$ Q_{2M}(LOOP), no operator credit

$\sum = 1.1 \times 10^{-2}$ Q_{2M}(LOOP), Failure to initiate in 20 min.

$\sum = 1.1 \times 10^{-2}$ Q_{2M}(LOOP), CREDIT FOR DESIGN CHANGE

ADDITIONAL CONTRIBUTORS TO Q_{2M}

GIVEN LOAC:

THIS TRAIN IS UNAVAILABLE GIVEN LOAC

$Q_{2M}(LOAC) = 0.$

(Asterisks denote failures deleted by design change.)

TABLE A.2

RESULTS FOR Q_1 AND Q_2, Credit for Design Change

	Q_{1H}	Q_{1M}	Q_{2H}	Q_{2M}
LMFW, operator credit	8.4×10^{-3}	1.5×10^{-2}	6×10^{-3}	1.1×10^{-2}
LMFW, no operator credit	8.4×10^{-3}	1.5×10^{-2}	1.2×10^{-2}	1.1×10^{-2}
LOOP, operator credit	8.4×10^{-3}	1.5×10^{-2}	4.2×10^{-2}	1.1×10^{-2}
LOOP, no operator credit	8.4×10^{-3}	1.5×10^{-2}	4.8×10^{-2}	1.1×10^{-2}
LOAC, operator credit	8.4×10^{-3}	1.5×10^{-2}	1	0
LOAC, no operator credit	8.4×10^{-3}	1.5×10^{-2}	1	0

Table A.3

Changes to Table 6.3 in New Design

Single Point and Common Failures

Note: $\epsilon \ll 10^{-4}$

Value	Deleted by Design Change	Description of Event
1×10^{-4}	***	Failure of CS-98 to remain open
1×10^{-4}	***	Failure of CS-99 to remain open
1×10^{-4}		Failure of CS-19 to remain open
1×10^{-4}		Failure of FW14 to remain open
1×10^{-4}		Failure of FW15 to remain open
1×10^{-4}		Failure of three-way valve to remain open
4.9×10^{-5}		Failure of both channels of initiate logic $(7\times10^{-3})^2$
or		
ϵ		Failure of both logic channels and failure to initiate manually
$\sum = 6.5\times10^{-4}$		Other, no operator credit, Before Design Change
$\sum = 6\times10^{-4}$		Other, failure to initiate in 20 minutes, Before Design Change
$\sum = 4.5\times10^{-4}$		Other, no operator credit, credit for design change
$\sum = 4\times10^{-4}$		Other, failure to initiate in 20 minutes, credit for design change

(Astrisks denote failures deleted by design change.)

Table A.4

Changes to Table 7.1 in New Design

EFWS Unavailability

Before and After Design Change

Values given here are calculated from
$Q = Q_{1H} Q_{2H} + Q_{1H} Q_{2M} + Q_{1M} Q_{2H} + \text{Other}$,
where

Q_1H = Hardware failures associated with P7A
Q_2H = Hardware failures associated with P7B
Q_1M = Maintenance unavailability associated with P7A
Q_2M = Maintenance unavailability associated with P7B

Contributions to Q_1H and Q_2H are given in Table A.1. Contributions to "other" are given in Table A.3.

	Before Design Change	After Design Change
LMFW, Operator Credit	9.8×10^{-4}	6.3×10^{-4}
LMFW, No Operator Credit(Dryout)	1.4×10^{-3}	8×10^{-4}
LOOP, Operator Credit	2.3×10^{-3}	1.5×10^{-3}
LOOP, No Operator Credit(Dryout)	2.7×10^{-3}	1.6×10^{-3}
LOAC, Operator Credit	3.6×10^{-2}	2.7×10^{-2}
LOAC, No Operator Credit(Dryout)	3.6×10^{-2}	2.8×10^{-2}

APPENDIX B: SUBMITTAL FROM AP&L TO NRC - AUGUST 11, 1982

ARKANSAS POWER & LIGHT COMPANY
POST OFFICE BOX 551 LITTLE ROCK, ARKANSAS 72203 (501) 371-4000

August 11, 1982

1CANØ882Ø2

Director of Nuclear Reactor Regulation
ATTN: Mr. J. F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

SUBJECT: Arkansas Nuclear One - Unit 1
Docket No. 50-313
License No. DPR-51
Questions on the Emergency
Feedwater System Upgrade
Reliability Analysis

Gentlemen:

Your letter of April 21, 1982, (1CNAØ48212) requested additional information pertaining to the report "Emergency Feedwater (EFW) System Upgrade Reliability Analysis for Arkansas Nuclear One, Unit No. 1". In AP&L's letter of May 26, 1982, (1CANØ58211) we proposed to submit the requested information by August 15, 1982. Therefore, attached is our response.

Very truly yours,

John R. Marshall
Manager, Licensing

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Aper. Dist

JRM:MCS:sc

Attachments

ADDITIONAL INFORMATION

CONCERNING

EMERGENCY FEEDWATER UPDRAGE RELIABILITY ANALYSIS

FOR

ARKANSAS NUCLEAR ONE, UNIT NO. 1

DOCKET NO. 50-313

Question 1

"The report's results are not presented in a manner that lends itself to a "NUREG-0611-type" comparison. For example, unavailability given LOOP is not tabulated. LOOP appears as a basic event on the fault tree; was this entered as the probability of LOOP given LMFW? How was this handled?"

Response 1

The presentation of these results in the format of NUREG-0611 does not imply that comparisons to NUREG-0611 are appropriate. Because the scope and assumptions of the analysis are different than for the NUREG-0611 analysis; there is no common basis for comparison. For example, the assumptions used for power availability illustrate the differences. NUREG-0611 assumed perfect DC power (i.e., failure probability of 0.0) for all cases, and one of two perfect diesel generators for this LOOP case. The analysis of ANO-1 EFW reliability evaluated power reliability in detail and assumed realistic probabilities for DC power and diesel generator failure.

The attached figure 1.1 "Reliability of ANO-1 EFW System" supplies the results of the report "Emergency Feedwater System Upgrade Reliability Analysis for the Arkansas Nuclear One Nuclear Generating Station Unit No. 1, April 1981" in the format of NUREG-0611. The attached table (Figure 1.2) "Unavailabilities for ANO-1 EFW" supplies the numerical results broken down into the three cases; loss of main feedwater (LMFW), loss of offsite power (LOOP), and loss of AC power (LOAC).

Question 2

"A narrative description of cut sets was provided, but no quantitative details were given. What were the contributions from the dominant cut sets?"

Response 2

The attached pages A-1 through A-3 explain the code used for the cut sets. The attached pages B-1 through B-36 supply the computer listing of

dominant cut sets for all of the analyzed cases. Each 8 letter code describes a basic event which can be found on the fault trees in Appendix B of the April 1981 Reliability Report.

Question 3

"Failure data were not given. What are they?"

Response 3

The attached pages C-1 through C-4 provide the basic event failure data used in the computer analysis of ANO-1 EFW Reliability.

Question 4

"The following questions pertain to the scenario discussed in point 4 of Section 3.2.1."

a. "At the bottom of p. 3-1, it is stated that "...AC powered valves CV-X2 and CV-X3 will not open." (Fig. D-7 seems to indicate that CV-X3 is DC-powered. Is this correct?) In paragraph D.2.3 (p. D-3), it is stated that "The flow of EFW to each SG is controlled by redundant normally-open modulating solenoid motor operated control valves in parallel paths." The fact that loss of AC fails the control valves closed suggests that they are normally closed, but the subsequent discussion says that they are normally open. What are the normal positions of all valves in the four discharge paths? In this scenario, why were they presumed closed?"

b. "Section 3.2.1.4 also talks about the opening of recirculation valves CV-2815 and CV-2816 during the loss-of-all AC power event which causes portion of turbine driven pump flow bypassing to the condensate storage tank. The ANO report recommends that an analysis be done to detemine if adequate flow will be available to the SGs with this bypass flow. Has the analysis been performed? How serious is the bypass in degrading the total flow to the SGs?"

Response 4a

Attached figure 4 is the latest P&ID for the EFW System, this figure will be referenced in response to the remaining questions. Figure 4 indicates that four modulating control valves are normally open and fail open on loss of control signal or motive power. The four motor operated isolation valves are also normally open and fail "as is".

Response 4b

The recirculation piping will be changed to that shown on figure 4. This will eliminate the common recirculation flow path and resolve the concerns expressed in this question. The analysis will therefore not be done. The recirculation flow will not significantly degrade flow to the SG. This is due to the automatic nature of the recirculation valves to

be installed versus the constant flow nature of the existing design. Pump recirculation will occur only during periods of low total flow, and was considered in pump capacity calculations.

Question 5

"What physical measurement(s) actually regulate the recirculation valves: (CV-2815 and CV-2816)? According to the text (p. D-3, paragraph D.2.5), flow elements upstream of the control valves are used to decide whether flow is being demanded from each pump; however, the diagram suggests that the positions of the control valves (CV-X2 and CV-X3) are sensed."

Response 5

The recirculation flow piping will be changed according to figure 4. All valves in the recirculation flow path will be normally open and recirculation flow controlled by FW10A and FW10B. FW10A & B use pump flow to regulate recirculation flow. These valves consist of a set of interlocked check valves. One check valve is in the discharge path to the OTSG, the other is in the recirculation path. When the discharge path check valves closes due to reduced flow, the interlock will open the check valve in the recirculation line. This method does not require electric measurement and interlocks to establish recirculation and by design eliminates common (P7A and B) recirculation flow control.

Question 6

"If actual flow is the parameter to determine the recirculation then a simple failure of the EMD pump will also cause the recirculation in the TD pump flow (to increase) during the loss of main feed pump event. This failure mode should be included in the fault tree."

Response 6

This question no longer applies because the new recirculation control valves and piping design make pump recirculation flow independent of each other.

Question 7

"Pump Trip: Under what conditions do the pumps trip? Are there trips which are supposed to operate during a test but not during an emergency?"

"The fault tree takes credit for operator recovery of suction source in the event that it had been inappropriately left valved off after maintenance? How much time was assumed to be available for this before pump damage occurred?"

Response 7

The electric pump trips on overcurrent.

The turbine pump trips on overspeed.

There are no trip functions which are bypassed during an emergency.

Recovery of the suction source was assumed to occur before pump damage occurred.

Question 8

"What valves are closed for pump maintenance? Are any of the discharge valves disabled for this purpose?"

"What action is taken to isolate steam from the turbine driven pump during maintenance."

Response 8

During maintenance activities all suction and discharge valves are closed and tagged out of service per ANO procedures. In addition the steam inlet valves to the turbine pump are closed and the circuit breaker for the electric pump is opened and tagged out of service.

Question 9

"Providing steam to the turbine pump: One "steam unavailable" scenario involves the following: One of the valves in the pressure reducing station fails open, and one or the other of the relief valves fails to reseat. According to the fault tree, the relief capacity is such that there is insufficient pressure to drive the turbine if a relief valve is stuck open. It seems likely that given a wide-open control valve, the relief valve will cycle open and closed, so that even a small cyclic failure probability will lead to a substantial overall failure probability as the valve is repetitively cycled. Doesn't this scenario therefore have essentially the probability of either of the control valves failing high?"

Response 9

As part of the EFW upgrade project, the existing turbine is being replaced with a high pressure model. This eliminates the need for pressure reducing and safety valves.

Question 10

a. "Isolation of the discharge paths: Are there single failures in the vector logic that can isolate both discharge paths from a given pump? Example: Channel D logic can isolate both discharge paths from the turbine driven pump. Are there failures in Channel D (e.g., power failures) that isolate both paths?"

b. "Are these valves commanded open by vector logic given a simple LMFW, or does the logic assume that they are already open as they are supposed to be?"

Response 10a

It is possible for a channel, in this case Channel C, to fail. It is conceivable that such a failure could isolate both discharge paths from the turbine driven EFW pump. However, the single failure criterion as applied to the EFW system requires that at least one pump be able to supply EFW to at least one steam generator. Isolation of the turbine driven pump would require the following additional failures before the EFW system would be inoperable:

1. Loss of offsite power (LOOP)

2. Loss of both Diesel Generators (LOAC)

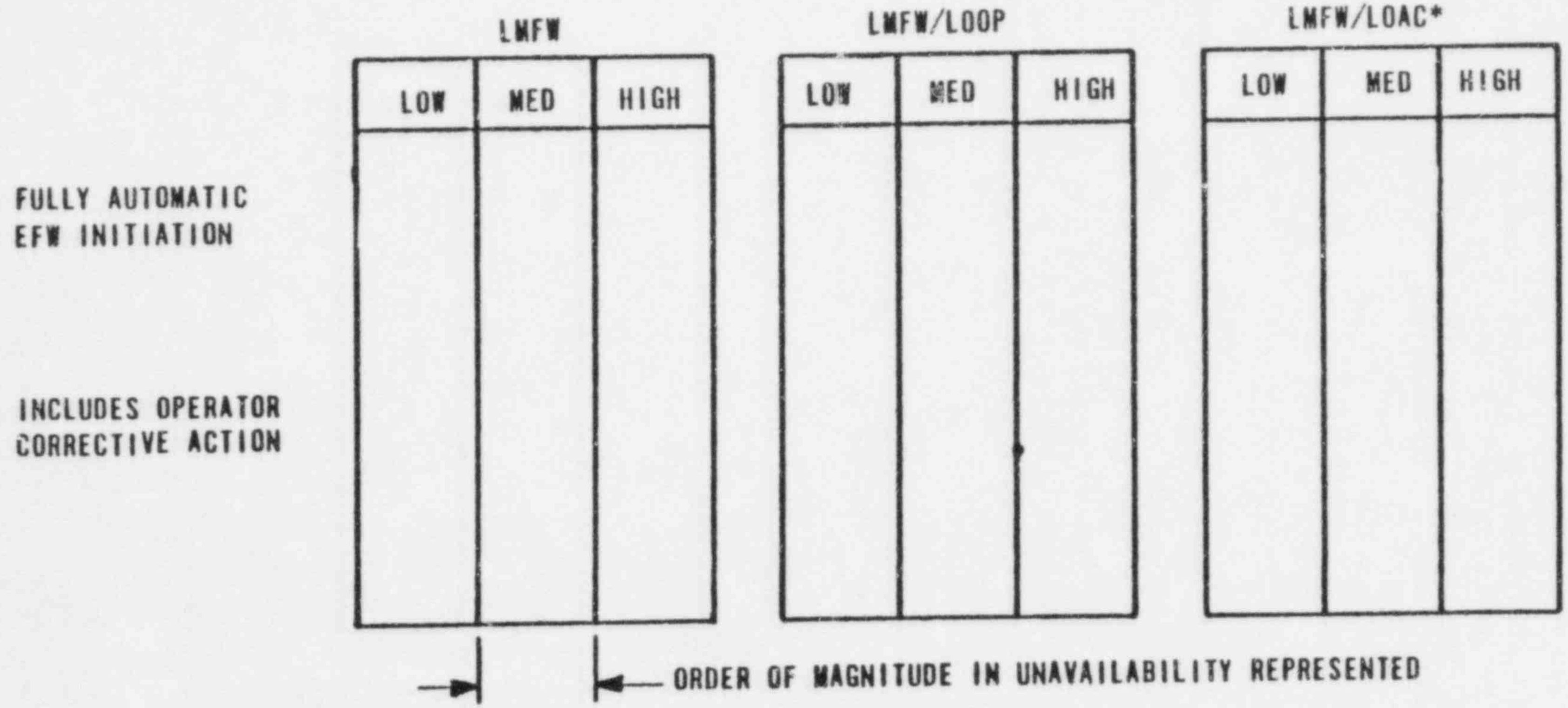
Thus the single failure of channel C would not render EFW inoperable.

Response 10b

These valves are normally open and commanded open by the vector logic. This is due to the system requirement that these valves must be closed during pump testing. An EFW initiation during a test will open these valves and close the test isolation valves, thus terminating the test and providing proper EFW system alignment.

The EFW vector logic commands the valves closed in the event of steam generator overfill or main steam isolation.

RELIABILITY OF ANO-1 EFW SYSTEM



NOTE: ASSUMPTIONS AND SCOPE FOR THIS ANALYSIS ARE DIFFERENT THAN THOSE USED IN NUREG-0611 AND COMPARISON WITH NUREG-0611 RESULTS IS INAPPROPRIATE.

* NOTE: THE SCALE FOR THIS EVENT IS NOT THE SAME AS THAT FOR THE LMFW AND LMFW/LOOP.

FIG 1.1

UNAVAILABILITIES FOR ANO-1 EFW

	Case 1 LMFW	Case 2 LOOP	Case 3 LOAC
EFW Initiate includes failure to initiate EFW due to fluid system failure, spurious isolation by FOGG or overfill protection, and EFIC initiation failure.			
Fully automatic initiation	$3.6x10^{-4}$	$5.2x10^{-4}$	$1.4x10^{-2}$
Includes operator corrective action within 20 minutes.	$1.4x10^{-5}$	$9.1x10^{-5}$	$5.7x10^{-3}$
EFIC Control			
Fully Automatic control	$8.0x10^{-3}$	$8.0x10^{-3}$	$9.7x10^{-3}$
Includes operator corrective action within 20 minutes.	$1.3x10^{-6}$	$1.3x10^{-6}$	$2.6x10^{-6}$
FOGG			
A > 600 psi B < 600 psi (feed only A)	$3.8x10^{-4}$	$3.8x10^{-4}$	$3.8x10^{-4}$
A < 600 psi B > 600 psi (feed only B)	$3.8x10^{-4}$	$3.8x10^{-4}$	$3.8x10^{-4}$
A < 600 psi B < 600 psi A 150 psi > B (feed only A)	$1.5x10^{-3}$	$1.5x10^{-3}$	$1.5x10^{-3}$
A < 600 psi B < 600 psi B 150 psi > A (feed only B)	$1.5x10^{-3}$	$1.5x10^{-3}$	$1.5x10^{-3}$
EFW Overfill Protection	$6.2x10^{-4}$	$6.2x10^{-4}$	$3.1x10^{-3}$

FIG 1.2

BASIC EVENT IDENTIFICATION CODE

XXYYYYFM

XX - Component Identification Code

YYYY - Unique Component Identifier

FM - Failure Mode

COMPONENT IDENTIFICATION CODE

COMPONENT	CODE
Buffler amp or battery (batteries have numbers, e.g., BAD07)	BA
Breaker	BR
Cabinet main circuit breaker	CB
Charger	CH
Controller	CN
Pressure sensor, delta P	DP
FOGG module	FC
FOGG module	FG
Inverter	IN
Level sensor	LS
Level transmitter	LT
Valve or human operator	OP
Proportioner	PR
Resistor	RE
Rate follower	RF
Relay	RY
Setpoint signal	SP
Sensor power supply transformer	SPT
Subtractor	SU
Trip cabinet	TC
Timer circuit	TI
Valve stem	VS

COMPONENT FAILURE MODES
IDENTIFICATION CODE

FAILURE MODE	CODE
All Modes	AM
Catastrophic Failure	CF
Erroneously Trips	ET
Flow Blockage	FB
Fails Closed	FC
Fails to Energize	FE
Fails to Reinitialize	FI
Fails Low	FL
Fails Open	FO
Fails to Run	FR
Fails to Start	FS
Fails to Switch	FW
Indicates Trip	IT
Left Closed	LC
Left Open	LO
Mechanical Failure	MF
Miscalibrated High	MH
Miscalibrated Low	ML
No Signal	NS
In Preventive Maintenance	PM
Fails to Reseat	RS
Spuriously Closes	SC
Shorts	SH
Spurious Signal	SS
Fails to Close	TC
Fails to Detect Trip	TD
Fails to Open	TO
In Test	TS
Unable to Trip	UT

DOMINANT CUT SETS

FOR

ANO-1 EFW UNAVAILABILITY

for

LMFW: Loss of Main Feedwater

LOOP: Loss of Offsite Power

LOAC: Loss of AC Power

Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

PDS-21037-1 (9-81)

GENERAL CALCULATIONS

LMFW
Initiate
Automatic

P7AZZZFS .4100000E-02	P7BZZZFR .3460000E-03	
P7AZZZFS .4100000E-02	P7BZZZFS .5300000E-03	
CST41ZAM .2000000E-05	SWSUCTOP .1000000E+01	
CS98ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
CS99ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
P7AZZZFR .3460000E-03	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7AZZZFS .4100000E-02	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7AZZZPM .7590000E-03	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7ARECCA .1000000E+01	P7ARECLO .3300000E-02	P7BZZZFR .3460000E-03
P7ARECCA .1000000E+01	P7ARECLO .3300000E-02	P7BZZZFS .5300000E-03
P7AZZZFS .4100000E-02	P7BRECOP .1000000E+01	P7BZZZTS .1390000E-02
CV2802LC .3300000E-02	CV2802RE .1000000E+01	P7BZZZFR .3460000E-03
CV2802LC .3300000E-02	CV2802RE .1000000E+01	P7BZZZFS .5300000E-03
CV2800LC .3300000E-02	CV2800RE .1000000E+01	P7AZZZFR .3460000E-03
CV2800LC .3300000E-02	CV2800RE .1000000E+01	P7AZZZFS .4100000E-02

PREPARED BY ______ DATE ______ DOC. NO. ______
REVIEWED BY ______ DATE ______ PAGE NO. B-2

CV2800LC	CV2800RE	P7AZZZPM	
.3300000E-02	.1000000E+01	.7590000E-03	
P7ARECCA	P7ARECLO	P7BRECCA	P7BRECLO
.1000000E+01	.3300000E-02	.1000000E+01	.3300000E-02
P7ARECOP	P7AZZZTS	P7BRECCA	P7BRECLO
.1000000E+01	.1390000E-02	.1000000E+01	.3300000E-02
P7ARECCA	P7ARECLO	P7BRECOP	P7BZZZTS
.1000000E+01	.3300000E-02	.1000000E+01	.1390000E-02
CV2802LC	CV2802RE	P7BRECCA	P7BRECLO
.3300000E-02	.1000000E+01	.1000000E+01	.3300000E-02
CV2802LC	CV2802RE	P7BRECOP	P7BZZZTS
.3300000E-02	.1000000E+01	.1000000E+01	.1390000E-02
CSVSGARS	CSVSGBRS	P7BRECCA	P7BRECLO
.1840000E-01	.1840000E-01	.1000000E+01	.3300000E-02
CV2800LC	CV2800RE	P7ARECCA	P7ARECLO
.3300000E-02	.1000000E+01	.1000000E+01	.3300000E-02
CV2800LC	CV2800RE	P7ARECOP	P7AZZZTS
.3300000E-02	.1000000E+01	.1000000E+01	.1390000E-02
CV2800LC	CV2800RE	CV2802LC	CV2802RE
.3300000E-02	.1000000E+01	.3300000E-02	.1000000E+01
CSVSGARS	CSVSGBRS	CV2800LC	CV2800RE
.1840000E-01	.1840000E-01	.3300000E-02	.1000000E+01

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REVIEWED BY ______ DATE ______ PAGE NO. B-3

LMFW
Initiate
with operator Corrective Action

P7AZZZFR .3460000E-03	P7BZZZFR .3460000E-03	
P7AZZZFS .4100000E-02	P7BZZZFR .3460000E-03	
P7AZZZPM .7590000E-03	P7BZZZFR .3460000E-03	
P7AZZZFR .3460000E-03	P7BZZZFS .5300000E-03	
P7AZZZFS .4100000E-02	P7BZZZFS .5300000E-03	
P7AZZZPM .7590000E-03	P7BZZZFS .5300000E-03	
FW10AZFB .1100000E-03	P7AZZZFS .4100000E-02	
CS98ZZFB .1100000E-03	SWSUCTOP .4000000E-01	
CS99ZZFB .1100000E-03	SWSUCTOP .4000000E-01	
CSVSGARS .1840000E-01	CSVSGBRS .1840000E-01	P7BZZZFR .3460000E-03
CSVSGARS .1840000E-01	CSVSGBRS .1840000E-01	P7BZZZFS .5300000E-03
CV2800LC .3300000E-02	CV2800RE .1900000E-01	P7AZZZFS .4100000E-02

Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

GENERAL CALCU

LMFW
Control
Automatic

OPEM02X1	OPFAILPT
.2000000E-02	.1000000E+01
OPEM02X2	OPFAILPT
.2000000E-02	.1000000E+01
OPEM02X3	OPFAILPT
.2000000E-02	.1000000E+01
OPEM02X4	OPFAILPT
.2000000E-02	.1000000E+01

B-5

PREPARED BY ______ DATE ______ DOC. NO. ______
REVIEWED BY ______ DATE ______ PAGE NO. ______

LMFW
Control
with operator corrective acti
action

OPEM02X1 .2000000E-02	OPFAILPT .1500000E-03
OPEM02X2 .2000000E-02	OPFAILPT .1500000E-03
OPEM02X3 .2000000E-02	OPFAILPT .1500000E-03
OPEM02X4 .2000000E-02	OPFAILPT .1500000E-03
BA02X1FL .9100000E-04	OPFAILPT .1500000E-03
BA02X2FL .9100000E-04	OPFAILPT .1500000E-03
BA02X3FL .9100000E-04	OPFAILPT .1500000E-03
BA02X4FL .9100000E-04	OPFAILPT .1500000E-03

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Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

PDS-21037-1 (9-81)

GENERAL CALCULATIONS

LMFW
F066
A<600 B>600

DPATCBFH .5500000E-02	DPATCCFH .5500000E-02
DPATCAFH .5500000E-02	DPATCDFH .5500000E-02
DPATCDFH .5500000E-02	DPBTCAFL .5500000E-02
DPATCCFH .5500000E-02	DPBTCBFL .5500000E-02
DPATCBFH .5500000E-02	DPBTCCFL .5500000E-02
DPBTCBFL .5500000E-02	DPBTCCFL .5500000E-02
DPATCAFH .5500000E-02	DPBTCDFL .5500000E-02
DPBTCAFL .5500000E-02	DPBTCDFL .5500000E-02
BIDPAAML .2800000E-02	DPATCDFH .5500000E-02
BIDPAAML .2800000E-02	DPBTCDFL .5500000E-02
BIDPABML .2800000E-02	DPATCCFH .5500000E-02
BIDPABML .2800000E-02	DPBTCCFL .5500000E-02
BIDPACML .2800000E-02	DPATCBFH .5500000E-02
BIDPACML .2800000E-02	DPBTCBFL .5500000E-02
BIDPABML .2800000E-02	BIDPACML .2800000E-02
BIDPADML .2800000E-02	DPATCAFH .5500000E-02
BIDPADML .2800000E-02	DPBTCAFL .5500000E-02
BIDPAAML .2800000E-02	BIDPADML .2300000E-02

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Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

PDS-21037-1 (9-81)

GENERAL CALCULATIONS

LMFW
F066
A <600, B<600, B150 >A

DPATCAFH	.5500000E-02	DPATCBFH	.5500000E-02
DPATCAFH	.5500000E-02	DPATCCFH	.5500000E-02
DPATCBFH	.5500000E-02	DPATCCFH	.5500000E-02
DPATCAFH	.5500000E-02	DPATCDFH	.5500000E-02
DPATCBFH	.5500000E-02	DPATCDFH	.5500000E-02
DPATCCFH	.5500000E-02	DPATCDFH	.5500000E-02
DPATCBFH	.5500000E-02	DPBTCAFL	.5500000E-02
DPATCCFH	.5500000E-02	DPBTCAFL	.5500000E-02
DPATCDFH	.5500000E-02	DPBTCAFL	.5500000E-02
DPATCAFH	.5500000E-02	DPBTCBFL	.5500000E-02
DPATCCFH	.5500000E-02	DPBTCBFL	.5500000E-02
DPATCDFH	.5500000E-02	DPBTCBFL	.5500000E-02
DPBTCAFL	.5500000E-02	DPBTCBFL	.5500000E-02
DPATCAFH	.5500000E-02	DPBTCCFL	.5500000E-02
DPATCBFH	.5500000E-02	DPBTCCFL	.5500000E-02
DPATCDFH	.5500000E-02	DPBTCCFL	.5500000E-02

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GENERAL CALCULATIONS

DPBTCAFL .5500000E-02	DPBTCCFL .5500000E-02
DPBTCBFL .5500000E-02	DPBTCCFL .5500000E-02
DPATCAFH .5500000E-02	DPBTCDFL .5500000E-02
DPATCBFH .5500000E-02	DPBTCDFL .5500000E-02
DPATCCFH .5500000E-02	DPBTCDFL .5500000E-02
DPBTCAFL .5500000E-02	DPBTCDFL .5500000E-02
DPBTCBFL .5500000E-02	DPBTCDFL .5500000E-02
DPBTCCFL .5500000E-02	DPBTCDFL .5500000E-02
BIA7BAML .2800000E-02	DPATCDFH .5500000E-02
BIA7BAML .2800000E-02	DPBTCDFL .5500000E-02
BIA7BBML .2800000E-02	DPATCCFH .5500000E-02
BIA7BBML .2800000E-02	DPBTCCFL .5500000E-02
BIA7BCML .2800000E-02	DPATCBFH .5500000E-02
BIA7BCML .2800000E-02	DPBTCBFL .5500000E-02
BIA7BBML .2800000E-02	BIA7BCML .2800000E-02
BIA7BDML .2800000E-02	DPATCAFH .5500000E-02
BIA7BDML .2800000E-02	DPBTCAFL .5500000E-02
BIA7BAML .2800000E-02	BIA7BDML .2800000E-02
BIB7AAKH .2800000E-02	DPATCDFH .5500000E-02
BIB7AAMH	DPBTCDFL

.2800000E-02	.5500000E-02
BIA7BDML .2800000E-02	BIB7AAMH .2800000E-02
BIB7ABMH .2800000E-02	DPATCCFH .5500000E-02
BIB7ABMH .2800000E-02	DPBTCCFL .5500000E-02
BIA7BCML .2800000E-02	BIB7ABMH .2800000E-02
BIB7ACMH .2800000E-02	DPATCBFH .5500000E-02
BIB7ACMH .2800000E-02	DPBTCBFL .5500000E-02
BIA7BBML .2800000E-02	BIB7ACMH .2800000F-02
BIB7ABMH .2800000E-02	BIB7ACMH .2800000E-02
BIB7ADMH .2800000E-02	DPATCAFH .5500000E-02
BIB7ADMH .2800000E-02	DPBTCAFL .5500000E-02
BIA7BAML .2800000E-02	BIB7ADMH .2800000E-02
BIB7AAMH .2800000E-02	BIB7ADMH .2800000E-02
BIDPAAML .2800000E-02	DPATCBFH .5500000E-02
BIDPAAML .2800000E-02	DPATCCFH .5500000E-02
BIDPAAML .2800000E-02	DPATCDFH .5500000E-02
BIDPAAML .2800000E-02	DPBTCBFL .5500000E-02
BIDPAAML .2800000E-02	DPBTCCFL .5500000E-02
BIDPAAML .2800000E-02	DPBTCDFL .5500000E-02
BIA7BDML .2800000E-02	BIDPAAML .2800000E-02

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BIB7ADMH	BIDPAAML
.2800000E-02	.2800000E-02
BIDPABML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPABML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPABML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPABML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCCFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BCML	BIDPABML
.2800000E-02	.2800000E-02
BIB7ACMH	BIDPABML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPABML
.2800000E-02	.2800000E-02
BIDPACML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPACML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BBML	BIDPACML
.2800000E-02	.2800000E-02
BIB7ABMH	BIDPACML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPACML
.2800000E-02	.2800000E-02
BIDPABML	BIDPACML

.2800000E-02	.2800000E-02
BIDPADML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPADML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BAML	BIDPADML
.2800000E-02	.2800000E-02
BIB7AAMH	BIDPADML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPADML
.2800000E-02	.2800000E-02
BIDPABML	BIDPADML
.2800000E-02	.2800000E-02
BIDPACML	BIDPADML
.2800000E-02	.2800000E-02

LMFW - Overfill Protection

DPOFABXX 5.5×10^{-3}	DPOFDBFL 5.5×10^{-3}
BAOFABXX 9.1×10^{-5}	DPOFDBFL 5.5×10^{-3}
BIOFABMH 2×10^{-3}	DPOFDBFL 5.5×10^{-3}
DPOFABXX 5.5×10^{-3}	BIOFDBMH 2×10^{-3}
BAOFABXX 9.1×10^{-5}	BIOFDBMH 2×10^{-3}
BIOFABMH 2×10^{-3}	BIOFDBMH 2×10^{-3}

LOOP
Initiate
Automatic

P7AZZZFS .4100000E-02	P7BZZZFR .3460000E-03	
P7AZZZFS .4100000E-02	P7BZZZFS .5300000E-03	
DG1ZZZFS .1340000E-01	P7AZZZFR .3460000E-03	
DG1ZZZFS .1340000E-01	P7AZZZFS .4100000E-02	
DG1ZZZFS .1340000E-01	P7AZZZPM .7590000E-03	
DG1ZZZFS .1340000E-01	FW109ZFB .1100000E-03	
CS741ZAM .2000000E-05	SWSUCTOP .1000000E+01	
CS98ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
CS99ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
P7AZZZFR .3460000E-03	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7AZZZFS .4100000E-02	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7AZZZPM .7590000E-03	P7BRECCA .1000000E+01	P7BRECLO .3300000E-02
P7ARECCA .1000000E+01	P7ARECLO .3300000E-02	P7BZZZFR .3460000E-03
P7ARECCA .1000000E+01	P7ARECLO .3300000E-02	P7BZZZFS .5300000E-03
P7AZZZFS .4100000E-02	P7BRECOP .1000000E+01	P7BZZZTS .1390000E-02

CV2802LC	CV2802RE	P7BZZZFR	
.3300000E-02	.1000000E+01	.3460000E-03	
CV2802LC	CV2802RE	P7BZZZFS	
.3300000E-02	.1000000E+01	.5300000E-03	
DG1ZZZFS	P7ARECCA	P7ARECLO	
.1340000E-01	.1000000E+01	.3300000E-02	
DG1ZZZFS	P7ARECOP	P7AZZZTS	
.1340000E-01	.1000000E+01	.1390000E-02	
CV2802LC	CV2802RE	DG1ZZZFS	
.3300000E-02	.1000000E+01	.1340000E-01	
CSVSGARS	CSVSGBRS	DG1ZZZFS	
.1840000E-01	.1840000E-01	.1340000E-01	
CV2800LC	CV2800RE	P7AZZZFR	
.3300000E-02	.1000000E+01	.3460000E-03	
CV2800LC	CV2800RE	P7AZZZFS	
.3300000E-02	.1000000E+01	.4100000E-02	
CV2800LC	CV2800RE	P7AZZZPM	
.3300000E-02	.1000000E+01	.7590000E-03	
P7ARECCA	P7ARECLO	P7BRECCA	P7BRECLO
.1000000E+01	.3300000E-02	.1000000E+01	.3300000E-02
P7ARECOP	P7AZZZTS	P7BRECCA	P7BRECLO
.1000000E+01	.1390000E-02	.1000000E+01	.3300000E-02
P7ARECCA	P7ARECLO	P7BRECOP	P7BZZZTS
.1000000E+01	.3300000E-02	.1000000E+01	.1390000E-02
CV2802LC	CV2802RE	P7BRECCA	P7BRECLO
.3300000E-02	.1000000E+01	.1000000E+01	.3300000E-02
CV2802LC	CV2802RE	P7BRECOP	P7BZZZTS
.3300000E-02	.1000000E+01	.1000000E+01	.1390000E-02
CSVSGARS	CSVSGBRS	P7BRECCA	P7BRECLO
.1840000E-01	.1840000E-01	.1000000E+01	.3300000E-02
CV2800LC	CV2800RE	P7ARECCA	P7ARECLO
.3300000E-02	.1000000E+01	.1000000E+01	.3300000E-02
CV2800LC	CV2800RE	P7ARECOP	P7AZZZTS
.3300000E-02	.1000000E+01	.1000000E+01	.1390000E-02
CV2800LC	CV2800RE	CV2802LC	CV2802RE
.3300000E-02	.1000000E+01	.3300000E-02	.1000000E+01
CSVSGARS	CSVSGBRS	CV2800LC	CV2800RE
.1840000E-01	.1840000E-01	.3300000E-02	.1000000E+01

LOOP
Initiate
with operator corrective action

P7AZZZFR	P7BZZZFR	
.3460000E-03	.3460000E-03	
P7AZZZFS	P7BZZZFR	
.4100000E-02	.3460000E-03	
P7AZZZPM	P7BZZZFR	
.7590000E-03	.3460000E-03	
P7AZZZFR	P7BZZZFS	
.3460000E-03	.5300000E-03	
P7AZZZFS	P7BZZZFS	
.4100000E-02	.5300000E-03	
P7AZZZPM	P7BZZZFS	
.7590000E-03	.5300000E-03	
DG1ZZZFS	P7AZZZFR	
.1340000E-01	.3460000E-03	
DG1ZZZFS	P7AZZZFS	
.1340000E-01	.4100000E-02	
DG1ZZZFS	P7AZZZPM	
.1340000E-01	.7590000E-03	
FW10AZFB	P7AZZZFS	
.1100000E-03	.4100000E-02	
DG1ZZZFS	FW10BZFB	
.1340000E-01	.1100000E-03	
CS98ZZFB	SWSUCTOP	
.1100000E-03	.4000000E-01	
CS99ZZFB	SWSUCTOP	
.1100000E-03	.4000000E-01	
CV2802LC	CV2802RE	DG1ZZZFS
.3300000E-02	.1100000E-01	.1340000E-01
CSVSGARS	CSVSGBRS	P7BZZZFR
.1840000E-01	.1840000E-01	.3460000E-03
CSVSGARS	CSVSGBRS	P7BZZZFS
.1840000E-01	.1840000E-01	.5300000E-03
CSVSGARS	CSVSGBRS	DG1ZZZFS
.1840000E-01	.1840000E-01	.1340000E-01
CV2800LC	CV2800RE	P7AZZZFS
.3300000E-02	.1900000E-01	.4100000E-02

LOOP
Control
Automatic

OPEM20X1	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X2	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X3	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X4	OPFAILPT
.2000000E-02	.1000000E+01

LOOP
Control
with operator corrective action

LS20X4NS .8700000E-04	OPFAILPT .1500000E-03
OPEM20X1 .2000000E-02	OPFAILPT .1500000E-03
OPEM20X2 .2000000E-02	OPFAILPT .1500000E-03
OPEM20X3 .2000000E-02	OPFAILPT .1500000E-03
OPEM20X4 .2000000E-02	OPFAILPT .1500000E-03
OPESEL28 .1000000E-03	OPFAILPT .1500000E-03
LS20X1NS .8700000E-04	OPFAILPT .1500000E-03
LS20X2NS .8700000E-04	OPFAILPT .1500000E-03
LS20X3NS .8700000E-04	OPFAILPT .1500000E-03
BA20X1FL .9100000E-04	OPFAILPT .1500000E-03
BA20X2FL .9100000E-04	OPFAILPT .1500000E-03
BA20X3FL .9100000E-04	OPFAILPT .1500000E-03
BA20X4FL .9100000E-04	OPFAILPT .1500000E-03

LOOP
F066
A<600, B>600

DPATCBFH .5500000E-02	DPATCCFH .5500000E-02
DPATCAFH .5500000E-02	DPATCDFH .5500000E-02
DPATCDFH .5500000E-02	DPBTCAFL .5500000E-02
DPATCCFH .5500000E-02	DPBTCBFL .5500000E-02
DPATCBFH .5500000E-02	DPBTCCFL .5500000E-02
DPBTCBFL .5500000E-02	DPBTCCFL .5500000E-02
DPATCAFH .5500000E-02	DPBTCDFL .5500000E-02
DPBTCAFL .5500000E-02	DPBTCDFL .5500000E-02
BIDPAAML .2800000E-02	DPATCDFH .5500000E-02
BIDPAAML .2800000E-02	DPBTCDFL .5500000E-02
BIDPABML .2800000E-02	DPATCCFH .5500000E-02
BIDPABML .2800000E-02	DPBTCCFL .5500000E-02
BIDPACML .2800000E-02	DPATCBFH .5500000E-02
BIDPACML .2800000E-02	DPBTCBFL .5500000E-02
BIDPABML .2800000E-02	BIDPACML .2800000E-02
BIDPADML .2800000E-02	DPATCAFH .5500000E-02
BIDPADML .2800000E-02	DPBTCAFL .5500000E-02
BIDPAAML .2800000E-02	BIDPADML .2800000E-02

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Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

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GENERAL CALCULATIONS

LOOP
F066
A<600, B<600, B 150> A

DPATCAFH	DPATCBFH
.5500000E-02	.5500000E-02
DPATCAFH	DPATCCFH
.5500000E-02	.5500000E-02
DPATCBFH	DPATCCFH
.5500000E-02	.5500000E-02
DPATCAFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCBFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCCFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPBTCAFL	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCCFL
.5500000E-02	.5500000E-02

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DPBTCAFL	DPBTCCFL
.5500000E-02	.5500000E-02
DPBTCBFL	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCAFL	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCBFL	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCCFL	DPBTCDFL
.5500000E-02	.5500000E-02
BIA7BAML	DPATCDFH
.2800000E-02	.5500000E-02
BIA7BAML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BBML	DPATCCFH
.2800000E-02	.5500000E-02
BIA7BBML	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BCML	DPATCBFH
.2800000E-02	.5500000E-02
BIA7BCML	DPBTCBFL
.2800000E-02	.5500000E-02
BIA7BBML	BIA7BCML
.2800000E-02	.2800000E-02
BIA7BDML	DPATCAFH
.2800000E-02	.5500000E-02
BIA7BDML	DPBTCAFL
.2800000E-02	.5500000E-02
BIA7BAMl	BIA7BDML
.2800000E-02	.2800000E-02
BIB7AAMH	DPATCDFH
.2800000E-02	.5500000E-02
BIB7AAMH	DPBTCDFL

.2800000E-02	.5500000E-02
BIA7BDML	BIB7AAMH
.2800000E-02	.2800000E-02
BIB7ABMH	DPATCCFH
.2800000E-02	.5500000E-02
BIB7ABMH	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BCML	BIB7ABMH
.2800000E-02	.2800000E-02
BIB7ACMH	DPATCBFH
.2800000E-02	.5500000E-02
BIB7ACMH	DPBTCBFL
.2800000E-02	.5500000E-02
BIA7BBML	BIB7ACMH
.2800000E-02	.2800000E-02
BIB7ABMH	BIB7ACMH
.2800000E-02	.2800000E-02
BIB7ADMH	DPATCAFH
.2800000E-02	.5500000E-02
BIB7ADMH	DPBTCAFL
.2800000E-02	.5500000E-02
BIA7BAML	BIB7ADMH
.2800000E-02	.2800000E-02
BIB7AAMH	BIB7ADMH
.2800000E-02	.2800000E-02
BIDPAAML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPAAML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPAAML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCCFL
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BDML	BIDPAAML
.2800000E-02	.2800000E-02

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BIB7ADMH	BIDPAAML
.2800000E-02	.2800000E-02
BIDPABML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPABML	DPATC[illegible]
.2800000E-02	.5500000[illegible]02
BIDPABML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPABML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCCFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BCML	BIDPABML
.2800000E-02	.2800000E-02
BIB7ACMH	BIDPABML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPABML
.2800000E-02	.2800000E-02
BIDPACML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPACML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BBML	BIDPACML
.2800000E-02	.2800000E-02
BIB7ABMH	BIDPACML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPACML
2800000E-02.	.2800000E-02
BIDPABML	BIDPACML

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.2800000E-02	.2800000E-02
BIDPADML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPADML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BAML	BIDPADML
.2800000E-02	.2800000E-02
BIB7AAMH	BIDPADML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPADML
.2800000E-02	.2800000E-02
BIDPABML	BIDPADML
.2800000E-02	.2800000E-02
3IDPACML	BIDPADML
.2800000E-02	.2800000E-02

LOOP - Overfill Protection

DPOFABXX	DPOFDBFL
5.5×10^{-3}	5.5×10^{-3}
BAOFABXX	DPOFDBFL
9.1×10^{-5}	5.5×10^{-3}
BIOFABMH	DPOFDBFL
2×10^{-3}	5.5×10^{-3}
DPOFABXX	BIOFDBMH
5.5×10^{-3}	2×10^{-3}
BAOFABXX	BIOFDBMH
9.1×10^{-5}	2×10^{-3}
BIOFABMH	BIOFDBMH
2×10^{-3}	2×10^{-3}

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GENERAL CALCULATIONS

LOAC
Initiate
Automatic

P7AZZZFR .3460000E-03		
P7AZZZFS .4100000E-02		
P7AZZZPM .7590000E-03		
FW10BZFB .1100000E-03		
P7ARECCA .1000000E+01	P7ARECLO .3300000E-02	
P7ARECOP .1000000E+01	P7AZZZTS .1390000E-02	
CV2802LC .3300000E-02	CV2802RE .1000000E+01	
CST41ZAM .2000000E-05	SWSUCTOP .1000000E+01	
CSVSGARS .1840000E-01	W6ZZZZFB .1100000E-03	
CSVSGBRS .1840000E-01	W5ZZZZFB .1100000E-03	
CSVSGARS .1840000E-01	CSVSGBRS .1840000E-01	
CS98ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
CS99ZZFB .1100000E-03	SWSUCTOP .1000000E+01	
BAD06ZAM .8460000E-03	CV2802LC .3300000E-02	
CVY1Y2OP .1000000E+01	CVY1ZZTO .4000000E-02	CVY2ZZTO .4000000E-02
BAD06ZAM .8460000E-03	CVY1Y2OP .1000000E+01	CVY2ZZTO .4000000E-02
BAD07ZAM .8460000E-03	CVY1Y2OP .1000000E+01	CVY1ZZTO .4000000E-02

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LOAC
Initiate, with operator corrective action

P7AZZZFR .3460000E-03	
P7AZZZFS .4100000E-02	
P7AZZZPH .7590000E-03	
FW10BZFB .1100000E-03	
P7ARECCA .2100000E-02	P7ARECLO .3300000E-02
P7ARECCP .4000000E-02	P7AZZZTS .1390000E-02
CV2802LC .3300000E-02	CV2802RE .1100000E-01
CSVSGARS .1840000E-01	W6ZZZZFB .1100000E-03
CSVSGBRS .1840000E-01	W5ZZZZFB .1100000E-03
CSVSGARS .1840000E-01	CSVSGBRS .1840000E-01
CS98ZZFB .1100000E-03	SWSUCTOP .4000000E-01
CS98ZZFB .1100000E-03	CV2806MF .4000000E-02
CS98ZZFB .1100000E-03	CV3851MF .4000000E-02
CS99ZZFB .1100000E-03	SWSUCTOP .4000000E-01
CS99ZZFB .1100000E-03	CV2806MF .4000000E-02
CS99ZZFB .1100000E-03	CV3851MF .4000000E-02
CVY3ZZFH .2070000E-03	PV6601RS .2300000E-02
CVY3ZZFH .2070000E-03	PV6602RS .2300000E-02
CVY4ZZFH .2070000E-03	PV6601RS .2300000E-02
CVY4ZZFH .2070000E-03	PV6602RS .2300000E-02
BAD06ZAM .8460000E-03	CV2802LC .3300000E-02

LOAC
Control
Automatic

OPEM20X1	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X2	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X3	OPFAILPT
.2000000E-02	.1000000E+01
OPEM20X4	OPFAILPT
.2000000E-02	.1000000E+01
BAD06ZAM	OPFAILPH
.8460000E-03	.1000000E+01
BAD07ZAM	OPFAILPH
.8460000E-03	.1000000E+01

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GENERAL CA

LOAC
Control
with operator corre
Corrective Action

LS20X4NS .8700000E-04	OPFAILPT .1500000E-03
OPEH20X1 .2000000E-02	OPFAILPT .1500000E-03
OPEH20X2 .2000000E-02	OPFAILPT .1500000E-03
OPEH20X3 .2000000E-02	OPFAILPT .1500000E-03
OPEH20X4 .2000000E-02	OPFAILPT .1500000E-03
OPESEL28 .1000000E-03	OPFAILPT .1500000E-03
LS20X1NS .8700000E-04	OPFAILPT .1500000E-03
LS20X2NS .8700000E-04	OPFAILPT .1500000E-03
LS20X3NS .8700000E-04	OPFAILPT .1500000E-03
BAD06ZAM .8460000E-03	OPFAILPH .7500000E-03
BAD07ZAM .8460000E-03	OPFAILPH .7500000E-03
BA20X1FL .9100000E-04	OPFAILPT .1500000E-03
BA20X2FL .9100000E-04	OPFAILPT .1500000E-03
BA20X3FL .9100000E-04	OPFAILPT .1500000E-03
BA20X4FL .9100000E-04	OPFAILPT .1500000E-03

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GENERAL CALCUL

LOAC
FOGG
A < 600, B > 6‥

DPATCBFH .5500000E-02	DPATCCFH .5500000E-02
DPATCAFH .5500000E-02	DPATCDFH .5500000E-02
DPATCDFH .5500000E-02	DPBTCAFL .5500000E-02
DPATCCFH .5500000E-02	DPBTCBFL .5500000E-02
DPATCBFH .5500000E-02	DPBTCCFL .5500000E-02
DPBTCBFL .5500000E-02	DPBTCCFL .5500000E-02
DPATCAFH .5500000E-02	DPBTCDFL .5500000E-02
DPBTCAFL .5500000E-02	DPBTCDFL .5500000E-02
BIDPAAML .2800000E-02	DPATCDFH .5500000E-02
BIDPAAML .2800000E-02	DPBTCDFL .5500000E-02
BIDPABML .2800000E-02	DPATCCFH .5500000E-02
BIDPABML .2800000E-02	DPBTCCFL .5500000E-02
BIDPACML .2800000E-02	DPATCBFH .5500000E-02
BIDPACML .2800000E-02	DPBTCBFL .5500000E-02
BIDPABML .2800000E-02	BIDPACML .2800000E-02
BIDPADML .2800000E-02	DPATCAFH .5500000E-02
BIDPADML .2800000E-02	DPBTCAFL .5500000E-02
BIDPAAML .2800000E-02	BIDPADML .2800000E-02

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GENERAL CALCULATIONS

LOAC
F066
A<600, B<600, B 150>A

DPATCAFH	DPATCBFH
.5500000E-02	.5500000E-02
DPATCAFH	DPATCCFH
.5500000E-02	.5500000E-02
DPATCBFH	DPATCCFH
.5500000E-02	.5500000E-02
DPATCAFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCBFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCCFH	DPATCDFH
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCAFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCBFL
.5500000E-02	.5500000E-02
DPBTCAFL	DPBTCBFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCDFH	DPBTCCFL
.5500000E-02	.5500000E-02

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DPBTCAFL	DPBTCCFL
.5500000E-02	.5500000E-02
DPBTCBFL	DPBTCCFL
.5500000E-02	.5500000E-02
DPATCAFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPATCBFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPATCCFH	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCAFL	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCBFL	DPBTCDFL
.5500000E-02	.5500000E-02
DPBTCCFL	DPBTCDFL
.5500000E-02	.5500000E-02
BIA7BAML	DPATCDFH
.2800000E-02	.5500000E-02
BIA7BAML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BBML	DPATCCFH
.2800000E-02	.5500000E-02
BIA7BBML	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BCML	DPATCBFH
.2800000E-02	.5500000E-02
BIA7BCML	DPBTCBFL
.2800000E-02	.5500000E-02
BIA7BBML	BIA7BCML
.2800000E-02	.2800000E-02
BIA7BDML	DPATCAFH
.2800000E-02	.5500000E-02
BIA7BDML	DPBTCAFL
.2800000E-02	.5500000E-02
BIA7BAML	BIA7BDML
.2800000E-02	.2800000E-02
BIB7AAMH	DPATCDFH
.2800000E-02	.5500000E-02
BIB7AAMH	DPBTCDFL

.2800000E-02	.5500000E-02
BIA7BDML	BIB7AAMH
.2800000E-02	.2800000E-02
BIB7ABMH	DPATCCFH
.2800000E-02	.5500000E-02
BIB7ABMH	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BCML	BIB7ABMH
.2800000E-02	.2800000E-02
BIB7ACMH	DPATCBFH
.2800000E-02	.5500000E-02
BIB7ACMH	DPBTCBFL
.2800000E-02	.5500000E-02
BIA7BBML	BIB7ACMH
.2800000E-02	.2800000E-02
BIB7ABMH	BIB7ACMH
.2800000E-02	.2800000E-02
BIB7ADMH	DPATCAFH
.2800000E-02	.5500000E-02
BIB7ADMH	DPBTCAFL
.2800000E-02	.5500000E-02
BIA7BAML	BIB7ADMH
.2800000E-02	.2800000E-02
BIB7AAMH	BIB7ADMH
.2800000E-02	.2800000E-02
BIDPAAML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPAAML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPAAML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCCFL
.2800000E-02	.5500000E-02
BIDPAAML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BDML	BIDPAAML
.2800000E-02	.2800000E-02

BIB7ADMH	BIDPAAML
.2800000E-02	.2800000E-02
BIDPABML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPABML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPABML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPABML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCCFL
.2800000E-02	.5500000E-02
BIDPABML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BCML	BIDPABML
.2800000E-02	.2800000E-02
BIB7ACMH	BIDPABML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPABML
.2800000E-02	.2800000E-02
BIDPACML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPACML	DPATCDFH
.2800000E-02	.5500000E-02
BIDPACML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPACML	DPBTCDFL
.2800000E-02	.5500000E-02
BIA7BBML	BIDPACML
.2800000E-02	.2800000E-02
BIB7ABMH	BIDPACML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPACML
.2800000E-02	.2800000E-02
BIDPABML	BIDPACML

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.2800000E-02	.2800000E-02
BIDPADML	DPATCAFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCBFH
.2800000E-02	.5500000E-02
BIDPADML	DPATCCFH
.2800000E-02	.5500000E-02
BIDPADML	DPBTCAFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCBFL
.2800000E-02	.5500000E-02
BIDPADML	DPBTCCFL
.2800000E-02	.5500000E-02
BIA7BAML	BIDPADML
.2800000E-02	.2800000E-02
BIB7AAMH	BIDPADML
.2800000E-02	.2800000E-02
BIDPAAML	BIDPADML
.2800000E-02	.2800000E-02
BIDPABML	BIDPADML
.2800000E-02	.2800000E-02
BIDPACML	BIDPADML
.2800000E-02	.2800000E-02

LOAC - Overfill Protection

DPOFABXX 5.5×10^{-3}	DPOFDBFL $5.5 \times 10^{-}$
BAOFABXX 9.1×10^{-5}	DPOFDBFL $5.5 \times 10^{-}$
BIOFABMH 2×10^{-3}	DPOFDBFL $5.5 \times 10^{-}$
DPOFABXX 5.5×10^{-3}	BIOFDBMH 2×10^{-3}
BAOFABXX 9.1×10^{-5}	BIOFDBMH 2×10^{-3}
BIOFABMH 2×10^{-3}	BIOFDBMH 2×10^{-3}
BADO7ZAM 8.46×10^{-4}	DPOFDBFL 5.5×10^{-3}
BADO7ZAM 8.46×10^{-4}	BIOFDBMH 2×10^{-3}
BADO7ZAM 8.46×10^{-4}	DPOFDAFL 5.5×10^{-3}
BADO7ZAM 8.46×10^{-4}	BIOFDAMH 2×10^{-3}

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Nuclear Power Generation Division

PDS-21037-

GENERAL CALCULATIC

Basic Event Unavailabilities

AEWTRPOP	.[illegible]000000E-02	BAARYAEO	.9100000E-04	BAARYBFO	.9100000E-04	BABRYAEO	.9100000E-04
BABRYBFO	.9100000E-04	BA[illegible]ZAM	.8460000E-03	BAD07ZAM	.8460000E-03	BAOFAAFL	.9100000E-04
BAOFABFL	.9100000E-04			BAOFDAFL	.9100000E-04	BAOFDBFL	.9100000E-04
BA02X1FL	.9100000E-04	BA02X2FL	.9100000E-04	BA02X3FL	.9100000E-04	BA02X4FL	.9100000E-04
BA20X1FL	.9100000E-04	BA20X2FL	.9100000E-04	BA20X3FL	.9100000E-04	BA20X4FL	.9100000E-04
BIA7BAET	.2200000E-04	BIA7BAML	.2600000E-02	BIA7BBET	.2200000E-04	BIA7BBML	.2800000E-02
BIA7BCET	.2200000E-04	BIA7BCML	.2800000E-02	BIA7BDET	.2200000E-04	BIA7BDML	.2800000E-02
BIB7AAMH	.2800000E-02	BIB7AAUT	.8700000E-04	BIB7ABMH	.2800000E-02	BIB7ABUT	.8700000E-04
BIB7ACMH	.2800000E-02	BIB7ACUT	.8700000E-04	BIB7ADMH	.2800000E-02	BIB7ADUT	.8700000E-04
BIDPAAML	.2800000E-02	BIDPAAUT	.8700000E-04	BIDPABML	.2800000E-02	BIDPABUT	.8700000E-04
BIDPACML	.2800000E-02	BIDPACUT	.8700000E-04	BIDPADML	.2800000E-02	BIDPADUT	.8700000E-04
BIDPBAET	.2200000E-04	BIDPBAMH	.2800000E-02	BIDPBAML	.2800000E-02	BIDPBBET	.2200000E-04
BIDPBBMH	.2800000E-02	BIDPBBML	.2800000E-02	BIDPBCET	.2200000E-04	BIDPBCMH	.2800000E-02
BIDPBCML	.2800000E-02	BIDPBDET	.2200000E-04	BIDPBDMH	.2800000E-02	BIDPBDML	.2800000E-02
BIOFAAFL	.8700000E-04	BIOFABFL	.8700000E-04	BIOFDAFL	.8700000E-04	BIOFDBFL	.8700000E-04

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Nuclear Power Generation Division

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GENERAL CALCULATIONS

		BRB51ZFO	.1720000E-06	BRB61ZFO	.1720000E-06	BRCAPZFO	.1720000E-06
BRCBPZFO	.1720000E-06	BRD01ZFO	.1720000E-06	BRD02ZEO	.1720000E-06	BRD11NFQ	.1720000E-06
BRD120FO	.1720000E-06	BRD21NFO	.1720000E-06	BRP7BZFO	.1720000E-06	CHD03ZAM	.4010000E-04
CHD04ZAM	.1390000E-03	CNAMBRFO	.1720000E-06	CNARYATC	.7000000E-05	CNARYCTC	.7000000E-05
CN3MBRFO	.1720000E-06	CNBRYATC	.7000000E-05	CNBRYCTC	.7000000E-05		
CSPTSDAM	.1200000E-04	CST41ZAM	.2000000E-05	CSVSGARS	.1840000E-01	CSVSGBRS	.1840000E-01
CS98ZZFB	.1100000E-03	CS99ZZFB	.1100000E-03	CVX1EIFL	.5490000E-05	CVX1VSFH	.7600000E-05
CVX1ZZSC	.4560000E-06	CVX1ZZTO	.1540000E-04	CVX2EIFL	.5490000E-05	CVX2INAM	.1230000E-04
CVX2VSFH	.7600000E-05	CVX2ZZSC	.4560000E-06	CVX2ZZTO	.1540000E-04	CVX3EIFL	.5490000E-05
CVX3INAM	.1230000E-04	CVX3VSFH	.7600000E-05	CVX3ZZSC	.4560000E-06	CVX3ZZTO	.1540000E-04
CVX4EIFL	.5490000E-05	CVX4VSFH	.7600000E-05	CVX4ZZSC	.4560000E-06	CVX4ZZTO	.1540000E-04
CVY1RYTC	.7000000E-05	CVY1Y2OP	.4000000E-02	CVY1ZZTO	.4000000E-02	CVY2RYTC	.7000000E-05
CVY2ZZTO	.4000000E-02	CVY3ZZFH	.2070000E-03	CVY4ZZFH	.2070000E-03	CV2620FC	.4560000E-06
CV2626FC	.4560000E-06	CV2627FC	.4560000E-06	CV2670FC	.4560000E-06	CV2800LC	.3300000E-02
CV2800MF	.4560000E-06	CV2800RE	.1900000E-01	CV2802LC	.3300000E-02	CV2802HF	.4560000E-06
CV2802RE	.1100000E-01	CV2803CA	.4000000E-02	CV2803HS	.1000000E-04	CV2803LA	.4000000E-02
CV2803MF	.4000000E-02	CV2806CA	.4000000E-02	CV2806HS	.1000000E-04	CV2806LA	.4000000E-02
CV2806MF	.4000000E-02	CV3850CA	.4000000E-02	CV3850HF	.4000000E-02	CV3851CA	.4000000E-02
CV3851MF	.4000000E-02	DG1ZZZFS	.1340000E-01	DG2ZZZFS	.1340000E-01	DPATCAFH	.5500000E-02
DPATCAFL	.5500000E-02	DPATCBFH	.5500000E-02	DPATCBFL	.5500000E-02	DPATCCFH	.5500000E-02
DPATCCFL	.5500000E-02	DPATCDFH	.5500000E-02	DPATCDFL	.5500000E-02	DPBTCAFL	.5500000E-02
DPBTCBFL	.5500000E-02	DPBTCCFL	.5500000E-02	DPBTCDFL	.5500000E-02	DPOFAAFL	.5500000E-02
DPOFABFL	.5500000E-02			DPOFDAFL	.5500000E-02	DPOFDBFL	.5500000E-02
FCCVX1SS	.1200000E-05	FCCVX2SS	.1200000E-05	FCCVX3FE	.4700000E-05	FCCVX4FE	.4700000E-05
FC2620SS	.1200000E-05	FC2626SS	.1200000E-05	FC2627FE	.4700000E-05	FC2670FE	.4700000E-05
FGOFAAFE	.4700000E-05	FGOFABFE	.4700000E-05	FGOFDAFE	.4700000E-05	FGOFDBFE	.4700000E-05
FW10AZFB	.1100000E-03	FW10BZFB	.1100000E-03	FW13AZFB	.1100000E-03	FW13BZFB	.1100000E-03
INCAPZAM	.1230000E-04	INCBPZAM	.1230000E-04			INY24ZAM	.1230000E-04
LFWNLOOP	.8450000E+00	LOOPZZZZ	.1550000E+00	LS20X1NS	.8700000E-04	LS20X2NS	.8700000E-04
LS20X3NS	.8700000E-04	LS20X4NS	.8700000E-04	LTCVX1FL	.5500000E-02	LTCVX2FL	.5500000E-02
LTCVX3FL	.5500000E-02	LTCVX4FL	.5500000E-02	OPEM02X1	.2000000E-02	CPEM02X2	.2000000E-02
OPEM02X3	.2000000E-02	OPEM02X4	.2000000E-02	OPEM20X1	.2000000E-02	OPEM20X2	.2000000E-02
OPEM20X3	.2000000E-02	OPEM20X4	.2000000E-02	OPESEL28	.1000000E-03	OPFAILPH	.7500000E-03
OPFAILPT	.1500000E-03	OPFAILSM	.6100000E-02	PR02X1FL	.1840000E-06	PR02X2FL	.1840000E-06
PR02X3FL	.1840000E-06	PR02X4FL	.1840000E-06	PR20X1FL	.1840000E-06	PR20X2FL	.1840000E-06
PR20X3FL	.1840000E-06	PR20X4FL	.1840000E-06	PV6601RS	.2300000E-02	PV6602RS	.2300000E-02
P7ARECCA	.2100000E-02	P7ARECLO	.3300000E-02	P7ARECOF	.4000000E-02	P7AZZZFR	.3460000E-03
P7AZZZFS	.4100000E-02	P7AZZZPM	.7590000E-03	P7AZZZTS	.1390000E-02	P7BRECCA	.2100000E-02
P7BRECLO	.3300000E-02	P7BRECOP	.4000000E-02	P7BZZZFR	.3460000E-03	P7BZZZFS	.5300000E-03
P7BZZZPM	.2060000E-04	P7BZZZTS	.1390000E-02	REARYASH	.3000000E-07	REARYBSH	.3000000E-07
REBRYASH	.3000000E-07	REBRYBSH	.3000000E-07	REDPBASH	.3000000E-07	REDPBBSH	.3000000E-07

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GENERAL CALCULATIONS

REDPBCSH	.3000000E-07	REDPBDSH	.3000000E-07	REOFAASH	.3000000E-07	REOFABSH	.3000000E-07
		REOFDASH	.3000000E-07	REOFDBSH	.3000000E-07	RE02X1SH	.3000000E-07
RE02X2SH	.3000000E-07	RE02X3SH	.3000000E-07	RE02X4SH	.3000000E-07	RE20X1SH	.3000000E-07
RE20X2SH	.3000000E-07	RE20X3SH	.3000000E-07	RE20X4SH	.3000000E-07	RYARYATC	.7000000E-05
RYARYBTC	.7000000E-05	RYBRYATC	.7000000E-05	RYBRYBTC	.7000000E-05	RYCVX1SS	.4200000E-07
RYCVX2SS	.4200000E-07	RYCVX3EE	.7000000E-05	RYCVX4EE	.7000000E-05	RYFGAAFE	.7000000E-05
RYFGABFE	.7000000E-05	RYFGDAFE	.7000000E-05	RYFGDBFE	.7000000E-05	RY1CAPTC	.7000000E-05
RY1CBPTC	.7000000E-05	RY1P7ATC	.7000000E-05	RY2CAPTC	.7000000E-05	RY2CBPTC	.7000000E-05
RY2P7ATC	.7000000E-05	RY2620SS	.4200000E-07	RY2626SS	.4200000E-07	RY2622FE	.7000000E-05
RY2670FE	.7000000E-05	RY28X1AM	.4200000E-07	RY28X2AM	.4200000E-07	RY28X3AM	.4200000E-07
RY28X4AM	.4200000E-07	SP02X1FH	.8900000E-07	SP02X2FH	.8900000E-07	SP02X3FH	.8900000E-07
SP02X4FH	.8900000E-07	SP20X1FH	.8900000E-07	SP20X2FH	.8900000E-07	SP20X3FH	.8900000E-07
SP20X4FH	.8900000E-07	SU02X1FL	.1840000E-06	SU02X2FL	.1840000E-06	SU02X3FL	.1840000E-06
SU02X4FL	.1840000E-06	SU20X1FL	.1840000E-06	SU20X2FL	.1840000E-06	SU20X3FL	.1840000E-06
SU20X4FL	.1840000E-06	SWSUCTOP	.4000000E-01	SW1322FB	.1100000E-03	TCAINZAM	.1230000E-04
TCAMBRFO	.1720000E-06	TCASPTAM	.1200000E-04	TCA15TAM	.1200000E-04	TCA48TAM	.1200000E-04
TCASTRAM	.1200000E-04	TCBINZAM	.1230000E-04	TCBMBRFO	.1720000E-06	TCBSPTAM	.1200000E-04

TCD15TAM	.1200000E-04	TCB48TAM	.1200000E-04	TCB5TRAM	.1200000E-04	TCCINZAM	.1230000E-04
TCCMBRFO	.1720000E-06	TCC15TAM	.1200000E-04	TCC48TAM	.1200000E-04	TCC5TRAM	.1200000E-04
TCDINZAM	.1230000E-04	TCDMBRFO	.1720000E-06	TCD15TAM	.1200000E-04	TCD48TAM	.1200000E-04
TCD5TRAM	.1200000E-04	T1RYX1SS	.4200000E-07	T1RYX2SS	.4200000E-07	T1RYX3SS	.4200000E-07
T1RYX4SS	.4200000E-07	W1ZZZZFB	.1100000E-03	W2ZZZZFB	.1100000E-03	W3ZZZZFB	.1100000E-03
W4ZZZZFB	.1100000E-03	W5ZZZZFB	.1100000E-03	W6ZZZZFB	.1100000E-03	W7ZZZZFB	.1100000E-03

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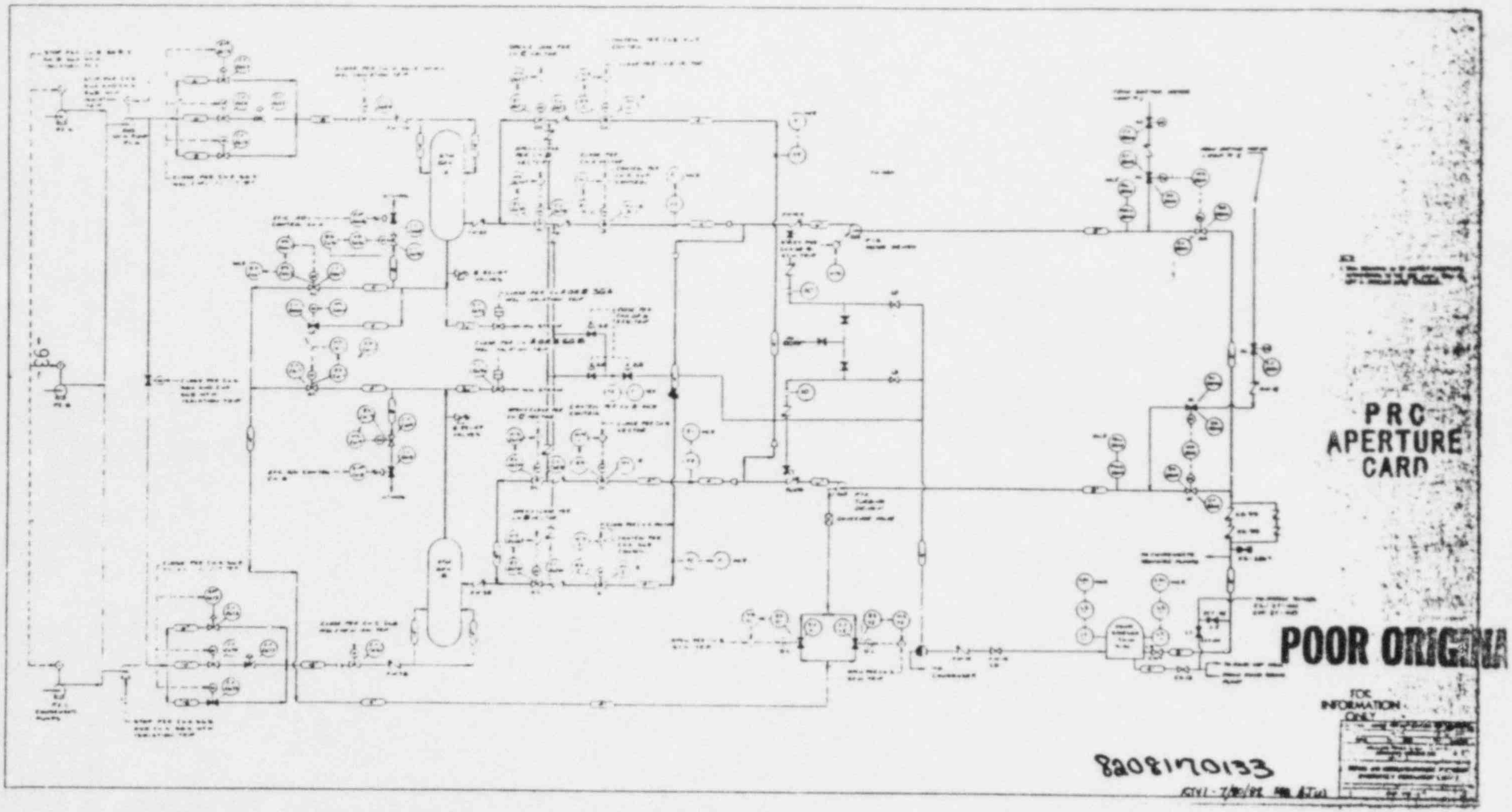
BAOFABXX	9.1×10^{-5}
BIOFABMH	2×10^{-3}
BIOFDBMH	2×10^{-3}
BRA120XX	1.72×10^{-7}
CSPTSAXX	1.2×10^{-5}
DPOFABXX	5.5×10^{-3}
DPOFDBFL	5.5×10^{-3}
INY11ZXX	1.23×10^{-5}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16. ABSTRACT *(200 words or less)*

The purposes of this report are: (1) to review the Emergency Feedwater System Upgrade Reliability Analysis for the Arkansas Nuclear One Nuclear Generating Station Unit No. 1, and (2) to estimate the probability that the Emergency Feedwater System will not perform its mission for each of three different initiators: (1) loss of main feedwater with offsite power available, (2) loss of offsite power, (3) loss of all 4160 VAC power. The scope, methodology, and failure data are prescribed by NUREG-0611, Appendix III.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Reliability Analysis
Auxiliary Feedwater System
Arkansas Nuclear One Nuclear Generating
  Station Unit No. 1
Pump and Valve Failure Rates

17b. IDENTIFIERS/OPEN-ENDED TERMS

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REVIEW OF THE ARKANSAS NUCLEAR ONE GENERATING STATION UNIT NO. 1
EMERGENCY FEEDWATER SYSTEM RELIABILITY ANALYSIS

FEBRUARY 1984