APPENDIX D

HUMAN RELIABILITY ANALYSIS

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D.1 OVERVIEW OF HUMAN RELIABILITY ANALYSIS FOR NORTH ANNA IPE

D.1.1 Introduction

The human reliability analysis (HRA) task of the North Anna IPE project was performed over a period of about 12 months. The general principles of Swain's "Human Reliability Handbook" (Swain, 1987) was used in this analysis. The task was organized into five steps:

1. identification of preliminary human error basic events by the system analysts,
2. collection of operator response times from the simulator,
3. determination of engineering time windows using the MAAP code,
4. detailed evaluation of each operator error included in the NAPS IPE, and
5. review of the final quantification results to confirm proper modeling of operator errors.

This report represents the complete analysis for the HRA task and provides all the background information to each human interaction (HI, also called Human Error Probability, HEP, throughout this report) that has been included in the system fault trees and functional fault trees.

Several factors influence the practical implementation of an HRA task. First, the content of the analysis procedures and instructions together with the available resources (time, budget, personnel) determine how the task is organized and integrated with other PRA study tasks. An equally important factor is the analytical style/experience of the event tree and fault tree modeler; the final decision whether to include/exclude certain HEPs is made in the event tree and fault tree tasks, whereas the human reliability expertise primarily provides input with respect to derivation of HEPs and interpretation of results.

The basic HRA methodology adopted for North Anna IPE is quite similar to the methodology used in other, current U.S. PRA projects. Expert judgment has been an essential aspect of the estimation of human interaction event probabilities, referred to henceforth, as HEPs, but, in order to provide a North Anna specific assessment, the quantitative HRA has been supported by simulator data and an analysis of the July 15, 1987, SGTR event at North Anna.

A series of simulator experiments were conducted during the winter of 1992. The emphasis of these experiments was to generate qualitative insights on a range of operator actions associated with emergency response following SGTR initiators. In addition, response time data were extracted for the operator actions for later use when quantifying non-response probability.

The scope of the current North Anna HRA encompasses a selection of test & maintenance (T&M) related operator errors, together with a relatively large number of emergency procedure based operator actions; the former are henceforth referred to as Type A operator actions, and the latter as Type C operator actions. No operator errors leading to initiating events are addressed explicitly in the North Anna HRA. The Type C category covers a very broad range of operator actions, from simple proceduralized operator responses to relatively complex ex-control room recovery actions (e.g., Unit 1 and Unit 2 cross-ties). There are a number of analytical limitations associated with the North Anna HRA and these are addressed in later sections as appropriate. Initially, only proceduralized recovery actions were addressed (NRC, NUREG-1335), but subsequently, there was some consideration of innovative recoveries.

The HRA task of the North Anna IPE project has been concerned with approximately 70 kinds of basic events representing human error probabilities summarized in Tables D.2-1 and D.3-1. This compares with approximately 100 kinds of HEPs in the Reactor Safety Study (Hall, 1981) and about 50 kinds of HEPs in NUREG/CR-4550 evaluation of Surry Power Station (Bertucio, 1990). Note that, in the final sequence quantification, the post-accident HEPs have been analyzed with respect to their sequence dependencies (if any). Hence, a certain kind of HEP could appear in several different accident sequences and with different HEPs because of differences with respect to equipment availability, or system time-windows. A prudent question to reflect upon is whether the results of the IPE are consistent with previous PRA studies of Surry Power Station (i.e., Reactor Safety Study of 1975, WASH-1400, and the NUREG-1150 effort) and whether new key operator actions have been identified relative to earlier studies.

In comparing the North Anna IPE and other PRA studies the following observations can be made: There are some significant similarities in that HEPs addressed by the IPE-project are also to be found in WASH-1400 and the NUREG-1150 study. During the fifteen years that have elapsed between the RSS and the IPE, significant progress has been made in the area of HRA; whereas the emphasis of WASH-1400 was on system related operator actions, the IPE mostly focuses on the overall accident response. The NUREG-1150 study provides an implementation of the prescriptive approach represented by the shortened version of the 'Human Reliability Handbook' (Swain, 1987). All-in-all, these studies represent different "snap-shots"

of the human reliability considerations associated with accident management at nuclear power stations similar to North Anna.

This appendix contains the complete analysis for the Type A and Type C operator actions addressed in the North Anna IPE. It is supported by analysis files for the Human Interaction, the Accident Sequence Analysis, the System Modeling and Sequence Quantification tasks.

Sections D.2 and D.3 provide an overview of the analysis of test and maintenance actions and control room crew responses to accidents, respectively. Sections D.3.2 and D.4 provide a discussion of the performance of simulator exercises at North Anna. Section D.5 provides the detailed analysis of test and maintenance actions together with the data and equations used in deriving HEPs. Similarly, Section D.6 provides the detailed analysis of the post-accident operator actions. For each HEP there is a summary of applicable procedures and the system time-windows (as applicable).

D.2 ANALYSIS OF TYPE A HUMAN ERROR PROBABILITIES

Human reliability research and development has focused on post-accident operator actions rather than on the pre-accident operator actions. In part this is due to the fact that from the point of view of overall plant safety (assessed severe core damage frequency), human errors associated with test & maintenance activities seldom appear as important. On the other hand, with respect to effective plant operations the potential errors that can be induced while carrying out testing or maintenance need to be assessed in detail. In the North Anna IPE an analysis framework has been adopted that acknowledge the procedures and practices that have been implemented at the power station. This framework builds on the framework used in the Oconee PRA (NSAC and Duke Power Company, 1984).

D.2.1 Quantification of Type A HEPs

For the majority of Type A human errors, test & maintenance operator actions, the THERP model is the generally accepted model for quantification. However, for all the type A events modelled, the error is such that a probability may be obtained directly from one of the tasks in NUREG/CR-1278.

However, the generic HEP (e.g., from NUREG/CR-1278) for a test or maintenance task is modified by accounting for the checking and/or verification in place per plant procedure/policy. For a component with no positive check or verification, the error probability is simply the probability obtained from the tables of NUREG/CR-1278. Table D.2-1 contains a summary of the Type A HEPs used in the North Anna IPE.

D.2.1.1 Impact of Positive Checking

If checking is performed it can actually take two forms: (i) positive check as operational or functional check which if performed, indicates that the component is in the correct position (e.g., flow through a component, differential pressure, indication of pump amps.); and (ii) visual check or verification which relies on plant personnel to confirm that a component is in the correct position. A positive check is normally more "reliable" than a visual check since actual diagnostics is involved requiring active operator involvement. If there is a positive check only, then the unavailability of the components should reflect this; an assumption is that the positive check always restores a misaligned component. Assume the frequency of manipulation is m, the probability of misalignment of the component is U_o, and the frequency of positive checking is V_1. Then the unavailability of the component with position checking is:

$$U_c = [m/(m \cdot U_o + V_1)]U_o \approx (m/V_1) \cdot U_o$$

This formula is analogous to the single component steady-state unavailability given constant failure rate and repair rate.

D.2.1.2 Impact of Verification (Non-Positive Checking)

In the majority of cases the component status is checked visually, e.g., the shift crew members is checking status lights on a control room board panel. This visual checking (or verification) is assumed imperfect (an assumption which is substantiated by operating experience) and there is a probability (say, R) that a previously misaligned valve is not restored. Assume the time between manipulations, on average, is T_m and that the average time between verification is T_v. While manipulating the component it can become misaligned (probability U_o) and will remain misaligned at least until the first verification. There is a likelihood that the verification is ineffective and the misaligned component not restored, probability R.

If a component is initially misaligned, then for a fraction of the time, given by T_v/T_m the component will remain misaligned. For the remainder of the time, $T_m - T_v$, it will have been verified to be available but may remain unavailable. The overall component unavailability, given verification, can now be written as:

$$U_v = (T_v/T_m) \cdot U_o + [(T_m - T_v)/T_m] * R * U_o$$

$$= (f_m/f_v)\ U_o + [(f_v - f_m)/f_v]\ R\ U_o$$

where f_m and f_v are the manipulation and verification frequency, respectively. If verification is a random process with respect to

maintenance, then the component unavailability accounting for verification only can be written as:

$$U_v = (f_m/2f_v) \cdot U_o + [(2f_v - f_m)/2f_v] \cdot R \cdot U_o$$

D.2.1.3 Impact of Positive Checking and Verification

If the frequency of verification f_v is higher than the frequency of checking f_c, and that the verification and checking are randomized with respect to the manipulation, then on average positive, checking occurs $T_c/2$ ($1/2\ f_c$) after maintenance, and on average the verification occurs $T_v/2$ ($1/2\ f_v$) after maintenance. If $T_v < T_c$, this means that verification occurs first on average. The component unavailability is now:

$$U_{c\text{-}v} = (f_m/2f_v) \cdot U_o + R * U_o \cdot [f_m/(2f_c \cdot f_v)] \cdot (f_v - f_c)$$

A detailed task analysis (to address impact of independent verification, post-maintenance operability test, etc.) combined with THERP usually provides results in agreement with the above set of equations. The difference is, if the above equations are used the overall evaluation of Type A HIs can be made more consistent and less time consuming.

D.2.2 Results and Insights

The results of the application of the above framework show the importance of positive checking of component status following a periodic test. Typically the derived HEP for T&M actions with and without positive checking differ by approximately an order of magnitude. Conversely, a change in a test procedure would have a direct impact on the potential human error susceptibility.

With respect to the overall PRA results (assessed severe core damage frequency) for North Anna Power Station, only a few of the Type A actions have any noticeable impact. Common to these actions is the fact that the test procedures do not have provisions for positive checks of component operability status.

In conclusion, the results are consistent with the results of other recent PRA studies. The models and data that have been developed within the North Anna IPE provide a basis for future PRA application studies involving test and maintenance activities and represent an extension of the work published by other investigators. The analysis is summarized in Section D.5.

D.3 ANALYSIS OF TYPE C HUMAN ERROR PROBABILITIES

All recent PRA studies have demonstrated the importance of post-accident operator (Type C) actions relative to the assessed severe core damage frequency. In the early PRA studies of PWR plants typical key Type C actions included the manual switchover to recirculation cooling during LOCA, response to SGTR and response to station blackout. These insights (i.e., PRA-based awareness) coupled with the impact of improved and more sophisticated simulator training, upgraded control rooms, improved emergency procedures, etc., have been acknowledged by all subsequent PRA efforts and subsequently what turned out to be important, say, ten years ago is less important today. Instead new insights have been generated, and typically the current PRA studies tend to generate insights that are much more tied to unique plant features than before, i.e., our understanding of human reliability has evolved to reflect the improved human reliability modeling capability. Section D.3.1 provides an overview of the unique aspects of the technical approach to analyzing Type C actions, and summarizes the insights and results. Section D.3.2 contains a description of the role of simulator exercises on the North Anna IPE. The analysis of Type C HEPs is documented in detail in Section D.6 of this Appendix. Table D.3-1 contains a summary of the Type C HEPs.

D.3.1 Analysis Framework for Type C Actions in North Anna IPE

The preferred approach to the estimation of type C HEP basic events is to use simulator measurements of response times whenever possible. Section D.3.2 discusses the performance of simulator exercises for the North Anna IPE. Section D.4.0 contains additional details of each simulator session. This approach was used whenever North Anna simulator measurements on the specific HEPs were available, and in other cases where it could be argued that, because of certain similarities, the response characteristics could be deduced from these other HEPs for which measurements existed. In other cases, the estimates of timing were obtained from the Accident Sequence Development analysis or engineering judgement whenever necessary.

The approach of the North Anna IPE Type C HEP analysis is based on the event tree representation of Figure D.3-1. There are three parameters of this representation: p_1 represents the probability of errors of cognition which are unrecovered, p_2 represents probability of non-response, and p_3 represents the probability of failure to correctly implement a step of an emergency procedure. The parameter p_1 can essentially be regarded as an appropriate value below which an HEP cannot be expected to be defendable. Because of the use of symptom based procedures, and the use of simulator training, this value is expected to be quite low, and for this study is arbitrarily set as 1E-4 (mean value).

The method for evaluating the parameters p_2 and p_3 attempts to capture the time dependence of the non-response probability. While the p_2 parameter is directly time-dependent, the p_3 parameter is only indirectly so. If a decision to respond (p_2) is taken too late, there may not be sufficient time to correctly implement a step in a procedure in place; e.g., if the automatic safety injection signal fails and the operators initially fail to detect that a safety injection did not take place and RCS pressure is well below the safety injection setpoint once the failure is detected, there may not be sufficient time to initiate the manual safety injection signal before core damage occurs. Hence, the outcome of p_3 is dependent upon the outcome of p_2 and in quantifying the p_2 parameter the analysts must always account for the time it actually takes to implement a procedure step.

Figure D.3-2 defines the time relationships of direct concern in quantifying human reliability. In most cases a shift crew is prompted to take action by an annunciator which sounds at the time of a reactor trip and safety injection actuation. This is defined as time T_0. There are cases, though, where the active/skilled crew may be able to detect an off-normal plant condition prior to reaching the reactor trip setpoint, and by the time the reactor trips the crew has already diagnosed the problem and taken actions to stabilize the plant. This is represented by time T_r in Figure D.3-2. The other times defined below relate to the discussion in the previous paragraph.

With the exception of the time T_w all the times defined above are observable in the simulator environment. Depending on the kind of initiating event that is simulated, it can be easy or quite complex to derive accurate measurements. In some cases it is necessary to observe the procedure reader and the primary side CRO and how they communicate, e.g., the critical procedure step may be on top of a page and by watching the SRO turning a page it is possible to accurately determine when action will be taken. This holds for the "passive" crew response. If the CROs are very experienced/knowledgeable they may be able to diagnose a plant state well ahead of the SRO and in those instances a video recording of the simulator exercise is very helpful in assessing the response time.

D.3.1.1 Estimation of p_2

The method adopted for estimating p_2 is based on the EPRI HCR/ORE correlation. This correlation is a representation of the probability of crew non-response as a function of normalized time (the normalized time is a dimensionless unit which reflects the ratio of time available to crew median response time). Each non-response curve is characterized by two crew response time parameters: A $T_{1/2}$ (crew median response time) and a σ (logarithmic standard deviation of normalized time). With these two parameters,

the probability of crew non-response in a time window T_w is given as:

$$P(T_w) = 1 - \Phi\ [(\ln(T_w/T_{1/2})/\sigma]$$

Where $\Phi(x)$ is the standard normal cumulative distribution (see Table D.3-2). It must be noted that p_2 in the equation is derived based on the assumption that the time window (T_w) is a constant (i.e., no uncertainty). In principle uncertainty in T_w can be handled by performing an integral over the uncertainty distribution function. However, in this study the T_w's are treated as constants obtained from thermal-hydraulic considerations.

D.3.1.2 Estimation of σ

The parameter σ is a measure of the crew-to-crew variability in responding to a specific cue. This variability stems from a range of different factors such as diagnostic difficulty, degree and kind of procedural guidance, level of operator experience, communications between crew members, different response strategies, purely random influences, etc. A problem with the σ is that an all-encompassing and validated data base is not available for HRA applications. The approach used here is to use a sliding scale with values in the range of 0.4 to 1.0 to represent different conditions, using the following considerations.

The basic assumption is that following a reactor trip, as we get further into the accident response one can expect to see larger deviations in crew response times. A large σ can be indicative of difficult diagnosis, need for monitoring meters/alarms, SPDS, or use of different response strategies; i.e., the σ is indicative of how demanding (and stressful) a transient is to the operators. The assumption is that the more demanding a transient the more likely there are to be greater differences in response times. The basis for defining the range of σ-values has been a review of available ORE-data in the context of the scenario descriptions, and observations (event chronologies).

If the crew-response is concerned with immediate actions that are memorized, the response can be regarded as being skill based, and a low value of σ is appropriate. Thus $\sigma = 0.4$ is chosen for HEPs which are in response to the immediate actions of the emergency procedures.

For later operator actions for which there is procedural guidance in the Emergency Operating Procedures and where there has been training, a σ value equal to 0.6 is used to calculate the P_2 term.

For non Emergency Operating Procedures such as Abnormal Procedures, APs, or Operating Procedures, OPs, and there has been training, a value of σ equal to 0.8 is selected.

For extreme cases, where procedural guidance is indirect, and there is no evidence of scenario specific training, but some indication that the crews are knowledgeable about the actions necessary, a σ of 1.0 is used.

D.3.1.3 Estimation of $T_{1/2}$

While some indications of appropriate values to use for the $T_{1/2}$ parameter can be derived by reviewing actuarial data found in accident investigation reports (e.g., SGTR events at R.E. Ginna and North Anna), the most appropriate approach to estimating $T_{1/2}$ is to obtain plant and HEP specific data. The only source of data for such estimates is simulator experiments on the appropriate scenario. Data will of necessity be limited by the number of crews available, and the corresponding uncertainty on the estimates and the non-response probability could be argued to be large. The ORE results show that for the majority of data sets the $T_{1/2}$'s converge relatively fast with a small number of data points, therefore, even when a limited number of trials is feasible, they can provide good estimates of plant and HEP specific $T_{1/2}$'s.

In situations where it was not possible, or convenient, to perform the necessary experiments, interviews with trainers and other knowledgeable persons were used as an alternative to obtaining estimates of $T_{1/2}$'s. If estimates of $T_{1/2}$ were not obtainable (with any degree of confidence), values from NUREG/CR-4550, Vol. 3, were used.

D.3.1.4 Estimation of p_3

The p_3 term is estimated using the tables from NUREG/CR-1278.

Because the North Anna operators are routinely working 12 hour shifts the p_3 term will be doubled as suggested by NUREG/CR-1278. This NUREG indicates that error rate during the last four hours of a twelve hour shift may be as high as 3 to 4 times the error rate during the first eight hours of that same shift. At North Anna the operators have not shown these tendencies of increasing operator error rates. However, to remain consistent with the NUREG/CR-1278 guidance all p_3 terms for Type C HEPs will be doubled and appropriate p_3 terms, which use operations staff rather than instrument technicians, electricians or mechanics, will also be doubled.

D.3.1.5 Immediate Recovery Term, R

The recovery term for Type C HEP basic events, R, was typically set equal to one unless sufficient time was available for recovery to occur. The EOPs do not usually have independent verification of

operator actions. However, there are multiple operators involved during the use of EOPs, so there is a possibility for an independent operator to observe an incorrect action and take recovery action. The general guidelines used to apply a non unity recovery term are dependent on the available time window, T_a.

If T_a is greater than one hour then additional station support personnel will be available due to staffing of the Technical Support Center. The TSC personnel will become independent verification of operator actions which can be monitored within the TSC (e.g., using SPDS or the displayed process parameters). In this case R = 0.1 is applied to the p_3 term only.

If T_a is greater than 12 hours then the TSC has its full manning and the original shift is assumed to be replaced by a new shift of operators. These new operators will provide additional independence and potential for error recovery. In this case R = 0.1 is applied to the p_2 and p_3 terms.

If T_a is greater than 24 hours then the TSC has its full manning and at least two shift changes have occurred. The on duty operators have resumed taking routine surveillance logs. These computerized and written logs are compared to standards and to previous readings to identify unacceptable values or trends. This active checking provides a greater assurance of recovering from previous operator errors. In this case R = 0.01 is applied to the p_2 and p_3 terms.

D.3.2 Role of Simulator Exercises in North Anna IPE

The use of training simulators to support the human reliability analysis (HRA) tasks of PRA studies was first proposed in the early 1980s. Although the basic concept of extracting information from simulator exercises for the purpose of enhancing the quality and applicability of plant specific HRA's is relatively old, few PRA projects have actually adopted the concept. This section provides an overview of work done by the nuclear industry with regard to utilization of simulator exercises for HRA purposes, and a description of the approach taken by Virginia Power for the North Anna IPE.

D.3.2.1 Background

In the context of HRA, a training simulator can be used to determine the time taken in performing a series of detection, diagnosis, and decision making tasks for shift crews responding to a repeated simulator exercise, and to gain qualitative insights on the use of emergency procedures, crew communications, man-machine interactions, etc. An opportunity to watch shift crews is in

itself valuable since it can help validate the PRA sequence descriptions and the way control room crew responses are modeled in such sequences. Assuming availability of a high fidelity simulator, then this can be a tool for enhancing PRA realism and to promote practical applications of PRA models and data.

For the North Anna IPE the training simulator was used for gaining further insights regarding the use of emergency procedures qualitative data on cognitive difficulties in accident response, and quantitative data on operator response times and task completion times for use with the modified HER correlation.

D.3.2.2 Simulator Exercises for the North Anna IPE

During the period of January and February 1992 members of the North Anna IPE team collected information on shift crew responses to SGTR accidents. The training exercises were part of the normal Licensed Operator Requalification Program (LORP) but modified somewhat to better meet the needs of the IPE; i.e., by modeling specific equipment failures that were included by the preliminary event trees and fault trees. Information was collected by observing the crew responses, and video tape records with sound tracks allowed the investigators to prepare detailed event chronologies and to identify when a diagnosis or decision was made. Data from a total of 7 scenarios were collected during the period in question.

The simulator exercises provided data on crew response times and task completion times, as well as qualitative insights on various human factors related influencing factors. They also provided qualitative insights on crew interactions (delegation of responsibilities), crew communications and the usage of procedures. The data on HEPs derived from the simulator exercises provide important input to the final quantification of human error probabilities (HEPs), but of equal importance is the qualitative information which identifies the ease/difficulty by which the shift crews respond to various cues.

D.3.2.3 Discrepancy Between Simulator and Actual Control Room

The subject of simulator fidelity (i.e., how closely does the simulator replicate the actual plant with regard to its response to various initiators) and its impact on shift crew responses has been raised by human factors researchers. For the present study a number of fidelity related issues have impacted the quality of derived insights. These specific issues are generic to any modern simulator facility, however. A common problem relates to ex-control room actions and interactions between the Control Room and Service Building / Auxiliary Building operators; the simulator instructors have to take an active role in the exercises when it

comes to ex-control room actions and this may impose biases when it comes to measuring response times.

At the North Anna Power Station a modern simulator has been installed and there is a one-to-one correspondence between the bench board, instrument and annunciator panel layouts in the simulator and the actual plant (in accordance with the 10CFR55.45 rule on "Operating Tests"). Furthermore, the simulated valve stroking times and the actual valve stroking times are the same for the most part; e.g., for the simulated Recirculation Mode Transfer (RMT) during large break LOCA the time for manual implementation is very realistic. Overall, the simulator exercises of this study are believed not to have been impacted in any significant negative way by potential simulator software limitations.

The subject simulator exercises were all part of the LORP at North Anna. Consequently, there were considerable simulator instructor intervention throughout the exercises and the crews knew beforehand (at least in general terms) which accidents they were to be exposed to. This could have imposed substantial biases on the derived data, but during all the important/critical phases of the accident response the instructors refrained from participating in the crew response. It was only during periods when a stable plant condition had been reached, or prior to implementing an accident, that the instructors intervened to elaborate on the emergency procedures or to provide critique.

D.3.2.4 Simulator Exercises and the p_2 Parameter

The basic assumption for the p_2 parameter is that it is time-dependent and bounded by the operators' ability to detect and diagnose an off-normal plant state before any safety limits of the NSSS is exceeded. If there is ample time available to respond, then there will also be opportunities to recover from any previous mistakes without impairing safety. If the available time is short, then it can be extremely important that timely response is made to avoid exceeding the "point-of-no-return". The human reliability technology has been devoted to the assessment of those factors that affect human errors in a control room environment. To better understand the potential error causes and error modes, various classification schemes have been proposed for mental (cognitive) processing and these schemes can be used to support the quantification of HEP's. One such classification scheme is, as already indicated, dividing the detection/diagnosis/decision-making into skill-based, rule-based and knowledge-based behavior (or information processing):

- **Skill-Based Processing**. This occurs in situations involving mainly simple physical operations of controls, or where equipment is manipulated from one position to another. The operator is sufficiently highly skilled or practiced such that

no conscious planning or monitoring is required to execute the actions.

- **<u>Rule-Based Processing</u>**. Involves diagnosis or action where a pattern of symptoms is associated with a cause by the operator using a written procedure; for the diagnosis a rule like IF <condition X> THEN <cause Y> is used, for an action or set of actions a rule like IF <situation X> THEN <do Y> is used.

- **<u>Knowledge-Based Processing</u>**. This is required if the operator cannot refer to any existing procedure or "rule-of-thumb", and therefore has to go back to first principles and utilize his/her overall technical understanding of the situation.

This is a relatively simplistic (but often used) classification scheme which is still lacking a formal verification and validation. Nevertheless, it helps provide a structure for observing and analyzing simple human actions. Simulator exercises can help identify cognitive behavior type. If, for example, the CRO's take corrective action prior to the SRO (procedure reader) calling out the relevant step of a procedure, then the shift crew is in a skill-based mode of operation. On the other hand, if the CRO's are not acting unless prompted by the procedure reader, the shift crew is in a rule-based mode of operation. In cases where there are no clear indications/alarms of an off-normal condition but the crew is able to deduce what the plant condition is by observing instrumentation trending, using SPDS, etc., the crew is in a knowledge-based mode of operation. Usually the emergency procedure in use does not directly address the plant condition when the knowledge-based processing is required; one such example would be, say, the V-sequence (interfacing systems LOCA), or loss of cooling during cold shutdown.

In certain instances, it is straightforward to identify the skill-based and rule-based processing during simulator exercises. For identification of knowledge-based processing it is a requirement that the observers have an intimate understanding of the simulated transient. It is also required that the simulator instructors and observers communicate sufficiently beforehand so that a transfer to knowledge-based processing can be identified. This holds, in general, for simple actions prior to a simulated accident and once a stable plant condition has been reached.

There are several complicating factors, though. Sometimes the crew responses are not clear-cut rule-based/skill-based/knowledge-based, instead they are a mixture of response types and there may even be transitions from one category to another while responding to a specific cue. When this is the case the observers need to carefully note this and provide sufficient background information to support a reasonable interpretation by the time the HR modeling takes place.

For the skill-based processing there are usually opportunities for recovery should the CRO's omit to take correct action since the procedure reader normally will be a couple of steps behind the CROs in his/her reading of the procedure. The skill-based processing is often representative of memorized "immediate action steps" in a procedure; i.e., the crews have been exposed to the particular scenario on numerous occasions and are also very familiar with the meaning/implications of the procedure steps.

With regard to quantitative information derived from simulator exercises, and assuming the use of the correlation as represented in EPRI NP-6560 (Moieni, et al, 1989) provides a reasonable approach to estimating the p_2 parameter, the following time measurements need to be established:

Tr = operator non-procedure initiated response time;
$T_{1/2}$ = operator procedure directed response time;
T_a = task action time (time for manual implementation).

The former is needed to derive a characteristic response time (median) for direct implementation in the correlation, the latter is required to compute accurate time windows for the crew response (see Section D.3.1).

D.3.2.5 Collection and Analysis of Simulator Data on Crew Responses

The following sections describe the approach taken to extract HEP information from the North Anna training simulator for incorporation into the IPE. The objective of this data collection was to derive a quantitative basis for selected North Anna specific estimates of HI event probabilities as well as qualitative information on how the shift crews approach accident response, support the validation of the overall representation of HI's in the event trees and fault trees; e.g., cognitive vs. control actions, dependent vs. independent actions, assumptions regarding the use of Unit 1/Unit 2 cross-ties, assumptions regarding stress levels, and on the interpretation of the event probabilities.

D.3.2.6 Collection of the Data

There are ways by which most of the simulator data collection can be automated, e.g., via the simulator computer it is feasible to get printouts of all the essential plant primary parameters as a function of time, and when in time hardware failures are introduced, as well as when in time operators take action (i.e., opening/closing valves). The problem with a highly automated data collection scheme is that the ensuing analysis of the data tends to become very time-consuming (and expensive). For the North Anna IPE a manual data collection was pursued.

At least one member of the North Anna IPE team was present at the simulator during all of the seven exercises. For each session notes were taken by the observer(s). These notes included key plant state transitions, entry into Emergency Procedure 1-E-0, transitions from one procedure to another, and the observed operator actions in response to annunciators. By following the shift crews in action and listening to the communications between (primarily) the SRO and the two CRO's it was possible to develop detailed chronologies of how the crews interacted with the plant through the control room. Also any difficulties in using the procedures or failures to take correct and timely action were noted.

During each session, video tape records (with sound tracks) were taken. These records provided a very useful back-up to the initial event chronologies developed by the observer. There were always three simulator exercises in the morning and three exercises in the afternoon. Upon completion of each day's simulator training the video records were reviewed and the written records developed by the observer were modified and enhanced as necessary to correctly represent the shift crew actions and the timing; i.e., the video records were an essential part of time response verification. Following this review the final event chronologies were prepared together with a commentary regarding interesting observations.

D.3.2.7 Analysis of Simulator Data

The emphasis of the analysis was on the determination of how the procedures were used by the crews and how the responsibility of bringing the plant to a stable condition was divided among the crew members. This analysis was done in parallel with the QC of the observer notes by reviewing the video records. Any deviations from the anticipated crew response was noted, particularly with reference to the use of emergency procedures.

The crews that participated in the simulator exercises consisted of regular shift crews (STA, SRO, and licensed and non-licensed CRO's) and non-shift crews (North Anna site support staff holding reactor operating licenses). For the most part, all of the crews responded to the simulated accidents in a consistent manner.

Before developing and discussing qualitative insights herein, it is emphasized that in HRA the focus is on understanding of which factors may cause operator errors. There is nothing "mechanistic" about assessing HR and any time data that are available must be well understood before adopted for use together with any HEP quantification scheme.

Another objective of the simulator experiments, however, was to collect time data on operator responses. This is presented in Section D.4. This was not done in order to measure the performance

of the crews, however. These data primarily provide for a way of extracting qualitative insights in a more structured manner than would have been the case otherwise. A review of the time data will simply help identify any significant deviations, i.e., if it turns out that, say, one crew requires a long time to respond this is usually due to some cause which can be attended to in the continued training program, and so on.

In a simulator environment there are some factors that can impose biases on the way a crew responds to a simulated accident. It is standard practice in operator training to rotate the job functions among the crew members. This was the case during the subject exercises as shown in Tables D.4-1 through D.4-7. Another factor of possible concern is that the simulator can affect the operator expectations or performance during an exercise, i.e., knowing that it will be exposed to a simulated event a crew may perform in an uncharacteristic manner. For the most part, though, the crews will perform under stress levels very similar to what would be the case in the plant.

In responding to the simulated accidents, two different styles of organizing the accident response were observed. A predominant style was that of letting a "dominant" SRO take complete charge and where all (or most) of the crew communications were prompted by requests from the SRO. This sometimes caused an inefficient response since the CRO's seemed to use "tunnel vision" by acting in a reactive mode only. In a few cases a relatively poor "management of communications" was noted because of the reluctance to delegate responsibilities in the accident response.

The other style of operation was characterized by active crew members and a SRO who let the CRO's carry out the immediate actions of 1-E-0, and later he/she followed up by verifying that the steps had actually been taken. Following completion of the immediate actions, the SRO always waited to proceed with reading the procedure until the CROs had completed a step.

It is obvious that the way the accident response is organized at the onset of reactor trip plays an important role in terms of efficiency. If an off-normal condition is detected and responded to early, the more time will be available for the other key steps of the response, and the overall stress level will go down.

There are equipment malfunctions that can become "masked" by other alarms/annunciators once a reactor trip has occurred. It is therefore important that the crew members clearly communicate any observed deviations while responding to, say, 1-E-0.

D.4 SIMULATOR EXERCISES

The simulator exercises were intended to provide additional insight into the operator response time for use in calculating the human error probabilities. Steam Generator Tube Ruptures were the accidents performed on the North Anna simulator.

Tables D.4-1 through D.4-7 provide the timing information for the seven simulator exercises. Table D.4-8 is a summary of the simulator results. The write up of the sessions are not intended to be exact quotes of the spoken words. Instead they are simplifications allowing sufficient detail to understand the timing of the events without analyzing the communication between operators. For example, the write ups will list the step number of each procedure without quoting every word spoken concerning the operator actions. Simplification is also used when non procedure actions are taken. Certainly not all operator actions are noted, only those which seemed to provide future benefit to understanding the simulator session, especially the timing of the Type C (post operator actions) HEPs basic events used in the North Anna IPE.

Attempts were made to identify which operator performed which actions. However, who actually took an action is not very important. The operators are considered as a group performing the actions directed by procedure or outside of the procedure.

Information contained within parenthesis is provided to enhance the understanding of the simulator sessions. It is typically information concerning what the simulator instructor is programming into the simulator computer. Also provided are RCS and SG parameters to assist in understanding the unit conditions.

Up to three operator response times for each HEP basic event are documented. The "operator initiative" timings are the times it takes for an operator to perform an action without being directed by the procedure. These operator actions are typically the immediate actions which are memorized verifications that the operator performs without the procedure reader directing the actions. This differential time is measured from when the SRO decides to initiate a reactor trip or safety injection until an operator takes the desired action or identifies an equipment malfunction. The "procedure" timings are the times it takes for the procedure to direct the operators to take a certain action. This differential time is measured from when the SRO decides to initiate a reactor trip or safety injection until the procedure reader verbalizes the desired operator action. The "step completion" timings are how long it takes to perform the actions required by the specific step represented by the basic event. This differential time is measured from when the procedure reader first reaches a particular step until the next step is reached.

D.5 DETAILED ANALYSIS OF OPERATOR ACTIONS DURING NORMAL OPERATION

D.5.1 1CHHEP-MOV-1270A

D.5.1.1 Analysis: 1CHHEP-MOV-1270A

- Equivalent Surry HRA: 1CHHEP-MOV-1270A
  see IPE report page D.2-6 & -7
  calculated mean = 1.092E-4

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-8.03	Charging Pump 1-CH-P-1C, Rev 9, 4-27-89.
1-OP-1.1	Unit Startup From Mode 5 at 140°F or less Mode 5 at less than 200°F, Rev 24, 10-18-90.
1-OP-1.3	Unit Startup From Mode 5 to Mode 4, Rev 27, 10-18-90.
1-OP-1.4	Unit Startup From Mode 4 to Mode 3, Rev 26, 10-2-90.
1-OP-8.1	Chemical and Volume Control System, Rev 22, 8-30-89.
1-OP-8.1A	Valve Checkoff Chemical and Volume Control System Auxiliary Building and Quench Spray Pump House, Rev 6-P1, 12-17-91.
1-PT-14.3	Charging Pump 1-CH-P-1C, Rev 18, 10-4-90.
1-PT-14.4	Charging Pump Head Curve Verification, Rev 4, 1-10-91.

- 1-LOG-4 does not verify 1-CH-MOV-1270A position.

- 1-MOP-8.03 provides directions for removing Charging Pump 1-CH-P-1C from service for maintenance and returning the pump to service after maintenance. The 5.3 series of steps are performed whenever the pump is being taken out of service for major mechanical maintenance. Step 5.3.3 closes 1-CH-MOV-1270A so that the valve is closed during maintenance of 1-CH-P-1C. Step 5.3.4 opens the electrical supply breaker 1H1-2SC3 which de-energizes the MOV. This step also places an red electrical danger tag on the breaker to prevent inadvertent re-closure of the breaker. This step also places a yellow mechanical danger tag on the handwheel of the valve. The 5.4 series of steps are performed whenever the pump is being returned to service after major mechanical maintenance. Step 5.4 removes the mechanical danger tag and crack opens 1-CH-MOV-1270A, this step is independently verified. Step 5.4.7 removes the electrical danger tag and closes the electrical breaker 1H1-2SC3, this step is independently verified. Step 5.4.9 instructs the CRO to open 1-CH-MOV-1270A, this step is independently verified. Step 4.8 is a precaution and limitation of 1-MOP-8.03 which states Attachment 1 is provided to help in completing tagging

reports. Item 15 of this attachment indicates that the breaker 1H1-2SC3 should be tagged in the open position and returned to the closed position. Item 20 of this attachment indicates that 1-CH-MOV-1270A should be tagged in the closed position and returned to the closed position.

- 1-OP-1.1 step 5.4 verifies Charging System flow path to RCS with a Charging Pump is operating in accordance with 1-OP-8.1. Step 5.13 verifies that the Charging System is in service by ensuring that a Charging Pump is operating in accordance with 1-OP-8.1.

- 1-OP-1.3 does not verify proper Charging Pump valve alignment.

- 1-OP-1.4 Step 5.10 instructs when the lowest T_c indicates RCS temperature is greater than 325°F then within one hour ensure that a second Charging Pump is operable. The step does not specifically require 1-OP-8.1 to be used. There is no mention of Charging Pump suction valves in this procedure. Step 2.3.2 is the Technical Reference for Operating Procedures. This step does not reference 1-OP-8.1 but does list eight other OPs.

- 1-OP-8.1 Section 4.2 is for starting or transferring Charging Pumps. Step 4.2.4 verifies open the normal discharge 1-CH-MOV-1286C, alternate discharge 1-CH-MOV-1287C, Recirculation 1-CH-MOV-1275C, normal suction 1-CH-MOV-1270A, alternate suction 1-CH-MOV-1270B, and common recirculation 1-CH-MOV-1373. This step is independently verified. This step is written to be applicable for all three Charging Pumps.

- 1-OP-8.1A does not list MOVs, only manual valves.

- 1-PT-14.3 is performed every three months. Step 6.3 opens 1-CH-MOV-1275C and 1-CH-MOV-1373 with independent verification. Step 6.4 states that if 1-CH-P-1C is supplying the charging header, then place 1-CH-P-1A or 1-CH-P-1B in service using 1-OP-8.1. Step 6.4 also closes 1-CH-MOV-1286C and 1-CH-MOV-1287C with independent verification. After the recirculation test is completed the procedure does not realign the Charging Pump valves or refer to 1-OP-8.1.

- HEP Calculation:

Input Parameters:

U_0 = 2E-2, 1E-2 is the estimated human error probability from NUREG/CR-1278 Table 20-7, item 4 estimated probabilities of errors of omission when written procedures are specified and when checkoff provisions are not correctly used. Error factor = 3. This high value is chosen because of the possible confusion of the proper valve position when using MOP-8.03 and the potential lack of valve verification when using 1-OP-1.4. When MOP-8.03 is rewritten to more clearly identify the correct position

of the Charging Pump MOVs and when 1-OP-1.4 specifically requires 1-OP-8.1 to be used to place a second Charging Pump in service then use U_0 = 3.0E-3 from NUREG/CR-1278, Table 20-7, item 2. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 2.0E-2

- Adjustment For Recovery:

R = 1, the recovery factor. No credit is taken for recovery from this Human Error. Even though MOP-8.03 uses independent verification for opening 1-CH-MOV-1270A, Attachment 1 appears to reverse this by suggesting the valve be placed in the closed position when returned to service. Also 1-OP-8.1 has independent verification but this procedure is not always utilized.

HEP(median) = HEP * R = 2.0E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 2.0E-2 * 1.25 = 2.50E-2

D.5.1.2 Summary: 1CHHEP-MOV-1270A

If a procedure change is made to verify the Charging pump suction valves are open on non running pumps once per shift then the point estimate for this HEP can be reduced to the value used for the Surry IPE, mean = 1.092E-4. With an error factor of 3 the median will be 8.736E-5.

Fault Trees: HH100, HR100, CH200.

Gates: GHH1744 (OR) Pump suction failures.
GHR1742 (OR) Pump 1C fails to start.
GCH2332 (OR) Pump fails to start.

Note that this event was inadvertently omitted from these gates before final quantification. To compensate for this omission the basic event point estimate for 1CHPAT-FS-1CHP1B and 1CHPAT-FS-1CHP1C has been increased by value for 1CHHEP-MOV-1270A. These

Physical Id: 1CHHEP-MOV-1270A

Description: CRO STARTS CHARGING PUMP C WHEN SUCTION MOV-1270A IS CLOSED

Failure Rate: 1.092E-4

Distribution: Lognormal
Median: 8.736E-5
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.2 1CHHEP-MOV-1275A

D.5.2.1 Analysis: 1CHHEP-MOV-1275A

- Equivalent Surry HRA: 1CHHEP-MOV-1275A
  see IPE report page D.2-8 & -9
  calculated mean = 9.8568E-4

- NAPS Procedures:

1-MOP-8.01	Charging Pump 1-CH-P-1A, Rev 9, 4-27-89.
1-OP-8.1	Chemical and Volume Control System, Rev 22, 8-30-89.
1-OP-8.1A	Valve Checkoff Chemical and Volume Control System Auxiliary Building and Quench Spray Pump House, Rev 6-P1, 12-17-91.
1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-PT-14.1	Charging Pump 1-CH-P-1A, Rev 16, 10-4-90.
1-PT-14.4	Charging Pump Head Curve Verification, Rev 4, 1-10-91.

- 1-LOG-4 does not verify 1-CH-MOV-1275A position.

- 1-MOP-8.01 provides directions for removing Charging Pump 1-CH-P-1A from service for maintenance and returning the pump to service after maintenance.

- 1-OP-1.1 Step 5.4 verifies Charging System flow path to RCS with a Charging Pump is operating in accordance with 1-OP-8.1. Step 5.13 verifies that the Charging System is in service by ensuring that a Charging Pump is operating in accordance with 1-OP-8.1.

- 1-OP-1.3 does not verify proper Charging Pump valve alignment.

- 1-OP-1.4 Step 5.10 instructs when the lowest T_c indicates RCS temperature is greater than 325°F then within one hour ensure that a second Charging Pump is operable. The step does not specifically require 1-OP-8.1 to be used. Step 2.3.2 is the Technical Reference for Operating Procedures. This step does not reference 1-OP-8.1 but does list eight other Ops.

- 1-OP-8.1 Section 4.2 is for starting or transferring Charging Pumps. Step 4.2.4 verifies open the normal discharge 1-CH-MOV-1286A, alternate discharge 1-CH-MOV-1287A, Recirculation 1-CH-MOV-1275A, normal suction 1-CH-MOV-1267A, alternate suction 1-CH-MOV-1267B, and common recirculation 1-CH-MOV-1373. This step is independently verified. This step is written to be applicable for all three Charging Pumps.

- 1-OP-8.1A does not list MOVs, only manual valves.

- 1-PT-14.1 is performed every three months. Step 6.3 opens 1-CH-MOV-1275A and 1-CH-MOV-1373 with independent verification. Step 6.4 states that if 1-CH-P-1C is supplying the charging header, then places 1-CH-P-1A or 1-CH-P-1B in service using 1-OP-8.1. Step 6.4 also closes 1-CH-MOV-1286A and 1-CH-MOV-1287A with independent verification. After the recirculation test is completed the procedure does not realign the Charging Pump valves or refer to 1-OP-8.1.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.2.2 Summary: 1CHHEP-MOV-1275A

Fault Trees: CH100

Gates: GCH1251 (OR) Pump dead heads due to inadvertent loss of mini-flow recirc, Charging Pump 1A.

Physical Id: 1CHHEP-MOV-1275A

Description: CRO LEAVES CHARGING PUMP A RECIRC VALVE MOV-1275A CLOSED___

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.3 1CHHEP-MOV-1275B

D.5.3.1 Analysis: 1CHHEP-MOV-1275B

- Equivalent Surry HRA: 1CHHEP-MOV-1275B
  see IPE report page D.2-10
  calculated mean = 9.8568E-4

- NAPS Procedures:

1-MOP-8.02	Charging Pump 1-CH-P-1B, Rev 11, 4-27-89.
1-OP-8.1	Chemical and Volume Control System, Rev 22, 8-30-89.
1-OP-8.1A	Valve Checkoff Chemical and Volume Control System Auxiliary Building and Quench Spray Pump House, Rev 6-P1, 12-17-91.
1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.

1-PT-14.2 Charging Pump 1-CH-P-1B, Rev 17, 8-9-91.
1-PT-14.4 Charging Pump Head Curve Verification, Rev 4, 1-10-91.

- 1-LOG-4 does not verify 1-CH-MOV-1275B position.

- 1-MOP-8.02 provides directions for removing Charging Pump 1-CH-P-1B from service for maintenance and returning the pump to service after maintenance.

- 1-OP-1.1 Step 5.4 verifies Charging System flow path to RCS with a Charging Pump is operating in accordance with 1-OP-8.1. Step 5.13 verifies that the Charging System is in service by ensuring that a Charging Pump is operating in accordance with 1-OP-8.1.

- 1-OP-1.3 does not verify proper Charging Pump valve alignment.

- 1-OP-1.4 Step 5.10 instructs when the lowest T_c indicates RCS temperature is greater than 325°F then within one hour ensure that a second Charging Pump is operable. The step does not specifically require 1-OP-8.1 to be used. Step 2.3.2 is the Technical Reference for Operating Procedures. This step does not reference 1-OP-8.1 but does list eight other OPs.

- 1-OP-8.1 section 4.2 is for starting or transferring Charging Pumps. Step 4.2.4 verifies open the normal discharge 1-CH-MOV-1286B, alternate discharge 1-CH-MOV-1287B, Recirculation 1-CH-MOV-1275B, normal suction 1-CH-MOV-1269B, alternate suction 1-CH-MOV-1269B, and common recirculation 1-CH-MOV-1373. This step is independently verified. This step is written to be applicable for all three Charging Pumps.

- 1-OP-8.1A does not list MOVs, only manual valves.

- 1-PT-14.2 is performed every three months. Step 6.3 opens 1-CH-MOV-1275B and 1-CH-MOV-1373 with independent verification. Step 6.4 states that if 1-CH-P-1C is supplying the charging header, then places 1-CH-P-1A or 1-CH-P-1B in service using 1-OP-8.1. Step 6.4 also closes 1-CH-MOV-1286A and 1-CH-MOV-1287A with independent verification. After the recirculation test is completed the procedure does not realign the Charging Pump valves or refer to 1-OP-8.1.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate

has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.3.2 Summary: 1CHHEP-MOV-1275B

Fault Trees: CH100

Gates: GCH1274 (OR) Transfer gate - other failures, Charging Pump 1B.

Physical Id: 1CHHEP-MOV-1275B

Description: CRO LEAVES CHARGING PUMP B RECIRC VALVE MOV-1275B CLOSED___

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
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Why modified: NAPS IPE Final Quantification Value

D.5.4 1CHHEP-MOV-1373

D.5.4.1 Analysis: 1CHHEP-MOV-1373

- Equivalent Surry HRA: 1CHHEP-MOV-1373
  see IPE report page D.2-11 & -12
  calculated mean = 9.8568E-4

- NAPS Procedures:

1-MOP-8.01	Charging Pump 1-CH-P-1A, Rev 9, 4-27-89.
1-MOP-8.02	Charging Pump 1-CH-P-1B, Rev 11, 4-27-89.
1-MOP-8.03	Charging Pump 1-CH-P-1C, Rev 9, 4-27-89.
1-OP-8.1	Chemical and Volume Control System, Rev 22, 8-30-89.
1-OP-8.1A	Valve Checkoff Chemical and Volume Control System Auxiliary Building and Quench Spray Pump House, Rev 6-P1, 12-17-91.
1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-PT-14.1	Charging Pump 1-CH-P-1A, Rev 16, 10-4-90.
1-PT-14.2	Charging Pump 1-CH-P-1B, Rev 17, 8-9-91.
1-PT-14.3	Charging Pump 1-CH-P-1C, Rev 18, 10-4-90.
1-PT-14.4	Charging Pump Head Curve Verification, Rev 4, 1-10-91.

- 1-MOP-8.01 -8.02 and -8.03 provide directions for removing Charging Pumps from service for maintenance and returning the pump to service after maintenance.

- 1-OP-1.1 step 5.4 verifies Charging System flow path to RCS with a Charging Pump is operating in accordance with 1-OP-8.1. Step 5.13 verifies that the Charging System is in service by ensuring that a Charging Pump is operating in accordance with 1-OP-8.1.

- 1-OP-1.3 does not verify proper Charging Pump valve alignment.

- 1-OP-1.4 Step 5.10 instructs when the lowest T_c indicates RCS temperature is greater than 325°F then within one hour ensure that a second Charging Pump is operable. The step does not specifically require 1-OP-8.1 to be used. Step 2.3.2 is the Technical Reference for Operating Procedures. This step does not reference 1-OP-8.1 but does list eight other OPs.

- 1-OP-8.1 section 4.2 is for starting or transferring Charging Pumps. Step 4.2.4 verifies open the normal discharge MOVs, alternate discharge MOVs, Recirculation MOVs, normal suction MOVs, alternate suction MOVs, and common recirculation 1-CH-MOV-1373.

This step is independently verified. This step is written to be applicable for all three Charging Pumps.

- 1-OP-8.1A does not list MOVs, only manual valves.

- 1-PT-14.1, -PT-14.2 and -PT-14.3 are performed every three months alternating between one PT each month. Step 6.3 opens the pump specific recirculation MOV and 1-CH-MOV-1373 with independent verification. After the recirculation test is completed the procedure does not realign the Charging Pump valves or refer to 1-OP-8.1.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.4.2 Summary: 1CHHEP-MOV-1373

Fault Trees: CH100

Gates:	GCH1251	(OR) Pump dead heads due to inadvertent loss of mini-flow recirc, Charging Pump 1A.
	GCH1274	(OR) Transfer gate - other failures, Charging Pump 1B.

Physical Id: 1CHHEP-MOV-1373

Description: CRO LEAVES CHARGING PUMP RECIRC VALVE MOV-1373 CLOSED

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.5.5 1FWHEP-HCV-100C

D.5.5.1 Analysis: 1FWHEP-HCV-100C

- Equivalent Surry HRA: 1FWHEP-1FW155156
  see IPE report page D.2-17
  calculated mean = 7.991E-4

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.01	Auxiliary Feedwater Pump 1-FW-P-3A, Rev 13, 1-8-87.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.
1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.2	Auxiliary Feedwater Pump (1-FW-P-3A) Test, Rev 32, 8-19-91.
1-PT-71.2Q	1-FW-P-3A Auxiliary Feedwater Pump, Rev 3, 8-19-91.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.
1-ST-13	Motor Driven Auxiliary Feedwater Pump Endurance Test, 11-15-79.

- 1-LOG-4 does not verify valve positions.

- 1-MOP-31.01 provides instructions for removing Auxiliary Feedwater Pumps 1-FW-P-3A from service for maintenance, and returning it to service upon the completion of maintenance. Step 4.2.5 removes mechanical danger tags and positions the manual valves appropriate for restoring the pump to service. These steps are independently verified. Step 4.2.5.2 closes 1-FW-166 discharge to MOV header. Step 4.2.5.3 locks open 1-FW-172 the manual valve for discharge to HCV header. Step 4.2.9 verifies operability of the pump with 1-PT-71.2 or 1-PT-71.2Q. HCV-100C is not specifically mentioned in this procedure.

- 1-OP-31.2 step 5.1.3 opens 1-FW-HCV-100C from 1-FW-P-3A to C SG. Step 5.1.4 verifies six annunciators listed are not lit. Annunciator 1A-B4 lit with a red light (most are white) whenever HCV-100C is not fully open. This annunciator will be detected even if not in 1-OP-31.2.

- 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-172 and 1-FW-HCV-100C are verified in the open position.

- 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 5.4.5 unlocks and closes 1-FW-172. Step 5.4.11 opens and locks 1-FW-172. This step is independently verified.

- 1-PT-71.2 verifies operability of 1-FW-P-3A and its associated flow path. It is performed every 31 days or after maintenance. Step 6.6.1 verifies 1-FW-HCV-100C is open, and 1-FW-172 is locked open. Step 6.6.5 closes 1-FW-HCV-100C. Step 6.6.12 fully opens 1-FW-HCV-100C. This step is independently verified. Step 6.6.13 verifies 1A-B4, Aux FW Pumps Discharge Vlv HCV-FW-100C Not Full Open, is not lit.

- 1FWHEP-HCV-100C will be used to represent the operator actions associated with misalignment of 1-FW-HCV-100C or other suction and discharge valves which prevent 1-FW-P-3A from delivering water to Steam Generator C.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:
HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:
R = 0.1. It is possible to use R = 0.0001 as the recovery factor. From NUREG/CR-1278, Table 20-23, The Annunciator Response Model estimated HEPs for multiple annunciators item 1 column 1. This is true for HCV-100C. For the manually operated valves it may be more appropriate to use at least 0.1 or 0.01 since these valves are independently verified within the restoration procedures and verified by system valve alignment check. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions, etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.5.2 Summary: 1FWHEP-HCV-100C

Fault Trees: AF100

Gates: GAF11323 (OR) Valves in HCV header to SGC fails.

Physical Id: 1FWHEP-HCV-100C_

Description: AFW_PUMP_3A_NOT____
ALIGNED_TO_SG_C____
HCV_HEADER_HCV-100C

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N
9-1-92

D.5.6 1FWHEP-MOV-100B

D.5.6.1 Analysis: 1FWHEP-MOV-100B

- Equivalent Surry HRA: 1FWHEP-1FW170171
  see IPE report page D.2-18
  calculated mean = 7.991E-4

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.02	Auxiliary Feedwater Pump 1-FW-P-3B, Rev 13, 11-22-89.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.
1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.3	Auxiliary Feedwater Pump (1-FW-P-3B) Test, Rev 32, 7-19-91.
1-PT-71.3Q	1-FW-P-3B Auxiliary Feedwater Pump, Rev 5, 8-12-91.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.

- 1-LOG-4 does not verify valve positions.

- 1-MOP-31.02 provides instructions for removing Auxiliary Feedwater Pump 1-FW-P-3B from service for maintenance, and returning it to service upon the completion of maintenance. Step 4.2.5 removes mechanical danger tags and positions the manual valves appropriate for restoring the pump to service. These steps are independently verified. Step 4.2.5.2 locks open 1-FW-184 discharge to MOV header. Step 4.2.5.3 closes 1-FW-190 the manual valve for discharge to HCV header. Step 4.2.9 verifies operability of the pump with 1-PT-71.3. 1-FW-MOV-100B is not specifically mentioned in this procedure.

- 1-OP-31.2 step 5.1.3 opens 1-FW-MOV-100B from 1-FW-P-3B to B SG. Step 5.1.4 verifies six annunciators listed are not lit. Annunciator 1A-F1 lit with a red light (most are white) whenever 1-FW-MOV-100B is not fully open. This annunciator will be detected even if not in 1-OP-31.2.

• 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-184 and 1-FW-MOV-100B are verified in the open position.

• 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 5.5.5 unlocks and closes 1-FW-184. Step 5.5.11 opens and locks 1-FW-184. This step is independently verified.

• 1-PT-71.3 verifies operability of 1-FW-P-3B and its associated flow path. It is performed every 31 days or after maintenance. Step 6.6.1 verifies 1-FW-MOV-100B is open, and 1-FW-184 is locked open. Step 6.6.5 closes 1-FW-MOV-100B. Step 6.6.12 fully opens 1-FW-MOV-100B. This step is independently verified. Step 6.6.13 verifies 1A-F1, Aux FW Pumps Discharge Vlv 1-FW-MOV-100B Or D Not Full Open, is not lit.

• 1FWHEP-MOV-100B will be used to represent the operator actions associated with misalignment of 1-FW-MOV-100B or other suction and discharge valves which prevent 1-FW-P-2 from delivering water to Steam Generator A. All associated valves will not be discussed but representative valves will be chosen as an example.

• HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

• Adjustment For Recovery:

R = 0.1. It is possible to use R = 0.0001 as the recovery factor. From NUREG/CR-1278, Table 20-23, The Annunciator Response Model estimated HEPs for multiple annunciators item 1 column 1. This is true for HCV-100C. For the manually operated valves it may be more appropriate to use at least 0.1 or 0.01 since these valves are independently verified within the restoration procedures and verified by system valve alignment check. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.6.2 Summary: 1FWHEP-MOV-100B

Fault Trees: AF100

Gates: GAF11223 (OR) Valves in MOV header to SGB fails.

Physical Id: 1FWHEP-MOV-100B_

Description: AFW_PUMP_3B_NOT____
ALIGNED_TO_SG_B____
MOV_HEADER_MOV-100B

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.5.7 1FWHEP-MOV-100D

D.5.7.1 Analysis: 1FWHEP-MOV-100D

- Equivalent Surry HRA: 1FWHEP-1FW140141
  see IPE report page D.2-15, D.2-16
  calculated mean = 7.991E-4

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.03	Auxiliary Feedwater Pump 1-FW-P-2, Rev 9, 11-22-89.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.

1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.1	1-FW-P-2, Auxiliary Feedwater Pump Test, Rev 34, 7-26-91.
1-PT-71.1Q	Auxiliary Feedwater Pump, 1-FW-P-2, And Valve Test, Rev 3, 8-12-91.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.

- 1-LOG-4 does not verify valve positions.

- 1-MOP-31.03 provides instructions for removing Auxiliary Feedwater Pump 1-FW-P-2 from service for maintenance, and returning it to service upon the completion of maintenance. Step 4.2.5 removes mechanical danger tags and positions the manual valves appropriate for restoring the pump to service. These steps are independently verified. Step 4.2.5.2 locks closed 1-FW-149 discharge to MOV header. Step 4.2.5.3 locks closed 1-FW-155 the manual valve for discharge to HCV header. Step 4.2.5.6 locks open 1-FW-278. Step 4.2.9 verifies operability of the pump with 1-PT-71.1. 1-FW-MOV-100D is not specifically mentioned in this procedure.

- 1-OP-31.2 step 5.1.3 opens 1-FW-MOV-100D from 1-FW-P-2 to A SG. Step 5.1.4 verifies six annunciators listed are not lit. Annunciator 1A-F1 lit with a red light (most are white) whenever 1-FW-MOV-100D is not fully open. This annunciator will be detected even if not in 1-OP-31.2.

- 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-278 and 1-FW-MOV-100D are verified in the open position.

- 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 5.3.5 unlocks and closes 1-FW-278. Step 5.5.11 opens and locks 1-FW-278. This step is independently verified.

- 1-PT-71.1 verifies operability of 1-FW-P-2 and its associated flow path. It is performed every 31 days or after maintenance. Step 6.3.2 verifies 1-FW-MOV-100D is open, and 1-FW-278 is locked open. Step 6.4.6 closes 1-FW-MOV-100B. Step 6.4.25 fully opens 1-FW-MOV-100D. This step is independently verified. Step 6.4.26 verifies 1A-F1, Aux FW Pumps Discharge Vlv 1-FW-MOV-100B Or D Not Full Open, is not lit.

- 1FWHEP-MOV-100D will be used to represent the operator actions associated with misalignment of 1-FW-MOV-100D or other suction and

discharge valves which prevent 1-FW-P-2 from delivering water to Steam Generator B. All associated valves will not be discussed but representative valves will be chosen as an example.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from Table 20-7, NUREG/CR-1278, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1. It is possible to use R = 0.0001 as the recovery factor. From NUREG/CR-1278, Table 20-23, The Annunciator Response Model estimated HEPs for multiple annunciators item 1 column 1. This is true for 1-FW-MOV-100D. For the manually operated valves it may be more appropriate to use at least 0.1 or 0.01 since these valves are independently verified within the restoration procedures and verified by system valve alignment check. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.7.2 Summary: 1FWHEP-MOV-100D

Fault Trees: AF100

Gates: GAF10823 (OR) Valves in direct line from TDP to SG-A fails.

Physical Id:	1FWHEP-MOV-100D_
Description:	AFW_PUMP_2_NOT_____ ALIGNED_TO_SG_A____ MOV_HEADER_MOV-100D
Failure Rate:	7.500E-4
Distribution:	Lognormal
Median:	6.000E-4
Error Factor:	3
Reference:	324MAF.N____________ 9-1-92______________
Why modified:	NAPS IPE Final Quantification Value

D.5.8 1FWHEP-1FW543

D.5.8.1 Analysis: 1FWHEP-1FW543

- Equivalent Surry HRA: none

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.03	Auxiliary Feedwater Pump 1-FW-P-2, Rev 9, 11-22-89.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.
1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.1	1-FW-P-2, Auxiliary Feedwater Pump Test, Rev 34, 7-26-91.
1-PT-71.1Q	Auxiliary Feedwater Pump, 1-FW-P-2, And Valve Test, Rev 5, 1-28-92.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.

- 1-LOG-4 does not verify valve positions.

- 1-MOP-31.03 provides instructions for removing Auxiliary Feedwater Pump 1-FW-P-2 from service for maintenance, and returning it to service upon the completion of maintenance. This procedure does not manipulate 1-FW-543.

- 1-OP-31.2 directs the operation of the Auxiliary Feedwater System. Step 4.4 mentions to prevent possible degradation to the AFW Pumps, minimize recirculation flow time. Section 5.4 is for placing the Turbine driven AFW Pump, 1-FW-P-2 in service to feed A SG and removing 1-FW-P-2 from service. Step 5.4.4 states to prevent lifting of the discharge relief valve when starting 1-FW-P-2 do the following valve lineup: a) unlock and throttle open three turns 1-FW-543, 1-FW-P-2 full flow recirc line. b) unlock and open 1-FW-545, full flow recirc line isolation to ECST. Step 5.4.6 restores 1-FW-543 and 1-545 to the lock closed position. This step is independently verified.

- 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-543 is verified in the locked closed position. This operator action is independently verified.

- 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 4.3 states to prevent degradation to the AFW Pumps, minimize recirculation flow time on normal recirculation flow. 1-FW-543 is not manipulated by this procedure.

- 1-PT-71.1 verifies operability of 1-FW-P-2 and its associated flow path. It is performed every 31 days or after maintenance. Step 4.5 states to minimize the time 1-FW-P-2 operate on minimum recirculation flow. Section 6.3 is the 1-FW-P-2 flow path operability check. Step 6.3.2 verifies that 1-FW-543 and 1-FW-545 are locked closed. Section 6.4 is the 1-FW-P-2 operability check. Step 6.4.6 unlocks and opens 1-FW-543 and 1-FW-545. Steps 6.4.12 and 6.4.17 throttle 1-FW-543 to adjust recirc flow. Step 6.4.21 locks closed 1-FW-543. Step 6.4.22 locks closed 1-FW-545. These two steps are independently verified.

- 1-PT-71.1Q verifies operability of 1-FW-P-2 and the associated flow path. This procedure is performed every 92 days. Step 6.4.2 verifies 1-FW-543 and 1-FW-545 are locked closed. Section 6.5 is the 1-FW-P-2 operability check. Step 6.5.6 unlocks and opens 1-FW-543 and 1-FW-545. Steps 6.5.12, 6.5.16, 6.5.32 and 6.5.34 throttle 1-FW-543 to adjust recirc flow. Step 6.5.37 closes 1-FW-543. Step 6.5.47 locks closed 1-FW-545. Step 6.5.48 locks 1-FW-545. These two steps are independently verified.

- 1-PT-71.4 measures the response of each AFW pump from a manual start signal and to verify the auto start logic for each pump. It is performed every 18 months. Step 4.7 states to prevent possible degradation to the AFW pumps, the amount of time spent on minimum recirculation flow should be minimized. Section 5.1 is the response time testing of 1-FW-P-2. Step 5.1.6 throttles open 1-FW-543, opens 1-FW-545, and verifies closed 1-FW-546 and 1-FW-548. Sections 5.2 and 5.3 are similar tests for the motor driven pumps. Step 5.7 verifies all four recirculation valves are locked closed. This step is independently verified.

- 1-PT-71.8 provides instructions for verifying that the alternate AFW flowpaths to the SG are operable while ensuring AFW check valves adequately seat. This test is performed each Cold Shutdown but not more than every 3 months or following maintenance. Step 6.4 records the initial position of all valves on Attachment 1, Valve lineup. Step 6.5 places the valves of Attachment 1 into their test position. Step 6.28 returns the valves of Attachment 1 to their initial positions. Attachment 1 requires that 1-FW-543, 1-FW-545, 1-FW-546 and 1-FW-548 be in the locked closed position during the test.

- 1FWHEP-1FW543 represents the operator action of leaving the 1-FW-P-2 full flow recirculation valve, 1-FW-543, and the common full flow recirculation valve, 1-FW-545, in the open position.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags. Also from Table 20-7, probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.8.2 Summary: 1FWHEP-1FW543

Fault Trees:	AF100
Gates:	GAF11524 (OR) Pump P-2 Discharge Faults.
Physical Id:	1FWHEP-1FW543___
Description:	CRO_LEAVES 1-FW-P-2 RECIRC_VALVE_OPEN__ TO_ECST,_1-FW-543__
Failure Rate:	7.500E-4
Distribution:	Lognormal
Median:	6.000E-4
Error Factor:	3
Reference:	324MAF.N____________ 9-1-92______________ ____________________
Why modified:	NAPS IPE Final Quantification Value

D.5.9 1FWHEP-1FW546

D.5.9.1 Analysis: 1FWHEP-1FW546

- Equivalent Surry HRA: none
- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.02	Auxiliary Feedwater Pump 1-FW-P-3B, Rev 13, 11-22-89.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.
1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.3	Auxiliary Feedwater Pump (1-FW-P-3B) Test, Rev 32, 7-19-91.
1-PT-71.3Q	1-FW-P-3B Auxiliary Feedwater Pump, Rev 2, 1-25-90.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.
1-ST-13	Motor Driven Auxiliary Feedwater Pump Endurance Test, 11-15-79.

- 1-MOP-31.03 provides instructions for removing Auxiliary Feedwater Pump 1-FW-P-2 from service for maintenance, and returning it to service upon the completion of maintenance. This procedure does not manipulate 1-FW-546.

- 1-OP-31.2 directs the operation of the Auxiliary Feedwater System. This procedure does not manipulate 1-FW-546.

- 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-546 is verified in the locked closed position. This operator action is independently verified.

- 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 4.3 states to prevent degradation to the AFW Pumps, minimize recirculation flow time on normal recirculation flow. 1-FW-546 is not manipulated by this procedure.

- 1-PT-71.3 verifies operability of 1-FW-P-3B and its associated flow path. It is performed every 31 days or after maintenance. Step 4.3 states to minimize the time 1-FW-P-3B operate on minimum recirculation flow. Section 6.6 is the 1-FW-P-3B flow path operability check. This section does not verify the position of the recirculation valves 1-FW-545 or 1-FW-546. Step 6.6.6 starts the 1-FW-P-3B on recirculation flow, but does not specifically mention the recirc valves by mark number. There are no steps in this procedure which identify the recirculation valves 1-FW-545 or 1-FW-546 to be locked or placed in the closed position.

- 1-PT-71.3Q verifies operability of 1-FW-P-3B and its associated flow path. It is performed every 92 days. Section 6.9 is the 1-FW-P-3B flow path operability check. This section does not verify the position of the recirculation valves 1-FW-545 or 1-FW-546. Step 6.9.6 starts the 1-FW-P-3B on recirculation flow, but does not specifically mention the recirc valves by mark number. There are no steps in this procedure which identify the recirculation valves 1-FW-545 or 1-FW-546 to be locked or placed in the closed position.

- 1-PT-71.4 measures the response of each AFW pump from a manual start signal and to verify the auto start logic for each pump. It is performed every 18 months. Step 4.7 states to prevent possible degradation to the AFW pumps, the amount of time spent on minimum recirculation flow should be minimized. Section 5.1 is the response time testing of 1-FW-P-2. Step 5.1.6 throttles open 1-FW-543, opens 1-FW-545, and verifies closed 1-FW-546 and 1-FW-548. Sections 5.2 and 5.3 are similar tests for the motor driven pumps. Step 5.7 verifies all four recirculation valves are locked closed. This step is independently verified.

• 1FWHEP-1FW546 represents the operator action of leaving the 1-FW-P-3B full flow recirculation valve, 1-FW-546, and the common full flow recirculation valve, 1-FW-545, in the open position.

• HEP Calculation:
Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags. Also from Table 20-7, probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

• Adjustment For Recovery:

R = 1, recovery factor. No credit is taken for recovery from his Human Error. Do not take credit for the independent verification performed in some procedures because 1-PT-71.3 does not specifically identify this valve to be locked closed.

HEP(median) = HEP * R = 6.0E-3

• Consideration of Dependency:
There is no dependency between this HEP and other Type A HEPs.

• HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 6.0E-3 * 1.25 = 7.50E-3

• Procedure improvements which add independent verification that the AFW recirculation valves have been closed after testing will decrease the point estimate of 1FWHEP-1FW546 to that calculated for 1FWHEP-1FW543 (from 7.5E-3 to 7.5E-4).

D.5.9.2 Summary: 1FWHEP-1FW546

Fault Trees: AF100

Gates: GAF11920 (OR) Pump P-3B Faults, Insufficient Flow from Pump 3B.

Physical Id: 1FWHEP-1FW546___

Description: CRO_LEAVES FW-P-3B_
RECIRC_VALVE_OPEN__
TO_ECST,_1-FW-546__

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.10 1FWHEP-1FW548

D.5.10.1 Analysis: 1FWHEP-1FW548

- Equivalent Surry HRA: none

- NAPS Procedures:

1-LOG-4	CRO Surveillance Sheets, Rev 14, 10-18-91.
1-MOP-31.01	Auxiliary Feedwater Pump 1-FW-P-3A, Rev 13, 1-8-87.
1-OP-31.2	Steam Generator Auxiliary Feedwater System, Rev 15, 4-18-91.
1-OP-31.2A	Valve Checkoff Auxiliary Feedwater, Rev 12, 4-10-91.
1-OP-31.09	Auxiliary Feedwater Check Valve Back-Leakage, Rev 0, 3-26-91.
1-PT-71.2	Auxiliary Feedwater Pump (1-FW-P-3A) Test, Rev 29, 7-19-90.
1-PT-71.2Q	1-FW-P-3A Auxiliary Feedwater Pump, Rev 2, 2-28-91.
1-PT-71.4	Auxiliary Feedwater Pump Time Response and Logic Test, Rev 12, 3-1-91.
1-PT-71.8	Valve Inservice Inspection - AFW Check Valves, Rev 1, 2-22-91.
1-ST-13	Motor Driven Auxiliary Feedwater Pump Endurance Test, 11-15-79.

- 1-MOP-31.03 provides instructions for removing Auxiliary Feedwater Pump 1-FW-P-2 from service for maintenance, and returning it to service upon the completion of maintenance. This procedure does not manipulate 1-FW-548.

- 1-OP-31.2 directs the operation of the Auxiliary Feedwater System. This procedure does not manipulate 1-FW-548.

- 1-OP-31.2A provides normal valve lineup for the Auxiliary Feedwater System. 1-FW-548 is verified in the locked closed position. This operator action is independently verified.

- 1-OP-31.09 provides instructions for venting and filling the AFW pumps following steam binding caused by check valve back-leakage. Step 4.3 states to prevent degradation to the AFW Pumps, minimize recirculation flow time on normal recirculation flow. 1-FW-548 is not manipulated by this procedure.

- 1-PT-71.2 verifies operability of 1-FW-P-3A and its associated flow path. It is performed every 31 days or after maintenance. Step 4.3 states to minimize the time 1-FW-P-3A operate on minimum recirculation flow. Section 6.6 is the 1-FW-P-3A flow path operability check. This section does not verify the position of the recirculation valves 1-FW-545 or 1-FW-548. Step 6.6.6 starts the 1-FW-P-3A on recirculation flow, but does not specifically mention the recirc valves by mark number. There are no steps in this procedure which identify the recirculation valves 1-FW-545 or 1-FW-548 to be locked or placed in the closed position.

- 1-PT-71.2Q verifies operability of 1-FW-P-3A and its associated flow path. It is performed every 92 days. Section 6.9 is the 1-FW-P-3A flow path operability check. Step 6.9.1 verifies 1-FW-545 and 1-FW-548 are locked closed. Step 6.9.6 opens 1-FW-545 and 1-FW-548. Step 6.9.10 throttles 1-FW-548. Step 6.9.13 closes 1-FW-548. Step 6.9.20 locks 1-FW-548. Step 6.9.21 locks closed 1-FW-545. These two steps are independently verified.

- 1-PT-71.4 measures the response of each AFW pump from a manual start signal and to verify the auto start logic for each pump. It is performed every 18 months. Step 4.7 states to prevent possible degradation to the AFW pumps, the amount of time spent on minimum recirculation flow should be minimized. Section 5.1 is the response time testing of 1-FW-P-2. Step 5.1.6 throttles open 1-FW-543, opens 1-FW-545, and verifies closed 1-FW-546 and 1-FW-548. Sections 5.2 and 5.3 are similar tests for the motor driven pumps. Step 5.7 verifies all four recirculation valves are locked closed. This step is independently verified.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags. Also from Table 20-7, probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate

has been doubled due to operators normally working 12 hour shifts.

- 1FWHEP-1FW548 represents the operator action of leaving the 1-FW-P-3A full flow recirculation valve, 1-FW-548, and the common full flow recirculation valve, 1-FW-545, in the open position.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 1, recovery factor. No credit is taken for recovery from this Human Error. Do not take credit for the independent verification performed in some procedures because 1-PT-71.2 does not specifically identify this valve to be locked closed.

HEP(median) = HEP * R = 6.0E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-3 * 1.25 = 7.50E-3

- Procedure improvements which add independent verification that the AFW recirculation valves have been closed after testing will decrease the point estimate of 1FWHEP-1FW548 to that calculated for 1FWHEP-1FW543 (from 7.5E-3 to 7.5E-4).

D.5.10.2 Summary: 1FWHEP-1FW548

Fault Trees: AF100

Gates: GAF11820 (OR) Pump 3A Faults, Insufficient Flow From Pump 3A.

Physical Id: 1FWHEP-1FW548___

Description: CRO_LEAVES FW-P-3A_
RECIRC_VALVE_OPEN__
TO_ECST,_1-FW-548__

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.5.11 1QSHEP-FLANGE

D.5.11.1 Analysis: 1QSHEP-FLANGE

- Equivalent Surry HRA: 1RSHEP-SFLNG-PT4 and 1RSHEP-SFLNG-PT6 see Surry IPE report page D.2-24 to D.2-27 calculated mean = 7.991E-5

- NAPS Procedures:

1-MOP-7.07	Quench Spray Pump 1-QS-P-1A, Rev 5, 11-30-89.
1-MOP-7.08	Quench Spray Pump 1-QS-P-1B, Rev 6, 11-30-89.
1-OP-7.4	Recirc of RWST Using QS Pumps, Rev 11, 12-1-88.
1-OP-7.4A	Valve Checkoff - Quench Spray System, Rev 6, 9-21-89.
1-PT-63.1A	Quench Spray System - "A" Subsystem, Rev 16, 11-30-90.
1-PT-63.1A.1	Quench Spray Pump Bearing Temperature (1-QS-P-1A), Rev 0, 9-12-85.
1-PT-63.1B	Quench Spray System - "B" Subsystem, Rev 19, 11-30-90.
1-PT-63.1B.1	Quench Spray Pump Bearing Temperature (1-QS-P-1A), Rev 0, 9-12-85.
1-PT-63.3	Quench Spray System Spray Header Air Test, Rev 4, 8-10-89.
1-PT-63.4	Quench Spray and Chemical Addition System Valve Line Up Verification, Rev 4, 10-18-90.

- 1-MOP-7.07 and 1-MOP-7.08 do not mention the Quench Spray header flanges.

- 1-OP-7.4 and 1-OP-7.4A do not mention the Quench spray header flanges.

- 1-PT-63.1A, 1-PT-63.1A.1, 1-PT-63.1B, and 1-PT-63.1B.1 do not mention the Quench spray header flanges.

- 1-PT-63.3 ensures that the spray nozzles are unobstructed in accordance with TS 4.6.2.1.d. This procedure is performed at least once every five years. Step 6.1 verifies that spectacle flanges, 1-QS-RO-101A and B, in each discharge header are turned to admit flow to the spray header. Step 6.2 verifies the spool piece is removed and the blind flange is installed on each Quench Spray header. There are no steps in this procedure to ensure that the

flanges are removed or restored to their normal operating condition.

- 1-PT-63.4 verifies that each unlocked, unsealed, or unsecured valve (manual, power operated or automatic) in the Quench Spray and Chemical Addition System flow paths is in its correct position. This procedure does not mention the Quench spray header flanges.

- 1QSHEP-FLANGE will represent the operator action which installs blank or spectacle flanges in the Quench Spray headers for either train A or B. The two trains are tested at the same time and the operator actions are the same.

Input Parameters:

U_0 = 1E-2 is the estimated HEPs related to failure of administrative control, from NUREG/CR-1278, Table 20-6, item 1, carry out a plant policy or scheduled tasks such as periodic tests or maintenance performed weekly, monthly, or longer intervals. Error factor = 5. This value was chosen due to 1-PT-63.3 installing the blank and spectacle flanges and not having a specific step to remove or verify the flanges are removed. Mechanics typically install flanges and engineers coordinate the test, the error rate has not been doubled due to 12 hour shift schedule.

Calculations:

HEP(median) = U_0 = 1.0E-2

- Adjustment For Recovery:

R = 1, recovery factor. No credit is taken for recovery from this Human Error.

HEP(median) = HEP * R = 1.0E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.6138 for an EF = 5

= 1.0E-2 * 1.6138 = 1.614E-2

- If the test procedures are revised to add specific steps to restore the piping to its operational configuration, including a specific step for each flange, elbows, spool piece or other device. Also independent verification that the spray piping is in its operational configuration is necessary to reduce the probability of human error. This independent verification would be best if performed by qualified Operations Department personnel as part of

a system walkdown at the end of an outage, prior to returning to power operation.

Input Parameters:

U_0 = 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3.

Calculations:

HEP(median) = U_0 = 3.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 3.0E-3 * 0.1 = 3.0E-4

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=EXP{[1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 3.0E-4 * 1.25 = 3.75E-4

D.5.11.2 Summary: 1QSHEP-FLANGE

Fault Trees: QS100

Gates: GQS1120 (OR) No Flow from A Train CKV to the Spray Ring.
GQS1125 (OR) No Flow from B Train CKV to the Spray Ring.

Physical Id: 1QSHEP-FLANGE___

Description: QS_SPRAY_HEADER____
FLANGE_NOT_REMOVED_
AFTER_1-PT-63.3____

Failure Rate: 3.750E-4

Distribution: Lognormal
Median: 3.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________

Why modified: NAPS IPE Final Quantification Value

D.5.12 1QSHEP-1QS5

D.5.12.1 Analysis: 1QSHEP-1QS5

- Equivalent Surry HRA: HEP-1CSHEP-1CS8
  see Surry IPE report page D.2-12 to D.2-13.
  calculated mean = 7.991E-4

- NAPS Procedures:

1-MOP-7.07	Quench Spray Pump 1-QS-P-1A, 1-7-88.
1-MOP-7.08	Quench Spray Pump 1-QS-P-1B, Rev 6, 11-30-89.
1-OP-7.4	Recirc of RWST Using QS Pumps, Rev 11, 12-1-88.
1-OP-7.4A	Valve Checkoff - Quench Spray System, Rev 6, 9-21-89.
1-PT-63.1A	Quench Spray System - "A" Subsystem, Rev 16, 11-30-90.
1-PT-63.1A.1	Quench Pump Bearing Temperature 1-QS-P-1A, 9-12-85.

- 1-MOP-7.07 provides instructions for the removal from and the return to service of 1-QS-P-1A. Preceding step 4.1.3 is a note which states to utilize Attachment 1 if desired, to aid in tagout. Step 4.1.10 request the Control Room operators to perform the required independent verification. Section 4.2 returns 1-QS-P-1A to service after maintenance. Step 4.2.8 removes the mechanical danger tags from 1-QS-5. Attachment 1 lists the tagged position and the returned to service position of 1-QS-5 as closed.

- 1-OP-7.4 provides detailed instructions for placing the Quench Spray Pumps on recirculation to the RWST. Section 5.1 places 1-QS-P-1A on recirc to the RWST. Step 5.1.8 opens 1-QS-5. Section 5.2 removes 1-QS-P-1A from recirc to RWST. Step 5.2.3 closes 1-QS-5 and is independently verified. Section 5.3 places 1-QS-P-1B on recirc to the RWST. Step 5.3.8 opens 1-QS-21. Section 5.4 removes 1-QS-P-1B from recirc to RWST. Step 5.4.3 closes 1-QS-21 and is independently verified.

- 1-PT-63.1A verifies operability of 1-QS-P-1A. Step 6.4 closes 1-QS-5. This procedure is performed at least once every 3 months or following pump maintenance. Step 6.6 opens 1-QS-5. Step 6.13 closes 1-QS-5 and is independently verified.

- 1-PT-63.1A.1 verifies operability of 1-QS-P-1A. This procedure is performed at least once every year or following pump maintenance. Step 4.1 closes 1-QS-5. Step 4.3 opens 1-QS-5. Step 4.7 closes 1-QS-5 and is independently verified.

- 1-PT-63.4 verifies that each unlocked, unsealed, or unsecured valve (manual, power operated or automatic) in the Quench Spray and Chemical Addition System flow paths is in its correct position. This procedure is performed at least every 31 days. Step 4.1 verifies 1-QS-5 and 1-QS-21 are in the closed position.

- 1QSHEP-1QS5 will represent the operator action which leaves 1-QS-5, 1-QS-P-1A recirculation line to the RWST, open.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.12.2 Summary: 1QSHEP-1QS5

Fault Trees: QS100

Gates: GQS1325 (OR) Maintenance outage.

Physical Id: 1QSHEP-1QS5_____

Description: CRO_LEAVES_1-QS-5__
RECIRC_VALVE_OPEN__
AFTER_1-PT-63.1A___

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.5.13 1QSHEP-1QS21

D.5.13.1 Analysis: 1QSHEP-1QS21

- Equivalent Surry HRA: 1CSHEP-1CS15
  see Surry IPE report page D.2-14.
  calculated mean = 7.991E-4

- NAPS Procedures:

1-MOP-7.07	Quench Spray Pump 1-QS-P-1A, Rev 5, 11-30-89.
1-MOP-7.08	Quench Spray Pump 1-QS-P-1B, Rev 6, 11-30-89.
1-OP-7.4	Recirc of RWST Using QS Pumps, Rev 11, 12-1-88.
1-OP-7.4A	Valve Checkoff - Quench Spray System, Rev 6, 9-21-89.
1-PT-63.1B	Quench Spray System - "B" Subsystem, Rev 19, 11-30-90.
1-PT-63.1B.1	Quench Pump Bearing Temperature 1-QS-P-1B, 9-12-85.

- 1-MOP-7.08 directs removing and returning 1-QS-P-1B to service. Preceding step 5.1.3 is a note which states to utilize Attachment 1 if desired, to aid in tagout. Section 5.1 removes 1-QS-P-1A from service for maintenance. Step 5.1.16 closes and mechanical danger tag on 1-QS-21. Section 5.2 returns 1-QS-P-1B to service after maintenance. No mention of 1-QS-21 can be found in this section. Attachment 1 lists the tagged position and the returned to service position of 1-QS-21 as closed.

- 1-OP-7.4 provides detailed instructions for placing the Quench Spray Pumps on recirculation to the RWST. Section 5.1 places 1-QS-P-1A on recirc to the RWST. Step 5.1.8 opens 1-QS-5. Section 5.2 removes 1-QS-P-1A from recirc to RWST. Step 5.2.3 closes 1-QS-5 and is independently verified. Section 5.3 places 1-QS-P-1B on recirc to the RWST. Step 5.3.8 opens 1-QS-21. Section 5.4 removes 1-QS-P-1B from recirc to RWST. Step 5.4.3 closes 1-QS-21 and is independently verified.

- 1-PT-63.1B verifies operability of 1-QS-P-1B. Step 6.4 closes 1-QS-21. This procedure is performed at least once every 3 months

or following pump maintenance. Step 6.6 opens 1-QS-21. Step 6.13 closes 1-QS-21 and is independently verified.

- 1-PT-63.1B.1 verifies operability of 1-QS-P-1B. This procedure is performed at least once every year or following pump maintenance. Step 4.1 closes 1-QS-21. Step 4.3 opens 1-QS-21. Step 4.7 closes 1-QS-21 and is independently verified.

- 1-PT-63.4 verifies that each unlocked, unsealed, or unsecured valve (manual, power operated or automatic) in the Quench Spray and Chemical Addition System flow paths is in its correct position. This procedure is performed at least every 31 days. Step 4.1 verifies 1-QS-5 and 1-QS-21 are in the closed position.

- 1QSHEP-1QS21 will represent the operator action which leaves 1-QS-21, 1-QS-P-1B recirculation line to the RWST, open.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence of tags. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.13.2 Summary: 1QSHEP-1QS21

Fault Trees: QS100

Gates: GQS1365 (OR) Maintenance outage.

Physical Id: 1QSHEP-1QS21____

Description: CRO_LEAVES_1-QS-21_
RECIRC_VALVE_OPEN__
AFTER_1-PT-63.1B___

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
6-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.5.14 1RSHEP-ELBOW

D.5.14.1 Analysis: 1RSHEP-ELBOW

- Equivalent Surry HRA: 1RSHEP-SFLNG-PT4 and 1RSHEP-SFLNG-PT6 see Surry IPE report page D.2-24 to D.2-27 calculated mean = 7.991E-5

- NAPS Procedures:

1-MOP-7.03	Inside Recirculation Pump 1-RS-P-1A, Rev 3, 5-14-87.
1-OP-7.6A	Valve Checkoff - Inside Recirc Spray System, Rev 3, 1-25-90.
1-PT-64.1A	Recirculation Spray Subsystem - "A" Pumps, Rev 17, 1-22-91.
1-PT-64.1B	Recirculation Spray Subsystem - "B" Pumps, Rev 19, 1-22-91.
1-PT-64.3	Recirculation Spray System - Spray Header Air Test, Rev 3, 7-16-85.
1-PT-64.8	Flow Test of the Inside Recirculation Spray Pumps, Rev 2, 1-10-91.

- 1-MOP-7.03 provides instructions for removing 1-RS-P-1A from service for maintenance and returning to service after maintenance. This procedure does not mention the RS recirculation test elbows.

- 1-OP-7.6A is the operating valve lineup for the Inside Recirculation Spray System. This procedure does not mention the RS recirculation test elbows.

- 1-PT-64.1A verifies operability of the A train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. This procedure does not mention the RS recirculation test elbows.

- 1-PT-64.1B verifies operability of the B train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. This procedure does not mention the RS recirculation test elbows.

- 1-PT-64.3 ensures that the recirculation spray nozzles are unobstructed in accordance with TS 4.6.2.2.1.d. Section 4.1 prepares the spray headers for the test. This test is performed at least once every five years. This procedure does not mention the RS recirculation test elbows.

- 1-PT-64.8 purpose is to periodically obtain and analyze pump head curve data for the inside RS pumps and to verify operability after maintenance. This test is performed every refueling outage. Step 2.4 requires that the recirculation line for the pumps have been installed. Step 4.3 removes the recirculation line elbow and reinstalls the spray nozzle elbow for 1-RS-P-1A. Step 4.4 removes the recirculation line elbow and reinstalls the spray nozzle elbow for 1-RS-P-1B. These two steps are independently verified.

- 1RSHEP-ELBOW will represent the operator action which installs and removes the recirculation line elbows and the spray header elbows for both trains of inside recirculation spray.

- HEP Calculation:

Input Parameters:

U_0 = 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified,when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Mechanics typically install flanges and engineers coordinate the test, the error rate has not been doubled due to 12 hour shift schedule.

Calculations:

HEP(median) = U_0 = 3.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 3.0E-3 * 0.1 = 3.0E-4

• Consideration of Dependency:
There is no dependency between this HEP and other Type A HEPs.

• HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.0E-4 * 1.25 = 3.750E-4

D.5.14.2 Summary: 1RSHEP-ELBOW

Fault Trees:	RS100
Gates:	GRS1613 (OR) Restoration errors for 1-RS-P-1A and 1-RS-P-1B.
Physical Id:	1RSHEP-ELBOW____
Description:	RS_SPRAY_HEADER____ ELBOW_NOT_INSTALLED AFTER_1-PT-64.8____
Failure Rate:	3.750E-4
Distribution:	Lognormal
Median:	3.000E-4
Error Factor:	3
Reference:	324MAF.N____________ 9-1-92______________ ___________________
Why modified:	NAPS IPE Final Quantification Value

D.5.15 1RSHEP-FLANGE

D.5.15.1 Analysis: 1RSHEP-FLANGE

• Equivalent Surry HRA: 1RSHEP-SFLNG-PT4 and 1RSHEP-SFLNG-PT6
see Surry IPE report page D.2-24 to D.2-27
calculated mean = 7.991E-5

• NAPS Procedures:

1-MOP-7.03	Inside Recirculation Pump 1-RS-P-1A, Rev 3, 5-14-87.
1-OP-7.6A	Valve Checkoff - Inside Recirc Spray System, Rev 3, 1-25-90.
1-PT-64.1A	Recirculation Spray Subsystem - "A" Pumps, Rev 17, 1-22-91.

1-PT-64.1B	Recirculation Spray Subsystem - "B" Pumps, Rev 19, 1-22-91.
1-PT-64.3	Recirculation Spray System - Spray Header Air Test, Rev 3, 7-16-85.
1-PT-64.8	Flow Test of the Inside Recirculation Spray Pumps, Rev 2, 1-10-91.

- 1-MOP-7.03 provides instructions for removing 1-RS-P-1A from service for maintenance and returning to service after maintenance. This procedure does not mention the RS blank flanges.

- 1-OP-7.6A is the operating valve lineup for the Inside Recirculation Spray System. This procedure does not mention the RS blank flanges.

- 1-PT-64.1A verifies operability of the A train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. This procedure does not mention the RS blank flanges.

- 1-PT-64.1B verifies operability of the B train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. This procedure does not mention the RS blank flanges.

- 1-PT-64.3 intended purpose is to ensure that the recirculation spray nozzles are unobstructed in accordance with TS 4.6.2.2.1.d. Section 4.1 prepares the spray headers for the test. This test is performed at least once every five years. Step 4.1.1 removes a spool piece between 1-RS-E-1A and 1-RS-P-1A, and installs a flange with a 2" threaded connection on the heat exchanger side of the recirc line. Step 4.1.2 does the same for 1-RS-E-1B. Step 4.1.5 verifies spool pieces have been removed and blind flanges installed on both ends of the each of the four 180° RS headers. Section 4.7 returns the system to its original condition. Step 4.7.1 removes the flange and installs the spool piece between 1-RS-E-1A and 1-RS-P-1A. Step 4.7.2 does the same for 1-RS-E-1A. Neither of these steps are independently verified. The procedure does not contain a specific step to return the eight 8" spool pieces and remove the blank flanges installed in step 4.1.5.

- 1-PT-64.8 purpose is to periodically obtain and analyze pump head curve data for the inside RS pumps and to verify operability after maintenance. This test is performed every refueling outage. Step 2.4 requires that the recirculation line for the pumps have been installed. No flanges are installed for this test. Spool pieces are installed and removed. These will be included in the analysis for 1RSHEP-ELBOW.

- 1RSHEP-FLANGE will represent the operator action which installs blank or test flanges in the four trains of Recirculation

Spray headers. The four trains are tested at the same time and the operator actions are the same.

- HEP Calculation:

Input Parameters:

U_0 = 1E-2 is the estimated HEPs related to failure of administrative control, from NUREG/CR-1278, Table 20-6, item 1, carry out a plant policy or scheduled tasks such as periodic tests or maintenance performed weekly, monthly, or longer intervals. Error factor = 5. This value was chosen due to 1-PT-64.3 removing the spool pieces and installing blank flanges and not having a specific step to remove or verify the flanges are removed and spool pieces restored. The flanges at the heat exchanger are likely to be removed due to steps 4.7.1 and 4.7.2 and have a lower probability of 3.0E-3. Because mechanics typically install flanges and engineers coordinate the test, the error rate has not been doubled due to the operators working 12 hour shift schedule.

Calculations:

HEP(median) = U_0 = 1.0E-2

- Adjustment For Recovery:

R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

HEP(median) = HEP * R = 1.0E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.6138 for an EF = 5

= 1.0E-2 * 1.6138 = 1.614E-2

- If the test procedures are revised to add specific steps to restore the piping to its operational configuration, including a specific step for each flange, elbows, spool piece or other device. Also independent verification that the spray piping is in its operational configuration is necessary to reduce the probability of human error. This independent verification would be best if performed by qualified Operations Department personnel as part of a system walkdown at the end of an outage, prior to returning to power operation. The new calculated HEP will be the same as that determined for 1QSHEP-FLANGE (3.75E-4).

D.5.15.2 Summary: 1RSHEP-FLANGE

Fault Trees: RS100

Gates:	GRS1354	(OR) Component failures after pump, ORS pump 2A.
	GRS1554	(OR) Component failures after pump, ORS pump 2B.
	GRS1613	(OR) Restoration errors for 1-RS-P-1A and 1-RS-P-1B.

Physical Id: 1RSHEP-FLANGE___

Description: RS_SPRAY_HEADER____
FLANGE_NOT_REMOVED_
AFTER_1-PT-64.3____

Failure Rate: 3.750E-4

Distribution: Lognormal
Median: 3.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.16 1RSHEP-MOV-155A

D.5.16.1 Analysis: 1RSHEP-MOV-155A

- Equivalent Surry HRA: none

- NAPS Procedures:

1-MOP-7.05	Outside Recirculation Pump 1-RS-P-2A, Rev 6, 11-30-89.
1-OP-7.5A	Valve Checkoff - Outside Recirc Spray System, Rev 6, 3-26-91.
1-PT-64.1A	Recirculation Spray Subsystem - "A" Pumps, Rev 17, 1-22-91.
1-PT-64.2A	Outside Recirculation Spray Pump, 1-RS-P-2A, Rev 7, 2-19-87.
1-PT-64.7	Outside Recirculation Spray and Casing Cooling System Valve Lineup Verification, Rev 1, 5-11-89.
1-PT-64.11	Outside Recirculation Spray Pump 1-RS-P-2A, Rev 0, 1-22-91.

* 1-MOP-7.05 provides instructions for removing 1-RS-P-2A from service for maintenance and returning to service after maintenance. Section 4.1 removes 1-RS-P-2A from service for maintenance. Step 4.1.8.1 closes 1-RS-MOV-155A. Step 4.1.8.2 closes 1-RS-MOV-156A. Step 4.1.9.1 opens breaker 1H1-2NK2 (MOV-155A) and places an electrical red tag. Step 4.1.9.2 opens breaker 1H1-2NK1 (MOV-156A) and places an electrical red tag. Step 4.1.10 verifies that the "B" train is operable if in Modes 1-4. Step 4.1.11 locally closes 1-RS-MOV-156A until valve is seated. Step 4.1.12 places mechanical danger tags on the handwheels for 1-RS-MOV-155A and 1-RS-MOV-156A. Section 4.2 returns 1-RS-P-2A to service after maintenance. Step 4.2.2.1 removes the mechanical danger tag from the handwheel of 1-RS-MOV-155A. Step 4.2.2.2 removes the mechanical danger tag from the handwheel of 1-RS-MOV-156A. Step 4.2.4.1 removes the electrical danger tag from breaker 1H1-2NK1 and step 4.2.4.2 removes the electrical danger tag from 1H1-2NK2. Step 4.2.5.1 closes the breaker 1H1-2NK2. Step 4.2.5.2 closes the breaker 1H1-2NK1. Step 4.2.6 locally opens 1-RS-MOV-156A the number of steps recorded in step 4.1.11.1. Step 4.2.8.1 requests independent verification that 1-RS-MOV-155A is energized and step 4.2.8.2 verifies 1-RS-MOV-156A is energized. Step 4.2.10 requires that 1-PT-64.2A be performed. Attachment 1 lists the desired tagged positions of breakers and valves, and the position these devices are to be returned to service. 1-RS-MOV-155A and 1-RS-MOV-156A are listed as tagged closed and returned to open. Breakers 1H1-2NK2 and 1H1-2NK1 are tagged open and returned closed.

* 1-OP-7.5A is the operating valve lineup for the Outside Recirculation Spray System. This procedure lists the normal position for 1-RS-MOV-155A and 1-RS-MOV-156A as open. These MOV are independently verified.

* 1-PT-64.1A verifies operability of the A train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. Step 4.1.2 closes 1-RS-MOV-156A. Step 4.1.3 closes 1-RS-MOV-155A. Step 4.1.4 deenergizes and red tags 1-RS-MOV-156A. Step 4.1.5 deenergizes and red tags 1-RS-MOV-155A. Step 4.1.43 removes the red tag and energizes 1-RS-MOV-155A. Step 4.1.44 removes the red tag and energizes 1-RS-MOV-156A. These two steps are independently verified. Step 4.1.45 opens 1-RS-MOV-155A and step 4.1.46 opens 1-RS-MOV-156A. These two steps are independently verified.

* 1-PT-64.2A verifies operability of 1-RS-P-2A. This test is performed every 18 months. This procedure does not directly manipulate 1-RS-MOV-155A or 1-RS-MOV-156A. It does coordinate the performance of this procedure with 1-PT-64.1A.

* 1-PT-64.7 verifies the correct position of each valve that is not locked, not sealed or not secured in the ORS or Casing Cooling flow paths. This procedure is performed every 31 days. Step 6.2 verifies 1-RS-MOV-155A and 1-RS-MOV-156A are open.

• 1RSHEP-MOV-155A will represent the operator actions related to 1-RS-MOV-155A and 1-RS-MOV-156A which could leave them in a closed de-energized condition as a result of test or maintenance. 1-RS-MOV-155A is the suction valve for 1-RS-P-2A. 1-RS-MOV-156A is the discharge valve for 1-RS-P-2A. These valves are normally energized in the open position and receive a CDA open signal. One HEP basic event will be used to represent leaving the suction MOV closed, the discharge MOV closed and both valves de-energized. Either 1-RS-MOV-155A or 1-RS-MOV-156A left closed will be included within one HEP. The same procedures manipulate these valves. There is no additional failures associated with leaving both valves closed (one valve or both valves closed yield the same results).

• HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

• Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

• Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

• HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.16.2 Summary: 1RSHEP-MOV-155A

Fault Trees: RS100

Gates: GRS1354 (OR) Component failures after pump, ORS pump 2A.

Physical Id: 1RSHEP-MOV-155A_

Description: CRO_LEAVES_MOV-155A
OR_MOV-156A_CLOSED_
OR_DEENERGIZED_____

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: Final Quantification Value

D.5.17 1RSHEP-MOV-155B

D.5.17.1 Analysis: 1RSHEP-MOV-155B

- Equivalent Surry HRA: none

- NAPS Procedures:

1-MOP-7.06	Outside Recirculation Pump 1-RS-P-2B, Rev 5, 12-31-87.
1-OP-7.5A	Valve Checkoff - Outside Recirc Spray System, Rev 6, 3-26-91.
1-PT-64.1B	Recirculation Spray Subsystem - "B" Pumps, Rev 19, 1-22-91.
1-PT-64.2B	Outside Recirculation Spray Pump, 1-RS-P-2A, Rev 7, 2-19-87.
1-PT-64.7	Outside Recirculation Spray and Casing Cooling System Valve Lineup Verification, Rev 1, 5-11-89.
1-PT-64.12	Outside Recirculation Spray Pump 1-RS-P-2B, Rev 0, 1-22-91.

- 1-MOP-7.06 provides instructions for removing 1-RS-P-2B from service for maintenance and returning to service after maintenance. Section 4.1 removes 1-RS-P-2B from service for maintenance. Step 4.1.8.1 closes 1-RS-MOV-155B. Step 4.1.8.2 closes 1-RS-MOV-156B. Step 4.1.9.1 opens breaker 1J1-2NK2 (1-RS-MOV-155B) and places an electrical red tag. Step 4.1.9.2 opens breaker 1J1-2NK1 (1-RS-MOV-156B) and places an electrical red tag. Step 4.1.10 verifies that the "B" train is operable if in Modes 1-4. Step 4.1.11 locally closes 1-RS-MOV-156B until valve is seated. Step 4.1.12 places mechanical danger tags on the handwheels for 1-RS-MOV-155B and 1-RS-MOV-156B. Section 4.2 returns 1-RS-P-2B to service after maintenance. Step 4.2.2.1 removes the mechanical danger tag from

the handwheel of 1-RS-MOV-155B. Step 4.2.2.2 removes the mechanical danger tag from the handwheel of 1-RS-MOV-156B. Step 4.2.4.1 removes the electrical danger tag from breaker 1J1-2NK1 and step 4.2.4.2 removes the electrical danger tag from 1J1-2NK2. Step 4.2.5.1 closes the breaker 1J1-2NK2. Step 4.2.5.2 closes the breaker 1J1-2NK1. Step 4.2.6 locally opens 1-RS-MOV-156B the number of steps recorded in step 4.1.11.1. Step 4.2.8.1 requests independent verification that 1-RS-MOV-155B is energized and step 4.2.8.2 verifies 1-RS-MOV-156B is energized. Step 4.2.10 requires that 1-PT-64.2B be performed. Attachment 1 lists the desired tagged positions of breakers and valves, and the position these devices are to be returned to service. 1-RS-MOV-155B and 1-RS-MOV-156B are listed as tagged closed and returned to open. Breakers 1J1-2NK2 and 1J1-2NK1 are tagged open and returned closed.

- 1-OP-7.5A is the operating valve lineup for the Outside Recirculation Spray System. This procedure lists the normal position for 1-RS-MOV-155B and 1-RS-MOV-156B as open. These MOV are independently verified.

- 1-PT-64.1B verifies operability of the B train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. Step 4.1.2 closes 1-RS-MOV-156B. Step 4.1.3 closes 1-RS-MOV-155B. Step 4.1.4 deenergizes and red tags 1-RS-MOV-156B. Step 4.1.5 deenergizes and red tags 1-RS-MOV-155B. Step 4.1.43 removes the red tag and energizes 1-RS-MOV-155B. Step 4.1.44 removes the red tag and energizes 1-RS-MOV-156B. These two steps are independently verified. Step 4.1.45 opens 1-RS-MOV-155B and step 4.1.46 opens 1-RS-MOV-156B. These two steps are independently verified.

- 1-PT-64.2B verifies operability of 1-RS-P-2B. This test is performed every 18 months. This procedure does not directly manipulate 1-RS-MOV-155B or 1-RS-MOV-156B. It does coordinate the performance of this procedure with 1-PT-64.1B.

- 1-PT-64.7 verifies the correct position of each valve that is not locked, not sealed or not secured in the ORS or Casing Cooling flow paths. This procedure is performed every 31 days. Step 6.3 verifies 1-RS-MOV-155B and 1-RS-MOV-156B are open.

- 1RSHEP-MOV-155B will represent the operator actions related to 1-RS-MOV-155B and 1-RS-MOV-156B which could leave them in a closed de-energized condition as a result of test or maintenance. 1-RS-MOV-155B is the suction valve for 1-RS-P-2B. 1-RS-MOV-156B is the discharge valve for 1-RS-P-2B. These valves are normally energized in the open position and receive a CDA open signal.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated

probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.17.2 Summary: 1RSHEP-MOV-155B

Fault Trees: RS100

Gates: GRS1554 (OR) Component failures after pump, ORS pump 2B.

Physical Id: 1RSHEP-MOV-155B_

Description: CRO_LEAVES_MOV-155B
OR_MOV-156B_CLOSED_
OR_DEENERGIZED_____

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.18 1RSHEP-1RS12

D.5.18.1 Analysis: 1RSHEP-1RS12

- Equivalent Surry HRA: 1RSHEP-1RS6
  see Surry IPE report page D.2-19 and D.2-20.
  calculated mean = 7.991E-4

- NAPS Procedures:

1-MOP-7.05	Outside Recirculation Pump 1-RS-P-2A, Rev 6, 11-30-89.
1-OP-7.5A	Valve Checkoff - Outside Recirc Spray System, Rev 6, 3-26-91.
1-PT-64.1A	Recirculation Spray Subsystem - "A" Pumps, Rev 17, 1-22-91.
1-PT-64.2A	Outside Recirculation Spray Pump, 1-RS-P-2A, Rev 7, 2-19-87.
1-PT-64.7	Outside Recirculation Spray and Casing Cooling System Valve Lineup Verification, Rev 1, 5-11-89.
1-PT-64.11	Outside Recirculation Spray Pump 1-RS-P-2A, Rev 0, 1-22-91.

- 1-MOP-7.05 provides instructions for removing 1-RS-P-2A from service for maintenance and returning to service after maintenance. Section 4.2 returns 1-RS-P-2A to service following maintenance. Step 4.2.3.4 closes 1-RS-12 and is independently verified.

- 1-OP-7.5A is the operating valve lineup for the Outside Recirculation Spray System. This procedure lists the normal position for 1-RS-12 and 1-RS-95 as closed. These manual valves are independently verified.

- 1-PT-64.1A verifies operability of the A train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. Step 4.1.10 opens 1-RS-12. Step 4.1.11 opens 1-RS-95. Step 4.1.40 closes 1-RS-12 and step 4.1.41 closes 1-RS-95. These two steps are independently verified.

- 1-PT-64.2A verifies operability of 1-RS-P-2A. This test is performed every 18 months. This procedure does not directly manipulate 1-RS-12 or 1-RS-95. It does coordinate the performance of this procedure with 1-PT-64.1A.

- 1-PT-64.7 verifies the correct position of each valve that is not locked, not sealed or not secured in the ORS or Casing Cooling flow paths. This procedure is performed every 31 days. Step 6.2 verifies 1-RS-12 and 1-RS-95 are closed.

• This HEP is used to represent leaving both 1-RS-12 and 1-RS-95 open. These valves are for 1-RS-P-2A recirculation line. 1-RS-12 is inside the pump cubicle and 1-RS-95 is located at the lower level of the safeguards area. Leaving both recirculation manual isolation valves open will cause a flow diversion which will prevent adequate flow to the RS spray headers. This operator error will not be easily revealed during a CDA event.

• HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

• Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. 1-PT-64.7 also acts as potential recovery from mispositioning. No credit is taken for this PT.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

• Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

• HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 6.0E-4 * 1.25 = 7.50E-4

D.5.18.2 Summary: 1RSHEP-1RS12

Fault Trees: RS100

Gates: GRS1354 (OR) Component failures after pump, ORS pump 2A.

Physical Id: 1RSHEP-1RS12____

Description: CRO_LEAVES RS-P-2A_
RECIRC_VALVES_OPEN_
1-RS-12_&_1-RS-95__

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.5.19 1RSHEP-1RS22

D.5.19.1 Analysis: 1RSHEP-1RS22

- Equivalent Surry HRA: 1RSHEP-1RS15
  see Surry IPE report page D.2-21.
  calculated mean = 7.991E-4

- NAPS Procedures:

1-MOP-7.06	Outside Recirculation Pump 1-RS-P-2A, Rev 6, 11-30-89.
1-OP-7.5A	Valve Checkoff - Outside Recirc Spray System, Rev 6, 3-26-91.
1-PT-64.1B	Recirculation Spray Subsystem - "B" Pumps, Rev 19, 1-22-91.
1-PT-64.7	Outside Recirculation Spray and Casing Cooling System Valve Lineup Verification, Rev 1, 5-11-89.
1-PT-64.12	Outside Recirculation Spray Pump 1-RS-P-2B, Rev 0, 1-22-91.

- 1-MOP-7.06 provides instructions for removing 1-RS-P-2A from service for maintenance and returning to service after maintenance. Section 4.2 returns 1-RS-P-2B to service following maintenance. Step 4.2.3.4 closes 1-RS-22 and is independently verified.

- 1-OP-7.5A is the operating valve lineup for the Outside Recirculation Spray System. This procedure lists the normal position for 1-RS-22 and 1-RS-96 as closed. These manual valves are independently verified.

- 1-PT-64.1B verifies operability of the B train of inside and outside Recirc Spray subsystems. This procedure is performed every three months. Step 4.1.10 opens 1-RS-22. Step 4.1.11 opens 1-RS-

96. Step 4.1.40 closes 1-RS-22 and step 4.1.41 closes 1-RS-96. These two steps are independently verified.

- 1-PT-64.2B verifies operability of 1-RS-P-2B. This test is performed every 18 months. This procedure does not directly manipulate 1-RS-22 or 1-RS-96. It does coordinate the performance of this procedure with 1-PT-64.1B.

- 1-PT-64.7 verifies the correct position of each valve that is not locked, not sealed or not secured in the ORS or Casing Cooling flow paths. This procedure is performed every 31 days. Step 6.3 verifies 1-RS-22 and 1-RS-96 are closed.

- This HEP is used to represent leaving both 1-RS-22 and 1-RS-96 open. These valves are for 1-RS-P-2B recirculation line. 1-RS-22 is inside the pump cubicle and 1-RS-96 is located at the lower level of the safeguards area. Leaving both recirculation manual isolation valves open will cause a flow diversion which will prevent adequate flow to the RS spray headers. This operator error will not be easily revealed during a CDA event.

- HEP Calculation:

Input Parameters:

U_0 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

HEP(median) = U_0 = 6.0E-3

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. 1-PT-64.7 also acts as potential recovery from mispositioning. No credit is taken for this PT.

HEP(median) = HEP * R = 6.0E-3 * 0.1 = 6.0E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type A HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 6.0E-4 * 1.25 = 7.50E-4

D.5.19.2 Summary: 1RSHEP-1RS22

Fault Trees: RS100

Gates: GRS1554 (OR) Component failures after pump, ORS pump 2B.

Physical Id: 1RSHEP-1RS22____

Description: CRO_LEAVES RS-P-2B_
RECIRC_VALVES_OPEN_
1-RS-22_&_1-RS-96__

Failure Rate: 7.500E-4

Distribution: Lognormal
Median: 6.000E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.0 DETAILED ANALYSIS OF OPERATOR ACTIONS DURING ACCIDENT CONDITIONS

D.6.1 HEP-0AP10

D.6.1.1 Analysis: HEP-0AP10

- Equivalent Surry HRA: none

- NAPS Procedures:

0-AP-10	Loss of Electrical Power, Rev 1, 5-16-91.
0-MOP-26.3	Transferring "A" RSS transformer From Bus 4 to Bus 5 and Returning to Bus 4 From Bus 5, Rev 0 4-4-91.
0-MOP-26.4	Transferring "B" RSS transformer From Bus 4 to Bus 5 and Returning to Bus 4 From Bus 5, Rev 0 4-4-91.
0-MOP-26.5	Transferring "C" RSS transformer From Bus 3 to Bus 5 and Returning to Bus 3 From Bus 5, Rev 0 3-19-91.

0-MOP-26.64	Switchyard Walkdown and Restoration, Rev 0, 3-28-91.
1-MOP-6.70	1H 4160 Volt Emergency Bus, Rev 8, 3-26-91.
1-MOP-6.71	1J 4160 Volt Emergency Bus, Rev 8, 3-26-91.
1-MOP-6.90	Emergency Diesel Generator 1-EE-EG-1H, Rev 15, 1-4-91.
1-MOP-6.91	Emergency Diesel Generator 1-EE-EG-1J, Rev 14, 1-4-91.

- 0-AP-10 is entered from step 3 of 1-E-0. This immediate operator action step is performed after every SI or reactor trip. If no AC emergency buses are energized the operators are directed to enter 1-ECA-0.0, Loss of All AC Power. If all AC emergency buses are not powered the operators are directed to use 1-AP10 to restore the buses.

- The basic event HEP-0AP10 is to represent the operator action required to identify which electrical buses are de-energized and to take the appropriate action within 0-AP-10 to restore the buses or MCCs. This HEP is intended for restoration of only one electrical train. Redundant equipment on the opposite train is considered to be operable. Total loss of offsite power recovery will be represented by other recovery basic events. This HEP will only be applicable to the operator actions such as operating electrical breakers or switches. It does not represent the recovery of several mechanical faults which require qualified electricians to repair.

- HEP Calculation:

Input Parameters:

T_b = 0 hours. The CRO will immediately become aware of electrical system failures.

T_e = 8 hours. System time-window is defined by Station Blackout coping time frame which is established as eight hours to be consistent with the mission time the EDGs are expected to run.

T_a = 15 minutes. Task action time to complete the breaker realignment once the correct steps of 0-AP-10 are identified. This is an estimated time value.

T_w = 465 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 60 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 0-AP-10 and progress through the procedure until the appropriate corrective action has been determine within 60 minutes. The length of time includes time to allow the operators to continue

with the emergency procedure in effect while using 0-AP-10.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(465/60) / 0.8)$
= $1 - \Phi(2.56)$
= 5.2E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 5.2E-3 / 1.25 = 4.16E-3

- Adjustment For Recovery:
  R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. It will be obvious to the CROs if the proper action has been taken to restore the electrical buses.

$p_3 = p_3 * R = 6.0E-3 * 0.01 = 6.0E-5$

HEP(median) = $p_2 + p_3$ = 4.16E-3 + 6.0E-5 = 4.22E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 4.22E-3 * 1.25 = 5.275E-3

D.6.1.2 Summary: HEP-0AP10

Fault Trees: E1H00, E1J00, E2H00, E2J00, EP100, EP200, ESY00

Gates:	GE1H152	(OR) Alternate source from station service bus 1B
	GE1H173	(OR) Cross tie 1H bus to 2J.
	GE1H734	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 1-I.
	GE1H832	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 1-II.
	GE1H972	(OR) No power supplied to vital bus from AC bus, vital bus 1-I.
	GE1H1072	(OR) No power supplied to vital bus from AC bus, vital bus 1-II.
	GE1H1272	(OR) No power supplied to semi vital bus from 1J1-1, semi vital bus 1C.
	GE1J152	(OR) Alternate source from station service bus 2B.
	GE1J632	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 1-III.
	GE1J732	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 1-IV.
	GE1J872	(OR) No power supplied to vital bus from AC bus, vital bus 1-III.
	GE1J972	(OR) No power supplied to vital bus from AC bus, vital bus 1-IV.
	GE2H173	(OR) Cross tie 2H Bus To 2J.
	GE2H632	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 2-I.
	GE2H732	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 2-II.
	GE2H872	(OR) No power supplied to vital bus from AC bus, vital bus 2-I.
	GE2H972	(OR) No power supplied to vital bus from AC bus, vital bus 2-II.
	GE2J632	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 2-III.
	GE2J732	(OR) No power supplied to DC bus from alternate 480 V bus, DC bus 2-IV.
	GE2J872	(OR) No power supplied to vital bus from AC bus, vital bus 2-III.
	GE2J972	(OR) No power supplied to vital bus from AC bus, vital bus 2-IV.
	GEP1144	(OR) Loss of station service transformer or breaker.
	GEP1244	(OR) Loss of station service transformer or breaker.
	GEP1344	(OR) Loss of station service transformer or breaker.
	GEP1434	(OR) No power supplied to bus 1A1 from 480 V bus 1C2.
	GEP1534	(OR) No power supplied from 4160 V bus 1B through bus 1B1.
	GEP1734	(OR) No power supplied to bus 1B1 from 480 V bus 1A2.

GEP1834	(OR) No power supplied from 4160 V bus 1B through bus 1C1.
GEP11034	(OR) No power supplied to bus 1C1 from 480 V bus 1B2.
GEP11134	(OR) No power supplied from 4160 V bus 1A through bus 1A1.
GEP2434	(OR) No power supplied to bus 2A1 from 480 V bus 2C2.
GEP2534	(OR) No power supplied from 4160 V bus 2B through bus 2B1.
GEP2634	(OR) No power supplied to bus 2B1 from 480 V bus 2A2.
GEP2734	(OR) No power supplied from 4160 V bus 2B through bus 2C1.
GEP2834	(OR) No power supplied to bus 2C1 from 480 V bus 2B2.
GEP2934	(OR) No power supplied from 4160 V bus 2A through bus 2A1.
GESY1552	(OR) No electric power to bus 1J from alternate AC diesel.
GESY1582	(OR) No electric power to bus 2H from alternate AC diesel.
GESY1652	(OR) No electric power to bus 1H from alternate AC diesel.
GESY1682	(OR) No electric power to bus 2J from alternate AC diesel.

Physical Id: HEP-0AP10

Description: 0-AP-10_LOSS_OF
ELECTRICAL_POWER

Failure Rate: 5.275E-3

Distribution: Lognormal
Median: 4.220E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.2 HEP-0AP12

D.6.2.1 Analysis: HEP-0AP12

D.6.2.1.1 Analysis: HEP-0AP12-10HR

- Equivalent Surry HRA: none

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-90.
0-AP-12	Loss of Service Water, Rev 1, 1-7-91.
1-OP-49.1	Service Water System Operation, Rev 2, 8-22-91.

- This HEP represents the operator action required to recover return flow to the SW Reservoir flow by opening the return header MOVs. Normally these valves are open except during the winter when the spray array bypass valves are open. It is assumed that there is some SW return flow through the bypass line. This HEP is for establishing additional SW cooling.

- 0-AP-12 step 3 verifies return header flow paths. Part a) verifies the A header (#4) return flow, and part b) verifies the B header return flow by checking the header flow indicators. The RNOs are to manually open valves, starting with the spray array valves, then the bypass spray array valves, and then the discharge to the CW tunnel if the system is aligned to Lake Anna.

- HEP-0AP12-10HR will be used to represent the probability of operator action to restore cooling to the Charging Pumps and to the ESGR chillers within 10 hours. It is assumed that SW is either restored or alternate cooling means implemented. Attachments are provided which have details for establishing alternate cooling sources. HEP-0AP12-20HR will be used for a 20 hour time window, HEP-0AP12-30HR for 30 hours, and HEP-0AP12-40HR for 40 hours.

- HEP Calculation:

Input Parameters:

T_b = 0 hours. The CROs should be able to immediately detect failure of the HVAC for the ESGR and MCR. This is an estimated value. The operators will become aware of a loss of HVAC to the ESGR during routine surveillance, log taking in the MCR or ESGR, or annunciators.

T_e = 10 hours. System time-window is defined by the Accident Sequence Development Analysis file.

T_a = 6 hours. Task action time to complete 0-AP-12. This is an estimated time value. The temperature of components cooled by SW are expected to

stabilize or decrease as soon as SW flow is restored.

T_w = 4 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 30 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 0-AP-12 within 30 minutes once he is aware of the need to re-establish SW cooling.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 2.0E-3, 1.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 1, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, short list <10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2})/ \sigma)$
= $1 - \Phi(\ln(240/30) / 0.8)$
= $1 - \Phi(2.60)$
= 4.7E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 4.7E-3 / 1.25 = 3.76E-3

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions, etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

  $p_3 = p_3 * R$ = 2.0E-3 * 0.1 = 2.0E-4

  HEP(median) = $p_2 + p_3$ = 3.76E-3 + 2.0E-4 = 3.960E-3

- Consideration of Dependency:

HEP-0AP12-30HR will appear in sequences with HEP-0AP12-10HR but never by itself. The point estimate value for HEP-0AP12-30HR will

be adjusted so that the operator error probability for this sequence will no be less than the probability for HEP-0AP12-30HR by itself.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 3.960E-3 * 1.25 = 4.95E-3

D.6.2.1.2 Analysis: HEP-0AP12-20HR

- Same as HEP-0AP12-10HR with the following changes:

- HEP Calculation:

T_e = 20 hours. System time-window is defined by the Accident Sequence Development Analysis file.

T_w = 14.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2})/ \sigma)$

= $1 - \Phi(\ln(840/30) / 0.8)$

= $1 - \Phi(4.17)$

< 1.0E-4

P_2(median) = HEP(mean) / M

where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 1.0E-4 / 1.25 = 8.00E-5

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:

R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the very long time window, >12 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. This recovery is applicable to both the p_2 and p_3 terms.

HEP(median) = HEP(median) * R = 2.08E-3 * 0.1 = 2.08E-4

- Consideration of Dependency:

There is a dependency between HEP-0AP12-20HR and HEP-0AP12-40HR. HEP-0AP12-40HR will appear in sequences with HEP-0AP12-20HR but never by itself. The point estimate value for HEP-0AP12-40HR will

be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP12-40HR by itself.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.080E-4 * 1.25 = 2.60E-4

D.6.2.1.3 Analysis: HEP-0AP12-30HR

- Same as HEP-0AP12-10HR with the following changes:

- HEP Calculation:

T_e = 30 hours. System time-window is defined by the Accident Sequence Development Analysis file.

T_w = 24.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(24/0.5) / 0.8)$
= $1 - \Phi(4.84)$
< 1.0E-4

P_2(median)= HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

HEP(median)= $p_2 + p_3$ = 8.0E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:

R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. Because of the very long time window, > 24 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. The new shift will act as a checker of the other, also routine surveillance logs will make the operators aware of the Control Room ambient temperature and take corrective action if it is abnormally high. This recovery is applicable to both the p_2 and p_3 terms.

HEP = HEP(median) * R = 2.08E-3 * 0.01 = 2.08E-5

- Consideration of Dependency:

There is a dependency between HEP-0AP12-10HR and HEP-0AP12-30HR. HEP-0AP12-30HR will appear in sequences with HEP-0AP12-10HR but never by itself. The point estimate value for HEP-0AP12-30HR will be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP12-30HR by itself.

$$\text{HEP-0AP12-30HR (adjusted)} = \frac{\text{HEP-0AP12-30HR}}{\text{HEP-0AP12-10HR}} = \frac{2.08E\text{-}5}{3.96E\text{-}3}$$

$$= 5.253E\text{-}3$$

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=EXP{[1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 5.253E-3 * 1.25 = 6.566E-3

D.6.2.1.4 Analysis: HEP-0AP12-40HR

- Same as HEP-0AP12-10HR with the following changes:

- HEP Calculation:

T_e = 40 hours. System time-window is defined by the Accident Sequence Development Analysis file.

T_w = 34.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(34/0.5) / 0.8)$
= $1 - \Phi(5.27)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where M=EXP{[(1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:

R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. Because of the very long time window, > 24 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift

change to a new group of operators. The new shift will act as a checker of the other, also routine surveillance logs will make the operators aware of the Control Room ambient temperature and take corrective action if it is abnormally high. This recovery is applicable to both the p_2 and p_3 terms.

HEP = HEP(median) * R = 2.08E-3 * 0.01 = 2.08E-5

- Consideration of Dependency:

There is a dependency between HEP-0AP12-20HR and HEP-0AP12-40HR. HEP-0AP12-40HR will appear in sequences with HEP-0AP12-20HR but never by itself. The point estimate value for HEP-0AP12-40HR will be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP12-40HR by itself.

$$\text{HEP-0AP12-40HR (adjusted)} = \frac{\text{HEP-0AP12-40HR}}{\text{HEP-0AP12-20HR}} = \frac{2.08E-5}{2.08E-4}$$

$$= 1.000E-1$$

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.000E-1 * 1.25 = 1.250E-1

D.6.2.2 Summary: HEP-0AP12

D.6.2.2.1 Summary: HEP-0AP12-10HR

Fault Trees: FFT00

Gates: GFFT1122 (OR) T6 Loss Of SW For RC101.

Physical Id: HEP-0AP12-10HR__

Description: 0-AP-12_LOSS_OF____
SERVICE_WATER______
RECOVERY_IN_10_HOUR

Failure Rate: 4.950E-3

Distribution: Lognormal
Median: 3.960E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.2.2.2 Summary: HEP-0AP12-20HR

Fault Trees: FFT00

Gates: GFFT1123 (OR) T6 Loss Of SW For RC201.

Physical Id: HEP-0AP12-20HR__

Description: 0-AP-12_LOSS_OF____
SERVICE_WATER______
RECOVERY_IN_20_HOUR

Failure Rate: 2.60E-4

Distribution: Lognormal
Median: 2.080E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.2.2.3 Summary: HEP-0AP12-30HR

Fault Trees: FFT00

Gates: GFFT1124 (OR) T6 Loss Of SW For RC201.

Physical Id: HEP-0AP12-30HR__

Description: 0-AP-12_LOSS_OF____
SERVICE_WATER______
RECOVERY_IN_30_HOUR

Failure Rate: 6.566E-3

Distribution: Lognormal
Median: 5.253E-3
Error Factor: 3

Reference: 324MAF.N___________
9-1-92_____________
____

Why modified: NAPS IPE Final Quantification Value

D.6.2.2.4 Summary: HEP-0AP12-40HR

Fault Trees: FFT00

Gates: GFFT1125 (OR) T6 Loss Of SW For RC302.

Physical Id: HEP-0AP12-40HR__

Description: 0-AP-12_LOSS_OF____
SERVICE_WATER______
RECOVERY_IN_40_HOUR

Failure Rate: 1.250E-1

Distribution: Lognormal
Median: 1.000E-1
Error Factor: 3

Reference: 324MAF.N___________
9-1-92_____________
____

Why modified: NAPS IPE Final Quantification Value

D.6.3 HEP-0AP12-ATTCH4

D.6.3.1 Analysis: HEP-0AP12-ATTCH4

- Equivalent Surry HRA: HEP-AP12:00
  see Surry IPE report page D.3-102 to D.3-103.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-90.
0-AP-12 Loss of Service Water, Rev 1, 1-7-91.
1-OP-49.1 Service Water System Operation, Rev 2, 8-22-91.

- This HEP represents the operator action required to recover SW flow to a header by aligning a redundant pump from the opposite header to the failed header. There are two SW headers and four SW pumps. Two pumps are normally aligned to each header. In the event that both pumps on one header have failed and both pumps are operable on the opposite header, then one of the operable pumps on

the opposite header may be aligned to supply flow to the header without SW flow. To align a pump from one header to another requires opening a manual valve at the pump discharge and closing a manual valve. To align the 1-SW-P-1B to the "A" SW header requires stopping the pump, closing the manual discharge valve to the "B" header (1-SW-11), opening the manual discharge valve to the "A" header (1-SW-13), then restarting the pump. Similar action is required to align the other pumps to either header. 0-AP-12 attachment 4 provides information on aligning SW pumps to the headers.

- 1-E-0 step 11 verifies SW pumps are running. The RNO is to manually start the pumps. No Procedure direction suggests realignment of the 1-SW-P-1B pump to the A header.

- 0-AP-12 step 2 verifies that at least two SW headers are available then verifies that at least one SW pump is running on each header. The RNO is to start at least on SW pump on each supply header using 1-OP-49.1. If at least one pump is running on one header the AP directs the operator to continue through the procedure. This will allow the operator to reach step 12 "Restore SW to affected header, check status of following: affected unit supply header available." The RNO for this step is to "cross connect SW to both units using Attachment 4.

- 0-AP-12 Attachment 4 is titled "Supplying Both SW Supply Headers When Two Pumps Are Running On One Header." The specific guidance identifies which header has two pumps, then allows the operator to choose which pump should be aligned to the opposite header, then provides specific guidance to align the pump to the header with no running pumps. This guidance includes throttling the discharge valve during the pump start.

- 1-OP-49.1 Steps 5.7.1 through 5.7.14 are titled "Shifting Service Water Pumps." These steps provide guidance for stopping and starting pumps on a single header. Guidance is not provided to transfer a pump from one header to another. The normal pump to header alignment is maintained.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information immediately available to determine that two SW pumps are available on one supply header and none on the other header.

T_e = 24 hours. The system time-window is defined by an engineering estimate that one train of Service Water system is adequate heat removal during the first 24 hours. It is assumed that one train of SW fails and that the other train has two SW pumps. The case of only one pump running is not included

because it would be outside the boundary of this HEP. The largest heat removal demand for the SW system during a CDA are the RS heat exchangers. One train of SW will provide flow to two RS heat exchanger. Additional failures would have to occur to limit flow to one RS heat exchanger. One heat exchanger could be used for an indefinite period. Twenty four hours is used as the system time window. The system time window also takes into consideration establishing RHR. One train of SW cooling to the CC heat exchangers is adequate for RHR operation. Also RHR may not be needed if RS is used because of damage to the RHR system. MAAP (analysis file 326MAF.N.5) case 1 confirms that one train of SW flow to one heat exchanger to provide adequate heat removal.

T_a = 1 hour. Task action time to complete 0-AP-12 steps 1 to 12 and Attachment 4. This is an estimated time value.

T_w = 23 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 2 hours. Operator median response time. It is estimated that the CRO in the Control Room will initiate 0-AP-12 within two hours of accident initiation as a response to one of six possible annunciators on the 1J annunciator panel. These annunciators include B-3 "SERV WTR RETURN HDR LO FLOW," D-3 "SW PP 1-P1A, 2-P1A AUTO TRIP," E-3 "AUX SW PP 1-P4 LO FLOW," H-3 "SW PP 1-P1B AUTO TRIP," D-4 "AUX SW PP 2-P4 LO FLOW," or E-4 "AUX SW PP 1-P4, 2-P4 AUTO TRIP."

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 1.2E-2, 6.0E-3, use (2 * 6E-3) since there are two valves to manipulate. 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Also p_3 =3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-13, item 2, estimated HEPs for selection errors for locally operated valves clearly and unambiguously labeled, part of a group of two or more valves that are similar in one of the following: size and shape, state, or presence

of tags. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(23/2) / 0.8)$
= $1 - \Phi(3.05)$
= 1.1E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.1E-3 / 1.25 = 8.80E-4

HEP(median) = $p_2 + p_3$ = 8.80E-4 + 1.2E-2 = 1.288E-2

- Adjustment For Recovery:
  R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error factor 5. 0-AP-12 steps 4 and 18 will verify that SW flow has been restored to both headers. This is considered an active check. Because of the very long time window, >12 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. This recovery is applicable to both the p_2 and p_3 terms.

HEP(median) = HEP(median) * R = 1.288E-2 * 0.01 = 1.288E-4

- Consideration of Dependency:

A dependency between the HEP-0AP12-ATTCH4 and HEP-1OP49:4A does exist and will be accounted for in the calculation for HEP-1OP49:4A.

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
use EF of 5 from Table 20-22 recovery term
where M=1.25 for an EF = 3
= 1.288E-4 * 1.25 = 1.610E-4

D.6.3.2 Summary: HEP-0AP12-ATTCH4

Fault Trees: SW200

Gates:	GSW2164	(OR) Service Water from 1-SW-P-1B unavailable.
	GSW2763	(OR) Service Water from 2-SW-P-1B unavailable.
	GSW2634	(OR) Valve Faults, SW from 1-SW-P-1A.

Physical Id: HEP-0AP12-ATTCH4

Description: 0-AP-12_LOSS_OF_SW_
ATTACHMENT_4:_TWO__
PUMPS_ON_ONE_HEADER

Failure Rate: 1.610E-4

Distribution: Lognormal
Median: 1.288E-4
Error Factor: 3

Reference: 324MAF.N___________
9-1-92____________
____

Why modified: NAPS IPE Final Quantification Value

D.6.4 HEP-1AP15-1E

D.6.4.1 Analysis: HEP-1AP15-1E

- Equivalent Surry HRA: HEP-1OP51:1
  see Surry IPE report page D.3-99.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-AP-15 Loss of Component Cooling, Rev 6, 10-5-90.

- The purpose of 1-AP-15 is to provide the actions to take in the event of a loss of Unit 1 Component Cooling System. The first step of this procedure locally checks SW flow to the CC heat exchangers and restores flow if SW is available. If not available then 1-AP-12, Loss of Service Water, is initiated.

- HEP Calculation:

Input Parameters:

T_b = 1 hour. The CRO may not immediately be able to determine that a CC system failure has occurred requiring operator action to take action to restore the system. The 1 hour time frame is an estimate.

T_e = 18 hours, engineering allowable system time-window. This time window is from MAAP (analysis file 326MAF.N.5) cases 28 and Z28. It is the amount of time until the ECST is emptied during a SGTR which is 100 hours if no RCS cooldown is performed or 18 hours if the RCS is cooldown at 50°F/hr to RHR initiation temperature of 300°F. This is the same time window used for HEP-1OP14:1-5:1. System time-

window is defined by engineering estimate of when the CC system will need to be restored. The most significant demand for the system will be to provide RHR cooling late in the accident sequence. CC also provides cooling to the RCP thermal barrier which is helpful in preventing a RCP seal failure. However, the CC pumps are not always available, they are de-energized whenever the emergency bus has experienced an undervoltage condition.

T_a = 1 hour. Task action time to complete all steps of 1-AP-15. This is an estimated time value. The CC system is expected to be immediately available to remove heat after completing the procedure.

T_w = 16 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 1 hour. Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-AP-15 within one hour once he is aware of the need to re-establish CC cooling.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(16/1) / 0.8)$
= $1 - \Phi(3.47)$
= 3.0E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.00E-4 / 1.25 = 2.40E-4

HEP(median) = $p_2 + p_3$ = 2.40E-4 + 6.0E-3 = 6.240E-3

- Adjustment For Recovery:
  R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine

tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the very long time window, >12 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. This recovery is applicable to both the p_2 and p_3 terms.

HEP(median) = HEP(median) * R = 6.24E-3 * 0.1 = 6.24E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 6.24E-4 * 1.25 = 7.80E-4

D.6.4.2 Summary: HEP-1AP15-1E

Fault Trees: CC100

Gates:	GCC1554	(OR) Shift to heat exchanger 1-CC-E-1B not completed.
	GCC1825	(OR) Insufficient SW supply from header B, insufficient SW supply to 1-CC-E-1A.
	GCC1875	(OR) Insufficient SW supply from header B, insufficient SW supply to 1-CC-E-1B.

Physical Id: HEP-1AP15-1E____

Description: 1-AP-15_LOSS_OF_CC_
STEP_1E_RESTORE_SW_
TO_CC_HEAT_EXCHANGR

Failure Rate: 7.80E-4

Distribution: Lognormal
Median: 6.240E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.5 HEP-1AP15-6

D.6.5.1 Analysis: HEP-1AP15-6

- Equivalent Surry HRA: none

- NAPS Procedures:

1-AP-15	Loss of Component Cooling, Rev 6, 10-5-90.
1-AP-33.1	Reactor Coolant Pump Seal Failure, Rev 0, 3-26-91.
1-AP-33.2	Loss of RCP Seal Cooling, Rev 2, 3-28-91.
1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-ECA-0.0	Loss of All AC Power, Rev 3, 12-27-89.
1-ECA-0.1	Loss of All AC Power Recovery Without SI Required, Rev 3, 12-27-89.
1-ECA-0.2	Loss of All AC Power Recovery With SI Required, Rev 1, 12-27-89.

- 1-AP-15 provides the actions to take in the event of a loss of Unit 1 Component Cooling system. Step 6 cross ties the Unit 1 and Unit 2 CC systems after checking to be sure that the Unit 2 system is available and that the Unit 1 CC system is intact. The action required to cross tie the CC systems is to locally open two valves, one of which requires obtaining a portable ladder to reach the valve. Step 6 also reminds the operator to enter the Action Statement for Technical Specification 3.7.3.1.

- 1-AP-33.1 provides instructions to follow in the event of a RCP seal failure.

- 1-AP-33.2 provides instructions for recovering from a loss of RCP seal cooling. Step 1 verifies the RCPs are stopped. Step 2 verifies RCP seal cooling is isolated. Step 4 verifies CC system is in service and the RNO is to initiate 1-AP-15.

- 1-ECA-0.0 provides instructions for the operator to attempt to restore electrical buses, the only operator action related to the RCP seals is to isolate RCP seal injection and RCP seal cooling.

- 1-ECA-0.1 step 1 verifies RCP seal cooling has been isolated if no Charging pumps are running, or continuing with the procedure if at least one Charging pump is running. Step 13 restores the CC system. Step 15 initiates 1-AP-33.2 with appropriate cautions preceding this step.

- 1-ECA-0.2 step 1 verifies RCP seal cooling has been isolated. Step 10 restores the CC system. Step 11 initiates 1-AP-33.2 with appropriate cautions preceding this step.

- HEP-1AP15-6 will be used to represent the operator action required to cross tie Unit 1 and Unit 2 CC systems. Since this HEP is used in the NAPS PRA model during the T1A event tree it will be

assumed that a LOOP has occurred and both EDG have failed. The operator response will be to initiate 1-ECA-0.0 then progress to either 1-ECA-0.1 or 1-ECA-0.2, which initiates 1-AP-33.2, then transitions to 1-AP-12 where the operator is directed to cross tie the CC systems.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine that RCP seal cooling has been lost and that Unit 2 CC system is available immediately after the event initiation without further delay.

T_e = 10 hours. System time-window is defined by the Accident Sequence Development analysis file 321MAF.1.N section 6.0. The station blackout mission time is determined by the performance of the RCP seal. The seal model for this PRA guarantees core uncovery from seal LOCA by 10 hours.

T_a = 20 minutes. Task action time to complete the actions required by step 6 of 1-AP-15. This is an estimated time value. It is estimated that the time to manipulate the two manual valves is ten minutes and that it will take ten minutes to find a ladder to reach one of these valves. CC Temperature is expected to stop or decrease immediately after opening the cross connect valves.

T_w = 580 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 125 minutes. Operator median response time. It is estimated that the operator will require one hour to complete 1-ECA-0.0 steps 1 through 26, and transition to the appropriate recovery method. It is estimated that it will take the operator thirty minutes to progress through either 1-ECA-0.1 step 13 or 1-ECA-0.2 step 11 to reach the instructions to initiate 1-AP-33.2. It is estimated that it will take the operator 15 minutes to progress through 1-AP-33.2 and reach step 4 where the RNO instructs the operator to initiate 1-AP-15. It is estimated that it will take another twenty minutes to reach step 6 of 1-AP-15 where the operator will begin to cross tie the two CC systems. These time estimates are considered to be conservative. If any one time is wrong then the others have sufficient margin to make the total time conservative. The operator times may appear to be long to some reviewers but they do include time to

complete other operator actions due to other procedures also being performed during this event.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(580/125) / 0.8)$
= $1 - \Phi(1.92)$
= 2.74E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.74E-2 / 1.25 = 2.192E-2

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term. Recovery may also be possible due to the annunciators present warning of CC system failure, or other personnel present due to TSC after the first 60 minutes.

  $p_3 = p_3 * R$ = 6.0E-3 * 0.1 = 6.0E-4

HEP(median) = $p_2 + p_3$ = 2.192E-2 + 6.0E-4 = 2.252E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 2.252E-2 * 1.25 = 2.815E-2

D.6.5.2 Summary: HEP-1AP15-6

Fault Trees:	FFT00	
Gates:	GFFT613	(OR) RCP seal LOCA, SBO No CCW From NAPS2 event Slc HEP FFT.
Physical Id:	HEP-1AP15-6_____	
Description:	1-AP-15_LOSS_OF_CC_ STEP_6_CROSS_TIE_CC IF_UNIT_2_AVAILABLE	
Failure Rate:	2.815E-2	
Distribution:	Lognormal	
Median:	2.252E-2	
Error Factor:	3	
Reference:	324MAF.N____________ 9-1-92______________ ____________________	

D.6.6 HEP-1AP22:5

D.6.6.1 Analysis: HEP-1AP22:5

- Equivalent Surry HRA: HEP-10P31:2:6
  see Surry IPE report page D.3-97 to D.3-98.
  calculated mean = 2.664E-3

1-AP-22.5 Loss of Emergency Condensate Storage Tank, Rev 0, 3-27-91.

- NAPS Procedures:

1-AP-22.5	Loss of Emergency Condensate Storage Tank, Rev 0, 3-27-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-FR-H.1	Response to Loss of Secondary Heat Sink, Rev 3, 5-31-90.

- 1-E-1 and 1-FR-H.1 direct the operator to initiate 1-AP-22.5 when the ECST reaches 40% level.

- 1-AP-22.5 provides instructions to necessary to refill the 100,000 gallon Emergency Condensate Storage Tank (ECST, 1-CN-TK-1) from the 300,000 gallon main Condensate Storage Tank (CST, 1-CN-TK-2).

• HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine a that inadequate AFW flow condition exists due to no water left in the ECST immediately as the tank empties.

T_e = 206 minutes. The system time-window is from MAAP (analysis file 326MAF.N.5) case 29. This is the time between reaching 40% ECST level, 100,000 gallons, and reaching 0% at 350 gpm.

T_a = 15 minutes. Task action time to complete the appropriate steps of 1-AP-22.5 which will restore water to the suction of the AFW pumps.

T_w = 191 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 10 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-AP-22.5 within 10 minutes of the ECST reaching 40% level. This includes time to complete any actions in progress and having an RO available to perform the local actions.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(191/10) / 0.8)$
= $1 - \Phi(3.69)$
= 1.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.0E-5

• Adjustment For Recovery:

R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to

detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. Could justify R = 0.0001, the recovery factor. From NUREG/CR-1278, Table 20-23, The Annunciator Response Model estimated HEPs for multiple annunciators item 1 column 1. Annunciators are expected for the ECST reaching low level, the SGs below low level and the AFW pumps tripping due to lack of water to the suction of the pumps. This recovery appears appropriate since the rate that the ECST is emptying is slow. The TSC will be manned and multiple persons outside of the control room will be aware of ECST level. Use R = 0.01 for a conservative value. Because of the long time window, > 1 hour, credit can also be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R = 6.0E-3 * 0.01 = 6.0E-5$

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 6.0E-5 = 1.40E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs. This HEP does not appear in the same cut set with other HEPs. But these operator actions are significantly different to justify no dependency.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=EXP{[1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 1.40E-4 * 1.25 = 1.75E-4

D.6.6.2 Summary: HEP-1AP22:5

Fault Trees: AF100

Gates: GAF12641 (OR) Insuf makeup from 300,000 gal CST 1-CN-TK-2.

Physical Id: HEP-1AP22:5_____

Description: 1-AP-22.5_LOSS_OF__
EMERGENCY_CONDNSATE
STORAGE_TANK_______

Failure Rate: 1.75E-4

Distribution: Lognormal
Median: 1.40E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.7 HEP-1AP33:1

D.6.7.1 Analysis: HEP-1AP33:1

- Equivalent Surry HRA: none

- NAPS Procedures:

1-AP-33.1	Reactor Coolant Pump Seal Failure, Rev 0, 3-26-91.
1-AP-33.2	Loss of RCP Seal Cooling, Rev 2, 3-28-91.
1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-OP-2.2	Unit Power Operation From Mode 1 to Mode 2, Rev 22, 7-7-91.
1-OP-3.1	Unit Shutdown From Mode 2 to Mode 3, Rev 12, 12-20-90.

- 1-AP-33.1 provides instructions to follow in the event of a RCP seal failure. The procedure is entered when abnormal seal leakoff is indicated or annunciators have alarmed for RCP seal leakoff high flow or RCP shaft seal water low differential pressure. It initiates a unit rampdown at 3% per minute and initiates 1-OP-2.2. When reactor power reaches less than 25% power or 30 minutes have elapsed since the onset of RCP seal failure then the reactor is tripped and transition to 1-E-0.

- 1-AP-33.2 provides instructions for recovering from a loss of RCP seal cooling. No steps recommend that the RCS should be cooldown to prevent RCP seal failure. The last step of 1-AP-33.2 instruct the operator to return to the procedure in effect. This procedure is referenced by 1-ES-1.1, SI Termination, 1-ES-1.2 Post LOCA Cooldown and Depressurization, 1-E-3, and 1-ECA-3 series.

- HEP-1AP33:1 will be used to represent the operator action required to cooldown the RCS sufficiently to minimize RCP seal leakage. A cooldown will be initiated only after 1-AP-33.1 is initiated. This may be too late because the 1-AP-33.2 anticipates a seal failure and 1-AP-33.1 is initiated once failure is thought to occur. The HEP timing will follow the guidelines of the Accident Sequence Development analysis file, 321MAF.1.N, and assume that the operator initiates 1-AP-33.1 before seal failure has occurred but that the cooldown rate is slow, 25°F per hour. This HEP will be calculated using the 321MAF.1.N timing.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to make a decision to cooldown or not without further significant delay.

T_e = 10 hours. System time-window is defined by the Accident Sequence Development analysis file 321MAF.1.N section 6.0. The station blackout mission time is determined by the performance of the RCP seal. The seal model for this PRA guarantees core uncovery from seal LOCA by 10 hours.

T_a = 8 hours. Task action time to complete a RCS cooldown from 550°F to 350°F at 25°F/hr, from 321MAF.a.N.

T_w = 120 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 90 minutes. Operator median response time. It is estimated that the operator will require one hour to complete determine that it RCP seal cooling has been lost and will not be recovered in the near future, leaving a RCS cooldown as the prudent course of action. The operator is expected to spend one hour using 1-AP-33.2 attempting to restore RCP seal cooling. 1-AP-33.1 will be implemented with a 30 minute ramp down in power from 100% power followed by a reactor trip.

σ = 1.0 for extreme cases, where procedural guidance is indirect, and there is not evidence of scenario specific training, but some indication that the crews are knowledgeable about the actions necessary.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$

= $1 - \Phi(\ln(120/90) / 1.0)$

= $1 - \Phi(0.29)$

= 3.859E-1

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.859E-1 / 1.25 = 3.087E-1

- Adjustment For Recovery:
R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R = 6.0E-3 * 0.1 = 6.0E-4$

HEP(median) = $p_2 + p_3$ = 3.087E-1 + 6.0E-4 = 3.093E-1

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:
HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.093E-1 * 1.25 = 3.866E-1

D.6.7.2 Summary: HEP-1AP33:1

Fault Trees: FFT00

Gates: GFFT362 (OR) T4 and T6 for 005

Physical Id: HEP-1AP33:1_____

Description: 1-AP-33.1_REACTOR__
COOLANT_PUMP_SEAL__
FAILURE_____________

Failure Rate: 3.866E-1

Distribution: Lognormal
Median: 3.093E-1
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.8 HEP-1AP49

D.6.8.1 Analysis: HEP-1AP49

- Equivalent Surry HRA: HEP-1E0-16
  see Surry IPE report page D.3-48 to D.3-50.
  calculated mean = 1.438E-3

- NAPS Procedures:

0-AP-48 Charging Pump Cross Connect, Rev 0, 3-28-91.
1-AP-49 Loss of Normal Charging, Rev 2, 3-27-91.

- HEP-1AP49 is used in the fault tree CH200 which is quantified for the function SLC, RCP seal cooling which appears in the T1 event tree. It is assumed that safety injection is not required for this sequence.

- 1-AP-49 step 8 directs the operator to "Verify VCT Available. The RNO for this step is to "line up the Charging Pump suction to RWST." The Charging Pump suction from the RWST valves, 1-CH-MOV-1115B and -1115D are opened, and the Charging Pump suction from the VCT isolation valves, 1-CH-MOV-1115C and -1115E are closed. For success of this HEP only one RWST valve has to be opened. It is a good practice to open both RWST valves to minimize the effects of inadvertent closure of one valve. Neither VCT valve has to be closed. Closing either valve will isolate this tank. As long as the RWST has water there should not be any effect on Charging pump performance. The VCT isolation valve are closed to prevent any possible flow diversion of RWST water into the VCT or VCT gas into the Charging pump suction. During a LOCA the VCT must be isolated before the RWST empties and the Charging pumps placed on recirculation. There are a total of 17 steps in 1-AP-49. The other steps verify operability of other parts of the Charging system.

- The Surry IPE HRA used HEP-1E0-16 to represent this basic event. The SLC function is separated from the D1 functions for the North Anna HRA. This results in HEP-1AP49 being considered independently from HEP-1E0-16.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO is will be able to immediately realize that the VCT is almost empty by an annunciator and the VCT level indicator.

T_e = 20 minutes. System time-window is defined by engineering estimate of the time it takes to empty the VCT once the low level annunciator has alarmed. This time is difficult to evaluate because of the

various possible RCS leak rates which will define how long it takes to drain a VCT.

T_a = 5 minutes. Task action time to complete 1-AP-49 through step 8 which aligns the Charging Pump suction from the VCT to the RWST. This is an estimated value and includes performing steps 1 to 7 and the valve stroke time for the RWST isolation valves.

T_w = 15 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 2 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-AP-49 within two minutes once the VCT low level annunciator has alarmed.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Since there are at least 17 steps in 1-AP-49 and the operator only has to open one RWST suction MOV for success of this HEP. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(15/2) / 0.8)$
= $1 - \Phi(2.52)$
= 5.9E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 5.9E-3 / 1.25 = 4.72E-3

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery for this HEP.

$p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 4.72E-3 + 6.0E-3 = 1.072E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:

  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.072E-2 * 1.25 = 1.340E-2

D.6.8.2 Summary: HEP-1AP49

Fault Trees: CH200

Gates: GCH2543 (AND) Failure to switch suction source to RWST.

Physical Id: HEP-1AP49_______

Description: 1-AP-49_LOSS_OF____
NORMAL_CHARGING____
____

Failure Rate: 1.340E-2

Distribution: Lognormal
Median: 1.072E-2
Error Factor: 3

Reference: 324MAF.N___________
9-1-92_____________
____

Why modified: NAPS IPE Final Quantification Value

D.6.9 HEP-0AP55

D.6.9 Analysis: HEP-0AP55

D.6.9.1.1 Analysis: HEP-0AP55-10HR

- Equivalent Surry HEP: REC-ESGR-ROOMCOOL
  see Surry IPE report page 3-260
  hardware failure probability = 4.69E-3
  human error probability = 2.66E-2
  Total = 3.13E-2

  Recovery of ESGR Unit 1 room cooling by starting fan in Unit 2 ESGR, opening fire door between ESGR's, and locating portable fans in necessary locations. Allowable time is 4 hours.

- NAPS Procedures:

0-AP-55 Loss of Control Room/Emergency Switchgear Room Air Conditioning, Rev 0, 3-28-91.

- 0-AP-55 provides instructions to follow in the event of a loss of Control Room or Emergency Switchgear Room Air Conditioning. This procedure is entered when either all three Control Room Air Conditioning Units on either unit has failed, or when both Control Room and Emergency Switchgear Room air handlers on either unit has failed. This procedure has the operators start two air handling units on the unaffected unit, opens the fire doors between the two units' Emergency Switchgear Rooms, and opens cabinet doors and provides potable ventilation.

- HEP-0AP55-10HR will be used to represent the probability of operator action to restore ESGR HVAC within 10 hours. HEP-0AP55-20HR will be used for a 20 hour time window, HEP-0AP55-30HR for 30 hours, and HEP-0AP55-40HR for 40 hours.

- HEP Calculation:

Input Parameters:

T_b = 5 hours. The CROs may not be able to immediately detect failure of the HVAC for the ESGR and MCR. This is an estimated value. The operators will become aware of a loss of HVAC to the ESGR during routine surveillance or log taking in the MCR or ESGR.

T_e = 10 hours. System time-window is defined by the Accident Sequence Development analysis.

T_a = 60 minutes. Task action time to complete 0-AP-55. This is an estimated time value. Temperature is expected to stabilize or decrease as soon as the ESGR doors are open and fans are in place.

T_w = 4.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 30 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 0-AP-55 within 30 minutes once he is aware of the need to re-establish ESGR cooling.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 2.0E-3, 1.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 1, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff

provisions are correctly used, short list <10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(240/30) / 0.8)$
= $1 - \Phi(2.60)$
= 4.7E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 4.7E-3 / 1.25 = 3.76E-3

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the very long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R$ = 2.0E-3 * 0.1 = 2.0E-4

HEP(median) = $p_2 + p_3$ = 3.76E-3 + 2.0E-4 = 3.96E-3

- Consideration of Dependency:

HEP-0AP55-30HR will appear in sequences with HEP-0AP55-10HR but never by itself. The point estimate value for HEP-0AP55-30HR will be adjusted so that the operator error probability for this sequence will no be less than the probability for HEP-0AP55-30HR by itself.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 3.960E-3 * 1.25 = 4.950E-3

D.6.9.1.2 Analysis: HEP-0AP55-20HR

- Same as HEP-0AP55-10HR with the following changes:

- HEP Calculation:
  T_e = 20 hours. System time-window is defined by the Accident Sequence Development analysis.

T_w = 14.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(840/30) / 0.8)$
= $1 - \Phi(4.16)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where M=EXP{[(1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

HEP(median) = $p_2 + p_3$ = 8.00E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:
  R = 0.1, the recovery factor. Because of the very long time window, 20 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. This recovery is applicable to both the p_2 and p_3 terms.

  HEP = HEP(median) * R = 2.08E-3 * 0.1 = 2.08E-4

- Consideration of Dependency:

There is a dependency between HEP-0AP12-20HR and HEP-0AP12-40HR. HEP-0AP12-40HR will appear in sequences with HEP-0AP12-20HR but never by itself. The point estimate value for HEP-0AP12-40HR will be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP12-40HR by itself.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=EXP{[1/1.645)* ln (EF)]^2/2}
  M=1.25 for an EF = 3
  = 2.080E-4 * 1.25 = 2.600E-4

D.6.9.1.3 Analysis: HEP-0AP55-30HR

- Same as HEP-0AP55-10HR with the following changes:

- HEP Calculation:
  T_e = 30 hours. System time-window is defined by the Accident Sequence Development analysis.

  T_w = 24.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(24/0.5) / 0.8)$
= $1 - \Phi(4.84)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

HEP(median) = $p_2 + p_3$ = 8.00E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:
  R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. Because of the very long time window, > 24 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. The new shift will act as a checker of the other, also routine surveillance logs will make the operators aware of the Control Room ambient temperature and take corrective action if it is abnormally high. This recovery is applicable to both the p_2 and p_3 terms.

  HEP = HEP(median) * R = 2.08E-3 * 0.01 = 2.08E-5

- Consideration of Dependency:

There is a dependency between HEP-0AP55-10HR and HEP-0AP55-30HR. HEP-0AP55-30HR will appear in sequences with HEP-0AP55-10HR but never by itself. The point estimate value for HEP-0AP55-30HR will be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP55-30HR by itself.

$$\text{HEP-0AP55-30HR (adjusted)} = \frac{\text{HEP-0AP55-30HR}}{\text{HEP-0AP55-10HR}} = \frac{2.08E\text{-}5}{3.960E\text{-}3}$$

= 5.253E-3

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645) * \ln(EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 5.253E-3 * 1.25 = 6.566E-3

D.6.9.1.4 Analysis: HEP-0AP55-40HR

- Same as HEP-0AP55-10HR with the following changes:

- HEP Calculation:

  T_e = 40 hours. System time-window is defined by the Accident Sequence Development analysis.

  T_w = 34.0 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(34/0.5) / 0.8)$
= $1 - \Phi(5.27)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 2.0E-3 = 2.08E-3

- Adjustment For Recovery:

  R = 0.01, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. Because of the very long time window, > 24 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. The new shift will act as a checker of the other, also routine surveillance logs will make the operators aware of the Control Room ambient temperature and take corrective action if it is abnormally high. This recovery is applicable to both the p_2 and p_3 terms.

HEP = HEP(median) * R = 2.08E-3 * 0.01 = 2.08E-5

- Consideration of Dependency:

There is a dependency between HEP-0AP55-20HR and HEP-0AP55-40HR. HEP-0AP55-40HR will appear in sequences with HEP-0AP55-20HR but never by itself. The point estimate value for HEP-0AP55-40HR will be adjusted so that the combined operator error probability for this sequence will no be less than the probability for HEP-0AP55-40HR by itself.

HEP-0AP55-40HR (adjusted) = $\frac{\text{HEP-0AP55-40HR}}{\text{HEP-0AP55-20HR}} = \frac{2.08E-5}{2.08E-4}$

= 1.000E-1

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=EXP{[1/1.645)* ln (EF)]^2/2}
  M=1.25 for an EF = 3
  = 1.000E-1 * 1.25 = 1.250E-1

D.6.9.2 Summary: HEP-0AP55

D.6.9.2.1 Summary: HEP-0AP55-10HR

Fault Trees: FFT00

Gates:
GFFT1431 (OR) T8 LOSS OF ESGR Cooling For RC102, T8 Probability of HV Non-Recovery In 10 Hours
GFFT1641 (OR) T1TR Probability of HV ESGR Unit 2 Cooling non recovery in 10 hours.
GFFT1671 (OR) RC103 HEP to recover ESGR Cooling.

Physical Id: HEP-0AP55-10HR__

Description: 0-AP-55_LOSS_OF____
MCR/ESGR_HVAC______
RECOVERY_IN_10_HOUR

Failure Rate: 4.950E-3

Distribution: Lognormal
Median: 3.960E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.9.2.2 Summary: HEP-0AP55-20HR

Fault Trees: FFT00

Gates:
GFFT1432 (OR) T8 LOSS OF ESGR Cooling For RC202, T8 Probability of HV Non-Recovery In 20 Hours

	GFFT1644	(OR) T1TR Probability of HV ESGR Unit 2 Cooling non recovery in 20 hours.
	GFFT1671	(OR) RC203 HEP to recover ESGR Cooling.

Physical Id: HEP-0AP55-20HR__

Description: 0-AP-55_LOSS_OF____
MCR/ESGR_HVAC______
RECOVERY_IN_20_HOUR

Failure Rate: 2.600E-4

Distribution: Lognormal
Median: 2.080E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

D.6.9.2.3 Summary: HEP-0AP55-30HR

Fault Trees: FFT00

Gates: GFFT1435 (OR) T8 Conditional Prob HV Non-Recovery In 30HR Given RC102.

Physical Id: HEP-0AP55-30HR__

Description: 0-AP-55_LOSS_OF____
MCR/ESGR_HVAC______
RECOVERY_IN_30_HOUR

Failure Rate: 6.566E-3

Distribution: Lognormal
Median: 5.253E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

D.6.9.2.4 Summary: HEP-0AP55-40HR

Fault Trees: FFT00

Gates: GFFT1434 (OR) T8 Conditional Prob HV Non-Recovery In 40HR Given RC202.

Physical Id: HEP-0AP55-40HR__

Description: 0-AP-55_LOSS_OF____
SERVICE_WATER______
RECOVERY_IN_40_HOUR

Failure Rate: 1.250E-1

Distribution: Lognormal
Median: 1.000E-1
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.10 HEP-1E0-1

D.6.10.1 Analysis: HEP-1E0-1

- Equivalent Surry HRA: HEP-1E0-1
  see Surry IPE report page D.3-23 to D.3-25.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-FR-S.1 Response To Nuclear Power Generation/ATWS, Rev 1, 12-27-89.

- 1-E-0 step 1 instructs the CRO to "Verify Reactor Trip," by opening both Reactor Trip Breakers, and checking that the Reactor Trip Breakers and Bypass breakers are open, the IRPIs are zero, the rod bottom lights are on and neutron flux is decreasing to less than 5%. The RNO is to initiate 1-FR-S.1.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO would not be in the 1-E-0 procedure unless a reactor trip has already been determined to be necessary.

T_e = 80 seconds. The system time-window is an engineering estimate of the time between initiation of an ATWS and the time that a reactor trip is required. For non LOCA events the timing is expected to be much longer. MAAP analysis file 326MAF.N.5) case 21 confirms that it will take 80

seconds to dry out a SG when the reactor remains at full power.

T_a = 4 seconds. Task action time to complete step 1 of 1-E-0. This time is from the Surry simulator analysis (D.3-24).

T_w = 76 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 15 seconds. Operator median response time data is from the Surry IPE simulator analysis (SPS IPE page D.3-24). The North Anna simulator operator response times indicates that 15 seconds may be conservative. Since the Surry data is specifically for an ATWS condition it may be more accurate to use the Surry data. Changing this time window will have no effect on the overall HEP value because the p_2 term is already <1.0E-4.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(76/15) / 0.4)$
= $1 - \Phi(4.06)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

$p_3 = p_3 * R$ = 1.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 1.0E-3 = 1.08E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.08E-3 * 1.25 = 1.35E-3

D.6.10.2 Summary: HEP-1E0-1

Fault Trees: RP100

Gates: GRP1141 (AND) No input signal, reactor trip switchgear fails.

Physical Id: HEP-1E0-1_______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_1_VERIFY______
REACTOR_TRIP_______

Failure Rate: 1.350E-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.11 HEP-1E0-7

D.6.11.1 Analysis: HEP-1E0-7

- Equivalent Surry HRA: HEP-1E0-8
  see Surry IPE report page D.3-31 to D.3-33.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- 1-E-0 step 7 instructs the CRO to "Verify SI Pumps Running." The action is to verify two Charging Pumps and two Low Head SI Pumps are running. The RNO is to manually start the pumps.

- HEP-1E0-7 will be used to represent the operator action of manually starting a Charging Pump or a Low Head SI Pump which failed to start due to an SI signal.

- The Feed and Bleed Cooling fault tree gate GFB4742 structure should be rewritten to include the actuation signal fault ANDed with the HEP-1E0-7.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be to determine if the SI pumps are running immediately after a SI signal.

T_e = 523 seconds. The system time-window is from MAAP analysis file 326MAF.N.5) case 22 which determined that the core would become uncovered in 523 seconds after a large break LOCA and no LHSI actuation.

T_a = 16 seconds. Task action time to complete SI pump verification NAPS step 7 of 1-E-0. This value is from the North Anna simulator data. This value is confirmed by the Surry IPE simulator analysis (SPS IPE page D.3-32). At SPS it takes an average of 16 seconds to complete SI pump verification (SPS step 8 of 1-E-0). The Surry simulator data is applicable because 1-E-0 step 7 for NAPS is equivalent to the operator action required by 1-E-0 step 8 for SPS.

T_w = 507 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 46 seconds. The operator response time data is from the North Anna simulator measurements. A weighted average was calculated using the five operator initiated times and the two procedure times resulting in a 46 second response time. This is consistent with approximately a 57 second estimate based on the Surry data. The Surry simulator analysis (SPS IPE page D.3-32) required interpretation since the NAPS and SPS 1-E-0 steps are slightly different. The Surry simulator data for the $T_{1/2}$ of reaching SPS step 8 of 1-E-0 was 57 seconds. Based on the operator actions required, the time to complete steps 1 to 7 at SPS should be longer than the time to complete steps 1 to 6 at NAPS.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate

has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(507/46) / 0.4)$
= $1 - \Phi(6.00)$
< 1.0E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

$p_3 = p_3 * R$ = 1.0E-3 * 1.0 = 1.0E-3

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 1.0E-3 = 1.08E-3

- Consideration of Dependency:

During initial quantification HEP-1E0-7 did appear in numerous cut sets with other HEPs. The other HEPs represent operator actions which do not involve the SI pumps. HEP-1ES1:2-S1, HEP-1AP33:1, HEP-1ECA3:3-27 and HEP-1ES1:2-S2 are cool down and depressurization, HEP-1FRC:1-11-S1 and HEP-1FRC:1-11-S2 are SG depressurization. These HEPs appear in the same cut sets because if the Safety Injection system fails then it is very important to cooldown and depressurize the RCS.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.08E-3 * 1.25 = 1.35E-3

D.6.11.2 Summary: HEP-1E0-7

Fault Trees: HH100, LH100, FB400

Gates:		
	GHH1281	(AND) Failure of pump to receive start signal, Charging Pump 1A fails to restart.
	GHH1643	(AND) Failure of pump to receive start signal, Charging Pump 1B fails to start.
	GHH1765	(AND) Start signal fails, Charging Pump 1C fails to start.
	GLH1354	(AND) Actuation faults, pump faults in LHSI train A, actuation probability is determined by an external transfer.

GLH1554	(AND) Actuation faults, pump faults in LHSI train B, actuation probability is determined by an external transfer.
GLH1612	(OR) Failure of 2/2 LHSI Pumps in Core Cooling Recovery.

Physical Id: HEP-1E0-7_______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_7_VERIFY_SI___
PUMPS_RUNNING______

Failure Rate: 1.350-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

D.6.12 HEP-1E0-8

D.6.12.1 Analysis: HEP-1E0-8

- Equivalent Surry HRA: HEP-1E0-5
  see Surry IPE report page D.3-29 to D.3-30.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- 1-E-0 step 8 instructs the CRO to "Verify Main Feedwater Isolation." The action is to verify the Main Feed Pumps have tripped, the standby Main Feed Pumps in P-T-L, the Main Feed MOVs closed, the Main Feed Reg valves closed, Main Feed Reg Bypass valves closed. The RNO is to stop the pumps, place in P-T-L or to close the appropriate valves.

- HEP-1E0-8 represents all of the operator actions described in step 8 of 1-E-0.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be to determine if Main Feedwater is not isolated immediately after a SI signal.

T_e = 1500 seconds (25 minutes). MAAP (analysis file 326MAF.N.5) case 23 shows that it will take 1500 seconds to fill the broken SG during a SGTR event.

T_a = 40 seconds. Task action time to complete step 8 of 1-E-0. This value is from the North Anna simulator data which show that it took an average of 40 seconds to complete the operator verification of MFW isolation.

T_w = 1460 seconds (24.3 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 128 seconds. Operator median response time data is from the North Anna simulator analysis. It is estimated that the CRO will reach step 8 within 128 seconds after progressing through steps 1 to 7.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(1460/128) / 0.4)$
= $1 - \Phi(6.09)$
= 1.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.000E-4 / 1.25 = 8.000E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

$p_3 = p_3 * R$ = 1.0E-3 * 1.0 = 1.0E-3

HEP(median) = $p_2 + p_3$ = 8.000E-5 + 1.0E-3 = 1.08E-3

- Consideration of Dependency:

There is a dependency between HEP-1E0-8 and HEP-1E3-3. The dependency is due to similarities between the operator actions. However, these are two independent procedures and step 8 of 1-E-0 is an immediate operator action.

- Conversion To A Mean:

  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.080E-3 * 1.25 = 1.350E-3

D.6.12.2 Summary: HEP-1E0-8

Fault Trees: SG100

Gates: GSG1634 (AND) Operator fails to isolate MFW.

Physical Id: HEP-1E0-8_______

Description: 1-E-0_RX_TRIP_OR_SI STEP_8_VERIFY_MAIN_ FEEDWATER_ISOLATION

Failure Rate: 1.350E-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.13 HEP-1E0-11

D.6.13.1 Analysis: HEP-1E0-11

- Equivalent Surry HRA: none

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- Step 11 of 1-E-0 checks if the SW pumps are running. The RNO is to manually start pumps as required. This is an immediate operator action step. Also Attachment 2 of 1-E-0 verifies the 2-SW-P-1A and 2-SW-P-1B are running.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information to immediately perform the actions required by Attachment 1.

T_e = 30 minutes. The system time window is an engineering estimate of how long the Charging pumps can operate without Service Water flow.

T_a = 30 seconds. Task action time to complete step 11 of 1-E-0. This is an estimated value.

T_w = 1770 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 233 seconds. Operator median response time data is from the North Anna simulator analysis for step 12 of 1-E-0. This is conservative since the operators have to complete step 11 prior to completing step 12.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(1770/233) / 0.4)$
= $1 - \Phi(5.07)$
< 1.E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R$ = 1.0E-3 * 1.0 = 1.0E-3

HEP(median) = $p_2 + p_3$ = 8.00E-5 + 1.0E-3 = 1.080E-3

- Consideration of Dependency:

There are no dependencies between this operator action and any others.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.080E-3 * 1.25 = 1.350E-3

D.6.13.2 Summary: HEP-1E0-11

Fault Trees: SW100

Gates: GSW2225 (AND) Failure to start pump, 1-SW-P-1B.
GSW2360 (AND) Failure to start pump, 2-SW-P-1B.

Physical Id: HEP-1E0-11

Description: 1-E-0_RX_TRIP_OR_SI
STEP_11_VERIFY_SW__
PUMPS_RUNNING______

Failure Rate: 1.350E-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.14 HEP-1E0-12

D.6.14.1 Analysis: HEP-1E0-12

- Equivalent Surry HRA: HEP-1E0-11
  see Surry IPE report page D.3-34 to D.3-36.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- 1-E-0 step 12 instructs the CRO to "Check if Main Steamlines Should Be Isolated." The action is to check annunciator E-3 on the "D" panel lit or containment pressure has exceeded 18 psia on 1-LM-PR-110B. The RNO is to go to step 14 in this procedure. Otherwise continuing with this step the CRO would verify MSTVs and Bypass Valves are closed.

- HEP-1E0-12 represents the operator actions of checking to see if MS line isolation is required and closing the appropriate valves if necessary.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be to determine if Main Steam lines should be isolated immediately after a SI signal.

T_e = 25 minutes. MAAP (analysis file 326MAF.N.5) case 23 shows that it will take 25 minutes to fill the broken SG during a SGTR event.

T_a = 36 seconds. Task action time to complete NAPS step 12 of 1-E-0. This value is from the North Anna simulator analysis which shows it took an average of 26 seconds to complete Main Steam line verification. An additional 10 seconds are added for valve stroke time. For the Surry HRA analysis 29 seconds (SPS IPE page D.3-36) was used for Main Steam line isolation (SPS step 11 of 1-E-0) task action time. The Surry simulator analysis shows it took an average of 19 seconds for the operator action and a maximum stroke time of 10 seconds.

T_w = 1464 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 233 seconds. Operator median response time data is from the North Anna simulator observations. The Surry IPE simulator analysis shows that a time of 221 seconds (SPS IPE page D.3-40) can be expected. The Surry simulator data is the $T_{1/2}$ for reaching step 12C of 1-E-0. Based on the operator actions required, the time to complete steps 1 to 11 at SPS should be approximately the same as the time to complete steps 1 to 11 at NAPS.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

$p_2(\text{mean}) = 1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$

$= 1 - \Phi(\ln(1464/233) / 0.4)$

= 1 - Φ(4.59)
< 1.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R = 1.0E-3 * 1.0 = 1.0E-3$

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 1.0E-3 = 1.08E-3

- Consideration of Dependency:

HEP-1E0-12 and HEP-1E3-3 are related because both require isolation of a SG. Since the procedures are different and the required operator action is different these will be treated as independent HEPs. However, these are two independent procedures and step 12 of 1-E-0 is an immediate operator action.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.08E-3 * 1.25 = 1.35E-3

D.6.14.2 Summary: HEP-1E0-12

Fault Trees: SG100

Gates: GSG1362 (AND) Operator fails to close valve, MS non return valves.
GSG1345 (AND) Operator fails to close trip valve, MS trip valves.

Physical Id: HEP-1E0-12______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_12_MAIN_STEAM_
LINES_ISOLATION____

Failure Rate: 1.350E-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.15 HEP-1E0-13

D.6.15.1 Analysis: HEP-1E0-13

- Equivalent Surry HRA: HEP-1E0-12-NOCLS
  see Surry IPE report page D.3-37 to D.3-38.
  calculated mean = 1.000E+0

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- 1-E-0 step 13 instructs the CRO to "Check if CDA Is Required." The action is to determine if containment pressure has exceeded 28 psia and to manually actuate CDA by simultaneously placing both CDA switches to Initiate, then initiate Attachment 1, verify CC pumps have tripped and to stop all RCPs. This is different from the Surry procedure which never has the operator using the CDA actuation switches. Instead the Surry procedure has the operator to manually align all equipment. The SPS point estimate of 1.0 is not appropriate for the NAPS analysis.

- HEP-1E0-13 represents the operator actions of checking to see if CDA is required and if containment pressure has exceeded 28 psia then the operator action of initiating CDA, stopping the CC and RCP pumps. The operator action required by Attachment 1, which verifies proper operation of CDA equipment, is not within the boundary of this HEP.

- HEP Calculation:

Input Parameters:

Tb = 0 minutes. The CRO has adequate information to determine immediately if containment pressure has been high enough to require CDA.

T_e = 40 minutes from MAAP (analysis file 326MAF.N.5) case 24 which shows that using minimum ESF equipment can depressurize the containment to subatmospheric within 55 minutes after initiation of a large break LOCA and a delay of 40 minutes before starting any CDA equipment.

T_a = 30 seconds. Task action time to complete NAPS step 13 of 1-E-0. This time is an estimated value. North Anna simulator data does not provide data for

this operator action. Surry data is not directly applicable because of the differences in the procedures.

T_w = 2370 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 259 seconds. Operator median response time data is from the North Anna simulator analysis. It is estimated that the CRO will reach NAPS step 13 within 259 seconds after progressing through steps 1 to 12. The actual simulator data is from the timing for reaching step 14. Step 13 is skipped during SGTR events so the North Anna simulator timing for step 14 is acceptable to be used for step 13 during LOCAs. The Surry simulator analysis (SPS IPE page D.3-44) determined the time to reach step 13 to be 274 seconds. The operator action for step 13 of the Surry procedure is verify SI flow (not check if CDA is required). However the time to reach step 13 for either NAPS or SPS should be approximately the same. Since the North Anna data is available and appears reasonable it should be applied.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 1.0E-3, 5.0E-4 is the estimated human error probability from NUREG/CR-1278, Table 20-10, item 1, estimated HEPs for errors of commission in reading and recording quantitative information from unannunciated displays, item 1 analog meter. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(2370/259) / 0.4)$
= $1 - \Phi(5.53)$
< 1.00E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.00E-4 / 1.25 = 8.00E-5

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R = 1.0E-3 * 1.0 = 1.0E-3$

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 1.0E-3 = 1.08E-3

- Consideration of Dependency:

There is a dependency between HEP-1E0-13 and HEP-1E0-ATTACH:1 because step 13, which initiates a CDA, instructs the operator to perform the verification of automatic actions using Attachment 1. Normally HRA logic follows the convention that the operator will never complete Attachment 1 without successfully completing step 13. However, since these are the immediate actions of the emergency procedures, they are so memorized and well practiced by the operator it is proper to treat these basic events as independent of each other. HEP-1E0-ATTACH:1 will be treated as a recovery to HEP-1E0-13 for specific equipment. HEP-1E0-13 will represent the operator action for recovering from failure of the automatic CDA signal. HEP-1E0-ATTACH:1 will represent the operator action for recovering from failure of the manual CDA signal. There is no dependency between the HEP-1ES1:2-S1 or HEP-1ES1:2-S2, operator fails to cooldown and depressurize the RCS, and HEP-1E0-13 even though they appear in the same cut sets. These HEPs require unrelated diagnosis skills and operator reactions to the event.

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 1.08E-3 * 1.25 = 1.35E-3

D.6.15.2 Summary: HEP-1E0-13

Fault Trees: CI100

Gates:	GCI1244	(AND) Common cause failure of press inst channels, no input signal CDA high high train A, CCF probability is 4.64E-4.
	GCI1250	(OR) No manual CDA act. following random failure of auto act.
	GCI1344	(AND) Common cause failure of press inst channels, no input signal CDA high high train B, CCF probability is 4.64E-4.
	GCI1350	(OR) No manual CDA act. following random failure of auto act.

Physical Id: HEP-1E0-13______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_13_CHECK_IF___
CDA_IS_REQUIRED____

Failure Rate: 1.35E-3

Distribution: Lognormal
Median: 1.080E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.16 HEP-1E0-14

D.6.16.1 Analysis: HEP-1E0-14

- Equivalent Surry HRA: none

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- For the HEP-1E0-14 basic events used at gates GHH1663 and GHH1781 there are no procedure steps to open 1-CH-MOV-1286B or 1-CH-MOV-1286C. These portions of the HH100 fault tree are attempting to represent the operator action of opening these valves if they were closed for 1-PT-14.2 or 1-PT-14.3 during a valid SI signal. Since these valves do not receive an SI signal only operator action will restore the valves. It may be possible to recover from this condition when SI flow is verified. However, 1-E-0 never specifically identifies these valves.

- The guidance document for the IPE states that operator actions which are not contained within a procedure will have a point estimate of 1.0.

D.6.16.2 Summary: HEP-1E0-14

Fault Trees: HH100

GHH1663 (OR) MOV-1286B fails to open, Charging Pump 1B unavailable due to PT-14.2.
GHH1781 (OR) MOV-1286C fails to open, Charging Pump 1C unavailable due to PT-14.3.

Physical Id: HEP-1E0-14

Description: 1-E-0_RX_TRIP_OR_SI
STEP_14_VERIFY_SI__
FLOW

Failure Rate: 1.000E+0

Distribution: Lognormal
Median: 1.000E+0
Error Factor: 1

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.17 HEP-1E0-15

D.6.17.1 Analysis: HEP-1E0-15

- Equivalent Surry HRA: HEP-1FRH:1-5
  see Surry IPE report page D.3-86 to D.3-87.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-AP-22.1	Loss of 1-FW-P-2 Turbine Driven AFW Pump, Rev 9, 3-28-91.
1-AP-22.2	Loss of 1-FW-P-3A Motor Driven AFW Pump, Rev 8, 3-28-91.
1-AP-22.3	Loss of 1-FW-P-3B Motor Driven AFW Pump, Rev 7, 3-28-91.
1-AP-22.4	Loss of Both Motor Driven AFW Pumps, Rev 1, 3-28-91.
1-AP-22.5	Loss of Emergency Condensate Storage Tank, Rev 0, 3-27-91.
1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-FR-H.1	Response to Loss of Secondary Heat Sink, Rev 3, 5-31-90.

- 1-E-0 step 15 directs the operator to verify AFW flow is indicated on three flow indicators, 1-FW-FI-100A, -100B, -100C, one for each of the three Steam Generators. This step also verifies the total flow is greater than 340 gpm. The RNOs are to manually align AFW valves or start pumps as necessary to restore flow to each SG. The step does not directly refer to the AP-22 series of procedures. If a minimum of 340 gpm can not be established when the SG narrow range level is less than 10% then the operator is to implement 1-FR-H.1. This procedure directs the operator to locally restore or realign AFW using the 1-AP-22 series procedures.

- The AP-22 series procedures provides detailed instructions for realigning the AFW system to establish AFW flow to all SG depending on which pumps or valves have failed. 1-AP-22.1 provides instructions for aligning AFW flow to the A SG when the turbine driven pump is inoperable. Attachments provide information for aligning both motor driven AFW pumps to the MOV header or to the

HCV header, then using that header to feed all three SGs. 1-AP-22.2 provides similar instructions during the loss of 1-FW-P-3A and 1-AP-22.3 during the loss of 1-FW-P-3B. 1-AP-22.4 provides instructions during the loss of both motor driven pumps and only the steam driven pump is available.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine a that inadequate AFW flow condition exists immediately after a reactor trip or SI signal.

T_e = 5545 seconds. The system time-window is from MAAP (analysis file 326MAF.N.5) case 29. This is the time between SG dryout for a SGTR with no MFW or AFW. The intact SG will become dry in 5549 seconds and the ruptured SG will become dry in 5545 seconds.

T_a = 10 minutes. The task action time to complete the appropriate AP-22 series procedure to realign AFW valves and pumps. This is an estimated time value.

T_w = 82.4 minutes (4945 seconds). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 430 seconds. Operator median response time. It is estimated that the CRO in the Control Room will initiate an 1-AP-22 series procedure within 430 seconds of a reactor trip. This includes time to progress through 1-E-0 steps 1 to 14, then start on step 15 which will then send the operator to 1-FR-H.1, then to the AP-22 series procedures to actually perform the realignment. North Anna simulator measurements show that it will take approximately 310 seconds to reach step 15 of 1-E-0. It is conservatively estimated to require an additional 120 seconds to transition to 1-FR-H.1 then to 1-AP-22.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-10, item 1, estimated HEPs for errors of commission in reading and recording quantitative information from unannunciated displays, item 1 analog meter. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) $= 1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
$= 1 - \Phi(\ln(4945/430) / 0.6)$
$= 1 - \Phi(4.07)$
$<$ 1.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.00E-5

- Adjustment For Recovery:
R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R$ = 6.0E-3 * 0.1 = 6.0E-4

HEP(median) = $p_2 + p_3$ = 8.00E-5 + 6.0E-4 = 8.600E-4

- Consideration of Dependency:

HEP-1FRH:1-11 and HEP-1E3-3 may appear in the same cut sets but these HEPs are for different operator actions using different procedures. The dependency is considered to be very weak.

- HEP Conversion To A Mean:
HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 8.60E-4 * 1.25 = 1.075E-3

D.6.17.2 Summary: HEP-1E0-15

Fault Trees: AF100

Gates:	GAF10281	(OR) P-2 discharge to HCV header fails.
	GAF10284	(OR) P-2 discharge to MOV header fails.
	GAF10384	(OR) Pump P-3A discharge to the MOV header fails.
	GAF10481	(OR) Pump P-3B discharge to the HCV header fails.
	GAF10912	(OR) HCV header to SG-A fails.
	GAF11012	(OR) MOV header to SG-A fails.
	GAF11112	(OR) HCV header to SG-B fails.
	GAF11412	(OR) MOV header to SG-C fails.

Physical Id: HEP-1E0-15_____

Description: 1-E-0_RX_TRIP_OR_SI
STEP_15_VERIFY_AUX_
FEEDWATER_FLOW_____

Failure Rate: 1.075E-3

Distribution: Lognormal
Median: 8.600E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.18 HEP-1E0-16

D.6.18.1 Analysis: HEP-1E0-16

- Equivalent Surry HRA: HEP-1E0-16
  see Surry IPE report page D.3-48 to D.3-51.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1 Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.

- HEP-1E0-16 represents the operator action of repositioning Charging Pump and SI MOVs due to failure of the actuation signal to automatically reposition the valves. The operator may identify one or more valves which were did not change to the desired position during a SI. The operator will then attempt to operate the valve from the Control Room. Local manual operation of the valves is not within the boundary of this HEP.

- 1-E-0 step 16 instructs the CRO to "Check Charging Pump Alignment." The action is to verify the correct position of the following valves.

1-CH-MOV-1115B	open	Charging Pump RWST suction
1-CH-MOV-1115D	open	Charging Pump RWST suction
1-CH-MOV-1115C	closed	Charging Pump VCT suction
1-CH-MOV-1115E	closed	Charging Pump VCT suction
1-CH-MOV-1289A	closed	Charging Pump normal discharge
1-CH-MOV-1289B	closed	Charging Pump normal discharge
1-CH-HCV-1200A	closed	Letdown orifice isolation
1-CH-HCV-1200B	closed	Letdown orifice isolation
1-CH-HCV-1200C	closed	Letdown orifice isolation

1-SI-TV-1884A	closed	BIT recirc valves
1-SI-TV-1884B	closed	BIT recirc valves
1-SI-TV-1884C	closed	BIT recirc valves
1-SI-MOV-1867C	closed	BIT outlet valves
1-SI-MOV-1867D	open	BIT outlet valves
1-SI-MOV-1867A	open	BIT inlet valves
1-SI-MOV-1867B	open	BIT inlet valves

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine a valve is misaligned immediately after a SI signal.

T_e = 1633 seconds (27 minutes) from MAAP (analysis file 326MAF.N.5) case 25. This is how long SI can be delayed before core damage occurs for a medium LOCA. 40 minutes was used in the Surry IPE analysis (SPS IPE page D.3-48).

T_a = 185 seconds. Task action time to complete step 16 of 1-E-0. This value is from the North Anna simulator data (65 seconds). An additional 120 seconds was added for valve stroke time. The Surry simulator analysis (SPS IPE page D.3-49) shows it takes an average of 49 seconds to complete step 16 and a maximum valve stroke time of 120 seconds.

T_w = 1448 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 200 seconds. Operator median response time data is from the North Anna simulator analysis shows that it required 359 seconds to reach step 16 when following the procedure. The Surry IPE simulator analysis (SPS IPE page D.3-49) shows that the operator response time may be shorter than the North Anna simulator timing. The Surry data takes into account the operator identifying a MOV out of position and taking corrective action before reaching step 16. The Surry $T_{1/2}$ for the five operator response times was 63 seconds. The $T_{1/2}$ for the four procedure response times was 191 seconds. The weighted average of these times is 120 seconds. The Surry simulator analysis shows that if a Charging pump MOV is mispositioned then the operators would identify the failure much quicker than the time required for the emergency procedure to identify the failure. It should also be recognized that the operator will also be directed by the procedure to verify the Charging pumps are running and to verify SI flow before reaching this step. Therefore an estimated valve of 200 seconds

will be used for $T_{1/2}$ instead of 359 second value from the simulator raw data. Future simulator analysis at North Anna could further justify this lower value.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. Also p_3 = 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-12, item 2, estimated probabilities of errors of commission in operating manual controls, select wrong control on a panel from an array of similar appearing controls, identified by labels only. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(1448/200) / 0.6)$
= $1 - \Phi(3.30)$
= 5.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 5.0E-4 / 1.25 = 4.0E-4

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error. Recovery is possible since Safety Injection flow will be monitored frequently, and verified by procedure 1-E-1 step 25.

  $p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 4.0E-4 + 6.0E-3 = 6.40E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 6.40E-3 * 1.25 = 8.00E-3

D.6.18.2 Summary: HEP-1E0-16

Fault Tree: HH100

Gates:	GHH1164	(AND) Failure of valve to receive open signal, failure of MOV-1867D to open.
	GHH1364	(AND) Failure of valve to receive open signal, failure of MOV-1867C to open.
	GHH1840	(AND) Failure of valve to get close signal, failure of MOV-1115C to close.
	GHH1854	(AND) Failure of valve to receive signal, failure of MOV-1115E to close.
	GHH11030	(AND) Failure of valve to receive signal, failure of MOV-1115B to open.
	GHH11044	(AND) Failure of valve to receive open signal, failure of MOV-1115D to open.
	GHH11733	(AND) Failure of valve to receive signal, failure of MOV-1867A to open.
	GHH11752	(AND) Failure of valve to receive signal, failure of MOV-1867B to open.

Physical Id: HEP-1E0-16______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_16_CHARGING___
PUMP_ALIGNMENT_____

Failure Rate: 8.000E-3

Distribution: Lognormal
Median: 6.400E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.19 HEP-1E0-22

D.6.19.1 Analysis: HEP-1E0-22

- Equivalent Surry HRA: HEP-1E0-21
  see Surry IPE report page D.3-54 to D.3-55.
  calculated mean = 5.648E-2

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- 1-E-0 step 22 instructs the CRO to "Check PRZR PORVs, Spray Valves, And Safety Valves" are closed. The RNOs attempt to close the PORVs or their isolation valves, close the spray valves or stop the associated RCP, or if the safety valves are open then go to 1-E-1.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information to immediately determine if the Pressurizer PORVs, spray valves or safety valves are open.

T_e = 2115 seconds from MAAP (analysis file 326MAF.N.5) case 26. This is the time until core uncovery after a reactor trip with one Pressurizer PORV stuck open.

T_a = 35 seconds. Task action time to complete step 22 of 1-E-0. This time is from the North Anna simulator analysis.

T_w = 2080 seconds (35 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 531 seconds. Operator median response time data is from the North Anna simulator analysis.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

$p_2(\text{mean}) = 1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
$= 1 - \Phi(\ln(2080/531) / 0.6)$
$= 1 - \Phi(2.28)$
$= 1.13E-2$

$P_2(\text{median}) =$ HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.13E-2 / 1.25 = 9.04E-3

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R = 6.0E-3 * 1.0 = 6.0E-3$

$HEP(\text{median}) = p_2 + p_3 = 9.04E-3 + 6.0E-3 = 1.504E-2$

- Consideration of Dependency:

HEP-1E0-22 and HEP-1ES1:3 may appear in the same cut sets but there is no true dependency between these operator actions. They are unrelated actions in different procedures.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 1.504E-2 * 1.25 = 1.880E-2

D.6.19.2 Summary: HEP-1E0-22

Fault Trees: RC100, RC300

Gates:
GRC1132 (OR) PORV block valve MOV-1536 fails to close.
GRC1165 (OR) PORV block valve MOV-1535 fails to close.
GRC3132 (OR) PORV block valve MOV-1536 fails to close.
GRC3165 (OR) PORV block valve MOV-1535 fails to close.

Physical Id: HEP-1E0-22______

Description: 1-E-0_RX_TRIP_OR_SI
STEP_22_PRZR_PORVS_
SPRAY_VALVES_CLOSED

Failure Rate: 1.880E-2

Distribution: Lognormal
Median: 1.504E-2
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.20 HEP-1E0-ATTACH:1

D.6.20.1 Analysis: HEP-1E0-ATTACH:1

- Equivalent Surry HRA: HEP-1E0-12D-E and HEP-1E0-ATTACH-1 see Surry IPE report page D.3-41 to D.3-43 and D.3-56. calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.

- Step 13 of 1-E-0 checks if CDA is required by observing containment pressure greater than 28 psia. If CDA is required the operator is directed to manually actuate CDA by placing the CDA switches to "Initiate," initiate Attachment 1, verifying CC pumps have tripped and stopping all RCPs. 1-E-0 Attachment 1 is used by the operator to verify phase B containment isolation and proper operation of safeguards equipment. This equipment should have performed its CDA function either due to an automatic CDA signal or due to the manual CDA initiation.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information to immediately perform the actions required by Attachment 1.

T_e = 2400 seconds (40 minutes). The system time window is from MAAP (analysis file 326MAF.N.5) case 24 which shows that using minimum ESF equipment can depressurize the containment to subatmospheric within 55 minutes after initiation of a large break LOCA and a delay of 40 minutes before starting any CDA equipment.

T_a = 150 seconds. Task action time to complete Attachment 1 of 1-E-0. This is an estimated value.

T_w = 2250 seconds (37.5 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 274 seconds. Operator median response time data is from the Surry IPE simulator analysis (SPS IPE page D.3-44). It is estimated that the CRO will reach NAPS step 13 and initiate Attachment 1 within 274 seconds after progressing through steps 1 to 12. This timing is an approximation. Based on the operator actions required, the time to complete steps 1 to 12 at SPS should be approximately the same as the time to complete steps 1 to 12 at NAPS.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(2250/274) / 0.6)$
= $1 - \Phi(3.51)$
= 2.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.0E-4 / 1.25 = 1.60E-4

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

$p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 1.60E-4 + 6.0E-3 = 6.160E-3

- Consideration of Dependency:

HEP-1E0-22 and HEP-1ES1:3 do appear in cut sets with HEP-1E0-ATTACH:1 but the operator actions are too different and in different procedures to a significant dependency. There is a dependency between HEP-1E0-13 and HEP-1E0-ATTACH:1 because step 13, which initiates a CDA, instructs the operator to perform the verification of automatic actions using Attachment 1. Normally HRA logic follows the convention that the operator will never complete Attachment 1 without successfully completing step 13. However, since these are the immediate actions of the emergency procedures,

they are so memorized and well practiced by the operator it is proper to treat these basic events as independent of each other. HEP-1E0-ATTACH:1 will be treated as a recovery to HEP-1E0-13. HEP-1E0-13 will represent the operator action for recovering from failure of the automatic CDA signal. HEP-1E0-ATTACH:1 will represent the operator action for recovering from failure of the manual CDA signal.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 6.16E-3 * 1.25 = 7.70E-3

D.6.20.2 Summary: HEP-1E0-ATTACH:1

Fault Trees: QS100, RS100, SW100

Gates:	GQS1224	(AND) No auto signal or manual action to open discharge valve.
	GQS1264	(AND) No auto signal or manual action to open discharge valve.
	GQS1332	(AND) No CDA signal or manual action to start pump.
	GQS1372	(AND) No CDA signal or manual action to start pump 1B.
	GRS1183	(AND) No CDA signal and no manual start 1-RS-P-1A.
	GRS1283	(AND) No CDA signal and no manual start 1-RS-P-1B.
	GRS1423	(AND) Failure of actuation signal, 1-RS-P-2A.
	GRS1463	(AND) Failure of actuation signal, 1-RS-P-2B.
	GRS1732	(AND) Failure of actuation signal, 1-RS-MOV-100A.
	GRS1832	(AND) Failure of actuation signal, 1-RS-MOV-100B.
	GRS1963	(AND) Failure of actuation signal, 1-SW-MOV-103A.
	GRS11053	(AND) No Actuation Signal to Valve, 1-SW-MOV-101A.
	GRS11075	(AND) No Actuation Signal to Valve, 1-SW-MOV-101B.
	GRS11443	(AND) Failure of actuation, 1-SW-MOV-103B.

Physical Id: HEP-1E0-ATTACH:1

Description: 1-E-0_RX_TRIP_OR_SI
ATTACHMENT_1_VERIFY
PHASE_B_ISOLATION__

Failure Rate: 7.70E-3

Distribution: Lognormal
Median: 6.160E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.21 HEP-1E1-25

D.6.21.1 Analysis: HEP-1E1-25

- Equivalent Surry HRA: none

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-FR-C.1	Response To Inadequate Core Cooling, Rev 3, 12-27-89.

- 1-E-1 step 25 instructs the CRO to "Establish Redundant Cold Leg Injection Flow Paths." The action aligns one Charging Pump to each SI flow path.

- 1-FR-C.1 step 15 instructs the CRO to "Verify SI Flow Indicated." The RNO states that if flow cannot be established then try to establish any alternate flow path. The paths listed are normal charging, loop fill, BIT bypass, and Charging cross tie. No direct mention is made of the path through 1-SI-MOV-1836.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will not have any reason to delay establishing the alternate SI flow path.

T_e = 1633 seconds (27 minutes). The system time-window is the allowable time delay until HHSI is required after a medium break LOCA. This timing is based on MAAP analysis file 326MAF.N.5 case 25. 40 minutes was used in Surry IPE analysis (SPS IPE page D.3-48).

T_a = 300 seconds. Task action time to complete step 25 of 1-E-1. This is an estimated value. This value

could be reduced to 185 seconds based on the time used for HEP-1E0-16.

T_w = 1333 seconds (22 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 1800 seconds (30 minutes). Operator median response time data is an estimated value. It is estimated that it will take a significant amount of time to reach step 25 of 1-E-1. The emergency procedures do not identify the alternate cold leg injection path, opening 1-SI-MOV-1836, as a possibility in the event of no SI flow.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

- Since $T_{1/2}$ is greater than T_w the value of p_2 will be one. If 1-E-0 is revised to consider opening 1-SI-MOV-1836 earlier than step 25 of 1-E-1 then the HEP point estimate will be decreased. The following changes can be made to the HEP calculation.

T_a = 185 seconds. Task action time to complete step 16 of 1-E-0. This value is based on the time used for HEP-1E0-16.

T_w = 1435 seconds (24 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 200 seconds (3.3 minutes). Operator median response time data is based on the operator response time from HEP-1E0-16 analysis. It is assumed that step 16 of 1-E-0 will be revised to add opening 1-SI-MOV-1836 to the RNO. The current emergency procedures do not identify the alternate cold leg injection path, opening 1-SI-MOV-1836, as a possibility in the event of no SI flow.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(1435/200) / 0.6)$
= $1 - \Phi(3.28)$
= 6.0E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 6.0E-4 / 1.25 = 4.8E-4

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 4.8E-4 + 6.0E-3 = 6.480E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 6.480E-3 * 1.25 = 8.100E-3

D.6.21.2 Summary: HEP-1E1-25

Fault Trees: HH100

Gates: GHH1432 (OR) Failure of MOV-1836 to open.

Physical Id: HEP-1E1-25

Description: 1-E-1_LOSS_OF_RX_OR
2ND_COOLANT_STEP_25
REDUNDANT_COLD_LEG_

Failure Rate: 8.100E-3

Distribution: Lognormal
Median: 9.400E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.22 HEP-1E3-3

D.6.22.1 Analysis: HEP-1E3-3

- Equivalent Surry HRA: HEP-1E3-3
  see Surry IPE report page D.3-59 to D.3-61.
  calculated mean = 2.260E-2

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3 Steam Generator Tube Rupture, Rev 4, 12-27-89.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3. Step 15 verifies AFW. Step 15b verifies AFW is greater than 340 gpm. The RNO is if the SG narrow level is greater than 10 % in any SG, then control feed flow to maintain narrow range level. Step 19 checks Tavg stable or trending to 547 F. The RNO includes stopping cooldown and adjusting AFW flow to 340 gpm until at least one SG narrow range level is greater than 10 %.

- 1-E-3 step 3 isolates flow from the ruptured SG(s) by closing the SG PORV (Atmospheric Steam Dump Valve), closing the Decay Heat Release Valve, verifying the SG blowdown valves are closed, closing the MSTV and bypass valves, and locally closing the steam supply valve to the Turbine Driven AFW Pump. Step 12 verifies flow from the ruptured SG has been isolated. The RNO is to complete step 3 unless the ruptured SG is required for RCS cooldown.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to isolate a ruptured SG without significant delay.

T_e = 3360 second (56 minutes). MAAP (analysis file 326MAF.N.5) case 23 shows that it will take 56 minutes to fill the broken SG during a SGTR event.

T_a = 102 seconds. This task action time is from the North Anna simulator analysis. The Surry HRA Analysis (SPS IPE page D.3-60) estimated this time to be 120 seconds.

T_w = 3258 seconds (54.3 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 10 minutes. Operator median response time. The timing from the North Anna simulator analysis is 731 seconds. This is the time it will take the operator to complete 1-E-0 steps 1 to 24 then 1-E-3 steps 1 and 2. Surry HRA Analysis used a time of 500 seconds (SPS IPE page D.30-60) which is based on the North Anna SGTR event of July 15, 1987. The simulator data shows that the operators can be expected to reach 1-E-0 step 15 within 310 seconds and complete this step in another 49 seconds. Step 15 directs the operator to reduce AFW flow to maintain SG level in the narrow range. The operator may isolate the SG at this point. A realistic response time for this HEP is 10 minutes.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts. A p_3 related to operators missing a step in a procedure due to the multiple steps verifying SG isolation.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(54.3/10) / 0.6)$
= $1 - \Phi(2.82)$
= 2.4E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.4E-3 / 1.25 = 1.92E-3

- Adjustment For Recovery:
  R = 1.0, recovery factor. No credit is taken for immediate recovery of this HEP. It might be possible to consider recovery of this HEP because of there are at least three other procedure steps which direct the operator to monitor SG level. The first is 1-E-0 step 15b RNO which reduces AFW to maintain SG level. The second is 1-E-0 step 19 RNO which will be entered because MAAP analysis, case 23, shows that the RCS will be less than 457°F which should cause the CRO to reduce AFW to the SGs. And the third time that the CRO will be directed to reduce AFW is 1-E-3 step 12. This step confirms that the isolation of

step 3 has been completed and that there is no flow to the SG.

$p_3 = p_3 * R = 1.0E-3 * 1.0 = 1.0E-3$

$HEP(median) = p_2 + p_3 = 1.920E-3 + 1.0E-3 = 2.920E-3$

- Consideration of Dependency:

HEP-1E3-3 does appear in cut sets with other HEPs, but none are significantly dependent on the operator action for SG isolation. The MFW isolation of HEP-1E0-8 or HEP-1E0-12 are independent of a SGTR accident. They are also immediate operator actions which are memorized action which are treated as independent. The dependence of SG isolation on operator failing to cooldown will be included in the calculations for the cooldown HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.920E-3 * 1.25 = 3.650E-3

D.6.22.2 Summary: HEP-1E3-3

Fault Trees: SG100

Gates:	GSG1182	(OR) Failure to isolate steam supply to AFW TDP.
	GSG1241	(OR) Operator fails to isolate, PORVs fail to close and operators fail to isolate.
	GSG1362	(AND) Operator fails to close valve, MS non return valves.
	GSG1345	(AND) Operator fails to close trip valve, MS trip valves.
	GSG1421	(OR) AFW not isolated.
	GSG1524	(AND) No auto or manual actuation to close blowdown trip valves, auto actuation failure probability is 2.66E-4.
	GSG1634	(AND) Operator fails to isolate MFW.

Physical Id: HEP-1E3-3_______

Description: 1-E-3_SGTR_________
STEP_3_ISOLATE_FLOW
FROM_RUPTURED_SG___

Failure Rate: 3.650E-3

Distribution: Lognormal
Median: 2.920E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.23 HEP-1E3-13

D.6.23.1 Analysis: HEP-1E3-13

- Equivalent Surry HRA: HEP-1E3-15
  see Surry IPE report page D.3-62 to D.3-63.
  calculated mean = 8.877E-2

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3 Steam Generator Tube Rupture, Rev 4, 12-27-89.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3.

- 1-E-3 step 13 is the first step to initiate a RCS cooldown. The purpose of this initial cooldown is to depressurize the RCS below the SG pressure so that water from the primary side will not continue flowing into the secondary side of the SG.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to cooldown the RCS to below the ruptured SG pressure without significant delay.

T_e = 75 minutes (4500 seconds). System time-window is defined by Accident Sequence Development Analysis File, 321MAF.1.N, section 10.0. The time to cooldown and depressurize the RCS below the setpoint of the relief valves in 45 minutes. 60 minutes is allowed if for the function O06 if SI is available. An additional 15 minutes is added to the system time window due to isolation of the SG, credit was also used in the Surry HRA page D.3-62.

T_a = 418 seconds. Task action time to complete the cooldown of step 13 of 1-E-3. This time is from the North Anna simulator analysis. Even though the simulator data is from only three sessions, the average appears reasonable and is comparable to actual North Anna SGTR event data. The operator is limited to a 100°F in a hour cooldown. The CRO can actually accomplish 100°F within a few minutes, but will then hold at that temperature for the remainder of the hour. Using the chart of step 13 100°F corresponds to a SG pressure of approximately 650 psig. Even if the actual pressure is lower, this amount of cooldown will significantly reduce the SG leak rate at the lower RCS pressure.

T_w = 4082 seconds (68 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 1100 seconds. Operator median response time. This is the time it will take the operator to complete 1-E-0 steps 1 to 24 then 1-E-3 steps 1 to 12. The timing is from the North Anna simulator analysis. Surry HRA Analysis (SPS IPE page D.30-62) used a time of 1200 seconds. During the July 15, 1987 SGTR event at North Anna the time for the operators to depressurize was 13 minutes.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(4082/1100) / 0.6)$
= $1 - \Phi(2.19)$
= 1.43E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.43E-2 / 1.25 = 1.144E-2

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

  $p_3 = p_3 * R = 6.0E-3 * 0.1 = 6.0E-3$

  HEP(median) = $p_2 + p_3$ = 1.144E-2 + 6.0E-3 = 1.744E-2

- Consideration of Dependency:

HEP-1E3-13 does appear in cut sets with HEP-1ECA3:1-16, late RCS cooldown. The dependency between early RCS cooldown and late RCS cooldown after a SGTR will be handled in the calculation of the HEPs representing the late cooldown operator action. The engineering time window will be adjusted to decrease the time available to complete the late cooldown by the time allowed for the early cooldown.

- HEP Conversion To A Mean:

  HEP(mean) = HEP(median) * M
  where M=EXP{[1/1.645)* ln (EF)]^2/2}
  M=1.25 for an EF = 3
  = 1.744E-2 * 1.25 = 2.180E-2

D.6.23.2 Summary: HEP-1E3-13

Fault Trees: FFT00, OD200

Gates: GFFT363 (OR) T7 SGTR for 006.
GOD2112 (OR) Failure to cooldown & depressurize the RCS from 1 of 3 SG.

Physical Id: HEP-1E3-13______

Description: 1-E-3_SGTR_________
STEP_13_INITIATE___
RCS_COOLDOWN_______

Failure Rate: 2.180E-2

Distribution: Lognormal
Median: 1.744E-2
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.24 HEP-1ECA3:1-16

D.6.24.1 Analysis: HEP-1ECA3:1-16

- Equivalent Surry HRA: HEP-1ECA3:1
  see Surry IPE report page D.3-66 to D.3-67.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3	Steam Generator Tube Rupture, Rev 4, 12-27-89.
1-ECA-3.1	SGTR With Loss of Reactor Coolant - Subcooled Recovery Desired, Rev 3, 12-27-89.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3.

- 1-E-3 step 13 is the first step to initiate a RCS cooldown. The purpose of this initial cooldown is to depressurize the RCS below the SG pressure so that water from the primary side will not continue flowing into the secondary side of the SG. For HEP-1ECA3:1-16 it is assumed that this cooldown was not completed rapidly enough.

- 1-ECA-3.1 provides instructions to cool down and depressurize the RCS to Cold Shutdown conditions following a SG Tube Rupture and loss of Coolant, while minimizing loss of RCS inventory an voiding in the RCS. This procedure is entered after completing steps 1 to 13 of 1-E-3 then transitioning to this procedure due the ruptured SG pressure decreasing or RCS subcooling less than 50°F from steps 14 or 15 of 1-E-3. Step 16 of 1-ECA-3.1 initiates RCS cooldown to Cold Shutdown. The cooldown rate will be close to be less than 100°F/hour. Step 21 depressurizes the RCS to refill the Pressurizer. Step 30 depressurizes the RCS to minimize break flow. Step 44 checks to see if hot leg temperatures are less than 200°F. The RNO is to return to step 15. Success of this step goes to step 45 which maintains the RCS in Cold Shutdown conditions.

- HEP-1ECA3:1-16 is used to represent the operator action necessary to cooldown the RCS to 200°F after successfully isolating the ruptured SG and failing to complete an early cooldown in a timely manner. 1-ECA-3.1 step 16 is considered to be one of

several possible procedure paths which may be followed depending on plant conditions. The operator actions necessary and the timing is considered conservatively represented by this procedure.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to cooldown the RCS to Cold Shutdown conditions without significant delay.

T_e = 7 hours. System time-window is defined by Accident Sequence Development Analysis File, 321MAF.1.N, section 10.0. This function is asked if early cooldown or SG isolation fails. Failure of early cooldown is assumed to lead to failure of SG integrity. At this point, the RCS must be cooled down to atmospheric pressure to mitigate the outflow. This can continue as long as RWST water remains available, or is replenished for injection. The time for RWST depletion with no operator action is about 8 hours. This amount of time for operator action results in the limiting value of operator error. The time window for early RCS cooldown, one hour, is subtracted from the late RCS cooldown window, 8 hours, to account for the dependency between the operator actions for early and late RCS cooldown.

T_a = 210 minutes. Task action time to complete the cooldown of 1-ECA-3.1 steps 16. Assuming the cooldown begins at 550°F and is complete at 200°F with a cooldown rate of 100°F/hour the time will be 3.5 hours, = 210 minutes. The Surry HRA for this HEP further reduced the system time window by 1 hour. This is an over conservative assumption and should actually be incorporated in the value for $T_{1/2}$.

T_w = 140 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 40 minutes. Operator median response time. This is the time it will take the operator to complete 1-E-0 steps 1 to 24, then 1-E-3 steps 1 to 14, followed by 1-ECA-3.1 steps 1 to 15. The timing is an estimate based on simulator observations. The time to complete the actions of 1-E-0 and 1-E-3 was approximately 20 minutes, see HEP-1E3-13. The time to complete 1-ECA-3.1 steps 1 to 15 is estimated to be approximately another 20 minutes.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. This value is selected rather than item 2 because 1-ECA-3.1 steps 16, 21, 30, 44 and 45 are also directing the operator to take actions to cooldown the RCS. It will be very difficult for the operator to not cooldown if the correct procedure is utilized. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(210/40) / 0.6)$
= $1 - \Phi(2.76)$
= 2.9E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.90E-3 / 1.25 = 2.320E-3

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. Ample personnel independently aware of the RCS conditions and the importance of cooling down the RCS will recognize the failure to initiate a cooldown. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R = 1.0E-3 * 0.1 = 1.0E-4$

HEP(median) = $p_2 + p_3$ = 2.320E-3 + 1.0E-4 = 2.420E-3

- Consideration of Dependency:

HEP-1E3-13, early RCS cooldown, does appear in cut sets with HEP-1ECA3:1-16, late RCS cooldown. The dependency between early RCS cooldown and late RCS cooldown after a SGTR will be handled in the calculation of the HEPs representing the late cooldown operator action. The engineering time window will be adjusted to decrease the time available to complete the late cooldown by the time allowed for the early cooldown. The time window for early cooldown

was 60 minutes. This was subtracted from the eight hour system time window for late cooldown. No further consideration is necessary.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.420E-3 * 1.25 = 3.025E-3

D.6.24.2 Summary: HEP-1ECA3:1-16

Fault Trees: FFT00

Gates: GFFT922 (OR) T7 SGTR for 0201.

Physical Id: HEP-1ECA3:1-16__

Description: 1-ECA-3.1_SGTR_WITH
SUBCOOLED_RCS______
STEP_16_COOLDOWN___

Failure Rate: 3.025E-3

Distribution: Lognormal
Median: 2.420E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.25 HEP-1ECA3:2-5

D.6.25.1 Analysis: HEP-1ECA3:2-5

- Equivalent Surry HRA: HEP-1ECA3:2
see Surry IPE report page D.3-68.
calculated mean = 1.625E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3	Steam Generator Tube Rupture, Rev 4, 12-27-89.
1-ECA-3.1	SGTR With Loss of Reactor Coolant - Subcooled Recovery Desired, Rev 3, 12-27-89.
1-ECA-3.2	SGTR With Loss of Reactor Coolant - Saturated Recovery Desired, Rev 4, 5-30-90.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3.

- 1-E-3 step 12 verifies that flow from the ruptured SG is isolated. The RNO is to transition to 1-ECA-3.1. Step 13 is the first step to initiate a RCS cooldown. The purpose of this initial cooldown is to depressurize the RCS below the SG pressure so that water from the primary side will not continue flowing into the secondary side of the SG. For HEP-1ECA3:1-16 it is assumed that this cooldown was not completed rapidly enough.

- 1-ECA-3.1 provides instructions to cool down and depressurize the RCS to Cold Shutdown conditions following a SG Tube Rupture and loss of Coolant, while minimizing loss of RCS inventory an voiding in the RCS. This procedure is entered after completing steps 1 to 13 of 1-E-3 then transitioning to this procedure due the ruptured SG pressure decreasing or RCS subcooling less than 50°F from steps 14 or 15 of 1-E-3. Step 16 of 1-ECA-3.1 initiates RCS cooldown to Cold Shutdown. The cooldown rate will be close to be less than 100°F/hour. Step 18 checks if subcooled recovery is appropriate by comparing the RWST sump level to the expected sump level. If saturated conditions exists the operator will then transition to 1-ECA-3.2.

- 1-ECA-3.2 step 5 initiates a RCS cooldown to Cold Shutdown. Step 6 checks RCS subcooling less than 30°F. The RNO is to go to step 20. Step 9 depressurizes the RCS to fill the Pressurizer. Step 18 depressurizes the RCS to saturation at core exit. Step 32 checks hot leg temperatures less than 200°F. The RNO is to return to step 4. Step 33 maintains the RCS in shutdown conditions.

- HEP-1ECA3:2-5 is used to represent the operator action necessary to cooldown the RCS to 200°F after unsuccessfully isolating the ruptured SG and failing to complete an early cooldown in a timely manner. 1-ECA-3.2 step 5 is considered to be one of several possible procedure paths which may be followed depending on plant conditions. The operator actions necessary and the timing is considered conservatively represented by this procedure.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to cooldown the RCS to Cold Shutdown conditions without significant delay.

T_e = 10 hours. System time-window is defined MAAP case 28 and Z28 (analysis file 325MFA.N.5) which show that core damage will not occur until 36950 seconds with a 50°F/hour cooldown or without any cooldown.

The Accident Sequence Development Analysis File, 321MAF.1.N, section 10.0, page 43 estimated the time window to be 8 hours. This function is not dependent on success of early RCS cooldown or SG isolation. Failure of early cooldown is assumed to lead to failure of SG integrity. At this point, the RCS must be cooled down to atmospheric pressure to mitigate the outflow. This function addresses the possibility of later operator action to cooldown. This can continue as long as RWST water remains available, or is replenished for injection. The time for RWST depletion with no operator action is approximately 10 hours. This amount of time for operator action results in the limiting value of operator error.

T_a = 210 minutes. Task action time to complete the cooldown of 1-ECA-3.2 steps 5. Assuming the cooldown begins at 550°F and is complete at 200°F with a cooldown rate of 100°F/hour (the maximum allowable cooldown rate) the time will be 3.5 hours, = 210 minutes.

T_w = 390 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 55 minutes. Operator median response time. This is the time it will take the operator to complete 1-E-0 steps 1 to 24, then 1-E-3 steps 1 to 14, followed by 1-ECA-3.1 steps 1 to 18 and 1-ECA-3.2 steps 1 to 5. The timing is an estimate based on simulator observations. The time to complete the actions of 1-E-0 and 1-E-3 is approximately 20 minutes, see HEP-1E3-13. The time to complete 1-ECA-3.1 steps 1 to 18 is estimated to be approximately another 25 minutes. Then the operator will take approximately 10 minutes to complete 1-ECA-3.2 step 1-4 then initiate the RCS cooldown of step 5.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. Item 2 was not chosen from Table 20-12 because ample personnel independently aware of the RCS conditions and the importance of cooling down the RCS will recognize the failure to initiate a cooldown. Also 1-ECA-3.1

step 16, 1-ECA-3.2 steps 9, 18, 32, and 33 are directing the operator to take actions to cooldown the RCS. Missing the step is not as probable as not effectively performing the cooldown. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(390/55) / 0.6)$
= $1 - \Phi(3.26)$
= 6.00E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 6.00E-4 / 1.25 = 4.80E-4

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

  $p_3 = p_3 * R$ = 1.0E-3 * 0.1 = 1.0E-4

HEP(median) = $p_2 + p_3$ = 4.80E-4 + 1.0E-4 = 5.800E-4

- Consideration of Dependency:

HEP-1E3-13, early RCS cooldown, does appear in cut sets with HEP-1ECA3:2-5, late RCS cooldown. The dependency between early RCS cooldown and late RCS cooldown after a SGTR will be handled in this HEP calculation. The engineering time window will be adjusted to decrease the time available to complete the late cooldown by the time allowed for the early cooldown. The time window for early cooldown was 60 minutes. This was subtracted from the eight hour system time window for late cooldown. No further consideration is necessary.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln(EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 5.800E-4 * 1.25 = 4.250E-4

D.6.25.2 Summary: HEP-1ECA3:2-5

Fault Trees: FFT00

Gates: GFFT923 (OR) T7 SGTR for 0202.

Physical Id: HEP-1ECA3:2-5___

Description: 1-ECA-3.2_SGTR_WITH
SATURATED_RCS______
STEP_5_COOLDOWN____

Failure Rate: 4.25E-4

Distribution: Lognormal
Median: 5.800E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.26 HEP-1ECA3:3-27

D.6.26.1 Analysis: HEP-1ECA3:3-27

- Equivalent Surry HRA: HEP-1ECA3:3
  see Surry IPE report page D.3-69.
  calculated mean = 1.625E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3	Steam Generator Tube Rupture, Rev 4, 12-27-89.
1-ECA-3.1	SGTR With Loss of Reactor Coolant - Subcooled Recovery Desired, Rev 3, 12-27-89.
1-ECA-3.2	SGTR With Loss of Reactor Coolant - Saturated Recovery Desired, Rev 4, 5-30-90.
1-ECA-3.3	SGTR Without Pressurizer Pressure Control, Rev 3, 12-27-89.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3.

- 1-E-3 step 13 is the first step to initiate a RCS cooldown. The purpose of this initial cooldown is to depressurize the RCS below the SG pressure so that water from the primary side will not

continue flowing into the secondary side of the SG. For HEP-1ECA3:3-16 it is assumed that this cooldown was not completed rapidly enough. 1-E-3 step 17 depressurizes the RCS using Pressurizer PORV to minimize break flow and to refill the Pressurizer. The action is for at least one Pressurizer PORV available. The RNO is to establish auxiliary spray and if that is not available (no charging pumps) then transition to 1-ECA-3.3.

- 1-ECA-3.3 provides instructions to cool down and depressurize the RCS following a SG Tube Rupture with coincident loss of normal and auxiliary spray and Pressurizer PORVs. The procedure initially attempts to establish Pressurizer PORVs or sprays. If successful transition is back to 1-E-3. The RNO continues 1-ECA-3.3. Step 27 initiates RCS cooldown to 350°F. Step 29 checks if RCS cooldown can be stopped. The RNO returns to step 25. Step 32 depressurizes the RCS and ruptured SG to 400 psig. Step 35 continues RCS cooldown to Cold Shutdown. Step 39 maintains Cold Shutdown.

- HEP-1ECA3:3-27 is used to represent the operator action necessary to for the early RCS cooldown to 350°F after failure of HHSI, successfully isolating the ruptured SG and failing to complete an early cooldown in a timely manner. HEP-1ECA3:3-27 is similar to HEP-1E3-13. 1-ECA-3.3 step 27 is considered to be one of several possible procedure paths which may be followed depending on plant conditions. HEP-1ECA3:3-27 will be used to represent the operator actions required during the early cooldown during a SGTR without high head SI available. The operator actions necessary and the timing is considered conservatively represented by this procedure. HEP-1ECA3:3-35 will be used to represent the operator completing a late cool down.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to cooldown the RCS to Cold Shutdown conditions without significant delay.

T_e = 266 seconds. System time-window is from MAAP (analysis file 326MAF.N.5) case 31. It is the time when the Pressurizer empties after a SGTR with AFW and no SI or Quench and Recirculation Spray. The Accident Sequence Development Analysis File, 321MAF.1.N, section 10.0 estimates the time window to be 60 minutes. For function 007, operator cooldown and depressurize with failure of SI auxiliary spray is assumed not available as D1 has failed although there may be failure combinations where HHSI has failed, but charging is available. Normal sprays are also assumed to be unavailable, as the RCPs may well be tripped on subcooling margins. As the small break continues with no SI,

the subcooling in the RCS will decrease. If the cooldown has not been accomplished by the time the pressurizer empties, the RCS will be at hot leg saturation pressure and the RCP will not be available.

T_a = 15 minutes. Task action time to complete the most significant part of the cooldown required by 1-ECA-3.3 step 27. This step calls for a cooldown to 350°F. Since this HEP is only representing the benefit from reducing the SG leakage by cooling down the RCS, the task action time from 1-E-3 will be used. The operator is limited to a 100°F in a hour cooldown. The CRO can actually accomplish 100°F within a few minutes, but will then hold at that temperature for the remainder of the hour. Using the chart of step 13 100°F corresponds to a SG pressure of approximately 650 psig. Even if the actual pressure is lower, this amount of cooldown will significantly reduce the SG leak rate at the lower RCS pressure.

T_w = 45 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 20 minutes. Operator median response time. This is from the analysis for HEP-1E3-3 since this is where the operator will begin the cooldown and 1-ECA-3.3 step 27 is being used only as representative of the SGTR early cooldown.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. Item 2 was not chosen from Table 20-12 because ample personnel independently aware of the RCS conditions and the importance of cooling down the RCS will recognize the failure to initiate a cooldown. Also multiple steps direct the operator to take actions to cooldown the RCS. Missing the step is not as probable as not effectively performing the cooldown. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(45/20) / 0.6)$
= $1 - \Phi(1.35)$
= 8.85E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 8.85E-2 / 1.25 = 7.08E-2

- Adjustment For Recovery:

R = 1, the recovery factor. No credit is taken for recovery from this Human Error. There is insufficient time to recover from not initiating a RCS cooldown early enough. The TSC will not be fully manned at this point so no assistance can be expected by support staff. Once the error is identified there will be insufficient time to accomplish the cooldown.

$p_3 = p_3 * R = 1.0E-3 * 1.0 = 1.0E-3$

HEP(median) = $p_2 + p_3$ = 7.08E-2 + 1.0E-3 = 7.18E-2

- Consideration of Dependency:

HEP-1ECA3:3-27, early RCS cooldown, does appear in cut sets with HEP-1E0-7, SI pumps running, HEP-1E0-13 check if CDA is required, HEP-1AP15-1E, restore CC heat exchanger, and HEP-1FRC:1-11, inadequate core cooling. But these operator actions and procedures are independent enough to treat the HEP calculations as independent. HEP-1ECA3:3-27 and HEP-1ECA3:3-35 do appear in one T7 sequence together. And similar to the way early and late cool down for HEP-1E3-13 and HEP-1ECA3:1-16 combination was treated, the time windows are defined in such a way that the HEP calculations will be treated as independent.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where $M=EXP\{[1/1.645)* \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 7.18E-2 * 1.25 = 8.975E-2

D.6.26.2 Summary: HEP-1ECA3:3-27

Fault Trees: FFT00

Gates: GFFT364 (OR) T7D1 SGTR W/O HPI for 007.

Physical Id: HEP-1ECA3:3-27

Description: 1-ECA-3.3_SGTR_&___
NO_PRESSURE_CONTROL
STEP_27_COOLDOWN___

Failure Rate: 8.975E-2

Distribution: Lognormal
Median: 7.180E-2
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.27 HEP-1ECA3:3-35

D.6.27.1 Analysis: HEP-1ECA3:3-35

- Equivalent Surry HRA: HEP-1ECA3:3
  see Surry IPE report page D.3-69.
  calculated mean = 1.625E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-3	Steam Generator Tube Rupture, Rev 4, 12-27-89.
1-ECA-3.1	SGTR With Loss of Reactor Coolant - Subcooled Recovery Desired, Rev 3, 12-27-89.
1-ECA-3.2	SGTR With Loss of Reactor Coolant - Saturated Recovery Desired, Rev 4, 5-30-90.
1-ECA-3.3	SGTR Without Pressurizer Pressure Control, Rev 3, 12-27-89.

- 1-E-0 step 1 to 23 provide initial instructions for operators to perform immediately after a reactor trip or SI. These step verify RCS stability and proper equipment response. Step 24 checks for ruptured SGs and transitions to 1-E-3.

- 1-E-3 step 13 is the first step to initiate a RCS cooldown. The purpose of this initial cooldown is to depressurize the RCS below the SG pressure so that water from the primary side will not continue flowing into the secondary side of the SG. For HEP-1ECA3:3-16 it is assumed that this cooldown was not completed rapidly enough. Step 17 depressurizes the RCS using Pressurizer PORV to minimize break flow and to refill the Pressurizer. The action is for at least one Pressurizer PORV available. The RNO is to establish auxiliary spray and if that is not available (no charging pumps) then transition to 1-ECA-3.3.

- 1-ECA-3.3 provides instructions to cool down and depressurize the RCS following a SG Tube Rupture with coincident loss of normal and auxiliary spray and Pressurizer PORVs. The procedure initially attempts to establish Pressurizer PORVs or sprays. If successful transition is back to 1-E-3. The RNO continues 1-ECA-3.3. Step 27 initiates RCS cooldown to 350°F. Step 29 checks if RCS cooldown can be stopped. The RNO returns to step 25. Step 32 depressurizes the RCS and ruptured SG to 400 psig. Step 35 continues RCS cooldown to Cold Shutdown. Step 39 maintains Cold Shutdown.

- HEP-1ECA3:3-27 is used to represent the operator action necessary to cooldown the RCS to 200°F after failure of HHSI, successfully isolating the ruptured SG and failing to complete an early cooldown in a timely manner. 1-ECA-3.3 step 27 is considered to be one of several possible procedure paths which may be followed depending on plant conditions. The operator actions necessary and the timing is considered conservatively represented by this procedure.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has sufficient instrumentation in the MCR to evaluate the need and perform the actions required to cooldown the RCS to Cold Shutdown conditions without significant delay.

T_e = 9 hours. System time-window is by MAAP analysis (325MAF.N.5) case 28 and Z28 which shows that the RWST will not be depleted until 10 hours after a SGTR. The Accident Sequence Development Analysis File, 321MAF.1.N, section 10.0 estimates a time window of 8 hours. The MAAP analysis ten hours should be used, which is then reduced by the time window allowed for early cooldown, 1 hour, 10 - 1 = 9 hours. This function is asked if early cooldown or SG isolation fails. Failure of early cooldown is assumed to lead to failure of SG integrity. At this point, the RCS must be cooled down to atmospheric pressure to mitigate the outflow . This function addresses the possibility of later operator action to cooldown. This can continue as long as RWST water remains available, or is replenished for injection. The time for RWST depletion with no operator action is about 8 hours. This amount of time for operator action results in the limiting value of operator error.

T_a = 280 minutes. Task action time to complete the cooldown of 1-ECA-3.3 steps 27 and 35. Assuming the cooldown begins at 550°F and is complete at 200°F with a cooldown rate of 75°F/hour (slightly below the maximum allowable 100°F/hour) the time

will be 4.67 hours, = 280 minutes. The Surry HRA for this HEP further reduced the system time window by 1 hour. This is an over conservative assumption and should actually be incorporated in the value for $T_{1/2}$.

T_w = 260 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 55 minutes. Operator median response time. This is the time it will take the operator to complete 1-E-0 steps 1 to 24, then 1-E-3 steps 1 to 17, followed by 1-ECA-3.3 steps 1 to 34. The timing is an estimate based on simulator observations. The time to complete the actions of 1-E-0 and 1-E-3 is approximately 20 minutes, see HEP-1E3-13. An additional 5 minutes is allowed to complete the actions of 1-E-3 steps 14 to 17. Then approximately 30 minutes to compete 1-ECA-3.3 steps 1 to 35 and initiate a RCS cooldown.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 NUREG/CR-1278 Table 20-12 item 4, EF=10, Errors of commission in operating manual controls, which are part of a well defined mimic layout. This is a median value. Item 2 was not chosen from Table 20-12 because ample personnel independently aware of the RCS conditions and the importance of cooling down the RCS will recognize the failure to initiate a cooldown. Also 1-ECA-3.3 steps 29, 32, 35 and 39 are directing the operator to take actions to cooldown the RCS. Missing the step is not as probable as not effectively performing the cooldown. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(260/55) / 0.6)$
= $1 - \Phi(2.59)$
= 4.80E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 4.80E-3 / 1.25 = 3.84E-3

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

  $p_3 = p_3 * R = 1.0E-3 * 0.1 = 1.0E-4$

  HEP(median) = $p_2 + p_3$ = 3.84E-3 + 1.0E-4 = 3.94E-3

- Consideration of Dependency:

HEP-1ECA3:3-27, late RCS cooldown, does appear in cut sets with HEP-1E0-7, SI pumps running, HEP-1E0-13 check if CDA is required, HEP-1AP15-1E, restore CC heat exchanger, and HEP-1FRC:1-11, inadequate core cooling. But these operator actions and procedures are independent enough to treat the HEP calculations as independent.

- HEP Conversion To A Mean:

  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 3.940E-3 * 1.25 = 4.920E-3

D.6.27.2 Summary: HEP-1ECA3:3-35

Fault Trees: FFT00

Gates: GFFT924 (OR) T7D1 SGTR without HPI for O203.

Physical Id: HEP-1ECA3:3-35

Description: 1-ECA-3.3_SGTR_&___
NO_PRESSURE_CONTROL
STEP_35_LATE_COOLDN

Failure Rate: 4.925E-3

Distribution: Lognormal
Median: 3.940E-3
Error Factor: 3

Reference: 324MAF.N___________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.28 HEP-1ES1:2-S1

D.6.28.1 Analysis: HEP-1ES1:2-S1

- Equivalent Surry HRA: HEP-1ES1:2-S1
  see Surry IPE report page D.3-70 to D.3-71.
  calculated mean = 1.0E+0

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.1	SI Termination, Rev 3, 12-27-89.
1-ES-1.2	Post LOCA Cooldown and Depressurization, Rev 4, 12-27-89.

- 1-E-0 provides proper response of the Reactor Protection and Emergency Core Cooling Systems following actuation of a Reactor Trip or Safety Injection. To assess plant conditions and identify the appropriate recovery procedure.

- 1-E-1 provides instructions to start recovery from a Loss of Reactor or Secondary Coolant. Step 20 checks if RCS cooldown and depressurization is required by checking if RCS temperature is greater than 250°F. The RNO continues with step 21 otherwise transition to 1-ES-1.2.

- 1-ES-1.2 provides instructions to cooldown and depressurize the RCS to Cold Shutdown conditions following a loss of Reactor Coolant inventory. This procedure is entered from 1-E-1 or 1-ES-1.1. Step 7 initiates RCS cooldown to Cold Shutdown. Step 8 checks RCS subcooling greater than 30°F. Step 11 depressurizes the RCS to refill the Pressurizer. Step 20 depressurizes the RCS to minimize break flow. Step 32 checks hot leg temperature less than 200°F. The RNO is to return to step 6. Step 33 maintains Cold Shutdown conditions.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the RCS conditions without any delay.

T_e = 3554 seconds (59.2 minutes). The system time-window is from MAAP (analysis file 326MAF.N.5) case 32 which determined the time to switch over SI suction from the RWST to the Containment sump is 3554 seconds during a 5" LOCA. The accident Sequence Development file 321MAF.1.N, section 4.0 estimates the time to be 55 minutes. The O function provides the failure probability from

normal cooldown and depressurization. It is only a valid question if D1, D2 and L succeed. The cooldown is accomplished with the Pressurizer and sprays. To be successful it is necessary that the SG atmospheric Dump valve on at least one available SG be operable, as well as either the normal or alternate pressurizer spray path. For medium LOCA this function is called O01. The following timing information is provided for use in the HEP analysis. A Surry MAAP (analysis file 326MAF.5) case 13 shows that for sequences in which AFW fails, changeover to recirculation will occur in 55 minutes at an RCS pressure of 310 psi (424°F) which is above the shutoff head of the LHSI pumps (approximately 150 psi (366°F). With AFW, the RCS will be depressurized enough to use LHR at 55 minutes. Assume cooldown rate of 100°F per hour. Cooldown required is (424-366) 58°F, so 36 minutes is required. Cooldown to start (55-36) in 19 minutes after the initiating event.

T_a = 36 minutes. Task action time to complete cooldown described above from the Accident Sequence Development analysis file.

T_w = 1394 seconds (23 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 1920 seconds (32 minutes). Operator median response time. This timing is from Surry IPE HRA analysis, simulator data, page D.3-71.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) $= 1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
$= 1 - \Phi(\ln(1394/1920) / 0.6)$
$= 1 - \Phi(-.53)$
$= 1.0E+0$

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1 for an EF = 1
= 1.0E+0 / 1.0 = 1.0E+0

- Adjustment For Recovery:
  R = 1, the recovery factor. No credit is taken for recovery from this Human Error. The procedures do not initiate a cooldown early enough for a medium break LOCAs.

$p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 1.0E+0 + 6.0E-3 = 1.0E+0

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645) * \ln(EF)]^2/2\}$
  M=1. for an EF = 1
  = 1.0E+0 * 1.0 = 1.0E+0

D.6.28.2 Summary: HEP-1ES1:2-S1

Fault Trees: FFT00

Gates: GFFT322 (OR) S1 medium LOCA for 001

Physical Id: HEP-1ES1:2-S1___

Description: 1-ES-1.2_POST_LOCA_
COOLDOWN_AND______
DEPRESSURIZATION_S1

Failure Rate: 1.0__E+0

Distribution: Lognormal
Median: 1.0__E+0
Error Factor: 1

Reference: 324MAF.N____________
9-1-92_______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.29 HEP-1ES1:2-S2

D.6.29.1 Analysis: HEP-1ES1:2-S2

- Equivalent Surry HRA: HEP-1ES1:2-S2
  see Surry IPE report page D.3-72 to D.3-73.
  calculated mean = 5.326E-2

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.1	SI Termination, Rev 3, 12-27-89.
1-ES-1.2	Post LOCA Cooldown and Depressurization, Rev 4, 12-27-89.

- 1-E-0 provides proper response of the Reactor Protection and Emergency Core Cooling Systems following actuation of a Reactor Trip or Safety Injection. To assess plant conditions and identify the appropriate recovery procedure.

- 1-E-1 provides instructions to start recovery from a Loss of Reactor or Secondary Coolant. Step 20 checks if RCS cooldown and depressurization is required by checking if RCS temperature is greater than 250 psig (525 psig adverse Containment conditions). The RNO continues with step 21 otherwise transition to 1-ES-1.2.

- 1-ES-1.2 provides instructions to cooldown and depressurize the RCS to Cold Shutdown conditions following a loss of Reactor Coolant inventory. This procedure is entered from 1-E-1 or 1-ES-1.1. Step 7 initiates RCS cooldown to Cold Shutdown. Step 8 checks RCS subcooling greater than 30°F. Step 11 depressurizes the RCS to refill the Pressurizer. Step 20 depressurizes the RCS to minimize break flow. Step 32 checks hot leg temperature less than 200°F. The RNO is to return to step 6. Step 33 maintains Cold Shutdown conditions.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the RCS conditions without any delay.

T_e = 19939 seconds (332 minutes). The system time-window is defined by MAAP (analysis file 326MAF.N.5) case 33 which is the time until SI pump suction is switched from the RWST to the Containment sump. The accident Sequence Development file 321MAF.1.N, section 5.0 estimates this time window to be 120 minutes). This O function is asked to set up the need for low pressure recirculation versus high pressure

recirculation, at the time of RWST inventory depletion. Upon completion of certain steps in the EOPs the operators are instructed to commence cooldown at a rate of 100°F/hour. The fastest time to RWST depletion occurs for sequences with both quench spray pumps operating. Successful cooldown and depressurization for the small LOCA has the same system components as the medium LOCA. However, the timing is much longer therefore a new function name is used, OO2. For a smaller break, CS initiation will be delayed for up to several hours. Since OO2 occurs with successful D1 & L, several hours are available for operator action.

T_a = 36 minutes. Task action time to complete cooldown described above from the Accident Sequence Development analysis file pages 14 and 20.

T_w = 17779 seconds (296 minutes). Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 32 minutes. Operator median response time. This timing is from Surry HRA analysis, simulator data, page D.3-73.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(17779/1920) / 0.6)$
= $1 - \Phi(3.71)$
= 1.0E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.0E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to

detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R = 6.0E-3 * 0.1 = 6.0E-4$

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 6.0E-4 = 6.800E-4

- Consideration of Dependency:

Other HEPs such as HEP-1ES1:3, failure to swap Charging pump suction from the RWST to the Containment sump, do appear in the same cut sets with HEP-1ES1:2-S2, RCS cooldown and depressurization. However the operator actions are unrelated and appear in different procedures.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=EXP{[1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 6.800E-4 * 1.25 = 8.50E-4

D.6.29.2 Summary: HEP-1ES1:2-S2

Fault Trees: FFT00, OD100, OD300

Gates:

Gates:	GFFT323	(OR) S2 small LOCA for 002.
	GFFT324	(OR) S2 very small LOCA for 003
	GFFT361	(OR) T1 LOOP use 002 with HOST1 for 004.
	GOD1112	(OR) Failure to cooldown & depressurize the RCS from 1 of 3 SG.
	GOD3112	(OR) Failure to cooldown & depressurize the RCS from 1 or 3 SG.

Physical Id: HEP-1ES1:2-S2___

Description: 1-ES-1.2_POST_LOCA_
COOLDOWN_AND_______
DEPRESSURIZATION_S2

Failure Rate: 8.500E-4

Distribution: Lognormal
Median: 6.800E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.30 HEP-1ES1:3

D.6.30.1 Analysis: HEP-1ES1:3

- Equivalent Surry HRA: HEP-1ES1:3
  see Surry IPE report page D.3-74 to D.3-76.
  calculated mean = 5.820E-2

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.3	Transfer To Cold Leg Recirculation, Rev 2, 12-27-89.

- 1-E-0 does not provide instructions for alignment of the SI system from the RWST to the Containment sump.

- 1-E-1 Continuous Action instructions direct the operators to go to 1-ES-1.3 if the RWST level decreases to less than 29%.

- 1-ES-1.3 provides instructions to swap the SI system from RWST to Containment Sump recirculation. The NAPS procedure has the operator immediately perform the actions required to align the SI system for recirculation upon initiation of 1-ES-1.3. The SPS procedure has the operator wait until automatic RMT occurs before verifying proper valve alignment. The NAPS method reverses this and has automatic RMT act as a backup to the manual alignment.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information immediately available to determine when the SI system needs to be aligned to recirculation.

T_e = 11.5 minutes. The system time-window is from MAAP (analysis file 326MAF.N.5) case 27a. It is the time between reaching 29% level in the RWST and SI pump cavitation with maximum safeguards equipment running.

T_a = 2 minutes. Task action time to complete step 6 of 1-E-0. This time is an estimated value.

T_w = 9.5 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 2 minutes. Operator median response time data is an estimate of the time between the RWST reaching 29% level and the operators implementing 1-ES-1.3. Included in this two minutes is the time for the operator to complete steps 1 to 5, verifications of equipment status.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(9.5/2) / 0.6)$
= $1 - \Phi(2.60)$
= 4.7E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 4.70E-3 / 1.25 = 3.76E-3

- Adjustment For Recovery:
  R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

  $p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

  HEP(median) = $p_2 + p_3$ = 3.76E-3 + 6.0E-3 = 9.76E-3

- Consideration of Dependency:

HEP-1ES1:3, failure to swap Charging pump suction from the RWST to the Containment sump, and HEP-1ES1:2-S1 (or HEP-1ES1:2-S2), RCS cooldown and depressurization do appear in the same cut sets. However, the operator actions are unrelated and appear in different procedures.

- Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=1.25 for an EF = 3
  = 9.76E-3 * 1.25 = 1.220E-2

D.6.30.2 Summary: HEP-1ES1:3

Fault Trees:	SI100, HR100, LR100	
Gates:	GSI12933	(AND) Fail of Manual Rec Mode Transfer When In Test Tr A, probability of RWST level prot train A in test is 1.40E-3.
	GSI12962	(AND) Fail of Manual Rec Mode Transfer When In Test Tr B, probability of RWST level prot train A in test is 1.40E-3.
	GHR1963	(AND) Failure of recirculation actuation signal.
	GHR11073	(AND) Failure of recirculation actuation signal.
	GLR1670	(AND) Failure of SI recirculation signal for 1860B. MOV-1860B flow from containment sump.
	GLR1770	(AND) Failure of SI recirculation signal for 1860A. MOV-1860A flow from containment sump.
	GLR1862	(AND) Failure of actuation for 1885D, MOV to fails to close.
	GLR1865	(AND) Failure of actuation for 1885A, MOV to fails to close.
	GLR1962	(AND) Failure of actuation for 1885B, MOV to fails to close.
	GLR1965	(AND) Failure of actuation for 1885C, MOV to fails to close.

Physical Id: HEP-1ES1:3______

Description: 1-ES-1.3_TRANSFER__
TO_COLD_LEG________
RECIRCULATION______

Failure Rate: 1.220E-2

Distribution: Lognormal
Median: 9.760E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.31 HEP-1ES1:4

D.6.31.1 Analysis: HEP-1ES1:4

- Equivalent Surry HRA: HEP-1ES1:4
  see Surry IPE report page D.3-77.
  calculated mean = 2.664E-4

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.4	Transfer To Hot Leg Recirculation, Rev 3, 12-27-89.
1-ES-1.5	Transfer From Hot Leg Recirculation to Cold Recirculation, Rev 0, 12-27-89.

- 1-E-0 does not provide instructions for alignment of the SI system from cold leg recirculation to hot leg recirculation.

- 1-E-1 provides instructions to start recovery from a loss of reactor or secondary coolant. Step 26 instructs that at 7 hours after event initiation, prepare for switchover to hot leg recirculation. Step 27 instructs that at 10 hours after event initiation, go to 1-ES-1.4. Step 28 evaluate an do long term operations including at 10 hours after establishing hot leg recirculation go to 1-ES-1.5.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information immediately available to determine when the SI system needs to be aligned to hot leg recirculation.

T_e = 3 hours. The system time-window is an engineering estimate based on the time to establish hot leg recirculation at ten hours after event initiation. The calculation for this time interval is part of the EOP background documentation. The ten hours represents the time to initiate hot leg recirculation based on analysis of the minimum time when boric acid concentration could approach the solubility limit in the reactor vessel following a double ended cold leg guillotine break. The WOG expected time frame for this time is between 14 and 24 hours. Three hour error is a reasonable assumed margin for this calculation.

T_a = 15 minutes. Task action time to complete the steps of 1-ES-1.4. This time is an estimated value.

T_w = 165 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 15 minutes. Operator median response time. This is an assumed time that the operator will have completed the actions required to prepare for hot leg recirculation, 1-E-1 step 26, before 10 hours after event initiation. Then the operator will be waiting for the ten hour point. The operators may be temporarily distracted by other duties for a few minutes, assume 15 minutes, until they begin the require actions of 1-ES-1.4.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(165/15) / 0.6)$
= $1 - \Phi(4.00)$
= 1E-4

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R$ = 6.0E-3 * 0.1 = 6.0E-4

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 6.0E-4 = 6.80E-4

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 6.80E-4 * 1.25 = 8.500E-4

D.6.31.2 Summary: HEP-1ES1:4

Fault Trees: LR100

Gates: GLR11012 (OR) Failure to switch to hot leg recirc at 10 hours.

Physical Id: HEP-1ES1:4______

Description: 1-ES-1.4_TRANSFER__
TO_HOT_LEG_________
RECIRCULATION______

Failure Rate: 8.500E-4

Distribution: Lognormal
Median: 6.800E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.32 HEP-1FRC:1-11-S1

D.6.32.1 Analysis: HEP-1FRC:1-11-S1

- Equivalent Surry HRA: HEP-1FRC:1-12-S1
see Surry IPE report page D.3-81 to D.3-82.
calculated mean = 1.0E+0

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.2	Post LOCA Cooldown and Depressurization, Rev 4, 12-27-89.
1-F-0	Critical Safety Function Status Trees, Rev 0, 12-27-89.

1-FR-C.1 Response To Inadequate Core Cooling, Rev 3, 12-27-89.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 25 checks that the RCS is intact by checking the containment radiation, pressure and sump level. The RNO is to transition to 1-E-1. Step 28 initiates monitoring of the Critical Safety Function Status Trees.

- 1-E-1 Step 20 checks if RCS cooldown and depressurization is required and transitions to 1-ES-1.2.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 2 is for Core Cooling. The red paths implement 1-FR-C.1, the orange paths implement 1-FR-C.2, the yellow paths implement 1-FR-C.3 and the green path is CSF satisfactory. The red paths are core exit thermocouple greater than 1200°F; or RCS subcooling less than 30°F when no RCP are running, core exit thermocouple greater than 700°F and RVLIS full range less than 48%.

- 1-FR-C.1 provides instructions to restore Core Cooling. This procedure is entered from the red terminus of the core cooling CSF status tree. Step 11 depressurizes all intact SGs to 120 psig. Step 14 depressurizes all intact SG to atmospheric pressure by dumping steam to the Condenser at the maximum rate. Step 19 tries to locally depressurize all intact SG to atmospheric pressure. Return to 1-E-1 is instructed once the core exit thermocouple are less than 1200°F, RVLIS is less than 67% and at least two hot leg temperatures are less than 345°F.

- HEP-1FRC:1-11-S1 represents the operator action required to identify and complete a rapid depressurization of the Steam Generators during a medium break LOCA. This is the Y function on the S1 event tree.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to immediately determine if 1-FR-C.1 should be implemented without any delay.

T_e = 210 seconds (3.5 minutes). The system time-window is defined by MAAP (analysis file 326MAF.N.5) case 34. The core gas exit temperature reaches 1200°F for a 3" LOCA with normal ESF equipment at 18.5 minutes and increases to 2200°F at 22 minutes. The Accident Sequence Development analysis file, 321MAF.N.1, section 4.0 predicts a time window of

400 seconds based on the following core cooling recovery information.

T_a = 5 minutes. Task action time to depressurize the SGs from 1000 psig to 120 psig. This is an estimated time value.

T_w = Insufficient time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 1200 seconds (20 minutes). Operator median response time. It is estimated that the CRO in the Control Room will require approximately 15 minutes to reach 1-E-0 step 25 to transition to 1-E-1. As discussed above, the core exit temperature will not reach 1200°F for 1350 seconds (18.5 minutes). This means the operator will have time to transition to 1-E-1 where he will then immediately transition to 1-FR-C.1 as soon as 1200°F is reached. Once in 1-FR-C.1 the operator will require only five minutes to reach step 11 and initiate SG depressurization. The total operator response time will be approximately 20 minutes.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= 1.0E+0

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.0 for an EF = 1
= 1.0E+0 / 1.00 = 1.0E+0

- Adjustment For Recovery:
  R = 1, the recovery factor. No credit is taken for recovery from this Human Error.

  $p_3 = p_3 * R = 6.0E-3 * 1.0 = 6.0E-3$

HEP(median) = $p_2 + p_3$ = 1.000E+0 + 6.0E-3 = 1.000E+0

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:

  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
  M=1.00 for an EF = 1
  = 1.000E+0 * 1.00 = 1.000E+0

D.6.32.2 Summary: HEP-1FRC:1-11-S1

Fault Trees: FFT00

Gates: GFFT421 (OR) S1 medium LOCA for Y01.

Physical Id: HEP-1FRC:1-11-S1

Description: 1-FR-C.1_INADEQUATE CORE_COOLING_STEP11 DEPRESSURIZE_SGS___

Failure Rate: 1.000E+0

Distribution: Lognormal
Median: 1.000E+0
Error Factor: 1

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.33 HEP-1FRC:1-11-S2

D.6.33.1 Analysis: HEP-1FRC:1-11-S2

- Equivalent Surry HRA: HEP-1FRC:1-12-S2
  see Surry IPE report page D.3-83 to D.3-84.
  calculated mean = 3.067E-1

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-E-1	Loss of Reactor Or Secondary Coolant, Rev 2, 12-27-89.
1-ES-1.2	Post LOCA Cooldown and Depressurization, Rev 4, 12-27-89.

1-F-0 Critical Safety Function Status Trees, Rev 0, 12-27-89.

1-FR-C.1 Response To Inadequate Core Cooling, Rev 3, 12-27-89.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 25 checks that the RCS is intact by checking the containment radiation, pressure and sump level. The RNO is to transition to 1-E-1. Step 28 initiates monitoring of the Critical Safety Function Status Trees.

- 1-E-1 Step 20 checks if RCS cooldown and depressurization is required and transitions to 1-ES-1.2.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 2 is for Core Cooling. The red paths implement 1-FR-C.1, the orange paths implement 1-FR-C.2, the yellow paths implement 1-FR-C.3 and the green path is CSF satisfactory. The red paths are core exit thermocouple greater than 1200°F; or RCS subcooling less than 30°F when no RCP are running, core exit thermocouple greater than 700°F and RVLIS full range less than 48%.

- 1-FR-C.1 provides instructions to restore Core Cooling. This procedure is entered from the red terminus of the core cooling CSF status tree. Step 11 depressurizes all intact SGs to 120 psig. Step 14 depressurizes all intact SG to atmospheric pressure by dumping steam to the Condenser at the maximum rate. Step 19 tries to locally depressurize all intact SG to atmospheric pressure. Return to 1-E-1 is instructed once the core exit thermocouple are less than 1200°F, RVLIS is less than 67% and at least two hot leg temperatures are less than 345°F.

- HEP-1FRC:1-11-S2 represents the operator action required to identify and complete a rapid depressurization of the Steam Generators during a small break LOCA. This is the Y function on the S2 event tree.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to immediately determine if 1-FR-C.1 should be implemented without any delay.

T_e = 91 minutes (5470 seconds). The system time-window is defined by MAAP analysis (325MAF.N.5) case 36A for a 2" inch break. This break sizes cause SG dryout in 91 minutes. The operator must fully

depressurize the Steam Generators before dry out occurs.

T_a = 5 minutes. Task action time to depressurize the SGs from 1000 psig to 120 psig. This is an estimated time value.

T_w = 86 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 20 minutes. Operator median response time. It is estimated that the CRO in the Control Room will require approximately 15 minutes to reach 1-E-0 step 25 to transition to 1-E-1. As discussed above, the core exit temperature will not reach 1200°F for 1350 seconds (18.5 minutes). This means the operator will have time to transition to 1-E-1 where he will then immediately transition to 1-FR-C.1 as soon as 1200°F is reached, or as soon as 700°F is reached and RVLIS < 40%. Once in 1-FR-C.1 the operator will require only five minutes to reach step 11 and initiate SG depressurization. The total operator response time will be approximately 20 minutes.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2})/ \sigma)$
= $1 - \Phi(\ln(86/20) / 0.6)$
= $1 - \Phi(2.43)$
= 7.5E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 7.5E-3 / 1.25 = 6.00E-3

- Adjustment For Recovery:
  R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to

detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

p_3(recovered) = p_3 * R = 6.0E-3 * 0.1 = 6.0E-4

HEP(median) = p_2 + p_3 = 6.00E-3 + 6.0E-4 = 6.60E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=EXP{[1/1.645)* ln (EF)]^2/2}
M=1.25 for an EF = 3
= 6.6E-3 * 1.25 = 8.25E-3

D.6.33.2 Summary: HEP-1FRC:1-11-S2

Fault Trees: FFT00, MS100

Gates:	GFFT422	(OR) S2 small LOCA for Y02.
	GFFT423	(OR) T1 LOOP for Y03.
	GFFT424	(OR) T4 Seal LOCA for Y04.
	GMS1112	(OR) Failure of operator to dump steam from 2 of 3 SG's.

Physical Id: HEP-1FRC:1-11-S2

Description: 1-FR-C.1_INADEQUATE CORE_COOLING_STEP11 DEPRESSURE_SGS__S2_

Failure Rate: 8.250E-3

Distribution: Lognormal
Median: 6.600E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.34 HEP-1FRH:1-5

D.6.34.1 Analysis: HEP-1FRH:1-5

- Equivalent Surry HRA: HEP-1FRH:1-5
  see Surry IPE report page D.3-86 to D.3-87.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-ES-0.1	Reactor Trip Response, Rev 8, 3-5-91.
1-F-0	Critical Safety Function Status Trees, Rev 0, 12-27-89.
1-FR-H.1	Response To Loss of Secondary Heat Sink, Rev 3, 5-31-90.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 4 checks if SI is actuated. The RNO is to transition to 1-ES-0.1.

- 1-ES-0.1 provides instructions to stabilize and control the plant following a Reactor Trip without Safety Injection. Step 2 check Feedwater status, including AFW status. Step 6 checks SG levels.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 3 is for Heat Sink. The red paths implement 1-FR-H.1, there are no orange paths, the yellow paths implement 1-FR-H.2 or -H.3, -H.4 or -H.5 and the green path is CSF satisfactory. The red path is valid when total feedwater flow to the SGs is less than 340 gpm and either narrow range SG level is less than 10% or pressure in all SG is less than 1135 psig.

- 1-FR-H.1 provides instructions to respond to a loss of secondary Heat Sink in all Steam Generators. Step 2 tries to establish AFW flow to at least on SG. Step 4 tries to establish Main Feed flow to at least one SG. Step 5 checks SG levels to determine if flow to at least one SG exists if so the operator is to wait for narrow range level to be restored. The RNO is to continue. Step 6 tries to establish feed flow from the Condensate system. Step 7 tries to establish feed flow from alternate sources. Step 8 checks SG narrow range levels. Step 9 checks SG wide range levels. Step 10 and after give up on feedwater flow and establish SI feed and bleed cooling.

- HEP-1FRH:1-5 represents the operator action required to identify and complete action to restore SG levels during the T2A or

T3 event trees. Event though step five is used as the representative step, all actions required by the first 9 steps of 1-FR-H.1 are considered within the bounds of this HEP. This is the M01 function on the T2A event tree, and the M02 function on the T3 event tree.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine a valve is misaligned immediately after a SI signal.

T_e = 2524 seconds (42 minutes). The system time-window is defined by MAAP (analysis file 326MAF.N.5) case 36 which show the time to SG dryout with no MFW, AFW and normal ESF, for a transient with no break. The Accident Sequence Development analysis file, 321MAF.1.N, section 7.0 suggests a time window of 1.9 hours.

T_a = 5 minutes. Task action time to complete the actions of the first nine steps of 1-FR-H.1. This is an estimated time value. Secondary heat removal is expected to stop or decrease RCS temperature immediately after successful completion of any these steps. AFW, MFW or Condensate (with RCS depressurization).

T_w = 37 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 359 seconds (6 minutes). Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-FR-H.1 once he is aware of the need to re-establish secondary heat removal. The time is short because of the rapid transition out of 1-E-0 allows implementation of 1-F-0 and 1-ES-0.1 which quickly focus attention on the SG levels and Feedwater flow. The time of six minutes is from the simulator time to reach step 15 (310 + 49 seconds).

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 1.0E-3, 5.0E-4 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items.

Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(37/6) / 0.6)$
= $1 - \Phi(3.03)$
= 1.20E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.20E-3 / 1.25 = 1.500E-3

- Adjustment For Recovery:
  R = 1.0, recovery factor. No credit is taken for immediate recovery of this HEP. A recovery factor can be considered after sequence quantification. 1-ES-0.1 and 1-FR-H.1 do have multiple steps which check SG level and attempt to restore AFW or MFW using multiple possible actions. The operator can misperform these actions only by being in the wrong procedure and ignoring the Critical Safety Function status trees. Also the T_w is sufficiently long to allow the TSC to be fully manned. The TSC is the primary means of recovering this function.

  $p_3 = p_3 * R$ = 1.0E-3 * 1.0 = 1.0E-3

  HEP(median) = $p_2 + p_3$ = 1.500E-3 + 1.0E-3 = 2.500E-3

- Consideration of Dependency:

Logically there should be a dependency between this HEP and the HEP to establish bleed. However, event trees were structured such that the feed and bleed operator actions are in different functions so that if the feed question is a failure, due to hardware or operator error, then core damage results and the bleed question is not asked. The bleed question is asked only for sequences which have success of the feed function. Therefore there are no dependencies between these HEPs.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln(EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 2.500E-3 * 1.25 = 3.125E-3

D.6.34.2 Summary: HEP-1FRH:1-5

Fault Trees: MF100, MF200

Gates: GMF1912 (OR) Faults in MFW pump 1-FW-P-1C.
GMF2601 (OR) Insufficient flow from the MFW pumps.

Physical Id: HEP-1FRH:1-5____

Description: 1-FR-H.1_LOSS_OF___
HEAT_SINK_STEP_5___
CHECK_SG_LEVELS____

Failure Rate: 3.125E-3

Distribution: Lognormal
Median: 2.500E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________
____

Why modified: NAPS IPE Final Quantification Value

D.6.35 HEP-1FRH:1-11

D.6.35.1 Analysis: HEP-1FRH:1-11

- Equivalent Surry HRA: HEP-1FRH:1-12
  see Surry IPE report page D.3-88 to D.3-89.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-ES-0.1	Reactor Trip Response, Rev 8, 3-5-91.
1-F-0	Critical Safety Function Status Trees, Rev 0, 12-27-89.
1-FR-H.1	Response To Loss of Secondary Heat Sink, Rev 3, 5-31-90.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 4 checks if SI is actuated. The RNO is to transition to 1-ES-0.1.

- 1-ES-0.1 provides instructions to stabilize and control the plant following a Reactor Trip without Safety Injection. Step 2 check Feedwater status, including AFW status. Step 6 checks SG levels.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange

or red path are encountered. Attachment 3 is for Heat Sink. The red paths implement 1-FR-H.1, there are no orange paths, the yellow paths implement 1-FR-H.2 or -H.3, -H.4 or -H.5 and the green path is CSF satisfactory. The red path is valid when total feedwater flow to the SGs is less than 340 gpm and either narrow range SG level is less than 10% or pressure in all SG is less than 1135 psig.

- 1-FR-H.1 provides instructions to respond to a loss of secondary Heat Sink in all Steam Generators. Step 2 through 9 attempt to establish feedwater flow to the SG to restore SG level. If these attempts fail then RCS feed and bleed is attempted as the means to provide RCS cooling. Step 10 manually initiates SI. Step 11 verifies RCS feed path by verifying Charging pumps running and proper valve alignment. Step 15 establishes RCS bleed path by opening both Pressurizer PORVs. Step 16 verifies both PORVs are open. Step 17 maintains RCS heat removal by maintaining SI flow and both PORVs open. Step 28 continues attempts to establish secondary heat sink.

- HEP-1FRH:1-11 represents the operator action required to identify and complete action to establish the SI portion of feed and bleed. This is the D102 function on the T1 event tree and D105 on the T1A, T2, T2A, and T3 trees.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the status of the RCS and SI without a delay.

T_e = 1.9 hours. System time-window is defined by the Accident Sequence Development analysis file, 321MAF.1.N, section 7.0. The time window is the time until SG dryout. The time window for feed and bleed are considered to be the same.

T_a = 5 minutes. Task action time to complete the actions of the step 11 of 1-FR-H.1. This is an estimated time value.

T_w = 109 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 40 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-FR-H.1 within ten minutes once he is aware of the need to re-establish secondary heat removal. This time is short because of the rapid transition out of 1-E-0 allows implementation of 1-F-0 and 1-ES-0.1 which quickly focus attention on the SG levels and Feedwater flow. From HEP-1FRH:1-5 analysis it will take the operator 30 minutes to

complete the first 9 steps of 1-FR-H.1 and decide to use feed and bleed cooling because SG level can not be restored.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = 1 - $\Phi(\ln(T_w/T_{1/2}) / \sigma)$
= 1 - $\Phi(\ln(109/40) / 0.6)$
= 1 - $\Phi(1.67)$
= 4.75E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)*\ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 4.75E-2 / 1.25 = 3.80E-2

- Adjustment For Recovery:

  R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. It may be acceptable to use an error factor of 0.01, from NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. This additional recovery factor can be considered after sequence quantification. The operator can misperform these actions only by being in the wrong procedure and ignoring the Critical Safety Function status trees. The operator could also be so focused on efforts to restore SG level that feed and bleed cooling is not attempted early enough to avoid core damage.

$p_3 = p_3 * R = 6.0E-3 * 0.1 = 6.0E-4$

HEP(median) = $p_2 + p_3$ = 3.80E-2 + 6.0E-4 = 3.86E-2

- Consideration of Dependency:

Logically there should be a dependency between this HEP and the HEP to establish bleed. However, event trees were structured such that the feed and bleed operator actions are in different functions so that if the feed question is a failure, due to hardware or operator error, then core damage results and the bleed question is not asked. The bleed question is asked only for sequences which have success of the feed function. Therefore there are no dependencies between these HEPs.

- HEP Conversion To A Mean:

HEP(mean) = HEP(median) * M

where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 3.86E-2 * 1.25 = 4.825E-2

D.6.35.2 Summary: HEP-1FRH:1-11

Fault Trees: FB400

Gates: GFB4110 (OR) Failure of feed and bleed cooling.
GFB4422 (OR) Failure of flow through valve to cold legs

Physical Id: HEP-1FRH:1-11___

Description: 1-FR-H.1_LOSS_OF___
HEAT_SINK_STEP_11__
RCS_FEED_PATH______

Failure Rate: 4.825E-2

Distribution: Lognormal
Median: 3.860E-2
Error Factor: 3

Reference: 324MAF.N____________
9-1-92_______________

Why modified: NAPS IPE Final Quantification Value

D.6.36 HEP-1FRH:1-15

D.6.36.1 Analysis: HEP-1FRH:1-15

- Equivalent Surry HRA: HEP-1FRH:1-16
  see Surry IPE report page D.3-90 to D.3-91.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0	Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-ES-0.1	Reactor Trip Response, Rev 8, 3-5-91.
1-F-0	Critical Safety Function Status Trees, Rev 0, 12-27-89.
1-FR-H.1	Response To Loss of Secondary Heat Sink, Rev 3, 5-31-90.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 4 checks if SI is actuated. The RNO is to transition to 1-ES-0.1.

- 1-ES-0.1 provides instructions to stabilize and control the plant following a Reactor Trip without Safety Injection. Step 2 check Feedwater status, including AFW status.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 3 is for Heat Sink. The red paths implement 1-FR-H.1, there are no orange paths, the yellow paths implement 1-FR-H.2 or -H.3, -H.4 or -H.5 and the green path is CSF satisfactory. The red path is valid when total feedwater flow to the SGs is less than 340 gpm and either narrow range SG level is less than 10% or pressure in all SG is less than 1135 psig.

- 1-FR-H.1 provides instructions to respond to a loss of secondary Heat Sink in all Steam Generators. Step 2 through 9 attempt to establish feedwater flow to the SG to restore SG level. If these attempts fail then RCS feed and bleed is attempted as the means to provide RCS cooling. Step 10 manually initiates SI. Step 11 verifies RCS feed path by verifying Charging pumps running and proper valve alignment. Step 15 establishes RCS bleed path by opening both Pressurizer PORVs. Step 16 verifies both PORVs are open. Step 17 maintains RCS heat removal by maintaining SI flow and both PORVs open. Step 28 continues attempts to establish secondary heat sink.

- HEP-1FRH:1-15 represents the operator action required to identify and complete action to opening both Pressurizer PORVs portion of feed and bleed. This is the P01 function on the S2,

T1A, T2LM and T7 event trees, and the P02 and P03 functions on the T1 tree. More recent MAAP analysis has shown that only one Pressurizer PORV is necessary for most transients. For these transients the HEP represents the operator opening one valve.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the status of the RCS without a delay.

T_e = 91 minutes (5470 seconds). System time-window is defined by MAAP analysis (326MAF.N.5) case 36a. The time window is the time until SG dryout. The time window for feed and bleed are considered to be the same. The Accident Sequence Development analysis file, 321MAF.1.N, section 7.0 estimated this time window to be 1.9 hours.

T_a = 5 minutes. Task action time to complete the actions of the step 15 of 1-FR-H.1. This is an estimated time value.

T_w = 86 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 20 minutes. Operator median response time. It is estimated that the CRO in the Control Room will initiate 1-FR-H.1 within ten minutes once he is aware of the need to re-establish secondary heat removal. This time is short because of the rapid transition out of 1-E-0 allows implementation of 1-F-0 and 1-ES-0.1 which quickly focus attention on the SG levels and Feedwater flow. 1-E-0 step 14 also has its own direct transition to 1-FR-H.1. From HEP-1FRH:1-5 analysis it will take the operator 5 minutes to complete the first 9 steps of 1-FR-H.1 and decide to use feed and bleed cooling because SG level can not be restored. The operator can transition to step 11 immediately if SG wide range level is < 7% in two SGs or RCS pressure is > 2335 psig. It is estimated to require an additional 5 minutes to reach step 15.

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff

provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

$p_2(\text{mean}) = 1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
$= 1 - \Phi(\ln(86/20) / 0.6)$
$= 1 - \Phi(2.43)$
$= 7.5E-3$

$P_2(\text{median}) = \text{HEP(mean)} / M$
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
$= 7.5E-3 / 1.25 = 6.00E-3$

- Adjustment For Recovery:

R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. It may be acceptable to use an error factor of 0.01, from NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 4, checking that involves active participation, such as special measurement. Error Factor = 5. This additional recovery factor can be considered after sequence quantification. The operator can misperform these actions only by being in the wrong procedure and ignoring the Critical Safety Function status trees. The operator could also be so focused on efforts to restore SG level that feed and bleed cooling is not attempted early enough to avoid core damage. The importance of verifying that both PORVs are open is also ensured by two additional steps within 1-FR-H.1 which verify that both are open. However, it will be the same operators performing these tasks. It may be possible for an operator to misdiagnosis or believe that one PORV is adequate. The TSC personnel will independently verify that both PORVs are open.

$p_3 = p_3 * R = 6.0E-3 * 0.1 = 6.0E-4$

$\text{HEP(median)} = p_2 + p_3 = 6.00E-3 + 6.0E-4 = 6.60E-3$

- Consideration of Dependency:

Logically there should be a dependency between this HEP and the HEP to establish bleed. However, event trees were structured such that the feed and bleed operator actions are in different functions so that if the feed question is a failure, due to hardware or operator error, then core damage results and the bleed question is not asked. The bleed question is asked only for sequences which have

success of the feed function. Therefore there are no dependencies between these HEPs.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where M=EXP{[1/1.645)* ln (EF)]^2/2}
  M=1.25 for an EF = 3
  = 6.60E-3 * 1.25 = 8.25E-3

D.6.36.2 Summary: HEP-1FRH:1-15

Fault Trees: FB100

Gates: GFB1112 (OR) Failure to open both PORVs for feed and bleed.

Physical Id: HEP-1FRH:1-15___

Description: 1-FR-H.1_LOSS_OF___
HEAT_SINK_STEP_15__
RCS_BLEED_PATH_____

Failure Rate: 8.250E-3

Distribution: Lognormal
Median: 6.600E-3
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.37 HEP-1FRS:1-4

D.6.37.1 Analysis: HEP-1FRS:1-4

- Equivalent Surry HRA: HEP-1FRS:1-4
  see Surry IPE report page D.3-92 to D.3-93.
  calculated mean = 1.438E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-FR-S.1 Response To Nuclear Power Generation/ATWS, Rev 1, 12-27-89.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 1 verifies reactor trip by

opening both reactor trip breakers, and checks that the reactor trip and bypass breakers are open, the IRPIs are at zero, the rod bottom lights are on, and neutron flux is decreasing to less than 5%. The RNO is to transition to 1-FR-S.1.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 1 is for Subcriticality. The red and orange paths implement 1-FR-S.1, the yellow paths implement 1-FR-S.2 and the green path is CSF satisfactory. The red path is chosen when the power range is less than 5% or when the intermediate range startup rate is positive.

- 1-FR-S.1 provides instructions for adding negative reactivity to a core that is observed to be critical when expected to be shutdown. Steps 1 to 4 are immediate operator actions. Step 1 verifies reactor trip similar to step 1 of 1-E-0. The RNO is to manually insert the control rods. Step 2 manually trips the turbine. Step 3 checks all AFW pumps running. Step 4 initiates emergency boration of RCS.

- HEP-1FRS:1-4 represents the operator action required to identify and complete the action to initiate emergency boration during an ATWS. This is in the D401 and D402 functions on the TH and TL event trees.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the status of the RCS without a delay.

T_e = 10 minutes. System time-window is defined by the Accident Sequence Development analysis file, 321MAF.1.N, section 11.0.

T_a = 34 seconds. Task action time to complete the actions of the step 4 of 1-FR-H.1. This time is from the SPS HRA simulator data for ATWS events.

T_w = 566 seconds. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 37 seconds. Operator median response time. This time is from the SPS simulator data.

σ = 0.4 is chosen for HEPs which are in response to the immediate operator actions steps of any procedure.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2,

estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$

= $1 - \Phi(\ln(566/37) / 0.4)$

= $1 - \Phi(6.82)$

< 1E-4

P_2(median) = HEP(mean) / M

where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$

M=1.25 for an EF = 3

= 1E-4 / 1.25 = 8.0E-5

- Adjustment For Recovery:

  R = 1, the recovery factor. No credit is taken for recovery from this Human Error. The time window is too short.

$p_3 = p_3 * R = 6.0E-3 * 1.0 = 6.0E-3$

HEP(median) = $p_2 + p_3$ = 8.0E-5 + 6.0E-3 = 6.08E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:

  HEP(mean) = HEP(median) * M

  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$

  M=1.25 for an EF = 3

  = 6.08E-3 * 1.25 = 7.60E-3

D.6.37.2 Summary: HEP-1FRS:1-4

Fault Trees: CH100

Gates: GCH1112 (OR) Failure of emergency boration from BAT or RWST.

Physical Id: HEP-1FRS:1-4____

Description: 1-FR-S.1_ATWS______
STEP_4_INITIATE____
EMERGENCY_BORATION_

Failure Rate: 7.600E-3

Distribution: Lognormal
Median: 6.080E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.38 HEP-1FRS:1-5

D.6.38.1 Analysis: HEP-1FRS:1-5

- Equivalent Surry HRA: HEP-AP12:00
  see Surry IPE report page D.3-102 to D.3-103.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-E-0 Reactor Trip or Safety Injection, Rev 9, 12-14-91.
1-FR-S.1 Response To Nuclear Power Generation/ATWS, Rev 1, 12-27-89.

- 1-E-0 verifies proper response of the Reactor Protection and Emergency Core Cooling Systems. Step 1 verifies reactor trip by opening both reactor trip breakers, and checks that the reactor trip and bypass breakers are open, the IRPIs are at zero, the rod bottom lights are on, and neutron flux is decreasing to less than 5%. The RNO is to transition to 1-FR-S.1.

- 1-F-0 provides a method for checking Critical Safety Factions. These status trees are monitored during all emergency procedures except during the first 25 steps of 1-E-0. Operators will immediately implement the applicable procedure whenever an orange or red path are encountered. Attachment 1 is for Subcriticality. The red and orange paths implement 1-FR-S.1, the yellow paths implement 1-FR-S.2 and the green path is CSF satisfactory. The red path is chosen when the power range is less than 5% or when the intermediate range startup rate is positive.

- 1-FR-S.1 provides instructions for adding negative reactivity to a core that is observed to be critical when expected to be shutdown. Steps 1 to 4 are immediate operator actions. Step 1 verifies reactor trip similar to step 1 of 1-E-0. The RNO is to manually insert the control rods. Step 2 manually trips the turbine. Step 3 checks all AFW pumps running. Step 4 initiates emergency boration of RCS. Step 5 checks if the following trips have occurred: reactor trip, turbine trip. The RNOs are to implement the appropriate Attachment. Attachment 1 is "Remote Turbine Trip." Attachment 2 "Remote Reactor Trip." The actions

are to locally trip the reactor from the rod drive room by tripping the reactor trip breakers, then try opening the MG set output breaker, then go to the 307 Switchgear Room and opening the MG set supply breaker.

- HEP-1FRS:1-5 represents the operator action required to identify and complete the action to trip the reactor from outside of the Main Control Room. This is in the MSL01, manual scram late, function on the TH and TL event trees.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO will be able to determine the status of the RCS without a delay.

T_e = 10 minutes. System time-window is defined by the Accident Sequence Development analysis file, 321MAF.1.N, section 11.0. The operator action is defined as follows. This function involves operator action to drive in the control rods or trip the power supply for the MG sets. This second option is the preferred modelling option. As this actions si an out of control room action, no credit was allowed for this action to prevent the need to have turbine trip, pressure relief, or start of AFW. However, it is reasonable to assume this action could be done prior to emergency boration (about 2 minutes). This action is an operator action to trip the power supply to or from the control rod drive MG sets. This action is effective against breaker faults, but not against mechanical rod binding. The probability of this function must consider this. The analysis file goes on to fix the timing for emergency boration as ten minutes.

T_a = 5 minutes. Task action time to complete the actions of the step 5 of 1-FR-H.1. This is an estimated time value.

T_w = 5 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 90 seconds. Operator median response time. It is estimated that the CRO in the Control Room will attempt step 1-E-0 and transition to 1-FR-S.1 immediately. It will require approximately one to two minutes to complete the actions of step 1 through 4 since these are memorized immediate operator action steps. Surry HRA simulator data shows (SPS IPE pages D.3-92 and -93) that operators required an average of 71 seconds to complete steps

1 through 4 of 1-FR-S.1. For NAPS use 90 seconds as a reasonable estimate of the time to complete steps 1 to 4 and to be prepared to initiate step 5 (Attachment 2).

σ = 0.6 for emergency procedure steps after the immediate operator action steps, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_W/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(300/90) / 0.6)$
= $1 - \Phi(2.01)$
= 2.22E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 2.22E-2 / 1.25 = 1.776E-2

- Adjustment For Recovery:
  R = 1, the recovery factor. No credit is taken for recovery from this Human Error. The time window is too short.

$p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 1.776E-2 + 6.0E-3 = 2.376E-2

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs.

- HEP Conversion To A Mean:
  HEP(mean) = HEP(median) * M
  where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
  M=1.25 for an EF = 3
  = 2.376E-2 * 1.25 = 2.970E-2

D.6.38.2 Summary: HEP-1FRS:1-5

Fault Trees: FFT00, RP100

Gates: GFFT513 (OR) Manual scram late open to trip MG set event MS1 HEP FFT.
GRP1183 (AND) No signal to open MG set breakers.

Physical Id: HEP-1FRS:1-5____

Description: 1-FR-S.1_ATWS______
STEP_5_DO_ATTACH_2_
REMOTE_REACTOR_TRIP

Failure Rate: 2.970E-2

Distribution: Lognormal
Median: 2.376E-2
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.39 HEP-1OP14:1-5:13

D.6.39.1 Analysis: HEP-1OP14:1-5:13

- Equivalent Surry HRA: HEP-1OP14:1-5:10
  see Surry IPE report page D.3-96.
  calculated mean = 2.664E-3

- NAPS Procedures:

1-OP-3.3 "Unit Shutdown From Mode 4 to Mode 5," Rev 19, 12-20-90. Step 5.6 initiates 1-PT-78.1, Step 5.13 places RHR in service using 1-OP-14.1.

1-OP-14.1 "Residual Heat Removal," Rev 28, 9-26-90. Step 5.3.15 opens the RHR inlet MOVs.

1-PT-78.1 "Residual Heat Removal System Monthly

- HEP Calculation:

Input Parameters:

T_b = 0 seconds. The CRO is immediately aware that a transient is in progress.

T_e = 18 hours, engineering allowable system time-window. This time window is from MAAP (analysis file 326MAF.N.5) cases 28 and Z28. It is the amount of time until the ECST is emptied during a SGTR which is 100 hours if no RCS cooldown is performed or 18 hours if the RCS is cooldown at 50°F/hr to RHR

initiation temperature of 300°F. This is the same time window used for HEP-1AP15-1E.

T_a = 1 hour, task action time. This time is estimated. It is intended to be a representative of a bounding time. It is assumed that the MOV fails to open due to an open interlock permissive failure. It is estimated that electricians will be able to jumper the interlock within one hour. Electricians will be on site by the time the unit is cooldown to RHR conditions.

T_w = 17 hours, time available for cognitive response. $T_w = T_e - T_b - T_a = 18 - 0 - 1$.

$T_{1/2}$ = 4 hour, operator median response time. This is a conservative estimate of the time when the control room operators will initiate 1-OP-14.1 and the time step 13 is reached after a SGTR. The operator may not stoke open the RHR inlet MOVs at four hours, but the RHR system can be expected to be warmed up and ready to be utilized when the RCS has been adequately cooled down and depressurized.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 NUREG/CR-1278 Table 20-12 item 2, EF=3, Errors of commission in operating manual controls, which are identified by labels only. This is a median value. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(17/4) / 0.8)$
= $1 - \Phi(1.81)$
= 3.51E-2

P_2(median) = HEP(mean) / M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.51E-2 /1.25 = 2.808E-2

HEP(median) = $p_2 + p_3$ = 2.808E-2 + 6.0E-3 = 3.408E-2

- Adjustment For Recovery:

R = 0.1, the recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to

detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the very long time window, 18 hours, credit can be taken for recovery of this operator action due to the TSC manning and shift change to a new group of operators. This recovery is applicable to both the p_2 and p_3 terms.

HEP(median) = HEP(median) * R = 3.408E-2 * 0.1 = 3.408E-3

- Consideration of Dependency:

There is no dependency between this HEP and other Type C HEPs. This HEP does appear in cut sets with HEP-1E3-13, RCS cooldown, and with HEP-1E3-3, isolate ruptured SG. These operator actions are unrelated to opening 1-RH-MOV-1700 or 1-RH-MOV-1701, or placing RHR in service.

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 3.408E-3 * 1.25 = 4.260E-3

D.6.39.2 Summary: HEP-1OP14:1-5:13

Fault Trees: RH100

Gates:
GRH1531 (AND) RCS HI pressure interlock from PT-1402 not cleared.
GRH1524 (AND) RCS HI pressure interlock from PT-1403 not cleared.

Physical Id: HEP-1OP14:1-5:13

Description: 1-OP-14.1 RHR
STEP 5.13, OPEN
MOV-1700 & MOV-1701

Failure Rate: 4.260E-3

Distribution: Lognormal
Median: 3.408E-3
Error Factor: 3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.40 HEP-1OP21:6

D.6.40.1 Analysis: HEP-1OP21:6

- Equivalent Surry HRA: HEP-1E0-18
  see Surry IPE report page D.3-51 to D.3-53.
  calculated mean = 1.438E-3

- NAPS Procedures:

0-AP-55	Loss of Control Room/Emergency Switchgear Room Air Conditioning, Rev 0, 3-28-91.
1-OP-21.6	Main Control And Relay Room Air Conditioning, Rev 10, 1-3-92.
0-OP-21.7	Main Control Room Emergency Ventilation Operation, Rev 1, 8-23-90.

- 1-OP-21.6 provides guidance for aligning ESGR AHU and chiller units. This OP is initiated directly by the CROs or indirectly from transitioning through 1-E-0 Attachment 2 step 7, then to 0-OP-21.7.

- HEP-1OP21:6 represents four basic events, 1HV-HEP-1HVAC7, 1HVHEP-1HVE4A, 1HV-HEP-1HVE4B, and 1HV-HEP-1HVE4C, used in the initial quantification. These basic events represented the operator action necessary to start a standby AHU and to start or swapover the chillers.

- HEP Calculation:

Input Parameters:

T_b = 1 hour. The CRO is may not realize that the running ESGR AHU has failed and another needs to be started. The one hour time value is an estimate.

T_e = 4 hours. System time-window is defined by engineering calculations which show that the ESGR will heat up to 120F, the maximum acceptable limit before equipment failure can be expected.

T_a = 30 minutes. Task action time to complete 1-OP-21.6. This is an estimated time value. Temperature is expected to stop or decrease immediately after completing the procedure.

T_w = 2.5 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 10 minutes. Operator median response time. It is estimated that the CRO in the Control Room will have someone initiate 1-OP-21.6 within ten minutes

once he is aware of the need to re-establish ESGR cooling.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from Table 20-7, NUREG/CR-1278, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(150/10) / 0.8)$
= $1 - \Phi(3.39)$
= 3E-4

P_2(median) = HEP(mean) / M
where $M = EXP\{[1/1.645) * \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.0E-4 / 1.25 = 2.4E-4

- Adjustment For Recovery:

R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R$ = 6.0E-3 * 0.1 = 6.0E-4

HEP(median) = $p_2 + p_3$ = 2.4E-4 + 6.0E-4 = 8.40E-4

- Consideration of Dependency:

There is a potential dependency between this HEP and the HEP for realignment of SW to the ESGR chillers. However this dependency appears to be applicable only during the T1 event tree and not true for other event trees. During typical event trees the operator action is needed to restore SW flow to the ESGR chillers only after Ftwo equipment failures, and operator action is needed to restore an AHU only after two equipment failures. Then the two HEPs would be in the same cut set with the four equipment failures. This cut set is too low to meet any reasonable cutoffs. During a T1 event if HEPs only one equipment failure is required before the operator action is required. For the T1 tree, it is possible for these two

HEPs to be in the same cut set with only two equipment failures. The dependency does exist for this cut set. If either HEP is adjusted then the non dependent cut sets will have too high of a probability. Since the T1 event tree is dominated by single failures and the ESGR heat load is reduced by 50% when one bus is loss, the dependency for these HEPs will be ignored.

Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 8.4E-4 * 1.25 = 1.050E-3

D.6.40.2 Summary: HEP-1OP21:6

Fault Trees: HV100

Gates:

GHV1332	(OR)	Stdby AHU 1-HV-AC-7 faults to fan motor & electric power.
GHV1621	(OR)	Standby 1-HV-E-4B chilled water faults.
GHV1721	(OR)	Standby 1-HV-E-4C chilled water faults
GHV1821	(OR)	Standby 1-HV-E-4A chilled water faults
GHV1921	(OR)	Spare 1-HV-E-4C chilled water faults.

Physical Id: HEP-1OP21:6_____

Description: 1-OP-21.6_MCR_AND__
RELAY_ROOM_AIR_____
CONDITIONING_______

Failure Rate: 1.05E-3

Distribution: Lognormal
Median: 8.400E-4
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.41 HEP-1OP49:1

D.6.41.1 Analysis: HEP-1OP49:1

- Equivalent Surry HRA: none

- NAPS Procedures:

0-AP-12 Loss of Service Water, Rev 1, 5-16-91.
1-OP-49.1 Service Water System Operation, Rev 2, 8-22-91.

- 0-AP-12 provides instructions to use in the event of a loss of SW. Step 1 checks SW system integrity by ensuring the SW reservoir level is greater than 310 feet. The RNO is to make a high volume makeup and if level can not be restored then place the Auxiliary Service Water pumps in operation on Lake-to-Lake using 1-OP-49.1. Step 2 checks SW supply header status by verifying at least one SW pump per supply header. The RNO is to start at least one pump or Auxiliary SW pump using 1-OP-49.1.

- 1-OP-49.1 provides instructions for putting the SW system in service. This includes placing the SW system in Lake to Lake operation.

- HEP Calculation:

Input Parameters:

T_b = 0 minutes. The CRO has adequate information to immediately perform the actions required by Attachment 1.

T_e = 30 minutes. The system time window is an engineering estimate of how long the Charging pumps can operate without Service Water flow.

T_a = 5 minutes. Task action time to complete 1-OP-49.1.

T_w = 25 minutes. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 10 minutes. Operator median response time data is an estimate of the time required for an operator to identify that SW flow has be lost due to a low SW flow annunciator or observation of the SW flow indicators.

σ = 0.8 for non emergency procedures for which there is procedural guidance, and there has been training.

p_3 = 6.0E-3, 3.0E-3 is the estimated human error probability from NUREG/CR-1278, Table 20-7, item 2, estimated probabilities of errors of omission per item of instruction when use of written procedures

is specified, when procedures with checkoff provisions are correctly used, long list >10 items. Error Factor = 3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(25/10) / 0.8)$
= $1 - \Phi(1.15)$
= 1.251E-1

P_2(median) = HEP(mean) / M
where $M=EXP\{[(1/1.645) * \ln(EF)]^2/2\}$
M=1.25 for an EF = 3
= 1.251E-1 / 1.25 = 1.0008E-1

- Adjustment For Recovery:
R = 1, recovery factor. No credit is taken for immediate recovery from this Human Error.

$p_3 = p_3 * R$ = 6.0E-3 * 1.0 = 6.0E-3

HEP(median) = $p_2 + p_3$ = 1.0008E-1 + 6.0E-3 = 1.0608E-1

- Consideration of Dependency:

There are no dependencies between this operator action and any others.

- Conversion To A Mean:
HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 1.0608E-1 * 1.25 = 1.326E-1

D.6.41.2 Summary: HEP-1OP49:1

Fault Trees: SW100

Gates:	GSW1322	(OR) Inadequate SW flow from header A when in Lake to Lake mode.
	GSW1522	(OR) Inadequate SW flow from header B when in Lake to Lake mode.

Physical Id: HEP-1OP49:1

Description: 1-OP-49.1_STARTUP__ AND_SHUTDOWN_OF_THE SERVICE_WATER_SYSTM

Failure Rate: 1.326E-1

Distribution:	Lognormal
Median:	1.061E-1
Error Factor:	3

Reference: 324MAF.N
9-1-92

Why modified: NAPS IPE Final Quantification Value

D.6.42 HEP-0OP49:4A

D.6.42.1 Analysis: HEP-0OP49:4A

- Equivalent Surry HRA: HEP-AP12:00
  see Surry IPE report page D.3-102 to D.3-103.
  calculated mean = 2.664E-3

- NAPS Procedures:

0-AP-12	Loss of Service Water, Rev 1, 5-16-91.
0-OP-49.4A	Valve Checkoff - Control Room A/C Service Water, Rev 1, 6-14-91.
1-OP-49.1	Service Water System Operation, Rev 2, 8-22-91.

- 0-OP-49.4A provides the position of the Service Water valves during normal lineup. During alternate SW supply header operation the operations personnel could reverse the position of these valves. No specific guidance is provided for realigning the SW flow to or from the ESGR chiller units. This OP is initiated whenever the CROs are realigning the SW valves.

- HEP-0OP49:4A represents the operator action necessary to realign the SW system supply and discharge headers to the ESGR chillers.

- HEP Calculation:

Input Parameters:

T_b = 1 hour. The CRO is may not immediately realize that the Service Water System needs to be realigned to ESGR chillers. The one hour time value is an estimate.

T_e = 4 hours. System time-window is defined by engineering calculations which show that the ESGR will heat up to 120F, the maximum acceptable limit before equipment failure can be expected.

T_a = 30 minutes. Task action time to complete 1-OP-49.4.A. This is an estimated time value.

Temperature is expected to stop or decrease immediately after completing the procedure.

T_w = 2.5 hours. Time available for cognitive response ($T_w = T_e - T_b - T_a$).

$T_{1/2}$ = 10 minutes. Operator median response time. It is estimated that the CRO in the Control Room will have someone initiate 1-OP-49.4A within ten minutes once he is aware of the need to re-establish ESGR cooling.

σ = 1.0 for extreme cases, where procedural guidance is indirect, and there is not evidence of scenario specific training, but some indication that the crews are knowledgeable about the actions necessary.

p_3 = 2.0E-2, 1.0E-2 is the estimated human error probability from Table 20-7, NUREG/CR-1278, item 4, estimated probabilities of errors of omission per item of instruction when use of written procedures is specified, when procedures without checkoff provisions are used, long list >10 items. Error Factor = 3.

Also NUREG/CR-1278, Table 20-13, item 2 suggests a value of 3E-3. The error rate has been doubled due to operators normally working 12 hour shifts.

Calculations:

p_2(mean) = $1 - \Phi(\ln(T_w/T_{1/2}) / \sigma)$
= $1 - \Phi(\ln(150/10) / 1.0)$
= $1 - \Phi(2.71)$
= 3.4E-3

P_2(median) = HEP(mean) / M
where $M=EXP\{[1/1.645)* \ln (EF)]^2/2\}$
M=1.25 for an EF = 3
= 3.4E-3 / 1.25 = 2.72E-3

- Adjustment For Recovery:
  R = 0.1, recovery factor. From NUREG/CR-1278, Table 20-22, Estimated probabilities that a checker will fail to detect errors made by others, item 1, checking routine tasks, checker using over the shoulder inspections, verifying positions etc. Error Factor = 5. Because of the long time window, > 1 hour, credit can be taken for recovery of this operator action due to the TSC manning. This recovery is applicable to only the p_3 term.

$p_3 = p_3 * R = 2.0E-2 * 0.1 = 2.0E-3$

$HEP(median) = p_2 + p_3 = 2.72E-3 + 2.0E-3 = 4.720E-3$

- Consideration of Dependency:

There is a low dependency between HEP-0OP49:4A and HEP-0AP12-ATTACH4. Use a the following equation to calculate this HEP. Use the median value for HEP-0AP12-ATTCH4 of 9.4E-4. Cut sets which do not have HEP-0AP12-ATTACH4 with this HEP can be recovered using the calculated HEP value while taking into account the conditional dependency between the basic events.

$$HEP_1 = (1 + 19*HEP_0)/20$$
$$= (1 + 19*1.288E-4)/20 = 5.0122E-2$$

- Conversion To A Mean:

HEP(mean) = HEP(median) * M
where M=1.25 for an EF = 3
= 5.0122E-2 * 1.25 = 6.265E-2

D.6.42.2 Summary: HEP-0OP49:4A

Fault Trees: HV100

Gates:	GHV11633	(OR) Insuff supply from alt SW supply to A and C chillers.
	GHV11730	(OR) Insufficient supply from normal SW supply to D chiller.
	GHV21133	(OR) Insufficient supply from alternate SW supply to A chiller.
	GHHV21230	(OR) Insufficient supply from normal SW supply to B & C chillers.

Physical Id: HEP-0OP49:4A____

Description: 0-OP-49.4A_VALVE___
CHECKOFF_MCR_A/C___
SERVICE_WATER______

Failure Rate: 6.265E-2

Distribution: Lognormal
Median: 5.012E-2
Error Factor: 3

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.6.43 HEP-NO-PROCEDURE

D.6.43.1 Analysis: HEP-NO-PROCEDURE

- The guidance for IPE does not allow taking credit for operator actions which are not specifically included in procedures. HEP-NO-PROCEDURE, with a point estimate of 1.0, is utilized in fault trees to identify potential operator actions which may allow recovery of equipment problems. Cut set where this basic event appears should be considered for further analysis to identify potential procedure improvements or consideration of recovery by some other operator action.

- The current abnormal and emergency procedures do not provide procedural guidance to the operator in the event of a Charging Pump discharge check valve failing open on a non running pump. The Charging Pump automatic start logic due to a safety injection signal in some configurations will stop a running pump and start another. For example, if all three Charging pumps are operable, when 'A' is the running pump and 'C' is powered from the H emergency bus, then a SI signal will stop the 'A' pump and start the 'C' pump. From a PRA perspective this is not a good practice. Stopping one pump and starting another introduces several potential failures which will prevent successful SI flow being delivered to the RCS. The most significant failure is for the 'A' pump discharge check valve to fail to close when the pump stops which will cause the discharge from the other pumps to recirculate back through the 'A' pump which prevents adequate SI flow to be delivered to the RCS. The control room operators may misdiagnose this condition because partial SI flow may be delivered to the RCS. Some of the other potential failures include the 'C' pump which is to be started may fail to start and run due to a electrical or mechanical fault associated with the pump (the 'A' pump may also fail to run for 24 hours, but fail to start is not an 'A' pump fault), or the 'C' pump may have a suction or discharge MOV closed.

- HEP-NO-PROCEDURE will be used to represent the operators failing to identify that inadequate SI flow is being delivered to the RCS because of recirculation through the 'A' pump when the discharge check valve has failed to close.

D.6.43.2 Summary: HEP-NO-PROCEDURE

Fault Trees: FB400, HH100, HR100

Gates:	GFB4243	(AND) Pump short circuits and operator fails to correct, 1-CH-P-1A.
	GFB4923	(OR) Operator fails to close discharge valve, (AND) flow diversion due to short circuit, 1-CH-P-1B.

GHH1285	(AND) Pump short circuits and operator fails to correct, 1-CH-P-1A.
GHH1923	(OR) Operator fails to close discharge valve, (AND) flow diversion due to short circuit, 1-CH-P-1B.
GHR1285	(AND) Pump short circuits and operator fails to correct, 1-CH-P-1A.
GHR1923	(OR) Operator fails to close discharge valve, (AND) flow diversion due to short circuit, 1-CH-P-1B.

Physical Id: HEP-NO-PROCEDURE

Description: NO_PROCEDURE_FOR___
THIS_OPERATOR______
ACTION______________

Failure Rate: 1.0E+0

Distribution: Lognormal
Median: 1.00E+0
Error Factor: 1

Reference: 324MAF.N____________
9-1-92______________

Why modified: NAPS IPE Final Quantification Value

D.7 SENSITIVITY RESULTS

Human error probability basic events are a significant part of the overall North Anna PRA model. To understand the HEPs several sensitivity studies were performed. Integrated point estimate results, Section D.7.1 show the importance of all HEPs which appear in cut sets with probabilities above 1E-10. The effect on core damage frequency by changing the HEP point estimates to one or zero is shown in Sections D.7.2, D.7.3 and D.7.4. These first four sections provide insight into which HEPs are most important in the North Anna IPE. Control Room Operators working 12 hour shifts versus 8 hours shifts is discussed in Section D.7.5. A comparison of the HEPs used in the North Anna IPE and Surry IPE is presented in Section D.7.6. Several procedure improvements were studied to determine if there are any improvements that are worth considering. The results of the procedure improvement sensitivity study may be found in Section D.7.7.

The first sensitivity that should be performed is to correct some conservative point estimates which were used during final quantification. The following basic events were conservative in determining the 6.8E-5/year CDF value used throughout this report.

Basic Event	Final Quantification Point Estimate	Current Analysis Point Estimate
HEP-1E1-25	1.175E-2	8.1E-3
HEP-1ECA3:2-5	7.25E-4	4.25E-4
HEP-1FRC:1-11-S2	1.062E-2	8.25E-3

Using the HEP point estimates based on current analysis results the CDF remaining at 6.8E-5 with less than a 0.37% decrease.

D.7.1 Integrated Point Estimate Results

The importance of human error probabilities (HEPs) basic events in the North Anna IPE can be seen in Table D.7-1. This table was made using an overall equation (NAPS.EQN) which combined cut sets above 1E-11 from all core damage sequences. The ranking number is the overall importance ranking for the basic events, there were 710 in the overall equation. Non HEPs basic events were removed from the table so that the importance of HEPs too each other could more easily be understood. A brief discussion of the most important operator actions included in the North Anna IPE follows.

HEP-1FRH:1-11, point estimate 5E-2, represents the operators failing to establishing safety injection flow when feed and bleed cooling is necessary. This HEP is used in the FB400 fault tree and appears in 30 sequences for the failure of function D102 or D105.

HEP-0AP55-10HR, point estimate = 5E-3, represents the operators failing to restore ESGR cooling within ten hours of equipment failure. This HEP is used in the FFT00 fault tree and appears in 22 sequences for the failure of function RC102 and RC103.

HEP-1FRC:1-11-S1, point estimate = 1.0, represents the operators failing to depressurize the Steam Generators within 3.5 minutes during a medium break LOCA and loss of HHSI, success of the Accumulators and Auxiliary Feedwater. The time until core exit temperatures reach 1200°F is too short for the operators to respond. This HEP is used in the FFT00 fault tree and appears in 4 S1 sequences for the failure of function Y01.

HEP-NO-PROCEDURE, point estimate = 1.0, represents the operators failing to identify that SI flow diversion is occurring through 1-CH-P-1A when its discharge check valve remains open. Flow diversion through a discharge check valve is possible when 1-CH-P-1A was the running pump, approximately 1/3 of the time, and both 1-CH-P-1B and 1-CH-P-1C are in auto-after-stop. The SI logic will stop the 1A pump and start 1B and 1C. If the discharge check for the 1A pump remains open,

flow from the other pumps will recirculate through the 1A pump preventing full SI flow to the RCS. Currently there are no administrative procedures to prevent occurrence of this event and the operators have no procedure guidance for correcting this condition. This HEP appears in 3 fault trees, FB400, HH100 and HR100, which are used for 14 functions, D1, D4 and H2 series, resulting in 68 sequences with this basic event.

HEP-1E3-13, point estimate = 2.18E-2, represents the operators failure to initiate a RCS cooldown so that the RCS pressure is less than the Steam Generator pressure within 68 minutes. This HEP appears in the FFT00 and OD200 fault trees, the O06 function and sequences T7P03 and T7P04.

HEP-1ES1:2-S1, point estimate = 1, represents the operators failure to initiate as RCS cooldown and depressurization within 23 minutes after a medium break LOCA. This HEP appears in the FFT00 fault tree, is used in the O01 function which appears in the sequences S1P08 to S1P12 and VXP03.

HEP-0AP55-20HR, point estimate = 2.6E-4, represents the operators failing to restore ESGR cooling within twenty hours of equipment failure. This HEP is used in the FFT00 fault tree and appears in 24 sequences for the failure of function RC202.

HEP-1AP22:5, point estimate = 1.75E-4, represent the operators failing to begin refilling the ECST when its level drops below 40% before it becomes empty, failing the AFW pumps.

The top HEPs in the importance analysis shows which operator actions could most benefit from future HRA analysis or station attention. This potential future work could include improved operator training, procedure enhancements and improved management oversight during accidents.

D.7.2 Individual HEPs Set Equal To One

The North Anna IPE results are sensitive to the point estimates selected for the human error probability basic events. A sensitivity of HEPs on core damage frequency (CDF) was performed by changing the value of each HEP to one. The results are shown in Table D.7-2. The table was organized to place the HEPs with the greatest effect on CDF at the top, followed by the HEPs with less effect on CDF. Recall the North Anna IPE overall core damage frequency is 6.8E-5/year.

The HEPs which can cause core damage to increase by greater than one percent are the HEPs in which the North Anna IPE is taking the most credit for successful operator action. Station efforts should focus on these operator actions to ensure that these HEPs are

maintained at least as low as assumed in the IPE model. This future work includes continuing operator training, management oversight during accidents and proper 10CFR50.59 consideration of procedure changes.

D.7.3 All HEPs Set Equal One

When all HEPs are set equal to one the overall core damage becomes greater than once per year. This very high number shows the importance of proper operator action after initiation of a potential core damage sequence. Not all sequences rely on operator action equally.

Table D.7-3 shows the difference in core damage frequency based on accident initiator when the HEPs are set equal to the North Anna IPE values and when the HEPs are set equal to one. This shows that the most significant credit is taken for operator action after the accident initiators T2A, T2 and T1. The top two sequences are T2AP15 (T2A L M P) and T2AP10 (T2A L M D1). These and all of the top sequences contain the function failure L, Auxiliary Feedwater. Future station training should ensure that licensed and non licensed operators remain proficient in the performance of tasks related to operation of Main and Auxiliary Feedwater.

Table D.7-4 shows the importance listing of HEPs when all are set equal to one with an overall core damage equation truncated to 1E-8. These are the ranking of operator actions which the most credit was taken during the North Anna IPE.

Table D.7-5 shows the effects on each sequence when the HEPs are set equal to one or to the North Anna IPE point estimates. This table also identifies all sequences which may be below 1E-7 using the IPE values but are greater than 1E-7 if no credit was taken for operator action.

D.7.4 All HEPs Set Equal Zero

As a comparison to setting all HEPs equal to one a study was made setting all HEPs equal to 1E-15. This assumes all operator required actions are performed perfectly. The results show that overall core damage frequency decreases from 6.8E-5 to 3.5E-5/year. More can be learned from studying the effects of increasing the point estimates of HEPs than by decreasing HEPs. This is due to the distribution of all core damage sequences resulting in no outlier cut sets and truncation of low value cut sets. Future sensitivity studies of HEPs will produce the most significant results when HEP values are increased rather than decreased from the initial point estimates.

D.7.5 Operators Working 8 or 12 Hour Shifts

The operators at North Anna Power Station are currently working 12 hour rotating shifts. The North Anna IPE assumed this shift rotation when calculating the HEP values. Recall that the HEPs were calculated based on two terms, p_2, the probability of non response in a given time window, and p_3, the probability of non recoverable slips. Performance shaping factors such as shift rotation are applied to the p_3 term. The guidance suggested by Allen Swain in NUREG/CR-1278 is to double the p_3 term for shifts extending beyond 8 hours. This means that the total HEP point does not necessarily double. Table D.7-5 shows the total HEP point estimates when the operators are working 12 hour or 8 hour shifts. This HRA methodology shows an overall core damage frequency decrease from 6.8E-5 to 6.5E-5/year, a 4.8% decrease, if the operators were to work an eight hour shift versus twelve hour shifts. Other HRA methods may show a larger or smaller effect on core damage frequency due to shift length. The North Anna operators fully comply with NRC guidelines concerning operator's work hours.

D.7.6 Comparison To Surry

The HRA method used for the North Anna IPE was similar to the Surry IPE. Table D.7-7 is a summary of the HEPs used in North Anna compared to Surry HEPs. Additional information concerning the Surry values may be found in section D.5 and D.6, details may be found in the Surry IPE (Virginia Power 1991).

The Type A, operator actions before accident initiation, HEPs for North Anna and Surry are essentially the same with the exception related to the RS and QS flanges. Surry IPE used an 8E-5 point estimate and a value of 3.8E-4 was used for North Anna. The lower point estimate may be justified for North Anna depending on procedure improvements to ensure the RS and QS spray headers are operable before power operation.

The Type C, operator actions after accident initiation, HEPs for North Anna and Surry are the similar except where the time windows used to calculate the p_2, time dependent probability, term was significantly different. Several HEPs associated with the SGTR are different between North Anna and Surry IPEs. The North Anna SGTR time windows are based on operator response times from simulator data and detailed MAAP analysis. The Surry SGTR time windows are engineering estimates. Four non SGTR Type C HEPs which are significantly different between North Anna and Surry IPEs discussed below. Future Surry PRA work may refine the Surry point estimates to be more similar to the North Anna HEPs

HEP-1ES1:2-S2, NAPS = 8.5E-4, SPS = 5.3E-2, represents the operators cooling down and depressurizing the RCS after a

small break LOCA. The Surry analysis uses an estimated engineering allowable time window of 120 minutes. The North Anna analysis uses a MAAP calculated time window of 332 minutes. These time windows represent the time from accident initiation until Safety Injection will have to switch from the RWST to recirculation. Low pressure recirculation is successful and high pressure recirculation fails for this HEP. The longer engineering time window, T_e, results in a lower HEP.

HEP-1ES1:3, NAPS = 1.2E-2 and SPS = 2.7E-4, represents the operators transferring to cold leg recirculation from injection. The time values for Surry may have been too optimistic. Swapover from the injection phase to recirculation phase does not appear to provide much time for operator response in the event of any equipment malfunction.

HEP-1FRC:1-11-S2, NAPS = 8.3E-3 and SPS = 3.1E-1, represents the operators depressurizing the Steam Generators after failure of HHSI and success of Auxiliary Feedwater. Depressurization must be accomplished before Steam Generator dry out. The 30 minute Surry engineering time window was an estimate based on generic Westinghouse analysis. The 91 minute North Anna time window was based on plant specific MAAP analysis. The longer engineering time window, T_e, results in a lower HEP.

HEP-1FRH:1-11, NAPS = 4.8E-2 and SPS = 2.7E-3, represents the operators manually initiating safety injection for the feed portion of feed and bleed cooling after failure of Auxiliary Feedwater. The Surry IPE did not consider time dependency of this HEP. The North Anna value is calculated consistent with all other Type C HEPs with a p_2, time dependent probability, and p_3, time independent probability of operator error.

The North Anna and Surry PRA models can be studied to determine if the differences in the results are due to human error probabilities or due to equipment modeling differences. The results of one limited method to identify differences in the two PRAs is shown in Table D.7-8. This table allows generalizations to be made concerning whether the HEPs values are the most significant reason for differences in CDFs between the two PRAs. Each row represent one accident initiator without taking into account the CDF due to transfers associated with failure of ESGR cooling. One column provides the CDFs using the North Anna sequence equations and the North Anna HEPs. The next column provides the CDFs using the North Anna sequence equations and the Surry HEPs. And the final column provides the CDFs using the Surry sequence equations and the Surry HEPs.

Generalizations concerning the two PRAs made be made by comparing the three columns of Table D.7-8. However, detailed analysis must

be used to confirm these observations. When the CDFs are the same for all three columns then the HEPs and the equipment modeling are most likely to be very similar. The large, medium, small and intersystem LOCAs, and the Reactor Vessel failure accident initiators have similar HEPs and equipment models for both the North Anna and Surry PRAs.

When the two columns using the North Anna sequences but different HEPs yield the same CDFs, and the Surry IPE has a different CDF then it can be assumed that the HEPs are most likely the same but there may be significantly variations in the equipment modeling. T5A and T5B are examples of equipment differences between North Anna and Surry PRAs where the HEPs are similar. The T5s are different because of the differences in the DC bus design differences. There are eight DC buses are North Anna and five at Surry (two per unit and one non emergency power bus). Other examples are the T2, T2A and T3 accident initiators which have approximately the same HEPs but the Auxiliary Feedwater systems are different between the stations. Surry has AFW cross connects between units. North Anna can not deliver AFW flow from one unit to another.

Differences in the North Anna and Surry HEPs without significant differences in equipment models is observed when the two columns of Table D.7-8 using the Surry HEPs results in a similar CDF, and there is a significant difference in the CDF when comparing the two columns which use the North Anna sequence equations. The T7, SGTR, CDF differences in North Anna and Surry appear to be a result of the HEP differences and not equipment differences. The North Anna more accurately defined the engineering allowable time windows by using MAAP analysis and improved the operator response times by utilizing simulator data.

D.7.7 Sensitivity Results For Procedure Improvements

The point estimates for the human error probability basic events were developed assuming that several procedure changes would be made to minimize operator errors for actions significant to the IPE. This section will perform a sensitivity on these assumed procedure changes and will consider additional procedure changes which may be beneficial to future PRA quantifications and station operation. The following is a summary of the sensitivity results for procedure improvements. The North Anna overall core damage frequency with the assumed procedure enhancements is 6.8E-5 per year.

D.7.7.1 AFW Full Flow Recirculation Valves

Revising all procedures which open the Auxiliary Feedwater full flow recirculation manual valves should have independent

verification that the valve are closed upon completion of the procedure was identified as a potential procedure improvement. Currently some procedures do not have independent verification. If a pump's full flow recirculation valve and the common full flow recirculation valve are left open the associated AFW pump will operate. However, inadequate flow will be delivered to the Steam Generator. When the recirculation valve are independently verified the probability that they are open when AFW is needed is 7.5E-3. If the MOVs are not independently verified to be closed, then the probability that the valves are mispositioned is approximately 7.5E-3. If the recirculation valves are open on a regular basis then the probability that they are mispositioned is 1.0E+0. Modifying basic events 1FWHEP-1FW543, 1FWHEP-1FW546 and 1FWHEP-1FW548 yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	7.5E-4	6.8E-5	
Without verification	7.5E-3	7.2E-5	+6%
Recirc open	1.0E+0	2.9E-3	+4199%

The procedure improvement is important to minimizing core damage frequency.

D.7.7.2 QS and RS Piping

Revising all procedures which realign the Quench Spray or Recirculation Spray headers for testing to add independent verification that the headers have been restored to fully operable was identified as a potential procedure improvement. Currently some procedures install blank flanges, elbow or reconfigure the piping between the system's pumps and the spray headers for a test do not have specific procedural guidance for system restoration. These same procedures do not have any form of independent verification to ensure the spray piping is fully operable. Depending on the test component's location, if left installed during operation the system will not deliver adequate flow to the spray headers. When system restoration specifically identifies all test devices, including exact location of each device, to be removed (and how to restore the piping) then the probability the system will function correctly is 3.8E-3. If the QS and RS system piping is independently verified to be operable by operator performing a walkdown at the end of each refueling outage then the probability that the system will function correctly is reduced to 3.8E-4. This independent verification assumes the use of a procedure which includes a list of all valves (and the operable position), all normally installed spool pieces, flanges, and elbows and the location of all potential test devices (flanges, elbows, etc.) which should have been removed. If the test flanges were left installed on the piping leading to the spray headers then the

point estimate for these basic events is 1.0E+0. Modifying basic events 1RSHEP-FLANGE and 1QSHEP-FLANGE yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	3.8E-4	6.8E-5	
Without verification	3.8E-3	7.0E-5	+3%
Flanges installed	1.0E+0	2.8E-4	+311%

The procedure improvement is important to minimizing core damage frequency. The change in CDF without the procedure improvement that the procedure change and a walkdown are not immediately required, but should be accomplished before the next refueling outage.

D.7.7.3 Alternate SI Header, 1-SI-MOV-1836

Revising 1-E-0, Reactor Trip or Safety Injection, to add opening 1-SI-MOV-1836 to the RNO of step 14, verify SI flow, or to the RNO of step 16, check Charging Pump alignment was identified as a potential procedure improvement. This MOV allows flow to the alternate SI flow path to the cold leg. PRA considers multiple failures which cause the single SI header to become inoperable. Design basis analysis requires only a single failure. During simulator observations when multiple failures prevented using the normal SI header two operator responses were observed. Half of the operators decided to send someone to attempt to locally open MOVs or attempt to fix failed components in the normal header. The other half of operators decided to open 1-SI-MOV-1836 on their own. No procedural guidance is provided. Eventually the operators will open the redundant SI flow path as directed by 1-E-1 step 25 but this action is too late in the procedures to prevent core damage. MAAP analysis shows that the proper operator response is to open 1-SI-MOV-1836 within 24 minutes of a small break LOCA.

When procedures are revised the probability for the operator opening 1-SI-MOV-1836 after failures in the normal SI flow path is 8.1E-3. If 1-E-0 is not revised then the operators have approximately a 50% chance of success based on simulator observations. However, IPE guidelines do not allow credit for operator action which is not proceduralized so the probability is 1.0E+0. Modifying basic events HEP-1E1-25 yields the following results. Note that a point estimate of 1.17E-2 was incorrectly (but conservatively used in the NAPS IPE).

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	1.17E-2	6.8E-5	
Correct HEP	8.1E-3	6.8E-5	-0.02
Without procedure change	1.0E+0	7.1E-5	+5%

The procedure improvement is important to minimizing core damage frequency. The change in CDF without the adding a RNO action to open 1-SI-MOV-1836 for 1-E-0 step 14, verify SI flow, or to the RNO of step 16, check Charging Pump alignment.

D.7.7.4 Loss of Service Water To MCR/ESGR Chillers

Revising 0-AP-12, Loss of Service Water, to add an attachment for restoring cooling water to at least one MCR/ESGR chiller was identified as a potential procedure improvement. This attachment should be similar to the current Attachment 2, Cooling Charging Pumps with PG when Service Water is not Available. Technical details need to be developed for this recommendation. If a proceduralized method for restoring cooling to the chillers existed then the probability of system failure following a loss of Service Water remains as currently modeled. Without specific procedure guidance the probability of system failure is estimated to be 1E-1. If no action is taken to restore chiller cooling after SW system failure then ESGR cooling has a certainty of failure (1.0E+0). Modifying basic events HEP-0AP12-10HR, HEP-0AP12-20HR, HEP-0AP12-30HR and HEP-0AP12-40HR yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	varies	6.8E-5	
Without attachment	1.0E-1	6.9E-5	+1
Without any cooling	1.0E+0	6.9E-5	+17%

The additional Attachment to 0-AP-12 to restore cooling to the chillers is not required due to the small change in CDF, but is worth consideration by North Anna due to the potential for loss of all emergency power if cooling is not restored.

D.7.7.5 Charging Pump Suction and Discharge Valves

Revising station operating practices to verify the suction and discharge MOV for non running Charging pumps to be verified in the open position at least once per shift was considered as a potential procedure improvement. This is not applicable for non operable Charging pumps. A safety injection signal will start the pumps but does not open these valves.

Also revising periodic test procedures which close the Charging Pump discharge valves during testing to add instructions which immediately open these valves if a safety injection signal occurs during the test was considered as a potential procedure improvement. 1-PT-14.1/14.2/14.3 close the discharge valves for a period of time during the procedure. A manual or an automatic SI signal does not open these valves. The operator is never directed to check these valves in the emergency procedures. The test procedure does not provide any guidance of action to take during a pump start with the valves closed.

Attempting to run a pump with either a suction or discharge MOV closed will damage the pump. When the MOVs are verified once per shift the probability that they are open when a Charging pump automatically starts is 1E-4. If the MOVs are not verified to be open once per shift then the probability that they are mispositioned is approximately 1E-2. If the valves are closed on a regular basis the probability that they are mispositioned is 1.0E+0. Modifying basic events 1CHPAT-FS-1CHP1B and 1CHPAT-FS-1CHP1C allows identifying the benefit of a shift check of the MOVs and if the MOVs are closed. Modifying basic event HEP-1E0-14 allows identifying the benefit of revising the PT or emergency procedures to open the discharge valves if a SI occurs during a test (1.4E-3) or if no procedure changes are made (1.0E+0). A sensitivity analysis yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	5.1E-3/1.0E+0	6.8E-5	
Revise PT	5.1E-3/1.4E-3	6.8E-5	-0.02%
Without shift check	1.5E-2 6.8E-5	+0%	
MOVs closed	1.0E+0	1.1E-4	+69%

The improvement is not required since the MOVs are typically open. However, and it is worth consideration by North Anna to verify the Charging pump suction and discharge MOVs are open once per shift due to the damage to a pump if started with a valve closed. Surry performs this verification once per shift. Consideration should be given to revising 1-E-0 step 16 to include Charging pump suction and discharge MOVs in the Charging Pump valve alignment check. Consideration should be given to adding instructions to the PT-14 series to open the Charging Pump discharge MOVs if a SI occurs during the test.

D.7.7.6 SI Flow Diversion Through Charging Pump Check Valve

Revising 1-E-0, Reactor Trip or Safety Injection, to prevent SI flow from recirculating through an open discharge check valve on a non running Charging Pump was identified as a potential procedure improvement. The current abnormal and emergency procedures do not

provide procedural guidance to the operator in the event of a Charging Pump discharge check valve failing open on a non running pump. An alternative change is to stop the operating practice which allows two Charging pumps on the same emergency bus from being in auto-after-stop and allow only one pump per emergency bus.

The Charging Pump automatic start logic due to a safety injection signal in some configurations will stop a running pump and start another. For example if all three Charging pumps are operable, when 'A' is the running pump and 'C' is powered from the H emergency bus, then a SI signal will stop the 'A' pump and start the 'C' pump. From a PRA perspective this is not a good practice. Stopping one pump and starting another introduces several potential failures which will prevent successful SI flow being delivered to the RCS. The most significant failure is for the 'A' pump discharge check valve to fail to close when the pump stops which will cause the discharge from the other pumps to recirculate back through the 'A' pump which prevents adequate SI flow to be delivered to the RCS. The control room operators may misdiagnose this condition because partial SI flow may be delivered to the RCS. Some of the other potential failures include the 'C' pump which is to be started may fail to start and run due to a electrical or mechanical fault associated with the pump (the 'A' pump may also fail to run for 24 hours, but fail to start is not an 'A' pump fault), or the 'C' pump may have a suction or discharge MOV closed.

At Surry the Charging pump automatic start logic is different from the North Anna start logic. A check valve remaining open is not a concern at Surry because the SI pump logic does not stop a running pump and start a "preferred pump" like the North Anna SI pump start logic.

When the emergency procedures are revised to identify recirculation through a non running pump or to close the discharge MOV of a pump which was running and is now stopped, or operating limitations are implemented to allow only one operable Charging Pump on each emergency bus then the probability that the operators will prevent inadequate SI flow after a check valve remains open is approximately 1.4E-3. If no procedure changes are made then the probability that a stuck open check valve will cause core damage is 1.0+0. Modifying basic event HEP-NO-PROCEDURE yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	1.0E+0	6.8E-5	
With procedure changes	1.4E-3	6.5E-5	-4%

The procedure improvement is important to minimizing core damage frequency. The current North Anna PRA assumes that the procedure change has not been made. Future updates to the PRA model take

advantage of any procedure changes, operating practice changes or hardware modifications made to resolve this issue. This is a complex issues because of recent NRC concerns at Surry regarding Charging pump operation which have not been considered as part of this review. This topic is worth further consideration in the future.

D.7.7.7 Swaping to Containment Recirculation

Revising 1-ES-1.3, Transfer To Cold Leg Recirculation, to decrease the probability of pump damage during this plant condition was considered for potential procedure improvement. Of all the operator actions reviewed for the North Anna IPE this HEP had one of the shortest engineering allowable times. MAAP shows that time between reaching 29% RWST level and pump cavitation is 11.5 minutes. Procedure enhancements to be considered may include stopping one train of pumps or swapping the pumps over at different times. Upon entering procedure 1-ES-1.3 if one train of pumps taking suction from the RWST were shutdown then the rate at which the RWST is emptying is decreased. Another potential change is to swap one train of pumps to the Containment sump based on RWST level and the other train of pumps based on adequate NPSH available in the Containment sump. Further engineering analysis is necessary before any procedure changes are made.

Without any procedure enhancements to 1-ES-1.3 the probability for unsuccessful operator action during SI realignment is 1.2E-2. With procedure improvements the probability of unsuccessful operator action may decrease to 1E-3 or 1E-4. If the operators were did not take any action the probability would be 1.0+0. Modifying basic event HEP-1ES1:3 yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	1.2E-2	6.8E-5	
With procedure changes	1.0E-3	6.7E-5	-1%
With procedure changes	1.0E-4	6.7E-5	-1%
No operator action	1.0E+0	1.2E-4	+76%

The procedure improvement is not necessary to minimizing core damage frequency but may be worth consideration.

D.7.7.8 1-FR-C.1 Step 11 Depressurizing All Steam Generators

Revising 1-FR-C.1, Response To Inadequate Core Cooling, to more quickly initiate rapid Steam Generator depressurization after a medium break LOCA and failure of high head safety injection was considered for potential procedure improvement. Currently 1-FR-C.1 does not begin to depressurize the Steam Generators until step 11.

Because of the rapid RCS heat up during this event MAAP analysis has shown that it is important to initiate the Steam Generator depressurization as early as possible. Procedure enhancements to be considered may include initiating Steam Generator depressurization upon entry into 1-FR-C.1 while continuing with the other steps of this procedure.

Without any procedure enhancements to 1-FR-C.1 the probability for core damage during a medium break LOCA and failure of high head safety injection is 1.0+0. With procedure improvements the probability of successful Steam Generator cooldown, allowing RCS heat removal may decrease to 1E-3 or 1E-4. Modifying basic event HEP-1FRC:1-11-S1 yields the following results.

	HEP Point Estimate	Core Damage Frequency (/year)	
Base case	1.0E+0	6.8E-5	
With procedure changes	1.0E-3	6.4E-5	-6%
With procedure changes	1.0E-4	6.7E-5	-6%

The procedure improvement does provide an improvement to core damage frequency and is worth further consideration. However, additional technical details concerning compliance with the generic Westinghouse Owners Group Emergency Response Guidelines need to be considered. This issue was also raised for the Surry IPE but has not be fully resolved.

D.8 TREATMENT OF DEPENDENCIES BETWEEN TYPE C HEPs BASIC EVENTS

Each of these combinations was reviewed to identify which combinations of HEP basic events are considered to be potentially dependent using the following guidelines:

a) If two HEP basic events are associated with responses to the same plant status (e.g., initiate startup feedwater pump, initiate feed and bleed), the cognitive part of the failure probabilities are considered to be totally dependent.

b) As a corollary to this, if in the chronological development of the scenarios, an HEP failure event follows a successful HEP, and the procedural instructions for both events are closely related, the cognitive failure probability of the second HEP should be very small and can be neglected, since the success in the first event implies a successful recognition of the scenario.

c) If human error probabilities are i) separate by significant time (i.e., time between distinct cues or

required responses), or ii) separate chronologically in the accident sequence by a successful action, or iii) responses to different cues in different part of the EOPs, they may be regarded as being independent.

d) In addition, the early memorized responses may be regarded as independent from those actions for which the procedures are expected to be providing the direction.

e) If an HEP is associated with execution of an AP or OP, called for by a step in the main EOP, then failure to perform the step in the EOP directly leads to failure of the operator action.

The consideration of dependency are addressed in the analysis for the individual HEPs. This is not the only time dependencies were considered. The most significant time dependencies was addressed was after the initial quantification. The system analyst developed fault trees which included basic events which were given names and point estimates based on the Surry IPE or engineering judgement. The results of the initial quantification were reviewed in detail to identify dependencies between HEPs. All event trees, sequence equations and cut sets were reviewed to identify multiple HEP basic events which may have an impact on each other. Also all operator actions was studied in detail to identify similarities between HEPs. These reviews resulted in renaming the HEPs so that similar operator actions or dependent HEPs were given the same 16 character names to ensure the final sequence quantification would properly allow identification of minimalization of dependent HEP basic events.

D.9 RECOMMENDATIONS

The Human Reliability Analysis for the North Anna IPE resulted in an understanding of the which operator actions are most important in preventing core damage. There are no operator actions which are considered outliers. There is no need to make any immediate changes in the way North Anna is operated. The sensitivity analysis does provide information which can be used in recommending procedure revisions which should be made in the near future and suggested procedure enhancements which should be studied further and implemented where feasible.

The procedure revisions which are essential to keeping the core damage frequency at 6.8E-6/year are as follows. Without these three procedure revisions the core damage frequency increases to 7.6E-5/year (+12%).

- Revising all procedures which open the Auxiliary Feedwater full flow recirculation manual valves to add independent verification that the valve are closed upon

completion of the procedure. Without independent verification of these valves the CDF increases to 7.2E-5/year. With independent verification of these valves the North Anna CDF remains at 6.8E-5/year.

- Revising all procedures which realign the Quench Spray or Recirculation Spray headers for testing to add independent verification that the headers have been restored to fully operable upon completion of the test. Currently some procedures install blank flanges, elbow or reconfigure the piping between the system's pumps and the spray headers during testing. There are no specific procedural guidance for system restoration. These same procedures do not have any form of independent verification to ensure the piping is fully operable. If some of these test flanges or other piping changes are left installed, the system will not deliver adequate flow to the spray headers. Without independent verification the CDF increases to 7.0E-5/year. If the QS and RS system piping are independently verified to be operable by a qualified operator performing a system walkdown at the end of each refueling outage then the North Anna IPE CDF remains at 6.8E-5/year.

- Revising 1-E-0, Reactor Trip or Safety Injection, to add opening 1-SI-MOV-1836 to the RNO of step 14, verify SI flow, or to the RNO of step 16, check Charging Pump alignment. Without procedural guidance to use the alternate SI header the CDF increases to 7.1E-5/year. With procedural improvement to open 1-SI-MOV-1836 if the normal path fails, the North Anna IPE CDF remains at 6.8E-5/year.

D.10 REFERENCES

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TABLE D.2-1
SUMMARY OF OPERATOR ACTIONS
TYPE A HEPs: TEST & MAINTENANCE ACTIONS

Basic Event Name	Point Estimate	Description
1CHHEP-MOV-1270A	1.1E-4	CRO STARTS CHARGING PUMP WHEN SUCTION MOV-1270A IS CLOSED
1CHHEP-MOV-1275A	7.5E-4	CRO LEAVES CHARGING PUMP A RECIRC VALVE MOV-1275A CLOSED___
1CHHEP-MOV-1275B	7.5E-4	CRO LEAVES CHARGING PUMP B RECIRC VALVE MOV-1275B CLOSED___
1CHHEP-MOV-1373	7.5E-4	CRO LEAVES CHARGING PUMP RECIRC VALVE MOV-1373 CLOSED
1FWHEP-HCV-100C_	7.5E-4	AFW_PUMP_3A_NOT____ ALIGNED_TO_SG_C____ HCV_HEADER_HCV-100C
1FWHEP-MOV-100B_	7.5E-4	AFW_PUMP_3B_NOT____ ALIGNED_TO_SG_B____ MOV_HEADER_MOV-100B
1FWHEP-MOV-100D_	7.5E-4	AFW_PUMP_2_NOT_____ ALIGNED_TO_SG_A____ MOV_HEADER_MOV-100D
1FWHEP-1FW543___	7.5E-4	CRO_LEAVES 1-FW-P-2 RECIRC_VALVE_OPEN__ TO_ECST,_1-FW-543__
1FWHEP-1FW546___	7.5E-4	CRO_LEAVES FW-P-3B_ RECIRC_VALVE_OPEN__ TO_ECST,_1-FW-546__
1FWHEP-1FW548___	7.5E-4	CRO_LEAVES FW-P-3A_ RECIRC_VALVE_OPEN__ TO_ECST,_1-FW-548__
1QSHEP-FLANGE___	3.8E-4	QS_SPRAY_HEADER____ FLANGE_LEFT________ INSTALLED_1-PT-63.3

TABLE D.2-1 (continued)
SUMMARY OF OPERATOR ACTIONS
TYPE A HEPs: TEST & MAINTENANCE ACTIONS

Basic Event Name	Point Estimate	Description
1QSHEP-1QS5_____	7.5E-4	CRO_LEAVES_1-QS-5__ RECIRC_VALVE_OPEN__ AFTER_1-PT-63.1A___
1QSHEP-1QS21____	7.5E-4	CRO_LEAVES_1-QS-21_ RECIRC_VALVE_OPEN__ AFTER_1-PT-63.1B___
1RSHEP-ELBOW____	3.8E-4	RS_SPRAY_HEADER____ ELBOW_REMOVED,_____ 1-PT-64.8__________
1RSHEP-FLANGE___	3.8E-4	RS_SPRAY_HEADER____ FLANGE_LEFT________ INSTALLED_1-PT-64.3
1RSHEP-MOV-155A_	7.5E-4	CRO_LEAVES_MOV-155A OR_MOV-156A_CLOSED_ OR_DEENERGIZED_____
1RSHEP-MOV-155B_	7.5E-4	CRO_LEAVES_MOV-155B OR_MOV-156B_CLOSED_ OR_DEENERGIZED_____
1RSHEP-1RS12____	7.5E-4	CRO_LEAVES RS-P-2A_ RECIRC_VALVES_OPEN_ 1-RS-12_&_1-RS-95__
1RSHEP-1RS22____	7.5E-4	CRO_LEAVES RS-P-2B_ RECIRC_VALVES_OPEN_ 1-RS-22_&_1-RS-96__

TABLE D.3-1
SUMMARY OF OPERATOR ACTIONS
TYPE C HEPs: POST ACCIDENT ACTIONS

Basic Event Name	Point Estimate	Description
HEP-0AP10_______	5.3E-3	0-AP-10_LOSS_OF____ ELECTRICAL_POWER___ ___________________
HEP-0AP12-10HR__	5.0E-3	0-AP-12_LOSS_OF____ SERVICE_WATER______ RECOVERY_IN_10_HOUR
HEP-0AP12-20HR__	2.6E-4	0-AP-12_LOSS_OF____ SERVICE_WATER______ RECOVERY_IN_20_HOUR
HEP-0AP12-30HR__	6.6E-3	0-AP-12_LOSS_OF____ SERVICE_WATER______ RECOVERY_IN_30_HOUR
HEP-0AP12-40HR__	1.3E-1	0-AP-12_LOSS_OF____ SERVICE_WATER______ RECOVERY_IN_40_HOUR
HEP-0AP12-ATTCH4	1.6E-4	0-AP-12_LOSS_OF_SW_ ATTACHMENT_4:_TWO__ PUMPS_ON_ONE_HEADER
HEP-1AP15-1E____	7.8E-4	1-AP-15_LOSS_OF_CC_ STEP_1E_RESTORE_SW_ TO_CC_HEAT_EXCHANGR
HEP-1AP15-6_____	2.8E-2	1-AP-15_LOSS_OF_CC_ STEP_6_CROSS_TIE_CC IF_UNIT_2_AVAILABLE
HEP-1AP22:5_____	1.8E-4	1-AP-22.5_LOSS_OF__ EMERGENCY_CONDNSATE STORAGE_TANK_______
HEP-1AP33:1_____	3.9E-1	1-AP-33.1_REACTOR__ COOLANT_PUMP_SEAL__ FAILURE____________

TABLE D.3-1 (Continued)
SUMMARY OF OPERATOR ACTIONS
TYPE C HEPs: POST ACCIDENT ACTIONS

Basic Event Name	Point Estimate	Description
HEP-1AP49_______	1.3E-2	1-AP-49_LOSS_OF____ NORMAL_CHARGING____ ____________________
HEP-0AP55-10HR__	5.0E-3	0-AP-55_LOSS_OF____ ESGR/MCR_HVAC______ RECOVERY_IN_10_HOUR
HEP-0AP55-20HR__	2.6E-4	0-AP-55_LOSS_OF____ ESGR/MCR_HVAC______ RECOVERY_IN_20_HOUR
HEP-0AP55-30HR__	6.6E-3	0-AP-55_LOSS_OF____ ESGR/MCR_HVAC______ RECOVERY_IN_30_HOUR
HEP-0AP55-40HR__	1.3E-1	0-AP-55_LOSS_OF____ ESGR/MCR_HVAC______ RECOVERY_IN_40_HOUR
HEP-1E0-1_______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_1_VERIFY______ REACTOR_TRIP_______
HEP-1E0-7_______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_7_VERIFY_SI___ PUMPS_RUNNING______
HEP-1E0-8_______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_8_VERIFY_MAIN_ FEEDWATER_ISOLATION
HEP-1E0-11______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_11_VERIFY_SW__ PUMPS_RUNNING______
HEP-1E0-12______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_12_MAIN_STEAM_ LINES_ISOLATION____

TABLE D.3-1 (Continued)
SUMMARY OF OPERATOR ACTIONS
TYPE C HEPs: POST ACCIDENT ACTIONS

Basic Event Name	Point Estimate	Description
HEP-1E0-13______	1.4E-3	1-E-0_RX_TRIP_OR_SI STEP_13_CHECK_IF___ CDA_IS_REQUIRED____
HEP-1E0-14______	1.0E+0	1-E-0_RX_TRIP_OR_SI STEP_14_VERIFY_SI__ FLOW_______________
HEP-1E0-15_____	1.1E-3	1-E-0_RX_TRIP_OR_SI STEP_15_VERIFY_AUX_ FEEDWATER_FLOW_____
HEP-1E0-16______	8.0E-3	1-E-0_RX_TRIP_OR_SI STEP_16_CHARGING___ PUMP_ALIGNMENT_____
HEP-1E0-22______	1.9E-2	1-E-0_RX_TRIP_OR_SI STEP_22_PRZR_PORVS_ SPRAY_VALVES_CLOSED
HEP-1E0-ATTACH:1	7.7E-3	1-E-0_RX_TRIP_OR_SI ATTACHMENT_1_VERIFY PHASE_B_ISOLATION__
HEP-1E1-25______	8.1E-3	1-E-1_LOSS_OF_RX_OR 2ND_COOLANT_STEP_25 REDUNDANT_COLD_LEG_
HEP-1E3-3_______	3.7E-3	1-E-3_SGTR_________ STEP_3_ISOLATE_FLOW FROM_RUPTURED_SG___
HEP-1E3-13______	2.2E-2	1-E-3_SGTR_________ STEP_13_INITIATE___ RCS_COOLDOWN_______
HEP-1ECA3:1-16__	3.0E-3	1-ECA-3.1_SGTR_WITH SUBCOOLED_RCS______ STEP_16_COOLDOWN___

TABLE D.3-1 (Continued)
SUMMARY OF OPERATOR ACTIONS
TYPE C HEPs: POST ACCIDENT ACTIONS

Basic Event Name	Point Estimate	Description
HEP-1ECA3:2-5___	4.3E-4	1-ECA-3.2_SGTR_WITH SATURATED_RCS______ STEP_5_COOLDOWN____
HEP-1ECA3:3-27	9.0E-2	1-ECA-3.3_SGTR_&___ NO_PRESSURE_CONTROL STEP_27_COOLDOWN___
HEP-1ECA3:3-35	4.9E-3	1-ECA-3.3_SGTR_&___ NO_PRESSURE_CONTROL STEP_35_LATE_COOLDN
HEP-1ES1:2-S1___	1.0E+0	1-ES-1.2_POST_LOCA_ COOLDOWN_AND_______ DEPRESSURIZATION_S1
HEP-1ES1:2-S2___	8.5E-4	1-ES-1.2_POST_LOCA_ COOLDOWN_AND_______ DEPRESSURIZATION_S2
HEP-1ES1:3______	1.2E-2	1-ES-1.3_TRANSFER__ TO_COLD_LEG________ RECIRCULATION______
HEP-1ES1:4______	8.5E-4	1-ES-1.4_TRANSFER__ TO_HOT_LEG_________ RECIRCULATION______
HEP-1FRC:1-11-S1	1.0E+0	1-FR-C.1_INADEQUATE CORE_COOLING_STEP11 DEPRESSURIZE_SGS___
HEP-1FRC:1-11-S2	8.3E-2	1-FR-C.1_INADEQUATE CORE_COOLING_STEP11 DEPRESSURE_SGS__S2_
HEP-1FRH:1-5____	3.1E-3	1-FR-H.1_LOSS_OF___ HEAT_SINK_STEP_5___ CHECK_SG_LEVELS____

TABLE D.3-1 (Continued)
SUMMARY OF OPERATOR ACTIONS
TYPE C HEPs: POST ACCIDENT ACTIONS

Basic Event Name	Point Estimate	Description
HEP-1FRH:1-11___	4.8E-2	1-FR-H.1_LOSS_OF___ HEAT_SINK_STEP_11__ RCS_FEED_PATH______
HEP-1FRH:1-15___	8.3E-3	1-FR-H.1_LOSS_OF___ HEAT_SINK_STEP_15__ RCS_BLEED_PATH_____
HEP-1FRS:1-4____	7.6E-3	1-FR-S.1_ATWS______ STEP_4_INITIATE____ EMERGENCY_BORATION_
HEP-1FRS:1-5____	3.0E-2	1-FR-S.1_ATWS______ STEP_5_DO_ATTACH_2_ REMOTE_REACTOR_TRIP
HEP-1OP14:1-5:13	4.3E-3	1-OP-14.1 RHR______ STEP 5.13,__OPEN___ MOV-1700_&_MOV-1701
HEP-1OP21:6_____	1.1E-3	1-OP-21.6_MCR_AND__ RELAY_ROOM_AIR_____ CONDITIONING_______
HEP-1OP49:1_____	1.3E-1	0-OP-49.1_STARTUP__ AND_SHUTDOWN_OF_THE SERVICE_WATER_SYSTEM
HEP-0OP49:4A____	6.3E-2	0-OP-49.4A_VALVE___ CHECKOFF_MCR_A/C___ SERVICE_WATER______
HEP-NO-PROCEDURE	1.0E+0	NO_PROCEDURE_FOR___ THIS_OPERATOR______ ACTION_____________

TABLE D.3-2
NORMAL PROBABILITY FUNCTION FOR HUMAN ERROR PROBABILITY CALCULATIONS

x	1 - F(x)	x	1 - F(x)
.00	5.000E-1	.40	3.446E-1
.01	4.960E-1	.41	3.409E-1
.02	4.920E-1	.42	3.372E-1
.03	4.880E-1	.43	3.336E-1
.04	4.840E-1	.44	3.300E-1
.05	4.801E-1	.45	3.264E-1
.06	4.761E-1	.46	3.228E-1
.07	4.721E-1	.47	3.192E-1
.08	4.681E-1	.48	3.156E-1
.09	4.641E-1	.49	3.121E-1
.10	4.602E-1	.50	3.085E-1
.11	4.562E-1	.51	3.050E-1
.12	4.522E-1	.52	3.015E-1
.13	4.483E-1	.53	2.981E-1
.14	4.443E-1	.54	2.946E-1
.15	4.404E-1	.55	2.912E-1
.16	4.364E-1	.56	2.877E-1
.17	4.325E-1	.57	2.843E-1
.18	4.286E-1	.58	2.810E-1
.19	4.247E-1	.59	2.776E-1
.20	4.207E-1	.60	2.743E-1
.21	4.168E-1	.61	2.709E-1
.22	4.129E-1	.62	2.676E-1
.23	4.090E-1	.63	2.643E-1
.24	4.052E-1	.64	2.611E-1
.25	3.859E-1	.65	2.578E-1
.26	3.974E-1	.66	2.546E-1
.27	3.936E-1	.67	2.514E-1
.28	3.897E-1	.68	2.483E-1
.29	3.859E-1	.69	2.451E-1
.30	3.821E-1	.70	2.420E-1
.31	3.783E-1	.71	2.389E-1
.32	3.745E-1	.72	2.358E-1
.33	3.707E-1	.73	2.327E-1
.34	3.669E-1	.74	2.296E-1
.35	3.632E-1	.75	2.266E-1
.36	3.594E-1	.76	2.236E-1
.37	3.557E-1	.77	2.206E-1
.38	3.520E-1	.78	2.177E-1
.39	3.483E-1	.79	2.148E-1

TABLE D.3-2 (Continued)
NORMAL PROBABILITY FUNCTION FOR
HUMAN ERROR PROBABILITY CALCULATIONS

x	1 - F(x)	x	1 - F(x)
.80	2.119E-1	1.20	1.151E-1
.81	2.090E-1	1.21	1.131E-1
.82	2.061E-1	1.22	1.112E-1
.83	2.033E-1	1.23	1.093E-1
.84	2.005E-1	1.24	1.075E-1
.85	1.977E-1	1.25	1.056E-1
.86	1.949E-1	1.26	1.038E-1
.87	1.921E-1	1.27	1.020E-1
.88	1.894E-1	1.28	1.003E-1
.89	1.867E-1	1.29	9.85E-2
.90	1.841E-1	1.30	9.68E-2
.91	1.814E-1	1.31	9.51E-2
.92	1.788E-1	1.32	9.34E-2
.93	1.762E-1	1.33	9.18E-2
.94	1.736E-1	1.34	9.01E-2
.95	1.711E-1	1.35	8.85E-2
.96	1.685E-1	1.36	8.69E-2
.97	1.660E-1	1.37	8.53E-2
.98	1.635E-1	1.38	8.38E-2
.99	1.611E-1	1.39	8.23E-2
1.00	1.587E-1	1.40	8.08E-2
1.01	1.562E-1	1.41	7.93E-2
1.02	1.539E-1	1.42	7.78E-2
1.03	1.515E-1	1.43	7.64E-2
1.04	1.492E-1	1.44	7.49E-2
1.05	1.469E-1	1.45	7.35E-2
1.06	1.446E-1	1.46	7.21E-2
1.07	1.423E-1	1.47	7.08E-2
1.08	1.401E-1	1.48	6.94E-2
1.09	1.379E-1	1.49	6.81E-2
1.10	1.357E-1	1.50	6.68E-2
1.11	1.335E-1	1.51	6.55E-2
1.12	1.314E-1	1.52	6.43E-2
1.13	1.292E-1	1.53	6.30E-2
1.14	1.271E-1	1.54	6.18E-2
1.15	1.251E-1	1.55	6.06E-2
1.16	1.230E-1	1.56	5.94E-2
1.17	1.210E-1	1.57	5.82E-2
1.18	1.190E-1	1.58	5.71E-2
1.19	1.170E-1	1.59	5.59E-2

TABLE D.3-2 (Continued)
NORMAL PROBABILITY FUNCTION FOR
HUMAN ERROR PROBABILITY CALCULATIONS

x	1 - F(x)	x	1 - F(x)
1.60	5.48E-2	2.00	2.28E-2
1.61	5.37E-2	2.01	2.22E-2
1.62	5.26E-2	2.02	2.17E-2
1.63	5.16E-2	2.03	2.12E-2
1.64	5.05E-2	2.04	2.07E-2
1.65	4.95E-2	2.05	2.02E-2
1.66	4.85E-2	2.06	1.97E-2
1.67	4.75E-2	2.07	1.92E-2
1.68	4.65E-2	2.08	1.88E-2
1.69	4.55E-2	2.09	1.83E-2
1.70	4.46E-2	2.10	1.79E-2
1.71	4.36E-2	2.11	1.74E-2
1.72	4.27E-2	2.12	1.70E-2
1.73	4.18E-2	2.13	1.66E-2
1.74	4.09E-2	2.14	1.62E-2
1.75	4.01E-2	2.15	1.58E-2
1.76	3.92E-2	2.16	1.54E-2
1.77	3.84E-2	2.17	1.50E-2
1.78	3.75E-2	2.18	1.46E-2
1.79	3.67E-2	2.19	1.43E-2
1.80	3.59E-2	2.20	1.39E-2
1.81	3.51E-2	2.21	1.36E-2
1.82	3.44E-2	2.22	1.32E-2
1.83	3.36E-2	2.23	1.29E-2
1.84	3.29E-2	2.24	1.25E-2
1.85	3.22E-2	2.25	1.22E-2
1.86	3.14E-2	2.26	1.19E-2
1.87	3.07E-2	2.27	1.16E-2
1.88	3.01E-2	2.28	1.13E-2
1.89	2.94E-2	2.29	1.10E-2
1.90	2.87E-2	2.30	1.07E-2
1.91	2.81E-2	2.31	1.04E-2
1.92	2.74E-2	2.32	1.02E-2
1.93	2.68E-2	2.33	9.9E-3
1.94	2.62E-2	2.34	9.6E-3
1.95	2.56E-2	2.35	9.4E-3
1.96	2.50E-2	2.36	9.1E-3
1.97	2.44E-2	2.37	8.9E-3
1.98	2.39E-2	2.38	8.7E-3
1.99	2.33E-2	2.39	8.4E-3

TABLE D.3-2 (Continued)
NORMAL PROBABILITY FUNCTION FOR HUMAN ERROR PROBABILITY CALCULATIONS

x	1 - F(x)	x	1 - F(x)
2.40	8.2E-3	2.80	2.6E-3
2.41	8.0E-3	2.81	2.5E-3
2.42	7.8E-3	2.82	2.4E-3
2.43	7.5E-3	2.83	2.3E-3
2.44	7.8E-3	2.84	2.3E-3
2.45	7.1E-3	2.85	2.2E-3
2.46	6.9E-3	2.86	2.1E-3
2.47	6.8E-3	2.87	2.1E-3
2.48	6.6E-3	2.88	2.0E-3
2.49	6.4E-3	2.89	1.9E-3
2.50	6.2E-3	2.90	1.9E-3
2.51	6.0E-3	2.91	1.8E-3
2.52	5.9E-3	2.92	1.8E-3
2.53	5.7E-3	2.93	1.7E-3
2.54	5.5E-3	2.94	1.6E-3
2.55	5.4E-3	2.95	1.6E-3
2.56	5.2E-3	2.96	1.5E-3
2.57	5.1E-3	2.97	1.5E-3
2.58	4.9E-3	2.98	1.4E-3
2.59	4.8E-3	2.99	1.4E-3
2.60	4.7E-3	3.00	1.3E-3
2.61	4.5E-3	3.01	1.3E-3
2.62	4.4E-3	3.02	1.3E-3
2.63	4.3E-3	3.03	1.2E-3
2.64	4.1E-3	3.04	1.2E-3
2.65	4.0E-3	3.05	1.1E-3
2.66	3.9E-3	3.06	1.1E-3
2.67	3.8E-3	3.07	1.1E-3
2.68	3.7E-3	3.08	1.0E-3
2.69	3.6E-3	3.09	1.0E-3
2.70	3.5E-3	3.10	1.0E-3
2.71	3.4E-3	3.11	9.E-4
2.72	3.3E-3	3.12	9.E-4
2.73	3.2E-3	3.13	9.E-4
2.74	3.1E-3	3.14	8.E-4
2.75	3.0E-3	3.15	8.E-4
2.76	2.9E-3	3.16	8.E-4
2.77	2.8E-3	3.17	8.E-4
2.78	2.7E-3	3.18	7.E-4
2.79	2.6E-3	3.19	7.E-4

TABLE D.3-2 (Continued)
NORMAL PROBABILITY FUNCTION FOR
HUMAN ERROR PROBABILITY CALCULATIONS

x	1 - F(x)	x	1 - F(x)
3.20	7.E-4	3.60	2.E-4
3.21	7.E-4	3.61	2.E-4
3.22	6.E-4	3.62	1.E-4
3.23	6.E-4	3.63	1.E-4
3.24	6.E-4	3.64	1.E-4
3.25	6.E-4	3.65	1.E-4
3.26	6.E-4	3.66	1.E-4
3.27	5.E-4	3.67	1.E-4
3.28	5.E-4	3.68	1.E-4
3.29	5.E-4	3.69	1.E-4
3.30	5.E-4	3.70	1.E-4
3.31	5.E-4	3.71	1.E-4
3.32	5.E-4	3.72	1.E-4
3.33	4.E-4	3.73	1.E-4
3.34	4.E-4	3.74	1.E-4
3.35	4.E-4	3.75	1.E-4
3.36	4.E-4	3.76	1.E-4
3.37	4.E-4	3.77	1.E-4
3.38	4.E-4	3.78	1.E-4
3.39	3.E-4	3.79	1.E-4
3.40	3.E-4	3.80	1.E-4
3.41	3.E-4	3.81	1.E-4
3.42	3.E-4	3.82	1.E-4
3.43	3.E-4	3.83	1.E-4
3.44	3.E-4	3.84	1.E-4
3.45	3.E-4	3.85	1.E-4
3.46	3.E-4	3.86	1.E-4
3.47	3.E-4	3.87	1.E-4
3.48	3.E-4	3.88	1.E-4
3.49	2.E-4	3.89	<1.E-4
3.50	2.E-4	3.90	<1.E-4
3.51	2.E-4	3.91	<1.E-4
3.52	2.E-4	3.92	<1.E-4
3.53	2.E-4	3.93	<1.E-4
3.54	2.E-4	3.94	<1.E-4
3.55	2.E-4	3.95	<1.E-4
3.56	2.E-4	3.96	<1.E-4
3.57	2.E-4	3.97	<1.E-4
3.58	2.E-4	3.98	<1.E-4
3.59	2.E-4	3.99	<1.E-4
		4.00	<1.E-4

TABLE D.4-1
NORTH ANNA SIMULATOR SESSION #1

1-10-92, 11:05 to 11:50
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 2 SROs, 3 CROs, 1 STA, 2 non licensed ROs.
SRO #1 is Shift Supervisor, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: "A" loop hot leg protection RTD will fail high, SGTR on "C" SG (550 gpm), 1-SI-P-1B will fail to start but may be manually started loss of offsite power, 1J EDG will initially operate then trip,, and 1-RC-PCV-455C will fail closed.

Time	Key Operator Actions Related to HEP
11:05:00	(Simulator in Run).
11:07:30	("A" Loop Hot Leg Protection RTD Fails High).
11:12:20	(SGTR "C" SG, beginning three minute ramp from 0 to 70% tube rupture).
11:12:27	(Annunciators for radiation monitors alarms).
11:13:06	SRO #1 asks CRO #1 to start a ramp down. Shift personnel are checking radiation monitors. Pressurizer level and SG levels are stable.
11:13:20	CRO #2 identifies SG "C" is the damaged SG.
11:13:54	SRO #1 asks for a reactor trip and transition to 1-E-0.
11:13:56	CRO #1 performs manual reactor trip.
11:13:58	CRO #2 performs manual reactor trip.
11:14:01	CRO #2 performs manual turbine trip.
11:14:15	SRO #2 transitions to 1-E-0 asks shift if they are ready for him to begin reading.
11:14:27	Step 1, 1-E-0, verify reactor trip.
11:14:56	Step 2, 1-E-0, verify turbine trip.
11:15:05	Step 3, 1-E-0, verify power to AC emergency busses.
11:15:19	Step 4, 1-E-0, check if SI is actuated.
11:16:13	Transitioning to 1-ES-0.1.
11:16:27	(Loss of Offsite Power, LOOP).
11:16:37	(EDGs 1H and 1J start and restore power to emergency buses).
11:17:05	SRO #1 requests RO #1 to initiate 1-AP-10.
11:17:20	SRO #1 requests CRO #3 to initiate 1-AP-24. SRO #2 is to continue with 1-ES-0.1.

TABLE D.4-1 (Continued)
NORTH ANNA SIMULATOR SESSION #1

11:17:49	Step 1, 1-ES-0.1, check RCS average temperature.
11:18:02	Step 2, 1-ES-0.1, check Feedwater status, SRO #2 ensures SRO #1 understands AFW status. CRO #2 places 1-FW-P-3A in Pull-To-Lock to stop flow to the damaged SG.
11:18:20	CRO #2 confirms 340 gpm from 1-FW-P-3B to "B" SG.
11:18:43	Step 3, 1-ES-0.1, verify all control rods fully inserted.
11:18:48	SRO #1 asks RO #2 to initiate AP for aligning the motor driven pumps to provide flow to the "A" and "B" SG.
11:18:50	Step 4, 1-ES-0.1, check Pressurizer level control, SRO #1 decides not to place letdown in service.
11:19:50	Step 5, 1-ES-0.1, check Pressurizer pressure control.
11:20:00	(Pressurizer level and SGs level are normal, the SGTR is increased to 100%, simulator instructors expected a 70% break to be sufficient, future scenarios will be modified).
11:20:28	Step 6, 1-ES-0.1, check SG level.
11:20:40	Step 7, 1-ES-0.1, verify all AC busses energized.
11:21:18	Step 8, 1-ES-0.1, transfer condenser steam dump to steam pressure mode.
11:21:21	CRO #1 identifies Pressurizer level is dropping.
11:21:38	SRO #1 requests going back to 1-E-0 and initiating SI.
11:21:40	CRO #1 and CRO #2 manually initiate SI.
11:21:42	Transition to 1-E-0.
11:21:56	CRO #2 identifies 1-SI-P-1B has failed to start and notifies SRO #1.
11:21:58	CRO #2 manually starts 1-SI-P-1B.
11:21:59	Step 1, 1-E-0, verify reactor trip.
11:22:05	Step 2, 1-E-0, verify turbine trip.
11:22:10	Step 3, 1-E-0, verify power to AC emergency busses.
11:22:16	Step 4, 1-E-0, check if SI is actuated.
11:22:24	Step 5, 1-E-0, manually initiate both trains of SI.
11:22:31	Step 6, 1-E-0, verify both emergency diesel generators running.
11:22:34	(EDG 1J fails and 1J buses de-energize.)
11:22:50	CRO #2 identifies no AFW to any SG.
11:23:07	Step 7, 1-E-0, verify SI pumps running.
11:23:17	Step 8, 1-E-0, verify Main Feedwater isolation.
11:23:33	Step 9, 1-E-0, verify AFW pumps running.
11:23:49	Step 10, 1-E-0, verify phase A isolation.
11:23:58	Initiated Attachment 2, 1-E-0, verification of Phase A isolation.
11:24:14	Step 11, 1-E-0, verify SW pumps.
11:24:42	Step 12, 1-E-0, check if Main Steam lines should be isolated, transition to step 14.
11:25:26	Step 14, 1-E-0, verify SI flow.
11:25:45	Step 15, 1-E-0, verify AFW.
11:26:40	Step 16, 1-E-0, check Charging Pump alignment.
11:27:31	Step 17, 1-E-0, check low head SI pump discharge valves.
11:27:41	Step 18, 1-E-0, have Unit 2 operator initiate 1-AP-47.
11:27:52	Step 19, 1-E-0, check Tave stable at or trending to 547°F
11:27:56	(Completed simulated realignment of 1-FW-P-3A to all three SGs.)

TABLE D.4-1 (Continued)
NORTH ANNA SIMULATOR SESSION #1

11:17:49	Step 1, 1-ES-0.1, check
11:28:14	Step 20, 1-E-0, check if RCPs must be stopped.
11:28:25	CRO #2 starts 1-FW-P-3A and adjusts AFW flow to SG "A" and "B."
11:28:35	Step 21, 1-E-0, verify notifications.
11:28:58	Step 22, 1-E-0, check Przr PORVs, spray and safety valves
11:29:17	Step 23, 1-E-0, check SGs not faulted.
11:29:29	Step 24, 1-E-0, check SGs not ruptured.
11:29:42	Transition to 1-E-3, SGTR.
11:30:07	Step 1, 1-E-3, check if RCPs must be stopped.
11:30:17	Step 2, 1-E-3, identify ruptured SGs.
11:30:49	Step 3, 1-E-3, isolate flow from ruptured SG.
11:31:16	Step 4, 1-E-3, check ruptured SG level.
11:32:40	Step 5, 1-E-3, check Przr PORVs and block valves.
11:33:12	Step 6, 1-E-3, check SGs not faulted.
11:33:23	Step 7, 1-E-3, check intact SG levels.
11:33:33	Step 8, 1-E-3, reset SI.
11:33:41	Step 9, 1-E-3, manually align condenser air ejector.
11:34:47	Step 10, 1-E-3, establish instrument air to containment.
11:35:10	Step 11, 1-E-3, verify all AC busses energized.
11:35:22	Step 12, 1-E-3, verify flow from ruptured SGs isolated.
11:36:01	Step 13, 1-E-3, initiate RC cooldown.
11:40:42	Step 14, 1-E-3, check ruptured SG pressure.
11:40:50	Step 15, 1-E-3, check RCS subcooling based on TCs.
11:41:00	Step 16, 1-E-3, depressurize RCS.
11:41:00	(RCS 450F, 1440psig, SGs 50/61/69% level, 420/420/1063 psig).
11:41:34	Step 17, 1-E-3, depressurize RC using Przr PORV.
11:46:03	Step 18, 1-E-3, check RCS pressure.
11:46:40	Step 19, 1-E-3, check if SI flow should be terminated.
11:47:21	Step 20, 1-E-3, stop all but one Charging pump.
11:47:25	Step 21, 1-E-3, verify Charging pump recirc.
11:48:45	Step 22, 1-E-3, establish Charging.
11:50:03	Simulator session ended.

Operator Response Times:

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	11:13:56	11:14:27	11:14:56
	11:13:54	11:13:54	11:14:27
	--------	--------	--------
	2 seconds	33 seconds	29 seconds
HEP-1E0-7	11:21:56	11:23:07	11:23:17
	11:21:40	11:21:38	11:23:07
	--------	--------	--------
	16 seconds	89 seconds	10 seconds

TABLE D.4-1 (Continued)
NORTH ANNA SIMULATOR SESSION #1

	Operator Initiative	Procedure	Step Completion
HEP-1E0-8	none	11:23:17 11:21:38 -------- 99 seconds	11:23:33 11:23:17 -------- 16 seconds
HEP-1E0-12	none	11:24:42 11:21:38 -------- 184 seconds	11:25:26 11:24:42 -------- 44 seconds
HEP-1E0-14	none	11:25:26 11:21:38 -------- 228 seconds	11:25:45 11:25:26 -------- 19 seconds
HEP-1E0-15	none	11:25:45 11:21:38 -------- 247 seconds	11:26:40 11:25:45 -------- 55 seconds
HEP-1E0-16	none	11:26:40 11:21:38 -------- 302 seconds	11:27:31 11:26:40 -------- 51 seconds
HEP-1E0-22	none	11:28:58 11:21:38 -------- 440 seconds	11:29:17 11:28:58 -------- 19 seconds
HEP-1E3-3	none	11:30:49 11:21:38 -------- 551 seconds	11:31:16 11:30:49 -------- 27 seconds
HEP-1E3-13	none	11:36:01 11:21:38 -------- 863 seconds	11:40:42 11:36:01 -------- 281 seconds

TABLE D.4-2
NORTH ANNA SIMULATOR SESSION #2

1-10-92, 12:55 to 13:48
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 3 SROs, 3 CROs, 1 STA, 1 non licensed ROs.
SRO #1 is Shift Supervisor is not normally part of this shift, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: "A" loop hot leg protection RTD will fail high, SGTR on "C" SG (550 gpm), 1-SI-P-1B will fail to start but may be manually started, loss of offsite power, 1J EDG will trip and fail, and 1-RC-PCV-455C will fail closed.

Time	Key Operator Actions Related to HEP
12:55:00	(Simulator in Run).
12:58:00	(RCS 582°F, 2249 psig, pzr level 64%. SGs: 49/49/49% level, 906/906/906 psig).
13:04:00	("A" Loop Hot Leg Protection RTD Fails High).
13:09:15	(SGTR "C" SG, beginning three minute ramp from 0 to 100% tube rupture).
13:09:43	(Annunciators for radiation monitors alarm).
13:09:58	Transition to 1-AP-24 SG tube leak.
13:10:15	CRO #1 announces Przr level is decreasing, CRO #2 announces SG "C" level is increasing.
13:10:25	(RCS 582°F, 2249 psig, pzr level 54%. SGs: 49/49/49% level, 904/904/904 psig).
13:10:36	SRO #1 asks for a manual Rx trip and SI as per standing order regarding primary to secondary leakage.
13:10:45	CRO #1 manual Reactor trip, CRO #2 trips Turbine.
13:10:46	CRO #2 manual Reactor trip.
13:10:59	Transition to 1-E-0.
13:11:13	Step 1, 1-E-0, verify reactor trip.
13:11:26	Step 2, 1-E-0, verify turbine trip.
13:11:38	SRO #1 stops SRO #2 from procedure reading and requests a manual SI.
13:11:42	CRO #1 & 2 manual SI.
13:12:06	SRO #1 identifies 1-SI-P-1B has failed to start and notifies CRO #2.

TABLE D.4-2 (Continued)
NORTH ANNA SIMULATOR SESSION #2

13:12:14	CRO #2 manually starts 1-SI-P-1B.
13:12:27	Step 3, 1-E-0, verify power to emergency busses.
13:12:38	Step 4, 1-E-0, check if SI is actuated.
13:12:50	Step 5, 1-E-0, manually initiate both trains of SI.
13:12:55	(Loss of offsite Power, LOOP).
13:13:01	Step 6, 1-E-0, verify both EDGs running.
13:13:03	(EDGs 1H and 1J restore power to the emergency busses).
13:13:10	SRO #1 has CRO #3 initiate 1-AP-10.
13:13:37	(Loss of EDG 1J and the 1J emergency busses).
13:13:50	Step 7, 1-E-0, verify SI pumps running.
13:14:07	Step 8, 1-E-0, verify Main Feedwater.
13:14:26	Step 9, 1-E-0, verify AFW pumps running.
13:14:48	Step 10, 1-E-0, verify Phase A isolation.
13:15:08	Initiated Attachment 2, 1-E-0, Verification of Phase A.
13:15:04	Step 11, 1-E-0, verify SW pumps running.
13:15:18	Step 12, 1-E-0, check if MS lines should be isolated, transition to step 14.
13:15:46	Step 14, 1-E-0, verify SI flow.
13:16:12	Step 15, 1-E-0, verify AFW flow.
13:16:30	(RCS 533°F, 1878 psig, pzr level 9%. SGs: 36/53/54% level, 1049/1059/1060 psig).
13:16:55	Step 16, 1-E-0, check Charging pump alignment.
13:17:10	SRO #1 calls a RO outside of the MCR and asks him to obtain a copy of the AP to realign one motor driven AFW pump to two SGs.
13:18:01	Step 17, 1-E-0, check low head SI pump valves.
13:18:15	Step 18, 1-E-0, have Unit 2 operator initiate 1-AP-47.
13:18:21	Step 19, 1-E-0, check Tavg stable or trending to 547°F.
13:18:45	Step 20, 1-E-0, check if RCPs must be stopped.
13:18:59	Step 21, 1-E-0, verify notifications.
13:19:06	Step 22, 1-E-0, check Przr PORVs, spray, safety valves.
13:19:30	SRO #1 stops 1-E-0 reading and summarizes the unit's condition, the condition of the tube leak, and which procedures are in progress.
13:20:00	(RCS 523°F, 1796 psig, pzr level 1%. SGs: 43/52/54% level, 1056/1053/1064 psig).
13:20:12	Step 23, 1-E-0, check SGs not faulted.
13:20:29	Step 24, 1-E-0, check SGs not ruptured.
13:20:40	Transition to 1-E-3, SGTR.
13:21:15	Step 1, 1-E-3, check if RCPs must be stopped.
13:21:43	Step 2, 1-E-3, identify ruptured SGs.
13:22:08	Step 3, 1-E-3, isolate flow form ruptured SGs.
13:22:30	(RCS 517°F, 1755 psig, pzr level 0%. SGs: 49/51/65% level, 1056/1053/1063 psig).
13:25:00	(RCS 513°F, 1738 psig, pzr level 0%. SGs: 53/51/65% level, 1056/1053/1063 psig).
13:25:35	Step 4, 1-E-3, isolate flow from ruptured SG.
13:25:56	Step 5, 1-E-3, check ruptured SG level.
13:26:20	Step 6, 1-E-3, check SGs not faulted.

TABLE D.4-2 (Continued)
NORTH ANNA SIMULATOR SESSION #2

13:26:36	Step 7, 1-E-3, check intact SG levels.
13:27:36	Step 8, 1-E-3, reset SI.
13:27:48	Step 9, 1-E-3, manually align condenser air ejector.
13:29:21	Step 10, 1-E-3, establish Instrument Air to Containment.
13:29:30	(Completed simulated realignment of 1-FW-P-3A to all three SGs).
13:29:42	Step 11, 1-E-3, verify all AC busses energized.
13:29:57	Step 12, 1-E-3, verify flow from ruptured SG isolated.
13:30:00	(RCS 504°F, 1718 psig, pzr level 0%. SGs: 51/55/69% level, 1047/1037/1064 psig).
13:31:28	SRO #1 declares Site Area Emergency.
13:31:50	Step 13, 1-E-3, initiate RCS cooldown.
13:32:00	(RCS 500°F, 1717 psig, pzr level 0%. SGs: 51/54/70% level, 1041/1032/1064 psig).
13:32:30	SRO #2 states that RCS is to be cooldown to 495°F.
13:32:38	Step 13b, 1-E-3, dump steam to Main Condenser.
13:35:50	SRO #1 stops procedure reading to summarize the unit status to MCR personnel.
13:36:00	(RCS 494°F, 1643 psig, pzr level 0%. SGs: 47/48/73% level, 660/630/1064 psig).
13:40:00	(RCS 467/494°F, 1433 psig, pzr level 0%. SGs: 36/39/74% level, 389/383/1064 psig).
13:40:26	Step 14, 1-E-3, check ruptured SGs pressure.
13:40:33	Step 15, 1-E-3, check RCS subcooling greater than 50°F.
13:40:43	Step 16, 1-E-3, depressurize RCS to minimize break flow.
13:41:42	Step 17, 1-E-3, depressurize RCS using Przr PORV.
13:42:00	(RCS 456/493°F, 1440 psig, pzr level 0%. SGs: 39/42/74% level, 438/422/1063 psig).
13:44:00	(RCS 447/489°F, 1229 psig, pzr level 0%. SGs: 41/43/75% level, 437/419/1063 psig).
13:44:45	SRO #2 announces to shift that Pressurizer level has recovered.
13:46:00	(RCS 442/484°F, 1043 psig, pzr level 25%. SGs: 43/44/75% level, 442/423/1063 psig).
13:46:00	Step 18, 1-E-3, check RCS pressure increasing.
13:46:36	Step 19, 1-E-3, check if SI flow should be terminated.
13:48:00	(RCS 436/480°F, 1089 psig, pzr level 32%. SGs: 44/45/75% level, 428/419/1055 psig).
13:47:20	Step 20, 1-E-3, stop all but one Charging pump.
13:47:28	Step 21, 1-E-3, verify Charging pump recirc.
13:47:48	Step 22, 1-E-3, establish charging.
13:48:43	Simulator session ended.
13:27:36	Step 8, 1-E-3, reset SI.

TABLE D.4-2 (Continued)
NORTH ANNA SIMULATOR SESSION #2

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	13:10:45 13:10:36 -------- 9 seconds	13:11:13 13:10:36 -------- 37 seconds	13:11:26 13:11:13 -------- 13 seconds
HEP-1E0-7	13:12:06 13:11:42 -------- 24 seconds	13:13:50 13:10:36 -------- 194 seconds	13:14:07 13:13:50 -------- 17 seconds
HEP-1E0-8	none	13:14:07 13:10:36 -------- 211 seconds	13:14:26 13:14:07 -------- 19 seconds
HEP-1E0-12	none	13:15:18 13:10:36 -------- 282 seconds	13:15:46 13:15:18 -------- 28 seconds
HEP-1E0-14	none	13:15:46 13:10:36 -------- 310 seconds	13:16:12 13:15:46 -------- 36 seconds
HEP-1E0-15	none	13:16:12 13:10:36 -------- 336 seconds	13:16:55 13:16:12 -------- 43 seconds
HEP-1E0-16	none	13:16:55 13:10:36 -------- 379 seconds	13:18:01 13:16:55 -------- 66 seconds

TABLE D.4-2 (Continued)
NORTH ANNA SIMULATOR SESSION #2

	Operator Initiative	Procedure	Step Completion
HEP-1E0-22	none	13:19:06 13:10:36 -------- 510 seconds	13:20:12 13:19:06 -------- 66 seconds
HEP-1E3-3	none	13:22:08 13:10:36 -------- 692 seconds	13:25:35 13:22:08 -------- 207 seconds
HEP-1E3-13	none	13:31:50 13:10:36 -------- 1274 seconds	13:40:26 13:32:38 -------- 470 seconds

TABLE D.4-3
NORTH ANNA SIMULATOR SESSION #3

1-30-92, 11:19 to 11:57
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 1 SRO, 4 CROs, 1 STA, no non-licensed ROs.

The SRO is Shift Supervisor, CRO #3 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: "A" loop hot leg protection RTD will fail high, SGTR on "C" SG (550 gpm), 1-SI-P-1B will fail to start but may be manually started, loss of offsite power, 1J EDG will trip and fail, and 1-RC-PCV-455C will fail closed.

Time	Key Operator Actions Related to HEP
11:19:00	(Simulator in Run).
11:19:30	("A" Loop Hot Leg Protection RTD Fails High).
11:20:00	(RCS 583°F, 2250 psig, pzr level 64%. SGs: 49/49/49% level, 911/911/911 psig).
11:22:43	(SGTR "C" SG, beginning three minute ramp from 0 to 100% tube rupture).
11:23:30	(RCS 582°F, 2249 psig, pzr level 61%. SGs: 49/49/49% level, 904/904/904 psig).
11:23:40	SRO #1 instructs CRO #1 to start a second Charging Pump.
11:24:14	SRO #1 asks for a manual Rx trip and SI.
11:24:24	CRO #1 and CRO #2 Manually trip Reactor.
11:24:36	CRO #1 and CRO #2 Manually SI.
11:24:50	Transition to 1-E-0.
11:25:02	(Loss of Offsite Power, LOOP).
11:25:30	CRO #2 manually starts 1-SI-P-1B.
11:26:31	Step 4, 1-E-0, check if SI is actuated.
11:26:40	Step 5, 1-E-0, manually initiate both trains of SI.
11:26:46	Step 6, 1-E-0, verify both EDGs running.
11:26:52	Step 7, 1-E-0, verify SI pumps running.
11:27:01	Step 8, 1-E-0, verify Main Feedwater isolation.
11:28:40	(Emergency Diesel Generator 1J fails to run).
11:57:00	Simulator session ended.

TABLE D.4-3 (Continued)
NORTH ANNA SIMULATOR SESSION #3

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	11:24:24 11:24:14 -------- 10 seconds	not available	not available
HEP-1E0-7	11:25:30 11:24:14 -------- 76 seconds	11:26:52 11:24:14 -------- 158 seconds	11:27:01 11:26:52 -------- 9 seconds

Review:

One operator refused to allow video taping for this simulator session. All information was obtained through direct observation and can not be accurately verified.

TABLE D.4-4
NORTH ANNA SIMULATOR SESSION #4

1-30-92, 13:05 to 13:45
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 2 SROs, 3 CROs, 1 STA, 1 non licensed RO.
SRO #1 is Shift Supervisor, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: "A" loop hot leg protection RTD will fail high, SGTR on "C" SG (550 gpm), 1-SI-P-1B will fail to start but may be manually started, loss of offsite power, 1J EDG will trip and fail, and 1-RC-PCV-455C will fail closed.

Time	Key Operator Actions Related to HEP
13:05:00	(Simulator in Run).
13:06:00	(RCS 614°F, 2249 psig, pzr level 64%. SGs: 49/49/49% level, 906/906/906 psig).
13:08:30	("A" Loop Hot Leg Protection RTD Fails High).
13:10:25	(RCS 582°F, 2249 psig, pzr level 54%. SGs: 49/49/49% level, 904/904/904 psig).
13:11:08	(SGTR "C" SG, beginning three minute ramp from 0 to 100% tube rupture).
13:11:43	SRO #1 asks for a manual Rx trip.
13:11:48	CRO #1 manually trips Reactor.
13:11:51	CRO #2 manually trips Turbine.
13:12:47	SRO #1 asks for manual SI.
13:12:51	CRO #1 manually SI.
13:13:23	CRO #2 manually starts 1-SI-P-1B.
13:14:39	(Emergency Diesel Generator 1J fails to run).
13:13:04	(Loss of Offsite Power).
13:13:10	(EDGs start and reenergize the emergency busses).
13:14:41	(EDG 1J fails, 1J busses deenergize).
13:17:30	(RCS 531°F, 1907 psig, pzr level 16%. SGs: 53/53/62% level, 1057/1057/1060 psig).
13:20:30	(RCS 523°F, 1814 psig, pzr level 6%. SGs: 53/54/63% level, 1054/1055/1060 psig).
13:22:00	Transition to 1-E-3.

13:26:00	(RCS 510°F, 1738 psig, pzr level 0%. SGs: 51/55/67% level, 1052/1053/1064 psig).
13:29:00	(RCS 506°F, 1724 psig, pzr level 0%. SGs: 52/55/68% level, 1045/1043/1063 psig).
13:30:49	SRO #1 announces to shift that he would like to cooldown the RCS.
13:33:30	(RCS 500°F, 1712 psig, pzr level 0%.
13:45:00	Simulator session ended.

Operator Response Times:

	Operator Initiative	Procedure	Step Completion
HEP-1E0-7	13:13:23 13:12:51 -------- 32 seconds	not available	not available

Review:

Incomplete data due to audio failure on video tape.

TABLE D.4-5
NORTH ANNA SIMULATOR SESSION #5

2-19-92, 12:49 to 14:33
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 2 SROs, 2 CROs, 1 STA, 2 non licensed ROs.
SRO #1 is Shift Supervisor, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: 1-FW-P-2 trips on over speed at SI initiation. SGTR on "B" SG will start out as a leak and will go (550 gpm), 1-SI-MOV-1867 A&B will fail to open may be manually. Also B control rod P-8 will be stuck and 1-MS-PCV-101B will be stuck open.

Time	Key Operator Actions Related to HEP
12:49:00	(Simulator in Run).
12:50:00	(RCS 30% power, RCS 558°F, 2232 psig, pzr level 36%. SGs: 47/47/47% level, 893/893/893 psig).
13:15:00	CRO #1 identifies control rod P-8 is stuck @ 148 steps. SRO #1 calls for instrument department assistance.
13:18:00	(Initiating very small SG leak 19.4 gallons per day.)
13:19:45	(N-16 monitor alarm) Shift responds - initiates 1-AP-24.
13:20:00	(RCS 36% power, RCS 558°F, 2249 psig, pzr level 38%. SGs: 48/48/48% level, 903/903/903 psig).
13:24:35	(Increase SG leak size to 70 gallons per day)
13:26:29	STA suggests possibly greater than 100 gpd (admin limit).
13:27:23	SRO asks for a manual Rx trip 168 gpd primary to secondary leakage indicated for SG "B" on radiation monitor.
13:27:26	CRO #1 and CRO #2 manual Reactor trip.
13:27:29	CRO #2 manual Turbine trip.
13:27:39	CRO #1 identifies one stuck control rod.
13:28:16	Transition to 1-E-0.
13:28:22	Step 1, 1-E-0, verify Reactor trip.
13:28:46	Step 2, 1-E-0, verify Turbine trip.
13:29:11	Step 3, 1-E-0, verify power to AC emergency busses.
13:29:20	Step 4, 1-E-0, check if SI is actuated.
13:29:30	(RCS 546°F, 2187 psig, pzr level 27%. SGs: 60/60/60%).

13:30:09	Transition to 1-ES-0.1
13:30:39	Step 1, 1-ES-0.1, check RCS average temperature 457°F.
13:30:48	Step 2, 1-ES-0.1, check Feedwater status.
13:31:06	Step 3, 1-ES-0.1, verify all control rods fully inserted.
13:31:26	Step 4, 1-ES-0.1, check Pressurizer level control.
13:31:55	Step 5, 1-ES-0.1, check Pressurizer pressure control.
13:32:10	Step 6, 1-ES-0.1, check SG levels
13:32:29	Step 7, 1-ES-0.1, verify all AC busses energized.
13:32:49	Step 8, 1-ES-0.1, transfer condenser steam dump to steam pressure mode.
13:34:03	Step 9, 1-ES-0.1, check RCP status.
13:34:13	Step 10, 1-ES-0.1, check source range detectors.
13:34:50	Step 11, 1-ES-0.1, shut down unnecessary plant equipment.
13:35:00	SRO #1 has CRO #2 resume 1-AP-24 in parallel with 1-ES-0.1
13:36:37	CRO #1 notifies SRO that charging flow is now 115 gpm and a second Charging pumps has been started.
13:40:39	SRO #1 reviews unit conditions with the shift.
13:41:39	Step 12, 1-ES-0.1, maintain stable plant conditions.
13:42:15	Step 13, 1-ES-0.1, identify and classify cause of trip.
13:42:25	Step 14, 1-ES-0.1, determine if natural circulation cooldown is required.
13:42:50	Transitioning to 1-AP-24 and 1-OP-3.2.
13:45:00	(Simulator in Freeze). Simulator instructor reviews the operator actions in 1-AP-24, SG tube leak.
13:52:00	(RCS 535°F, 2264 psig, pzr level 30%. SGs: 66/65/66% level, 918/924/919 psig).
13:57:10	(Simulator in run).
13:59:45	(RCS 535°F, 2139 psig, pzr level 15%)
13:59:50	(Increased SG leak to a break 1100 gpm ramp over 2 minutes.)
14:00:00	CRO #1 announces that Charging is not able to maintain Pressurizer level.
14:00:09	CRO #2 announces that SG "B" level is rapidly increasing.
14:00:14	SRO #1 requests CROs to manually SI.
14:00:16	CRO #1 and CRO #2 manual SI.
14:00:20	Transition to 1-E-0.
14:00:24	Step 1, 1-E-0, verify Reactor trip.
14:00:26	Step 2, 1-E-0, verify Turbine trip.
14:00:33	Step 3, 1-E-0, verify power to AC emergency busses.
14:00:42	Step 4, 1-E-0, check if SI is actuated.
14:01:00	STA identifies BIT inlet valves are still closed
14:01:03	CRO #2 attempts 1-SI-MOV-1867 A&B
14:01:45	STA recommends opening 1-SI-MOV-1836.
14:01:47	CRO #2 opening 1-SI-MOV-1836
14:01:04	Step 5, 1-E-0, manually initiate both trains of SI.
14:01:23	Step 6, 1-E-0, verify both EDGs running.
14:01:30	Step 7, 1-E-0, verify SI pumps running.
14:01:41	Step 8, 1-E-0, verify Main Feedwater isolation.

TABLE D.4-5 (Continued)
NORTH ANNA SIMULATOR SESSION #5

14:02:10	Step 9, 1-E-0, verify AFW pumps running.
14:02:21	Step 10, 1-E-0, verify Phase A isolation.
14:02:35	Initiate Attachment 2, 1-E-0, verification of Phase A.
14:02:35	Step 11, 1-E-0, verify SW pumps running.
14:02:45	(RCS 538°F, 1866 psig, pzr level 0%. SGs: 67/71/65% level, 932/1007/932 psig).
14:02:57	Step 12, 1-E-0, check if MS lines should be isolated, transition to step 14.
14:03:17	Step 14, 1-E-0, verify SI flow.
14:03:58	Step 15, 1-E-0, verify AFW flow.
14:04:00	SRO #1 calls TSC to have an operator and maintenance personnel attempt to locally open the BIT valves.
14:04:41	Step 16, 1-E-0, check Charging pump alignment.
14:05:55	Step 17, 1-E-0, check low head SI pump valves.
14:06:03	Step 18, 1-E-0, have Unit 2 operator initiate 1-AP-47.
14:06:15	Step 19, 1-E-0, check Tavg stable or trending 547°F.
14:06:30	(RCS 534°F, 1712 psig, pzr level 0%. SGs: 65/72/65% level, 935/922/888 psig).
14:06:37	Step 20, 1-E-0, check if RCPs must be stopped.
14:06:54	Step 21, 1-E-0, verify notifications.
14:07:10	Step 22, 1-E-0, check Przr PORVs, spray, safety valves.
14:07:45	Step 23, 1-E-0, check SGs not faulted.
14:08:06	Step 24, 1-E-0, check SGs not ruptured.
14:08:49	Transition to 1-E-3, SGTR.
14:09:34	Step 1, 1-E-3, check if RCPs must be stopped.
14:09:50	Step 2, 1-E-3, identify ruptured SGs.
14:10:15	Shift agrees "B" has rupture.
14:10:50	Step 3, 1-E-3, isolate flow form ruptured SG.
14:12:20	Step 4, 1-E-3, check ruptured SG level.
14:12:46	Step 5, 1-E-3, check Przr PORVs and block valves.
14:13:00	(RCS 527°F, 1581 psig, pzr level 0%. SGs: 65/70/65% level, 913/804/918 psig).
14:13:13	Step 6, 1-E-3, check SGs not faulted.
14:13:28	Step 7, 1-E-3, check intact SG levels.
14:13:40	Step 8, 1-E-3, reset SI.
14:14:00	SRO #1 receives a report of steam coming out of the MSVH (1-MS-PCV-101B has failed open).
14:16:41	(Simulator in freeze).
14:19:30	(Simulator in run.)
14:20:10	Restart after 7 minute discussion of 1-E-3 steps.
14:20:10	Step 8, 1-E-3, reset SI.
14:20:18	Step 9, 1-E-3, manually align Condenser air ejector discharge to Containment.
14:21:29	Step 10, 1-E-3, establish Instrument Air to Containment.
14:21:51	Step 11, 1-E-3, verify all AC busses energized by offsite power.
14:21:57	Step 12, 1-E-3, verify flow from ruptured SG isolated.

TABLE D.4-5 (Continued)
NORTH ANNA SIMULATOR SESSION #5

14:23:05	Step 13, 1-E-3, initiate RCS cooldown.
14:31:27	Step 14, 1-E-3, check ruptured SG pressure stable or increasing.
14:25:00	(RCS 509°F, 1432 psig, pzr level 0%. SGs: 56/67/57% level, 659/662/642 psig).
14:30:00	(RCS 460°F, 874 psig, pzr level 0%. SGs: 62/68/56% level, 492/414/389 psig).
14:31:00	1-FW-P-2 returned to service.
14:33:00	(Simulator in freeze).

Operator Response Times:

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	13:27:26	13:28:22	13:28:46
	13:27:23	13:27:23	13:28:22
	--------	--------	--------
	3 seconds	59 seconds	24 seconds
HEP-1E0-7	none	14:01:30	14:01:41
		14:00:14	14:01:30
		--------	--------
		76 seconds	11 seconds
HEP-1E0-8	none	14:01:41	14:02:10
		14:00:14	14:01:41
		--------	--------
		87 seconds	29 seconds
HEP-1E0-12	none	14:02:57	14:03:17
		14:00:14	14:02:57
		--------	--------
		163 seconds	20 seconds
HEP-1E0-14	none	14:03:17	14:03:58
		14:00:14	14:03:17
		--------	--------
		183 seconds	41 seconds

TABLE D.4-5 (Continued)
NORTH ANNA SIMULATOR SESSION #5

	Operator Initiative	Procedure	Step Completion
HEP-1E0-15	none	14:03:58 14:00:14 -------- 224 seconds	14:04:41 14:03:58 -------- 43 seconds
HEP-1E0-16	none	14:04:41 14:00:14 -------- 267 seconds	14:05:55 14:04:41 -------- 74 seconds
HEP-1E0-22	none	14:07:10 14:00:14 -------- 416 seconds	14:07:45 14:07:10 -------- 35 seconds
HEP-1E3-3	none	14:10:50 14:00:14 -------- 636 seconds	14:12:20 14:10:50 -------- 90 seconds
HEP-1E3-13	none	14:23:05 14:00:14 -------- 951 seconds	14:31:27 14:23:05 -------- 502 seconds

Seven minutes has been subtracted from the time for step 13 of 1-E-3 due to the interruption of the scenario to provide training instruction concerning the 1-E-3 procedure. Discussions concerning what action to take may occur during real SGTR but this discussion was training oriented.

TABLE D.4-6
NORTH ANNA SIMULATOR SESSION #6

2-19-92, 15:00 to 16:03
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 2 SROs, 2 CROs, 1 STA, 2 non licensed ROs.
SRO #1 is Shift Supervisor, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator. SRO #2 is not normally part of this shift.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: 1-FW-P-2 trips on over speed at SI initiation. SGTR on "B" SG will start out as a leak and will go (550 gpm), 1-SI-MOV-1867 A&B will fail to open may be manually. Also B control rod P-8 will be stuck and 1-MS-PCV-101B will be stuck open.

Time	Key Operator Actions Related to HEP
15:00:00	(Simulator in Run).
15:00:00	(RCS 558°F, 2251 psig, pzr level 38%. SGs: 48/48/48% level, 912/912/912 psig).
15:01:00	(Initiated SG tube leak).
15:01:16	(Radiation monitors alarm).
15:01:27	Initiated 1-AP-24, SG Tube Leak. (The timing for each step will not be collected.)
15:18:50	(N-16 monitor reflashes).
15:25:50	Shift identifies possible SG leak >100 gpd, waiting for chemistry confirmation
15:29:10	(N-16 alarm reflashes).
15:29:23	Chemistry notifies SRO #1 SG B > 100 gpd.
15:30:53	SRO #1 asks for a manual Rx trip and transition to 1-E-0.
15:30:56	CRO #1 and #2 manual Reactor trip.
15:30:58	CRO #2 manual Turbine trip.
15:31:02	CRO #1 identifies stuck control rod P-8.
15:31:36	Step 1, 1-E-0, verify Reactor trip.
15:32:04	Step 2, 1-E-0, verify Turbine trip.
15:32:34	Step 3, 1-E-0, verify power to AC emergency busses.
15:32:44	Step 4, 1-E-0, check if SI is actuated.
15:33:48	Transition to 1-ES-0.1, Reactor Trip Response.
15:34:10	Step 1, 1-ES-0.1, check RCS Tavg 547°F.

TABLE D.4-6 (Continued)
NORTH ANNA SIMULATOR SESSION #6

15:34:23	Step 2, 1-ES-0.1, check Feedwater status.
15:34:46	Step 3, 1-ES-0.1, verify all Control Rods fully inserted.
15:34:58	Step 4, 1-ES-0.1, check Przr level control.
15:35:28	Step 5, 1-ES-0.1, check Przr pressure control.
15:35:57	Step 6, 1-ES-0.1, check SG levels.
15:36:24	Step 7, 1-ES-0.1, verify all AC busses energized.
15:36:40	Step 8, 1-ES-0.1, transfer Condenser steam dump to pressure mode.
15:38:14	Step 9, 1-ES-0.1, check RCP status.
15:38:41	Step 10, 1-ES-0.1, check if source range detectors.
15:39:03	(Simulator in freeze. Simulator instructor discussing 1-AP-24, SG Tube Leak, actions.)
15:47:20	Simulator in run.
15:47:44	(SG tube rupture, 2 minute ramp to 100% tube flow).
15:47:53	Step 11, 1-ES-0.1, shut down unnecessary plant equipment.
15:48:00	(RCS: 0% power, 544°F, 2248 psig, pzr level 25%. SGs: 64/66/65% level, 991/996/984 psig).
15:49:05	CRO #1 announces that Pressurizer level is now 13%, starting second charging pump.
15:49:39	CRO #1 announces Pressurizer level is now 10 %.
15:49:45	SRO #1 asks for SI and return to 1-E-0 and carry out immediate operator actions.
15:49:49	CRO #1 and #2 manual SI.
15:50:00	(RCS: 544°F, 1794 psig, pzr level 10 %. SGs: 63/73/64% level, 991/1065/992 psig).
15:50:32	Step 1, 1-E-0, verify Reactor trip.
15:50:37	Step 2, 1-E-0, verify Turbine trip.
15:50:40	Step 3, 1-E-0, verify power to AC emergency busses.
15:50:48	Step 4, 1-E-0, check if SI is actuated.
15:50:56	Step 5, 1-E-0, manually initiate both trains of SI.
15:51:03	Step 6, 1-E-0, verify both EDGs running.
15:51:11	Step 7, 1-E-0, verify SI pumps running.
15:51:31	Step 8, 1-E-0, verify Main Feedwater isolation.
15:51:50	CRO #1 identifies BIT inlet valves still closed. CRO #2 attempts to open valves.
15:51:55	CRO #1 identifies that the BIT valves are closed.
15:51:56	CRO #2 attempts to open BIT valves, 1-SI-MOV-1867A & B.
15:52:14	SRO #1 stops procedure until BIT valves are addressed.
15:52:18	SRO #1 asks CRO #2 to open 1-SI-MOV-1836, informs SRO #2 and CRO #1.
15:52:19	CRO #2 opens 1-SI-MOV-1836.
15:52:25	(Cold leg SI flow indicated).
15:52:39	CRO #2 opens 1-SI-MOV-1836.
15:52:40	Step 9, 1-E-0, verify AFW pumps running.
15:52:54	Step 10, 1-E-0, verify Phase A isolation.
15:52:59	Initiated Attachment 2, 1-E-0, Phase A verification.

15:53:20	SRO #1 calls for RO to get a HP tech and go open 1-SI-MOV-1867A & B.
15:53:40	Step 11, 1-E-0, verify Service Water pumps running.
15:53:46	Step 12, 1-E-0, check if Main Steam lines should be isolated, transfer to step 14.
15:54:02	Step 14, 1-E-0, verify SI flow.
15:55:46	Step 15, 1-E-0, verify AFW flow.
15:56:10	(MOVs-1867 A&B are opened).
15:56:30	SRO #1 asks CRO #2 to close 1-SI-MOV-1836.
15:56:38	Step 16, 1-E-0, check Charging pump alignment.
15:57:49	Step 17, 1-E-0, check low head SI pump valves.
15:58:00	Step 18, 1-E-0, have Unit 2 initiate 1-AP-47.
15:58:27	Step 19, 1-E-0, check Tavg 547°F.
16:00:00	(RCS: 539°F, 1663 psig, pzr level 0%. SGs: 63/66/63% level, 977/878/977 psig).
16:00:21	Step 20, 1-E-0, check if RCPs must be stopped.
16:00:58	Step 21, 1-E-0, verify notifications.
16:01:14	Step 22, 1-E-0, check Przr PORVs, spray, safety valves.
16:01:44	Step 23, 1-E-0, check SGs not faulted.
16:01:50	SRO #1 calls for RO to go look at MSVH to see if 1-MS-PCV-101B is relieving steam.
16:03:00	(Simulator in freeze.)

Operator Response Times:

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	15:30:56	15:31:36	15:32:04
	15:30:53	15:30:53	15:31:36
	--------	--------	--------
	3 seconds	43 seconds	28 seconds
HEP-1E0-7	none	15:51:11	15:51:31
		15:49:45	15:51:11
		--------	--------
		86 seconds	20 seconds
HEP-1E0-8	none	15:51:31	15:52:40
		15:49:45	15:51:31
		--------	--------
		106 seconds	69 seconds

TABLE D.4-6 (Continued)
NORTH ANNA SIMULATOR SESSION #6

	Operator Initiative	Procedure	Step Completion
HEP-1E0-12	none	15:53:46 15:49:45 -------- 241 seconds	15:54:02 15:53:46 -------- 16 seconds
HEP-1E0-14	none	15:54:02 15:49:45 -------- 257 seconds	15:55:46 15:54:02 -------- 104 seconds
HEP-1E0-15	none	15:55:46 15:49:45 -------- 361 seconds	15:56:38 15:55:46 -------- 52 seconds
HEP-1E0-16	none	15:56:38 15:49:45 -------- 413 seconds	15:57:49 15:56:38 -------- 71 seconds
HEP-1E0-22	none	16:01:14 15:49:45 -------- 689 seconds	16:01:44 16:01:14 -------- 30 seconds

TABLE D.4-7
NORTH ANNA SIMULATOR SESSION #7

2-20-92, 12:45 to 15:29
North Anna Simulator: LORP "Training" Exercise.

HEPs: HEP-1E0 series and HEP-1E3 series.

Crew: 2 SROs, 2 CROs, no STA, no non licensed ROs.
SRO #1 is Shift Supervisor, SRO #2 is SRO/procedure reader, CRO #1 is primary RO, CRO #2 is BOP operator. SRO #1 is not normally part of this shift.

Pre-shift briefing: Unit at 100% power. 1-FW-P-2 is out of service as well as 1-RC-PCV-1456 being closed, isolated and power removed from its block valve.

Failures scheduled: "A" loop hot leg protection RTD will fail high, SGTR on "C" SG (550 gpm), 1-SI-P-1B will fail to start but may be manually started loss of offsite power, 1J EDG will trip and fail, and 1-RC-PCV-455C will fail closed.

Time	Key Operator Actions Related to HEP
12:42:10	(Simulator in Run).
12:45:40	("A" Loop Hot Leg Protection RTD Fails High).
12:51:43	(SGTR "C" SG, beginning three minute ramp from 0 to 100% tube rupture).
12:51:46	Radiation monitor indicates 1000 gpd.
12:52:50	SRO #1 requests letdown be removed from service.
12:52:54	SRO #1 asks for a manual Rx trip.
12:52:59	CRO #1 and #2 manual Reactor trip.
12:53:04	CRO #2 manual Turbine trip.
12:53:29	Step 1, 1-E-0, verify Reactor trip.
12:53:36	(Loss of offsite power, LOOP).
12:53:40	(EDGs restore emergency busses).
12:54:17	Step 2, 1-E-0, verify Turbine trip.
12:54:37	Step 3, 1-E-0, verify power to AC emergency busses.
12:54:53	Step 4, 1-E-0, check if SI is actuated.
12:55:57	Transition to 1-ES-0.1, Reactor Trip Response.
12:56:30	(RCS: 543°F, 1926 psig, pzr level 17%. SGs: 54/56/58% level, 1062/1060/1060 psig).
12:56:34	CRO #1 announces VCT is empty and he is switching Charging pump suction to the RWST.
12:57:01	Step 1, 1-ES-0.1, check RCS Tavg 547°F.
12:57:19	Step 2, 1-ES-0.1, check Feedwater status.

TABLE D.4-7 (Continued)
NORTH ANNA SIMULATOR SESSION #7

12:57:39	CRO #1 starts second Charging pump.
12:57:42	Step 3, 1-ES-0.1, verify all control rods inserted.
12:57:54	Step 4, 1-ES-0.1, check Pressurizer level control.
12:57:55	(RCS 537°F, 1835 psig, pzr level 12%. SGs: 53/56/58% level, 1059/1056/1059 psig).
12:57:57	SRO #1 requests a SI and transition back to 1-E-0.
12:58:03	CRO #1 and #2 manual SI.
12:58:10	CRO #2 announces 1-SI-P-1B did not start and attempts to start this pump.
12:58:12	(EDG 1J fails and deenergizes the 1J emergency busses).
12:58:56	Step 1, 1-E-0, verify Reactor trip.
12:58:58	Step 2, 1-E-0, verify Turbine trip.
12:59:09	Step 3, 1-E-0, verify power to AC emergency busses.
12:59:16	Step 4, 1-E-0, check if SI is actuated.
12:59:22	Step 5, 1-E-0, manually initiate both trains of SI.
12:59:30	Step 6, 1-E-0, verify both EDGs running.
12:59:47	Step 7, 1-E-0, verify SI pumps running.
13:00:00	(RCS 532°F, 1813 psig, pzr level 5%. SGs: 53/56/59% level, 1057/1056/1057 psig).
13:00:14	Step 8, 1-E-0, verify Main Feedwater isolation.
13:01:10	CRO #1 request RO to manually close FW MOVs
13:01:20	Step 9, 1-E-0, verify AFW pumps running.
13:01:36	Step 10, 1-E-0, verify Phase A isolation.
13:02:07	CRO #2 asks SRO #1 for OK to initiate 1-AP-22 to switch 1-FW-P-3A discharge to the A and B SGs.
13:02:24	CRO #1 calls RO and requests realignment of AFW from A motor pump to feed the A and B SGs.
13:02:32	Step 11, 1-E-0, verify Service Water pumps running.
13:02:52	Step 12, 1-E-0, check if MS lines should be isolated, transition to step 14.
13:03:16	Step 14, 1-E-0, verify SI flow.
13:04:20	Step 15, 1-E-0, verify AFW flow.
13:05:10	Step 16, 1-E-0, check Charging pump alignment.
13:07:46	CRO #2 begins steps in 0-AP-10.
13:06:15	Step 17, 1-E-0, check low head SI pump valves.
13:06:22	Step 18, 1-E-0, have Unit 2 initiate 1-AP-47.
13:06:37	Step 19, 1-E-0, check Tavg 547°F.
13:07:12	Step 20, 1-E-0, check if RCPs must be stopped.
13:07:22	CRO #1 takes over primary and secondary sides of the control board while CRO #2 initiates 1-AP-10.
13:07:40	Step 21, 1-E-0, verify notifications.
13:07:58	Step 22, 1-E-0, check Przr PORVs, spray, safety valves.
13:08:23	Step 23, 1-E-0, check SGs not faulted.
13:08:36	Step 24, 1-E-0, check SGs not ruptured.
13:09:00	Transition to 1-E-3, SGTR.
13:09:25	Step 1, 1-E-3, check if RCPs must be stopped.
13:09:37	Step 2, 1-E-3, identify ruptured SGs.
13:10:20	Step 3, 1-E-3, isolate flow from ruptured SGs.

TABLE D.4-7 (Continued)
NORTH ANNA SIMULATOR SESSION #7

13:11:43	Step 4, 1-E-3, check ruptured SGs level.
13:12:20	Step 5, 1-E-3, check Przr PORVs and block valves.
13:13:00	(RCS 504°F, 1705 psig, pzr level 0%. SGs: 51/56/66% level, 1044/1036/1064 psig).
13:13:09	Step 6, 1-E-3, check SGs not faulted.
13:13:23	Step 7, 1-E-3, check intact SG levels.
13:14:35	CRO #2 finishes 1-AP-10 and briefs SRO #1.
13:14:36	Step 8, 1-E-3, reset SI.
13:15:25	CRO #2 receives a turnover from CRO #1 and resumes duties on secondary plant boards.
13:16:20	Step 9, 1-E-3, manually align Condenser air ejector.
13:17:20	(Reestablish AFW to SG A & B).
13:17:40	Step 10, 1-E-3, establish Instrument Air to Containment.
13:18:00	Step 11, 1-E-3, verify all AC busses energized.
13:18:30	(RCS 496°F, 1708 psig, pzr level 0%. SGs: 52/60/70% level, 1033/995/1064 psig).
13:18:41	Step 12, 1-E-3, verify flow from ruptured SG isolated.
13:19:47	Step 13, 1-E-3, initiate RCS cooldown, cooldown RCS until ruptured SG is 495°F.
13:21:00	(RCS 492°F, 1692 psig, pzr level 0%. SGs: 53/54/72% level, 833/710/1064 psig).
13:23:00	(RCS 486°F, 1571 psig, pzr level 0%. SGs: 48/49/73% level, 549/506/1064 psig).
13:24:00	CRO #2 has completed diagnosis of 0-AP-10.
13:25:30	(RCS 467°F, 1436 psig, pzr level 0%. SGs: 37/49/73% level, 395/379/1063 psig).
13:25:35	Ruptured SG now 495°F, secured cooldown.
13:26:07	Step 14, 1-E-3, check ruptured SG pressure stable.
13:26:10	Step 15, 1-E-3, check RCS subcooling greater than 50°F.
13:21:30	Step 16, 1-E-3, depressurize RCS to minimize break flow.
13:27:00	Step 17, 1-E-3, depressurize RCS using Przr PORV
13:27:43	CRO #1 identifies pressurizer PORV-1455C will not open, attempts key switch.
13:29:27	(Simulator in freeze.)

Operator Response Times:

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1	12:52:59	12:53:29	12:54:17
	12:52:54	12:52:54	12:53:29
	--------	--------	--------
	5 seconds	35 seconds	48 seconds

TABLE D.4-7 (Continued)
NORTH ANNA SIMULATOR SESSION #7

	Operator Initiative	Procedure	Step Completion
HEP-1E0-7	12:58:10 12:57:57 -------- 13 seconds	12:59:47 12:57:57 -------- 110 seconds	13:00:14 12:59:47 -------- 27 seconds
HEP-1E0-8	none	13:00:14 12:57:57 -------- 137 seconds	13:01:20 13:00:14 -------- 66 seconds
HEP-1E0-12	none	13:02:52 12:57:57 -------- 295 seconds	13:03:16 13:02:52 -------- 24 seconds
HEP-1E0-14	none	13:03:16 12:57:57 -------- 319 seconds	13:04:20 13:03:16 -------- 64 seconds
HEP-1E0-15	none	13:04:20 12:57:57 -------- 383 seconds	13:05:10 13:04:20 -------- 50 seconds
HEP-1E0-16	none	13:05:10 12:57:57 -------- 433 seconds	13:06:15 13:05:10 -------- 65 seconds
HEP-1E0-22	none	13:07:58 12:57:57 -------- 601 seconds	13:08:23 13:07:58 -------- 25 seconds

TABLE D.4-7 (Continued)
NORTH ANNA SIMULATOR SESSION #7

	Operator Initiative	Procedure	Step Completion
HEP-1E3-3	none	13:10:20 12:57:57 -------- 1046 seconds	13:11:43 13:10:20 -------- 83 seconds
HEP-1E3-13	none	13:19:47 12:57:57 -------- 1310 seconds	not available

TABLE D.4-8
SUMMARY OF SIMULATOR OPERATOR RESPONSE TIMES

	Operator Initiative	Procedure	Step Completion
HEP-1E0-1			
Session #1	2 seconds	33 seconds	29 seconds
Session #2	9 seconds	37 seconds	13 seconds
Session #3	10 seconds	not available	not available
Session #5	3 seconds	59 seconds	24 seconds
Session #6	3 seconds	43 seconds	28 seconds
Session #7	5 seconds	35 seconds	48 seconds
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	5 seconds	41 seconds	28 seconds
HEP-1E0-7			
Session #1	16 seconds	89 seconds	10 seconds
Session #2	24 seconds	194 seconds	17 seconds
Session #3	76 seconds	158 seconds	9 seconds
Session #4	32 seconds	not available	not available
Session #5	not available	76 seconds	11 seconds
Session #6	not available	86 seconds	20 seconds
Session #7	13 seconds	110 seconds	27 seconds
	----------	-----------	----------
	32 seconds	119 seconds	16 seconds
HEP-1E0-8			
Session #1		99 seconds	16 seconds
Session #2		211 seconds	19 seconds
Session #5		87 seconds	29 seconds
Session #6		106 seconds	69 seconds
Session #7		137 seconds	66 seconds
		-----------	----------
		128 seconds	40 seconds
HEP-1E0-12			
Session #1		184 seconds	44 seconds
Session #2		282 seconds	28 seconds
Session #5		163 seconds	20 seconds
Session #6		241 seconds	16 seconds
Session #7		295 seconds	24 seconds
		-----------	----------
		233 seconds	26 seconds

TABLE D.4-8 (Continued)
SUMMARY OF SIMULATOR OPERATOR RESPONSE TIMES

	Operator Initiative	Procedure	Step Completion
HEP-1E0-14			
Session #1		228 seconds	19 seconds
Session #2		310 seconds	36 seconds
Session #5		183 seconds	41 seconds
Session #6		257 seconds	104 seconds
Session #7		319 seconds	64 seconds
		259 seconds	53 seconds
HEP-1E0-15			
Session #1		247 seconds	55 seconds
Session #2		336 seconds	43 seconds
Session #5		224 seconds	43 seconds
Session #6		361 seconds	52 seconds
Session #7		383 seconds	50 seconds
		310 seconds	49 seconds
HEP-1E0-16			
Session #1		302 seconds	51 seconds
Session #2		379 seconds	66 seconds
Session #5		267 seconds	74 seconds
Session #6		413 seconds	71 seconds
Session #7		433 seconds	65 seconds
		359 seconds	65 seconds
HEP-1E0-22			
Session #1		440 seconds	19 seconds
Session #2		510 seconds	66 seconds
Session #5		416 seconds	35 seconds
Session #6		689 seconds	30 seconds
Session #7		601 seconds	25 seconds
		531 seconds	35 seconds

TABLE D.4-8 (Continued)
SUMMARY OF SIMULATOR OPERATOR RESPONSE TIMES

	Operator Initiative	Procedure	Step Completion
HEP-1E3-3			
Session #1		551 seconds	27 seconds
Session #2		692 seconds	207 seconds
Session #5		636 seconds	90 seconds
Session #7		1046 seconds	83 seconds
		-----------	-----------
		731 seconds	102 seconds
HEP-1E3-13			
Session #1		863 seconds	281 seconds
Session #2		1274 seconds	470 seconds
Session #5		951 seconds	502 seconds
Session #7		1310 seconds	not available
		------------	-----------
		1100 seconds	418 seconds

TABLE D.7-1
HEP IMPORTANCE ANALYSIS FROM FINAL QUANTIFICATION

Rank	Event Name	Point Estimate	Fessell-Vesely Importance	Risk Achievement Worth	Risk Reduction Worth
5	HEP-1FRH:1-11	4.824E-2	1.163E-1	3.29	1.132
16	HEP-0AP55-10HR	4.949E-3	7.078E-2	15.23	1.076
20	HEP-1FRC:1-11-S1	1.000E+0	5.962E-2	1.00	1.063
35	HEP-NO-PROCEDURE	1.000E+0	3.910E-2	1.00	1.041
36	HEP-1E3-13	2.180E-2	3.881E-2	2.74	1.040
38	HEP-1ES1:2-S1	1.000E+0	3.860E-2	1.00	1.040
39	HEP-0AP55-20HR	2.600E-4	3.677E-2	142.42	1.038
42	HEP-1AP22:5	1.750E-4	3.367E-2	193.37	1.035
47	HEP-1OP49:1	1.326E-1	2.497E-2	1.16	1.026
71	HEP-0AP55-40HR	1.250E-1	1.656E-2	1.12	1.017
80	HEP-1FRC:1-11-S2	1.062E-2	1.332E-2	2.24	1.013
97	HEP-1ECA3:1-16	3.025E-3	9.604E-3	4.17	1.010
100	HEP-1ES1:3	1.220E-2	9.378E-3	1.76	1.009
109	HEP-1FRH:1-15	8.249E-3	8.273E-3	1.99	1.008
112	HEP-1E3-3	3.650E-3	7.421E-3	3.03	1.007
118	HEP-1ES1:4	8.499E-4	6.308E-3	8.42	1.006
144	HEP-1ES1:2-S2	8.499E-4	4.624E-3	6.44	1.005
159	HEP-1ECA3:3-27	8.974E-2	3.578E-3	1.04	1.004
178	HEP-1AP15-6	2.815E-2	2.952E-3	1.10	1.003
199	1FWHEP-1FW548	7.499E-4	2.219E-3	3.96	1.002
200	1FWHEP-1FW546	7.499E-4	2.168E-3	3.89	1.002
215	HEP-1OP14:1-5:13	4.259E-3	1.728E-3	1.40	1.002
226	HEP-1E0-7	1.350E-3	1.645E-3	2.22	1.002
230	1FWHEP-1FW543	7.499E-4	1.567E-3	3.09	1.002
252	HEP-1ECA3:2-5	7.249E-4	1.219E-3	2.68	1.001
266	1RSHEP-FLANGE	3.750E-4	9.962E-4	3.66	1.001
316	HEP-1E1-25	1.175E-2	6.087E-4	1.05	1.001
335	HEP-1FRS:1-5	2.970E-2	4.696E-4	1.02	1.000
344	HEP-1FRH:1-5	3.125E-3	3.829E-4	1.12	1.000
357	HEP-0AP55-30HR	6.565E-3	3.173E-4	1.05	1.000
390	HEP-1ECA3:3-35	4.924E-3	2.157E-4	1.04	1.000
398	HEP-1E0-14	1.000E+0	1.952E-4	1.00	1.000
408	HEP-1OP21:6	1.050E-3	1.703E-4	1.16	1.000
409	1QSHEP-FLANGE	3.750E-4	1.700E-4	1.45	1.000
415	HEP-1AP33:1	3.866E-1	1.552E-4	1.00	1.000
433	HEP-1E0-22	1.880E-2	1.340E-4	1.01	1.000
451	HEP-1AP15-1E	7.799E-4	8.620E-5	1.11	1.000
477	HEP-0AP10	5.274E-3	6.366E-5	1.01	1.000

TABLE D.7-1 (Continued)
HEP IMPORTANCE ANALYSIS FROM FINAL QUANTIFICATION

Rank	Event Name	Point Estimate	Fessell-Vesely Importance	Risk Achievement Worth	Risk Reduction Worth
505	HEP-0AP12-10HR	4.949E-3	4.434E-5	1.01	1.000
539	HEP-0AP12-20HR	2.600E-4	2.177E-5	1.08	1.000
610	1QSHEP-1QS21	7.499E-4	4.557E-6	1.01	1.000
611	1QSHEP-1QS5	7.499E-4	4.522E-6	1.01	1.000
625	HEP-1E0-15	1.075E-3	2.979E-6	1.00	1.000
628	HEP-0AP12-40HR	1.250E-1	2.721E-6	1.00	1.000
676	1FWHEP-MOV-100B	7.499E-4	5.379E-7	1.00	1.000
685	1FWHEP-MOV-100D	7.499E-4	3.866E-7	1.00	1.000
691	1FWHEP-HCV-100C	7.499E-4	3.236E-7	1.00	1.000
700	HEP-0AP12-30HR	6.565E-3	1.723E-7	1.00	1.000

TABLE D.7-2
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
HEPs INDIVIDUALLY SET EQUAL TO ONE

Basic Event Name	Point Estimate	Core Damage Frequency When HEPs = 1	% Increase In CDF When HEPs = 1
HEP-1AP22:5	1.8E-4	1.3E-2	19,237
HEP-0AP55-20HR	2.6E-4	9.7E-3	14,142
HEP-0AP55-10HR	5.0E-3	1.0E-3	1423
HEP-1ES1:4	8.5E-4	5.7E-4	742
HEP-1ES1:2-S2	8.5E-4	4.4E-4	544
HEP-1ECA3:1-16	3.0E-3	2.8E-4	317
1FWHEP-1FW548	7.5E-4	2.7E-4	296
1FWHEP-1FW546	7.5E-4	2.6E-4	289
1RSHEP-FLANGE	3.8E-4	2.5E-4	266
HEP-1FRH:1-11	4.8E-2	2.2E-4	229
1FWHEP-1FW543	7.5E-4	2.1E-4	209
HEP-1E3-3	3.7E-3	2.1E-4	203
HEP-1E3-13	2.2E-2	1.9E-4	174
HEP-1ECA3:2-5	7.3E-4	1.8E-4	168
HEP-1FRC:1-11-S2	8.3E-3	1.5E-4	124
HEP-1E0-7	1.4E-3	1.5E-4	122
HEP-1FRH:1-15	8.3E-3	1.4E-4	99
HEP-1ES1:3	1.2E-2	1.2E-4	76
1QSHEP-FLANGE	3.8E-4	9.9E-5	45
HEP-1OP14:1-5:13	4.3E-3	9.5E-5	40
HEP-1OP21:6	1.1E-3	7.9E-5	16
HEP-1OP49:1	1.3E-1	7.9E-5	16

TABLE D.7-2 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
HEPs INDIVIDUALLY SET EQUAL TO ONE

Basic Event Name	Point Estimate	Core Damage Frequency When HEPs = 1	% Increase In CDF When HEPs = 1
HEP-1FRH:1-5____	3.1E-3	7.6E-5	12
HEP-0AP55-40HR__	1.3E-1	7.6E-5	12
HEP-1AP15-1E____	7.8E-4	7.5E-5	11
HEP-1AP15-6_____	2.8E-2	7.5E-5	10
HEP-0AP12-20HR__	2.6E-4	7.4E-5	8
HEP-0AP55-30HR__	6.6E-3	7.1E-5	5
HEP-1E1-25______	8.1E-3	7.1E-5	5
HEP-1ECA3:3-27	9.0E-2	7.0E-5	4
HEP-1ECA3:3-35	4.9E-3	7.1E-5	4
HEP-1FRS:1-5____	3.0E-2	6.9E-5	2
1QSHEP-1QS5_____	7.5E-4	6.8E-5	1
1QSHEP-1QS21____	7.5E-4	6.8E-5	1
HEP-0AP10_______	5.3E-3	6.9E-5	1
HEP-0AP12-10HR__	5.0E-3	6.8E-5	1
HEP-1E0-22______	1.9E-2	6.8E-5	1
1FWHEP-HCV-100C_	7.5E-4	6.8E-5	0
1FWHEP-MOV-100B_	7.5E-4	6.8E-5	0
1FWHEP-MOV-100D_	7.5E-4	6.8E-5	0
HEP-0AP12-30HR__	6.6E-3	6.8E-5	0
HEP-0AP12-40HR__	1.3E-1	6.8E-5	0
HEP-1AP33:1_____	3.9E-1	6.8E-5	0
HEP-1FRC:1-11-S1	1.0E+0	6.8E-5	0

TABLE D.7-2 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
HEPs INDIVIDUALLY SET EQUAL TO ONE

Basic Event Name	Point Estimate	Core Damage Frequency When HEPs = 1	% Increase In CDF When HEPs = 1
HEP-NO-PROCEDURE	1.0E+0	6.8E-5	0
HEP-1ES1:2-S1___	1.0E+0	6.8E-5	0
HEP-1E0-14______	1.0E+0	6.8E-5	0
HEP-1E0-15_____	1.1E-3	6.8E-5	0
1CHHEP-MOV-1270A	1.1E-4	**	*
1CHHEP-MOV-1275A	7.5E-4	*	*
1CHHEP-MOV-1275B	7.5E-4	*	*
1CHHEP-MOV-1373	7.5E-4	*	*
1RSHEP-ELBOW____	3.8E-4	*	*
1RSHEP-MOV-155A_	7.5E-4	*	*
1RSHEP-MOV-155B_	7.5E-4	*	*
1RSHEP-1RS12____	7.5E-4	*	*
1RSHEP-1RS22____	7.5E-4	*	*
HEP-0AP12-ATTCH4	1.6E-4	*	*
HEP-1AP49_______	1.3E-2	*	*
HEP-1E0-1_______	1.4E-3	*	*
HEP-1E0-8_______	1.4E-3	*	*
HEP-1E0-11______	1.4E-3	*	*
HEP-1E0-12______	1.4E-3	*	*
HEP-1E0-13______	1.4E-3	*	*
HEP-1E0-16______	8.0E-3	*	*

TABLE D.7-2 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
HEPs INDIVIDUALLY SET EQUAL TO ONE

Basic Event Name	Point Estimate	Core Damage Frequency When HEPs = 1	% Increase In CDF When HEPs = 1
HEP-1E0-ATTACH:1	7.7E-3	*	*
HEP-1FRS:1-4____	7.6E-3	*	*
HEP-0OP49:4A____	6.3E-2	*	*

* = HEP basic events not found in cut sets greater than 1E-11.
** = HEP basic event not included in fault trees.

TABLE D.7-3
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
ALL HEPs SET EQUAL TO ONE

Accident Initiator	CDF per year using NAPS IPE HEPs (% of total)	CDF per year using HEPs Equal To One (% of total)
S2	1.01E-5 (14.8%)	7.13E-2 (2.7%)
T1A	7.98E-6 (11.7)	5.18E-4 (0.0%)
T1TR	7.27E-6 (10.7%)	1.16E-3 (0.0%)
T7	7.02E-6 (10.3%)	1.22E-1 (4.6%)
S1	6.64E-6 (9.8%)	7.12E-5 (0.0%)
T8	6.56E-6 (9.7%)	7.47E-2 (2.8%)
T1	4.60E-6 (6.8%)	8.96E-1 (33.9%)
A	4.09E-6 (6.0%)	1.03E-3 (0.0%)
T3TR	4.06E-6 (6.0%)	1.28E-2 (0.5%)
T9ATR	3.26E-6 (4.8%)	1.57E-2 (0.6%)
T2ATR	1.65E-6 (2.4%)	5.12E-3 (0.2%)
VX	1.60E-6 (2.4%)	1.68E-6 (0.0%)
T2	8.86E-7 (1.3%)	3.81E-1 (12.0%)
T9B	5.81E-7 (0.9%)	1.19E-3 (0.0%)
TH	4.20E-7 (0.6%)	1.87E-6 (0.0%)
T9A	4.15E-0 (0.6%)	1.57E-4 (0.0%)
RX	2.68E-7 (0.4%)	8.00E-7 (0.0%)
T2TR	1.44E-7 (0.2%)	8.48E-5 (0.0%)
T5A	1.11E-7 (0.2%)	3.72E-4 (0.0%)
T5B	1.09E-7 (0.2%)	3.72E-4 (0.0%)
T3	7.61E-8 (0.1%)	7.54E-3 (0.3%)
T9BTR	6.78E-8 (0.1%)	1.55E-6 (0.0%)
T2A	6.11E-8 (0.1%)	1.12E+0 (42.2%)
T4	1.07E-8 (0.0%)	2.00E-6 (0.0%)
T6	4.52E-9 (0.0%)	3.04E-5 (0.0%)
TL	0.00E+0 (0.0%)	0.00E+0 (0.0%)

TABLE D.7-4
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
IMPORTANCE ANALYSIS ALL HEPs SET EQUAL TO ONE

Rank	Event Name	Point Estimate	Fessell-Vesely Importance	Risk Achievement Worth	Risk Reduction Worth
1	HEP-1AP22:5	1.000E+0	8.491E-1	1.00	6.625
2	HEP-1FRH:1-15	1.000E+0	4.653E-1	1.00	1.870
3	HEP-1FRH:1-11	1.000E+0	4.594E-1	1.00	1.850
5	HEP-1FRH:1-5	1.000E+0	4.206E-1	1.00	1.726
9	1RSHEP-FLANGE	1.000E+0	1.560E-1	1.00	1.185
10	1QSHEP-FLANGE	1.000E+0	1.339E-1	1.00	1.155
12	1FWHEP-1FW546	1.000E+0	9.118E-2	1.00	1.100
13	1FWHEP-1FW548	1.000E+0	8.828E-2	1.00	1.097
14	1FWHEP-1FW543	1.000E+0	7.795E-2	1.00	1.085
21	HEP-0AP55-20HR	1.000E+0	2.074E-2	1.00	1.021
22	HEP-1E3-3	1.000E+0	1.829E-2	1.00	1.019
23	HEP-0AP55-10HR	1.000E+0	1.472E-2	1.00	1.015
24	HEP-1ES1:3	1.000E+0	1.394E-2	1.00	1.014
26	HEP-1ES1:2-S2	1.000E+0	1.064E-2	1.00	1.011
27	HEP-1OP21:6	1.000E+0	8.045E-3	1.00	1.008
28	HEP-0AP55-40HR	1.000E+0	7.910E-3	1.00	1.008
32	HEP-1E0-15	1.000E+0	6.930E-3	1.00	1.007
42	HEP-1E3-13	1.000E+0	4.171E-3	1.00	1.004
45	HEP-1ECA3:2-5	1.000E+0	3.812E-3	1.00	1.004
47	HEP-1ECA3:1-16	1.000E+0	3.741E-3	1.00	1.004
51	HEP-0AP55-30HR	1.000E+0	2.721E-3	1.00	1.003
54	1FWHEP-MOV-100D	1.000E+0	2.490E-3	1.00	1.002
59	1FWHEP-MOV-100B	1.000E+0	1.450E-3	1.00	1.001
66	HEP-1OP14:1-5:13	1.000E+0	6.272E-4	1.00	1.001
68	HEP-NO-PROCEDURE	1.000E+0	6.174E-4	1.00	1.001
72	HEP-1ES1:4	1.000E+0	3.797E-4	1.00	1.000
80	1QSHEP-1QS5	1.000E+0	2.794E-4	1.00	1.000
87	1QSHEP-1QS21	1.000E+0	1.984E-4	1.00	1.000
91	HEP-1AP15-1E	1.000E+0	1.723E-4	1.00	1.000
99	HEP-1E0-7	1.000E+0	1.406E-4	1.00	1.000
102	HEP-1FRC:1-11-S2	1.000E+0	1.340E-4	1.00	1.000
104	HEP-1E1-25	1.000E+0	1.296E-4	1.00	1.000
117	HEP-1AP15-6	1.000E+0	1.086E-4	1.00	1.000
160	HEP-1ECA3:3-27	1.000E+0	3.682E-5	1.00	1.000
172	HEP-1OP49:1	1.000E+0	2.575E-5	1.00	1.000
189	HEP-1ECA3:3-35	1.000E+0	1.775E-5	1.00	1.000
214	HEP-1ES1:2-S1	1.000E+0	1.007E-5	1.00	1.000
219	1FWHEP-HCV-100C	1.000E+0	9.114E-6	1.00	1.000
245	HEP-1FRC:1-11-S1	1.000E+0	6.221E-6	1.00	1.000
262	HEP-0AP12-10HR	1.000E+0	5.097E-6	1.00	1.000
267	HEP-0AP10	1.000E+0	4.137E-6	1.00	1.000
271	HEP-0AP12-20HR	1.000E+0	4.033E-6	1.00	1.000

TABLE D.7-4 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
IMPORTANCE ANALYSIS ALL HEPs SET EQUAL TO ONE

Rank	Event Name	Point Estimate	Fessell-Vesely Importance	Risk Achievement Worth	Risk Reduction Worth
293	HEP-0AP12-40HR	1.000E+0	2.151E-6	1.00	1.000
309	HEP-1E0-22	1.000E+0	1.599E-6	1.00	1.000
316	HEP-1E0-14	1.000E+0	1.529E-6	1.00	1.000
347	HEP-1AP33:1	1.000E+0	5.141E-7	1.00	1.000

TABLE D.7-5
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T2AP15	5.53E-1	1.23E-8	T2A L M P
T2AP10	5.52E-1	4.55E-8	T2A L M D1
T1P10	2.56E-1	2.71E-6	T1 L D1
T1P15	1.44E-1	5.16E-7	T1 L P
T1P19	1.15E-1	1.91E-7	T1 L P Qs
T1P14	1.15E-1	2.07E-7	T1 L D1 Qs
T1P18	1.14E-1	1.30E-10	T1 L P Rs
T1P13	1.14E-1	7.42E-10	T1 L D1 Rs
T2P09	5.81E-2	7.22E-7	T2 L D1
T2P14	5.79E-2	1.30E-7	T2 L P
T2P13	5.02E-2	1.42E-9	T2 L D1 Qs
T2P18	5.02E-2	3.26E-10	T2 L P Qs
T2P12	5.01E-2	2.53E-10	T2 L D1 Rs
T2P17	5.01E-2	4.53E-11	T2 L P Rs
S2P26	4.54E-2	5.45E-8	S2 L P
T7P14	2.45E-2	3.15E-8	T7 L SGI
T7P15	2.42E-2	2.59E-8	T7 L P
S2P28	2.34E-2	1.34E-10	S2 L P Rs
T7P10	1.39E-2	1.04E-9	T7 L Rs
T8P22	1.38E-2	3.17E-6	T8 Lt RC1
T7P19	1.29E-2	2.60E-10	T7 L P SGI
T1P16	1.23E-2	4.39E-9	T1 L P H1
T7P18	1.22E-2	6.48E-11	T7 L P Qs
T7P17	1.21E-2	9.25E-12	T7 L P Rs
T1P11	1.19E-2	2.21E-8	T1 L D1 H1
T1P07	1.16E-2	5.66E-7	T1 L H2 H1
T2AP05	1.04E-2	3.37E-12	T2A L M Rs
T7P07	1.01E-2	1.10E-7	T7 SGI O2
T7P04	9.89E-3	2.98E-6	T7 O O2
T9ATrP02	7.29E-3	8.33E-7	T9ATr RC2
T8P25	7.23E-3	1.13E-8	T8 Lt RC1 Qs
T8P26	7.19E-3	2.02E-8	T8 Lt RC1 RC3
T8P24	7.19E-3	1.29E-9	T8 Lt RC1 Rs
T8P10	5.99E-3	1.05E-8	T8 O Rs
T8P20	5.99E-3	8.72E-10	T8 O RC2 RC3
T8P06	5.97E-3	6.06E-7	T8 RC2 RC3
T8P05	5.65E-3	6.35E-9	T8 RC2 Qs
T8P16	5.24E-3	7.70E-9	T8 O RC2
T8P04	5.22E-3	9.19E-10	T8 RC2 Rs
T8P02	5.22E-3	2.52E-6	T8 RC2
T3TrP06	4.24E-3	2.83E-7	T3Tr RC2 RC3
T3TrP11	4.02E-3	1.67E-6	T3Tr O D1

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T3P15	3.88E-3	1.92E-8	T3 L M P
T3TrP02	3.68E-3	5.83E-8	T3Tr RC2
T3P10	3.60E-3	4.87E-8	T3 L M D1
T9ATrP06	2.95E-3	1.07E-7	T9ATr RC2 RC3
T1P05	2.11E-3	2.55E-10	T1 L Rs
T9ATrP14	2.04E-3	3.88E-7	T9ATr O H1
T9ATrP08	1.78E-3	1.53E-6	T9ATr Lt RC1
T2ATrP06	1.72E-3	1.90E-11	T2ATr RC2 RC3
T2ATrP11	1.63E-3	6.78E-7	T2ATr O D1
T2ATrP02	1.50E-3	1.98E-8	T2ATr RC2
T7P06	1.16E-3	1.10E-6	T7 SGI W
T7P03	1.14E-3	1.98E-6	T7 O W
T9ATrP22	9.80E-4	2.01E-8	T9ATr O RC1
T2P04	9.47E-4	9.38E-11	T2 L Rs
T1TrP17	8.36E-4	4.00E-6	T1Tr O D1
T9ATrP16	5.68E-4	9.42E-10	T9ATr O Rs
T3TrP22	5.53E-4	1.21E-7	T3Tr Lt RC1
AP07	5.02E-4	1.69E-9	A Qs Dh
AP02	5.00E-4	5.17E-7	A Dh
S2P22	4.81E-4	4.37E-11	S2 L Rs
S2P47	4.18E-4	3.27E-7	S2 D1 L
S2P16	4.00E-4	3.50E-10	S2 Fm O Rs
T9BP06	3.97E-4	1.78E-8	T9B L Qs
T9BP02	3.97E-4	2.37E-7	T9B L
T1TrP14	3.08E-4	1.01E-6	T1Tr O H1
T1AP16	2.71E-4	3.22E-9	T1A Slc Rs
T9BP03	2.24E-4	1.15E-8	T9B L H1
T2ATrP22	1.92E-4	4.75E-8	T2ATr Lt RC1
T1P06	1.78E-4	1.69E-7	T1 L H2
T1P17	1.78E-4	3.50E-10	T1 L P Ch
T1P12	1.76E-4	1.48E-9	T1 L D1 Ch
T9BP05	1.62E-4	1.26E-10	T9B L Rs
T5BP06	1.57E-4	9.33E-9	T5B L Qs
T5AP06	1.57E-4	9.63E-9	T5A L Qs
T9AP02	1.51E-4	1.72E-7	T9A L
T5BP02	1.40E-4	9.37E-8	T5B L
T5AP02	1.40E-4	9.36E-8	T5A L
S2P50	1.30E-4	1.20E-4	S2 D1 L Qs
S2P49	1.20E-4	7.28E-11	S2 D1 L Rs
S2P43	1.19E-4	1.19E-6	S2 D1 Y
S2P35	1.19E-4	5.15E-6	S2 D1 D3
S2P46	1.18E-4	9.83E-9	S2 D1 Y Qs

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
S2P45	1.18E-4	4.41E-10	S2 D1 Y Rs
S2P38	1.12E-4	3.26E-8	S2 D1 D3 Qs
S2P37	1.12E-4	2.02E-9	S2 D1 D3 Rs
T2P06	1.03E-4	2.43E-8	T2 L H2 H1
T3TrP10	9.87E-5	1.27E-8	T3Tr O Rs
T2P15	8.40E-5	1.44E-10	T2 L P H1
T9ATrP17	8.00E-5	3.07E-7	T9ATr O D1
T2P16	7.81E-5	1.54E-10	T2 L P Ch
T2P11	7.81E-5	8.98E-10	T2 L D1 Ch
T5AP05	7.14E-5	6.05E-11	T5A L Rs
T5BP05	7.14E-5	6.05E-11	T5B L Rs
S2P17	6.76E-5	9.02E-8	S2 Fm O H2
T1AP51	6.56E-5	2.99E-6	T1A Lt B B1
T2TrP02	6.42E-5	1.29E-9	T2Tr RC2
T1P09	6.09E-5	1.32E-9	T1 L H2 Rs
T1AP55	5.58E-5	8.08E-9	T1A Lt B B1 Qs
T1AP54	5.58E-5	1.11E-9	T1A Lt B B1 Rs
T2P10	5.07E-5	2.16E-9	T2 L D1 H1
S2P23	4.99E-5	1.20E-8	S2 L H2
T7P26	4.80E-5	3.85E-7	T7 D1 SGI
T7P23	4.77E-5	1.80E-7	T7 D1 O D3
T7P25	4.71E-5	8.44E-8	T7 D1 O O2
T3P05	4.63E-5	3.04E-12	T3 L M Rs
T9ATrP05	4.15E-5	1.17E-8	T9ATr RC2 Qs
T8P11	3.29E-5	9.57E-8	T8 O D1
S2P27	3.28E-5	6.45E-11	S2 L P Ch
T3TrP15	3.16E-5	5.09E-9	T3Tr O D1 Qs
T3TrP14	3.15E-5	6.08E-10	T3Tr O D1 Rs
T3TrP20	3.14E-5	1.76E-9	T3Tr O RC2 RC3
T1AP46	3.09E-5	1.41E-6	T1A Lt B
S2P19	3.06E-5	2.85E-9	S2 Fm O H2 Rs
T3TrP16	2.75E-5	1.44E-8	T3Tr O RC2
T2P08	2.57E-5	8.24E-10	T2 L H2 Rs
T7P11	2.35E-5	5.62E-9	T7 L H2
S2P09	2.02E-5	1.40E-11	S2 O Rs
S2P03	2.02E-5	7.56E-9	S2 Rs
S1P09	2.00E-5	7.50E-9	S1 O Rs
S1P15	2.00E-5	1.31E-12	S1 L Rs
T7P09	1.74E-5	4.13E-9	T7 L Ch
T8P08	1.66E-5	5.85E-8	T8 O H1
T7P16	1.54E-5	3.04E-11	T7 L P Ch
T2ATrP10	1.54E-5	5.15E-9	T2ATr O Rs

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T1TrP16	1.52E-5	1.10E-8	T1Tr O Rs
T2ATrP15	1.29E-5	2.07E-9	T2ATr O D1 Qs
T2ATrP14	1.28E-5	2.48E-10	T2ATr O D1 Rs
T2ATrP20	1.28E-5	8.18E-10	T2ATr O RC2 RC3
S2P25	1.14E-5	3.65E-10	S2 L H2 Rs
T2ATrP16	1.12E-5	5.989E-9	T2ATr O RC2
T2TrP22	1.07E-5	2.91E-9	T2Tr Lt RC1
T8P15	1.07E-5	4.93E-11	T8 O D1 Qs
T8P14	1.07E-5	1.52E-11	T8 O D1 Rs
T3TrP23	1.02E-5	1.84E-7	T3Tr Lt RC1 Ch
AP10	1.01E-5	1.21E-10	A Qs Rs
AP05	1.00E-5	4.28E-9	A Rs
T3P07	9.98E-6	1.15E-9	T3 L M H2 H1
T8P09	9.54E-6	3.90E-8	T8 O Ch
T2P05	9.18E-6	2.28E-9	T2 L H2
T8P03	8.30E-6	1.01E-8	T8 RC2 Ch
T1AP37	8.25E-6	2.36E-10	T1A Lt L P
T3TrP05	7.58E-6	3.84E-9	T3Tr RC2 Qs
T3TrP04	7.51E-6	5.89E-10	T3Tr RC2 Rs
T3TrP03	7.51E-6	1.57E-6	T3Tr RC2 Ch
T3TrP17	7.44E-6	5.90E-9	T3Tr O RC2 Ch
T6P08	6.85E-6	2.89E-9	T6 Lt RC1
T6P22	6.29E-6	1.08E-10	T6 O RC1
T6P16	6.29E-6	8.16E-12	T6 O Rs
T9BP10	5.73E-6	1.79E-7	T9 B Q H2
S1P42	5.70E-6	1.36E-8	S1 D1 L
T6P06	5.69E-6	1.85E-10	T6 RC2 RC3
S1P38	5.68E-6	4.04E-6	S1 D1 Y
S1P41	5.56E-6	1.53E-8	S1 D1 Y Qs
T3TrP26	5.50E-6	9.96E-10	T3Tr Lt RC1 RC3
S1P40	5.38E-6	1.67E-9	S1 D1 Y Rs
T7P13	5.37E-6	1.72E-10	T7 L H2 Rs
T9ATrP19	5.34E-6	1.69E-8	T9ATr O D1 Ch
T6P02	4.97E-6	1.29E-9	T6 RC2
S2P04	4.37E-6	2.45E-6	S2 H1
S1P10	4.25E-6	2.45E-6	S1 O H2
T2ATrP23	4.16E-6	7.51E-8	T2ATr Lt RC1 Ch
T2AP07	4.07E-6	4.69E-10	T2A L M H2 H1
T9ATrP11	3.82E-6	1.89E-8	T9ATr Lt RC1 Qs
T1AP26	3.69E-6	1.04E-7	T1A Slc B B1
T7P22	3.61E-6	3.10E-8	T7 D1 O W
S2P06	3.54E-6	5.13E-8	S2 H1 Rs

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T3TrP08	3.53E-6	6.67E-8	T3Tr O H1
T3TrP25	3.48E-6	1.35E-10	T3Tr Lt RC1 Qs
T3TrP24	3.46E-6	6.74E-11	T3Tr Lt RC1 Rs
T5AP03	3.45E-6	3.56E-9	T5A L H1
T1AP29	3.42E-6	3.61E-11	T1A Slc B B1 Rs
T1AP30	3.42E-6	3.61E-11	T1A Slc B B1 Qs
T5BP03	3.40E-6	3.51E-9	T5B L H1
T1P04	3.36E-6	9.95E-10	T1 L Ch
T2ATrP05	3.08E-6	1.56E-9	T2ATr RC2 Qs
T2ATrP04	3.06E-6	2.40E-10	T2ATr RC2 Rs
T2ATrP03	3.06E-6	6.40E-7	T2ATr RC2 Ch
T9AP10	3.05E-6	1.31E-7	T9A Q H2
T2ATrP17	3.03E-6	2.40E-9	T2ATr O RC2 Ch
S1P12	2.83E-6	5.09E-8	S1 O H2 Rs
T9AP06	2.81E-6	6.25E-9	T9A L Qs
T1TrP21	2.47E-6	2.22E-6	T1Tr O D1 Qs
T9BP12	2.41E-6	3.47E-11	T9B Q H2 Rs
S2P31	2.27E-6	5.99E-10	S2 D1 Rs
T7P27	2.25E-6	7.20E-8	T7 D1 L
AP20	2.13E-6	7.68E-9	A D2 Qs
AP16	2.12E-6	2.07E-9	A D2 Dh
AP15	2.12E-6	2.12E-6	A D2
S2P10	2.07E-6	3.84E-9	S2 O H2
T2TrP11	2.06E-6	6.06E-8	T2Tr O D1
T1P21	1.84E-6	8.17E-8	T1 Q H1
AP03	1.78E-6	8.26E-7	A H1
T7P28	1.74E-6	8.03E-10	T7 D1 L SGI
T1AP22	1.74E-6	4.89E-8	T1A Slc B
S1P16	1.60E-6	3.37E-10	S1 L H2
T2ATrP26	1.55E-6	3.83E-10	T2ATr Lt RC1 RC3
VXP07	1.52E-6	1.52E-6	VX Fm
T2P03	1.50E-6	3.94E-10	T2 L Ch
T1AP24	1.47E-6	1.55E-11	T1A Slc B Rs
T1AP25	1.47E-6	1.55E-11	T1A Slc B Qs
T1AP07	1.38E-6	1.38E-6	T1A B B1
T1AP11	1.32E-6	1.43E-9	T1A B B1 Qs
T1AP10	1.32E-6	4.94E-10	T1A B B1 Rs
T1AP50	1.29E-6	3.27E-9	T1A Lt B Qs
T1AP49	1.28E-6	4.81E-10	T1A Lt B Rs
THP46	1.26E-6	2.14E-7	TH K M Tt Q
T2TrP15	1.17E-6	1.87E-10	T2Tr O D1 Qs
T2TrP20	1.16E-6	7.43E-11	T2Tr O RC2 RC3

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T2TrP14	1.16E-6	2.10E-11	T2Tr O D1 Rs
T1AP41	1.16E-6	5.41E-10	T1A Lt L D1
T2ATrP25	1.15E-6	4.08E-11	T2ATr Lt RC1 Qs
T2ATrP24	1.15E-6	2.70E-11	T2ATr Lt RC1 Rs
T1AP14	1.13E-6	3.18E-8	T1A Slc H1
T2TrP10	1.10E-6	4.67E-10	T2Tr O Rs
T2TrP16	1.02E-6	5.31E-10	T2Tr O RC2
T8P23	9.97E-7	5.61E-9	T8 Lt RC1 Ch
AP08	9.97E-7	1.90E-9	A Qs H1
T1AP67	8.86E-7	8.86E-7	T1A Q B B1
T1AP71	8.45E-7	2.37E-9	T1A Q B B1 Qs
T1AP70	8.42E-7	3.16E-10	T1A Q B B1 Rs
T1P24	8.00E-7	2.13E-11	T1 Q Rs
T8P12	7.83E-7	3.21E-9	T8 O D1 H1
T4P17	7.74E-7	3.06E-9	T4 O Y
S2P21	7.39E-7	1.75E-10	S2 L Ch
S2P39	7.33E-7	5.20E-7	S2 D1 D2
T1AP02	6.51E-7	6.51E-7	T1A B
S2P15	6.38E-7	1.18E-9	S2 Fm O Ch
T2TrP06	6.28E-7	8.32E-9	T2Tr RC2 RC3
T4P08	6.05E-7	5.84E-9	T4 O D3
T1AP06	6.03E-7	2.26E-10	T1A B Qs
T1AP05	6.03E-7	2.26E-10	T1A B Rs
T4P22	6.00E-7	1.43E-10	T4 L
AP11	5.88E-7	5.88E-7	A D3
AP14	5.67E-7	1.81E-9	A D3 Qs
AP13	5.65E-7	2.24E-10	A D3 Rs
T1TrP19	5.39E-7	1.20E-8	T1Tr O D1 Ch
S2P42	5.18E-7	3.46E-10	S2 D1 D2 Qs
S2P41	5.18E-7	1.82E-10	S2 D1 D2 Rs
T2ATrP08	4.73E-7	2.71E-8	T2ATr O H1
T9BTrP14	4.65E-7	2.53E-8	T9BTr O H1
T9BTrP16	4.45E-7	1.67E-10	T9BTr O Rs
T9BTrP22	4.21E-7	2.08E-9	T9BTr O RC1
T9BP04	4.20E-7	5.44E-10	T9B L Ch
T1AP58	4.17E-7	4.17E-7	T1A Q B
T1AP15	4.06E-7	1.14E-8	T1A Slc Ch
T1AP61	3.97E-7	1.49E-10	T1A Q B Rs
T2TrP23	3.78E-7	6.82E-9	T2Tr Lt RC1 Ch
T6P12	3.60E-7	1.17E-11	T6 Lt RC1 RC3
T7P24	2.85E-7	1.86E-8	T7 D1 O D2
T2TrP03	2.78E-7	5.82E-8	T2Tr RC2 Ch

TABLE D.7-5 (Continued)
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
SEQUENCES WHEN ALL HEPs SET EQUAL TO ONE

Sequence	CDF with HEPs = 1 (per year)	CDF with HEPs = IPE values (per year)	Functional Failures
T2TrP05	2.78E-7	1.42E-10	T2Tr RC2 Qs
T2TrP04	2.77E-7	2.15E-11	T2Tr RC2 Rs
T2TrP17	2.75E-7	2.17E-10	T2Tr O RC2 Ch
RXP04	2.67E-7	9.71E-10	RX Qs
RXP03	2.66E-7	1.13E-10	RX Rs
RXP01	2.66E-7	2.66E-7	RX
T5BP04	2.40E-7	2.89E-10	T5B L Ch
T5AP04	2.40E-7	2.89E-10	T5A L Ch
THP30	2.06E-7	2.06E-7	TH K M Pr
THP32	2.06E-7	7.72E-11	TH K M Pr Rs
THP33	2.06E-7	7.72E-11	TH K M Pr Qs
T9BP13	2.04E-7	1.30E-7	T9B Q D1
S2P32	1.72E-7	9.12E-8	S2 D1 H1
T9AP13	1.35E-7	1.02E-7	T9A Q D1
S2P44	1.13E-7	1.26E-9	S2 D1 Y Ch
T9BTrP06	1.09E-7	2.71E-9	T9BTr RC2 RC3

TABLE D.7-6
HUMAN ERROR PROBABILITIES COMPARISON
12 HOUR AND 8 HOUR SHIFTS

North Anna IPE Basic Event Name	Operators On 12 Hour Shifts Point Estimate	Operators On 8 Hour Shifts Point Estimate
1CHHEP-MOV-1270A	1.1E-4	1.1E-4
1CHHEP-MOV-1275A	7.5E-4	3.8E-4
1CHHEP-MOV-1275B	7.5E-4	3.8E-4
1CHHEP-MOV-1373	7.5E-4	3.8E-4
1FWHEP-HCV-100C	7.5E-4	3.8E-4
1FWHEP-MOV-100B	7.5E-4	3.8E-4
1FWHEP-MOV-100D	7.5E-4	3.8E-4
1FWHEP-1FW543	7.5E-4	3.8E-4
1FWHEP-1FW546	7.5E-4	3.8E-4
1FWHEP-1FW548	7.5E-4	3.8E-4
1QSHEP-FLANGE	3.8E-4	3.8E-4
1QSHEP-1QS5	7.5E-4	3.8E-4
1QSHEP-1QS21	7.5E-4	3.8E-4
1RSHEP-ELBOW	3.8E-4	3.8E-4
1RSHEP-FLANGE	3.8E-4	3.8E-4
1RSHEP-MOV-155A	7.5E-4	3.8E-4
1RSHEP-MOV-155B	7.5E-4	3.8E-4
1RSHEP-1RS12	7.5E-4	3.8E-4
1RSHEP-1RS22	7.5E-4	3.8E-4
HEP-0AP10	5.3E-3	5.2E-3
HEP-0AP12-10HR	5.0E-3	4.8E-3
HEP-0AP12-20HR	2.6E-4	1.4E-4

TABLE D.7-6 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
12 HOUR AND 8 HOUR SHIFTS

North Anna IPE Basic Event Name	Operators On 12 Hour Shifts Point Estimate	Operators On 8 Hour Shifts Point Estimate
HEP-0AP12-30HR	6.6E-3	3.8E-3
HEP-0AP12-40HR	1.3E-1	1.3E-1
HEP-0AP12-ATTCH4	1.6E-4	8.6E-5
HEP-1AP15-1E	7.8E-4	4.1E-4
HEP-1AP15-6	2.8E-2	2.8E-2
HEP-1AP22:5	1.8E-4	1.4E-4
HEP-1AP33:1	3.9E-1	3.9E-1
HEP-1AP49	1.3E-2	9.7E-3
HEP-0AP55-10HR	5.0E-3	4.8E-3
HEP-0AP55-20HR	2.6E-4	1.4E-4
HEP-0AP55-30HR	6.6E-3	3.8E-3
HEP-0AP55-40HR	1.3E-1	1.3E-1
HEP-1E0-1	1.4E-3	7.3E-4
HEP-1E0-7	1.4E-3	7.3E-4
HEP-1E0-8	1.4E-3	7.3E-4
HEP-1E0-11	1.4E-3	7.3E-4
HEP-1E0-12	1.4E-3	7.3E-4
HEP-1E0-13	1.4E-3	7.3E-4
HEP-1E0-14	1.0E+0	1.0E+0
HEP-1E0-15	1.1E-3	4.8E-4
HEP-1E0-16	8.0E-3	4.3E-3
HEP-1E0-22	1.9E-2	1.5E-2

TABLE D.7-6 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
12 HOUR AND 8 HOUR SHIFTS

North Anna IPE Basic Event Name	Operators On 12 Hour Shifts Point Estimate	Operators On 8 Hour Shifts Point Estimate
HEP-1E0-ATTACH:1	7.7E-3	4.0E-3
HEP-1E1-25	8.1E-3	4.4E-3
HEP-1E3-3	3.7E-3	2.4E-3
HEP-1E3-13	2.2E-2	1.4E-2
HEP-1ECA3:1-16	3.0E-3	3.0E-3
HEP-1ECA3:2-5	7.3E-4	6.6E-4
HEP-1ECA3:3-27	9.0E-2	8.9E-2
HEP-1ECA3:3-35	4.9E-3	4.9E-3
HEP-1ES1:2-S1	1.0E+0	1.0E+0
HEP-1ES1:2-S2	8.5E-4	4.8E-4
HEP-1ES1:3	1.2E-2	8.5E-3
HEP-1ES1:4	8.5E-4	4.8E-4
HEP-1FRC:1-11-S1	1.0E+0	1.0E+0
HEP-1FRC:1-11-S2	8.3E-3	7.9E-3
HEP-1FRH:1-5	3.1E-3	2.5E-3
HEP-1FRH:1-11	4.8E-2	4.8E-2
HEP-1FRH:1-15	8.3E-3	7.9E-3
HEP-1FRS:1-4	7.6E-3	3.9E-3
HEP-1FRS:1-5	3.0E-2	2.6E-2
HEP-1OP14:1-5:13	4.3E-3	3.9E-2
HEP-1OP21:6	1.1E-3	5.4E-4
HEP-1OP49:1	1.3E-1	1.3E-1

TABLE D.7-6 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
12 HOUR AND 8 HOUR SHIFTS

North Anna IPE Basic Event Name	Operators On 12 Hour Shifts Point Estimate	Operators On 8 Hour Shifts Point Estimate
HEP-OOP49:4A	6.3E-2	6.3E-2
HEP-NO-PROCEDURE	1.0E+0	1.0E+0

TABLE D.7-7
HUMAN ERROR PROBABILITIES COMPARISON
NORTH ANNA AND SURRY IPEs

Basic Event Name	North Anna IPE Point Estimate	Surry IPE Point Estimate
1CHHEP-MOV-1270A	1.1E-4	1.1E-4
1CHHEP-MOV-1275A	7.5E-4	9.9E-4
1CHHEP-MOV-1275B	7.5E-4	9.9E-4
1CHHEP-MOV-1373	7.5E-4	9.9E-4
1FWHEP-HCV-100C	7.5E-4	8.0E-4
1FWHEP-MOV-100B	7.5E-4	8.0E-4
1FWHEP-MOV-100D	7.5E-4	8.0E-4
1FWHEP-1FW543	7.5E-4	none
1FWHEP-1FW546	7.5E-4	none
1FWHEP-1FW548	7.5E-4	none
1QSHEP-FLANGE	3.8E-4	8.0E-5
1QSHEP-1QS5	7.5E-4	8.0E-4
1QSHEP-1QS21	7.5E-4	8.0E-5
1RSHEP-ELBOW	3.8E-4	8.0E-5
1RSHEP-FLANGE	3.8E-4	8.0E-5
1RSHEP-MOV-155A	7.5E-4	none
1RSHEP-MOV-155B	7.5E-4	none
1RSHEP-1RS12	7.5E-4	8.0E-4
1RSHEP-1RS22	7.5E-4	8.0E-4
HEP-0AP10	5.3E-3	none
HEP-0AP12-10HR	5.0E-3	none
HEP-0AP12-20HR	2.6E-4	none

TABLE D.7-7 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
NORTH ANNA AND SURRY IPEs

Basic Event Name	North Anna IPE Point Estimate	Surry IPE Point Estimate
HEP-0AP12-30HR	6.6E-3	none
HEP-0AP12-40HR	1.3E-1	none
HEP-0AP12-ATTCH4	1.6E-4	2.7E-3
HEP-1AP15-1E	7.8E-4	2.7E-3
HEP-1AP15-6	2.8E-2	none
HEP-1AP22:5	1.8E-4	2.7E-3
HEP-1AP33:1	3.9E-1	none
HEP-1AP49	1.3E-2	1.4E-3
HEP-0AP55-10HR	5.0E-3	2.7E-2
HEP-0AP55-20HR	2.6E-4	none
HEP-0AP55-30HR	6.6E-3	none
HEP-0AP55-40HR	1.3E-1	none
HEP-1E0-1	1.4E-3	1.4E-3
HEP-1E0-7	1.4E-3	1.4E-3
HEP-1E0-8	1.4E-3	1.4E-3
HEP-1E0-11	1.4E-3	none
HEP-1E0-12	1.4E-3	1.4E-3
HEP-1E0-13	1.4E-3	1.0E+0
HEP-1E0-14	1.0E+0	none
HEP-1E0-15	1.1E-3	2.7E-3

TABLE D.7-7 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
NORTH ANNA AND SURRY IPEs

Basic Event Name	North Anna IPE Point Estimate	Surry IPE Point Estimate
HEP-1E0-16	8.0E-3	1.4E-3
HEP-1E0-22	1.9E-2	5.6E-2
HEP-1E0-ATTACH:1	7.7E-3	1.4E-3
HEP-1E1-25	8.1E-3	none
HEP-1E3-3	3.7E-3	2.3E-2
HEP-1E3-13	2.2E-2	8.9E-2
HEP-1ECA3:1-16	3.0E-3	2.7E-3
HEP-1ECA3:2-5	7.3E-4	1.6E-3
HEP-1ECA3:3-27	9.0E-2	1.6E-3
HEP-1ECA3:3-35	4.9E-3	1.6E-3
HEP-1ES1:2-S1	1.0E+0	1.0E+0
HEP-1ES1:2-S2	8.5E-4	5.3E-2
HEP-1ES1:3	1.2E-2	2.7E-4
HEP-1ES1:4	8.5E-4	2.7E-4
HEP-1FRC:1-11-S1	1.0E+0	1.0E+0
HEP-1FRC:1-11-S2	8.3E-3	3.1E-1
HEP-1FRH:1-5	3.1E-3	2.7E-3
HEP-1FRH:1-11	4.8E-2	2.7E-3
HEP-1FRH:1-15	8.3E-3	2.7E-3
HEP-1FRS:1-4	7.6E-3	1.4E-3
HEP-1FRS:1-5	3.0E-2	2.7E-3

TABLE D.7-7 (Continued)
HUMAN ERROR PROBABILITIES COMPARISON
NORTH ANNA AND SURRY IPEs

Basic Event Name	North Anna IPE Point Estimate	Surry IPE Point Estimate
HEP-1OP14:1-5:13	4.3E-3	2.7E-3
HEP-1OP21:6	1.1E-3	1.4E-3
HEP-1OP49:1	1.3E-1	none
HEP-0OP49:4A	6.3E-2	2.7E-3
HEP-NO-PROCEDURE	1.0E+0	none

TABLE D.7-8
HUMAN ERROR PROBABILITIES SENSITIVITY RESULTS
HUMAN ERROR PROBABILITIES COMPARISON
NORTH ANNA AND SURRY IPEs

	CDF per year using NAPS IPE HEPs	CDF per year using NAPS IPE & SPS HEPs	CDF per year using SPS IPE & SPS HEPs
A	4E-6	4E-6	5E-6
S1	7E-6	5E-6	5E-6
S2	1E-5	3E-5	1E-5
T1	5E-6	8E-6	T1B 7E-6
T1A	8E-6	8E-6	8E-6
T2	9E-7	2E-6	5E-7
T2A	6E-8	6E-8	7E-7
T3	8E-8	7E-8	2E-6
T7	7E-6	2E-5	1E-5
T5A	1E-7	3E-7	7E-7
T5B	1E-7	3E-7	7E-7
T4	1E-8	2E-9	8E-7
T6	4E-9	3E-11	1E-6
T8	7E-6	2E-5	2E-5
VX	2E-6	2E-6	2E-6
RX	3E-7	3E-7	3E-7
TH	4E-7	4E-7	3E-7
TL	0E+0	0E+0	2E-9

Intentionally Left Blank

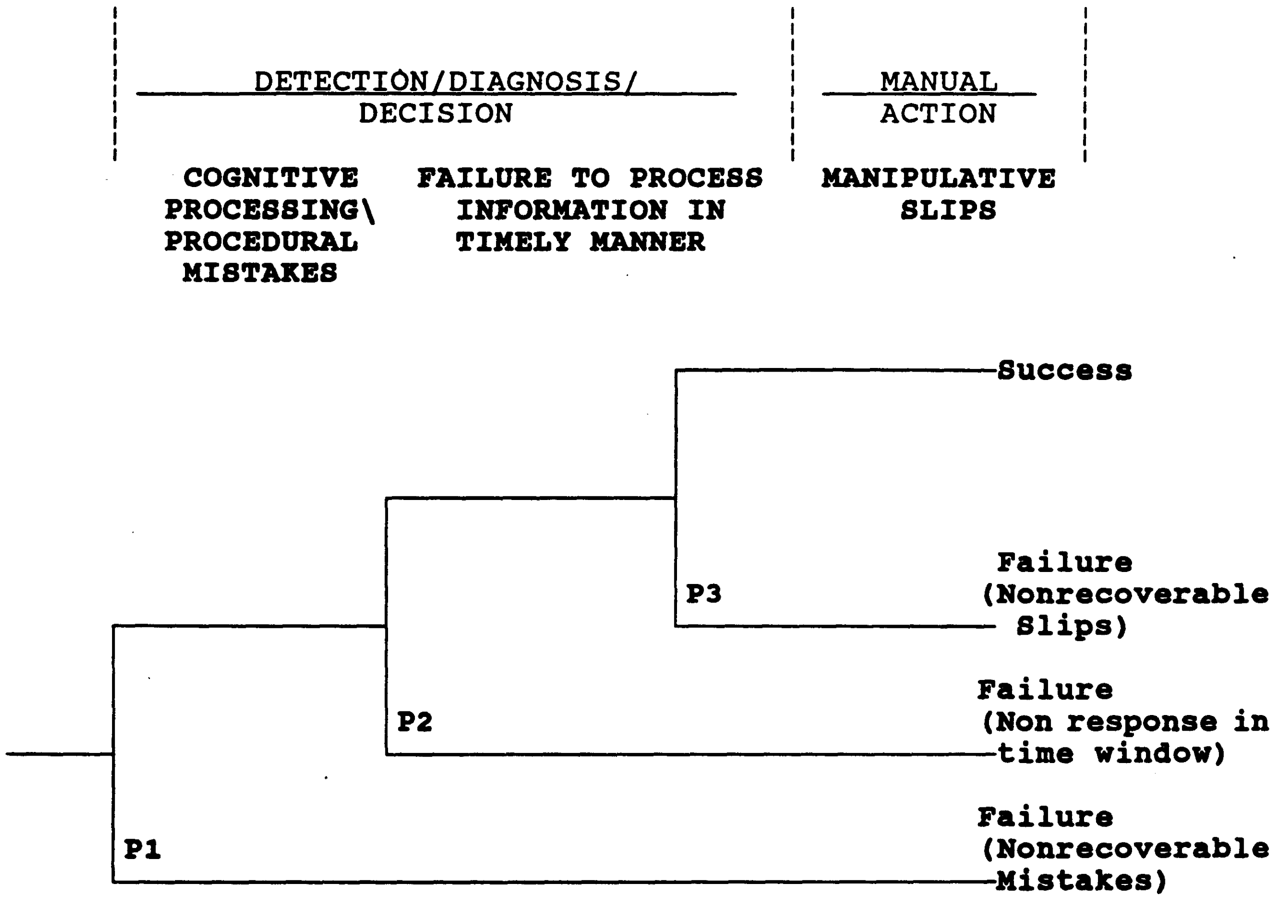
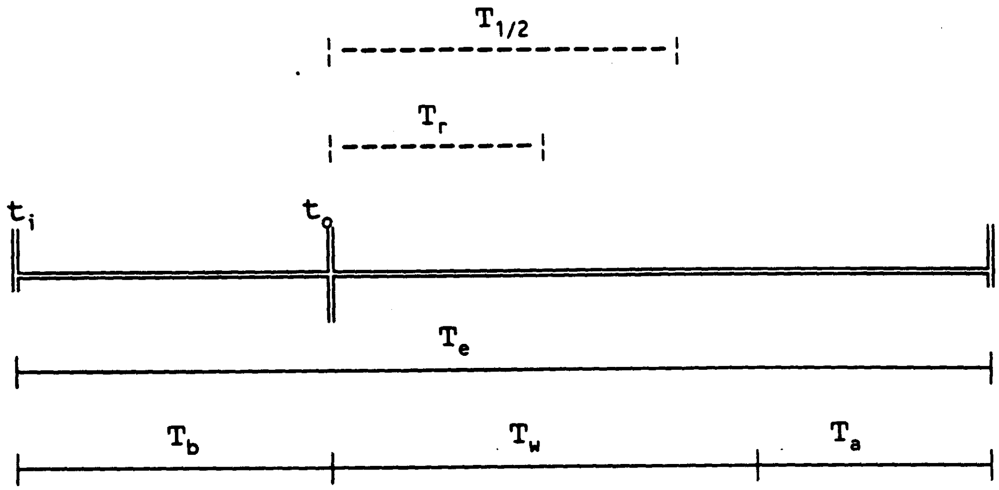


FIGURE D.3-1
GENERALIZED TYPE C HUMAN ERROR EVENT TREE REPRESENTATION



t_i = Time that transient starts.

t_o = Time that Control Room Operator receives first indication of a transient.

T_b = Time difference between t_i and t_o. The CRO is not aware that a transient is in progress.

T_e = Engineering or system time-window (as determined by MAAP runs or other types of analysis). This is the time from initiation of a transient until an undesirable condition exists.

T_a = Task action time (or implementation time) which accounts for the complexity of the step in question (how many controls have to be operated) and waiting times (e.g., valve stroking times).

T_w = Time available for cognitive response. This operator response time window is defined as the time difference between the system time window and the time before the CRO is aware of a transient minus the task action response time ($T_w = T_e - T_b - T_a$);

$T_{1/2}$ = Operator procedure directed median response time. Determined from simulator measurements or task analysis estimates. It is the time until operators respond as directed by procedures.

T_r = Operator non procedure initiated response time. Determined from simulator measurements. It is the time until operators respond to a condition before being directed by a procedure.

FIGURE D.3-2
TIME WINDOW DEFINITION