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HUMAN ERROR PROBABILITY ESTIMATION USING LICENSEE EVENT REPORTS

K.J. Voska and J.N. O'Brien

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Prepared by
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ABSTRACT

The objective of this report is to determine the utility of a method for estimating human error probabilities (HEPs) using data in the Licensee Event Reports (LER) file which is maintained by the U.S. Nuclear Regulatory Commission (NRC). A method was developed for calculating human error rates (HERs) for human errors reported at nuclear power plants (NPPs). HERs are used as estimated HEPs.

HEPs are used as input to Probabilistic Risk Assessments (PRAs) of NPPs. Specifically, the probability of human errors must be used as input along with probabilities of equipment failures to assess the overall probability of a reactor failure. HEPs have been estimated using four types of approaches: (1) structured expert judgment, (2) analysis of training simulator data, (3) performance modeling, and (4) analysis of operational (i.e., field) data. NRC is currently investigating the utility of the first three approaches in other research efforts. This report addresses the utility of analyzing field data. The method which was developed (called the LER-HEP Method) is fully described. This method is generally useful for estimating HEPs from any field data but it is discussed only in terms of LERs.

The utility of analyzing LERs was assessed by examining the practicality, acceptability, and usefulness of implementing a program using the method developed in this report. Practicality was assessed by examining the availability of human error related LERs, the process necessary for determining HERs, and the logistics and support requirements for implementing the method as a full-scale program. Acceptability was assessed by conducting a survey of PRA practitioners to ascertain whether they would use HEPs derived from LER data. Usefulness was assessed by examining how compatable HEPs derived from LER data would be with current HEP data banks and references.

This report concludes that the utility of analyzing LER data to estimate HEPs is reasonable according to the criteria outlined above. Recommendations are made to further improve the utility of such a method.

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Finally, the authors are happy to acknowledge the help of all who participated in the surveys. The extensive comments provided on the questionnaires not only provided a means for evaluating the LER-HEP methodology but should also be of use in improving the LER system to provide more accurate information about the human errors that occur in nuclear power plants.

1. INTRODUCTION

1.1 Purpose

The purpose of this report is to examine the practicality, acceptability, and usefulness of using Licensee Event Reports (LERs) as a data source in estimating Human Error Probabilities (HEPs). HEPs are used as input to Probabilistic Risk Assessments (PRAs) of nuclear power plants (NPPs). Data on human errors (in terms of probability of error), and data on equipment failures (in terms of probability of failure) are combined in PRAs to assess the probability of failure, potential consequences, and therefore, overall risk posed by the operation of a NPP.

The probability of a human error (i.e., an HEP) is a quantitative statement of how likely it is that an error will occur during the performance of a certain human action. Therefore, a given human error, necessarily or conditionally occurring in a specified accident sequence, can be factored in with the likelihood of equipment failures in a consistent fashion to estimate the overall likelihood of reactor failure.

There are four types of activities currently under investigation to estimate HEPs for use in PRAs. These are the use of: (1) structured expert judgment, (2) training simulator data, (3) performance modeling, and (4) analysis of field data. This report concerns the use of field data and in particular examines the analysis of LERs in an analytic method for estimating HEPs related to certain human activities at NPPs. (It should be noted that although the original intent was to develop a methodology for use with existing LERs, the basic methodology presented in this report can be applied to any field data to estimate HEPs. Examples of field data are licensing dockets, inspection and enforcement reports, and plant operating and maintenance records, etc.)

Field data, which can be defined as any type of actuarial information on the past performance of NPPs, provide a source from which error rates may be estimated. While a rate and a probability are not explicitly the same, they are related. Observed rates are often used to predict probabilities. An error rate is a fraction which identifies how often a given error has occurred in a certain number of opportunities. An error probability is a fraction which indicates the likelihood that an error will be made on any single opportunity. In this report, rates are considered reasonable data upon which to estimate the probabilities. Rates resulting from an analysis of LERs can be considered useful as estimated human error probabilities.

Human error rates (HERs) are defined according to the following equation:

$$\text{HER} = \frac{\text{number of human errors of a particular type}}{\text{number of opportunities for that type of error}}$$

Further, as discussed earlier, HEPs can be estimated directly from HERs when the rates are considered reasonable data.

This report presents a set of formalized procedures for the analysis and documentation of human error information contained in LERs. The objective of this methodology is to develop HERs from past performance at NPPs and use those rates as estimated HEPs in PRAs. These procedures have been entitled the "LER-HEP Method" and allow for the estimation of HEPs based on LERs and other plant operational data. The complete set of procedures making up the LER-HEP Method are presented in Appendix A.

The LER system has been in operation for several years and contains a collection of reports on events which resulted in certain unsafe or potentially unsafe conditions in commercial NPPs. The U.S. Nuclear Regulatory Commission (NRC) requires licensees to submit LERs in the event of "reportable occurrences" which are frequently violations of the plant's technical specifications. An example of the criteria defining reportable occurrences for a generic type of plant is presented in Appendix B. Such reportable occurrences range from simple failure to perform a required test or surveillance activity according to schedule to more serious events involving releases of radioactivity or reactor core damage. The length of a single LER ranges from a few paragraphs to several pages depending on the severity and complexity of the event being reported. Currently, the LER system is maintained by the NRC and contains reports of over 30,000 events, a number which historically has grown by approximately 5,000 events each year. With the advent of the new LER rule, it is expected that the yearly increase in LER events will be reduced to approximately 2,500 each year beginning in 1984. Many of the events reported in LERs were the results of human error so that LERs often contain either an explicit or implicit description of human errors that have actually occurred at NPPs. An explicit description of a human error would be one in which the LER clearly lists personnel error as the cause. An implicit human error can be identified by examination and analysis of LERs where human errors are obvious, but not explicitly stated. For example, the cause of a pump unavailability on testing was identified in one LER as a mechanical failure. However, if the suction and discharge valves on the pump had been correctly lined up by the operators, it would not have "failed." Hence the human error of failing to correctly line up the valves on a pump can be implied. The LER-HEP Method was developed to systematically extract this type of LER (or other field data) human error information for use in estimating HEPs.

The purpose of the LER-HEP Method presented in this report is to make use of the large amount of objective field data on human errors present in existing LERs in order to estimate HEPs with optimal accuracy and credibility. PRA practitioners are dependent for many calculations on human and equipment reliability data that have not been objectively validated. Many HEPs used in PRA are best estimates based on subjective expert judgment. Objective field data used in estimating HEPs can have the effect of improving the accuracy and credibility of PRA results because of their "real life" nature. LERs are generated as the result of actual NPP operation; the human errors they include are the result of real NPP conditions (environment, stress, procedures, etc.) which are difficult to duplicate with other methods used for estimating HEPs. As such, they shoud be used in conjunction with other sources and methods of estimation currently under examination.

1.2 Scope and Limitations

As discussed earlier, this report presents a methodology for estimating HEPs for use in PRA. The purpose of this report is to demonstrate the utility of estimating HEPs based on the use of the LER-HEP Method with existing LERs. A demonstration of the LER-HEP Method is presented along with investigations into the issues of its practicality, acceptability, and usefulness as a tool in PRA. This report is as an assessment of the utility of the method, not a source of HEP data.

The analyses presented in this report address the practicality, acceptability, and usefulness of implementing the LER-HEP Method for an ongoing program of human reliability data development. Data reliability and validity in a scientific inferential sense can only be determined after large-scale application of the LER-HEP Method and examination of events that subsequently occur to see if derived rates truly reflect likelihoods. In addition, the accuracy of LER data is dependent on a number of factors that are beyond the immediate scope of the research conducted in this project, (e.g., such issues as those associated with the effects of observation, recording, and reporting of human errors in NPPs as well as the NRC's subsequent processes of LER review and storage). In order for optimally accurate HEPs to result, a number of conditions concerning the process of reporting events should be met. A complete list of these conditions is presented in Appendix C and should be reviewed before developing HEPs from existing LERs.

1.3 Organization of Report

Section 2 (Background) discusses earlier work done by Brookhaven National Laboratory (BNL) and others on the use of LERs to develop human reliability data. The LER-HEP Method is introduced and the issues of practicality, acceptability, and usefulness defined.

Section 3 (The LER-HEP Method) presents a description of the LER-HEP Method which includes all work sheets and cross-references to specific entries and sections so the reader can develop an understanding of how it is used. Detailed procedures for using LER-HEP are shown in APPENDIX A.

Section 4 (Results of the Utility Analysis) assesses the utility of using existing LERs and the LER-HEP Method to develop HEPs which can be used in PRA. Within this section, the availability of LERs, the process necessary to estimate opportunities for error, and the logistics and support requirements of an LER based method are discussed in terms of their practicality. This section also presents the views of PRA practitioners toward the acceptability of using existing LERs and the LER-HEP Method to develop HEPs.

In addition, this section provides an evaluation of the usefulness of existing LERs and the LER-HEP Method to PRA. This involves an analysis of the compatibility of LER-identified human errors with the human reliability data needs of PRA.

Section 5 (Summary and Conclusions) summarizes the results of these analyses.

Section 6 (Recommendations) provides direction for future work in the development of human reliability data from field data. In addition, changes to the LER form and LER system, which should improve the practicality, acceptability, and usefulness of using the method to develop human reliability data, are recommended.

2. BACKGROUND

2.1 Previous Research on Analyzing LERs

Research on human error quantification based on LER data began at BNL during 1980. The EG&G Idaho, Inc. (EG&G) computer-based file of one-line data summary descriptive interpretations of LERs[1,2] was used as a source to count human errors associated with three specific categories of safety system components: remotely operated valves, manually-operated valves, and pumps. Interpretation of the EG&G summaries by individuals with licensed Senior Reactor Operator experience along with analysis of piping and instrumentation diagrams, enabled BNL to develop generic HEPs for interfaces with the three above-mentioned categories of components.[3] The calculation of these HEPs provided the first independent nuclear systems approach to developing HEPs as a benchmark of comparison for existing derived and/or best judgment HEPs.

A BNL report published in February 1982[4] expanded this technique by applying the same analysis to the one-line EG&G summaries associated with a fourth category, instrumentation and control system components.[5] This yielded HEPs associated with the operation, testing, maintenance, and calibration of instrumentation and control components found in a number of plant safety systems for which one-line data summaries were available.

Work on the expansion of the use of LERs as a human error data source to estimate HEPs continued at BNL with the analysis of LER abstracts retrieved from the Department of Energy, Nuclear Safety Information Center (NSIC) DOE/RECON Data Base. This analysis of over 11,800 LER abstracts during a 4 1/2 year period starting in 1976 led to the identification of 384 human errors related to pump and valve events[6] and over 729 human errors related to electrical/electronic component events.[7] This analysis involved the manual evaluation of LER abstracts so that human errors could be identified where human error was implied in the LER text, but not directly stated, in addition to where explicitly stated in the LER texts or key word. The resulting data base was several times larger than would be available had only explicit human error statements been considered. Overall, human errors could be identified in 9% (384 + 729)/11,800 of these LERs. For more details, see Appendix D.

Other than the work described above, there has been little effort in developing methods for using LERs to estimate human error probabilities. The only other attempt to estimate HEPs from LERs was made by the Nuclear Safety Research Group, Engineering Research Institute of Iowa State University. This work is documented in a report entitled "Evaluation of Gross Operator Error Rates Based on Past Experience in Commercial Nuclear Power Plants" (NUREG/CR-2143).[8] Although NUREG/CR-2143 does propose a method for estimating HEPs on a per unit time or frequency basis, it fails to produce HEPs which are useful to PRA. The only quantitative expression of HEPs presented in NUREG/CR-2143 is termed "Gross Operator Failure Rate" and is given on the basis of failures per hour. No attempt was made to derive HERs or estimate HEPs for specific human actions. Instead, all operator errors for a given period of time at several plants were divided by that time to arrive at a rate. For this reason, the few data developed in NUREG/CR-2143 are of limited use in PRA-activities.

2.2 Introduction to the LER-HEP Method

A great deal of information on human errors committed in NPPs is present in existing LERs. Additionally, in at least some cases, this human error information can be quantified and expressed as estimated HEPs.[3,4] Although previous work does show that it is feasible to obtain HEPs from analyses of LERs, it did not demonstrate the utility of using LERs in a large-scale program of human reliability data development to support PRA. The major limitation of the earlier work was that procedures for HEP estimation were not formally established but rather described in the text so that the technique developed was limited in use to those who actually developed it. The sources of information used in earlier efforts were not well documented and, as such the results are not generally reproducible.

The goal in developing the LER-HEP Method presented in this report is to establish a method that is:

1. Objective - requiring the use of field data and standardized references minimizing the effects of bias inherent in subjective judgment.

2. Structured - so that the analysis is sufficiently formalized and documented that results are reproducible.

3. Stand-alone - so that the analysis could be conducted by qualified individuals with a minimum of support.

In this way, effective use can be made of the human error information present in LERs to estimate HEPs which can be used in PRA.

2.3 Summary of Utility Analysis

The utility of analyzing LERs to estimate HEPs was investigated in terms of three types of issues: (1) practicality, (2) acceptability, and (3) usefulness. This section provides definitions of these three issues.

The practicality issues consider, for example, the availability of LERs, the process necessary to estimate opportunity for error, and the necessary logistics and support considerations. The availability of LERs was determined by consulting with the NRC Office for Analysis and Evaluation of Operational Data (AEOD) where comprehensive LER files are maintained. The practicality of opportunity for error estimation was determined by having two BNL researchers independently review the human errors identified in NUREG/CR-2417[6] and -2987[7] to identify which activities can be best quantified in terms of opportunities for error. Logistics and support requirements were determined using past experience in analyzing LERs.

Issues of acceptability concern the potential acceptance of the overall process of LER evaluation to produce HEPs as viewed by PRA practitioners. This was determined by conducting a small survey in the form of a mailed questionnaire to a group of individuals who currently conduct PRAs.

Usefulness issues concern the compatibility of errors identified in LERs and estimated HEPs with the human reliability data needs of PRA. In other words, whether or not an application of the LER-HEP Method would provide useful input to PRA. In order to be useful, the taxonomy of estimated HEPs derived from LERs must be similar to the taxonomic structure of human activities analyzed in PRA. To assess the compatibility of HEPs esimated from human error data contained in LERs with the needs of PRA, the human reliability data categorization and storage system developed in NUREG/CR-1278[9] (handbook of human reliability analysis) and NUREG/CR-2744[10] (human error data bank) were considered. Attempts were made to enter LER identified human errors into both data bank structures.

3. THE LER-HEP METHOD

3.1 Description of the Method

The LER-HEP Method consists of three work sheets and a detailed set of instructions which are presented in their entirety in Appendix A. This is a general purpose method which can be adapted for use with any field data on human performance in NPPs. The first work sheet involves the analysis of LERs in order to identify and categorize the human errors they indicate. The second work sheet is used to conduct plant-specific task analyses and equipment inventories and to make subjective estimates of the opportunities for error for a specific category of human action for the plant at which the error(s) occurred. The final work sheet combines the results of a survey of LERs with corresponding opportunities for error to calculate HERs and estimate from them, HEPs.

The LER-HEP Method (described in Appendix A) starts with an overview section, which provides a general introduction. The purpose of the LER-HEP Method is defined. A short discussion of each of the three parts is provided to familiarize the user with how the three parts fit together to estimate an HEP. To assist in understanding how the LER-HEP Method is set up, copies of the three work sheets are included at the end of this section.

Part I (see Figure 3.1a) of the LER-HEP Method describes how to locate relevant information on an LER and fill out the first work sheet. A line-by-line set of instructions in Appendix A explains exactly where to find the required information on the LER form and how to enter it on the work sheet. Human actions and equipment characteristics are classified in this part of the analysis. The LER-HEP Methods used the taxonomies developed in a parallel project by General Physics Corporation for Sandia National Laboratories (SNL), which is documented in NUREG/CR-2744.[10] A list of human action and equipment descriptors from NUREG/CR-2744 is included in the LER-HEP Method. Since it is desirable to use the HEPs developed as input to the Data Bank described in NUREG/CR-2744, it is important to use the descriptors and their definitions as established for the data bank.

The instructions specific to the first work sheet start on page 4 of Appendix A. For the purpose of illustration, a sample LER printout is provided on page 5. This is done to help the user locate the necessary information on the LER printout being evaluated. The first block of this work sheet is called "Basic Information." The data to be entered on these nine lines (according to the instructions which begin on page 6) provide basic documentation on the plant, the LER, and the event. The second block (also beginning on page 6) called "Error Information" is used to document information specific to the the human error, the number and types of similar errors, and whether or not the error was part of a periodic activity. In order to specifically define the human action which was done incorrectly, a block called "Human Actions" (with instructions beginning on page 8) is provided. This block requires information on the position and duty area of the individual committing the error as well as a description of the task. To provide information on the equipment interfaced with, a block called "Equipment Characteristics" (with instructions on page 9) has been included. This block requires the identification of the system, subsystem, component, and element involved in the human error. A short block called "Interface" is provided (with instructions beginning on page 9) to document information on the nature of the man-machine interface with which the human error is associated. To identify any human factors evident on the LER, a block called: "Performance Shaping Factors," is provided (with instructions on page 10). Finally, to summarize the human error into a one-sentence description, a block called "Summary" (with instructions beginning on page 10) is provided at the end of the first work sheet.

The second work sheet provides a structure for use in plant specific task analyses and equipment inventories to determine the number of opportunities for that error (see Figure 3.1b). Complete task analyses for all human activities and comprehensive equipment inventories are not necessary if the probability of success or failure of only a select group of human activities associated with specific equipment is to be estimated. However, the availability of such completed analyses and inventories would greatly facilitate the application of the LER-HEP Method if it were implemented on a large scale basis to provide HEPs for PRA.

First, all tasks similar to those specified on the first work sheet are to be identified and the frequency with which these tasks are repeated on a yearly basis must be determined. Then, it is necessary to identify all other pieces of equipment in the plant on which tasks similar to the ones in question are performed. Considerations must be made for those devices in the plant that have a human interface frequency similar, but not identical, to the device in question. Then combining the number of repeated actions with the number of similar pieces of equipment, opportunities for error can be calculated.

The instructions for the second work sheet begin on page 12 of Appendix A with a general introduction. The first two items on this work sheet, "Page Number" and "Number of Unique Classes," are to be filled out later in the analysis and will be referred to again. The specific instructions for entries on the second work sheet begin with the "Inventory of Human Actions" block (page 13). This block is used to itemize human actions similar to the one in which the human error was committed and the number of times each activity is normally repeated in a one-year period. The "Equipment Inventory" block (instructions begin on page 14) is used to itemize pieces of equipment that involve similar human actions. As part of the opportunity calculation, reference is made once again to the two items at the top of the work sheet which were left blank. These items are used when unique classes of equipment are identified that require additional second work sheets to be filled out. The final block, "Opportunity" (instructions on page 14) is used to combine the number of human actions repeated on the various pieces of equipment to derive the total annual opportunities for the given human action for that plant.

The third work sheet (see Figure 3.1c) combines information from the first two work sheets with data on plant operating history. In order to estimate an HEP, a survey should be conducted over a suitable length of time so that a number of human errors of that type have occurred. Once this survey period is defined, the total number of human errors of that type which occurred during that period must be counted and divided by the total opportunities for the given type of error within the given time period. Considerations must be made for plant outages during which the activity n question was not performed, so these periods of time should not be included n the estimation of the opportunities for the error to occur.

The instructions for combining the number human errors (numerator) with the number of opportunities for that error (denominator) are provided with the third work sheet (starting on Appendix A, page 16). The first block on the third work sheet, called "Error Classification" (page 16), requires information from the other work sheets. The "Survey Period" block (page 16) is used to define the time during which LERs were considered. The "Plant Information" block (with instructions on page 16) is used to list all similar plants considered in the survey along with a factor indicating the percentage of the total survey time each was operational. The "Total Opportunity" block (instructions on page 17) is then used to combine the total number of plants with their respective operational factors to derive the total operation time considered in the survey. Combining this with the total annual opportunity (from the second work sheet), the total number opportunities for that error are determined. The "Human Error List" (instructions on page 17) requires the itemization of human errors of the given type in all LERs occurring during the survey period. The final block, "Human Error Rate" (instructions on page 16), is used to divide the total number of human errors by the total number of opportunities to obtain a HER. This HER is used as the estimated HEP.

3.2 Demonstration of the LER-HEP Method

To demonstrate the LER-HEP Method, the data base of human error related LERs identified in NUREG/CR-2417[6] was used (see Appendix D). The human error events presented in NUREG/CR-2417 are the results of an analysis of over 3,000 LER abstracts which were obtained from the NRC's LER files, at that time called the NIH file (National Institutes of Health LER Data Base). This analysis resulted in the identification of 384 human errors related LERs that were generated by licensed commercial NPPs which were operational during the period from January 1, 1976 through June 30, 1980. These events are specifically related to pumps, valves, and valve operations in the following systems:

Reactor core isolation systems and controls
Residual heat removal systems and controls
Emergency core cooling system
Other engineered safety feature systems and controls
Engineered safety feature instrument systems
Feedwater systems and controls
Other auxiliary water systems and controls
Chemical and volume control, and liquid poison systems and controls

For the purpose of this demonstration, two unique human error events were chosen as examples: (1) Quad Cities 2, LER Number 78-022 and (2) Zion 2, LER Number 77-03. Figure 3.2 shows how these LERs appear as found in the computerized NIH data. The completed work sheets filled out to calculate HEPs are presented in Appendix E. (This method could be applied to any field data or human errors in NPPs.)

The human error in the first example (Quad Cities 2) was identified as an error of omission: "failure to restore safety system to its proper normal lineup after testing." Appendix E pages 1 through 3 show the work sheets filled out for this human error. The opportunity for error at Quad Cities 2 for this error was estimated to be 25 opportunities per year by a licensed senior reactor operator familiar with the plant by making references to Technical Specifications and Quad Cities drawings (see Appendix E page 2). A total of 22 General Electric Boiling Water Reactor Plants were included in the analysis for the 4.5 year survey period to yield a total number of opportunities for that type of error of 1732 (see Appendix E page 3). Since only one unique human error of this type was found in the data base of NUREG/CR-2417, the HER was obtained by dividing 1 error by 1732 opportunities to yield an estimated HEP of 5.8×10^{-4}.

The human error in the second example (Zion 2) was identified as a commission error: "error in draining the wrong accumulator." Appendix E pages 4 through 6 shows the work sheets filled out for this human error. The opportunity for error at Zion 2 for this error was determined to be eight opportunities per year by a formerly licensed senior reactor operator with experience on the Zion simulator by relating to plant experience and Zion Drawings (see page H-5). A total of 24 Westinghouse Pressurized water reactor plants were included in the analysis for the 4.5 year survey period to yield a total number of opportunities for that type of error of 479 (see Appendix E page 6). Since only one unique human error of this type was found in the data base of NUREG/ CR-2417, the HER was obtained by dividing one error by 479 opportunities to yield an estimated HEP of 2.1×10^{-3}.

HEP WORK SHEET PART I

Basic Information	Docket:			1.
	LER Number:	2.	Control Number:	3.
	Plant Name:	4.	Sister Dockets:	5.
	Plant Type:	6.	Reactor Vendor:	7.
	Event Date:	8.	Peport Date:	9.
Error Information	Error Date:		Source:	10.
	Number of Identical Errors:			11.
	Number of Dissimilar Errors:	12.	Page Number:	13.
	Periodic:		Source:	14.
	Error Type:		Source:	15.
	Error Description:		Source:	16.
Human Actions		Descriptor	Source	
	Position:			17.
	Duty Area:			18.
	Task:			19.
	Task Element:			20.
Equipment Characteristics		Descriptor	Source	
	System:			21.
	Subsystem:			22.
	Component:			23.
	Element:			24.
Interface	Interface Level:			25.
Performance Shaping Factors			Weight:	26.
			Weight:	27.
			Weight:	28.
Summary				29.

Figure 3.1a

HEP WORK SHEET PART II

Page Number:	Number of Unique Classes:

	Activity	Similar Human Actions	Annual Repetition	Source
Inventory of Human Actions				
	Total Annual Repetition			

	Identical Equipment	Quantity	Source
Equipment Inventory			
	Total Similar Equipment		

Opportunity

Total Annual Repetition [ ] × Total Similar Equipment [ ] = Total Opportunity (this Page) [ ]

Total Opportunity (other Pages) ⟶ + [ ]

Total Annual Opportunity [ ]

Figure 3.1b

HEP WORK SHEET PART III

Error Classification	Position:	1.	System:	5.
	Duty Area:	2.	Subsystem:	6.
	Task:	3.	Component:	7.
	Task Element:	4.	Element:	8.
	Interface Level:			9.
Survey Period	Survey Begin:	10.	Survey End:	11.
	Survey Length, Years:	Months:	Decimal:	12

	Plant	Factor	Plant	Factor
Plant Information	13.			

Total Opportunity	Total No. of Plants:	14.	Average Factor:	15.
	Total Plant Years:	16.	Total Operation Time:	17.
	Total Annual Opportunity:	18.	Total Opportunity:	19.

	LER Number	Errors	LER Number	Errors
Human Error List	20.			
	Total Number of Errors:			21.

Human Error Probability	Total Number of Errors (Line 21) / Total Opportunity (Line 19) =	22. ____ 23.	24.

Figure 3.1c

Facility/System/ Component/Component Subcode Cause/Cause Subcode/ Component Manufacturer	Docket No./ LER No./ Control No./ NSSS	Event Date/ Report Date/ Report Type	Event Description/ Cause Description
Quad Cities-2 Emerg Core Cooling Sys + Cont Pumps Centrifugal Personnel Error Licensed & Senior Operators Bingham Pump Co.	05000265 78-022/031-0 021561 GE	052178 062078 30-Day	While performing control room panel checks, the operator noticed the 2A core spray pump was in pull-to-lock and the pump suction valve MO 2-1402-3A was closed. This was contrary to T.S.3.5.A.1 which states both core spray subsystems shall be operable before startup. Safe plant operation was maintained since the 2B core spray system was operable should the need for core cooling have arisen. Since each loop is a full capacity system. The cause of this occurrence was operator error. The immediate corrective action was to return the pump to normal status. A discussion was held explaining the seriousness of such an occurrence. To prevent reoccurrence, a program to identify equipment that is in a condition other than its normal status is being implemented.
Zion-2 Emerg Core Coling Sys + Cont Accumulators Subcomponent not Applicable Personnel Error Cause Subcode not Provided Westinghouse Electric Corp.	05000304 77 03L 019137 West	083177 092677 30-Day	(RO 77-55) While attempting to lower level in 2C accumulator, operator opened wrong accumulator drain valve & lowered level in 2D accumulator to 872.40 CF which was 27.60 CF below T.S. limits. Other 3 accumulators were operable. Operator error. The operator has been cautioned. Accumulator was refilled.

Figure 3.2 LERs as obtained from the computerized NIH data base.

4. RESULTS OF THE UTILITY ANALYSIS

The purpose of this section is to examine the utility of the LER-HEP Method using existing LERs to estimate HEPs for use in PRA. Included here are discussions of practicality, acceptability, and usefulness of the method.

4.1 Practicality

For the LER-HEP Method to be practical, several criteria must be satisfied. LERs must be readily available for analysis, estimation techniques for determining the opportunities for error must be credible, and the logistic and support necessary to sustain a program must be reasonable.

4.1.1 LER Availability

Licensee Event Reports (LERs) have existed in several different forms and have been sorted and filed by different organizations since the initial requirement (around 1965) that licensees report "abnormal occurrences" to the Atomic Energy Commission. The 30,000 LERs that have been generated to date are available in files maintained by NRC. Since the start of the LER program the reporting format and filing system have changed several times. LERs are public documents, so the question of availability simply concerns how to most easily obtain LERs from the various storage systems in which they reside. The various systems by which one might obtain copies of LERs and the means by which they might be sorted are discussed in this section.

The NRC maintains the Document Control System (DCS) to provide a permanent record of documents or correspondence it writes or receives. Copies of LERs as originally submitted by licensees are stored in this system and are identifiable on video terminals throughout NRC and retrievable through computerized terminal and on microfiche. A drawback of this system is that it also contains correspondence between licensees and NRC. No routines exist to sort LERs from unrelated correspondence so the use of this system would be impractical if a large number of LERs were needed for analysis.

The NRC Office for Analysis and Evaluation of Operational Data (AEOD) maintains files of LERs on microfiche. Copies of LERs (on fiche) may be obtained for NRC contract work by request from AEOD. LERs were submitted in various formats and the AEOD filing system has been changed as follows:

- 1965 to 1969. Any reports submitted by licensees during this period are not available from AEODs files. It may be possible, however, to obtain such records from the Public Document Room.

- 1969 to 1973. Records for this period consist of the LER forms written by AEC in 1973 as part of a back-fit program done by analysis of reports submitted by the licensees. Only a one-page LER form is available from AEOD for these years.

- 1973 to 1975. The original report forms as submitted by the licensee are available along with the LER one-page forms as written by NRC.

- 1975 to 1981. The LER one-page form as written by the licensee and attached pages explaining the incident are available for this period. NRC did not write one-page reports during this period.

- 1981 to Present. The same records are available as for the 1975 to 1981 period except that such files are maintained by the Institute of Nuclear Power Operations (INPO). The INPO microfiche files are available through AEOD.

INPO currently maintains the computerized data base. INPO obtained a copy of the NIH-LER file from the NRC in 1981 and continues to enter LERs into the data base. The format is a coded data base with a brief abstract taken from the LER one-page form. LERs from 1969 to the present are filed in this computer data base.

The advantage of the INPO data base is that its sorting routines provide the ability to search for LERs by locating any of the specific items coded on the form or any key words in the texts of reports. The computer abstracts can either be printed directly or cross-reference lists can be generated to access the original LER reports. For example, a list of all LERs that include operator error on certain plant systems could be obtained using the computer search routine explicitly maybe, implicitly no, then the actual LERs could be obtained from AEOD's files for analysis.*

To summarize, LERs dating back to 1969 are available for analysis. The user of the LER-HEP Method should be familiar with the various filing systems described above to best obtain the required LERs.

4.1.2 Estimation of Opportunities for Error

The estimation of HEPs in this method is done by estimating an HER (rate) and assuming that rate indicates the likelihood of that error occurring again (a probability). The first part of this method involves counting the number of human errors of a specific type on a particular plant system. In order to derive a rate, the number of opportunities for committing that error must be

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*When INPO began maintaining its system in 1981, it changed the way in which LERs were numbered in the cross-reference lists. AEOD had previously assigned control numbers to the LERs as they were entered into the computer system. Any list of certain types of LERs would identify the LERs by control numbers. INPO lists the LERs by docket, date, and LER number as assigned by the licensee. However, this does not present a significant problem because the LERs are also put on microfiche according to docket, date, and LER number. Computer searches are made only for INPO members and NRC.

estimated. The resulting rate will reflect the likelihood that a particular act will be done incorrectly. That likelihood (HEP) is then used in PRA accident sequences including that particular human action.

The technique used for estimating opportunities for error must be credible for the resulting HEPs to be of use. The overall objective of the LER-HEP Method is to minimize the use of expert judgment so resulting HEPs can be compared to those which are derived from structured expert judgments, training simulators, and computer modeling data. In order to accomplish this, maximum use should be made of plant drawings, technical specifications, procedures, and other relevant documents. To meet the objective of minimizing judgment, these criteria must be met:

1. The LER being analyzed must clearly identify a human error and not a mechanical failure ambiguously associated with an error.

2. The human error must be a result of activities which are repeated on a fixed periodic basis (e.g., monthly testing or a pre-startup routine done after each refueling).

3. The frequency with which the human activities are repeated (i.e., opportunity for error) must be documented in some external source (e.g., from testing requirements established in technical specifications or historical data on refueling outages).

In order to have an indication of how many LERs containing human errors meet all three of these criteria two knowledgeable evaluators independently reviewed the one-line LER human error descriptions used in NUREG/CR-2417[6] and-2987.[7] In all, 325 descriptions of pump- and valve-related human errors (from NUREG/CR-2417) and 192 descriptions of electrical and electronic related human errors (from NUREG/CR-2987) were evaluated. Below is a tabulation of the results of both evaluators. The values given in the table represent the percentage of the total one line descriptions that met all three criteria.

NUREG/CR-	Evaluator A	Evaluator B
2417	13%	21%
2987	18%	25%

Approximately 20% of the one line error descriptions evaluated from NUREG/CR--2417 and -2987 can be considered suitable for use in HEP estimation. Appendix D lists those LERs obtained from the above analysis which could potentially be used to estimate HEPs.

As discussed in Section 2.1, previous research done at BNL indicated that roughly 10% of all LERs contain information about human errors. Of this 10% about one-fifth meet the criteria necessary for determining opportunities for error. It can be concluded that one-fifth of 10% or 2% of all LERs contain human error information which could be used in estimating HEPs. Assuming that 30,000 LERs exist to date and that the relative percentage of those containing quantifiable human error information is constant, it can be estimated that roughly 600 LERs are available for use in HEP estimation.

If an LER does not meet all three criteria, expert judgment can be used to estimate the number of opportunities for a particular error to occur. This would be done using structure expert judgment techniques presently under development.[11,12] These techniques are the subject of other NRC research and, therefore, are beyond the scope of this report. However, since expert judgment could be used to estimate opportunities for error, additional LERs may be subject to analysis substantially enlarging the number of LERs which can be used to estimate HEPs.

4.1.3 Logistics and Support for an LER-based Program for Developing HEPs

The purpose of this section is to discuss personnel, facilities, and time required for development of HEPs based on the LER-HEP Method. Since the LER-HEP Method is organized in three independent parts (i.e., three separate work sheets) each with different requirements, this section discusses the logistics and support requirements for each part separately. As discussed earlier, the present LER files contain approximately 30,000 entries and roughly 2,500 LERs will be added each year. For this reason, the logistics and support requirements must be defined relative to two efforts: first, a back-fit program analyzing the 30,000 existing LERs and, second, an ongoing program to analyze LERs as they are received.

4.1.3.1 Part I: LER Analysis (First Work Sheet)

The first part of the LER-HEP Method is used to analyze and classify LERs. Because the individual(s) performing this analysis will be required to read technical drawings and specifications he or she must be familiar with NPP systems, the LER system, and the Human Reliability Data Bank Implementation Plan. The organization evaluating LERs must have a means of obtaining LERs from AEOD and storing the LERs they receive. Since most LERs are readily available on microfiche, a microfiche reader is necessary. Previous analyses of LERs at BNL have shown that one qualified individual can read and analyze about 25 LERs per day. For the back-fit program, this would require 1,200 staff-days (about six staff-years) to analyze the 30,000 existing LERs. For the ongoing program, about 100 days (approximately one-half staff-year) would be needed to analyze the 2,500 LERs submitted each year.

The NRC has developed a new system for retrieving LERs which will identify human errors and provide a computerized access routine. This system is called the Sequence Coding and Search System (SCSS). The use of the SCSS would greatly reduce the staff requirements for LER analyses since human errors will already be identified and classified as part of NRC review. While the SCSS is operational, it is still too early to determine precisely how much more efficient such a system would be, although it is expected to be significant.

4.1.3.2 Part II: Opportunity for Error Calculations (Second Work Sheet)

The second part of the LER-HEP Method determines opportunities for error for those groups of LERs which are found to contain human error. Prior research has shown that 10% of all LERs contain specific information on human errors. A back-fit program would then require the analysis of approximately 3,000 LERs identified and classified in Part I to determine opportunities for error. The ongoing program would require the analysis of about 250 LERs per year. The estimation of opportunities for error can be done by using plant documentation (the objective method) or by using expert judgment techniques (the subjective method). With an objective method, reference must be made to plant-specific drawings, operations, and maintenance procedures and technical specifications to document the information needed to estimate opportunities for error. While the subjective method requires less reference to such documentation to be credible, the analyst must have an intimate knowledge of plant layout and operations procedures. In the objective case, the analyst must be familiar with the general layout of NPPs as well as the overall organization and use of references such as plant drawings and procedures. In the subjective case, the analyst would have to have in-depth experience in operating plants similar to those in the analysis.

The documents required for an objective analysis of opportunity for error are complete sets of technical drawings, operations and maintenance procedures, and technical specifications for all plants to be included in the analysis. Some of this documentation may be more useful if it is stored as a computer routine, in which case, a computer would be necessary. Large computing and storage capabilities are not needed, so a personal computer would be most appropriate. Once lists of human activities and inventories of safety-related equipment are developed and computerized, the process of calculating opportunities for error should be greatly facilitated. As a result, there may be a significant learning curve associated with a program using plant documentation as a source of data for estimating opportunities for error.

With regard to time requirements, an objective method may initially require a day or more to review all of the information needed for each opportunities for error estimation. It may be helpful to establish a direct link (e.g., telephone contact) between the analyst estimating the opportunities for error and the various licensees in order to expedite the process of listing human activities and items of equipment. If each LER containing a human error could produce a unique error rate (as in previous studies) the objective analysis of 3,000 LERs would require 3,000 days (over 12 staff-years) for the back-fit program and 250 days or about one staff-years each year for the ongoing program. If the only LERs analyzed were those which meet the criteria set out in Section 4.1.2, only 500 LERs would be analyzed. The back-fit program would require 600 days (about 2.5 staff-years) and the ongoing program about 50 days per year (about 0.3 staff-years). However, many human errors may be analyzed using subjective techniques for estimating opportunities for error discussed in Section 4.1.2. With extensive use of subjective techniques, the time required for Part II could be drastically reduced. Assuming 10 or more opportunities for error per day could be generated using a well-developed and effective subjective technique, it would require 300 days (1.5 staff-years) for the back-fit program and 25 days (0.13 staff-years) for the ongoing program.

In summary, if LERs satisfy the criteria necessary for using plant documentation to estimate opportunities for error are analyzed with an objective technique and all other LERs indicating human error analyzed with a subjective technique it would require about 900 days (almost 5 staff-years) for the back-fit program and 75 days per year (about 0.3 staff-years) for the ongoing program.

4.1.3.3 Part III: HEP Estimation (Third Work Sheet)

Completion of the Part III work sheets requires relatively little technical knowledge. For the most, Part III entails taking information from other work sheets and performing basic mathematical calculations (e.g., addition, subtraction, and multiplication). The only part which requires additional information on NPPs is the plant information section. Here, estimates of the actual amount of time particular plants were operational must be made. It will most likely be possible to obtain factors (i.e., the fraction of all time that the plants actually operated) from simple analysis of plant operating data. For these reasons, there are minimal skill requirements for an individual performing this part of the analysis. However, the analyst filling out the Part III work sheets must be familiar with the structure of the other work sheets and the basic requirements of the data storage system (i.e., the Data Bank).

The materials required for this part of the analysis would be storage for the work sheets and a simple hand calculator. If it is desired to maintain the HEPs by updating them as more field data become available (i.e., LERs as they are submitted), a personal computer could be used.

The time requirement for each Part III work sheet is estimated to be about 30 minutes. For the back-fit program, it would then require 200 days (almost one staff-year) to complete the analysis of existing LERs. For the ongoing program, analyses 250 human error LERs a year, 15 days (0.09 staff-years) would be required each year. Logistics and support requirements for an LER-based method of HEP estimation are shown in Tables 4.1a-4.1c.

4.2 Acceptability

The question of acceptability is concerned with the potential acceptance of the use of the LER-HEP Method to produce HERs for use in PRA as perceived by PRA-HRA practitioners.

Table 4.1a Personnel Qualifications.

Part I	Familiarity with NPP systems and the Data Bank structure.
Part II	(Objective): Familiarity with NPP systems and NPP drawings, procedures, and technical specifications.
Part II	(Subjective): Experience equivalent to a nuclear power plant operator, intimate knowledge of several types of plants.
Part III	Basic mathematical skills, familarity with LER-HEP Method and the Data Bank structure.

Table 4.1b Required Facilities.

Part I	Microfiche reader, storage for LERs obtained from NRC and access to SCSS
Part II	(Objective): Plant-specific drawings, maintenance and operations procedures, technical specifications, and a personal computer.
Part II	(Subjective): Dependent on expert judgment technique used.
Part III	Filing system for LER-HEP work sheets, and a personal computer.

Table 4.1c Resources (Staff-Time).

	Programs	
Time	Back-fit	Ongoing
Part I	6.0	0.5
Part II (Objective)	12.0	1.0
Part II (Subjective)	1.5	0.13
Part II (Both)	5.0	0.3
Part III	1.0	0.09

As a means of assessing the acceptability of using the LER-HEP Method a number of human reliability experts in the field of PRA were contacted. Questionnaires were mailed to 20 individuals who are experienced in the field of Human Reliability Assessment and are familiar with the LER system. In all, 12 responses (60%) were received. The results of the survey are documented in Appendix F.

The survey results indicate that the responding individuals view the LER-HEP Method and existing LERs as providing a moderately useful HER data source for PRA. Among those responding to the survey, there seems to be moderate to low confidence in HEPs developed from LERs. Three responses indicated no confidence in LER data; while none placed high confidence in them. Many of the experts responding indicated that the existing LER human error data may be of limited accuracy because: (1) licensees may not be completely and correctly reporting human errors, and (2) the definition of reportable occurrences may preclude some reporting of safety significant human errors.

Respondents were asked to rank order four major sources of human reliability data in terms of accuracy and credibility: computer modeling, expert judgment, LER analysis, and simulator experiments. In the responses simulator experiments were ranked as the most accurate followed very closely by expert judgment. However, it did not appear that the difference in the ranking assigned to expert judgment and simulator experiments was significant. The next most accurate source was LER analysis and finally, ranked lowest was computer modeling.

In summary, most of the respondents viewed the LER-HEP Method as a useful tool in PRA, although most tend to indicate, at best, moderate confidence in the HEPs developed. An analysis of existing LERs was viewed as providing less accurate results than simulator experiments or expert judgment, but more accurate than computer modeling.

The responses to questions dealing with (1) the confidence each expert would be willing to place in HEPs developed from LERs, (2) the accuracy of LERs as a source of human reliability data, and (3) the usefulness of the LER-HEP Method are presented in Table 4.2.

Table 4.2 Survey Results.

	Number of Responses			
Question	Very High	Moderate	Low	Very Low
1. Confidence	0	5	4	3
2. Accuracy	0	2	7	3
3. Usefulness	0	7	4	1

4.3 Usefulness

As a means of assessing the usefulness of HEPs developed using the LER-HEP Method and existing LERs, the compatibility of LER identified human errors with human reliability data requirements of PRA was evaluated. To be compatible with the needs of PRA, human errors analyzed from LERs must be of the same type needed for PRA and they must be described in sufficient detail so they may be used in accident sequences. For example, there is need for specific HEP of "failing to fully open a rising stem gate valve in primary containment by inexperienced personnel with no written procedures during a loss of coolant accident" and the only level of information available from LERs is on the larger category of "human interface with gate valve," then it would seem the LER source and the PRA need are not completely compatible. To be useful to PRA, analyses of LERs must provide a reasonable number of HEPs of the type needed for PPA.

Because a specific summary of types of human error data required for use in PRAs is not available at this time, two publications are considered to indicate the human reliability data requirements of PRA. The first will be referred to as the "Handbook" and is entitled, "The Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications" (NUREG/CR-1278).[9] The second is entitled "Human Reliability Data Bank for Nuclear Power Plant Operations, Volume 2: A Data Bank Concept and System Description" (NUREG/CR-2744)[10] and will be referred to as the "Data Bank." The Handbook and Data Bank are intended as references for PRA practitioners and not a survey of PRA data requirements. However, these two sources are well-known and useful references. The Handbook presents 27 tables of human error probability data. The Data Bank consists of 16 matrices broken down by equipment characteristics and human actions. The following sections present a discussion of how data compatibility was assessed by using the Handbook and the Data Bank.

4.3.1 Compatibility of LER Data with the Data Requirements of the Handbook

A meeting was held with the authors of the Handbook to discuss the usefulness of LER information on human error as a source of data for the methods discussed in the Handbook. The purpose of this meeting was to determine if LER data could be used as input to the Handbook or as a means of comparing or validating the human reliability data already contained in the Handbook. Human error data in the Handbook are dependent on the identification of a number of Performance Shaping Factors (PSFs) such as time to diagnose the problem, number of operators available at the time, administrative controls and written procedures, type of instructions, tagging, stress, and experience. Without such detailed information, HEPs cannot be determined. In some instances the HEP varies from .0001 to 1.0 depending on the effect of relevant PSFs. LERs are deficient in information about PSFs, because there is no requirement to report the PSF affecting a human error. Only in the infrequent case that the individual filling out the LER form indicating something with regard to relevant PSF will this information be available. As a result, the HEPs developed through analysis of LERs appear to be too generic to be useful in the Handbook. However, it may be possible to obtain PSF information about LER events by directly contacting licensees for follow-up interviews after those LER events which are of greatest concern to PRA are reported. Such a communication channel between the licensee and the PRA analyst does not exist at this time. However, with the implementation of the new LER rule, there should be the opportunity for better communications.

4.3.2 Compatibility of LER Data with Storage Requirements of the Data Bank

The structure of the Data Bank is oriented toward identification of the class or category of human action and the equipment characteristics involved in human errors than identification of specific PSFs. HEPs are filed in the Data Bank according to the human actions and equipment characteristics involved. If PSF information is available, it can also be stored. However, locating the proper HEP in the Data Bank does not depend on detailed knowledge of PSFs. Hence, the Data Bank does allow for the classification of LER-identified human errors and associated HEPs.

As an illustration of how human errors identified in LERs could be entered into the Data Bank, a number of one-line human error descriptions from NUREG/CR-2987[7] were analyzed by two of the developers of the Data Bank (NUREG/CR-2744[10]). This analysis is reproduced in Appendix G. A total of 29 one-line human error descriptions were evaluated, and 27 of the 29 events were entered into the Data Bank. (The two event descriptions not entered were deficient in specific human error information.) There were some differences between the results of the two evaluators performing this analysis. However, for the most part, both evaluators were able to enter the LER items into five of the 16 matrices of the Data Bank (approx. 30%). In some cases, the authors were unsure of which matrix cells should be used to uniquely classify the descriptors. In others, it was observed that the human errors could be entered into more than one matrix cell. Some of the discrepancies may have been resolved if the analysis had involved actual LERs rather than the condensed one-line summary descriptions. In addition, it should be noted that the researchers developing the Data Bank are currently writing detailed procedures for establishing and maintaining the Data Bank. This development will further assist the categorization of LER-identified human errors.

Independent of the analysis performed by the Data Bank developers, two BNL researchers evaluated 104 LER human error events for input into the Data Bank. The results of this analysis are reproduced in Appendix H. The BNL researchers were able to enter all 104 events into three of the 16 Data Bank matrices (approx. 16%). (These three matrices were the same ones used by the Data Bank developers in their analysis.)

It appears that LER-identified human errors can provide useful input to the Data Bank. However, results of these limited analyses tend to indicate that many of the Data Bank HEP cells could not be made available by analyzing LERs. Of the 16 matrices used in the Data Bank, only five were used in the above analyses.

The Data Bank is divided into three levels according to the nature of the man-machine interface. The three possible interface levels are system, component, and element (elements are displays, instruments, and controls). As a result of the experience gained from the analysis of over 11,800 LERs, it can be concluded that virtually all human errors in LERs are identified at the component level. By way of illustration, a component level human error found in LERs may be "failure to open or close a valve" or "failure to perform a pump test." System-level human errors such as the failure to "operate or monitor a system" are seldom reported in LERs. Similarly, element-level errors such as "incorrect reading of a meter" or "failure to observe an annunicator light" are also rare in LERs. This should not be taken to indicate that such errors do not occur in NPPs; but rather that personnel filling out the LER forms have a tendency to describe human errors at the component level. Other levels of the Data Bank may be addressed by other types of analysis. For example, although simulator experiments may not be useful in providing human error information on correct testing of a pump (component level), it may provide useful information on displays, instruments, and controls (element level). The general conclusion based on these analyses is that LER analyses will most likely be useful to the Data Bank only at the "component level," and therefore can produce HEPs for between 10 to 30% of the human error data cells of the Data Bank.

5. SUMMARY AND CONCLUSIONS

The purpose of this report is to present a methodology for the estimation of HEPs based on an analysis of LERs and assess the utility of applying the method to generate human reliability data in support of PRA in terms of the method's practicality, acceptability, and usefulness. The method presented here is specific to LERs, but the method can also be used to analyze other type of field data on human performance in NPPs. Table 5.1 summarizes the results of this investigation.

Table 5.1 Summary of Results.

Issues	Results
Practicality	
- LER Availability	- Generally available from AEOD and INPO.
- Opportunity for Error Calculation	- Possible to determine objectively in about 20% of all human error LERs. Possible to determine opportunity subjectively in other cases.
- Logistic and Support	- Varies according to number of LERs to be evaluated and the accuracy required. Probably about 5 staff-years to analyze all past LERs and 0.3 staff-years to continue analysis of new LERs.
Acceptability	
- PRA-HRA Practitioners	- Generally considered acceptable with low to moderate confidence in the accuracy of the data.
Usefulness	
- Compatibility with NUREG/CR-1278	- LER data not generally compatible due to lack of PSF information.
- Compatibility with NUREG/CR-2744	- LER data compatible with component level of Data Bank. LER analyses not likely to yield significant results at other levels.

With regard to practicality, it was shown that LERs are available from the NRC for use in human reliability data development. Several systems are used to store LERs. The most comprehensive file of LERs is maintained in the form of microfiche by the NRC Office for Analysis and Evaluation of Operational Data (AEOD). In addition to maintaining up to date files of all existing LERs on microfiche, AEOD is developing a computerized system called the Sequence Coding and Search System (SCSS) for the storage of LER data. The use of this system will greatly facilitate the use of LERs to provide quantitative human error data. INPO currently maintains a data base as well, which can be accessed by agreement with NRC.

In order to estimate HEPs based on human errors identified in LERs, it is also necessary to determine the opportunities for those errors. The LER-HEP Method presented in this report is based primarily on an objective analysis using various documents such as plant procedures and technical specifications. Investigations presented in the practicality section have shown that about 20% of LER-reported human errors can be expressed as HERs by developing opportunity for error using objective techniques. Many human errors are the results of human actions which occur nonperiodically. Estimation of opportunity for errors for these actions must involve subjective techniques (e.g., NUREG/CR-3518[11] and -3688[12]). Therefore, in order to make optimal use of the human error information present in existing LERs, it will be necessary to use subjective estimation techniques for determining opportunities for error in about 80% of the cases.

Of the three parts in the LER-HEP Method, the part for determining opportunities for error is the most demanding with regard to logistics and support requirements. To analyze all 3,000 of the existing human error LERs using objective techniques would require 12 or more staff-years and extensive plant specific documentation such as technical drawings, operation, and maintenance procedures, technical specifications, and perhaps interviews with plant personnel. Using subjective methods, approximately 1.5 staff-years would be required to generate HEPs based on all 30,000 existing LERs or about 0.13 staff-years per year to generate HEPs based on the 2,500 LERs to be written each year by the licensees. However, the time savings of subjective techniques would be at the cost of a possible reduction in perceived accuracy. If a mixture of objective and subjective techniques are used, the back-fit program would require 5 staff-years and an ongoing program 0.3 staff-years per year.

With regard to acceptability most of the PRA-HRA practitioners responding to a survey indicated that analysis of LERs could provide human reliability data is useful to PRA. However, most experts would place only moderate confidence in the resulting HEP data. The reason given for this confidence level is that most of the surveyed experts are unsure of the accuracy and comprehensiveness of the human error information contained in existing LERs. According to the experts surveyed, an analysis of existing LERs is viewed as providing less accurate results than simulator experiments or expert judgment, but more accurate than computer modeling.

In order to assess the usefulness of the LER-HEP Method if used with existing LERs to provide support to PRA, the compatibility of LER human error data with the data requirements of PRA was determined. Two well known references were used to establish the human error data requirements of PRA: (1) NUREG/CR-1278, the "Handbook," and (2) NUREG/CR-2744,[10] the "Data Bank."

The Handbook is structured around the identification of PSF information which is usually not present on LER. Unless it is possible to document the important human factors information surrounding LER reported human errors, it is most likely that HEP developed using the LER-HEP Method will be too generic for use in the Handbook.

The data structure of the Data Bank is more general and will allow for classification and storage of human error data without knowledge of specific PSFs. Independent analyses conducted by the developers of the Data Bank and BNL researchers indicate that most LER-identified human errors can be classified using the scheme provided in the Data Bank. Because of the way LERs are usually written, only a portion (10-30%) of the Data Bank HEP cells could be assigned using LER analyses. This is due to the fact that most LERs identify component-level man-machine interactions while the Data Bank provides for storage of data at three levels: system, component, and element. Other levels of the Data Bank may be better served by other techniques or other types of field data. For example, simulator experiments may provide more useful data on the element level (i.e., displays, instruments, and controls).

In conclusion, this report has shown that the evaluation of LERs (i.e., using the LER-HEP Method) is generally a practical, acceptable, and useful means of supplying human error data for use in PRA. However, developing the LER-HEP Method does not completely solve the difficult problem of providing reliable, valid and objective data on human reliability for use in PRA. The following section makes recommendations which should improve the utility of analyzing field data in support of PRA.

6. RECOMMENDATIONS

The purpose of this section is to make recommendations which should improve the utility of a process by which LERs are used to supplement the human reliability data requirements of PRA.

6.1 Use of Sequence Coding and Search System

With regard to practicality, LERs are generally available from the NRC for HEP development. However, the identification and analysis of human error LERs for HER calculations could be greatly expedited if efforts were coordinated with the Sequence Coding and Search System (SCSS) being operated by the NRC/Office for Analysis and Evaluation of Operational Data. Since human errors are to be identified and classified by the SCSS, there would be no need to repeat the first part of the analysis in the LER-HEP Method. This would result in a considerable savings of time and resources.

Recommendation: Conduct a feasibility study to consider integrating efforts in LER analyses for estimation of HEPs with efforts for refining SCSS.

6.2 Revised LER Form and Guidance in NUREG-1022

An important problem with regard to the issue of practicality was the determination of opportunities for error. A totally objective determination of opportunity for error can be costly, and subjective techniques may be of limited credibility. For this reason it is recommended that the LER system be revised to require the licensee to provide information on the number of opportunities for error. A question on the LER form such as "How often is the activity in which the human error occurred repeated on a yearly basis?" would be extremely useful. The licensees are best qualified to answer such a question.

Recommendation: Revise the LER Form 364 to include an opportunity for error entry. Also revise NUREG-1022 to provide guidance and instructions for this entry.

6.3 Effects of Punitive Action

A concern that limits the general acceptability of the LER-HEP Method, as viewed by those experts surveyed, was that licensees may not be reporting all human errors that occur in their plants and hence the HERs obtained through LER analyses would be correspondingly low. There must be a means to motivate the licensees to report human errors completely and accurately in order to obtain optimal results. The most obvious reason that licensees may not report all human errors is the threat of punitive action by the NRC based on such reporting. Hence it is essential that a system be developed that the licensees could use to report human error without fear of punitive action.

Recommendation: Study the feasibility of an anonymous form of reporting in which licensees could report human error to a neutral agency (e.g., as proposed in NUREG/CR-3119)[19].

6.4 Improved Observation of Plant Operation

The acceptability of LER analysis is dependent on the perceived accuracy of the data obtained. It would be unrealistic to put high confidence in data obtained through any process, be it expert judgement, simulator experiments, or an evaluation of LERs, until these data can be validated. The most accurate way to validate such data is by making direct observations at the plants themselves. The observer must be highly knowledgeable in plant operations and must not be very obvious to plant personnel or the licensees are likely react to the fact that they are being observed and artificially produce fewer human errors. Perhaps an experienced NRC resident inspector could be used. An unobtrusive device such as a voice and control board input recorder would be very useful in obtaining accurate data on human error provided that the results are evaluated by someone very knowledgeable in NPP operations.

Recommendation: Conduct additional studies which make direct observations of human activities in NPPs to validate HEP estimation techniques.

6.5 Use of Human Factors Information

The general lack of information on PSFs (i.e., stress, training, procedures, etc.) in LERs limits the usefulness of HERs developed through LER analyses to support or validate HEP data such as those presented in the Handbook (NUREG/CR-1278).[9] It is generally recognized that PSFs have a strong influence on the HEPs for certain human actions. In order to obtain human factors information relevant to LER events, it will be necessary to contact the licensees filling out LERs after reported events.

Recommendation: Establish a direct channel between the licensees and analysts developing HEPs from LERs to document the necessary human factors information.

6.6 Improved Inventory of Useful Human Errors

Finally, the evaluation of usefulness presented in this report was limited by the fact that only the data banks of NUREG/CR-1278 and -2744 were considered indicative of the human error data requirements of PRA. A summary of the types of human errors included in PRAs and their impact on NPP safety is not available at this time. It is quite possible that LERs could be considered a more useful source of human error data once these data requirements have been more clearly defined.

Recommendation: Conduct in-depth surveys of the types of human error data required in PRA and analyze the various effects of human errors on NPP safety.

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APPENDIX A

"THE LER-HEP METHOD"

A METHOD FOR CALCULATING HUMAN ERROR RATES BASED ON INFORMATION CONTAINED IN LICENSEE EVENT REPORTS AND NUCLEAR POWER PLANT EXPERIENCE

(Instructions and Work Sheets)

From NUREG/CR-3519

THE LER-HEP METHOD

A Method for Calculating Human Error Rates Based on Information Contained in Licensee Event Reports and Nuclear Power Plant Experience

Overview

The purpose of this method is to derive Human Error Probabilities (HEPs) from an analysis of Licensee Event Reports (LERs). The LER-HEP Method accomplishes this by identifying and classifying human errors reported in LERs, determining the opportunities for those errors (based on experience in nuclear power plant (NPP) operation and references to plant drawings and procedures) and finally combining the results of a survey of LERs with the corresponding opportunities and plant outage data to calculate HERs.* If the intent of using the LER-HEP Method is to derive HEPs which can be used in the "Data Bank" (which was presented in NUREG/CR-2744 "Human Reliability Data Bank for Nuclear Power Plant Operations, Volume 2: A Data Bank Concept and System Description") then it is important that the work sheets of the LER-HEP Method be filled out in a way that is consistent with the Data Bank structure and the procedures established in the "Human Reliability Data Bank Implementation Plan."** The Data Bank definitions and procedures were used in the LER-HEP Method where possible. The user is referred to the "Human Reliability Data Bank Implementation Plan" for procedures detailing how HERs are to be entered into the Data Bank.

The instructions and work sheets of the LER-HEP Method are divided up into three parts corresponding to: (1) the analysis of LERs, (2) the determination of opportunities for error, and (3) the calculation of HEPs. The information required on the work sheets can be found in LERs and other sources. Some subjective judgment may be necessary to complete a HEP calculation. Although the three parts of the LER-HEP Method are independent and may be done by different individuals at different times, it is recommended that the same individual make any subjective estimations on all three parts. The LER-HEP Method is intended as an objective means of using field data (LERs) to calculate HERs. For the sake of accuracy, the source of all information entered on the work sheet should be documented and the amount of subjective estimation kept to a minimum.

The following paragraphs introduce each of the three parts of the LER-HEP Method and provide general instructions for its use.

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*Human error rate has been defined as:

$$\text{HER} = \frac{\text{number of human errors of a particular type}}{\text{total number of opportunities for above errors.}}$$

HEPs can be estimated directly from HERs when the rates are considered reasonable data.

**Any reference to the "Data Bank" in this methodology is intended as a reference to the Human Reliability Data Bank of NUREG/CR-2744.

Part I: LER Analysis

Part I of the LER-HEP Method provides a structure for the analysis of LERs one at a time to document the important human error information. For the most part, the information required in Part I can be found directly on the LER. However, some judgment must be used in the evaluation. The individual filling out the forms of Part I must be familiar with the LER system and NUREG/CR-0161: "Instructions for Preparation of Data Entry Sheets for Licensee Event Reports." It is also necessary for the user of the LER-HEP Method to have a good working knowledge of NPP systems. In order for the LER-HEP Method to produce results that can be used in the Data Bank, the user must be familiar with the structure of the Data Bank and the various definitions used for types of equipment and human actions. Finally, the user must keep abreast of any changes in the LER system and the Data Bank so that HEPs obtained from an analysis of LERs can be entered consistently into the Data Bank.

The results of Part I will be a number of Part I work sheets filled out for LERs occurring within a given time period. Each LER will result in at least one Part I work sheet. These work sheets must be grouped into categories according to the type of error identified (i.e., human action and equipment characteristic). If it is possible to use a given LER for more than one category or cell of the Data Bank, a copy of the work sheet must be made for each possible entry.

Part II: Opportunity for Error

Part II of the LER-HEP Method is used to derive opportunity for error for a specific human action on a specific piece of equipment. The information in Part II must usually be obtained from sources other than the LER. In order to determine the inventory of similar tasks and the number of times each is repeated, it will be helpful to reference technical specifications and plant procedures. The equipment inventory information may be obtained from plant drawings such as piping and instrumentation diagrams. In order to obtain meaningful results in this part the user of the LER-HEP Method must have extensive knowledge of NPP operations and specific plant designs. Ideally, task analyses and equipment inventories should be conducted on a plant specific basis to derive the most accurate opportunities. Realizing that this may not be possible, estimations of opportunity for error can be made by experienced power plant personnel with references to drawings, procedures, or technical specifications. The degree of detail used in the analysis will be dictated by the required accuracy of the results and the resources available.

Part III: HEP Calculation

The purpose of Part III is to combine the results of the first two parts of the LER-HEP Method in order to calculate an HEP. This part consists of the transfer of data from other work sheets to Part III and the calculation of an HEP. The only other information required is plant outage data, which may be obtained from sources such as "Operating Experience with Nuclear Power States," International Atomic Energy Agency, Vienna, Austria, or "Licensing Operating Reactors, Status Summary Report" (NUREG-0020) or a factor may be assumed. The user requirements for this last part are simpler than for the first two. There are no requirements here for knowledge of the LER system or of the specifics of NPP operation. However, the user should be familiar with the Data Bank if it is intended that the resulting HEPs be entered into the Data Bank.

General Instructions

Before attempting to develop any HEPs, it is important to read through the entire LER-HEP Method to determine what type of analysis is to be performed. There is more than one way to obtain a HEP. Depending on the accuracy required, the resources available and other specifics regarding the human-machine interface different analyses may be performed. These options are discussed in the parts of the methodology where they are relevant. Although the LER-HEP Method is divided up into Parts I, II, and III they need not be done in this 1-2-3 sequence. Actually, it may help to begin with the Part III work sheet to define the HEP in question. The Part III sections on "Error Classification," "Survey Period," and "Plant Information" will help with this definition. Each Part III work sheet will calculate one HEP, however, several of the Part I and II work sheets may be needed for a single HEP. By identifying the survey period, the plants of interest and the human error classification it will be possible to sort out the LERs required for each HEP analysis. Once these LERs are retrieved from the LER files, Part I work sheets can be filled out; one for each LER identified human error. The Part II work sheets can be used to estimate the opportunity for error for this group of human errors. Finally, taking the results of Parts I and II and making some estimations of plant operational data, the Part III work sheet can be completed to obtain an HEP.

PART I: LER ANALYSIS

The information required in this part of the work sheet can be found, for the most part, directly on the Licensee Event Report (LER). It must be assumed that the information contained in the LER is accurate and reliable. However, some judgement must be used in the evaluation. For example, the LER form only allows for the identification of one cause code. Clearly some incidents are the result of a combination of causative factors, some of which may be human errors. Any human errors that can be identified on the LER that contributed to the occurrence of the incident should be described on the work sheet. A sample of the LER form is given on the next page.

A LER consists of two paragraphs: Item 10; the event description and probable consequences and: Item 27; the cause description and corrective actions. In addition to this textual information, a number of codes are used to provide information about the system, cause, component, effects, etc.

In order to obtain a clear understanding of all the circumstances surrounding the incident, all of the LER items should be read and the codes identified. The meanings of these code letters should be looked up in NUREG-0161: Instructions for Preparation of Data Entry Sheets for Licensee Event Reports to ensure that the LER is properly interpreted.

If Item 23 ("Attachment Submitted") of the LER contains a "Y" this means that additional pages are attached to the LER to provide more detailed and in-depth information. In which case these pages should also be read, as they are considered an integral part of the report.

In some instances, the information required on the work sheet is not readily available from the LER. Additional sources may be referenced or certain assumptions might be made based on experience. For example: by referencing plant drawings it may be determined that the component involved in the human error is part of a given system even though this information was not provided on the LER. For those lines of the work sheet where it is possible for information to be obtained from other sources or from assumptions based on experience, the word "source" appears. In these cases, identify the source of the information you have entered on that line, be it the LER, some other reference or some assumption based on knowledge or experience. It is important to complete the entire worksheet even if this requires making an educated guess. Be sure to fill out every line of the work sheet. If the only way to fill out a line is to make an assumption, then do so. But identify "best judgment" or "experience" as the source of the information. In every case identify the source of the information where requested, however, the LER should be considered the primary and most reliable source.

NRC FORM 366
(7-77)

SAMPLE

U. S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT

CONTROL BLOCK: (1) (PLEASE PRINT OR TYPE ALL REQUIRED INFORMATION)

0 1 — LICENSEE CODE (2) — LICENSE NUMBER (3) — LICENSE TYPE (4) — CAT (5)

CON'T

0 1 — REPORT SOURCE (6) — DOCKET NUMBER (7) — EVENT DATE (8) — REPORT DATE (9)

EVENT DESCRIPTION AND PROBABLE CONSEQUENCES (10)

0 2

0 3

0 4

0 5

0 6

0 7

0 8

0 9 — SYSTEM CODE (11) — CAUSE CODE (12) — CAUSE SUBCODE (13) — COMPONENT CODE (14) — COMP. SUBCODE (15) — VALVE SUBCODE (16)

(17) LER RO REPORT NUMBER — EVENT YEAR — SEQUENTIAL REPORT NO. — OCCURRENCE CODE — REPORT TYPE — REVISION NO.

ACTION TAKEN (18) — FUTURE ACTION (19) — EFFECT ON PLANT (20) — SHUTDOWN METHOD (21) — HOURS (22) — ATTACHMENT SUBMITTED (23) — NPRD-4 FORM SUB. (24) — PRIME COMP. SUPPLIER (25) — COMPONENT MANUFACTURER (26)

CAUSE DESCRIPTION AND CORRECTIVE ACTIONS (27)

1 0

1 1

1 2

1 3

1 4

1 5 — FACILITY STATUS (28) — % POWER (29) — OTHER STATUS (30) — METHOD OF DISCOVERY (31) — DISCOVERY DESCRIPTION (32)

1 6 — ACTIVITY RELEASED (33) — CONTENT OF RELEASE (34) — AMOUNT OF ACTIVITY (35) — LOCATION OF RELEASE (36)

PERSONNEL EXPOSURES

1 7 — NUMBER (37) — TYPE (38) — DESCRIPTION (39)

PERSONNEL INJURIES

1 8 — NUMBER (40) — DESCRIPTION (41)

LOSS OF OR DAMAGE TO FACILITY (43)

1 9 — TYPE (42) — DESCRIPTION

PUBLICITY

2 0 — ISSUED (44) — DESCRIPTION (45) — NRC USE ONLY

NAME OF PREPARER ______________________ PHONE: ______________________

Basic Information

Line 1. Docket number: can be found on the LER Item 7.

Line 2. LER number: event year - sequential report no./occurrence code can be found on LER Item 17.

Line 3. Control Number: LER Item 1 (if a control number has not been provided enter NA for "not available").

The following four items may be found by referencing Exhibit A "List of Plants by Docket," which is at the end of the methodology:

Line 4. Plant Name: the official name of the power plant, include the number as indicated, i.e., Dresden 2.

Line 5. Sister Dockets: many plants are, for all practical purposes, identical to one or two sister plants. The second table in Appendix A lists the Docket numbers of the sister plants. If the plant given on Line 4 has one or two sister plants, indicate the Docket numbers of the sister plants on Line 5. (Note that all sister plants have the same name but all plants of the same name are not necessarily sister plants. For example, Millstone 1 and 2 are not sister plants.)

Line 6. Plant Type: enter plant type either BWR for boiling water reactor or PWR for pressurized water reactor, as indicated in the Appendix.

Line 7. Reactor Vendor: indicate the reactor vendor: GE for General Electric, WE for Westinghouse, CE for Combustion Engineering, and BW for Babcock and Wilcox, as listed in the Appendix.

Line 8. Event Date: the date of the event as indicated by the LER, Item 8.

Line 9. Report Date: the date of the LER as given by Item 9 on the LER.

Error Information

If it is clear that the event reported on the LER was not the result of human error, enter "No human errors" on Line 10 and discontinue the analysis.

Line 10. Error Date: the error date to be entered on the Work Sheet may not necessarily be the event date listed on the LER Item 8. In many cases the LER serves to identify a previous human error. In this case the actual error date to be entered on the work sheet Line 10 will be some previous date (i.e., the date on which the human error occurred--not the date it was discovered). If possible, enter the date the human error, reported in the LER, actually occurred. If not, leave Line 10 blank.

Because the LER is used to report various types of simple and complex incidents, a single LER may contain several human errors. All human errors must be identified. A number of identical errors may be reported on the same work sheet, however, each unique human error must be described on a separate work sheet. Identical errors are defined as errors that occur involving the same human actions on the same pieces of equipment.

Line 11. Number of Identical Errors: if the LER identifies more than one identical human error indicate the number of errors of that specific type.

Line 12. Number of Dissimilar Errors: if applicable, indicate the number of dissimilar or unique errors that have been identified on the same LER.

Line 13. Page Number: in the event dissimilar human errors are reported on the LER, they should be identified on separate work sheets and each work sheet should be numbered. Enter the page number of the total number of work sheets that this work sheet represents.

Note: If the LER contains only one human error, Line 11 should contain a "1", Line 12 a "0", and Line 13 should be left blank.

Line 14. Periodic: some tasks are performed on a fixed periodic basis. For example, there is often a requirement that certain tests and calibrations be performed daily, monthly, quarterly, etc. If the human action that was done incorrectly or omitted is normally performed on this type of fixed periodic basis, indicate so by entering "fixed testing" or "fixed calibration." If the human error was part of preventive maintenance that is normally done on a routine periodic basis, enter "periodic maintenance." If the human error occurred as part of normal routine operations, and these operations may be considered to be periodic, enter "routine operation." An example of a routine operation would be a normal start-up or shutdown. An example of a non-routine operation would be a reactor SCRAM or TRIP - in which case enter "non-periodic". Many maintenance and repair tasks are not performed periodically. In these instances enter "non-periodic."

Line 15. Error Type: human errors can be classified as either errors of omission or commission. An error of omission is a failure to perform a required task. A commission error is one in which a task was incorrectly performed or where the wrong task was performed. Indicate whether the error was an omission or a commission error.

Line 16. Error Description: both omission and commission type errors can be described in more detail. For Line 16, indicate the specifics of the error. The following are given as examples.

Errors of omission can be categorized as follows: was the entire task omitted or was a step within a task omitted? Commission errors are of several types. For example:

- Inadvertent or accidental actions: such as brushing against a switch and activating it or stepping on a junction box and damaging it.

- Timing error: task or step not performed in its proper sequence, either too early or too late,

- Qualitative error: required action performed to too great or too little of an extent,

- Selection error: task was performed properly, but on the wrong device.

Human Actions

The purpose of this section is to identify and categorize the reported human action that was done incorrectly or omitted. In order to categorize human errors so that they can be entered into the Data Bank consistently, it will be necessary to use the descriptors and definitions presented in NUREG/CR-2744 "Human Reliability Data Bank for Nuclear Power Plant Operations." A list of the various descriptors is given in Exhibit B at the end of the LER-HEP Method. At the time this methodology was published, the various descriptors and definitions used in the Data Bank were still being revised. The user is referred to the most recent Data Bank publication for definitions of these terms. Condensed definitions presently available from the Data Bank are given below.

Line 17. Position: "a group of duties and responsibilities constituting the principal work assignment of one person or group of people." Enter the job title of: Control Room Operator, Equipment Operator or Maintenance Technician to reflect the position of the individual responsible for the incident reported on the LER.

Line 18. Duty Area: "one of the major subdivisions of work performed by an individual. Duty areas are groups of tasks that are associated with operating plant systems using approved operating procedures." Enter the duty area identified from the LER; enter check, diagnose, operate or test as defined in the Data Bank.

Line 19. Task: identify the task that the involved individual was attempting to do when the human error was committed. A task is defined as "a unit of work; one or more sets of related actions that change or verify a system state. A task can be described as having the following characteristics: (1) it has a specific purpose, (2) it has a definite beginning and end, (3) it occurs in a relatively short period of time, (4) it can be interruptable, and (5) it may involve multiple crew members."

Line 20. Task Element: identify the task element, specific action or motion that was done incorrectly. A task element is defined as "a single action that contributes to the accomplishment of a task. An element can be described as having the following characteristics: (1) it is performed by one person, (2) it can be interspersed in time with elements of another task, and (3) it is not interruptable."

Equipment Characteristics

The purpose of this section is to uniquely identify the specific piece of mechanical equipment involved in the incident. Exhibit C lists descriptors adapted from NUREG/CR-2744, which should be used to identify the equipment characteristics. Again, the user is referred to NUREG/CR-2744 for complete definitions of these terms.

Line 21. System: identify the system in which the error occurred (see LER Item 11). A system is defined in the Data Bank as "an integral part of a nuclear plant comprising electrical, electronic, or mechanical components (or combinations thereof). A system may be operated as a separate entity to perform a particular function." A system is a set of interrelated components working together toward some common objective.

Line 22. Subsystem: identify the subsystem in which the error occurred. The Data Bank does not currently provide a definition for subsystem. However, a subsystem may be used to describe a lower hierarchical level within a given system. For example, the condensate polisher is a sybsystem in support of the condensate system.

Line 23. Component: identify the component involved in the error (see LER Items 14, 15, and 16). The Data Bank defines component as "an assembly of interconnected parts that constitutes an identifiable device, instrument, or piece of equipment. A component can be disconnected, removed as a unit and replaced with a spare. It has definable performance characteristics that permit it to be tested as a unit."

Line 24. Element: identify the element involved in the error. In the case of displays, instruments, or controls the definition given by the Data Bank for these elements is: "electrical, electronic, or mechanical devices (or combinations thereof) that constitute the direct point of contact for the man/machine interface, including controls, displays, portable test equipment, and hand tools."

Interface

The purpose of this section is to determine the level(s) at which the human interface with the equipment can best be described. A "Level" constitutes a combination of human actions and equipment characteristics. According to the Data Bank, there are three possible interface levels: (1) Duty Area-System (or Subsystem), (2) Task-Component, and (3) Task Element-Equipment Element. Each human action may be described at one or more of these levels. The level of the interface determines the matrix of the Data Bank which will be used to store the HER once it is generated. To determine the interface level(s) it is necessary to consider the possible combinations of human actions and equipment characteristics as defined by the Data Bank. For a Level 1 interface (Duty Area-System or Subsystem), it must be possible to describe the human error using the verbs: diagnose, monitor, operate, or test along with the specific system or subsystem. For a Level 2 interface (Task-Component) the human action must be one of the tasks listed in Exhibit B and the component one of those listed in Exhibit C. For a Level 3 interface (Task Element-Equipment Element), the human action must be one of the task elements listed in Exhibit B and one of the displays, instruments, or controls (equipment elements) from Exhibit C.

Although it may be possible to identify all of the human action and equipment characteristics descriptors required on the work sheet, human errors are usually best described using one or perhaps two pairs of descriptors. The purpose of identifying the interface level(s) is to indicate which pair(s) of descriptors best describes the human error.

> Line 25. Interface: according to the best possible combination(s) of human action and equipment characteristics descriptors, enter the interface level(s) as "(1) Duty Area-System or Subsystem," "(2) Task Component" and/or "(3) Task Element-Equipment Element" on Line 25.

Performance Shaping Factors

In some cases, a number of factors or conditions may have affected the performance of the individual(s) responsible for the human error(s). Such factors are referred to as Performance Shaping Factors (PSFs). The Data Bank identifies four basic types of PSFs: stress, experience, procedures, and tagging. The Human Reliability Data Bank Implementation Plan discusses these PSFs and provides a procedure (see Appendix A-4 of the Implementation Plan) for assigning weights to these four PSFs. The user is referred to the Implementation Plan if it is desired to weight the PSFs for use in the Data Bank.

> Line 26 through 28. Performance Shaping Factors: if any PSFs were identified on the LER or through an analysis of the event as having contributed to the human error, they should be listed on Lines 26, 27, and 28 of the work sheet. If it is possible to weight the effects of stress, experience, procedures, and/ or tagging according to Procedure A-4 of the Human Reliability Data Bank Implementation Plan, then enter the weights obtained on the work sheet. If it is not possible to use this weighting procedure, leave the "weight" column on the work sheet blank.

Summary

In order to provide a complete description of the human error, it is helpful to write a sentence combining the information provided on this work sheet. Other important information about the error that is not available elsewhere on the work sheet can be included. For example, given the descriptors "Equipment Operator," "value," "omission," and "close" and other information provided on the LER, a summary such as: "Equipment Operator failed to close suction valve on RHR pump after pump test" may be appropriate.

Line 27. Write a one-line or one-sentence summary of the human error summarizing the situation.

PART II: OPPORTUNITY FOR ERROR

The calculation of Human Error Probability (HEP) is dependent on both the number of human errors of a particular type and the total number of opportunities for those errors. The purpose of this part is to determine the opportunity for error based on the human action identified in Part I. Opportunity for error is defined as the total number of times the identified human action is repeated. This opportunity is found by conducting an inventory of all human actions and all similar equipment in the plant. The following sections provide a framework for itemizing both human actions and equipment.

Licensee Event Reports (LERs) must be submitted in certain circumstances which are termed "reportable occurrences." Reportable occurrences are defined in the Technical Specifications for BWR and PWR plants and in the Code of Federal Regulations. It is important to be familiar with the definition of reportable occurrences when attempting to identify similar actions for opportunity for error.

Because LERs are required in the event of a reportable occurrence, all those similar actions, which, if done incorrectly or omitted would result in a reportable occurrence, must be included in the opportunity for error in order to calculate meaningful and consistent HEPs. For example, the miscalibration of an off-site, substation circuit breaker would not result in a reportable occurrence while the miscalibration of a safety system circuit breaker would. Therefore, the actions on the substation circuit breaker should not be included in the total opportunity for error while all such actions on safety system circuit breakers should be included. It is important to itemize all similar actions that could result in a reportable occurrence in order to determine the opportunity for error accurately.

Ideally, the information required in this section should be available from plant specific drawings, procedures manuals, technical specifications, and surveillance requirements and task analyses. If these guides are used by someone with experience in the particular plant in question, an accurate estimation of opportunity for error should be obtained. However, if this plant specific information is not available and individuals with plant specific experience are able to assist in the analysis, an estimation may be made by using the expert's best judgment. The user is warned that unless the experts performing the analysis are truly qualified as having appropriate operations, maintenance testing, and NPP experience, little reliability of data should be expected.

The right hand column on the work sheet is titled "source." This is where the basis for the numbers entered in the previous columns should be indicated. In each case indicate: plant drawings, procedures manuals, technical specifications and surveillance requirements, task analyses, plant experience, or expert's judgment as the source of the information as appropriate.

Inventory of Human Actions

The purpose of this section is to itemize all human actions which are similar repetitions of the action identified in Part I. These human actions considered here only involve interface with the equipment specifically identified in Part I. Additional pages are required for additional equipment other than specifically identified in Part I. More will be said about this in the Equipment Inventory section. But for the purpose of this section, only those human interactions with the specific equipment identified in the Equipment Characteristics section of Part I are to be considered. For now, skip the lines marked Page Number and Number of Unique Classes.

First, it is necessary to obtain the Interface Level from Line 25 of the Part I work sheet. The three possible interface levels are (1) Duty Area-System or Subsystem, (2) Task-Component, and (3) Task Element-Equipment Element. If more than one interface level is given in Part I a separate Part II work sheet must be filled out to determine opportunity for error at each level. Depending on the interface level, look up the human action at that level by referencing Lines 18, 19, or 20 of Part I as follows: Line 18 for Duty Area, Line 19 for Task, or Line 20 for Task Element.

The same basic human action may be repeated as part of various activities. Human actions are defined as similar if they involve the same action and equipment description and are performed by the same personnel group. For example, control room operators may monitor a certain system during start-up,, shutdown, and load follow operations. In this case, the activities would be "start-up," "shutdown," and "load follow" and the human action would be monitor. As another example, maintenance technician may energize a certain valve operator during pump tests and system tests (each done on a different frequency). In which case, the activities would be "pump test" and "system test" and the human action would be "energize."

Starting on the first line of the Inventory of Human Actions section, list all activities involving the human action identified in Part I. Then, for each of the activities enter the number of times the given human action is repeated within that activity during in a 1-year period in the Annual Repetition column. For example, if a pump test procedure requires that the given valve be opened and this test is performed four times a year then the activity is "Pump Test" and the "Annual Repetition" for that test is four. If the human action is repeated less than once a year, enter a decimal as appropriate (e.g., something done every refueling or every 18 months: 12 months/year divided by 18 months per repetition equals .67 repetitions/year).

After all similar human actions are itemized, add up the annual repetitions to come up with the total number of repetitions of the given human action on the given equipment in a 1-year period. Enter this sum on the line marked Total Annual Repetition.

Equipment Inventory

In addition to itemizing human actions on the one specific piece of equipment identified in Part I, it is also necessary to take a complete inventory of all equipment in the plant involved with similar human actions. Depending on the Interface Level (Line 25 of Part I) components, or elements should be itemized that involve similar human actions. Two physically dissimilar items of equipment might be quite similar in terms of the human behaviors related to their operation, maintenance, testing, or calibration. For example, if the task element is to calibrate a certain integrated circuit board, then circuit boards in all safety systems that are calibrated in a similar fashion should be itemized. As an example, at the "Task-Component" level, if the task is to line up a pump, then all pumps that are lined up in the same way should be itemized. However, if the human action is at the system (or subsystem) level, it will not be possible to include other systems (or subsystems) unless those systems (or subsystems) are redundant or identical to the original.

Some physically similar pieces of equipment may also have human actions associated with them that would result in an inventory of human actions quite similar to that listed above. Examples of these would be redundant or stand-by units such as a pair of AC emergency supply systems that can be used interchangeably or multiple units such as the control rod drives. Other equipment may involve similar human actions but have an inventory of human actions different than that given above. Such equipment is referred to as a unique class of eqipment. A class of equipment may contain one device or it may contail several items. For each unique class of equipment a separate page must be filled out, similar to this one, to itemize all the human actions. Members of the "class" are defined as having an inventory of human actions identical to all other members of that class.

All equipment to be listed in the Equipment Inventory section of this Part II work sheet must have exactly the same breakdown of human actions as given by the Inventory of Human Actions section. In other words, all equipment listed in this section must be involved with the same number of human actions as part of the same activities listed in the Inventory of Human Actions. Starting on the first line under Common Class Equipment list those pieces of equipment that have the same human action breakdown as given in the Inventory of Human Actions section. If there are two or more pieces of identical equipment they may be listed on the same line. Then enter the number of those pieces of equipment in the Quantity column. For single pieces of equipment, enter a "1" in the Quantity column. Add up the numbers in the Quantity column to come up with the total number of items of similar equipment in the plant and enter this sum in the box labeled Total Similar Equipment.

Opportunity

Opportunity for error is found by multiplying the Total Annual Repetition from the Inventory of Human Actions section times the Total Similar Equipment from the Equipment Inventory section. Enter these numbers in the boxes as appropriate and the product in the Total Opportunity (this Page) box.

Fill out as many Part II pages as necessary to itemize all unique classes of equipment. Once this is done, count up the total number of unique classes and enter that number in the box at the top of the Part II page marked Number of Unique Classes. Number each page starting with the original equipment identifed in Part I as page 1, entering the number of each page on the line marked Page Number at the top of the page.

Add up all of the Opportunity (this Page) quantities and place the sum in the Total Opportunity (other Pages) box on the first page of the series of pages in Part II. Add the Total Opportunity (this Page) to the Total Opportunity (other Pages) and place the same in the Total Annual Opportunity box. This is the total opportunity for error for the given human action in the the power plant for a 1-year period.

PART III: HEP CALCULATION

The purpose of this part is to combine the results of a survey of human errors identified from Licensee Event Reports (LERs) with the corresponding data on opportunity for error to calculate Human Error Probabilities (HEPs). The work sheets of Part I have identified and classified human errors. The work sheets of Part II have quantified the annual opportunity for the class of error identified in Part I. Combining this information with data on plant operational history, Part III enables the user to calculate an HER.

The work sheets filled out in Part I should be sorted into categories with common Human Action and Equipment Characteristics. That is, all of those Part I work sheets that have common human action and equipment characteristic descriptions should be grouped together. The opportunity for error calculations of Part II are based on these categories. Then a Part III work sheet should be filled out for each error category.

Error Classification

Lines 1 through 9 of the Part III work sheet may be filled out by referencing Lines 17 through 25 of the Part I work sheet. Position, Duty Area, Task, Task Element, System, Subsystem, Component, Element, and Interface Level should all be copied from the Part I work sheets to the Part III work sheets as appropriate.

Survey Period

The dates to be entered in this section are the dates between which all human error LERs, of the category described above, have been analyzed.

Line 10. Survey Begin: enter the date that the time period of LERs to be considered starts.

Line 11. Survey End: enter the date that the time period of LERs to be considered stops. For example, if all LERs between 1/1/79 and 12/31/81 were analyzed, enter 1/1/79 for Survey Begin and 12/31/81 as Survey End.

Line 12. Survey Length: enter the length of time between survey beginning and survey end in years and months. For "Decimal" calculate the survey length in years and express in a deciman fashion. For example, three years, four months would be expressed as 3.33.

Plant Information

The purpose of this section is to determine which plants are similar and should be included in the survey. If the intent is to supply HEPs to the Data Bank, it will be necessary to list plants by common vendor. That is all plants with the same reactor vendor should be listed. It may be necessary to list plants based on some other criteria such as reactor type (e.g., pressurized water reactor [PWR] vs. boiling water reactor [BWR]). However, in this situation, HEPs will be developed that spread across matrices of the Data Bank. These HEPs may be useful as "generic" error rates.

Starting on Line 13, list all plants that are included in the survey under the "Plant" column. Continue on the reverse side if necessary. For "Factor" estimate the fraction of the total amount of time the given plant was critical during the survey period. This factor is defined as:

$$\frac{\text{total amount of time reactor was critical during survey period}}{\text{total amount of time in survey period (see Line 12).}}$$

For example, if a given reactor was critical for 3.0 years out of a 4.5 year, survey, the factor to be entered is .67. (Note, if it is not possible to estimate the factor for each plant, or make an estimate for the plants listed as a whole and enter this number on Line 15.

Total Opportunity

The purpose of this section is to combine opportunities across the plants listed to come up with the total opportunity for the given error in all plants combined.

Line 14. Total Number of Plants: enter the total number of plants entered in the previous section.

Line 15. Average Factor: average the factors listed for each of the plants (starting with Line 13) by summing all the factors and dividing by the number of plants. Enter this number on Line 15.

Line 16. Total Plant Years: multiply the "Total Number of Plants" (Line 14) times the "Survey Length" (Line 12) and enter this product on Line 16.

Line 17. Total Operating Time: multiply the "Total Plant Years" (Line 16) by the "Average Factor" (Line 15) to indicate the total number of plant operational years within the survey period. Enter this number on Line 17.

Line 18. Total Annual Opportunity: enter the total opportunity for the given human action as developed on the last line of the Part II work sheet.

Line 19. Total Opportunity: multiply the "Total Annual Opportunity" (Line 18) by the "Total Operation Time" (Line 17) and enter this product on Line 19. This is the total opportunity for the given category of human errors.

Human Error List

The purpose of this section is to develop the numerator of the HEP equation by including all human errors of the given type obtained from the survey of LERs. Starting on Line 20, list all LERs, by number, that were identified as containing the human error of the Error Classification shown on Lines 1 through 9. Under the "Error" column, enter the number of similar human errors identified on each LER. If more space is needed, use the back of the paper.

Line 21. Total Number of Errors: sum up all of the LER identified human errors listed in this section starting on Line 20 and place the sum on Line 21.

Human Error Probability

By dividing the "Total Number of Errors" by the "Total Opportunity" an HER can be obtained.

Line 22. Total Number of Errors: copy the total number of errors given on Line 21 onto Line 22.

Line 23. Total Opportunity: copy the total opportunity developed on Line 19 onto Line 23.

Line 24. Human Error Probability: divide Line 22 by Line 23 and enter the quotient on Line 24. This is the HEP for the given human action in the given plants as reported on LERs.

EXHIBIT A

LIST OF PLANTS BY DOCKET NUMBERS

Docket	Name	Vendor	Type
50003	Indian Pt. 1	BW	PWR
50010	Dresden 1	GE	BWR
50029	Yankee Rowe	WE	PWR
50133	Humbolt Bay	GE	BWR
50155	Big Rock Pt.	GE	BWR
50206	San Onofre 1	WE	PWR
50213	Haddam Neck	WE	PWR
50219	Oyster Creek	GE	BWR
50220	Nine Mile Pt. 1	GE	BWR
50237	Dresden 2	GE	BWR
50244	Ginna	WE	PWR
50245	Millstone 1	GE	BWR
50247	Indian Pt. 2	WE	PWR
50249	Dresden 3	GE	BWR
50250	Turkey Pt. 3	WE	PWR
50251	Turkey Pt. 4	WE	PWR
50254	Quad Cities 1	GE	BWR
50255	Palisades	CE	PWR
50259	Browns Ferry 1	GE	BWR
50260	Browns Ferry 2	GE	BWR
50261	Robinson 2	WE	PWR
50263	Monticello	GE	BWR
50265	Quad Cities 2	GE	BWR
50266	Point Beach 1	WE	PWR
50267	Ft. St. Vrain	GA	HTGR
50269	Oconee 1	BW	PWR
50270	Oconee 2	BW	PWR
50271	Vermont Yankee	GE	BWR
50272	Salem 1	WE	PWR
50277	Peach Bottom 2	GE	BWR
50278	Peach Bottom 3	GE	BWR
50280	Surry 1	WE	PWR
50281	Surry 2	WE	PWR
50282	Prairie Is. 1	WE	PWR
50285	Ft. Calhoun 1	CE	PWR
50286	Indian Pt. 3	WE	PWR
50287	Oconee 3	BW	PWR
50389	Three Mile Is. 1	BW	PWR
50293	Pilgrim 1	GE	BWR
50295	Zion 1	WE	PWR
50296	Browns Ferry 3	GE	BWR
50298	Cooper	GE	BWR
50301	Point Beach 2	WE	PWR
50302	Crystal River 3	BW	PWR
50304	Zion 2	WE	PWR
50305	Kewaunee	WE	PWR
50306	Prairie Is. 2	WE	PWR
50309	Maine Yankee	CE	PWR
50311	Salem 2	WE	PWR
50312	Rancho Seco 1	BW	PWR
50313	Arkansas 1	BW	PWR
50315	Cook 1	WE	PWR
50316	Cook 2	WE	PWR
50317	Calvert Cliffs 1	CE	PWR
50318	Calvert Cliffs 2	CE	PWR
50320	Three Mile Is. 2	BW	PWR
50321	Hatch 1	GE	BWR
50324	Brunswick 2	GE	BWR
50325	Brunswick 1	GE	BWR
50327	Sequoyah 1	WE	PWR
50331	Arnold	GE	BWR
50333	Fitzpatrick	GE	BWR
50334	Beaver Valley 1	WE	PWR
50335	St. Lucie 1	CE	PWR
50336	Millstone 2	CE	PWR
50338	North Anna 1	WE	PWR
50339	North Anna 2	WE	PWR
50344	Trojan	WE	PWR
50346	Davis Besse 1	BW	PWR
50348	Farley 1	WE	PWR
50361	San Onofre 2	CE	PWR
50362	San Onofre 3	CE	PWR
50364	Farley 2	WE	PWR
50366	Hatch 2	GE	BWR
50368	Arkansas 2	CE	PWR
50369	McGuire 1	WE	PWR

EXHIBIT A (Cont'd)

LIST OF SISTER PLANTS WITH DOCKET NUMBERS

Name	Docket Numbers
Browns Ferry 1,2,3	50259, 50260, 50296
Brunswick 1,2	50325, 50324
Calvert Cliffs 1,2	50317, 50318
Cook 1,2	50315, 50316
Dresden 2,3	50237, 50249
Farley 1,2	50348, 50364
Hatch 1,2	50321, 50366
Oconee 1,2,3	50269, 50270, 50287
Peach Bottom 2,3	50277, 50278
Point Beach 1,2	50266, 50301
Prairie Is. 1,2	50282, 50306
Quad Cities 1,2	50254, 50265
Salem 1,2	50272, 50311
San Onofre 2,3	50361, 50362
Surry 1,2	50280, 50281
Turkey Pt. 3,4	50250, 50251
Zion 1,2	50295, 50304

EXHIBIT B

HUMAN ACTION DESCRIPTORS*

Position	Duty Area	Task	Task Element
Control Room	Check	Assemble/	Adjust
Operator	Diagnose	Dissamble	Calculate
Equipment Operator	Operate	Check	Choose
Maintenance	Test	Calibrate	Communicate
Technician		Connect/	Compare
		Disconnect	Diagnose
		Energize/	Hear
		Fill/Drain	Hold
		Install/Remove	Identify
		Isolate	Inspect
		Lineup	Monitor
		Maintain	Observe
		Monitor	Position
		Open/Close	Push/Pull
		Operate	Read
		Repair	Record
		Restore	Remember
		Start/Stop	Speak
		Tag	Verify
		Test	Write

*Adapted in part from NUREG/CR-2744, Volume 2.

EXHIBIT C

EQUIPMENT CHARACTERISTICS
(from NUREG/CR-2744)

Systems

Heat Production Control

- Emergency core cooling systems:

  Containment atmosphere inerting
  Containment combustible gas control
  Containment isolation
  Containment pressure suppression
  Containment spray
  Core spray
  High pressure coolant injection
  Low pressure coolant injection
  Automatic depressurization
  Emergency (residual heat removal) service water
  Safety injection
  Engineered safety feature actuation system
  Isolation valve seal water
  Penetration pressurization
  Refueling water storage tank
  Fluid block
  Penetration pressurization
  Borated water storage tank

- Inventory control:

  Feedwater
  Reactor water cleanup
  Chemical and volume control
  Makeup

- Reactivity control:

  Control rod drive
  Standby liquid control

- Reactor coolant:

  Reactor recirculation system
  Residual heat removal
  Decay heat
  Reactor coolant system

- Reactor pressure vessel:

  Pressure vessel
  Reactor assembly
  Reactor internals

Steam Production and Utilization

- Circulating water system:

  Cooling towers

- Condensate system:

  Condensate storage and transfer
  Condensate polishing
  Air removal

- Feedwater system:

  Reactor core isolation cooling
  Main feedwater
  Auxiliary feedwater
  Emergency feedwater

- Main steam system

  Steam bypass
  Steam dump

- Turbine

  Extraction steam
  High pressure turbine
  low pressure turbine
  Turbine lube oil
  Electro-hydraulic control

Electrical Production and Distribution

- Ex-plant distribution:

  Switchyard

EXHIBIT C (Cont'd)

Systems

- Main generator:

  Hydrogen system
  Seal oil
  Stator cooling
  Exciter
  Buss duct cooling

- In-plant ac distribution
- Standby ac power system;

  Diesel generators
  Starting air system
  Fuel oil storage and transfer system
  Lube oil system
  Jacket water system

- dc power systems
- Vital ac power systems

Support Services

- Communication system
- Lighting system
- Security
- Component cooling:

  Service water
  Reactor building closed cooling water
  Turbine building closed cooling water
  Secondary services component cooling water
  Nuclear services component cooling water

- Fire protection system:

  Fire water system
  CO_2
  Halon

- Heating, Ventilation, and Air Conditioning:

  Standby gas treatment
  Emergency core cooling system ventilation
  Building ventilation
  Control room ventilation
  Room coolers

- Instrumentation and control:

  ac instrument power
  dc instrument power
  Feedwater control
  Process instrumentation
  Nuclear Instrumentation
  Radiation Monitoring
  Reactor protection system
  Recirculation control
  Traversing in-core probe
  Steam generator water level control
  Integrated control system
  Steam generator rupture detection
  Non-nuclear instrumentation
  In-core instrumentation

- Radwaste:

  Liquid radwaste
  solid radwaste
  off-gas system

- Refueling:

  Fuel handling equipment
  Fuel pool cooling
  Fuel storage

- Air systems:

  Service air
  Instrument air

- Process sampling system:

  Primary sampling
  Secondary sampling

- Makeup water treatment system
- Compressed gas system

EXHIBIT C (Cont'd)

Components

- Batteries:

  Lead-acid
  Nickel-cadmium

- Blowers

  Compressor
  Fan

- Circuit closures/interrupters:

  Circuit breaker
  Contactor
  Controller
  Relay
  Starter
  Switch
  Switchgear, motor-operated disconnects

- Computers
- Demineralizers/filters
- Electrical conductors:

  Bus
  Control cable
  Power cable
  Signal cable
  Terminal blocks
  Thermocouple extension wire

- Electrical equipment:

  Alternator
  Amplidyne
  Converter
  Dynamotor
  Generator
  Inverter
  Rectifier
  Stator
  Transformer
  Voltage regulator
  Battery charger

- Heat exchangers:

  Boiler
  Condenser
  Cooler
  Evaporator
  Heater/cooler
  Heater/superheater
  Steam generator

- Motors:

  Capcitor
  dc commutator
  hydraulic
  Induction
  Pneumatic
  Split-phase
  Synchronous
  Induction

- Pumps:

  Axial
  Centrifugal
  diaphragm
  electromagnetic
  Gear
  Jet
  Radial
  Reciprocating
  Rotary
  Vacuum
  Vane type

- Sensors and control instruments:

  Flow
  Level
  Nuclear
  Position
  Pressure
  Temperature
  Vibration
  Conductivity
  Current
  Voltage

EXHIBIT C (Cont'd)

Components

RPM
Frequency

- Valves:

  Angle
  Ball
  Butterfly
  Check
  Diaphragm
  Gate
  Globe
  Needle
  Plug
  Quick-opening
  Three-way
  Four-way
  Relief

- Valve operators

  Electric motor - ac
  Electric motor - dc
  Explosive, Squib
  Float
  Hydraulic
  Mechanical
  Pneumatic/diaphram/cylinder
  Solenoid - ac
  Solenoid - dc

- Vessels/tanks:

  Accumulators
  Pressure vessels
  Tanks

- Equipment - nonspecific

- - - - - - - - - -

Displays

Qualitative Displays

- Status lights

  Circular lamps
  Legend lights

- Annuniciators

  Alarm Windows or tiles
  Computer alarmed printer

- CRT text
- Charts/Diagrams

Quantitative Displays

- Counters - digital readout
- Circular/semicircular scales

  Linear scale
  Logarithmic scale

- Printing recorder

  Linear scale
  Logarithmic scale

- Chart recorder

  Linear scale
  Logarithmic scale

- Graphs

  Linear scale
  Logarithmic scale

EXHIBIT C (Cont'd)

Displays

- CRT displays

  Linear scale
  Logarithmic scale

- Horizontal Scale

  Linear scale
  Logarithmic scale

- Vertical scale

  Linear scale
  Logarithmic scale

- Computer Alarmed Printer

- - - - - - - - - - -

Controls

- Push button

  Illuminated legend
  Multifunction push botton matrix
  Push and hold
  Other

- Protected controls

  Keylocked switches
  Padlocked valves & circuit breakers
  Protective covered switches

- Two-position switches

  Knob
  Rocker
  Toggle

- Multiposition selectors

  J-handle
  Rotary
  Stepping push button
  Toggle switch - 3-position

- Continuously variable controls

  Knobs
  Levers
  Thumb wheel
  Valve wheel

- Keyboard

  Calculator
  Computer
  Thermal
  Typewriter

- - - - - - - - - - - -

Instruments

- Tools

  Air-operated wrenches
  Cranes
  Fuse pullers
  General mechanics' tools - screwdriver, hammer
  Grease guns
  Hoists
  Torque wrenches
  Valve wrenches

- Electrical test equipment

  Amprobes
  Continuity checker

EXHIBIT C (Cont'd)

Instruments

Digital Voltmeters
Fuse Puller
High-voltage test lamps
Multimeters
Oscilloscopes

- Measurement test equipment

Gas detection meters

Heat detectors
Hydrometers
Micrometers
Pyrometers and thermometers
Scales
Stroboscope
Test Gauges
Vibration detectors

- - - - - - - - - - - -

Communication

- Records

Tags
Log books

- Communications

Telephone
Two-way radio

Page-party system (PA)
Face-to-face
Sound-powered microphone

- Acoustical equipment

Headphone
Speaker

HEP WORK SHEET PART I

Basic Information	Docket:			1.
	LER Number:	2.	Control Number:	3.
	Plant Name:	4.	Sister Dockets:	5.
	Plant Type:	6.	Reactor Vendor:	7.
	Event Date:	8.	Report Date:	9.
Error Information	Error Date:		Source:	10.
	Number of Identical Errors:			11.
	Number of Dissimilar Errors:	12.	Page Number:	13.
	Periodic:		Source:	14.
	Error Type:		Source:	15.
	Error Description:		Source:	16.

		Descriptor	Source
Human Actions	Position:		17.
	Duty Area:		18.
	Task:		19.
	Task Element:		20.

		Descriptor	Source
Equipment Characteristics	System:		21.
	Subsystem:		22.
	Component:		23.
	Element:		24.

Interface	Interface Level:		25.
Performance Shaping Factors		Weight:	26.
		Weight:	27.
		Weight:	28.
Summary			29.

HEP WORK SHEET PART II

Page Number:	Number of Unique Classes:

	Activity	Similar Human Actions	Annual Repetition	Source
Inventory of Human Actions				
	Total Annual Repetition			

	Identical Equipment	Quanity	Source
Equipment Inventory			
	Total Similar Equipment		

Opportunity

Total Annual Repetition [ ] × Total Similar Equipment [ ] = Total Opportunity (this Page) [ ]

Total Opportunity (other Pages) → + [ ]

Total Annual Opportunity [ ]

HEP WORK SHEET PART III

Error Classification	Position:	1.	System:	5.
	Duty Area:	2.	Subsystem:	6.
	Task:	3.	Component:	7.
	Task Element:	4.	Element:	8.
	Interface Level:			9.
Survey Period	Survey Begin:	10.	Survey End:	11.
	Survey Length, Years:	Months:	Decimal:	12
Plant Information	Plant	Factor	Plant	Factor
	13.			
Total Opportunity	Total No. of Plants:	14.	Average Factor:	15.
	Total Plant Years:	16.	Total Operation Time:	17.
	Total Annual Opportunity:	18.	Total Opportunity:	19.
Human Error List	LER Number	Errors	LER Number	Errors
	20.			
	Total Number of Errors:			21.
Human Error Probability	Total Number of Errors (Line 21) / Total Opportunity (Line 19) =	22. / 23.		24.

APPENDIX B

REPORTABLE OCCURRENCE DEFINING CRITERIA

(From Standard Technical Specifications for BWR Plants)

REPORTABLE OCCURRENCE DEFINING CRITERIA

(From Standard Technical Specifications for BWR Plants)

- Failure of the reactor protection system or other systems subject to limiting safety system settings to initiate the required protective function by the time a monitored parameter reaches the setpoint specified as the limiting safety system setting in the technical specifications or failure to complete the required protective function.

- Operation of the unit or affected systems when any parameter or operation subject to a limiting condition for operation is less conservative than the least conservative aspect of the Limiting Condition for Operation established in the Technical Specifications.

- Abnormal degradation discovered in fuel cladding, reactor coolant pressure boundary, or primary containment.

- Reactivity anomalies involving disagreement with the predicted value of reactivity balance under steady state conditions during power operation greater than or equal to 1% $\Delta k/k$; a calculated reactivity balance indicating a SHUTDOWN MARGIN less conservative than specified in the Technical Specifications; short-term reactivity increases that correspond to a reactor period of less than 5 seconds or, if subcritical, an unplanned reactivity insertion of more than 0.5% $\Delta k/k$; or occurrence of any unplanned criticality.

- Failure of malfunction of one or more components which prevents or could prevent, by itself, the fulfillment of the functional requirements of system(s) used to cope with accidents analyzed in the Safety Analysis Report (SAR).

- Personnel error or procedural inadequacy which prevents or could prevent, by itself, the fulfillment of the functional requirements of systems required to cope with accidents analyzed in the SAR.

- Conditions arising from natural or man-made events that, as a direct result of the event require unit shutdown, operation of safety systems, or other protective measures required by Technical Specifications.

- Errors discovered in the transient or accident analyses or in the methods used for such analyses as described in the safety analysis report or in the basEs for the Technical Specifications that have or could have permitted reactor operation in a manner less conservative than assumed in the analyses.

- Performance of strctures, systems, or components that requires remedial action or corrective measures to prevent operation in a manner less conservative than assumed in the accident analyses in the safety analysis report or Technical Specifications bases; or discovery during unit life of conditions not specifically considered in the safety analysis report or Technical Specifications that require remedial action or corrective measures to prevent the existence or development of an unsafe condition.

- Reactor protection system or engineered safety feature instrument settings which are found to be less conservative than those established by the Technical Specifications but which do not prevent the fulfillment of the functional requirements of affected systems.

- Conditions leading to operation in a degraded mode permitted by a Limiting Condition for Operation or plant shutdown required by a Limiting Condition for Operation.

- Observed inadequacies in the implementation of administrative or procedural controls which threaten to cause reduction of degree of redundancy provided in reactor protection systems or engineered safety feature systems.

- Abnormal degradation of systems other than those specified in the Technical Specifications designed to contain radioactive material resulting from the fission process.

APPENDIX C

NECESSARY CONDITIONS FOR ACCURATE HEP DEVELOPMENT BASED ON LER ANALYSES

NECESSARY CONDITIONS FOR ACCURATE HEP DEVELOPMENT BASED ON LER ANALYSES

A. REAL WORLD EVENTS

A definition of the events to be considered must be given.

1. Only U.S. commercial Nuclear Power Plants that are operational at the time of data collection shall be considered.

2. Only safety related events defined as Reportable Occurrences in the Technical Specifications can be considered, because only these are reported in LERs.

3. It is quite probable that a large number of human errors are not recorded because they do not violate Technical Specifications or are recovered before Technical Specifications are violated.

B. OBSERVATION

The human error must be observed.

1. Sufficient knowledge of the plant operation is necessary in order to determine that an error has been made.

2. If the system is automated (i.e., self correcting) it is very possible the error will go undetected.

3. Personnel must be motivated to look for errors.

4. Personnel may often correct error conditions without realizing that an error had ever been committed.

5. During situations with other than low stress conditions, personnel involved in the performance of the given task or procedure would be too occupied with that task to take note of all errors that are committed.

6. Human errors could be made that effectively hide other errors. For example, an error in calibrating a radiation detection device may disable it and allow a series of human errors resulting in the release of radioactivity to go unnoticed.

7. A human error may be made in reading an instrument (or recording the reading) that would prevent the identification of previously committed human error.

C. RECORDING

1. Open communication channels must exist between the observing individual and the utility personnel responsible for recording an event.

2. A chain of command from maintenance and repair personnel, test and calibration technicians to operations personnel and ultimately to plant management is needed.

3. Motivation to report and record events (errors) within the plant is necessary.

4. Peer and other social pressures that would adversely affect reporting an incident to a superior must be minimal (e.g., punitive action must not be employed or an anonymous reporting scheme should be used).

5. The person observing the error must not be distracted. Someone may notice and decide to report an error but they may forget.

D. REPORTING

1. Errors that have been noticed and recorded must be recognized as significant and/or reportable as per regulations.

2. Personnel from management down to each individual who could potentially identify a human error must be aware of the regulations as to what types of events are reportable.

3. The utility must decide to report an error even though they realize punitive action may result.

4. The utility must properly identify human errors when completing the LER.

5. An analysis of the event by utility management is necessary in order to determine if the error was caused by a mechanical failure or by some underlying human error.

6. The utility must fill out a LER properly (i.e., completely and unambiguously).

7. The LER must be filled out by someone who was directly involved in the event or there must be good communication between the person observing and the person reporting the event.

8. The individual filling out the LER must be familiar with the form and NUREG-0161. (Instructions for the preparation of LER Data Entry Sheets).

9. The individual filling out the LER must be familiar with the on-going process or procedure at the time of the event.

10. Management of the utility must evaluate the LER for completeness and accuracy.

11. Management at the utility must decide to forward the LER to the NRC.

12. The utility must get feedback from the NRC (even if no punitive action occurs) to motivate them to continue submitting complete and accurate LERs.

13. Feedback must also be positive (i.e., reduction in testing requirements, given performance improvements).

14. The reporting scheme must be adequate to handle complicated and multiple events. The LER must allow for an accurate description of all components of human error.

15. There must be consistency as to who submits the LER to the NRC, and this person must be available if there are any questions in interpreting the LER.

E. NRC REVIEW

LERs must be submitted by the utilities to one of five NRC Regional Offices.

1. The NRC must review the LER for completeness and accuracy.

2. The LERs coming in to the five Regional Offices must be accumulated and stored in one place as public record.

3. The NRC must provide for the updating or revision of previously filed LERs.

F. ABSTRACTION/CODING

In the event coded forms or abstracts, for example, the Oak Ridge Abstracts, are used in lieu of the original document, errors in this coding or abstraction might occur.

1. Errors may occur in reading handwritten LERs.

2. General typing errors may be present (note the high information density of some of the terms and/or acronyms used, e.g., HPCI vs. LPCI)

3. Incomplete LERs may be incorrectly completed (e.g., filling in the wrong component code when not provided) by someone in the abstraction process.

4. Information available on the LER (original) may be falsely interpreted due to insufficient knowledge of the particular plant in question.

5. Any sort of abstraction or re-writing of the original LER will result in inaccuracies because it introduces another level of removal from the actual fact.

6. The original LER document with any additional or attached pages should always be available: (1) as a check of the abstraction/coding technique and (2) in the event insufficient information is available on the abstraction to properly identify and classify human error.

G. FILING

All incoming LERs must be filed in some cental storage facility.

1. Due to the large number of LERs generated, the LERS (or Abstracts) must be entered into some type of computer system.

2. Errors could conceivably occur in data entry.

H. STORAGE

There must be a facility for the storage of LERs.

1. The files of LERs must be maintained and updated as necessary.

2. There is a possibility that data are lost or other updates to data are not done in a timely fashion.

I. RETRIEVAL AND SORTING

1. Data stored on magnetic tape or disc must be available to the user.

2. There must be a certain amount of cooperation and coordination between the data filing and storage organization and the ultimate user of the data.

3. A scheme must exist to sort out by type of classification those LERs needed.

4. Sort techniques should include sort by: key word, event date, plant, utility, plant type, system, component, activity, type of error, cause, etc., or basically any category as required in NUREG-0161.

5. Subsorting should also be possible.

J. DISTRIBUTION

LERs on file must be available to analysts so that HERs can be obtained.

1. There must be a means of distributing the information retrieved from the NRC to the analyst for determination of human error.

2. There must be a way for the user to verify that all the data requested was delivered.

K. DELIVERY

There must be a channel to physically supply LERs in bulk to analysts.

1. Possible errors could occur if mailings are lost.

2. In the case of multiple mailings it may not be noticed that part of the shipment is missing.

L. ANALYSIS

The analysis involves the actual reading of the LER and a reconstruction of the event.

1. If human error is not identified explicitly, it will be impossible to use a computer search technique to sort out the LERs that deal with human error.

2. Human error must often be identified manually which is a very costly and time consuming process as each individual LER must be read.

3. Any manual evaluation for human error identification must rely on subjective judgement.

4. There may be disparity between the subjective judgements of different analysts or within one analyst across time.

5. There must be some minimum experience or background level required for the analyst. An analyst with no experience would have no working knowledge of the procedures as they should be followed. An analyst with a great deal of experience may tend to read too much into the written LERs.

6. Analyst biases must be considered with regard to conservative or liberal judgements. One attitude might be, "Any error could be related to human error in one way or another." On the other hand, "people seldom make errors unless distracted by adverse conditions."

M. IDENTIFICATION OF HUMAN ERROR

There must be a mechanism for the consistent identification of human error in LERs.

1. Definite criteria must be established in order to infer human error, where not explicitly stated. Criteria such as "conservative" or "realistic" or "without doubt" are not adequate.

2. It might be possible to improve the identification of human error method if a channel existed between the LER analysts and personnel at the utility.

N. CLASSIFICATION

In order to be useful, identified human error must be classified as to type.

1. In the event a human error is not clearly identified on the LER and human error has been inferred by the analyst, it will be difficult to come up with a unique classification as to type and cause of postulated error.

2. Licensees are under no obligation to use any established human action taxonomy. Hence there may be considerable discrepancies in the use of various action descriptors. For example: tune, adjust, calibrate, turn, position could be used interchangeably to some extent.

3. Attempts are still ongoing to define various action verbs for a unique taxonomy which will be used for an established data bank. One data bank (NUREG/CR-2744) uses about 20 defined descriptors while a task analysis of a control room operator position used over 100 descriptors.

O. OPPORTUNITY

In order to calculate HER the opportunity for error must be obtained.

1. Not all errors that have been identified as human error can be used for HER calculation because the opportunity for error is often not available or obtainable.

2. Many human errors are the result of human actions that are not performed on a periodic basis, hence there will be no fixed "opportunity" for such actions.

3. Errors in written procedure are not quantifiable with regard to opportunity for error.

4. Inadvertant actions such as accidental activation or damage cause reportable occurences but opportunity for error is not obtainable.

5. Only test and calibrations operations are quantifiable by consulting the Technical Specifications, or similar.standards, e.g., ASME Boiler code.

6. There may be significant variations in test requirements between plants (i.e., opportunity for error will vary).

7. Other human error LERs may be useful if plant operations are considered. However, it is not possible to develop any sort of standard opportunities for errors list that would apply across plants due to the high degree of diversity in design, different operating procedures and different operational records.

8. An estimation of the opportunity for error as determined by plant personnel and available on the LER would improve the accuracy of the analysis.

P. HEP TABULATION

The resulting HEPs must be tabulated and published.

1. The resulting reports must be read by persons conducting a PRA.

2. Once a computerized data bank is established, the most logical solution would be to allow for direct "write" access to the data bank at this point.

3. Data added to files would be subject to review by other organizations and by a controlling body (i.e., the Data Clearinghouse as described in NUREG/CR-2744).

Q. RELIABILITY/VALIDITY

In order to be useful, the HER data must be checked for reliability and validity. Data Reliability is defined as the degree to which data generated under similar conditions are similar (reproducibility). Data Validity is defined as the degree to which data obtained are an accurate representation of the event that generated the data (applicability).

1. The present evaluation process does not allow for consideration of PSFs; either internal or external. This information is simply not available on the LERs.

2. Because there are so few data available, the LER analysis is not based on a population sampling technique.

3. There is no way of knowing how representative the LERs are as a sample of the total pupulation of human error.

4. At present the LER analysis does not allow for a consideration of the important question of dependence of events.

5. LERs contain both recoverable and nonrecoverable events. Considering the present analysis, no distinctions can be made using LER information.

6. The LER —> HER process relies on accidental data. If an accident does not occur no data will be available.

7. LERs provide no information on cognitive type errors. The cognitive action cannot be identified.

APPENDIX D

HUMAN ERRORS IDENTIFIED IN NUREG/CR-2417 and 2987 SUITABLE FOR HEP CALCULATION

HUMAN ERRORS IDENTIFIED IN NUREG/CR-2417 and -2987 SUITABLE FOR HER CALCULATION

D.1 Pump and Valve Human Error LERs from NUREG/CR-2417

Plant	Date	Activity
Arkansas 1	12/21/79	Operations
Beaver Valley 1	01/21/78	Testing
Big Rock Point	02/02/76	Operations
"	10/31/77	"
Browns Ferry 2	06/27/78	Testing
Brunswick 1	12/05/79	"
"	12/07/79	"
"	12/19/79	Operatios
Brunswick 2	05/07/77	"
Calvert Cliffs 1	08/28/79	Testing
"	05/20/80	Operations
Calvert Cliffs 2	11/15/78	"
Cooper 1	03/03/77	Unknown
"	12/06/79	Testing
Crystal River 3	01/01/77	"
Davis Besse 1	06/12/77	"
"	08/18/77	"
"	12/16/77	"
"	04/30/78	Maintenance
"	07/18/78	Testing
"	03/06/79	Operations
Dresden 2	03/22/76	Maintenance
"	11/22/77	Testing
"	04/28/78	Operations
Dresden 3	12/16/77	"
Duane Arnold	02/19/77	Testing
Hatch 1	06/22/80	Operations
Hatch 2	01/11/79	Testing
"	11/29/79	Operations
Fitzpatrick 1	03/21/76	Testing
"	02/24/77	"
"	09/06/79	Maintenance
Robinson 2	11/23/77	Operations
"	04/13/78	Unknown
Farley 1	07/10/77	Operations
"	10/27/79	Testing
Kewaunee 1	02/23/79	Operations
"	02/23/80	Maintenance
LaCrosse	03/21/78	Operations

D.1 Pump and Valve Human Error LERs from NUREG/CR-2417 (Cont'd)

Plant	Date	Activity
Maine Yankee	10/20/77	Testing
"	03/19/80	Operations
"	05/07/80	"
North Anna 1	11/06/79	Testing
Oconee 1	05/01/80	Operations
Oconee 2	12/09/79	Maintenance
Palisades 1	07/25/80	Testing
Peach Bottom 2	04/05/76	"
"	09/13/77	Maintenance
Point Beach 2	07/28/77	Testing
"	06/19/80	Testing/Oper.
Prairie Island 1	02/04/78	Unknown
Prairie Island 2	12/15/76	Operations
"	01/08/77	"
"	05/29/80	Testing
Quad Cities 2	05/21/78	Unknown
Rancho Seco 1	12/15/78	Operations
Salem 1	01/08/77	"
"	05/06/77	"
"	12/27/77	Testing
St. Lucie 1	07/23/76	Operations
Three Mile Is. 1	02/21/76	Testing
"	12/12/76	Testing/Oper.
Turkey Point 3	10/31/79	Unknown

D.2 Electrical/Electronic Component Human Error LERs from NUREG/CR-2987

Plant	Date	Activity
Arkansas 1	02/27/81	Testing
Beaver Valley 1	11/17/80	"
Brunswick 1	02/13/77	"
"	06/02/81	"
Brunswick 2	06/12/78	"
"	08/27/81	"
Cooper 1	01/05/77	"
"	08/17/77	"
"	06/20/79	"
"	06/23/80	"
Davis Besse 1	05/19/77	"
"	01/30/79	Maintenance
Dresden 1	01/04/80	Testing
Dresden 2	03/19/81	"
Duane Arnold 1	02/19/77	"
"	07/05/79	"
"	11/12/79	"

D.2 Electrical/Electronic Component Human Error LERs from NUREG/CR-2987 (Cont'd)

Plant	Date	Activity
Fitzpatrick 1	10/02/77	Testing
"	12/15/78	"
"	05/01/80	"
"	01/29/81	"
"	10/07/81	"
Hatch 1	04/27/78	"
"	10/31/78	"
"	03/03/79	"
"	12/16/79	"
"	07/13/80	"
Hatch 2	01/09/80	"
"	03/20/80	"
Kewaunee 1	06/19/79	"
Millstone 2	01/10/78	"
Oyster Creek 1	05/04/77	"
"	11/03/79	"
Peach Bottom 2	07/17/78	"
"	01/12/79	"
Prairie Is. 1	08/05/77	"
Prairie Is. 2	12/15/76	Unknown
"	03/07/78	Maintenance
Quad Cities 1	11/03/78	Testing
Robinson 2	11/23/77	Operations
Salem 1	04/19/78	Testing
"	07/21/80	"
"	11/26/80	"
"	03/08/81	"
San Onofre 1	08/18/78	Maintenance
Three Mile Is. 1	05/07/81	Testing
Trojan 1	09/06/79	"
Yankee Rowe 1	05/24/77	"
"	12/26/78	"
Zion 1	11/02/78	"
"	05/23/79	"
Zion 2	07/23/80	Operations

APPENDIX E

DEMONSTRATION OF THE LER-HEP METHODOLOGY

HEP WORK SHEET PART I

Basic Information	Docket: 50-265		1.
	LER Number: 78-022 (2.)	Control Number: 021561	3.
	Plant Name: Quad Cities 2 (4.)	Sister Dockets: 50-254	5.
	Plant Type: BWR (6.)	Reactor Vendor: GE	7.
	Event Date: 05/21/78 (8.)	Report Date: 06/20/78	9.
Error Information	Error Date:	Source:	10.
	Number of Identical Errors: 1		11.
	Number of Dissimilar Errors: 0 (12.)	Page Number:	13.
	Periodic: fixed testing	Source: Tech Specs	14.
	Error Type: Omission	Source: LER	15.
	Error Description: Failure to restore after test	Source: "	16.

		Descriptor	Source	
Human Actions	Position:	Control Room Operator	LER	17.
	Duty Area:	Test	"	18.
	Task:	Lineup (better "Restore")	"	19.
	Task Element:	Position	"	20.
Equipment Characteristics	System:	Core Spray	LER	21.
	Subsystem:	Pump Suction & Pump	"	22.
	Component:	Pump & Valve	"	23.
	Element:	Control Switches	"	24.

Interface	Interface Level: Task - Component	25.
Performance Shaping Factors	Weight:	26.
	Weight:	27.
	Weight:	28.
Summary	Error of not restoring a safety system to it's proper normal lineup after testing	29.

HEP WORK SHEET PART II

Page Number: Quad Cities 2	Number of Unique Classes:

Inventory of Human Actions

Activity	Similar Human Actions	Annual Repetition	Source
Pump Test		4	Tech Spec - ASME
Pump Maintenance		1	Plant Experience
Total Annual Repetition		5	

Equipment Inventory

Identical Equipment	Quantity	Source
Other Core Spray Pump	1	Quad Cities Drawings
RHR-LPCI Pumps	4	" " "
Total Similar Equipment	5	

Opportunity

Total Annual Repetition		Total Similar Equipment		Total Opportunity (this Page)
5	×	5	=	25
Total Opportunity (other Pages)			→ +	0
Total Annual Opportunity				25

HEP WORK SHEET PART III

Error Classification	Position: Control Rm Oper. (1.)	System: Core Spray (5.)
	Duty Area: Test (2.)	Subsystem: Pump Suction & Pump (6.)
	Task: Lineup (Restore) better ... (3.)	Component: Pump & Valve (7.)
	Task Element: Position (4.)	Element: Control Switches (8.)
	Interface Level: Task - Component (9.)	
Survey Period	Survey Begin: 01/01/76 (10.)	Survey End: 07/01/80 (11.)
	Survey Length, Years: 4 Months: 6	Decimal: 4.5 (12)

Plant Information (13.)

Plant	Factor	Plant	Factor
Brunswick 1		Millstone 1	
Brunswick 2		Monticello	
Browns Ferry 1		Nine Mile Pt 1	
Browns Ferry 2 Browns Ferry 3		Pilgrim	
Cooper		Peach Bottom 2	
Dresden 2 Dresden 3		Peach Bottom 3	
Duane Arnold		Pilgrim	
Fitzpatrick		Quad Cities 1	
Hatch 1		Quad Cities 2	
Hatch 2		Vermont Yankee	

Total Opportunity

Total No. of Plants: 22 (14.)	Average Factor: 0.7 (15.)
Total Plant Years: 99 (16.)	Total Operation Time: 69.3 (17.)
Total Annual Opportunity: 25 (18.)	Total Opportunity: 1,732 (19.)

Human Error List (20.)

LER Number	Errors	LER Number	Errors
78-022/Quad Cities 2	1		

Total Number of Errors: 1 (21.)

Human Error Probability

$$\frac{\text{Total Number of Errors (Line 21)}}{\text{Total Opportunity (Line 19)}} = \frac{1}{1,732.5} = 5.8 \times 10^{-4}$$

(22.) (23.) (24.)

HEP WORK SHEET PART I

		Descriptor	Source	
Basic Information	Docket: 50-304			1.
	LER Number: 77-03			2.
	Control Number: 019137			3.
	Plant Name: Zion 2			4.
	Sister Dockets: 50-295			5.
	Plant Type: PWR			6.
	Reactor Vendor: WE			7.
	Event Date: 08/31/77			8.
	Report Date: 09/26/77			9.
Error Information	Error Date:		Source:	10.
	Number of Identical Errors: 1			11.
	Number of Dissimilar Errors: 0			12.
	Page Number:			13.
	Periodic:		Source:	14.
	Error Type: Commission		Source:	15.
	Error Description: Draining wrong Accumulator		Source:	16.
Human Actions		Descriptor	Source	
	Position:	Control Room Operator	LER	17.
	Duty Area:	Operate	"	18.
	Task:	Fill/Drain	"	19.
	Task Element:	Choose	"	20.
Equipment Characteristics		Descriptor	Source	
	System:	Safety Injection	LER	21.
	Subsystem:	Accumulator	"	22.
	Component:	Valve	"	23.
	Element:	Control Switch	"	24.
Interface	Interface Level: Task - Component			25.
Performance Shaping Factors		Weight:		26.
		Weight:		27.
		Weight:		28.
Summary	Error of draining the wrong accumulator			29.

HEP WORK SHEET PART II

Page Number: Zion 2	Number of Unique Classes:

Inventory of Human Actions

Activity	Similar Human Actions	Annual Repetition	Source
Change Accumulator Inventory		2	Plant Experience
Total Annual Repetition		2	

Equipment Inventory

Identical Equipment	Quantity	Source
Other Accumulators	4	Zion Drawings
Total Similar Equipment	4	

Opportunity

Total Annual Repetition		Total Similar Equipment		Total Opportunity (this Page)
2	×	4	=	8
Total Opportunity (other Pages)			→ +	0
Total Annual Opportunity				8

HEP WORK SHEET PART III

Error Classification

Position: Control Rm Oper (1.)	System: Safety Injection (5.)
Duty Area: Operate (2.)	Subsystem: Accumulator (6.)
Task: Fill/Drain (3.)	Component: Valve (7.)
Task Element: Choose (4.)	Element: Control Switch (8.)
Interface Level: Task-Component (9.)	

Survey Period

Survey Begin: 01/01/76 (10.)	Survey End: 06/30/80 (11.)	
Survey Length, Years: 4	Months: 6	Decimal: 4.5 (12.)

Plant Information (13.)

Plant	Factor	Plant	Factor
Beaver Valley 1 (3/4)		Trojan	
Cook 1		Turkey Pt 3 (3/4)	
Cook 2		Turkey Pt 4 (3/4)	
Haddam Neck		Zion 1	
Indian Pt 2		Zion 2	
Indian Pt 3			
Farley (3/4)			
Kewaunee (1/2)			
North Anna 1 (3/4)			
Prairie Is. 1 (1/2)			
Prairie Is 2 (1/2)			
Point Beach 1 (1/2)			
Point Beach 2 (1/2)			
Ginna (3/4)			
Robinson 2			
Salem 1			
San Onofre			
Surry 1 (3/4)			
Surry 2 (3/4)			

Total Opportunity

Total No. of Plants: 19 (14.)	Average Factor: 0.7 (15.)
Total Plant Years: 85.5 (16.)	Total Operation Time: 59.9 (17.)
Total Annual Opportunity: 8 (18.)	Total Opportunity: 479 (19.)

Human Error List (20.)

LER Number	Errors	LER Number	Errors
77-03/Zion 2	1		

Total Number of Errors: 1 (21.)

Human Error Probability

$$\frac{\text{Total Number of Errors (Line 21)}}{\text{Total Opportunity (Line 19)}} = \frac{1}{479} = 2.1 \times 10^{-3}$$

(22.) (23.) (24.)

APPENDIX F

SURVEY RESULTS

SURVEY RESULTS

On September 12, 1983, a limited survey was conducted by mailing a questionnaire (along with a cover letter explaining the purpose of the survey; see Exhibit 1) and copies of the LER-HEP Method to 20 human reliability experts. By November 30, 1983, 12 responses (60% response rate) were received and the survey was concluded. A list of those responding can be found in Exhibit 2 (except for one individual who wished to remain anonymous).

The questionnaire included five questions about the usefulness and credibility of HER data obtained from LERs and three questions to ascertain the qualifications of the respondents. The participants in the survey were asked to choose one of a number of responses to indicate their opinions on each statement. The responses to each of the questions are given here, along with the number of participants responding.

Question 1

In your overall judgment, how useful would the LER-HEP Method be, if used with existing License Event Reports, for providing a source of human error rate (HER) data for Probabilistic Risk Assessment (PRA)?

Response	Number Responding
Very useful	0
Somewhat useful	7
Not very useful	4
Useless	1
TOTAL	12

Of those indicating that the LER-HEP Method was not useful, the following reasons were offered:

1. The procedures for completing the methodology are inadequate.

2. The existing LER data are inadequate for the task.

3. Both the procedure and the data are poor.

4. Other (please be specific): ____________________

Response	Number Responding
1.	1
2.	3
3.	2
4.	1
TOTAL	7

Question 2

How much confidence would you have in using human error probabilities, developed from Licensee Event Reports, in a Probabilistic Risk Assessment that you are involved in?

Response	Number Responding
High confidence	0
Moderate confidence	5
Low confidence	4
No confidence	3
TOTAL	12

Question 3

What sort of experience would a person using the LER-HEP Method need as a minimum in order to produce accurate results? (You may check more than one item.)

Response	Number Responding
Nuclear power plant operation	10
Nuclear power plant management	0
Nuclear systems analysis	8
Human reliability assessment	9
NRC licensing requirements	1
Probabilistic risk assessment	2
Other (please be specific)	1

Question 4

Do you feel that the existing LER files contain an accurate (valid and reliable) statement of human error?

Response	Number Responding
Yes, very accurate	0
Yes, reasonably accurate	2
No, not very accurate	7
No, very inaccurate	3
TOTAL	12

Question 5

Below are four sources of human reliability data. Please rank them from one to four according to which sources are the most accurate. Give a "1" to the most accurate source and a "4" to the least.

The table below indicates the ranks given by each of the responding individuals to each source of data.

Source	Respondant 1	2	3	4	5	6	7	8	9	10	11
Computer modeling	2	4	4	4	4	4	4	4	4	4	3
Expert judgment	1	2	1	2	2	1	3	3	3	3	1
Licensee event report eval.	4	3	2	3	3	3	1	2	3	3	2
Simulator experiments	2	1	3	1	1	2	2	1	1	2	4

The average ranks assigned to each data source are given below:

Computer modeling	3.7
Expert judgment	2.0
Licensee event report eval.	2.6
Simulator experiments	1.8

Question 6

In which of the following areas do you have a year or more experience?

Response	Number Responding
Human factors engineering	9
Probabilistic risk assessment	6
Human reliability assessment	12
Nuclear power plant operation	2
Nuclear power plant management	0

Question 7

Have you ever read a full Licensee Event Report?

Response	Number Responding
Yes	8
No	4
TOTAL	12

Question 8

Have you ever read abstracts or reports summarizing Licensee Event Reports?

Response	Number Responding
Yes	12
No	0
TOTAL	12

For conclusions based on the results of this survey, please refer to the text, Section 5.3 In addition, the many comments provided by the participants were incorporated in the text where possible.

Exhibit 1 - Cover Letter

bnl
aui

BROOKHAVEN NATIONAL LABORATORY

ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

(516) 282
FTS 666

September 12, 1983

Dear (participant):

Human error, though crucial to the safety of commercial nuclear power plants, is difficult to quantify because of a lack of suitable data. This difficulty has prompted the development of several methodologies to address the problem. A recently proposed methodology emphasizes the use of the extensive file of existing Licensee Event Reports (LER's)--with the expectation that human error data collected from LERs could be used to arrive at improved human error probability (HEP) estimates. Before this Licensee Event Report to Human Error Probability (LER-HEP) method is implemented it would be useful to know the views of experts over its feasibility and its ability to achieve its objectives.

Because you are an expert in Probabilistic Risk Assessment (PRA) you are especially qualified to pvovide valuable input in evaluating the LER-HEP method. You are one of only several PRA experts we are asking to evaluate the method, so your knowledge is especially valuable. To assist in your evaluation, I have enclosed a brief questionnaire together with a description of the LER-HEP method itself. You should first read through the instructions and work sheets entitled "LER-HEP Method." Then complete the questionnaire and return it in the pre-addressed stamped envelope.

You may be assured of complete confidentiality. The questionnaire has an ID number for record keeping purposes only. Your name will not be associated with specific results or conclusions drawn from the study. With your permission I will be pleased to acknowledge your assistance by listing you and your organization in the professional credits.

I would appreciate receiving your completed questionnaire within two weeks from the time you receive it. If you have any questions whatsoever, please do not hesitate to contact me.

Thank you for your capable assistance in improving the usefulness of this study.

Sincerely,

Kenneth J. Voska
Engineering Analysis & Human Factors Group

KJV:sd
attachment
cc: R. Hall
W. Luckas

APPENDIX G

DATA FIT RESULTS

PERFORMED BY GENERAL PHYSICS CORP. ANALYSTS

DATA FIT RESULTS
PERFORMED BY GENERAL PHYSICS CORP. ANALYSTS

In order to determine how LER identified human errors might be stored in the Data Bank of NUREG/CR-2744, 29 one-line descriptions of human errors, identified in LERs relative to electrical and electronic components, were obtained from NUREG/CR-2987. These descriptions were then used to identify the matrix and cell of the Data Bank into which HERs developed from these LERs could be entered, assuming an HER could be calculated. The actual process of fitting the one-line human error descriptions into the Data Bank was performed by the developers of the Data Bank (see NUREG/CR-2744) for a discussion of the Data Bank).

In summary, the input to this process was raw LER data on human error. The process itself was the entry of raw data into the Data Bank according to guidelines set down in NUREG/CR-2744. The output was the identification of a matrix number and the descriptors identifying a unique cell of the Data Bank. This appendix includes a list of the human error descriptions and the matrices and cells of the Data Bank into which they were entered. In most instances, more than one data matrix was appropriate for data storage. In which case, additional matrices are indicated.

The following illustrates how the data are presented in this appendix for each of the 29 examples:

Plant: Date: Activity: Component Responsibility:	Description (One Line description from NUREG/CR-2987)	Data Bank Entry: Matrix: (Number) Cell: (Equipment characteristics) (Task)

- -

Example 1

Brunswick 1 1/05/77 Testing Monitor Defective procedures	Average power range monitor startup - high flux trip set too high. Incorrect calibration due to defective procedures.	Matrix: 15 Sensors and control Instruments Calibrate - or - Matrix: 16 Procedures Write - or - Matrix: 3 Nuclear Instruments Test

Example 2

Dresden 2 01/28/77 Testing Indicator Defective procedures	Average power range monitor flow bias indication incorrect. Calibration procedure defective.	Matrix: 16 Quantitiative displays Inspect - or - Matrix: 16 Procedures Write - or - Matrix: 3 Nuclear instruments Test

Example 3

Dresden 3 01/28/77 Testing Indicator Defective procedures	Average power range monitor flow bias indication incorrect. Calibration procedure defective.	Matrix: 16 Quantitiative displays Inspect - or - Matrix: 16 Procedures Write - or - Matrix: 3 Nuclear instruments Test

Example 4

E. I. Hatch 1 02/19/77 Testing Monitor Technicians	Average power range monitor test and calibration not performend by due date. Personnel oversight	Matrix: 15 Sensors and control instruments Calibrate and test - or - Matrix: 16 Procedures Remember - or - Matrix: 3 Nuclear Instruments Test

Example 5

Dresden 2 04/25/77 Testing Monitor Defective procedures	High APRM/RBM flow bias indication. Procedure did not take into account the correlation between recirculation drive flow and total core flow.	Matrix: 15 Sensors and control instruments Calibrate and test - or - Matrix: 16 Procedures Write - or - Matrix: 3 Nuclear instruments Test

Example 6

Duane Arnold 1 05/31/77 Testing Monitor Technicnans	High flux APRM calibration completed by due date. Personnel error.	Matrix: 15 Sensors and control instruments Calibrate - or- Matrix: 16 Procedures Remember - or - Matrix: 3 Nuclear instruments Test

Example 7

Oyster Creek 1 07/22/77 Maintenance Cable Maintenance	Two intermediate range monitors inoperable. Leads disconnected and damaged by maintenance personnel.	Matrix: 15 Electrical conductors Connect-disconnect - or - Matrix: 3 Nuclear Instruments Diagnose

Example 8

Duane Arnold 1 09/15/77 Testing Cable Maintenance	Intermediate downscale trip inoperable. Pressure switch connections not tightened.	Matrix: 15 Power cable Connect-disconnect - or - Matrix: 3 Nuclear instruments Test

Example 9

Peach Bottom 3 10/01/7 Unknown Switch Unknown	SCRAM bypass alarm inoperable, switches inoperable due to water leakage into closed junction boxes.	Matrix: 15 Terminal blocks Maintain - or - Matrix: 15 Circuit closures Maintain - or - Matrix: 15 Switch Assemble/disassemble

Example 10

Brunswick 2 11/04/77 Maintenance Cable Maintenance	Intermediate power range monitor inoperable. Cables not reconnected after CRD overhaul.	Matrix: 15 Power cable Connect-disconnect - or - Matrix: 3 Control rod drive system Test

Example 11

Duane Arnold 1 11/28/77 Testing Cable Technicians	Errors induced in four APRM channels. Input and output recorder leads reversed.	Matrix: 15 Electrical conductors Connect isconnect

Example 12

Dresden 2 12/22/7 Testing Monitor Defective procedures	APRM flow bias set point non-conservative. Flow counters not calibrated due to defective procedures.	Matrix: 15 Flow instruments Calibrate - or - Matrix: 16 Procedures Write

Example 13

Vermont Yankee 02/03/78 Maintenance Monitor	IRM channel did not respond to increasing neutron flux. Maintenance personnel did not connect high voltage cable properly.	Matrix: 15 Power cable Connect-disconnect

Example 14

Quad Cities 2 02/28/78 Unknown Cable Unknown	MSL RM read downscale. High voltage leads not properly attached and fell off.	Matrix: 15 Power cable Connect-disconnect

Example 15

Big Rock Point 1 03/02/78 Operations Switch Defective procedures	CRD pilot valve control switch improperly reset. Inadequate instructions	Matrix: 15 Valve operator Check - or - Matrix: 16 Push button Push/pull

Example 16

Nine Mile Pt. 1 05/26/78 Maintenance Cable Maintenance	Two low range power monitors connected to wrong average power range monitors. Cabling error by maintenance personnel.	Matrix: 15 Electrical conductor Connect-disconnect

Example 17

Cooper 1 05/27/78 Testing Monitor Operations	Two MSL RM trip points not adjusted following source calibration. Procedure defective.	Matrix: 15 Sensors and control Instrumentation Calibrate - or - Matrix: 16 Procedure Write - or - Matrix: 3 Radiation monitor Test

Example 18

Monticello 1 06/06/78 Testing Monitor Technicians	Average power range monitor trip settings low. LPRM gain settings improperly adjusted	Matrix: 15 Sensors and control instrumentation Calibrate - or - Matrix: 3 Nuclear sensor Test

Example 19

Quad Cities 1 06/15/78 Maintenance Switch Maintenance	Low reactor water level switch inoperable. Merciod switch misaligned in relation to magnet.	Matrix: 15 Level instrument Assemble-disassemble

Example 20

Duane Arnold 1 06/17/78 Unknown Switch Unknown	Scram occurred during control valve testing. RPS relay auxiliary switch was loose because of untightened retaining screw.	Matrix: 15 Relay Assemble-disassemble - or - Matrix: 16 Switch Assemble - or - Matrix: 3 Nuclear instruments Test

Example 21

Brunswick 1 09/22/7 Testing Monitor Defective procedures	APRM thermal tip set point found high. Procedure omitted instructions for checking these settings.	Matrix: 15 Temperator sensor Calibrate - or - Matrix: 3 Nuclear instruments Test

Example 22

Brunswick 1 11/02/77 Testing Monitor Defective procedures	APRM high trip tested monthly instead of weekly. Defective procedures.	Matrix: 15 Sensors and control instrumentation Test - or - Matrix: 13 Sensors and control instrumentation Test - or - Matrix: 14 Sensors and control instrumentation Test - or - Matrix: 3 Nuclear instrumentation Test - or - Matrix: 16 Procedures Write

Example 23

E. I. Hatch 2 09/14/78 Testing Monitor Technicians	Weekly IRM test not completed on schedule. Personnel oversight.	Matrix: 15 Sensors and control instruments - or - Matrix: 3 Nuclear instruments Test

Example 24

Oyster Creek 1 10/19/78 Maintenance Monitor Maintenance	Intermediate range monitor inoperable. Cable damaged during maintenance activity.	Matrix: 15 Electrical conductors Connect-disconnect - or - Matrix: 15 Nuclear sensor Maintain

Example 25

Browns Ferry 3 10/29/78 Maintenance Cable Maintenance	Two IRM channels in same trip system inoperable.	Not enough information provided.

Example 26

E. I. Hatch 2 10/11/78 Testing Monitor Defective procedures	APRM high flux set point set too high. Defective procedure did not reflect NRC Regulatory Guide 1.68.	Matrix: 15 Temperature sensor Calibrate - or - Matrix: 3 Nuclear instruments Test

Example 27

Pilgrim 1 11/21/78 Maintenance Monitor Maintenance	Number of operable SRMs below minimum. With SRM D already bypassed, maintenance personnel jumped all of A logic instead of downscale trip only.	Matrix: 15 Sensors and control instrumentation Maintain - or - Matrix: 3 Nuclear instruments Test

Example 28

Browns Ferry 3 11/28/78 Maintenance Monitor Defective procedures	All LRMs found connected in reverse order. Defective procedure.	Matrix: 15 Sensors and control instrumentation Connect-disconnect - or - Matrix: 15 Signal cable Connect/disconnect

Example 29

Fitzpatrick 1 12/14/78 Maintenance Cable Maintenance	Wiring to two MSIVs 10% closure switch found reversed.	Not enough information provided.

APPENDIX H

DATA FIT RESULTS

PERFORMED BY BROOKHAVEN NATIONAL LABORATORY ANALYSTS

DATA FIT RESULTS
PERFORMED BY BROOKHAVEN NATIONAL LABORATORY ANALYSTS

The following is a condensed list of the 104 one-line human error descriptions (as identified from LERs in NUREG/CR-2987) and the Data Bank matrix cells ito which each could be filed.

LER Data		Data Bank Matrix		
Plant	Date	Matrix No.	Equipment Characteristic	Human Action
Nine Mile Point 1	08/30/77	15	Relay	Calibrate
Duane Arnold 1	04/16/77	15	Switch	Calibrate
Oyster Creek 1	05/04/77	14	Flow sensor	Test
Dresden 2	02/18/78	15	Temperature sensor	Install
Brunswick 1	03/01/78	15	Power supply	?
Dresden 3	03/27/78	15	Nuclear sensors	Calibrate
Brunswick 2	05/07/79	15	Limit switch	Calibrate
Dresden 1	01/04/80	15	Pressure sensor	Maintain
E.I. Hatch 2	03/20/80	15	Temperature sensor	Calibrate
Browns Ferry 2	04/25/81	15	Relay	Test
Cooper 1	10/26/81	15	Switch	Install
Davis-Besse 1	08/29/80	15	dc soleniod	Install
Brunswick 2	12/17/76	15	Switch	Install
Brunswick 2	04/04/77	15	Pressure switch	?
Quad Cities 2	07/27/80	13	Flow controller	Operate
Dresden 3	09/24/77	14	Circuit breaker	Operate
Browns Ferry 3	09/11/78	15	Switch	Maintain
Dresden 3	09/17/78	15	Flow sensor	Calibrate
Peach Bottom 3	11/17/78	15	Terminal block	Maintain
Brunswick 1	08/04/79	15	Circuit breaker	Maintain
Browns Ferry 3	12/12/79	15	Terminal block	Connect
Duane Arnold 1	11/12/79	15	Pressure sensor	Calibrate
E.I. Hatch 2	02/03/80	13	Switch	Operate
Fitzpatrick 1	05/01/80	15	Temperature sensor	Test
Monticello 1	05/15/80	15	Relay	Install
Browns Ferry 3	08/25/80	15	RPM sensor	Test
Brunswick 2	09/07/80	15	Flow sensor	Install
E.I. Hatch 2	02/22/81	15	Flow controller	Install
Cooper 1	01/05/77	15	Pressure sensor	Calibrate
Brunswick 1	02/13/77	15	Temperature sensor	Calibrate
Duane Arnold 1	02/19/77	14	Relay	Test
Cooper 1	03/03/77	14	Switch	Operate
Pilgrim 1	04/25/77	15	Switch	Connect
Oyster Creek 1	07/27/77	15	Circuit breaker	Calibrate
Cooper 1	08/17/77	15	Pressure stiwch	Calibrate
Quad Cities 1	08/16/77	15	Level Sensor	Calibrate
Fitzpatrick 1	10/02/77	15	Pressure sensor	Calibrate
Browns Ferry 2	12/18/77	13	Flow controller	Operate

LER Data		Data Bank Matrix		
Plant	Date	Matrix No.	Equipment Characteristic	Human Action
Duane Arnold 1	01/16/78	16	Log book	Record
Brunswick 2	02/12/78	15	Pressure sensor	Calibrate
E.I. Hatch 1	04/27/78	15	Temperature sensor	Test
Duane Arnold 1	05/17/78	16	Log book	Record
Fitzpatrick 1	07/19/78	15	Pressure controller	Maintain
Peach Bottom 3	08/09/78	15	RPM controller	Calibrate
Fitzpatrick 1	09/23/78	14	Circuit breaker	Tag
Fitzpatrick 1	12/15/78	15	Temperature sensor	Calibrate
E.I. Hatch 1	12/26/78	15	Flow sensor	Check
Brunswick 1	01/17/79	15	Pressure sensor	Calibrate
E.I. Hatch 1	03/03/79	15	Pressure sensor	Calibrate
Peach Bottom 2	05/24/79	15	Relay	Connect
Duane Arnold 1	07/05/79	15	Relay	Maintain
Brunswick 1	08/16/79	15	Switch	Assemble
Fitzpatrick 1	09/05/79	15	Signal cable	Assemble
Fitzpatrick 1	09/05/79	15	Flow sensor	Assemble
Fitzpatrick 1	10/13/79	15	Signal cable	Connect
Oyster Creek 1	11/03/79	15	Circuit breaker	Install
E.I. Hatch 1	12/16/79	15	Pressure sensor	Calibrate
Cooper 1	12/06/79	14	Flow sensor	Test
Browns Ferry 1	03/12/80	15	Relay	Install
E.I. Hatch 2	04/15/80	15	Sensor	Install
Pilgrim 1	05/19/80	15	Signal cable	Install
Cooper 1	06/23/80	15	Flow sensor	Calibrate
Duane Arnold 1	07/09/80	15	Pressure sensor	Calibrate
E.I. Hatch 1	07/13/80	15	Pressure sensor	Maintain
E.I. Hatch 2	07/26/80	15	Relay	Connect
Dresden 3	12/31/80	15	Pressure sensor	Calibrate
Fitzpatrick 1	01/29/81	15	Position sensor	Maintain
Brunswick 2	05/13/81	14	Switch	Isolate
Brunswick 1	06/02/81	15	Pressure sensor	Maintain
Vermont Yankee 1	07/31/81	13	Switch	Close
Brunswick 2	08/27/81	15	Flow sensor	Calibrate
Brunswick 2	08/28/81	15	Signal cable	Disconnect
Brunswick 2	09/02/81	15	Signal cable	Install
Fitzpatrick 1	10/07/81	15	Level sensor	Test
Brunswick 2	10/29/81	15	Signal cable	Connect
Prairie Island 2	12/15/76	14	Circuit breaker	Tag
Oconee 1	04/09/77	15	Temperature sensor	Install
Yankee Rowe 1	05/24/77	15	Level sensor	Calibrate
Prairie Island 1	05/18/77	13	Switch	Operate
J.A. Farley 1	08/02/77	13	Switch	Operate
Rancho Seco 1	11/11/77	15	Switch	Install
H.B. Robinson 2	11/23/77	14	Circuit breaker	Tag
Millstone 2	01/10/78	15	Level sensor	Calibrate
Davis-Besse 1	01/16/78	15	Circuit breaker	Install

LER Data		Data Bank Matrix		
Plant	Date	Matrix No.	Equipment Characteristic	Human Action
Crystal River 3	12/22/77	13	Switch	Operate
Prairie Island 2	03/07/78	15	Relay	Calibrate
San Onofre 1	08/18/78	15	Signal cable	Install
Zion 1	11/02/78	15	Sensor	Calibrate
Crystal River 3	10/05/78	15	Signal cable	Connect
Yankee Rowe 1	12/26/78	13	Switch	Operate
R.E. Ginna 1	01/03/79	15	Signal cable	Connect
Arkansas 2	01/15/79	15	Circuit breaker	?
Kewaunee 1	04/24/79	15	Relay	Calibrate
Kewaunee 1	06/19/79	15	Level sensor	Calibrate
R.E. Ginna 1	08/04/79	13	Circuit breaker	Operate
Zion 1	05/23/79	15	Push button	Operate
Turkey Point 3	10/31/79	13	Valve	Tag
H.B. Robbinson 2	11/12/79	15	Flow sensor	Install
Point Beach 1	12/26/79	15	Circuit breaker	Maintain
Yankee Rowe 1	02/01/80	15	Signal cable	Connect
Trojan 1	09/06/79	15	Relay	Remove
Zion 2	07/23/80	13	Relay	Operate
Davis Besse 1	11/27/79	15	Signal cable	Connect
Sequoyah 1	8/27/80	13	Switch	Operate

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The objective of this report is to present a method for using field data from nuclear power plants to estimate human error probabilities (HEPs). These HEPs are then used in probabilistic risk activities. This method of estimating HEPs is one of four being pursued in NRC-sponsored research. The other three are (1) structured expert judgment, (2) analysis of training simulator data, and (3) performance modeling.

The type of field data analyzed in this report is from Licensee Event Reports (LERs) which are analyzed using a method specifically developed for that purpose. However, any type of field data or human errors could be analyzed using this method with minor adjustments.

This report assesses the practicality, acceptability, and usefulness of estimating HEPs from LERs and comprehensively presents the method for use.

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