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PEER-REVIEW STUDY OF THE DRAFT HANDBOOK FOR
HUMAN-RELIABILITY ANALYSIS WITH EMPHASIS ON
NUCLEAR-POWER-PLANT APPLICATIONS, NUREG/CR-1278

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ABSTRACT

This report describes a peer review of the draft Handbook for Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278. The purpose of the study was to determine to what extent peers agree with the human behavior models and estimates of human error probabilities (HEPs) contained in the Handbook. Twenty-nine human factors experts participated in the study. Twenty of the participants were Americans; nine were from other countries. The peers performed human reliability analyses of a variety of human performance scenarios describing operator activities in nuclear power plant settings. They also answered questionnaires pertaining to the contents and application of the Handbook. An analysis of peer solutions to the human reliability analysis problems and peer responses to the questionnaire was performed. Recommendations regarding the format and contents of the Handbook were developed from the study findings.

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SUMMARY

In February 1981, HPT Inc. began a peer review study of the draft Handbook for Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278. The study was performed under the technical direction of Sandia National Laboratories. It was sponsored by the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission. The purpose of the study was to determine the extent to which other human factors experts agreed with the human behavior models and estimates of human error probabilities (HEPs) developed by the authors of the Handbook. Twenty-nine experts participated in the study. This peer group was composed of 10 Americans with predominantly academic backgrounds, 10 Americans from applied settings, and nine foreign peers from Europe, South Africa, and Japan. The peers were presented a variety of scenarios describing human performance problems in nuclear power plant settings. Their task was to develop problem solutions using the human reliability analysis techniques, human performance models, and HEPs presented in the Handbook. After completing the problems, they answered a questionnaire pertaining to the use and contents of the Handbook.

The problem solutions and questionnaire responses constituted the study data. Analyses were performed and the findings were used to formulate recommendations for the format and contents of the Handbook. The major findings were:

1. The concept of the Handbook was generally well-received by the peers. The Handbook was viewed as a useful and needed basic document for solving human reliability analysis problems.
2. The peers were generally willing to accept the human error probability (HEP) estimates provided in the Handbook. However, their acceptance was qualified by the position that a more complete data base for estimating human error rates in applied settings is needed.
3. There was wide variation among the problem solutions developed by the peers in estimating probabilities of failure for the human performance scenarios. The variability among solutions appears to be largely attributable to:
 - a. lack of uniformity among the peers in the human reliability analysis approaches they used to solve the human performance problems
 - b. usability problems associated with the selection and application of the tables listing HEPs in Chapter 20 of the Handbook

4. Peer solutions to the human performance scenarios did not appear to be affected by differences in peer backgrounds (Academic, Applied, Foreign).

The peers offered many specific suggestions for improving the usability of the Handbook and the tables contained in Chapter 20. Recommendations aimed at structuring the human reliability analysis process to reduce variability of results and improving the usability of HEP tables are described in the report.

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Lastly, the study team especially wishes to acknowledge the support of the 29 human factors experts who so generously agreed to participate in the study in spite of heavy demands upon their time from other duties and obligations.

PEER REVIEW STUDY OF THE DRAFT HANDBOOK FOR
HUMAN RELIABILITY ANALYSIS WITH EMPHASIS ON
NUCLEAR POWER PLANT APPLICATIONS, NUREG/CR-1278

CHAPTER I

INTRODUCTION

Objective of Study

This report describes a study of peer reviews of human error probability estimates and human performance models presented in the draft Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278.*

Background

A.D. Swain and H.E. Guttmann of Sandia National Laboratories** developed the Handbook as a part of a long-term Sandia project sponsored by the Probabilistic Analysis Staff, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission (PAS/NRC). The Handbook is designed for use by scientists and engineers involved with the safety and reliability of complex engineering systems, particularly those associated with nuclear reactors. A manuscript of the draft Handbook was distributed in October 1980 for interim use and comment. A revised edition is scheduled for release late in 1982.

The Handbook contains estimates of human error probabilities (HEPs) for a large variety of tasks descriptive of those likely to be encountered in nuclear power plants. The HEP estimates are intended to assist system analysts, reliability engineers, human factors practitioners, and others in evaluating the impact of equipment characteristics, work conditions, administrative controls, etc. upon the reliability of human performance. Because the HEPs will contribute to decisions with potentially severe economic, environmental, and safety consequences, it is important that they be based on as solid a footing as currently possible. However, a shortcoming of the Handbook is that many of the HEPs and human performance models presented in it are based on the judgment of the authors. There is no complete body of actuarial data on HEPs in applied settings such as nuclear power plant operations.

*Hereinafter referred to as the Handbook

**Hereinafter referred to as Sandia

One step in the direction of overcoming this problem is to determine how well the HEP estimates are supported by other experts on human behavior—particularly when they view the behavior in the context of specific work scenarios. Also, if other experts are able to identify experimental or actuarial data regarding HEPs, the relevance of these sources to nuclear power plant operations could be assessed and, if warranted, replace or supplement Handbook values.

The Handbook also contains procedures for performing a human reliability analysis. Persons using the methodology described in the Handbook should be able to arrive at similar solutions to the work scenarios. The study would provide an opportunity to determine the usability of the methodology.

In view of these considerations, PAS/NRC decided to sponsor a study to determine the extent to which other experts in the field of human factors agreed or disagreed with the data in the Handbook. Sandia awarded a contract to HPT Inc. in February 1981 to perform the study. The study methodology is described in Chapter II. Chapter III presents the analysis of data and findings. The results are discussed in Chapter IV along with specific recommendations for revisions to the Handbook.

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CHAPTER II

DESCRIPTION OF STUDY

Subjects

Thirty persons with expertise in the psychology of human performance and/or nuclear power plant operations were to be selected to participate in the study. Twenty of the participants were to be chosen from the United States; 10 from other nations. Of the 20 Americans, persons from both the academic and applied communities were to be sought.

Twenty Americans agreed to participate in the study. Eighteen of these participants had doctorate degrees in a field of psychology; two had masters degrees. The average participant had 17 years of experience in a field of human behavior. Eighteen participants were members of the Human Factors Society. All had achieved prominence in their profession or were recommended by persons who are recognized leaders in their profession.

Nine foreign judges agreed to participate in the study. They were selected by Dr. Alan D. Swain of Sandia and Dr. William E. Vesely, then of PAS/NRC. The European judges were selected from the Group of Experts on Human Error Data and Assessment of the Committee for Safety of Nuclear Installations (CSNI) of the Organization for Economic Cooperation and Development (OECD) and from other organizations in Scandinavia which are doing human reliability analyses. Human reliability experts from South Africa and Japan also participated. Thus, a total of 29 peers participated in the study.

Methodology

Each of the participants received the following materials:

1. A copy of Swain, A.D. and Guttman, H.E., Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278. (October 1980 draft copy.)
2. Exercise Workbook
3. Problem Worksheets, Event Tree Worksheets
4. Questionnaire
5. Biographical Data Sheet

The peers were instructed to review the Handbook with the objectives of becoming familiar with human reliability analysis methodology, the tables

in Chapter 20, and the models used to develop them. After completing the review they were to complete the Exercise Workbook, which appears in Appendix A.

The workbook contains six human reliability analysis problems describing personnel activities that are associated with nuclear power plant operations. The scenarios are greatly simplified versions of real-life operations but do provide the information required to perform human reliability analyses and develop estimates of the probability of success (or failure) associated with the operation. The first two problems along with their solutions were provided to familiarize the peers with the use of the Handbook and with the process of constructing event trees used in the reliability analysis. It also introduced them to the use of the Problem Worksheets and the Event Tree Worksheets (Appendix A) developed by HPT for this study. The peers were instructed to develop solutions for the remaining four problems. Solutions developed by Sandia for these problems are contained in Appendix B.

After completing the exercises, the participants were requested to respond to a questionnaire. Part 1 of the questionnaire solicited opinions pertaining to the general usability of the Handbook. Part 2 of the questionnaire invited opinions about the usability of each of the 27 tables contained in Chapter 20 of the Handbook and about the values for HEPs estimated by the Handbook authors.

An additional study objective was to determine whether persons with different backgrounds responded differently. Therefore, the participants were requested to fill out a brief biographical data sheet so that they could be grouped for purposes of comparison. Thus, the data for the study consisted of:

1. Biographical data.
2. Peer solutions to human reliability analysis problems.
3. Peer responses to a questionnaire dealing with the contents and application of the Handbook.

The analyses and findings from these data are described in the following chapter.

CHAPTER III

ANALYSIS AND FINDINGS

This chapter is organized into three sections describing the different kinds of analyses that were performed. They are:

1. Tests for Homogeneity of Groups. This section describes the analysis of group differences on several measures of peer performance and opinions.
2. Analysis of Peer Solutions to Human Reliability Analysis Problems. This section describes the analysis of peer performance on several variables contributing to their solutions to human reliability analysis problems.
3. Analysis of Peer Responses to Questionnaire. This section describes the analysis of peer opinions about selected contents of the Handbook and its application.

Tests for Homogeneity of Groups

An initial task of this analysis was to determine whether or not the differences between groups of peers with respect to background introduced differences in their performance of human reliability analyses or their opinions about the Handbook tables containing the HEPs. If statistically significant differences were found, they might be attributable to particular characteristics of the groups; if not, the data could be combined for subsequent analyses.

Three variables were selected as yielding comprehensive and meaningful measures. They were:

1. the probabilities of failure (P_f 's) that the participants calculated as solutions to the human reliability analysis problems,
2. the frequencies of using the Handbook tables in developing the problem solutions, and
3. the extent to which peers expressed agreement with the Handbook tables.

Homogeneity of Groups on Calculated Probabilities of Failure (P_f 's)

It was previously stated that one of the study objectives was to determine whether there are differences in performance among the three

groups participating in the study. The primary measure of performance was the peer solution (calculated P_f) to each human performance scenario composing the problem set.

The P_f 's were tabulated for each group—10 Americans with academic backgrounds, 10 Americans from applied settings, and nine foreign experts. The approach was to perform an analysis of variance, using the raw P_f values as the data. If the overall test yielded an F ratio significant beyond the .05 level of significance, further tests of significance were warranted. The F ratios would then be computed for each of the human reliability analysis problems completed by the peers. The problems (3a, 4a, 5a, 5b, and 6a) are presented in Appendix A.

An overall test was performed on the P_f 's averaged (for each peer) across all problems. In the few instances that a peer did not complete one of the problems, a value equal to the mean P_f for all remaining peers in his group was entered for the missing value.

Tables 3.1 and 3.2 present the results of the comparison among groups on calculated P_f 's across all problems. The mean P_f 's range from a low value of .067 for the foreign experts to a high estimate of .257 for the academic group. The F ratio of 8.714, shown in Table 3.2, exceeds the .01 level of significance, indicating that the groups differ with respect to problem solutions. This finding justified an examination of group performance on the individual problems.

Table 3.3 presents a breakdown of the data for groups by problems. The F ratios for each problem are provided in Table 3.4. The results of the analysis indicate that the between group differences found in the overall analysis are assignable to problems 5a, 5b, and 6a. No significant differences between groups were demonstrated for problems 3a or 4a.

Next, "t" tests were performed between pairs of group means for problems 5a, 5b, and 6a. The results, summarized in Table 3.5, indicate that P_f 's calculated by American peers from academic settings are significantly higher than those calculated by American peers from applied settings or by the foreign peers (who are, with one exception, working in applied settings). In every comparison with the applied groups on these three problems the difference exceeds the .01 level of significance. The academicians were more conservative in their solutions to these problems than the applied peers.*

*The variable of interest, P_f , is a count variable and it appears that the variability, as expected, is proportional to the mean. In such a situation it is recommended that a logarithmic or square root transformation be used to stabilize the variance. Thus, the analyses of variance were performed using the raw scores, square root of scores, and log scores. The result was that the basic conclusions of the experiment were essentially the same regardless of the transform used. Since the conclusions were independent of transformation it was decided to present the results in terms of raw score for ease of interpretation.

Table 3.1 P_f 's Calculated by Academic, Applied, and Foreign Peers for Human Reliability Analysis Problems (P_f 's across all Problems)

Value	Group		
	Academic	Applied	Foreign
N	10	10	9
Mean P_f	0.257	0.093	0.067
s^2	0.0285	0.0034	0.0028
s	0.169	0.059	0.053

Table 3.2 Analysis of Variance of P_f 's Calculated by Academic, Applied, and Foreign Peers

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Between Groups	0.2071	2	0.1035	
Within Groups	0.3089	26	0.0119	
Total	0.5160	28		8.714**

N = 29

** $F_{.01} \geq 5.53$

Table 3.3 P_f 's Calculated by Academic, Applied, and Foreign
Peers for Individual Human Reliability Analysis Problems

Group	Value	Problem				
		3a	4a	5a	5b	6a
Academic N = 10	Mean P_f	0.116	0.060	0.330	0.523	0.257
	s^2	0.0318	0.0016	0.1266	0.1411	0.1014
	s	0.178	0.039	0.356	0.376	0.318
Applied N = 10	Mean P_f	0.029	0.096	0.099	0.215	0.027
	s^2	0.0036	0.0280	0.0075	0.0409	0.0007
	s	0.060	0.167	0.086	0.202	0.026
Foreign N = 9	Mean P_f	0.020	0.045	0.051	0.187	0.032
	s^2	0.0003	0.0253	0.0040	0.0422	0.0010
	s	0.016	0.159	0.064	0.205	0.032
Total N = 29	Mean P_f	0.056	0.068	0.164	0.313	0.108
	s^2	0.0134	0.0101	0.0596	0.0980	0.0452
	s	0.116	0.100	0.244	0.313	0.213

Table 3.4 Analysis of Variance of
P_f's by Groups of Peers and Problems

Problem	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
3a	Between Groups	0.0552	2	0.0276	2.244
	Within Groups	0.3208	26	0.0123	
	Total	0.3760	28		
4a	Between Groups	0.0130	2	0.0065	0.628
	Within Groups	0.2690	26	0.0103	
	Total	0.2820	28		
5a	Between Groups	0.4311	2	0.2155	4.524*
	Within Groups	1.2387	26	0.0476	
	Total	1.6698	28		
5b	Between Groups	0.6803	2	0.3401	4.282*
	Within Groups	2.0650	26	0.0794	
	Total	2.7453	28		
6a	Between Groups	0.3393	2	0.1697	4.760*
	Within Groups	0.9269	26	0.0356	
	Total	1.2662	28		

N = 29

*F_{.05} ≥ 3.37

Table 3.5 Summary of "t" Tests on Paired Group Mean
 P_f 's for Problems Yielding Significant F Ratios

Problem	Value	Paired Groups		
		Applied/Academics	Applied/Foreign	Academic/Foreign
5a	$M_1 - M_2$	0.2309	0.0474	0.2783
	$S_{M_1 - M_2}$	0.0579	0.0176	0.0602
	t	3.989**	2.701*	4.621**
5b	$M_1 - M_2$	0.3081	0.0280	0.3361
	$S_{M_1 - M_2}$	0.0693	0.0467	0.0725
	t	4.447**	0.599	4.636**
6a	$M_1 - M_2$	0.2300	0.0052	0.2248
	$S_{M_1 - M_2}$	0.0505	0.0066	0.0534
	t	4.552**	0.788	4.210**
Ave. P_f 's	$M_1 - M_2$	0.1641	0.0260	0.1901
	$S_{M_1 - M_2}$	0.0283	0.0127	0.0293
	t	5.805**	2.044	6.481**
	d. f.	18	17	17
	*t _{.05}	2.101	2.110	2.110
	**t _{.01}	2.878	2.898	2.898

It was felt that an explanation for the differences in group performance might be suggested from a closer examination of their backgrounds. For example, familiarity with nuclear power plant settings might influence group performance. Therefore, responses to the biographical data sheets were reviewed to permit a regrouping of the peers on this factor. In the biographical data sheets the study participants were asked to identify their employers and to provide a brief description of their experience with the nuclear industry. From the responses, the following five groups were identified on the basis of differences in background and experience:

1. Applied Nuclear. Six (6) U.S. experts indicated they were in applied occupations and had human factors work experience in nuclear power settings.
2. Applied Non-Nuclear. Four (4) U.S. experts indicated they were in applied occupations but had no experience in nuclear settings.
3. Academic Nuclear. Four (4) U.S. experts indicated they were primarily academic (university) but had human factors experience with the nuclear industry as consultants.
4. Academic Non-Nuclear. Six (6) U.S. experts indicated they were primarily academic (university) and had no experience in nuclear power settings.
5. Foreign. Nine (9) foreign experts participated in the study. Eight (8) had nuclear experience, generally as their primary employment; one (1) expert was academic with no nuclear experience.

An analysis of variance was applied to the raw P_f 's of the five groups of peers. The overall analysis used the total P_f calculated by each subject across all problems (3a, 4a, 5a, 5b, and 6a). The results of the analysis are summarized in Tables 3.6 and 3.7. The F ratio of 3.72 is significant at the .05 level. The mean P_f 's displayed in Table 3.6 indicate that the academic peers arrived at more conservative estimates of failure probabilities than the applied groups or the foreign group.

Table 3.6 P_f 's Calculated by Five Different Groups of Peers for Human Reliability Analysis Problems (P_f 's across All Problems)

Values	Academic Non-Nuclear	Academic Nuclear	Applied Non-Nuclear	Applied Nuclear	Foreign
N	6	4	4	6	9
Total Mean P_f	1.2201	1.3375	0.4290	0.5020	0.3364
s^2	0.2557	1.8222	0.0513	0.1171	0.0665
s	0.506	1.350	0.227	0.342	0.253

Table 3.7 Analysis of Variance of P_f 's
Calculated by Five Different Groups of Peers

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Between Groups	4.9672	4	1.218	
Within Groups	8.0179	24	0.3341	
Total	12.9851	28		3.72*

N = 29

* $F_{.05} \geq 2.78$

Because of the finding of significance, a more detailed analysis was warranted in order to ascertain more specifically the locus of significance. Therefore, an analysis of variance was performed for groups by individual problems. The results are summarized in Tables 3.8 and 3.9. The mean P_f 's presented in Table 3.8 are shown graphically in Figure 3.1. They display a profile of each group's solutions to the human reliability analysis problems. It appears that the applied Americans and the foreign peers constitute one family of profiles and academicians another, with the academic peers providing more conservative estimates of probabilities of failure. The Sandia solutions are illustrated for comparison. They appear to be somewhat more optimistic than those developed by the other applied groups (including the foreign group). Statistical evidence for group differences was sought.

Table 3.9 shows that significant F ratios were obtained with regard to group performance on problems 5a and 6a. Between group differences on these two problems were then examined by means of "t" tests. The results were as follows:

- The comparison between the mean P_f 's calculated for problem 5a by the academic nuclear group and the foreign group resulted in a "t" = 2.59 which was significant at the .05 level. (For 11 degrees of freedom and .05 level of significance, "t" must exceed 2.18.)
- The comparison between the mean P_f 's calculated for problem 6a by the academic non-nuclear peers and the applied nuclear peers resulted in a "t" = 2.11 which was not significant at the .05 level. (For 10 degrees of freedom, "t" must exceed 2.23 at the .05 level of significance.)

The conclusion drawn by the investigators from the analysis of variance and the subsequent "t" tests, when considering the fact that only problem 5a showed significance, is that there is no justification for grouping peer solutions with respect to peer backgrounds. Therefore, the P_f 's were combined for subsequent analyses.

Homogeneity of Groups on Approaches to Human Reliability Analysis

The measure "number of times that a peer entered the Handbook tables to develop the solution for a human reliability analysis problem" was selected as an indicator of the complexity or comprehensiveness of a peer's analytic approach. The table entries had been recorded by each peer on the worksheet prepared for each problem. The number of table entries were tabulated separately for problems 3a, 4a, 5a, 5b, and 6a. An overall analysis of variance of the mean frequency with which each of the five groups of peers entered the Handbook tables (summed across all problems) was performed. The results of the analysis are presented

Table 3.8 P_f 's Calculated by Five Different Groups of Peers for Individual Human Reliability Analysis Problems

Group	Value	Problem				
		3a	4a	5a	5b	6a
Academic Non-Nuclear	N	6	6	6	6	6
	Mean P_f	0.057	0.050	0.232	0.531	0.351
	s^2	0.0053	0.0007	0.0415	0.0903	0.1492
	s	0.073	0.026	0.204	0.301	0.386
Academic Nuclear	N	4	4	4	4	4*
	Mean P_f	0.206	0.075	0.476	0.512	0.065
	s^2	0.0690	0.0030	0.2628	0.3024	0.0028
	s	0.263	0.055	0.513	0.550	0.053
Applied Non-Nuclear	N	4	4	4	4	4
	Mean P_f	0.054	0.057	0.091	0.191	0.037
	s^2	0.0092	0.0024	0.0115	0.384	0.0011
	s	0.096	0.049	0.107	0.196	0.034
Applied Nuclear	N	6	6	6**	6**	6**
	Mean P_f	0.012	0.122	0.109	0.240	0.017
	s^2	0.0001	0.0468	0.0064	0.1186	0.0004
	s	0.009	0.216	0.080	0.344	0.020
Foreign	N	9	9*	9	9	9
	Mean P_f	0.020	0.045	0.051	0.187	0.032
	s^2	0.0003	0.0005	0.0040	0.0422	0.0010
	s	0.016	0.022	0.064	0.205	0.031
	N	29	29	29	29	29
	Mean P_f	0.056	0.068	0.165	0.315	0.100
	s^2	0.134	0.0101	0.0595	0.977	0.0446
	s	0.116	0.100	0.244	0.313	0.211

*One subject did not solve problem
 **Two subjects did not solve problem

The means of the remaining peers were used in computations.

Table 3.9 Analysis of Variance of P_f 's by
Five Groups of Peers and Problems

Problem	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
3a	Between Groups	0.1127	4	0.0282	2.57
	Within Groups	0.2633	24	0.0110	
	Total	0.3760	28		
4a	Between Groups	0.0246	4	0.0061	0.57
	Within Groups	0.2575	24	0.0107	
	Total	0.2821	28		
5a	Between Groups	0.5710	4	0.1428	3.13*
	Within Groups	1.0951	24	0.0456	
	Total	0.6661	28		
5b	Between Groups	0.6768	4	0.1692	1.97
	Within Groups	2.0601	24	0.8583	
	Total	2.7369	28		
6a	Between Groups	0.4811	4	0.1203	3.76*
	Within Groups	0.7678	24	0.0320	
	Total	1.2489	28		

N = 29 $*F_{.05} \geq 2.78$

Figure 3.1 Profiles of Group Solutions to Human Reliability Analysis Problems

in Tables 3.10 and 3.11. It is noted that persons with Academic Nuclear backgrounds used the tables more frequently than all other peers, thus contributing disproportionately to the variance between groups. However, the F ratio indicates that there is no reason to reject the null hypothesis, i.e., there are no significant differences between the groups with respect to the frequency with which they used the tables in solving the problems.

To the extent that frequency of table use is a measure of the complexity or comprehensiveness of approaches to the problems, it appears that all groups performed in-depth analyses of the problems. That is, all groups gained adequate familiarity with the use of the Handbook tables—and, thus, their comments about them were regarded to be authoritative. The findings support combining their responses to the study questionnaire concerning the Handbook tables.

Homogeneity of Groups on Expressed Opinions of Handbook Tables

Each peer was asked to complete a questionnaire about the contents of the Handbook. Part 2 of the questionnaire presented four questions about the tables in Chapter 20. They were answered separately for each of the 27 tables in the chapter. The questions and the favorable response categories are:

1. "Is it easy to understand how to enter and use the table?"
Yes ____ No ____ . "Yes" = agreement.
2. "Does the table contain appropriate detail, e.g., . . . "
Yes ____ No ____ . "Yes" = agreement.
3. "What is your opinion of the general magnitude of the HEPs in the table?" Too pessimistic ____ Reasonable ____
Too optimistic ____ . "Reasonable" = agreement.
4. "Do the relative values of the HEPs in this table seem reasonable to you?" Yes ____ No ____ . "Yes" = agreement.

For any particular question, a peer could register "agreement" for as many as 27 tables. This would result in a maximum "agreement" score of 27 on that question, or a total maximum "agreement" score for all questions of 108. This "agreement" score was tabulated for each subject. An overall analysis of variance was performed of mean "agreement" scores calculated for each group across all four questions. The results appear in Tables 3.12 and 3.13. The F ratio was not significant. Therefore, it was decided that there was no reason to treat the responses from the groups separately when analyzing peer responses to the questionnaire. The questionnaire analysis, described beginning on page 3-41, was performed using the combined responses from all peers.

Table 3.10 Frequency of Using Handbook Tables by Different Groups of Peers in Solving Human Reliability Analysis Problems

Value	Group					Total
	Academic Non-Nuclear	Academic Nuclear	Applied Non-Nuclear	Applied Nuclear	Foreign	
N	6	4	4	6	9	29
Mean Freq.	28.50	46.50	29.50	25.63	27.24	30.14
s ²	115.5	495.5	147.0	41.6	89.4	168.3
s	10.75	22.26	12.12	6.45	9.46	12.97

Note: No entries were recorded on six worksheets. In these cases, the authors used frequencies equal to the mean of the frequencies of table entries by the remainder of the group.

Table 3.11 Analysis of Variance of Frequency with Which Different Groups of Peers Used Handbook Tables

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Between Groups	1286.10	4	321.53	
Within Groups	3426.49	24	142.77	
Total	4712.59	28		2.25

N = 29

$F_{.05} \geq 2.78$

Table 3.12 Summary of "Agreement" Scores
for Questions 1—4, Part 2 by Different Groups of Peers

Value	Group					Total
	Academic Non-Nuclear	Academic Nuclear	Applied Non-Nuclear	Applied Nuclear	Foreign	
N	6	4	4	6	7*	27*
Mean Agree- ment Score	86.67	72.25	73.50	81.33	73.14	77.89
s ²	91.9	468.3	422.3	363.5	587.1	360.3
s	9.58	21.64	20.55	19.06	24.23	18.98

*Two foreign peers did not return the completed questionnaire.

Table 3.13 Analysis of Variance of "Agreement"
Scores by Different Groups of Peers

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Between Groups	895.39	4	223.85	
Within Groups	8471.28	22	385.06	
Total	9366.67	26		0.58

N = 27 $F_{.05} \geq 2.82$

Analysis of Peer Solutions to Human Reliability Analysis Problems

Exercises 1 and 2 in the workbook (Appendix A) were provided as examples to introduce the participants to a specific methodology for performing human reliability analysis. This familiarization should serve to reduce variability among their solutions. Detailed discussions of the human performance problems involved in the exercises and the reasoning accompanying the problem solution processes were presented with the examples. Use of the problem worksheets and the construction of event trees was explained. The participants were instructed to complete problem worksheets and construct event trees for each of the problems described in exercises 3 through 6 of the workbook.

The completed worksheets and event trees were analyzed to determine:

- the uniformity among peers in applying the Handbook to analyze human performance problems. If there were variability among problem approaches and solutions, the sources of variability would be identified.
- the correspondence between peer performance of reliability analysis, using the Handbook, and peer opinions of the Handbook.

The following variables of peer performance were selected for analysis:

1. Peer calculations of probabilities of human performance failures (P_f 's).
2. Construction characteristics of event trees.
3. Use of Handbook tables in selecting human error probabilities (HEPs).
4. Task/error analyses of human performance scenarios by peers.

Peer Calculations of Probabilities of Human Performance Failures (P_f 's)

The distribution of P_f 's calculated by the peers for each problem appear in Table 3.14. They are tabulated in rank order from the highest to lowest values. Solutions are shown for problem 3a, along with its lower and upper bounds, and problems 4a, 5a, 5b, and 6a. The quartiles for each distribution are indicated. It is pointed out that not all peers provided solutions for all problems—the number of responses ranges from 25 to 29. The ranges of values in the distribution are extreme. In four cases, they encompass almost the entire range of possible probability values.

Table 3.14 Distribution of Probabilities of Failure (P_f 's)
Calculated by Peers for Human Reliability Analysis Problems

Problem							
	3a	3b _l	3b _u	4a	5a	5b	6a
3rd Quartile	0 594	0 4995	0 939	0 563	0 995	0 999	0 990
	0 198	0 1875	0 824	* 0 131	0 839	0 976	0 500
	0 172	0 0440	0 675	0 130	0 536	0 914	0 497
	0 124	0 0440	0 624	0 114	0 441	0 721	0 128
	0 121	0 0354	0 534	0 100	0 260	0 716	0 081
	0 092	0 0320	0 460	0 082	0 241	0 670	
	0 058		0 317	0 060			0 0785
		0 0214			0 200	0 570	
2nd Quartile	0 028		0 281	0 060			0 070
	* 0 025	0 0140			0 160	0 480	
		*	0 262	0 060			
	0 024	0 0115	*		0 110	0 455	0 070
			0 224	0 048			
	0 023	0 0104	0 200	0 042	0 106	0 410	0 070
					*		
	0 020	0 0100	0 195	0 040	0 095	0 305	0 060
			0 186	0 040	0 090	0 224	0 055
	0 018	0 0100					
	0 016	0 0078	0 128	► 0 038	0 085	0 224	0 054
					*		
	- 0 016	0 0075			0 060	0 150	0 040
			0 090	0 037			
	0 014	0 0070	0 080	0 036	0 050	0 146	0 026
1st Quartile	0 010	0 0054	0 078	0 035	0 049	0 120	0 020
	0 008	0 0040	0 078	0 034	0 040	0 120	0 017
			0 073	0 032	0 037	0 096	0 0079
	0 008	0 0040	0 073	0 032	0 033	0 074	0 006
	0 008	0 0040	0 054	0 032	0 033	0 074	0 006
	0 008	0 0040	► 0 050	0 032	0 031	0 064	
	0 008	0 0040			0 022	0 050	0 005
		0 008	0 049	0 031			0 001
	0 008	0 0030	0 040	0 031	► 0 020	0 044	
	0 006	0 0030	0 037	0 030	0 020	0 040	0 0005
	0 006	► 0 0025	0 030	0 025	0 020	► 0 032	0 0004
	► 0 005	0 0019	0 030	0 023	* 0 010	0 026	0 0001
		*	*			*	
	0 004	0 0010	0 010	0 020	0 006	0 008	* 0 000057
	0 004	0 0000	0 005	* 0 012	0 004	0 008	► 0 00001
						*	
	N=29	N=27	N=28	N=28	N=27	N=27	N=25
<u>Sandia Solution</u>							
P _f (►)	0 005	0 0025	0 05	0 039	0 02	0 032	0 000011
Lower Limit (*)	0 0025	0 00125	0 025	0 0195	0 01	0 016	0 0000055
* Upper Limit (*)	0 025	0 0125	0 25	0 195	0 1	0 16	0 000055

* These limits underestimate by a factor of two or more the usual uncertainty bounds that would be calculated by a Monte Carlo procedure. Were the wider bounds used, considerable more of the peers' responses would lie within the usual uncertainty bounds of the Sandia solution.

The P_f values provided by Sandia in the candidate solutions for these problems (Appendix B) are also shown in Table 3.14. Upper and lower limits were computed for these values using Sandia guidelines of dividing the P_f by two to estimate the lower limit and multiplying the P_f by five to estimate an upper limit. They are shown in the table. The Sandia values are presented for comparison purposes only. They are not offered as the "absolute correct" solutions to the problems, but as reasonable solutions to the problems obtained by the use of conventional human reliability analysis processes. However, they do emphasize the extreme spread of the peer solutions in that many of the peer solutions fall well outside the ranges estimated for the Sandia P_f 's. Also, with the exception of problem 4a, the peer solutions yielded higher p_f 's than the Sandia solutions. The findings are compared graphically in Figure 3.2. The P_f 's and limits were transformed to log values for plotting. The lower and upper limits were calculated around the medians of the peer distributions using the Sandia guidelines (i.e., divide by two for the lower limit; multiply by five for the upper limit).

Because of these findings an effort was undertaken to identify the causes of variability. An initial task in seeking to explain the variability of peer solutions was to determine whether or not some of the participants tended to arrive at extremely high or low values consistently, thus contributing disproportionately to the variances of the distributions. Product-moment correlations were computed to ascertain the intercorrelations among the basic problems, 3a, 4a, 5a, and 6a. The results are listed in Table 3.15. The mean P_f and standard deviation are shown for each problem. The intercorrelations range from $-.069$ to $.758$ with only one of the six values exceeding $.13$. The investigators can offer no interpretation of the single high correlation. The covariability or percent of variability attributed to the tendency of a subject to reach consistently high or low P_f 's for $r = .13$ is less than two percent. Therefore, it was concluded that the extreme ranges of P_f distributions do not appear to be attributable to bias of individual peers. Other factors would have to be examined to account for the generally wide ranges of peer solutions.

Construction Characteristics of Event Trees

The structure of an event tree provides a graphic description of the analytic approach used in solving a workbook problem. If meaningful quantifiable characteristics of the event trees could be identified, comparisons of problem-solving approaches could be made and relationships between the problem-solving approaches and problem solutions (calculated probabilities of failure) identified. Two characteristics were selected. They were:

1. The number of branches (human actions with HEPs) identified

Figure 3.2 Comparison between Peer and Sandia Solutions to Human Reliability Analysis Problems

Table 3.15 Intercorrelations between P_f 's Calculated by Peers
for Different Human Reliability Analysis Problems

Problem	Problem			
	3a	4a	5a	6a
3a	X	X	X	X
4a	+.107 N = 28 *	X	X	X
5a	+.758 N = 27	+.126 N = 26	X	X
6a	-.069 N = 25	+.027 N = 24	+.018 N = 24	X
Mean P_f	.058	.070	.169	.111
Std. Dev.	.116	.101	.248	.221

* Some participants did not submit solutions to all problems so the number of paired estimates varies for each problem.

- by a peer on the longest success path* of an event tree, and
2. the number of success paths in an event tree.

These characteristics were tabulated for the event trees constructed by the peers and Sandia for problems 3a, 4a, 5a, 5b, and 6a. They are presented in Tables 3.16 through 3.20. The tables provide graphic representations of the distributions of event trees on the above characteristics. For example, in Table 3.16 the distribution of the 29 event trees for problem 3a is displayed. The first entry indicates that three of the event trees have one success path. Furthermore, there are three branches in the longest (in this case, only) success path. Seven event trees have one success path and each success path has four branches. The remaining entries are interpreted in a similar manner. Entry 7 is circled because the event tree constructed by Sandia also has these characteristics (one success path with four branches). The P_f 's calculated from the seven event trees were then compared with the Sandia P_f . Their distribution is shown in Table 3.16. All of the P_f 's differed from the Sandia value of $P_f = .005$, which indicates that different HEPs were used. This finding suggests that different human errors were identified by the peers, and consequently, different Handbook tables of HEPs were used in their reliability analyses. However, it should be observed that the distribution of P_f 's associated with similar event trees is much more restricted than the overall distribution of P_f 's for problem 3a (see Table 3.14). Similar findings are indicated for the remaining problems, Tables 3.17—3.20. Together, they suggest that greater structuring of the human reliability analysis process can substantially reduce variability among analysts. The distribution of event tree characteristics in the tables demonstrates that the analytic process, as currently structured, allows a great deal of variability in the performance of human reliability analysis.

Use of Handbook Tables

The participants recorded (on their problem worksheets) the Handbook tables they used to obtain the HEPs for each human action they identified in their analysis. Thus, the worksheets provided data for determining:

1. the tables that were used,
2. the number of times each table was used, and
3. the distribution of table use among the peers.

Table 3.21 presents a summary of the frequency of use of the different

*A success path is defined as a path for which a probability of success (P_s) is calculated.

Table 3.16 Characteristics of Event Trees
for Problem 3a

No. of Branches in Longest Path	No. of Success Paths								Total
	1	2	3	4	5	6	7	8	
1									0
2									0
3	3		1						4
4	7*								7
5	5								5
6	4	1	1					1	7
7	1		1						2
8	2								2
9	1								1
10	1								1
Total	24	1	3	0	0	0	0	1	29

Distribution of P_f 's

P_f	freq.
0.008	5
0.007	0
0.006*	1
0.005	0
0.004	1
	<u>7</u>

*Sandia solution

Table 3.17 Characteristics of Event Trees
for Problem 4a

No. of Branches in Longest Path	No. of Success Paths							Total
	1	2	3	4	5	6	7	
1								0
2								0
3	1	1						2
4		5*	1	1				7
5	1	3	1					5
6			1			1		2
7		1						1
8	1	1					1	3
9	1	1						2
10								0
11								0
12								0
13		2						2
14								0
15		1						1
16	1	1						2
28							1	1
Total	5	16	3	1	0	1	2	28

Distribution of P_f 's

P_f	freq
0.042	1
0.040	1
0.039*	
0.035	1
0.0315	1
0.031	1
	<u>5</u>

* Sandia solution

Table 3.18 Characteristics of Event Trees
for Problem 5a

No. of Branches in Longest Path	No. of Success Paths								Total
	1	2	3	4	5	6	7	8	
1									0
2									0
3	2	1							3
4	1								1
5	5	1							6
6	5*								5
7	3								3
8	1								1
9	1								1
10	1	1							2
11	1								1
12	1								1
13	1		1						2
14	1								1
15									0
16									0
17									0
18									0
19								1	1
Total	23	3	1	0	0	0	0	1	28**

Distribution of P_f 's

P_f	freq
0.16	1
0.09	1
0.02*	2
**	<u>1</u>
	5

* Sandia solution

** One peer did not calculate P_f

Table 3.19 Characteristics of Event Trees
for Problem 5b

No. of Branches in Longest Path	No. of Success Paths								Total
	1	2	3	4	5	6	7	8	
1									0
2									0
3	2	1							3
4	1								1
5	4								4
6	6*								6
7	4								4
8	1								1
9	1								1
10	1								1
11	1			1					2
12	1								1
13									0
14	1	1							2
15							1		1
16									0
17									0
18									0
19								1	1
Total	23	2	0	1	0	0	1	1	28**

Distribution of P_f 's

P_f	freq
0.670	1
0.305	1
0.120	1
0.050	1
0.032*	1
**	1
	<u>6</u>

* Sandia solution

** One peer did not calculate P_f

Table 3.20 Characteristics of Event Trees
for Problem 6a

No. of Branches in Longest Path	No. of Success Paths																Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1																	0
2	2																2
3	2	3															5
4	2	4															6
5	1	1	1*	1													4
6	1			1		1											3
7			1							1	1						3
8																	0
9		1														1	2
Total	8	9	2	2	0	1	0	0	0	1	1	0	0	0	0	0	25

* The single subject with the same branch and success path solution as Sandia's had a P_f of 0.0001 while Sandia's solution was 0.000011.

Table 3.21 Summary of Frequency of
Use of Handbook Tables

Table Number	No. of Peers Who Used Table	Total No. of Times Table Was Used	Table Number	No. of Peers Who Used Table	Total No. of Times Table Was Used
1	2	4	15	14	36
2	3	7	16	7	7
3	3	6	17	1	1
4	1	10	18	25	133
5	25	71	19	4	10
6	1	1	20	26	111
7	13	25	21	13	35
8	0	0	22	21	63
9	4	11	23	6	26
10	6	11	24	0	0
11	2	6	25	7	19
12	0	0	26	2	7
13	15	68	27	3	11
14	26	164			

Handbook tables for all human reliability analysis problems. The number of peers using each table is also listed. It is shown that 23 of the 27 tables in Chapter 20 of the Handbook were used. However, only three of the tables, 20-14, 20-18, and 20-20, accounted for almost half (48.5%) of all table entries. No single table was used by all peers in performing their human reliability analyses. Tables 3.22 through 3.26 provide a breakdown of table use for each problem. The entries are the number of times a table was used by the analyst. For comparison purposes, the tables used in the Sandia solutions are shown. Table 3.27 is a composite of Tables 3.22 through 3.26. The wide variability in the processes the analysts used in solving the human reliability problems is portrayed.

Analysis of Human Performance Scenarios by Peers

A detailed analysis of problems 3a and 4a was undertaken in order to ascertain the specific sources of variability among problem solutions that was reported in the previous sections. The information contained in the problem worksheets for problems 3a and 4a was analyzed to determine the following factors:

1. The human performance errors identified by the peers. A performance error was included if any peer identified it and used the related HEP in calculating the problem solution.
2. The number of peers identifying the error.
3. The table entered to obtain the HEP.
4. The item number within the table selected.
5. The tabled HEP.
6. The adjusted HEP as used in the solution.

The results of this analysis are shown in Tables 3.28 and 3.29. The performance errors identified by Sandia in their problem solutions are indicated with asterisks.

Problem 3a. Eleven different performance errors were identified by the 29 peers who completed the exercise. It is to be noted that no one peer used them all. The number of errors identified by the peers in their solutions ranged from three to 11, with five representing the median number of errors. Errors #6 and #11 were identified by the largest number of peers—27. However, within error #6, six different tables resulting in three different HEPs were used. For error #11, seven different tables were used, yielding six different HEPs. Another example of

Table 3.22 Tables Cited by Peers to
Solve Problem 3a

Peer No.	Table 20-																											To- tal
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1					2																	1						3
2					3													1							1			5
3					1								3					1										5
4							2						2					1										5
5	1				2																							3
6					2													2										4
7	3				4													2										9
8					4													1										5
9					1		3						3					1										8
10					4																							4
11					3		1											1										5
12					2													3										5
13					4													5										9
14					4													1							1			6
15					4																							4
16											4																	4
17											2							1		1								4
18		3			1													1							1			6
19					4													3										7
20					4																							4
21					4																							4
22					3		3		1																			7
23					3													1										4
24													1															1
25					2													1										3
26					2													1										3
27					2													1	3									6
28																		1							1	1	1	4
29					1								2		1													4
Sandia					1																							1
Peer Totals	4	3	0	0	66	0	9	0	1	0	6	0	11	0	1	0	0	29	3	1	0	1	0	0	4	1	1	Av. 4.9

Table 3.23 Tables Cited by Peers to
Solve Problem 4a

Peer No.	Table 20-																											To- tal
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1	1																			2		3						6
2																				3								3
3													1							7		1						9
4					1	1							1	2						2								7
5													2	1						4								7
6														2		1				1		2						6
7														2	2					2		1						7
8																				3		1						4
9														12														12
10														2	2													4
11									1				1	1						2								5
12					4									10						9								23
13													9	2						12		1	1					25
14														2	2								1					5
15														2						2								4
16							1													1								2
17														1				1		3	2	1						8
18														2						2		1						5
19														1	1	1						1						4
20														4						2		1						7
21																				3								3
22									1											3	1	1						6
23																				3		1						4
24														2						3		1						6
25																												0
26																				4		3						7
27							1						2					1		2					1			7
28														6						2		1						9
29														4						3								7
Sandía	3																			6		1						10
Peer Totals	0	1	0	0	5	1	2	0	2	0	0	0	17	58	7	1	0	2	0	80	3	21	1	0	1	0	0	Av. 5.8

Table 3.24 Tables Cited by Peers to
Solve Problem 5a

Peer No.	Table 20-																											To- tal
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1																												0
2			1																							1		2
3													5										4					9
4							1										3									2		6
5													2	2			2											6
6																												0
7													3				5					3						11
8													1				1					1						3
9									2	3																		5
10													3		3													6
11															2													2
12													3					10										13
13																		8							3			11
14													6					1		5								12
15																		3										3
16														2				3										5
17			2										3	3				3				1						12
18													2	1	1			2										6
19													3	2				2								1	3	11
20													3					1										4
21			1											3														4
22									1				9					1										11
23													4															4
24													1															1
25													1					1										2
26													7					1										8
27				5														3					8					16
28																		1					2		2	2		7
29													2					1										3
Sandia		1												4									1					6
Peer Totals	0	1	3	5	0	0	1	0	3	3	0	0	20	49	8	0	0	52	0	5	0	5	14	0	6	3	5	Av. 6.8

Table 3.25 Tables Cited by Peers to
Solve Problem 5b

Peer No.	Table 20-																											To- tal
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1	1																											1
2																						1			1			2
3														5									4					9
4							1											3								2		6
5														2	2			2										6
6																												0
7														3				4				3						10
8														1				1				1						3
9									2	3																		5
10													3		3													6
11															2													2
12														3				10										13
13																		7						4				11
14														6				1		5								12
15																		3										3
16															2			3										5
17			2											3	3			3				1						12
18														2	1	1		2										6
19														3	2			2								1	3	11
20														3				1										4
21		1													3													4
22									1						9			1										11
23															4													4
24															1													1
25															1			1										2
26															7			1										8
27				5														3					1					9
28																		1					2		2	2		7
29															2			1										3
Sandia		1													4								1					6
Peer Totals	0	2	2	5	0	0	1	0	3	3	0	0	20	49	8	0	0	50	0	5	0	6	7	0	7	3	5	Av. 6.3

Table 3.26 Tables Cited by Peers to
Solve Problem 6a

Peer No.	Table 20-																											To- tal
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1															1						1	2						4
2																						3	1					4
3							1								1								1					3
4																												0
5		1														1			2		3							7
6																												0
7							2														4		3					9
8																						3	1					4
9															1													1
10							2																					2
11									1	1																		2
12														1		1					2							4
13																				2	3	3	3					11
14														3	5	1					1							10
15							1								1					1								3
16										1														1				2
17																					2	2	2					6
18							2			1				2						3	1							9
19							2								1	1							2					6
20							2			1													1					4
21															1							2	1	3		1		8
22																					2		3					5
23																						3	2					5
24														1		1					1	3	1					7
25																					2	3	1					6
26														1			1				1		1					4
27									1						1								2					4
28															1							3	2					6
29										1												3	1					5
Sandia															1						2	1	2			1		7
Peer Totals	0	0	1	0	0	0	12	0	2	5	0	0	0	8	12	6	1	0	7	20	31	30	4	0	1	0	0	Av. 5.3

Table 3.27 Tables Cited by Peers:
Composite Frequency across all Problems

Peer No.	Table 20-																											Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1		2			2										1					2	1	6						14
2			1		3									4	10	1		1		3	3	2			3			16
3					1		1						4	3	2			1		7		2	8					35
4					1	1	4						3	2				7		2						4		24
5	1		1		2								2	5	4	1		4	2	4	3							29
6					2									2		1		2		1		2						10
7	3				4		2							8	2			11		6		10						46
8					4									2				3		3	3	4						19
9					1		3		4	6			3	12	1			1										31
10					4		2						6	2	8													22
11					3		1		2	1			1	1	4					2								16
12					6									17		1		23		11								58
13					4								9	2				20	2	15	3	4	1		7			67
14					4								12	5	7	1		3		11		1			1			45
15					4		1							2	1			6		3								17
16							1			1	4			4				6		1			1					18
17			4								2			6	7			8		6	4	5						42
18		3			1		2			1			4	6	2			5	3			1			1			32
19					4		2						7	5	2	1		7		3		3				2	6	39
20					4		2			1			6	4				2		2		2						23
21		2			4									6		1				3	2	1	3		1			23
22					3		3		4					18				2		5	1	4						40
23					3									8				1		3	3	3						21
24													1	5		1				4	3	2						16
25					2									2				3		2	3	1						13
26					2									15			1		3		5	4						30
27				10	2		1		1				2		1			8	3		2	2	9		1			42
28														6	1			3		2	3	3	4		5	5	1	33
29					1					1			2	8	1			2		3	3	1						22
Total	4	7	6	10	71	1	25	0	11	11	6	0	68	164	36	7	1	133	10	111	35	63	26	0	19	7	11	843

Table 3.28 Performance Errors Identified by Peers in Human Reliability Analysis of Problem 3a

Performance Error	No. of Peers Identifying Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**			
*1. Failure to initiate task	13	20-18	1	9	.001	.000(1)	.0005(1)	.001(2)	.002(5)
		20-18*	6	1	.000	.000(1)			
		20-22	1	1	.01	.02 (1)			
		Personal Estimate	-	2	-	.000(2)			
2. Failure to select proper equipment	2	20-13	1	1	.003	.003(1)			
		20-25	3	1	.003	.006(1)			
3. Failure to recall instruction or failure to set	14	20-18	1	6	.001	.002(6)			
		20-18	3	1	.01	.02 (1)			
		20-18	4	1	.03	.06 (1)			
		20-18	5	1	.1	.2 (1)			
		20-18	7	1	.001	.002(1)			
		20-25	3	1	.003	.006(1)			
		20-25	5	1	.003	.006(1)			
		Note 2	-	2	.05	.1 (2)			
4. Failure to perform calculation	1	Note 2	-	1	.05	.1 (1)			
5. Incorrect calculation	1	20-20	5b	1	.01	.02 (1)			
*6. Set reference voltage incorrectly	27	11-2	?	2	.001	.002(2)	.003(1)	.005(1)	
		20-5*	2	19	.001	.002(17)			
		20-5	6	1	.001	.002(1)			
		20-7	1	1	.001	.002(1)			
		20-11	2	2	.001	.002(2)			
		20-18	7	1	.001	.002(1)			
		20-27	9	1	.001	.002(1)			
7. Failure to read indicator correctly	3	20-5	1	1	.003	.006(1)			
		20-5	2	2	.001	.002(2)			

Table 3.28 Performance Errors Identified by Peers in Human Reliability Analysis of Problem 3a (cont'd)

Performance Error	No. of Peers Identify- ing Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**
8. Failure to connect to amplifier	2	14-2 20-18	2 2	1 1	.003 .003	.006(1) .006(1)
9. Connect to wrong ampli- fier or improper connection	3	12-1 20-13 20-13	1 7 8	1 1 1	.003 .001 .01	.006(1) .002(1) .02 (1)
10. Failure to apply voltage to amplifier	2	20-18 20-25	5 5	1 1	.1 .003	.02 (1) .006(1)
11. Failure to adjust trip correctly	27	14-2 20-2 20-5 20-5 20-7 20-7 20-11 20-13 Personal Estimate Personal Estimate	2 - 2 6 1 7 2 7 - - -	1 1 16 1 2 1 2 1 1 1 1	.003 - .001 .001 .001 .001 .001 .001 .001 - - -	.006(1) .0025(1) .001(2) .002(1) .002(2) .001(1) .002(2) .002(1) .00002(1) .000
12. ***						.002(14)

* Used in Sandia solution

** Frequencies are shown in parentheses

*** Repeat tasks 8, 9, 10, and 11 for amplifiers 2 and 3

Table 3.29. Performance Errors Identified by Peers in Human Reliability Analysis of Problem 4a

Performance Error	No. of Peers Identifying Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**
1. Failure to initiate task	1	20-18	1	1	.001	.001(1)
2. Failure to use written procedure	20	20-20	5b	4	.01	.01 (4)
		20-20	5a	1	.3	.3 (1)
		20-22	3	2	.01	.01 (2)
		20-22	5b	2	.01	.01 (1)
		20-22*	6	5	.05	.05 (5)
		20-22	7	3	.3	.3 (3)
		Note 2	-	3	.05	.05 (3)
3. Failure to use procedures correctly	5	14-3	2	1	.01	.01 (1)
		20-20	1c	1	-	.05 (1)
		20-20	5b	1	.01	.01 (1)
		20-22	6	1	.05	.05 (1)
		20-22	8	1	.5	.7 (1)
4. Failure to align valves	3	20-14	2	1	.005	.005(1)
		20-20	5b	1	.01	.01 (1)
		Note 2	-	1	.05	.05 (1)
5. Align wrong valve	5	p. 14-7	-	1	-	.006 (1)
		20-13	1	1	.003	.003 (1)
		20-14	7	3	.003	.003 (3)
6. Failure to set pump pressure correctly	2	20-5	1	1	.003	.5 (1)
		20-7	2	1	.001	.001 (1)
7. Failure to record pressure reading correctly	1	20-6	2	1	.001	.001 (1)
8. Tagging error	3	20-15	1	2	.001	.001 (2)
		20-15	7	1	.001	.001 (1)

Table 3.29 Performance Errors Identified by Peers in Human Reliability Analysis of Problem 4a (cont'd)

Performance Error	No. of Peers Identifying Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**	
9. Failure to close valves	22	13-1	2	1	.01	.01 (1)	
		20-14	7	1	.003	.006(1)	
		20-15	1	1	.003	.003(1)	
		20-20	2a	4	.003	.003(4)	
		20-20*	2b	15	.01	.01 (14)	.05 (1)
10. Failure to close valve correctly	6	20-14	2	2	.005	.005(2)	
		20-14	8	3	.003	.003(3)	
		20-14	11	1	.001	.001(1)	
11. Failure to close correct valves	12	20-13	1	2	.003	.003(2)	
		20-14	2	1	.005	.005(1)	
		20-14	3	1	.005	.005(1)	
		20-14	7	5	.003	.003(4)	.01 (1)
		20-20	2a	1	.003	.003(1)	
		20-20	5b	1	.01	.01 (1)	
		20-21	7	1	.003	.003(1)	
12. Failure to detect error	1	20-16	1	1	.03	.03 (1)	
*13. Failure to stop pumps	15	13-1	2	1	.01	.01 (1)	
		20-2	-	1	.005	.005(1)	
		20-13	2	1	.001	.001(1)	
		20-20	2a	1	.003	.003(1)	
		20-20	2b	7	.01	.01 (7)	
		-	-	1	-	.01 (1)	
		-	-	2	-	.000(2)	
		Text*	-	1	-	.005(1)	
14. Failure to stop correct pump	2	20-13	1	1	.003	.003(1)	
		Text	-	1	.003	.003(1)	
15. Failure to complete change	1	20-14	8	1	.003	.003(1)	

Table 3.29 Performance Errors Identified by Peers in Human Reliability Analysis of Problem 4a (cont'd)

Performance Error	No. of Peers Identifying Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**
16. Failure to use alignment list	2	20-22 Personal Estimate	4	1	.01	.01 (1)
			-	1	-	.1 (1)
17. Failure to read instrument correctly	1	20-7	-	1	.003	.003(1)
18. Failure to open valves	24	13-1	2	1	.01	.01 (1)
		20-14	3	1	.005	.005(1)
		20-20	2a	4	.003	.003(4)
		20-20	2b	13	.01	.01 (13)
		20-25	3	1	.003	.003(1)
		Note 2	-	1	.05	.05 (1)
		Personal Estimate	-	2	-	.01 (2)
		Personal Estimate	-	1	-	.02 (1)
*19. Failure to open valves correctly	10	20-13	4	2	.0005	.0005(2)
		20-14	2	1	.005	.005(1)
		20-14	7	2	.003	.003(2)
		20-14	8	1	.003	.003(1)
		20-15	6	1	.01	.01 (1)
		20-20	5b	1	.01	.01 (1)
		p. 14-7	-	1	-	.006(1)
		Text*	-	1	-	.02 (1)
20. Failure to open correct valves	9	20-14	2	1	.005	.005(1)
		20-14	7	5	.003	.003(5)
		20-21	7	1	.003	.003(1)
		Text	-	1	.003	.003(1)
		-	-	1	.003	.003(1)

Table 3.29 Performance Errors Identified by Peers in Human Reliability Analysis of Problem 4a (cont'd)

Performance Error	No. of Peers Identifying Error	Table Entered	Table Item No.	No. of Times Item Used	Tabled HEP	HEP Used in Solution**
21. Failure to check other valves	3	13-1	2	1	.01	.01 (1)
		20-9	2	1	.2	.2 (1)
		20-20	2a	1	.003	.003(1)
22. Failure to check valve position	1	13-1	2	1	.01	.01 (1)
23. Check wrong valve as closed	1	12-1	1	1	.003	.003(1)
24. Check wrong valve as open	1	12-1	1	1	.003	.003(1)
25. Fail to restore	1	20-18	-	1	.01	.01 (1)

* Used in Sandia solution

** Frequencies are shown in parentheses

variability in approach is illustrated by error #3. For this error, identified by 13 peers, only two different tables were entered. However, from these two tables seven different table items were selected, resulting in seven different HEPs.

Problem 4a. A total of 25 different performance errors was identified by the 28 peers who completed the exercise. The number of errors identified by peers in arriving at solutions ranged from three to 25, with a median of five errors. The same variability in table and item selection that was reported for problem 3a is also evident here. No single error was identified by all peers.

Errors #2, 3, and 16 are of special interest. They all involve administrative control errors. They exhibit the same degree of variability in use as do all the other errors. However, the magnitude of the variation of the values of these HEPs is much greater. For error #2, the values of the HEPs range from .01 to .3. For error #3, the HEPs range from .01 to .5. For error #16 which was identified by only two peers, the HEPs were .01 and .1. Of particular concern is that, as a group, the values for administrative controls are generally one or two orders of magnitude greater than for other classes of errors. The overuse or misapplication of administrative controls can therefore have a profound effect on the final value of the probability of success or failure determined from a human reliability analysis.

The performance of the peers in solving problems 3a and 4a, as indicated by the results of the above analysis, are consistent with the findings of the analysis of the event trees. In both analyses it was found that:

1. there is great variability in the way the peers perceive the operator's tasks (and identify possible performance errors), and
2. even when there is agreement on performance errors, there is variability in the selection of the table and HEP to be applied.

If more consistent user performance is to be obtained, it appears that additional information and/or instruction must be provided relative to the construction of event trees and the use of the tables. In addition, the tables should be reviewed to remove any ambiguities of interpretation that they may contain.

Analysis of Peer Responses to Questionnaire

After they had completed the human reliability analysis problems, the participants answered a two-part questionnaire. Part 1 sought opinions of the overall composition and general applicability of the Handbook; Part 2 queried the peers about the HEP tables in Chapter 20 of the Handbook.

Peer Opinions of General Usability of Handbook

Part 1 of the questionnaire consisted of three questions pertaining to the Handbook and a fourth item for open-ended comments. Each question was answerable with Yes or No. Space was provided after each question for comments.

Twenty-six Part 1 questionnaires were returned from the 29 peers. Each Yes or No response was evaluated against the comments submitted by the peer on that question. In many instances, it was found that the comments qualified the Yes/No response, and, in some cases, opposed the response. When a contradiction was found, more weight was given to the written comment and the Yes/No response was changed for purposes of tabulation. The comments were then grouped according to their subject matter and frequency tabulations of peer responses were made. The results of this review are presented on a question by question basis.

Question 1. In working the exercises, did you have difficulty in locating and selecting the tables you used?

Twenty-six peers responded. Fourteen (54%) reported difficulty; 12 (46%) reported no difficulty. Fifteen peers commented, offering a total of 26 comments. They were categorized as follows:

<u>Comment</u>	<u>freq.</u>
1. Table format confusing	13
2. Need better indexing system	10
a. Table headings should be clarified	8
b. Tasks should be numbered	1
c. Tables should contain more instructions on how listed values are to be applied	1
3. Chapter disorganized—tables not arranged in a meaningful manner	3
	<u>26</u>

Discussion

Fifty-four percent of the peers who responded indicated that they had difficulty in locating and selecting tables. This finding is consistent with the variability found in table selection and use reported in the previous section.

The specific comments made by the peers were of two types, general (indexing and chapter organization) and table specific (format and instruction). The conclusions drawn from the general comments are:

1. Improve indexing of tables.
2. Reorganize Chapter 20 to achieve more functional groupings of the tables.

Recommendations pertaining to specific tables are reported in the analysis of peer responses to Part 2 of the questionnaire.

Question 2. Do you disagree with any of the human performance models and theories used to develop the tables?

Twenty-six peers responded to this question. Eleven (42%) reported disagreement with models and theories, five (19%) expressed qualified disagreement, and 10 (38%) reported no disagreement. Sixteen peers commented, submitting a total of 18 comments. The comments dealt with the following topics:

<u>Comment</u>	<u>freq.</u>
<u>General</u>	
1. Backup for models seems thin, but I don't have anything better to offer	5
2. General approach misleading	1
3. Models should include more complex behavior	2
4. Models should include more PSFs and physical attributes of hardware	$\frac{1}{9}$
<u>Specific</u>	
1. Disagree with Uncertainty Bounds Model	3
a. Too subjective	2
b. False sense of rigor	1
2. Disagree with Stress Model	3
a. Effect of training and experience inadequate	2
b. Need time and task qualifiers	1

<u>Comment</u>	<u>freq.</u>
3. Disagree with Memory Model	1
4. Disagree with Dependency Model	1
5. Unavailability Model should be time dependent	$\frac{1}{9}$

Discussion

Sixty-one percent of the peers responding to the question reported some degree of disagreement with the models and theories used. Five of the peers or 31% of this group, however, volunteered that they could offer nothing better. A review of the comments indicates that most of the disagreements are directed toward a general lack of support data, the subjectivity of the models, and the incompleteness of the models.

In Chapter 1 of the Handbook, Swain and Guttman acknowledge these specific weaknesses in their models and HEPs. They state:

"The scarcity of objective and quantitative data on human performance in NPPs is a serious limitation. Most of the HEPs in this handbook are what we call derived data. In some cases, they are extrapolations from related (sometimes only marginally related) performance measures. In other cases the HEPs represent our best judgment based on our experience in complex systems (including NPPs) and on our background in experimental and engineering psychology. This necessity of relying on judgment is a regrettable state of affairs, but a start needs to be made, and this handbook is a first step towards what is really needed—a large data bank of human performance information directly related to NPP tasks."

The general qualitative and often subjective content of the peers' comments appears to indicate that the models are, in large part, a reflection of the limited information that exists in this area. The need for the development of an adequate human performance data bank is critical. Without such a data base very little can be done to update the models. There is still "nothing better to offer".

In the nine cases where a specific model is identified only two, Uncertainty Bounds and Stress, were mentioned by more than one subject. The three responses recorded for these two models represent only 11.5% of the peers responding. This figure is not large enough to mandate an immediate modification of the models. It does, however, suggest a need for updating these models when the necessary data become available. Additional comments on model adequacy are reported in the analysis of Part 2 of the questionnaire.

Question 3. Do you think the Handbook can be used by persons who do not have a human factors background?

Four (15%) of the respondents answered Yes, 15 (58%) offered a qualified Yes (see Comment 1 below), six (23%) stated No, and one peer expressed a qualified No (see Comment 3). Sixteen peers commented, offering a total of 22 comments. They are described by the following breakdown:

<u>Comment</u>	<u>freq.</u>
1. Need for additional training	19
a. Persons should have human factors training before using Handbook	15
b. Human factors personnel also need additional training before using Handbook	4
2. Non-human factors personnel may be better than human factors personnel	1
3. No one should use Handbook	1
4. Only a limited number of human factors personnel are qualified	$\frac{1}{22}$

Discussion

Only four of the 26 peers who responded offered an unqualified Yes with regard to the use of the Handbook by persons not trained in human factors. However, more than half (58%) of the respondents indicated that with additional training use by such persons would be acceptable. This training was not to be limited to non-human factors personnel. Four of the subjects indicated the human factors personnel would also require additional training.

The training suggested for the non-human factors personnel was in the area of human factors. The training suggested for human factors personnel was in the area of probability theory. A seminar was the preferred method of training. Expanded and/or additional sections in the Handbook was the second choice. Because there is no way of assuring that all persons who have access to the Handbook can or will attend a training seminar, it is suggested that consideration be given to the expansion of the Handbook or the development of supplemental training manuals.

Question 4. Do you have any additional comments?

Sixteen peers offered 38 additional comments categorized as follows:

<u>Comments</u>	<u>freq.</u>
1. Need more background and instructional information	17
a. More information on analytic techniques	7
b. More information on probability theory	3
c. More examples	2
d. Restrict examples to NPP situations only	2
e. Chapters 5 & 6 of Handbook are inadequate	1
f. Add information on effects of protective clothing	1
g. More information on human reliability	1
2. Format of Handbook	7
a. Chapter 20 should be a separate volume	3
b. Handbook should be in loose leaf format	3
c. Organization of Handbook disjointed	1
3. Handbook well done	3
4. Tables confusing	3
a. Do not stand on their own	1
b. Content not homogeneous	1
c. Should all be written in "Failure to" mode	1
5. Use of Handbook	3
a. Handbook potentially dangerous	2
b. Not confident in application	1
6. General	3
a. Use abbreviations more sparingly	1
b. List of abbreviations is incomplete	1
c. Overemphasis on redesign of systems	1
7. Standardization	2
a. Not consistent in rounding values	1
b. Use standard practice for writing decimals, e.g., write 0.002 not .002	1
	<u>38</u>

Discussion

The general comments submitted by the peers tend to substantiate and to a large extent repeat the responses made to the previous three questions.

The comments reflect a predominant need for more instructional and background information, followed by reorganization of the Handbook and tables that are confusing. The extreme range of acceptance/non-acceptance of the Handbook is illustrated by the three peers who indicated "well done" and the three who indicated, "dangerous" or "not confident".

Peer Opinions of Handbook Tables and Human Error Probabilities

The purpose of Part 2 of the questionnaire was to obtain data relative to the format, content, and understandability of each of the 27 tables in Chapter 20 of the Handbook. It consisted of four questions dealing with these topics. With one exception, each question was answerable with Yes or No. Comments were also solicited. This part of the questionnaire was to be answered after Part 1 was completed. Twenty-seven peers completed and returned the Part 2 forms.

The analysis was similar to that performed on Part 1 of the questionnaire. Each peer's Yes or No response to a question was reviewed and compared with his or her comments, if any, pertaining to the question. In those cases where the comments conflicted with the Yes/No response, the comment was given precedence and the Yes/No response was changed accordingly for tabulating the response frequencies. Figures 3.3 through 3.6 display the profiles of Yes/No responses across all 27 Handbook tables for each of the questions.*

The comments were then reviewed and classified by subject matter. Six different categories of comments were identified. They were:

1. Model Applicability
2. Table Information (Detail)
3. Back-up Information and Instructions (Supporting text for table)
4. Table Format
5. HEP/Bounds Acceptance
6. Misc.

Figure 3.7 presents the distribution of the negative comments for all tables, classified by subject matter. Forty-seven percent of all the comments submitted reflected dissatisfaction with the level and quality of the instructions for the use of the tables.

The comments reflecting peer disagreement with the HEPs/Bounds, Models,

*The figures provide a graphic means for identifying the tables viewed most negatively with respect to the characteristic addressed by the question.

Figure 3.3 Profile of Peer Responses to the Question, "Is it easy to enter and use the table?"

Figure 3.4 Profile of Peer Responses to the Question, "Does the table contain appropriate detail?"

Figure 3.5 Profile of Peer Responses to the Question, "What is your opinion of the general magnitude of the HEPs in the table?"

Figure 3.6 Profile of Peer Responses to the Question, "Do the relative values of the HEPs in the table seem reasonable to you?"

Figure 3.7 Distribution of Categorized Negative Peer Comments on Chapter 20 Tables

and Backup Information (19%, 14%, and 9%, respectively) are for the most part qualitative, e.g., "too pessimistic", "too optimistic", "not enough research", etc. Rarely was a comment accompanied by a quantitative correction. These comments are a reflection of the state-of-the-art of the human factors data bank. This paucity of human error data was acknowledged by the authors of the Handbook as one of its (the Handbook's) limitations.

Organization of Review of Handbook Tables

The Yes/No responses and comments were tabulated for each of the 27 tables in Chapter 20. The review of each table is organized as follows. The first page contains a reproduction of the table as it appears in the Handbook. (Item numbers were added by the analysts to designate rows as an aid in referring to table entries.) The table is followed by a Peer Response Sheet that summarizes peer responses to each of the questions in Part 2 of the questionnaire. The comments are tabulated under the six categories of subject matter previously described. The total frequency in a category is underlined; the frequency of a specific comment is shown in parentheses following the comment. A discussion of the responses and the HPT recommendations regarding the table are presented immediately after the summary of peer responses.

Table 20-1. Conditional Probabilities of Success or Failure for Task "N" for the Five Levels of Dependence, Given Failure on Task "N-1" (from Table 7-2)

Task "N" Conditional Probabilities*

Item	ZD**		LD		MD		HD		CD	
	S	F	S	F	S	F	S	F	S	F
1	.75	.25	.71	.29	.64	.36	.37	.63	0	1.0
2	.9	.1	.85	.15	.77	.23	.45	.55	0	1.0
3	.95	.05	.9	.1	.81	.19	.47	.53	0	1.0
4	.99	.01	.94	.06	.85	.15	.49	.51	0	1.0
5	.995	.005	.95	.05	.85	.15	.50	.50	0	1.0
6	.999	.001	.95	.05	.86	.14	.50	.50	0	1.0
7	.9995	.0005	.95	.05	.86	.14	.50	.50	0	1.0
8	.9999	.0001	.95	.05	.86	.14	.50	.50	0	1.0
9	.99999	.00001	.95	.05	.86	.14	.50	.50	0	1.0

*All probabilities are rounded. Equations 7-14 through 7-18 were used to calculate the values in the F columns. The values in the S columns were obtained by subtraction.

**The conditional probabilities given ZD are the basic probabilities for Task "N."

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-1

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>85</u>	No <u>15</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>78</u>	No <u>18</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>7</u>	R <u>63</u> O <u>0</u>	NR <u>30</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>66</u>	No <u>8</u>	NR <u>26</u>

Summary of Comments

Number of peers commenting	<u>15</u>
Percent of peers commenting	<u>56</u>
Number of comments	<u>25</u>

Comments:

1. Model Applicability 6
 - a. Needs multi-level model, e.g., calibration, maintenance (1)
 - b. Disagrees with model formula (2)
 - c. Could not determine level of dependency (3)
2. Table Information 10
 - a. Difficulty in entering table—needs ordinate (3)
 - b. Easier to use formula (3)
 - c. Spell out column headings (1)
 - d. Add to Footnote * "all conditional probabilities" (2)
 - e. Reword title to emphasize "given failure in task N-1 . . ." (1)
3. Backup Information and Instructions 3
 - a. Needs more examples (3)

Table 20-1 (cont'd)

4. Table Format 3
 - a. Use P_f 's only (2)
 - b. Delete last three rows—they are redundant (1)
5. HEP/Bounds Acceptance 3
 - a. Too pessimistic (1)
 - b. Too optimistic (1)
 - c. Don't round table values (1)
6. Misc.
No comments

Discussion

Although Table 20-1 was generally well received, as indicated by the Yes/No responses to the questions, a considerable number of specific negative comments are submitted. The comments generally address two areas of concern; table information and format, and determination of the level of dependency to be used.

The problems related to table information and format are:

1. Table lacks a clearly defined ordinate.
2. Table 20-1 and Table 20-2 are the only tables in Chapter 20 that present P_s values along with the P_f 's.
3. The last three rows present P_f 's that are either negligible or redundant.

The problem associated with the determination or level of dependency is simply whether the human reliability analyst, in a NPP situation, can discriminate the five levels of dependency that are listed in the table. Without the aid of laboratory instrumentation, they regard this as highly questionable.

Recommendations

1. Reduce the number of dependency levels from five to three, specifically, ZD, MD, and CD.
2. Provide more examples in the text to guide the user in making the

discriminations.

3. Provide a clearly defined ordinate for the table.
4. Use P_f 's only.
5. Delete the last three rows.
6. Add to table footnote* "all conditional probabilities.

Table 20-2. Conditional Probabilities of Success or Failure for Task "N" for the Five Levels of Dependence, Given Success on Task "N-1" (from Table 7-3)

Task "N" Conditional Probabilities*

Item	ZD**		LD		MD		HD		CD	
	S	F	S	F	S	F	S	F	S	F
1	.75	.25	.76	.24	.79	.21	.87	.13	1.0	0
2	.9	.1	.9	.1	.91	.09	.95	.05	1.0	0
3	.95	.05	.95	.05	.94	.06	.97	.03	1.0	0
4	.99	.01	.99	.01	.991	.009	.995	.005	1.0	0
5	.995	.005	.995	.005	.996	.004	.997	.003	1.0	0
6	.999	.001	.999	.001	.999	.001	.9995	.0005	1.0	0
7	.9995	.0005	.9995	.0005	.9996	.0004	.9997	.0003	1.0	0
8	.9999	.0001	.9999	.0001	.99991	.00009	.99995	.00005	1.0	0
9	.99999	.00001	.99999	.00001	.999991	.000009	.999995	.000005	1.0	0

*All conditional probabilities are rounded. Equations 7-9 through 7-13 were used to calculate the values in the S columns. The values in the F columns were obtained by subtraction.

**The conditional probabilities given ZD are the basic probabilities for Task "N."

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-2

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>81</u>	No <u>19</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>74</u>	No <u>22</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>7</u>	R <u>67</u> O <u>0</u>	NR <u>26</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>62</u>	No <u>8</u>	NR <u>30</u>

Summary of Comments

Number of peers commenting	<u>11</u>
Percent of peers commenting	<u>41</u>
Number of comments	<u>15</u>

Comments:

1. Model Applicability 3
 - a. Needs multi-level model, e.g., calibration, maintenance . . . (1)
 - b. Could not determine level of dependency (2)
2. Table Information 7
 - a. Difficulty in entering table—needs ordinate (2)
 - b. Easier to use formula (3)
 - c. Reword title to emphasize "given success in task N-1 . . ." (1)
 - d. Spell out column headings (1)
3. Backup Information and Instructions 2
 - a. Needs more examples (2)
4. Table Format 1
 - a. Delete last three rows—they are redundant (1)

Table 20-2 (cont'd)

- 5. HEP/Bounds Acceptance 1
 - a. Too pessimistic (1)
- 6. Misc. 1
 - a. Don't understand the difference between 20-1 and 20-2 (1)

Discussion and Recommendations

This section is the same as presented for Table 20-1 with the single exception that recommendation #6 is not applicable.

Table 20-3. Probabilities of Error for
Annunciated Legend Lights

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Respond to an annunciated legend light (one of one) (p 10-9)	.0001 (.00005 to .001)
2	Reading the message (this figure includes the probability of reading the wrong legend light) (p 10-6)	.001 (.0005 to .005)
3	Resume attention to a legend light within 1 minute after an inter- ruption (sound and blinking cancelled before interruption) (p 10-11)	.001 (.0001 to .01)
4	Respond to a legend light if more than 1 minute elapses after an interruption (sound and blinking cancelled before interruption) (p 10-12)	.95 (.9 to .99)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-3

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>7</u>	NR <u>4</u>
2. Does the table contain appropriate detail?	Yes <u>52</u>	No <u>48</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>28</u> R <u>37</u> O <u>20</u>	NR <u>15</u>	
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>41</u>	No <u>44</u>	NR <u>15</u>

Summary of Comments

Number of peers commenting	<u>19</u>
Percent of peers commenting	<u>70</u>
Number of comments	<u>38</u>

Comments:

1. Model Applicability 10
 - a. Model does not include physical characteristics of annunciator and/or PSF (10)
2. Table Information 3
 - a. Need to know percent of operations responding in <1 min. vs. >1 min. (3)
3. Backup Information and Instruction 5
 - a. Define "response" and use consistently (3)
 - b. HEPs should vary between shifts (1)
 - c. Add reference to Table 20-4 for more than one light (1)
4. Table Format

No comments

Table 20-3 (cont'd)

5. HEP/Bounds Acceptance 19

- a. Differences between Item 3 & 4 too great (3)
- b. Item 3 too optimistic (2)
- c. Item 4 too pessimistic (9)
- d. Item 1 too pessimistic (2)
- e. Item 1 too optimistic (1)
- f. Item 2 too pessimistic (1)
- g. Item 2 too optimistic (1)

6. Misc. 1

- a. Items 3 & 4 refer erroneously to p. 10-10 rather than 10-11 (1)

Discussion

This table elicited the largest number of comments (38) and the second largest number of respondents (70%) of all the tables in Chapter 20.

The primary areas of concern expressed by the comments are the lack of consideration of the physical characteristics of the annunciator and the difference in the large HEP values between Items 3 and 4 (.001 to .95).

Recommendations

- 1. The table should incorporate the physical characteristics of annunciators or specifically state the rationale for the exclusion.
- 2. The difference between the HEP values for Items 3 and 4 is so large as to warrant inclusion of an intermediate step.
- 3. Reword the task descriptions in a "failure to" mode, e.g., failure to read annunciator . . . , etc.

Table 20-4. Probability of Failure to Respond to One Randomly Selected Annunciator of Several (from Table 10-2, right column)

<u>Item</u>	<u>Number of Annunciators</u>	<u>HEP</u>
1	1	.0001 (.00005 to .001)
2	2	.0006 (.00006 to .006)
3	3	.001 (.0001 to .01)
4	4	.002 (.0002 to .02)
5	5	.003 (.0003 to .03)
6	6	.005 (.0005 to .05)
7	7	.009 (.0009 to .09)
8	8	.02 (.002 to .2)
9	9	.03 (.003 to .3)
10	10	.05 (.005 to .5)
11	11-15	.10 (.01 to .999)
12	16-20	.15 (.015 to .999)
13	21-40	.20 (.02 to .999)
14	> 40	.25 (.025 to .999)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-4

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>11</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>67</u>	No <u>33</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>9</u>	R <u>67</u>	O <u>13</u> NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>63</u>	No <u>22</u>	NR <u>15</u>

Summary of Comments

Number of peers commenting	<u>14</u>
Percent of peers commenting	<u>52</u>
Number of comments	<u>19</u>

Comments:

1. Model Applicability 3
 - a. For greater than 10 annunciators, correcting for stress yields an HEP greater than 1.0 (3)
2. Table Information 12
 - a. Table does not include effects of physical attributes of annunciators (9)
 - b. Table does not include effects of PSFs (1)
 - c. Add reference to Table 20-3 for 1 of 1 annunciator (1)
 - d. Clarify title and refer to p. 20-8 (1)
3. Backup Information and Instruction

No comment

Table 20-4 (cont'd)

4. Table Format

No comment

5. HEP/Bounds Acceptance 3

- a. Too optimistic for <11 (1)
- b. Too pessimistic for >11 (1)
- c. Too optimistic for >11 (1)

6. Misc. 1

- a. Is time interval involved in entering table? (1)

Discussion

This table is generally well received except for some comments concerning level of detail and modelling. In the latter case, there was some confusion in the application of the corrective stress factors.

Recommendations

- 1. Include footnote in table clarifying the application of the corrective stress factors.
- 2. Clarify title and headings in terms of definition on p. 20-8.
- 3. Include physical attributes of annunciators, e.g., size, grouping, color, etc.

Table 20-5. Probabilities of Errors of Commission
in Reading Quantitative Information from Displays

<u>Item</u>	<u>Reading Task</u>	<u>HEP</u>
1	Analog meter (p 11-7)	.003 (.001 to .01)
2	Digital readout (p 11-7)	.001 (.0005 to .005)
3	Chart recorder (p 11-8)	.006 (.002 to .02)
4	Printing recorder with large number of parameters (p 11-8)	.05 (.01 to .2)
5	Graphs (p 11-8)	.01 (.005 to .05)
6	Values from indicator lamps that are used as quanti- tative displays (p 11-9)	.001 (.0005 to .005)
7	Recognize that an instrument being read is jammed, if there are no indicators to alert the user (p 11-12)	.1 (.02 to .2)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-5

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>11</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>63</u>	No <u>37</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>4</u>	R <u>70</u>	O <u>18</u> NR <u>8</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>70</u>	No <u>22</u>	NR <u>8</u>

Summary of Comments

Number of peers commenting	<u>17</u>
Percent of peers commenting	<u>63</u>
Number of comments	<u>28</u>

Comments:

1. Model Applicability
 - No comment
2. Table Information 15
 - a. Needs to include physical attributes of displays (6)
 - b. The word "display" too general; provide specific list of displays in table (3)
 - c. Table does not include PSFs described in Ch. 11 (3)
 - d. Item 7 should be correction factor to Items 1-6 (1)
 - e. Should include reference to extent of reading error (1)
 - f. Item 7 too complex to be covered by one HEP (1)
3. Backup Information and Instruction 2
 - a. Needs more examples (2)

Table 20-5 (cont'd)

4. Table Format

No comment

5. HEP/Bounds Acceptance 11

- a. Item 1 too optimistic (1)
- b. Item 2 too pessimistic (1)
- c. Item 2 too optimistic (2)
- d. Item 3 too pessimistic (1)
- e. Item 3 too optimistic (1)
- f. Item 4 too pessimistic (1)
- g. Item 5 too optimistic (1)
- h. Item 7 too optimistic—should be 0.5 (1)
- i. Item 7 too pessimistic (1)
- j. Items 3 through 7 too optimistic—should range from .05 to 0.2 (1)

6. Misc.

No comment

Discussion

The overall acceptance of the table is good. The major areas of concern as reflected in the comments are the inadequacy of table information and acceptance of HEPs/Bounds.

The problem areas appear to be that there is a lack of consideration of the physical characteristics of displays and inadequate descriptions of the displays. This would be a particular problem for non-human factors users of the Handbook. The 11 comments relative to the acceptance of HEPs/Bounds tend to balance each other out and are therefore not considered to represent a serious problem.

Recommendations

- 1. The table should include the physical attributes of the displays.
- 2. The descriptions of the displays should be expanded or examples should be provided in the text.
- 3. The words "large number" in Item 4 should be defined.
- 4. Item 9 is questionable. It stipulates that no indicator exists. This is contrary to the title of the table. Delete the item.

Table 20-6. Probabilities of Errors in Recording Readings (p 11-7)

<u>Item</u>	<u>Number of Digits to be Recorded</u>	<u>HEP</u>
1	≤ 3	Negligible
2	> 3	.001 (.0005 to .005)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-6

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>11</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>67</u>	No <u>33</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable <u>O</u> - Optimistic, <u>NR</u> - No Response	P <u>7</u>	R <u>67</u>	O <u>22</u> NR <u>4</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>70</u>	No <u>22</u>	NR <u>8</u>

Summary of Comments

Number of peers commenting	<u>15</u>
Percent of peers commenting	<u>56</u>
Number of comments	<u>21</u>

Comments:

1. Model Applicability
 - No comment
2. Table Information 13
 - a. Add additional level(s) of entry (6)
 - b. Need item for recording digits with decimals (1)
 - c. Format of the recording form not considered (2)
 - d. Number of recordings per unit time not considered (3)
 - e. Add footnote referencing Table 20-5 (1)
3. Backup Information and Instruction 3
 - a. Rewrite instructional paragraph or table footnote (2)
 - b. Combine Table 20-6 into Table 20-5 as an additional column (1)

Table 20-6 (cont'd)

4. Table Format 1
 - a. Table is not discriminable from text (1)
5. HEP/Bounds Acceptance 4
 - a. Range too optimistic (2)
 - b. Range too pessimistic (For less than 3, HEP should be 0.001; for more than 3, HEP should be 0.003) (1)
 - c. Item 2 too optimistic, (Respondent knows of study giving value of .0163 for 4 digits. Respondent did not provide reference.) (1)
6. Misc.
 - No comment

Discussion

The brevity of this table is the major source of comment.

Recommendations

1. The number of levels of entry into the table should be increased beyond the two presently used.
2. Consideration should be given to expanding the table to include such items as:
 - a. Use of decimals
 - b. Number of digits/unit time
 - c. The characteristics of the recording sheets

Table 20-7. Probabilities of Errors of
Commission in Check-Reading Displays

<u>Item</u>	<u>Check-Reading Task</u>	<u>HEP</u>
1	Digital indicators (these must be read - there is no true check-reading function for digital displays) (p 11-14)	.001 (.0005 to .005)
2	Analog meters with easily seen limit marks (p 11-14)	.001 (.0005 to .005)
3	Analog meters with difficult-to-see limit marks, such as scribe lines (p 11-14)	.002 (.001 to .01)
4	Analog meters without limit marks (p 11-14)	.003 (.001 to .01)
5	Analog type chart recorders with limits (p 11-14)	.002 (.001 to .01)
6	Analog type chart recorders without limit marks (p 11-14)	.006 (.002 to .02)
7	Confirming a status change on a status lamp (p 11-16)	Negligible
8	Checking the wrong indicator lamp (in an array of lamps) (p 11-16)	.003 (.001 to .01)
9	Misinterpreting the indication on the indicator lamps (p 11-16)	.001 (.0005 to .005)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-7

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>100</u>	No <u>0</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>70</u>	No <u>30</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>7</u>	R <u>74</u> O <u>11</u>	NR <u>8</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>85</u>	No <u>11</u>	NR <u>4</u>

Summary of Comments

Number of peers commenting	<u>12</u>
Percent of peers commenting	<u>44</u>
Number of comments	<u>14</u>

Comments:

1. Model Applicability
 - No comment
2. Table Information 10
 - a. Does not include physical attributes (4)
 - b. Needs more complete item description (2)
 - c. Needs correction for PSFs (2)
 - d. What is the difference between "check-reading", "check-lists", and "check-off"? (1)
 - e. Item 1 is not a check reading display (1)
3. Backup Information and Instruction 1
 - a. Needs clear definition of purpose of table (1)
4. Table Format
 - No comment

Table 20-7 (cont'd)

- 5. HEP/Bounds Acceptance 3
 - a. Item 4 too optimistic (2)
 - b. Item 9 too optimistic (1)
- 6. Misc.
 - No comment

Discussion

Although all of the peers indicated that this table was easy to use (Question 1), 30% indicated that more detail was necessary. The comments generally refer to an inconsistency in the presentation of the tasks and a need for clearer definitions. For example, Items 1 through 6 are indicator descriptions, not tasks. In addition there is some confusion among the non-human factor personnel as to the definition of "check reading" and type of display.

Recommendations

- 1. Reorganize the table so that the major heading for each item is a description of the display involved and the minor headings are the descriptions of the physical qualifiers of the display. Consider the possibility of adding graphic examples of each type of display to the text. This is for the benefit of the non-human factors user.
- 2. Provide a more detailed definition of "check reading", either in the table or in the text.
- 3. Use "Failure to . . . " mode.

Table 20-8. Probabilities of Error in Walk-arounds,
One Operator, No Checklist (from Table 8-1)

<u>Item</u>	<u>Day #</u>	<u>HEP</u>
1	1	.9 (.5 to .99)
2	2	.95 (.6 to .995)
3	3	.975 (.7 to .999)
4	4	.99 (.8 to .999)
5	5-30	.999 (.9 to .999)
6	> 30	1.0

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-8

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>96</u>	No <u>4</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>78</u>	No <u>22</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>18</u>	R <u>74</u>	O <u>0</u> NR <u>8</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>85</u>	No <u>11</u>	NR <u>4</u>

Summary of Comments

Number of peers commenting	<u>12</u>
Percent of peers commenting	<u>44</u>
Number of comments	<u>18</u>

Comments:

1. Model Applicability
No comment
2. Table Information 3
 - a. Correct for PSFs (1)
 - b. Clarify "one operation/once a day" (1)
 - c. Table should have values for 3 shifts—Japan uses 4-5 shifts (1)
3. Backup Information and Instruction 10
 - a. Table does not adequately reflect material in Ch. 8 (9)
 - b. Formulas in Ch. 8 too complex to apply (1)
4. Table Format
No comment

Table 20-8 (cont'd)

- 5. HEP/Bounds Acceptance 5
 - a. Too pessimistic (5)
- 6. Misc.
 - No comment

Discussion

Except for the five peers who indicated that the HEPs were too pessimistic, the general thrust of the comments does not reflect on the table per se but rather on the lack of additional tables to adequately present the data contained in Chapter 8.

Recommendations

Expand or add tables to provide more adequate representation of the walk-around data in Chapter 8.

Table 20-9. Probabilities that a Checker will Fail to Detect Errors (from Table 15-1)

<u>Item</u>	<u>Checking Operation</u>	<u>HEP</u>
1	Usual monitoring in NPP with some kind of checklist or written procedure (includes tasks such as over-the-shoulder checking and checking written lists or procedures)	.10 (.05 to .5)
2	Same as above but without written materials	.20 (.10 to .9)
3	Special short-term, one-of-a-kind checking (e.g., supervisor checks performance of a novice)	.05 (.01 to .10)
4	Hands-on type of checking that involves special measurements or other activities	.01 (.005 to .05)
5	Repeated checking of one person's work by different individuals during or after completion of a standard or routine task	Assume HD among checkers; no recovery credit for more than 2 checkers
6	Two-man team, with one person the doer and the other the reader/checker	Assume HD between doer and reader/checker
7	Checking of valve status	Use HEPs from Tables 20-16 and 20-17
8	Walk-around checking operation	Use HEPs from Table 20-8

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-9

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>74</u>	No <u>26</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>70</u>	No <u>30</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>11</u>	R <u>78</u> O <u>0</u>	NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>78</u>	No <u>11</u>	NR <u>11</u>

Summary of Comments

Number of peers commenting	<u>11</u>
Percent of peers commenting	<u>41</u>
Number of comments	<u>20</u>

Comments:

1. Model Applicability 2
 - a. Table of limited value for real NPP application (1)
 - b. Should personnel redundancy improve a BHEP? Model only shows cost (1)
2. Table Information 11
 - a. Item 3, define "special short-term" and "one-of-a-kind" (5)
 - b. Define "checker" as opposed to "operator" (1)
 - c. Item 1, "usual monitoring" not meaningful (1)
 - d. Define Item 2 more precisely (1)
 - e. Confusion on Items 1, 2, & 7 (1)
 - f. Needs footnote identifying conditions of use (1)
 - g. Table confusing (1)

Table 20-9 (cont'd)

3. Backup Information and Instruction 2
 - a. Explain relationship between Table 20-9 and 20-10, 20-16, 20-18, 20-21, 20-22 (2)
4. Table Format

No comment
5. HEP/Bounds Acceptance 5
 - a. Items 1 & 2 too pessimistic (1)
 - b. Items 5 & 6 too pessimistic (4)
6. Misc.

No comment

Discussion

The comments indicate a lack of understanding of the terms contained in the table as well as some confusion as to the purpose and use of the table, e.g., the table's relationship with the other tables referenced. Some confusion may stem from the fact that Items 5 and 6 are not HEPs but corrective factors.

Recommendations

1. Provide instructions, logic diagrams, or use matrix to clarify table's relationship with Tables 20-10, 20-16, 20-18, 20-21, and 20-22.
2. List Items 5 and 6 as footnotes to the table or in a separate corrective action table.
3. Clarify definitions for:
 - a. Special short term (Item 3)
 - b. One of a kind (Item 3)
 - c. Checker as opposed to operator (title)
 - d. Usual monitoring (Item 1)

Table 20-10. Probabilities of Error on Initial Audit
No Special Alerting Cues, and Only One Deviant Display

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Deviant meter with limit marks (p 11-22)	.05 (.01 to .1)
2	Deviant meter without limit marks (p 11-26)	.15 (.03 to .3)
3	Annunciator light requiring action, which is no longer annunciating (p 10-8)	.9 (.8 to .98)
4	Incorrect status of a legend light, other than an annunciator light (p 11-18)	.98 (.96 to .996)
5	Incorrect status of an indicator lamp (p 11-18)	.99 (.98 to .998)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-10

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>85</u>	No <u>11</u>	NR <u>4</u>
2. Does the table contain appropriate detail?	Yes <u>56</u>	No <u>40</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>24</u>	R <u>63</u>	O <u>2</u> NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>59</u>	No <u>26</u>	NR <u>15</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>18</u>

Comments:

1. Model Applicability 3
 - a. "Special Alerting Cues" needed (3)
2. Table Information 10
 - a. What about use of checklists? (3)
 - b. Define difference between "audit" and "inspecting" (2)
 - c. Add analog chart HEPs (1)
 - d. Clarify Title: Probabilities of Errors "of omission" on Initial Audit (1)
 - e. Should take into account physical attributes (2)
 - f. Item 3 should take time factor into account (1)

Table 20-10 (cont'd)

3. Backup Information and Instruction 2
 - a. Need additional instruction on how to use (1)
 - b. Explain relationship between Tables 20-10 and 20-9 (1)
4. Table Format
No comment
5. HEP/Bounds Acceptance 2
 - a. Item 3 too pessimistic (1)
 - b. Items 4 & 5 pessimistic (1)
6. Misc. 1
 - a. Eliminate table—as it is repeated in column 1 of 20-12 except for limits (1)

Discussion

The 56% Yes responses to Question 2 regarding level of detail represent the second lowest acceptance value among all tables for this question. The comments generally reflect a need for more detailed definition of terms and the addition of physical attributes and PSFs. Since this table is repeated in greater detail in column 1 of Table 20-12 it appears to be redundant.

Recommendations

Eliminate table. (See comment for Table 20-12.)

Table 20-11. Probabilities of Failure to Detect at Least One of One to Five Deviant Unannunciated Displays (Condensed from Table 9-1)

Item	Number of Deviant Indications					Uncertainty Bounds
	1	2	3	4	5	
1	.99	.985	.98	.975	.97	For HEPs < .5,
2	.95	.93	.90	.88	.86	Lower Bound = HEP x .2
3	.90	.85	.81	.77	.73	Upper Bound = HEP x 2
4	.80	.72	.65	.58	.52	
5	.70	.59	.51	.43	.37	
6	.60	.48	.39	.31	.25	
7	.50	.37	.28	.21	.16	For HEPs ≥ .5
8	.40	.28	.20	.14	.10	Lower Bound = 1 - 2(1-HEP)
9	.30	.19	.13	.08	.05	Upper Bound = 1 - .2(1-HEP)
10	.20	.12	.07	.04	.03	
11	.10	.05	.03	.02	.01	
12	.05	.03	.01	.007	.004	
13	.01	.005	.003	.001	.001	

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-11

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>30</u>	No <u>70</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>66</u>	No <u>30</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>0</u>	R <u>70</u> O <u>0</u>	NR <u>30</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>67</u>	No <u>0</u>	NR <u>33</u>

Summary of Comments

Number of peers commenting	<u>22</u>
Percent of peers commenting	<u>81</u>
Number of comments	<u>34</u>

Comments:

1. Model Applicability 5
 - a. Disagree with model formula 9-1 (2)
 - b. Don't know how to enter Table (3)
2. Table Information 27
 - a. Provide ordinate (12)
 - b. Legends and captions confusing (4)
 - c. Needs PSFs (3)
 - d. Table values are corrective factors, not HEPs (1)
 - e. What do rows represent? (1)
 - f. Reference to Table 9-1 in title—not "condensed" but "modified" (1)
 - g. Don't understand how table is to be used (1)

Table 20-11 (cont'd)

- h. Repeat formula 9-1 (2)
- i. Table should indicate that its values are 1 minus the values in Table 9-1 (2)
- 3. Backup Information and Instruction
 - No comment
- 4. Table Format 1
 - a. Reverse sequence of Tables 20-11 and 20-12—enter Table 20-11 with data from 20-12 (1)
- 5. HEP/Bounds Acceptance
 - No comment
- 6. Misc. 1
 - a. Prefer to use equation 9-1 rather than table (1)

Discussion

Seventy percent of the peers responded with a No to Question 1. This table received more negative comments in terms of understandability and use than all other tables in Chapter 20.

Recommendations

- 1. Reconsider need for table.
- 2. If the table is to be retained:
 - a. Add text to clarify meaning and application of the table.
 - b. Provide an ordinate.
 - c. Rewrite legends and captions.

Table 20-12. Probabilities of Failure to Detect One (of One) Deviant Unannunciated Display* at Each Scan, When Scanned Hourly**

Item	Display Type	Hourly Scans							
		1	2	3	4	5	6	7	8
1	Meter with limit marks (p 11-22)	.05	.31	.50	.64	.74	.81	.86	.90***
2	Meter without limit marks (p 11-26)	.15	.47	.67	.80	.87	.92	.95	.97
3	Chart recorders with limit marks (p 11-26)	.10	.40	.61	.74	.83	.89	.92	.95
4	Chart recorders without limit marks (p 11-26)	.30	.58	.75	.85	.91	.94	.97	.98
5	Annunciator light no longer annunciating (p 10-8)	.9	.95	.95	.95	.95	.95	.95	.95
6	Legend light other than annunciator light (p 11-18)	.98	.98	.98	.98	.98	.98	.98	.98
7	Indicator lamp (p 11-18)	.99	.99	.99	.99	.99	.99	.99	.99
8	Digital readout (p 11-19)	(These are not part of the scanning model, because they must be read. See Table 20-5.)							

*One display refers to a single display or a group of completely dependent displays.

**For fewer than 8 hourly scans, see the special instructions on p 9-6.

***In estimating uncertainty bounds for HEPs $< .5$, lower bound = $\text{HEP} \times 0.2$ and upper bound = $\text{HEP} \times 2$. For HEPs $\geq .5$, lower bound = $1 - 2(1-\text{HEP})$ and upper bound = $1 - 0.2(1-\text{HEP})$.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-12

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>85</u>	No <u>15</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>81</u>	No <u>15</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>17</u>	R <u>70</u>	O <u>2</u> NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>70</u>	No <u>11</u>	NR <u>19</u>

Summary of Comments

Number of peers commenting	<u>10</u>
Percent of peers commenting	<u>37</u>
Number of comments	<u>15</u>

Comments:

1. Model Applicability 1
 - a. Disagree with use of exponential model (1)
2. Table Information 7
 - a. Is checklist used or not (2)
 - b. Rewrite title to include "time intervals between scans" (1)
 - c. Rewrite title to say "probability of failure to detect deviant display during an hourly scan given that the deviant display was undetected (2)
 - d. Is "hourly scan #1" the audit or the first scan after the audit (1)
 - e. Footnote ** refers to p. 9-6—page 9-6 doesn't explain it (1)

Table 20-12 (cont'd)

3. Backup Information and Instruction

No comment

4. Table Format 1

- a. Omit last item or make it a footnote (1)

5. HEP/Bounds Acceptance 6

- a. Items 6 & 7 too pessimistic (2)
- b. Expand uncertainty bounds (1)
- c. When HEPs are adjusted for HD, values are too optimistic (1)
- d. When HEPs are adjusted for MD, values are too pessimistic (1)
- e. Item 5 too pessimistic (1)

6. Misc.

No comments

Discussion

This table was generally well received by the peers. Relatively few peers commented and relatively few comments were made by those who did.

It was previously recommended that Table 20-10 be incorporated into column 1 of this table. The comments submitted indicated a need for more detailed definition of headings and conditions of use.

Recommendations

- 1. Re-identify hourly scans so that #1 equals initial audit.
- 2. Define difference between "audit" and "inspection".
- 3. Correct Footnote^{**}, p. 9-6. It does not give required explanation.
- 4. Make last item a footnote.
- 5. Clarify whether checklist is used or not.

Table 20-13. Probabilities of Errors of Commission
in Operating Manual Controls (from Table 12-1)

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Select wrong control in a group of identical controls identified by labels only	.003 (.001 to .01)
2	Select wrong controls from a functionally grouped set of controls	.001 (.0005 to .005)
3	Select wrong control from a panel with clearly drawn mimic lines	.0005 (.0001 to .001)
4	Turn control in wrong direction (no violation of populational stereotypes)	.0005 (.0001 to .001)
5	Turn control in wrong direction under normal operating conditions (violation of a strong populational stereotype)	.05 (.01 to .1)
6	Turn control in wrong direction under high stress (violation of a strong populational stereotype)	.5 (.1 to .9)
7	Set a multiposition selector switch to an incorrect setting	.001 (.0001 to .1)
8	Improperly mate a connector	.01 (.005 to .05)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-13

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>100</u>	No <u>0</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>59</u>	No <u>41</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>2</u>	R <u>77</u>	O <u>13</u> NR <u>8</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>81</u>	No <u>11</u>	NR <u>8</u>

Summary of Comments

Number of peers commenting	<u>8</u>
Percent of peers commenting	<u>30</u>
Number of comments	<u>14</u>

Comments:

1. Model Applicability
 - No comment
2. Table Information 5
 - a. Add physical attributes of hardware (4)
 - b. Change task description to "failure to" (1)
3. Backup Information and Instruction 5
 - a. How is HEP adjusted when more than one control requires adjusting (1)
 - b. Page 20-19 restricts table to non-valve controls, p. 20-20 contradicts (2)
 - c. Rewrite text on p. 20-19 to clarify use of table for applicable hardware (1)

Table 20-13 (cont'd)

- d. Change HEP Heading to BHEP (1)
- 4. Table Format
 - No comment
- 5. HEP/Bounds Acceptance 4
 - a. Item 5 too pessimistic (1)
 - b. Item 6 too pessimistic (2)
 - c. HEPs too optimistic (1)
- 6. Misc.
 - No comment

Discussion

This table is one of the two tables in Chapter 20 that received a 100% Yes response to Question 1 (ease of use and understandability). The comments reflect relatively minor dissatisfaction with the level of detail.

Recommendations

- 1. Rewrite tasks in "Failure to . . ." mode.
- 2. Eliminate Item 6. It is a stress correction and Table 20-23 should be used for this purpose.
- 3. Paragraph 1 on p. 20-20 needs to be reconciled with description paragraph on p. 20-19.
- 4. Change sentence #4 in description paragraph on p. 20-19 to: "If controls are handled in pairs, assume CD between them; otherwise assume ZD".
- 5. Item 8 is not a manual control. Clarify.

Table 20-14. Probabilities of Errors of Commission by
Operator Changing or Restoring Valves

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Writing any one item when preparing a list of valves (or tags) (p 13-5)	.003 (.001 to .01)
2	Change or tag wrong valve where the desired valve is one of two or more adjacent, similar-appearing manual valves, and at least one other valve is in the same state as the desired valve, or the valves are MOVs of such type that valve status cannot be determined at the valve itself (p 13-5)	.005 (.002 to .02)
3	Restore the wrong manual valve where the desired valve is one of two or more adjacent, similar appearing valves, and at least two are tagged out for maintenance (p 13-5)	.005 (.002 to .02)
4	Reversal error: change a valve, switch, or circuit breaker that has already been changed and tagged (p 13-5)	.0001 (.00005 to .001)
5	Reversal error, as above, if the valve has been changed and NOT tagged (p 13-5)	.1 (.01 to .5)
6	Note that there is more than one tag on a valve, switch, or circuit breaker that he has decided to restore (p 13-5)	.0001 (.00005 to .0005)
7	Change or restore wrong MOV switch or circuit breaker in a group of similar appearing items (In case of restoration, at least two items are tagged) (p 13-6)	.003 (.001 to .01)

Table 20-14 (Con't)

<u>Item</u>	<u>Task</u>	<u>HEP</u>
8	Complete a change of state of an MOV of the type that requires the operator to hold the switch until the change is completed as indicated by lamp (p 13-6)	.003 (.001 to .01)
9	Given that a manual valve sticks, operator erroneously concludes that the valve is fully open (or closed) (p 13-6):	
	<u>Rising-stem valves</u>	
10	If the valve sticks at about three-fourths or more of its full travel (no position indicator* present)	.005 (.002 to .02)
11	If there is an indicator showing the full extent of travel	.001 (.0005 to .01)
	<u>All other valves</u>	
12	If there is a position indicator on the valve	.001 (.0005 to .01)
13	If there is a position indicator located elsewhere (and extra effort is required to look at it)	.002 (.001 to .01)
14	If there is no position indicator	.01 (.003 to .1)

*A position indicator is a scale that indicates the position of the valve relative to a fully opened or fully closed position.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-14

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>81</u>	No <u>19</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>56</u>	No <u>44</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable <u>O</u> - Optimistic, <u>NR</u> - No Response	P <u>4</u>	R <u>77</u>	O <u>8</u> NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>81</u>	No <u>8</u>	NR <u>11</u>

Summary of Comments

Number of peers commenting	<u>15</u>
Percent of peers commenting	<u>56</u>
Number of comments	<u>22</u>

Comments:

1. Model Applicability 2
 - a. Mixes tagging models with valve restoration—corrective factor should be independent of task (1)
 - b. Concern about the probability that various events will occur (1)
2. Table Information 14
 - a. Difficult to distinguish between tasks—description confusing (7)
 - b. Is checklist used or not (1)
 - c. Needs time correction (1)
 - d. "Valve sticking" should be a footnote (1)
 - e. Need HEP for tagging wrong valve when not adjacent (1)
 - f. Need HEP for when no tag is used (1)

Table 20-14 (cont'd)

- g. Rewrite tasks in terms of "Failure to . . . " (1)
- h. Item 1 redundant with Item 1 of Table 20-19 (1)
- 3. Backup Information and Instruction 1
 - a. Clarify what table(s) are referred to in last paragraph of p. 20-20 (1)
- 4. Table Format 1
 - a. Reorganize table to fit single page (1)
- 5. HEP/Bounds Acceptance 4
 - a. Items 4 & 5 unreasonable (1)
 - b. Item 9 too optimistic (1)
 - c. HEPs too optimistic—double values (1)
 - d. Question value of taking HEPs to 10^{-5} (1)
- 6. Misc.
 - No comment

Discussion

The 56% Yes responses for Question 2 is the second lowest acceptance value obtained for "level of detail". In all other questions the table maintained a relatively high level of acceptance. Most of the comments express some confusion in the interpretation of the task descriptions. The level of detail of the task descriptions in this table is considerably higher than in the previous tables. It appears that in attempting to keep the length of the text at a minimum, the descriptions became too cryptic and hence confusing. A second concern expressed in the comments reflects the heterogeneity of the tasks described. Item 1 deals with tag preparation. It is redundant to Item 1 of Table 20-19. Items 2 through 8 deal with valve manipulation. Item 9 is simply a statement of valve condition. Finally Items 10 through 14 deal with the operator's ability to discriminate valve position with or without an indicator.

In brief, in attempting to provide highly specific task descriptions, the table has become overly long, complex, and, to some peers, confusing.

Table 20-14 (cont'd)

Recommendations

1. Eliminate Item 1. It appears in Table 20-19.
2. Reorganize into three tables.
 - a. Manipulation of Valves.
 - b. Discrimination of Valve Position.
 - c. Corrections for all Tagging Levels.
4. Item 9 should be a footnote, not a task.
5. Rewrite task in "Failure to . . ." mode.
6. If tagging is to be part of the task description, then add to table "a" those valve manipulation tasks that are performed with other tagging levels as well as without tags.

Table 20-15. Probabilities of Errors of Omission
by Operators Changing or Restoring Valves

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Omit an item when preparing a list of valves or set of tags (p 13-7)	.003 (.001 to .01)
2	Failure to carry out a specific oral instruction to change or restore a valve (for more than one oral instruction use Table 20-18)	.001 (.0005 to .005)
3	With Level 1 tagging, CD is assumed between all steps in a task for errors of omission - if the first step is performed, all steps will be performed. The only error of omission is the failure to initiate the task (p 13-7)	.001 (.0005 to .005)
4	Omit a particular valve change or restoration when using written procedures	Table 20-20
5	If written procedures not used	Table 20-18
6	Checkoff provision of procedure is misused (check off several items at a time) (p 13-7)	.5 (.1 to .9)
7	Failure to follow established procedures or policies in valve changes or restoration (p 13-7)	.01 (.005 to .05)
8	Failure to tag a valve, circuit breaker, or switch after changing it (p 13-9)	.001 (.0005 to .05)
9	Failure to lock a valve after restoration (if required) (p 13-9)	.003 (.001 to .01)
10	Failure to lock a valve after restoration, (if required), with Level 1 lock and key control (p 13-9)	.001 (.0005 to .005)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-15

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>11</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>63</u>	No <u>33</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>0</u>	R <u>77</u> O <u>8</u>	NR <u>15</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>81</u>	No <u>8</u>	NR <u>11</u>

Summary of Comments

Number of peers commenting	<u>12</u>
Percent of peers commenting	<u>44</u>
Number of comments	<u>17</u>

Comments:

1. Model Applicability 4
 - a. The 4th & 5th "HEPs" are corrective factors—not HEPs—model is violated (3)
 - b. Difficulty in determining which task to use in entering table (1)
2. Table Information 10
 - a. Tasks not clear—overlap and confusing (3)
 - b. Application of tagging model incomplete (4)
 - c. Tasks do not cover all conditions (2)
 - d. Write tasks as "Failure to . . . " (1)
3. Backup Information and Instruction 1
 - a. Need more complete instruction (1)

Table 20-15 (cont'd)

4. Table Format

No comment

5. HEP/Bounds Acceptance 2

a. Items 6, 7, & 8 are too optimistic (1)

b. Why are bounds for Items 3 and 8 different (1)

6. Misc.

No comment

Discussion

With the exception of Item 8, 9, and 10 all the tasks listed in this table are not unique to valves. They are generic to all errors of omission and appear in other tables as follows:

Item 1 - Table 20-19

Item 2 - Table 20-18

Item 3 - Table 20-18

Item 4 - Table 20-20

Item 5 - Table 20-18

Item 6 - Table 20-22

Item 7 - Table 20-22

The bulk of the comments express some aspect of confusion or dissatisfaction with the tasks.

Recommendations

Delete Items 1 through 7.

Table 20-16. Probabilities of Errors by Operators or Maintainers
Checking Valve Operations Performed by Others

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Failure to detect an error of commission (p 13-9)	Use the basic HEP times 10 (limited to .9)
2	Failure to detect an error of omission (p 13-10)	.1 (.05 to .5)
3	Failure to detect errors of commission or omission on a list of valves or set of tags (p 13-10)	.1 (.05 to .5)
4	Failure to detect that a manual valve was not completely "home" after being changed (p 13-11)	.5 (.1 to .9)
5	Failure to detect that a manual valve was not completely "home" after being restored (p 13-11):	
a	Valves with position indicators	Basic HEP x 10 (limited to .9)
b	Valves without position indicators	Basic HEP x 20 (limited to .9)
6	Failure of a maintainer to detect a reversal error by an operator changing valves (p 13-12)	.5 (.1 to .9)
7	For the case of an operator checking a maintainer, divide the above HEPs by two (p 13-12)	
8	If recovery procedures consist of checking paper work only, allow no credit for recovery (p 13-12)	

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-16

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>93</u>	No <u>7</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>67</u>	No <u>33</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>7</u>	R <u>74</u> O <u>4</u>	NR <u>15</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>81</u>	No <u>0</u>	NR <u>19</u>

Summary of Comments

Number of peers commenting	<u>10</u>
Percent of peers commenting	<u>37</u>
Number of comments	<u>14</u>

Comments:

1. Model Applicability
 - No comment
2. Table Information 11
 - a. Better description of tasks (3)
 - b. Item 3 is not an HEP (1)
 - c. Include tagging levels (1)
 - d. Item 5 should contain HEPs rather than a reference to Boundary Calculations (1)
 - e. Do Items 1 & 2 assume "over the shoulder" verification (1)
 - f. Subdivide Item 4 like Item 5 (1)
 - g. Item 1, 2, & 3 not independent (1)

Table 20-16 (cont'd)

- h. Does not cover all failures (1)
- i. Item 5 should list HEPs (1)
- 3. Backup Information and Instructions 1
 - a. Need more and better instructions
- 4. Table Format
 - No comment
- 5. HEP/Bounds Acceptance 2
 - a. HEPs too pessimistic (1)
 - b. HEPs too gross—doubt value (1)
- 6. Misc.
 - No comment

Discussion

There appears to be no major problems indicated in the comments. However, the lack of adequate reference information to the tables containing the appropriate HEPs in Items 1 through 6 was of some concern.

Recommendations

- 1. For Items 1, 5a, and 5b indicate that Table 20-14 is to be used to obtain the appropriate HEPs.
- 2. Items 7 and 8 should be footnotes.

Table 20-17. Probabilities that Maintainer Will Fail to Check Valve Status Before Maintenance* (from Table 13-2)

Type of List Used									
Factor	Short List**			Typical NPP Procedures or Long List**			No List+		
Checkoff Used	Yes++	No		Yes++	No				
Valve Within Field of View	Yes No			Yes No			Yes	No	
Personal Safety Affected									
Yes	.0004	.0006	.0008	.0005	.0006	.0008	.0008	.001	
No	.001	.003	.005	.002	.005	.01	.01	.01	

NOTES: *In view of speculative nature of the HEPs, estimates of uncertainty bounds are even more speculative. For HEPs greater than 10^{-3} , use a divisor of 5 for the lower bound and a factor of 5 for the upper bound. For HEPs of 10^{-3} or smaller, use a factor of 5 for the upper bound and a constant 10^{-4} for the lower bound.

**Assume ZD between valves.

+For more than one valve, Table 14-1, p 14-2, indicates the HEP increase as the number of items to remember increases.

++Credit for checkoff must be modified by the percentage of people who fail to use checkoff (Table 14-3, p 14-13).

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-17

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>70</u>	No <u>26</u>	NR <u>4</u>
2. Does the table contain appropriate detail?	Yes <u>77</u>	No <u>15</u>	NR <u>8</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>0</u>	R <u>70</u> O <u>12</u>	NR <u>18</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>81</u>	No <u>4</u>	NR <u>15</u>

Summary of Comments

Number of peers commenting	<u>9</u>
Percent of peers commenting	<u>33</u>
Number of comments	<u>12</u>

Comments:

1. Model Applicability 2
 - a. Footnote ** refers to % of people failing and refers to Table 20-20. Table 20-20 does not use % and model doesn't describe how to use (2)
2. Table Information 2
 - a. Define "personal safety" (2)
3. Backup Information and Instruction 3
 - a. Footnote * needs instructions as to incorporation of Table 20-18 data (2)
 - b. Rewrite headings—need examples (1)
4. Table Format 4
 - a. Excellent format (2)
 - b. Table format confusing (2)

Table 20-17 (cont'd)

5. HEP/Bounds Acceptance

No comment

6. Misc. 1

a. Don't understand table (1)

Discussion

This table received a moderately high percentage of negative responses to Question 1. The comments indicate that the problem may stem from inconsistencies in the footnoted items and the lack of detailed instruction on the use of the table.

Recommendations

1. Need definition of "within field of view" and "personal safety".
2. Needs explanation as to how to apply information in Tables 20-18 and 20-20 as referenced to Footnotes^{*} and^{**}.
3. Clarify Footnote^{**}. Table 20-20 does not yield modification "by the percentage of people".
4. Provide backup instructions on how to use.

Table 20-18. Probabilities of Errors in Recalling
Special Instruction Items Given Orally
(from Table 14-1)

<u>Item</u>	<u>Task</u>	<u>HEP</u>
<u>Items not Written Down by Recipient</u>		
	Recall any given item, given the following number of items to remember:	
1	1 (same as failure to initiate task)	.001 (.0005 to .005)
2	2	.003 (.001 to .01)
3	3	.01 (.005 to .05)
4	4	.03 (.01 to .1)
5	5	.1 (.05 to .5)
6	Recall any item if supervisor checks to see that the task was done	Negligible
<u>Items Written Down by Recipient</u>		
7	Recall any item (exclusive of errors in writing - see Table 20-19)	.001 (.0005 to .005)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-18

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>89</u>	No <u>11</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>78</u>	No <u>22</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>4</u>	R <u>70</u> O <u>8</u>	NR <u>18</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>74</u>	No <u>18</u>	NR <u>8</u>

Summary of Comments

Number of peers commenting	<u>9</u>
Percent of peers commenting	<u>33</u>
Number of comments	<u>10</u>

Comments:

1. Model Applicability
No comment
2. Table Information 5
 - a. Define "failure to initiate task" (2)
 - b. Use "failure to recall" in title (1)
 - c. Need larger number of items (1)
 - d. Table does not take into account recalling items in a given sequence (1)
3. Backup Information and Instruction (2)
 - a. Need examples and more explanation (2)
4. Table Format 1
 - a. Format blends with text (1)

Table 20-18 (cont'd)

5. HEP/Bounds Acceptance 2

a. HEPs too optimistic (range of .01 to .05 more reasonable) (2)

6. Misc.

No comments

Discussion

This was the second most frequently used table in the solution of the exercises. It received relatively high acceptance in all questions.

Recommendations

None

Table 20-19. Probabilities of Error in Preparation
of Written Procedures

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Omitting an item (p 14-7)	.003 (.001 to .01)
2	Writing an item incorrectly (p 14-7)	.003 (.001 to .01)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-19

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>100</u>	No <u>0</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>74</u>	No <u>22</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>4</u>	R <u>63</u>	O <u>18</u> NR <u>15</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>64</u>	No <u>18</u>	NR <u>18</u>

Summary of Comments

Number of peers commenting	<u>11</u>
Percent of peers commenting	<u>41</u>
Number of comments	<u>15</u>

Comments:

1. Model Applicability
No comment
2. Table Information 9
 - a. Far from complete—other factors should be added (9)
3. Backup Information and Instruction
No comment
4. Table Format 1
 - a. Table blends with text (1)
5. HEP/Bounds Acceptance (4)
 - a. Item 1 too optimistic (1)
 - b. Item 2 too optimistic (3)

Table 20-19 (cont'd)

6. Misc. 1

- a. Seems reasonable (1)

Discussion

A comment submitted by one third of the peers best describes this table. It is "far from complete". The two items listed are trivia compared to the potential error involved in writing a procedure. The list presented is more appropriate to preparing a list of tags for valves to be changed. For the purpose of the type of analysis called out by the Handbook, it would probably be best to assume that the procedures used are complete and technically correct.

Recommendations

1. Change title to read: Probabilities of Error in Preparation of a Written List (tags, valve alignment list, checklist, etc.).
2. Consider the development of a model in which a good procedure would decrease the BHEP whereas an inadequate procedure would increase the BHEP.

Table 20-20. Probabilities of Error of Omission in Use of
Written Procedures in Nonpassive Tasks
(from Tables 14-2, 14-3, and 15-2)

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Procedures with checkoff provisions* (p 14-11)	
a	Short list $\leq$ 10 items	.001 (.0005 to .005)
b	Long list $>$ 10 items	.003 (.001 to .01)
c	Checkoff provision improperly used (p 15-10) (Consider procedures with improperly used checkoff provisions to be the same as procedures with no check- off provisions.)	
2	Procedures with no checkoff provisions* (p 14-11)	
a	Short list $\leq$ 10 items	.003 (.001 to .01)
b	Long list $>$ 10 items	.01 (.005 to .05)
3	Performance of simple arithmetical calculations (p 14-14)	.01 (.005 to .05)
4	If two people use written procedures correctly - one reading and checking the other doing the work - assume HD between their performances (p 15-3)	
5	Procedures available but not used (p 15-10)	
a	Maintenance tasks	.3 (.05 to .9)
b	Valve change or restoration tasks	.01 (.005 to .05)

*Assume ZD between written
steps (p 14-9)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-20

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>70</u>	No <u>26</u>	NR <u>4</u>
2. Does the table contain appropriate detail?	Yes <u>63</u>	No <u>33</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>0</u>	R <u>81</u> O <u>8</u>	NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>67</u>	No <u>15</u>	NR <u>18</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>27</u>

Comments:

1. Model Applicability 3
 - a. Model should include additional parameters other than ± 10 (3)
2. Table Information 12
 - a. Define "passive" and "non-passive" (3)
 - b. Items are too interactive (1)
 - c. Why is administrative control included in table (1)
 - d. Redefine task to indicate whether HEP is a result of misreading, not using procedure, or not doing the task (1)
 - e. Item 2 should include HEP for improper use as does Item 1. (3)
 - f. Use Table 14-2 and 14-3 instead of Table 20-20 (1)
 - g. Add Table 14-3 to Table 20-20 (1)
 - h. List HEP for Item 4 (1)

Table 20-20 (cont'd)

3. Backup Information and Instruction 6
 - a. Need logic tree to prioritize interaction with other tables (2)
 - b. Define difference between "maintainer" and "operator" in Glossary (1)
 - c. Need more examples (1)
 - d. Clarify difference between Table 20-20 and 20-21—when to apply each one (1)
 - e. When referring to page, include table number (1)
4. Table Format 4
 - a. Make table format similar to that of Table 20-17 (2)
 - b. Numerically identify items (1)
 - c. Use "Failure to" format (1)
5. HEP/Bounds Acceptance 2
 - a. Last HEP should be greater than HEP Number 3 (2)
6. Misc.
No comment

Discussion

The comments reflect a general concern and confusion as to the interaction of Table 20-20 and Tables 20-21 and 20-22. There is sufficient overlap and redundancy in these tables to warrant this concern. They all draw on Tables 14-2, 14-3, and 15-2 as their source material. The confusion stems from the fact that all three tables address, to varying degrees, the problem of use and/or misuse of written procedures and checklists. As indicated in the task analysis results, there is considerable variability in HEPs associated with these two factors. Since some of the HEPs involved are of considerable magnitude the influence that they exert on the final solution can be profound. The overlap and confusion related to these tables must be eliminated.

Recommendations

1. Expand the instructional material in Chapters 14 and 15 emphasizing the

Table 20-20 (cont'd)

interaction of the tables.

2. Write tasks in "Failure to . . ." mode.
3. Item 4 should be a footnote.
4. Item 5 belongs in Table 20-22.

Table 20-21. Estimated Probabilities of Error in Use of
Checklists for Passive Tasks Such as the Walk-Around Inspection
(from Table 14-2 and Chapter 15)

<u>Item</u>	<u>Task</u>	<u>HEP</u>
1	Use checklist properly (p 15-10)	.5 (.1 to .9)
2	Recognize an incorrect status when using a checklist properly (p 14-11)	.01 (.005 to .05)
3	Recognize an incorrect status when using a checklist improperly (p 14-11)	.1 (.05 to .5)
4	If two people use checklist properly, one reading, the other inspecting, assume HD (p 15-3)	

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-21

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>85</u>	No <u>15</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>74</u>	No <u>26</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>2</u>	R <u>81</u> O <u>6</u>	NR <u>11</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>78</u>	No <u>4</u>	NR <u>18</u>

Summary of Comments

Number of peers commenting	<u>11</u>
Percent of peers commenting	<u>41</u>
Number of comments	<u>17</u>

Comments:

1. Model Applicability 4
 - a. Model should include design of checklist, PSFs, active tasks, and improper use of checklist (4)
2. Table Information 9
 - a. Why no entry for <10 or >10 ? (1)
 - b. Provide HEP for Item 4 (1)
 - c. Define "properly" (2)
 - d. Table should be combined with Table 20-22 (1)
 - e. Item 1 belongs to Table 20-22 (1)
 - f. Items 2 & 3 are not errors in the use of checklists, but are errors which result from incorrect use of checklist (1)

Table 20-21 (cont'd)

- g. Define "passive" (1)
- h. Item 3 is at variance with HEP #5 Table 20-10 (1)
- 3. Backup Information and Instruction
 - No comment
- 4. Table Format 1
 - a. Use "Failure to" format (1)
- 5. HEP/Bounds Acceptance 3
 - a. Item 1 too pessimistic (1)
 - b. Item 3 too optimistic (2)
- 6. Misc.
 - No comment

Discussion

Same as Table 20-20.

Recommendations

- 1. Expand the instructional material in Chapters 14 and 15 emphasizing the interaction of the tables.
- 2. Write tasks in "Failure to . . . " mode.
- 3. Item 1 belongs in Table 20-22.
- 4. Item 4 should be a footnote.

Table 20-22. HEPs Related to Failure of Administrative Control
(from Table 15-2)

<u>Item</u>	<u>Operation</u>	<u>HEP</u>
1	Carry out a plant policy when there is no check on a person	.01 (.005 to .05)
2	Initiate a checking function	.001 (.0005 to .005)
3	Use control room written procedures under operating conditions that are	
a	Normal	.01 (.005 to .05)
b	Abnormal	no basis for estimate
4	Use a valve restoration list	.01 (.005 to .05)
5	Use written calibration procedures	.05 (.01 to .1)
6	Use written maintenance procedures when available	.3 (.05 to .9)
7	Use a checklist properly (i.e., perform one step and check it off before proceeding to next step)	.5 (.1 to .9)

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-22

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>81</u>	No <u>19</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>78</u>	No <u>22</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable <u>O</u> - Optimistic, <u>NR</u> - No Response	P <u>2</u>	R <u>67</u>	O <u>13</u> NR <u>18</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>74</u>	No <u>11</u>	NR <u>15</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>19</u>

Comments:

1. Model Applicability 1
 - a. Need distinction between types of procedures (1)
2. Table Information 7
 - a. Combine with Table 20-21 (1)
 - b. Define "no check on person" (2)
 - c. Title awkward and inappropriate (1)
 - d. Define "policy" (3)
3. Backup Information and Instruction 3
 - a. Need better instruction on interaction between Tables 20-21 and 20-22 (2)
 - b. Need examples (1)

Table 20-22 (cont'd)

4. Table Format 1
 - a. Use "Failure to" format (1)
5. HEP/Bounds Acceptance 7
 - a. Item 2 too optimistic, recommends .005 (1)
 - b. Item 7 too pessimistic (2)
 - c. Item 4 & 5 seem similar—why the large difference in HEPs (1)
 - d. HEPs too variable and ranges too narrow (2)
 - e. All HEPs too optimistic (1)
6. Misc.

No comments

Discussion

There is a concern expressed by the peers relative to the meaning and use of the HEPs in this table. The general consensus is that they are not HEPs but rather they are probabilities of events that may have a profound influence on other BHEPs. As such, it is contended that they should be treated in the same manner as stress, experience, and dependency, i.e., as adjustments to the BHEPs.

Recommendations

1. Expand the instructional material in Chapters 14 and 15 emphasizing the interaction of the tables.
2. Write tasks in "Failure to . . . " mode.
3. Develop a logic tree, flow chart, or matrix illustrating the frequency, use, and the points of application of the HEPs in this table.

Table 20-2. Probabilities of Error and Uncertainty Bounds
for Levels of Stress for Experienced Personnel and Novices
(from Chapter 17 and Table 18-1)

<u>Item</u>	<u>Stress Level</u>	<u>HEPs*</u>	<u>Uncertainty Bounds</u>
<u>Experienced Personnel (Ch. 17)</u>			
1	Very Low	2 x tabled HEPs**	2 x tabled values**
2	Optimum	Tabled HEPs	Tabled values
3	Moderately High:		
a	Step-by-step tasks	2 x tabled HEPs	2 x tabled values
b	Dynamic tasks	5 x tabled HEPs	5 x tabled values
4	Extremely High	.25	.03 to .75
<u>Novices*** (Ch. 18)</u>			
5	Very Low	1 x tabled HEPs**	2 x tabled values**
6	Optimum		
a	Step-by-step tasks	Tabled HEPs	Tabled values
b	Dynamic tasks	2 x tabled HEPs	2 x tabled values
7	Moderately High		
a	Step-by-step tasks	4 x tabled HEPs	4 x tabled values
b	Dynamic tasks	10 x tabled HEPs	10 x tabled values
8	Extremely High	.25	.03 to .75

*Absolute lowest HEP is 5×10^{-5} and absolute highest HEP is .999.

**Tabled HEPs and uncertainty bounds refer to those in the other tables in Chapter 20.

***Novices are defined as NPP personnel with less than 6 months experience in the jobs for which they are qualified.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-23

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>93</u>	No <u>7</u>	NR <u>0</u>
2. Does the table contain appropriate detail?	Yes <u>85</u>	No <u>15</u>	NR <u>0</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>10</u>	R <u>59</u> O <u>9</u>	NR <u>22</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>59</u>	No <u>22</u>	NR <u>19</u>

Summary of Comments

Number of peers commenting	<u>10</u>
Percent of peers commenting	<u>37</u>
Number of comments	<u>12</u>

Comments:

1. Model Applicability 10
 - a. Disagreement with model for novice vs. experience:
 1. Novices could be much worse (2)
 2. Model should consider novice's familiarity with procedure (2)
 - b. Disagreement with stress model
 1. Doubts values for "very low" stress (1)
 2. Dynamic tasks should be less stressful than step-by-step (1)
 3. Value for extremely high stress/experience is too pessimistic (1)
 4. Value for "very low" stress "novice", too optimistic (1)
 5. Can't justify equal values for novice v. experienced personnel for extremely high stress (1)
 6. How is stress level determined in order to enter the table (1)

Table 20-23 (cont'd)

2. Table Information 1
 - a. Add explanation of interaction between uncertainty bounds and corrective factors (1)
3. Backup Information and Instruction
No comment
4. Table Format
No comment
5. HEP/Bounds Acceptance
No comment
6. Misc. 1
 - a. Why the difference between the values of Table 20-23 and the HEPs listed for Items 5 & 6 of Table 20-13 (1)

Discussion

The bulk of the comments expressed disagreement with the values presented. This is not surprising, since the subject of stress is a controversial issue. However, there was not sufficient uniformity of opinion among the peers to warrant any change.

A second class of comments reflected the problems inherent in the determination of the stress level to be used.

Recommendations

Clarify by example, if possible, how the user should align stress levels to the task being analyzed.

Table 20-24. Effects of Several Operators in Control Room
in an Abnormal Situation (p 17-24)

<u>Item</u>	<u>Time After Initiation of Abnormal Event</u>	<u>Number of Operators Present and Level of Dependence between Them</u>
1	0 - 5 min	Only on-duty control room reactor operator is present.
2	5 - 20 min	Shift supervisor is now present. Assume MD-to-HD between regular operator and shift supervisor. If regular operator is a novice, assume shift supervisor takes over.
3	20 min - 2 hr	A third reactor operator is now present. Assume HD-to-CD between him and the other two operators.
4	After 2 hr	Additional qualified personnel are present. We cannot assess their influence; it may be positive or negative.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-24

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>78</u>	No <u>15</u>	NR <u>7</u>
2. Does the table contain appropriate detail?	Yes <u>63</u>	No <u>33</u>	NR <u>4</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>15</u>	R <u>48</u>	O <u>4</u> NR <u>33</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>52</u>	No <u>8</u>	NR <u>40</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>19</u>

Comments:

1. Model Applicability 13
 - a. Table meaningless (5)
 - b. Doesn't match plant practice (4)
 - c. Disagrees with assumptions of p. 17-24 (4)
2. Table Information 5
 - a. What are the effects on HEPs (2)
 - b. What about levels of experience of operators and dependencies (1)
 - c. Need more information on how to use table (2)
3. Backup Information and Instruction
 - No comment

Table 20-24 (cont'd)

4. Table Format

No comment

5. HEP/Bounds Acceptance

No comment

6. Misc. 1

Not comfortable with table (1)

Discussion

This table is highly controversial. It appears to differ with many plant practices and its usefulness is questionable since it does not contain any BHEPs or corrective factors.

Recommendations

Eliminate table.

Table 20-25. General Error Rate Estimates from Table III 6-1 in
WASH-1400(a,b)

Item	Estimated Rates	Activity
1	10^{-4}	Selection of a key-operated switch rather than a non-key switch (this value does not include the error of decision where the operator misinterprets situation and believes key switch is correct choice).
2	10^{-3}	Selection of a switch (or pair of switches) dissimilar in shape or location to the desired switch (or pair of switches), assuming no decision error. For example, operator actuates large handled switch rather than small switch.
3	3×10^{-3}	General human error of commission, e.g., misreading label and therefore selecting wrong switch.
4	10^{-2}	General human error of omission where there is no display in the control room of the status of the item omitted, e.g., failure to return manually operated test valve to proper configuration after maintenance.
5	3×10^{-3}	Errors of omission, where the items being omitted are embedded in a procedure rather than at the end as above.
6	3×10^{-2}	Simple arithmetic errors with self-checking but without repeating the calculation by re-doing it on another piece of paper.
7	$1/x$	Given that an operator is reaching for an incorrect switch (or pair of switches), he selects a particular similar appearing switch (or pair of switches), where x = the number of incorrect switches (or pair of switches) adjacent to the desired switch (or pair of switches). The $1/x$ applies up to 5 or 6 items. After that point the error rate would be lower because the operator would take more time to search. With up to 5 or 6 items he doesn't expect to be wrong and therefore is more likely to do less deliberate searching.
8	10^{-1}	Given that an operator is reaching for a wrong motor operated valve MOV switch (or pair of switches), he fails to note from the indicator lamps that the MOV(s) is (are) already in the desired state and merely changes the status of the MOV(s) without recognizing he has selected the wrong switch(es).
9	~ 1.0	Same as above, except that the state(s) of the incorrect switch(es) is (are) <u>not</u> the desired state.
10	~ 1.0	If an operator fails to operate correctly one of two closely coupled valves or switches in a procedural step, he also fails to correctly operate the other valve.

Table 20-25 (Con't)

Table 20-25. General Error Rate Estimates from Table III 6-1 in
WASH-1400(a,b)

Item	Estimated Rates	Activity
11	10^{-1}	Monitor or inspector fails to recognize initial error by operator. Note: With continuing feedback of the error on the annunciator panel, this high error rate would not apply.
12	10^{-1}	Personnel on different work shift fail to check condition of hardware unless required by check list or written directive.
13	5×10^{-1}	Monitor fails to detect undesired position of valves, etc., during general walk-around inspections, assuming no check list is used.
14	.2 - .3	General error rate given very high stress levels where dangerous activities are occurring rapidly.
15	$2^{(n-1)}x$	Given severe time stress, as in trying to compensate for an error made in an emergency situation, the initial error rate, x , for an activity doubles for each attempt, n , after a previous incorrect attempt, until the limiting condition of an error rate of 1.0 is reached or until time runs out. This limiting condition corresponds to an individual's becoming completely disorganized or ineffective.
16	~ 1.0	Operator fails to act correctly in the first 60 seconds after the onset of an extremely high stress condition, e.g., a large LOCA.
17	9×10^{-1}	Operator fails to act correctly after the first 5 minutes after the onset of an extremely high stress condition.
18	10^{-1}	Operator fails to act correctly after the first 30 minutes in an extreme stress condition.
19	10^{-2}	Operator fails to act correctly after the first several hours in a high stress condition.
20	x	After 7 days after a large LOCA, there is a complete recovery to the normal error rate, x , for any task.

(a) Modification of these underlying (basic) probabilities were made on the basis of individual factors pertaining to the tasks evaluated.

(b) Unless otherwise indicated, estimates of error rates assume no undue time pressures or stresses related to accidents.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-25

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>59</u>	No <u>26</u>	NR <u>15</u>
2. Does the table contain appropriate detail?	Yes <u>52</u>	No <u>30</u>	NR <u>18</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>0</u>	R <u>70</u> O <u>4</u>	NR <u>26</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>63</u>	No <u>4</u>	NR <u>33</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>23</u>

Comments:

1. Model Applicability 3
 - a. Doubts validity of stress model used (not compatible with Table 20-23) (2)
 - b. Models fuzzy and anecdotal (1)
2. Table Information 16
 - a. Hodge-podge, no rational organization (8)
 - b. Too much detail—obtuse (4)
 - c. Item 13 not consistent with Table 20-8 (2)
 - d. Data hard to apply to specific conditions other than listed (1)
 - e. What is difference between Item 6 of this table and Item 3 of 20-20 (1)

Table 20-25 (cont'd)

3. Backup Information and Instruction

No comment

4. Table Format

No comment

5. HEP Bounds Acceptance

No comment

6. Misc. 4

- a. Compare values with values in other tables (1)
- b. Eliminate table (2)
- c. Doubts usefulness of table (1)

Discussion

The information in this table is redundant and occasionally conflicting with other tables. It is primarily of historic value.

Recommendations

Eliminate table or relocate in background chapters.

Table 20-26. General Guidelines for Estimating Uncertainty
Bounds for Estimated HEPs* (from Table 16-2)

Item	Task and/or HEP Guidelines	Uncertainty Bounds**	
		Lower	Upper
<u>HEP-Oriented</u>			
1	Estimated HEP < .001	HEP + 10, 5 x 10 ⁻⁵	HEP x 10
2	Estimated HEP .001 to .01	HEP + 3	HEP x 3
3	Estimated HEP > .01	HEP + 5	HEP x 2 to x 5
<u>Task-Oriented</u>			
4	Task consists of step-by-step procedure conducted under routine circumstances and is essentially static (e.g., calibration task).	HEP + 3 to + 5	HEP x 3 to x 5
5	Same as above, but estimated HEP is < .001.	HEP + 10	HEP x 10
6	Task consists of step-by-step procedure, but is carried out in nonroutine circumstances specifically involving a potential turbine/reactor trip.	HEP + 5	HEP x 10
7	Task consists of relatively dynamic interplay between operator and system indications, but task is done under routine conditions; e.g., increasing or reducing power.	HEP + 10	HEP x 10
8	Task is performed under severe stress conditions, e.g., large LOCA, conditions in which the status of ESFs is not perfectly clear, or conditions in which the initial operator responses have proved to be inadequate and now severe time-pressure is felt.	.03	.75

*The estimates in this table apply to experienced personnel. The performance of novices is discussed in Chapter 18.

**The lowest lower bound is 5 x 10⁻⁵ and the highest upper bound is .999.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-26

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>78</u>	No <u>15</u>	NR <u>7</u>
2. Does the table contain appropriate detail?	Yes <u>63</u>	No <u>22</u>	NR <u>15</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>4</u>	R <u>58</u> O <u>8</u>	NR <u>30</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>66</u>	No <u>4</u>	NR <u>30</u>

Summary of Comments

Number of peers commenting	<u>13</u>
Percent of peers commenting	<u>48</u>
Number of comments	<u>21</u>

Comments:

1. Model Applicability 4
 - a. Too much guess work (2)
 - b. Why distinguish between "HEP-Oriented" and "Task-Oriented" (1)
 - c. Bounds so broad as to be meaningless (1)
2. Table Information 3
 - a. What is a step-by-step procedure (1)
 - b. Too much detail (1)
 - c. Define sub-heading "HEP-Oriented" and "Task-Oriented" (1)
3. Backup Information and Instruction 2
 - a. Needs statement of precondition and assumptions used for establishing uncertainty bounds (1)
 - b. How do you apply table. Chapter 16 doesn't help (1)

Table 20-26 (cont'd)

4. Table Format

No comment

5. HEP/Bounds Acceptance 2

- a. Last item too optimistic (1)
- b. Last item too pessimistic (1)

6. Misc. 10

- a. Why this table when other tables give bounds (2)
- b. Item 2, lower bound should read - not $\pm$ (4)
- c. Table very helpful (3)
- d. Difficult to understand (1)

Discussion

Since bounds are provided for each specific BHEP in other tables this table is out of place in Chapter 20. However, it has definite value as an instructional tool and for computing the uncertainty bounds for unique situations.

Recommendations

Delete from Chapter 20 and relocate in Chapter 18.

Table 20-27. Legend for Figure 20-1

<u>Task</u>	<u>HEP</u>
Commission Errors	
1. Walk-around inspections: recognize incorrect status, using checklist correctly	.01 (.005 to .05)
2. Walk-around inspections: recognize incorrect status, using checklist incorrectly	.1 (.05 to .5)
3. Walk-around inspections: recognize incorrect status, no checklist, first walk-around	.9 (.5 to .99)
4. Use checklist correctly	.5 (.1 to .9)
5. Follow established policies or procedures	.01 (.003 to .03)
6. Passive inspection	.1 (.05 to .5)
7. Respond to an annunciator (one of one)	.0001 (.00005 to .001)
8. Read annunciated lamp	.001 (.0005 to .005)
9. Read digital display	.001 (.0005 to .005)
10. Read analog meter	.003 (.001 to .01)
11. Read analog chart recorder	.006 (.002 to .02)
12. Read graph	.01 (.005 to .05)
13. Read printing recorder (cluttered)	.05 (.01 to .2)
14. Record more than 3 digits	.001 (.0005 to .005)
15. Detect a deviant meter with limit marks during initial audit	.05 (.01 to .1)
16. Check-read specific meters with limit marks	.001 (.0005 to .005)

<u>Task</u>	<u>HEP</u>
Commission Errors	
17. Check-read specific meters without limit marks	.003 (.001 to .01)
18. Check wrong indicator lamp in a group of similar lamps	.003 (.001 to .01)
19. Note incorrect status of an indicator lamp (in a group)	.99 (.98 to .998)
20. Note incorrect status of a legend lamp (in a group)	.98 (.96 to .996)
21. Remember oral instructions, one of one	.001 (.0005 to .005)
22. Select wrong panel control:	
a. Among a group of similar controls	.003 (.001 to .01)
b. If functionally grouped	.001 (.0005 to .005)
c. If part of a mimic-type panel	.0005 (.0001 to .001)
23. Set a multiposition switch	.001 (.0001 to .1)
24. Mate a connector	.01 (.005 to .05)
25. Turn control in wrong direction:	
a. If no violation of populational stereotype	.0005 (.0001 to .001)
b. If populational stereotype is violated	.05 (.01 to .1)
26. Select manual valve from a group of similar valves	.005 (.002 to .02)

<u>Task</u>	<u>HEP</u>
Omission Errors*	
27. Each item on a short list**, using checkoff	.001 (.0005 to .005)
28. Each item on a long list, using checkoff	.003 (.001 to .01)
29. Each item on a short list, not using checkoff	.003 (.001 to .01)
30. Each item on a long list, not using checkoff	.01 (.005 to .5)

*Omission errors include steps in any kind of procedure: valve operations, switching operations, locking of valves, etc.

**Short list = 10 items or less; long list = more than 10 items.

PEER RESPONSES TO QUESTIONNAIRE—PART 2

Handbook Table 20-27

Responses to Questions

<u>Question</u>	<u>Percent of Responses</u>		
1. Is it easy to understand how to enter and use the table?	Yes <u>78</u>	No <u>4</u>	NR <u>18</u>
2. Does the table contain appropriate detail?	Yes <u>70</u>	No <u>4</u>	NR <u>26</u>
3. What is your opinion of the general magnitude of the HEPs in the table? P - Pessimistic, R - Reasonable O - Optimistic, NR - No Response	P <u>4</u>	R <u>59</u>	O <u>4</u> NR <u>33</u>
4. Do the relative values of the HEPs seem reasonable to you?	Yes <u>63</u>	No <u>4</u>	NR <u>33</u>

Summary of Comments

Number of peers commenting	<u>11</u>
Percent of peers commenting	<u>41</u>
Number of comments	<u>19</u>

Comments:

1. Model Applicability 2
 - a. Include physical attributes of hardware (2)
2. Table Information 1
 - a. Task description too general (1)
3. Backup Information and Instruction
No comment
4. Table Format 1
 - a. Use functional groupings (1)
5. HEP/Bounds Acceptance 2
 - a. Item 30, upper bound of 0.05 in Table 20-20 does not agree with Figure 20-1 (1)
 - b. Tasks 18 or 19 (19 or 20), too pessimistic (1)

Table 20-27 (cont'd)

6. Misc. 13

- a. Redundant with prior tables (4)
- b. Figure 20-1 not useful (4)
- c. Figure 20-1 useful (1)
- d. Figure 20-1 very interesting (3)
- e. Table very useful (1)

Discussion

This table is redundant in Chapter 20. However, it has value as an instructional tool.

Recommendations

Relocate in a prior chapter.

CHAPTER IV

DISCUSSION AND RECOMMENDATIONS

This chapter supplements the table-specific recommendations presented in Chapter III with recommendations that are applicable to larger segments of the Handbook.

The Handbook was generally well received by the peers in terms of both purpose and content. It was recognized to be a presentation of the state-of-the-art of human reliability analysis. The models and HEPs were generally accepted as being reasonable. (The exceptions are noted in the analysis of peer comments in Chapter III.) This is not to say that there was overall satisfaction with the state-of-the-art. The overwhelming consensus was that the development of a more complete data bank and the inclusion of updated data in the Handbook are critical to the future applicability of the document.

The Handbook is of necessity a large document. It is cumbersome to use in working out problems. It is therefore recommended that the capability of removing Chapter 20 from the Handbook (perhaps in loose leaf form) or the publication of a separate Chapter 20 be considered for future editions.

The peer performance data obtained from the analysis of their solutions to the human reliability analysis problems indicate that there was considerable variability in the application of the data in Chapter 20. The bulk of the responses to Part 2 of the questionnaire reflect a confusion as to how to interpret and apply the data contained in Chapter 20. The discussion that follows is directed toward the overall format and content of Chapter 20.

Organization of Handbook Chapter 20

Based on the data reported in this study, it is recommended that Chapter 20 be reorganized into four major sections. They are:

1. Instruction Section
2. BHEP Section
3. Corrective Factors Section
4. Administrative Control Section

Instruction Section

The purpose of the instruction section is twofold. It is aimed at

1) providing a self-contained chapter that can stand by itself if the user desires to separate it from the rest of the Handbook, and 2) reducing the variability exhibited by users in solving human reliability analysis problems.

Since the background and training of the intended users of the Handbook will be varied, it is necessary to rely on a set of relatively explicit instructions to standardize the analysis process. The rules and limits of the task/error analysis must be specified. There should be no discussion of theory or modeling in this section. The instructions should be limited to "how to". It is recommended that the instructions be ordered, in so far as possible, in the general sequence to be followed in the construction of the event tree. The instructions should provide the guidelines necessary to assist the user in defining the scope and level of detail of the analysis to be performed.

The guidelines should include instructions with respect to the following topics:

1. Where to start
2. When to develop alternative success paths
3. How and when to apply the administrative control factors
4. How and when to apply corrective factors
5. When to assume an effect is negligible
6. Limits on the level of detail of the task analysis
7. How to analyze self-recovery

Consideration should be given to the use of such performance aids as logic trees and flow charts in the presentation of the instructions. The instructions should be supplemented with examples of event trees constructed for basic tasks, e.g., setting switch, reading dials, walk-around, restoring valves, etc. Each of these tasks or examples should be expanded to demonstrate effects of different combinations of performance errors, PSFs, and administrative control factors. The result would be a reference library of typical trees that can guide the users through this phase of the analysis with a high degree of consistency.

The instructions should also address the selection and use of the tables and HEPs. Guidelines should include such items as:

1. Table selection
2. Adjustment of BHEPs

3. Use of PSFs
4. Application of Administrative Controls
5. Calculation of P_f 's and P_s 's
6. Interactions between Tables

It is also recommended that these instructions be supplemented with a multi-level indexing system. For example, assume an index system which is entered by identifying a basic task. Then, by tracing the task through successively lower levels such as type of equipment involved and related potential human errors, the correct table could be identified. A similar index could be developed for corrective factors. In this index, the entry would be from a description of the PSFs involved. Such an indexing system is amenable to presentation as a logic tree. As a secondary benefit, such a system would identify unnecessary table redundancies.

BHEP Section

This section represents the bulk of Chapter 20. It excludes only the corrective factor tables and the administrative control tables. As stated on page 20-1 of the Handbook, "The HEPs listed are premised on the "average" industrial conditions". They are to be adjusted at the discretion of the user to take into account the differences between the "average" condition and the condition being analyzed.

One of the intended uses of the uncertainty bounds (which should also be provided in this section) is to provide the user with a set of limits for making the necessary adjustments. The data obtained in this study indicate that the users rarely took advantage of this feature. They used the tabled HEPs without adjustment. They did, however, frequently recommend that the tables be expanded to include the most critical attributes of hardware and environment and that a specific HEP be listed for each condition. To accomplish such a task would be extremely difficult and could easily result in impractically long tables. It is therefore recommended that either additional corrective factors tables be developed to provide the guidance and motivation necessary to adjust the HEPs or that the instruction section include such information.

The tables in Chapter 20 present a multitude of different formats which tended to irritate and confuse the users. It is recommended that a standard format(s) be used which will include at least the following:

1. Provide an identifying number for each item or task.
2. List all BHEPs as P_f 's.
3. Describe BHEP tasks/items in the failure mode, e.g., failure to read , etc.

4. Format the tables so that they are easily distinguishable from the text.
5. Provide the uncertainty bounds in all the tables or footnote the formula.

A considerable number of comments reflected concern with the fact that the tables in Chapter 20 did not contain information that was presented in the backup chapters. In many cases this condensation of information was justified—however, it was not explained. In cases where information contained in a previous chapter is deliberately excluded from a table, a statement as to what information has been excluded and the reason for the exclusion should be provided in the text or as a footnote to the table. This may prevent the user from injecting irrelevant conditions into an analysis (conditions which are based on the missing information).

Corrective Factor Section

This section should consist of those tables that list values to be applied to the HEPs in order to adjust them to include the effects of applicable PSFs. Many of the users expressed some confusion resulting from the inclusion of corrective factors in tables containing BHEPs. It is recommended that all corrective factors be deleted from such tables and placed in this section.

Two basic types of corrective factors have been identified; specific and general. The specific corrective factors, e.g., stress, dependency, etc., do not necessarily affect each task BHEP in the event tree the same way. They must therefore be applied, as appropriate, to each individual task being analyzed.

The general corrective factors, e.g., type of procedures, experience, etc., affect all tasks equally and need be applied only once as a general correction. It is recommended that corrective factors be identified as to type to minimize the probability that they will be incorrectly applied.

Administrative Control Section

The administrative controls are found primarily in Table 20-22. As a group, these factors and their application are the least understood and most questioned items in the Handbook. It was frequently commented that the values listed were neither HEPs nor corrective factors and that they were probabilities of events occurring that would lead to an increase in the probability of human error. The peers repeatedly asked for a corrective factor that could be applied to the HEPs once a particular event has occurred. This confusion as to the definition and purpose of administrative controls manifested itself in the variability of application of these factors in the solution of the workbook problems. It is recommended

that this area of confusion be clarified by expanding the relevant section of Chapter 15 of the Handbook to provide a fuller explanation of the use of administrative controls.

Conclusion

As a result of this study, the draft Handbook has undergone an intensive review by experts versed in human factors and/or nuclear power plant operations. Through their use of the Handbook in solving human reliability analysis problems, they became sufficiently familiar with it to formulate judgments regarding its concept and contents. The study recommendations are derived from the performance and comments of these experts. Their incorporation into the Handbook will add to its usefulness for persons performing human reliability analysis.

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APPENDIX A
EXERCISE WORKBOOK

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Section 1. Introduction	A-1
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SECTION 1. INTRODUCTION

The purpose of this workbook is twofold:

1. to familiarize you with the use of the Handbook in performing human reliability analysis, and
2. to provide the data necessary to assess the consistency of the responses obtained from a group of specialists in solving a series of human performance problem exercises.

The workbook consists of a series of exercises* that are greatly simplified descriptions of real-world situations. In a real-world setting, you, as the analyst, will observe many aspects of any situation that will not be mentioned in the exercises. Some of the aspects you observe will not affect reliability and safety, whereas others may have significant effects, and you will have to judge which ones should be included in your analysis. In the exercises that follow, only the most relevant factors are listed. The exercises are hypothetical presentations of generic problems. They are not representative of any specific situation at any specific NPP. You should keep in mind that, when equipment is mentioned, your concern is not with the system function of the equipment but rather with the operator interface. For example, in the case of a motor-operated valve (MOV), this is a switch in the control room; for a locally operated valve, it is a turning wheel at the valve site.

The exercises are divided into two sections in the workbook. They are:

Section 2. Example Exercises

This section consists of two completed exercises that illustrate how to use the Handbook and the worksheets in developing the solutions. The solutions provided are by no means definitive. They merely represent one reasonable approach to the problem. You may not necessarily agree with the solutions. If you do not, feel free to comment on the areas of disagreement.

* These exercises are based, in part, on:

Bell, B.J., Guttman, H.E., Swain, A.D., Sample Human Reliability Analysis Problems, An Appendix to the NREP Chapter on Human Reliability Analysis Methodology, Sandia National Laboratories, Albuquerque, NM, April 21, 1981

Section 3. Problem Exercises

This section consists of four exercises that you are to work out.

Each section contains the instructions necessary to complete the required work.

The following supplementary notes are provided to aid in the completion of the problem exercises and to update the Handbook.

Note 1: Some of the exercises use the following equations from Chapter 6, "Unavailability," in the Handbook.

$$A = \frac{\bar{u}}{\bar{u} + \bar{d}} \quad (\text{Eq. 6-1, p. 6-1})$$

$$U = 1 - A = 1 - \frac{\bar{u}}{\bar{u} + \bar{d}} = \frac{\bar{d}}{\bar{u} + \bar{d}} \quad (\text{Eq. 6-2, p. 6-1})$$

$$U = \frac{p\bar{d}}{\bar{T}} \quad (\text{Eq. 6-3, p. 6-2})$$

$$p = ER \quad (\text{Eq. 6-4, p. 6-2})$$

$$\bar{d}_T = h_1 + C_1 h_2 + C_1 C_2 h_3 + \dots + C_1 C_2 \dots C_{m-1} h_m \quad (\text{Eq. 6-5, p. 6-3})*$$

where

A = Availability—the probability that the component is operating or will operate satisfactorily if called on,

U = Unavailability—the probability that the component is not operating or will fail to operate satisfactorily if called on,

p = Probability that an error will be made and will not be recovered at that time,

$\bar{d}$ = Average downtime—the average time that transpires before the error is recovered,

* This equation is corrected from the one stated and defined on p. 6-3 of the Handbook.

$\bar{u}$ = Average uptime--the total time $\bar{T}$ between tests minus $\bar{d}$,

$\bar{T}$ = Average uptime plus average downtime--the average time between tests,

E = Probability of committing the error per act,

R = Probability of failing to recover the error at or about the time the error is committed,

$\bar{d}_T$ = Total average downtime--the sum of the $\bar{d}$ values for the time periods between the first test and the first check, between all subsequent checks, and between the last check and the next test,

h_1, h_2, h_3 = The number of hours between the test and the first check, the first check and the second check, and the second check and the next test, respectively (for the case in which there are two checks performed between tests), and

C_1, C_2, C_{m-1} = The probabilities of nondetection at the first, second, and last checks performed between the two tests, respectively.

Note 2: The October 1980 draft issue of the Handbook does not address the probabilities of forgetting to perform some required human action (or of performing that action incorrectly) when an operator fails to use the available written procedures. These probabilities will be addressed in the October 1982 final version of the Handbook. For the present set of exercises, use an HEP for errors of omission of .05 (.01 to .1) per step in the written procedures when no written procedures are used despite plant policy that they should be. That is, use .05 (.01 to .1) as the probability of forgetting any item when the operator relies on memory instead of using the written procedures. However, in using this HEP take into account any dependence that may link one or more items. Refer to the discussion on "Functional Relatedness Among Tasks" beginning on p. 7-13 of the Handbook.

Likewise, for errors of commission, there should be relative increases in the HEPs across the cases in which the written procedures are used correctly, misused, or not used at all, respectively. For these exercises, use the

nominal value for the HEP when the procedures are used correctly, double it when they are misused, and use the upper bound when they are available but not used. For example, considering a selection error made in choosing one control from a group of identical controls identified by labels only (Table 20-13, #1), use .003 (.001 to .01), .006 (.002 to .02), and .01 (.005 to .05) for the cases of correct, incorrect, and non-use of the written procedures.

Note 3: Chapter 15 in the Handbook describes the importance of administrative control, i.e., the kinds of checking of human performance mandated in a plant and the extent to which plant policies are carried out and monitored, including tagging controls and lock and key controls for valves and other components. One of the most serious errors that could be made in a human reliability analysis of a specific plant is to assume, without investigating, that all plant policies will invariably be carried out.

Reference to Item 6 on Page 13-7 of the Handbook notes that, "Since there is ample history in NPPs of valves left in inappropriate positions having affected the availability of safety systems, the user must evaluate the probability that NPP personnel will not faithfully follow plant policies and procedures. A probability of .99 that every person in an NPP intends to carry out plant policies and procedures (whether or not he makes errors of omission or commission in carrying out this intent) would indicate a plant with reasonably good quality control."

SECTION 2. EXAMPLE EXERCISES

Review the two example exercises contained in this section. Familiarize yourself with the format of the exercises and the application of the Handbook data to their solutions. Note how the Problem Worksheet and the Event Tree Worksheet are used. Instructions for the use and interpretation of the Problem Worksheet (Figure 1) are provided below.

INSTRUCTIONS FOR USING PROBLEM WORKSHEET

1. Exercise No./Problem No. - Identify exercise and problem.
2. Performance Shaping Factors - The use of these entries is optional. The problem scenarios frequently describe Performance Shaping Factors that affect the performance of an entire procedure. These factors, in turn, affect the selection and use of tables in Chapter 20 of the Handbook. A record of these general Performance Shaping Factors on the worksheet will serve as a reminder and facilitate the completion of the remainder of the worksheet.
3. Written Procedure Step No. or Task Description - Record the Task or Step No. and/or enough information to aid recall of the content of the action.
4. Dependence - If applicable, record the level of dependence between the actions stated. Enter ZD for zero dependence, LD for low dependence, etc.
5. Potential Error - Enter a brief description of the error(s) that could be committed by someone performing the step or action.
6. Table Number and Item Number - Identify table number and item number used to obtain the HEP associated with the error. (In determining the item number count the HEPs starting from the top of the table.)
7. Tabled HEP - Record the HEP and its lower and upper bounds.
8. Stress/Skill Factor - Record multiplier of HEP as a result of the combined stress/skill level associated with performance of the task described in the step or action.

PROBLEM WORKSHEET

Page of

1. Exercise No. _____ Problem No. _____

2. Performance Shaping Factors:

<u>Instruction</u>	<u>Experience</u>	<u>Stress Level</u>	<u>Tagging Level</u>
Written :	≤ 6 months	Low	1
≤ 10 items	> 6 months	Optimum	2
> 10 items		Mod. High	3
Oral		High	NA
None			

3. Written Procedure Step No. or Task Description	4. Depend- ence	5. Potential Error	6. Table No. & Item No.	7. Tabled HEP	8. Stress/ Skill Fac.	9. Adjusted HEP	10. Comments *

*Cite studies, if available, to back up any disagreement with the stated HEP.

Figure 1. Worksheet to be Used for Exercises 2 through 6

A-6

9. Adjusted HEP -

- a. Record the value of the HEP multiplied by the stress weight, or
- b. If you disagree with the tabled HEP (Column 7), record the new estimated HEP.

10. Comments - If you disagree with the Handbook values or models related to the errors described in Column 5 (e.g. HEPs, uncertainty bounds, dependence value, stress/skill weights), identify the basis of your disagreement (judgment or related data).

Possible sources of related data might be experimental studies, power generating industry reports, findings from other industries, etc. If studies or other documents are cited, identify them in enough detail that they can be obtained by the investigators. If the disagreement is based on personal judgment, describe why you disagree.

EXERCISE #1 (EXAMPLE)

MONTHLY TEST OF DIESEL GENERATOR

Background

The diesel generator test is a routine test performed under optimal stress. It is performed by an experienced auxiliary operator who is directed to perform it by the shift supervisor. The probability of the supervisor's failing to order the test will be disregarded. The area of concern is the influence of human actions on the post-test availability of the diesel generator (DG), not the mechanical reliability of the component. Assume that the generator is already in the automatic start mode and that it will start upon receipt of a start signal. Thus, if the test is not carried out at all, the availability of the generator is unaffected by human actions. If the test is carried out, the availability of the component after the test will depend almost entirely on whether step 4.7 in Figure 2 is carried out. Note that the performance of the generator during the 2-hour test does not affect the probability that the component will start if called on—only the status of the start mode (automatic or manual) affects this probability. Therefore, consider the probability that the operator has left the component in the manual start mode instead of returning it to the automatic mode.

Task Description

Exercise #1 is based on the written operating procedures of a nuclear power plant (NPP). The actual procedures include some plant-specific instructions which have been omitted from the condensed procedures shown in Figure 2.

Problem

In evaluating the performance of the test, address two questions:

1. What is the probability that the diesel generator will fail to start if it is called on after the test?
2. What additional recovery factors do you recommend?

EMERGENCY DIESEL GENERATOR NO. 3

INITIALS

1.0 Purpose

- 1.1 To determine that the emergency diesel generators will respond promptly and properly every month.

2.0 Initial Conditions

- _____ 2.1 Normal station operation will not be affected by this test.
- _____ 2.2 Unit will be at stable operating conditions with no anticipated large load changes or shutdown.
- _____ 2.3 The "No. 1 and No. 2" diesel will be ready for automatic start-up and placed in standby.
- _____ 2.4 Reference Initial Conditions and use OP-6 to perform this check.
- _____ 2.5 Verify that this test is to be performed on Unit 1.

3.0 Precautions

- _____ 3.1 Reference Precautions in OP-6.
- _____ 3.2 Advise Shift Supervisor to notify system operator that the load will be put on the system at Step 4.

4.0 Instructions

- _____ 4.1 Start the emergency diesel generator by following OP-6.
- _____ 4.2 Advise the Shift Supervisor to notify the system operator that the diesel generator will be synchronized onto the system.
- _____ 4.3 Manually synchronize the diesel with other power sources and assume load on diesel up to 2750 kW.
- _____ 4.4 After approximately two (2) hours of operation, notify the system operator that the diesel will be shutdown.
- _____ 4.5 Stop the diesel as stated in OP-6.

Figure 2. Procedures for Monthly Test of Emergency Diesel Generator (page 1 of 2).

INITIALS

Operator 4.6 Notify the electrical maintenance department that the test is complete.

Electrician Personnel from this department must verify that the mechanical terminal connections are tight on the voltage regulator. The individual making the check shall initial the space provided to indicate that he has made the verification.

 4.7 Verify that the diesel is set for automatic start when the test is complete.

 4.8 Notify the Shift Supervisor that the test is complete.

Completed By

Date

Figure 2.(Continued). Procedures for Monthly Test of Emergency Diesel Generator (page 2 of 2).

Performance Shaping Factors

1. The task is routine and the stress level optimal; i.e., normal.
2. The task is performed by an experienced auxiliary operator.
3. Written procedures with checkoff provision and having more than 10 items in the list are available.
4. There is no checking by another person.
5. The only indication of start mode status is at the diesel generator.

An Approach to Exercise #1

First we will discuss the failure of the DG to start. Given the preceding PSFs, we have defined (see Figure 3) five human error events: (1) failure to use the written procedure, (2) omitting step 4.7 when the procedure is not used, (3) failure to use the checkoff provision properly, (4) omitting step 4.7 when the checklist is used improperly, and (5) omitting step 4.7 when the checklist is used properly. The event tree for this portion of the exercise, which illustrates the five human error events previously defined, is as shown in Figure 4.

The estimated HEPs and uncertainty bounds for the events in Figure 3 involving the correct or incorrect use of procedures are found in tables in Chapter 20 of the Handbook as noted in the figure. The probability of failure to use the procedures is also found in Chapter 20. Summing the three failure paths (F_1 , F_2 , and F_3) from Figure 4 yields a probability of .009 that the diesel generator will be left in the wrong state and will not be available if called on. The unavailability of the component can be calculated using Eq. 6-3:

$$U = \frac{.009 \times 720}{720} = .009$$

We assume that the error will be detected the next time the generator is tested, therefore, $\bar{d} = 720$ (30 days times 24 hours) and $\bar{T}$ also equals 720. Since $\bar{d}$ and $\bar{T}$ are equal, the unavailability, U , numerically equals p , the probability of the original error.

PROBLEM WORKSHEET

Page 1 of 1

1. Exercise No. 1 Problem No. 1a

2. Performance Shaping Factors:

Instruction	Experience	Stress Level	Tagging Level
Written :	≤ 6 months	Low	1
≤ 10 items	< 6 months	Optimum	2
> 10 items	✓	Mod. High	3
Oral		High	NA
None			✓

3. Written Procedure Step No. or Task Description	4. Depend- ence	5. Potential Error	6. Table No. & Item No.	7. Tabled HEP	8. Stress/ Skill Fac.	9. Adjusted HEP	10. Comments
4.7 Verify diesel set for Auto start	ZD	A. Failure to use written Procedure.	20-22 #6	.05 (.01-.1)	-	-	-
		B Failure to use % provision properly.	20-21 #1	.5 (.1-.9)	-	-	-
		C Omit step 4.7, long list checkoff used properly.	20-20 #2	.003 (.001-.01)	-	-	-
		D Omit step 4.7, long list checkoff use improperly	20-20 #5	.01 (.005-.05)	-	-	-
		E Omit Step 4.7, Procedures not used.	see text	.05 (.01-.1)	-	-	-

Figure 3. Worksheet for Event Tree for Restoring Diesel Generator to Automatic Mode after Test

$$\begin{aligned}
 \text{Pr } [F] &= (.05 \times .05) + (.95 \times .5 \times .01) + (.95 \times .5 \times .003) \\
 &= .0025 + .00475 + .001425 \\
 &= .008675 \approx .009
 \end{aligned}$$

Figure 4. Event Tree for Restoring Diesel Generator to Automatic Start Mode after Test

If an inspection is made in the middle of the month (360 hours after the completion of the test), with an HEP of .05 for the inspection (from Table 20-9, p. 20-14, #3 from the Handbook*), $\bar{d}$ will change as follows:

$$\bar{d} = 360 + (.05 \times 360) = 378 \text{ h}$$

and

$$U = \frac{.009 \times 378}{720} = .004725 \approx .005$$

Note that in preparing the event tree, we used the tabled value of .5 for the probability that the checkoff requirements of the written procedures would not be followed properly. This is the value to use when no more information is available than was furnished here. In an actual situation, you might observe that the administrative control is excellent and judge that the probability of improper use of the checkoff provisions is much lower than the Handbook value of .5. On the other hand, in a plant with very poor administrative control, a value greater than .5 might be appropriate. Obviously, you would use the value that seemed to be most realistic.

In addressing the second question (What additional recovery factors do you recommend?), several approaches are feasible. The most obvious is that of providing human redundancy by requiring a second person to verify the status of the diesel shortly after completion of the test. If performed in response to an oral instruction as an individual task, the HEP for this checking task will be quite small. Let us assume that the supervisor is supposed to designate a second operator to check the switch—there is a probability of .01 that the supervisor will not do so (Table 20-22, p. 20-31, #1). The designated operator will be carrying out a verbal order, indicating an HEP of .001 for errors of omission (Table 20-18, p. 20-28, #1). The probability of his making a discrimination error is the basic HEP for errors of commission, .003 (Table 20-25, p. 20-34, #3). Thus, the probability that an incorrect switch status will be noticed by a checker can be illustrated by the event in Figure 5 and in the event tree in Figure 6.

*References to tables or pages beginning with "20-" are from Chapter 20 of the Handbook.

PROBLEM WORKSHEET

Page 1 of 1

1. Exercise No. 1 Problem No. 1b

2. Performance Shaping Factors:

Instruction

Written :

≤10 items

>10 items

Oral ✓

None

Experience

≤6 months

>6 months ✓

Stress Level

Low

Optimum ✓

Mod. High

High

Tagging Level

1

2

3

NA ✓

3. Written Procedure Step No. or Task Description	4. Depend- ence	5. Potential Error	6 Table No. & Item No.	7. Tabled HEP	8. Stress/ Skill Fac	9. Adjusted HEP	10. Comments
Verify diesel set for Auto Start.	ZD	A. Supervisor fails to order 2 nd open to check status switch	20-22 #1	.01 (.005-.05)	-	-	-
		B. 2 nd open. fails to check status of switch	20-18 #1	.001 (.0005-.005)	-	-	-
		C. 2 nd open fails to recognize an incorrect status (if incorrect)	20-25 #3	.003 -	-	-	-

Figure 5. Worksheet for Development of Event Tree for Additional
Checker for Test Procedures Shown in Figure 2

$$\begin{aligned}
 \Pr [F] &= (.01) + (.99 \times .001) + (.99 \times .999 \times .003) \\
 &= .01 + .00099 + .002997 \\
 &= .013987 \approx .014
 \end{aligned}$$

Figure 6. Event Tree for Addition of a Checker for Test Procedures Shown in Figure 2

Summing the failure paths (F_1 , F_2 , and F_3) for the recovery factor tree yields a failure probability of .014. Assuming that there are no additional checks of the diesel's automatic start status other than that of the auxiliary operator who performs the test and that of the second operator who checks the status soon after completion of the test, the probability that the diesel generator will be left unavailable after the completion of the test (given the recovery factor of human redundancy) is $U = .009 \times .014 \approx .00013$. Thus, the assignment of a second operator to serve as a checker will reduce human unreliability by a factor of 71; i.e., $.009 \div (.009 \times .014) = 71.4$. Keep in mind that this sizeable reduction in human unreliability is based on the issuance of an oral instruction by the checker's supervisor. Ordinarily, the incorporation of human redundancy in the form of a checker will not result in such a substantial reduction in the probability of an unrecovered error.

EXERCISE #2 (EXAMPLE)

PERIODIC PUMP TEST

Background

This exercise involves the monthly test of a high-pressure injection pump, part of the Emergency Core Cooling System (ECCS). The major concern is that the system tested be available for use after the test is completed (restored to operating condition). The test requires that the pump be valved out of (isolated from) the ECCS and tested. The valves are then restored so that the pump is again available for ECCS use. This exercise requires that the position of three valves be changed: two motor-operated valves (MOVs) and one large locally operated valve (see Figure 7). The switches for the MOVs and for the pump are located in the control room.

Task Description

A hypothetical procedure for the monthly test is presented in Figure 8. Note that errors committed on steps 1 through 6 in the procedure will not affect the post-test availability of the system. Such errors will only invalidate the test. For example, an error of omission on step 1 would prevent the carrying out of step 4, and errors of omission or commission on steps 1 through 6, such as operating a wrong valve, would also result in a bad test. However, only steps 7 through 9 are crucial for the availability of the system after the test; therefore, the analysis should begin with step 7. If, in performing steps 7 through 9, the operator notices an earlier error, he will correct it and start the test again.

Problems to be Worked

You are to estimate the probability that the ECCS system tested will be available if called on after the test. The system will not be available if any of the valves are in the wrong state or if the pump is in the manual mode. Potential errors of omission or commission for other items of equipment will be ignored for this problem.

Using the nominal HEPs in Chapter 20 of the Handbook, derive two probability

Figure 7. Schematic of Components in Monthly Test of a High-Pressure Injection Pump

INJECTION PUMP TEST

1. Set SI pump with switch #2SW1880 to "Manual."
2. Close SI pump valves 2MOV1880A and 2MOV1880B.
3. Open SI pump recirc. valve #2V1880C.
4. Start SI pump, switch #2P1880.
5. After 15 minutes, record flow rate in pump discharge leg.

Flow rate _____

6. Stop SI pump, switch #2P1880.
7. Close SI pump recirc. valve #2V1880C.
8. Open SI pump valves 2MOV1880A and 2MOV1880B.
9. Set SI pump switch #2SW1880 to "Auto."

Figure 8. Hypothetical Test Procedure for Monthly Test of High-Pressure Injection Pump

estimates of the post-test availability of the ECCS based on the following different assumptions about the test situation.

Performance Shaping Factors

General

1. A Level 2 tagging system is used, as described in Table 15-3, p. 15-11, of the Handbook. This is the usual type of tag control employed in nuclear power plants (NPPs). Tags are not accounted for individually—the operator may take an unspecified number of tags and use them as required. In such a case, the number of tags in his possession does not provide any cues as to the number of items remaining to be tagged. Note that with a Level 2 tagging system, no adjustments to the Handbook's tabled HEPs are necessary. Note also that in this exercise errors of tag preparation will not affect availability. If a tag is made out incorrectly and the wrong valve is changed as a consequence, the test will be invalid. Ultimately, the condition will be corrected and the test re-run. Therefore, for the purpose of this exercise it can be assumed that the valves and switches in question are in their respective correct positions for normal operating conditions prior to the test.
2. The test is a routine operation, placing no unusual demands upon the operator. This scenario reflects an optimal stress level, as defined in Chapter 17 of the Handbook.
3. For the purposes of this exercise, the test (steps 7, 8, and 9) will be conducted by an operator using the written procedures. Checkoff is not required.
4. Upon completion of the test, the operator will sign the test form and give it to the shift supervisor. The shift supervisor will note the flow rate reading on the form and will verify that the operator has signed the form.
5. The operator has more than six months experience.

Specific to Problem 2a

1. The MOV switches are the type that does not have to be held by the operator until its operating cycle is complete.

2. The MOV switches are close together and are operated as a unit, i.e., completely dependent, and they are readily distinguishable from other switches on the panel.
3. The locally operated rising-stem valve, 2V1880C, is readily identifiable.
4. There is a position indicator on the locally operated valve, and the valve does not stick while being restored.

Specific to Problem 2b

1. The MOV switches are the type that has to be held while the valve cycles and the switches are widely separated so that restoration involves two separate acts.
2. The MOV switches and the rising-stem manual valve are located among similar appearing items, at least one of which is also tagged, so that selection errors must be considered.
3. The manual valve sticks when restored and there is no position indicator on it. Consequently, there is a probability of failing to restore it completely.

An Approach to Exercise #2

The task in Exercise #2 is to "Estimate the probability that the ECCS system will be available if called on after the monthly test." For the first case, the MOVs are treated as a completely dependent unit and the locally operated rising-stem valve is distinct from the others nearby and does not stick as it is being restored. The problem worksheet and the event tree for this case, as shown in Figures 9 and 10, consist of only three branches, depicting errors of omission for steps 7 through 9 of the procedure.

Using the nominal HEP of .003 for each step, the probability of failure is $1 - .997^3 \simeq .01$. Note that no credit is allowed for the fact that the supervisor signs off on the procedures since his signature indicates only that he has approved the flow rate recorded at step 5 and that he has seen the operator's signature on the form. In some plants, this type of supervisor signoff is erroneously considered a verification of test accuracy. In reality, it verifies only the operator's signature.

For the second estimate, the assumptions are that the MOVs are separated and have to be held until activation, that the MOVs and the manual valve could be confused with other valves, and that the rising-stem manual valve sticks as it is restored and has no position indicator. In this case, errors of omission and of selection (commission) must be considered for each valve and for the pump switch. The problem worksheet is shown in Figure 11. The event tree for the restoration now consists of 10 branches, shown in Figure 12.

In the event tree shown in Figure 12, every branch in the success path must be accomplished for the system to be available. Using the nominal HEPs, the probability of failure is $1 - (.995^2 \times .997^8) \simeq .03$.

Note: It has been estimated that the probability of a rising-stem valve's sticking is .001. We assume that if a rising-stem valve does not stick as it is being restored, the probability of the operator's failing to restore it completely is negligibly small. If we include this assumption in our analysis, the probability of system failure does not change materially; i.e., $1 - (.995 \times .997^8)$ still rounds to .03.

AFTER YOU HAVE COMPLETED THE REVIEW OF SECTION 2, PROCEED TO SECTION 3.

PROBLEM WORKSHEET

Page 1 of 1

1. Exercise No. 2 Problem No. 2a

2. Performance Shaping Factors:

Instruction

Written :

≤10 items ✓

>10 items

Oral

None

Experience

≤6 months

>6 months ✓

Stress Level

Low

Optimum ✓

Mod. High

High

Tagging Level

1

2 ✓

3

NA

3. Written Procedure Step No. or Task Description	4. Dependence	5. Potential Error	6. Table No. & Item No.	7. Tabled HEP	8. Stress/ Skill Fac.	9. Adjusted HEP	10. Comments
7. Close SI Pump recirc Valve 2V1880C	-	A. Failure to close valve 2V1880C	20-20 #4	.003(.001-.01)	-	-	-
8. Open SI Pump valves 2MOV1880A & 2MOV1880B	CD	B. Failure to open 2MOV1880A and 2MOV1880B	20-20 #4	.003(.001-.01)	-	-	-
9. Set SI pump switch 2SW1880 to "Auto"	-	C. Failure to set switch 2SW1880 to "Auto"	20-20 #4	.003(.001-.01)	-	-	-

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Figure 9. Worksheet for the Development of Human-Caused Unavailability of High-Pressure Injection Pump after Monthly Test

$$\text{Pr}[F] = 1 - .997^3 \approx .01$$

Figure 10. Event Tree of Human-Caused Unavailability of High-Pressure Injection Pump after Monthly Test

PROBLEM WORKSHEET

Page 1 of 2

1. Exercise No. 2 Problem No. 2b

2. Performance Shaping Factors:

<u>Instruction</u>	<u>Experience</u>	<u>Stress Level</u>	<u>Tagging Level</u>
Written :	≤ 6 months	Low	1
≤ 10 items <u>✓</u>	> 6 months <u>✓</u>	Optimum <u>✓</u>	2 <u>✓</u>
> 10 items		Mod. High	3
Oral		High	NA
None			

A-25

3. Written Procedure Step No. or Task Description	4. Dependence	5. Potential Error	6. Table No. & Item No.	7. Tabled HEP	8. Stress/ Skill Fac	9. Adjusted HEP	10. Comments
7. Close SI Pump recirc Valve 2V1880C 8. Open SI Pump Valves 2MOV1880A & 2MOV1880B	-	A Omit step 7	20-20 #4	.003(001-.01)	-	-	-
		B Select wrong valve	20-14 #3	.005(002-.02)	-	-	-
		C Fail to close valve fully	20-14 #2	.005(002-.02)	-	-	-
	ZD	D Omit 2MOV1880A	20-20 #4	.003(001-.01)	-	-	-
		E Select wrong Mov switch	20-14 #7	.003(001-.01)	-	-	-
		G Fail to open Mov fully	20-14 #1	.003(001-.01)	-	-	-
		H Omit 2MOV1880B	20-20 #4	.003(001-.01)	-	-	-
		I Select wrong Mov switch	20-14 #7	.003(001-.01)	-	-	-
		J Fail to open Mov fully	20-14 #1	.003(001-.01)	-	-	-

Figure 11. Worksheet for the Development of the Modification of the Figure 10 Event Tree by Incorporating Some Human Factors Problems

PROBLEM WORKSHEET

Page 2 of 2

1. Exercise No. 2 Problem No. 2b (cont)

2. Performance Shaping Factors:

Instruction	Experience	Stress Level	Tagging Level
Written :	≤ 6 months	Low	1
≤ 10 items	> 6 months	Optimum	2
> 10 items		Mod. High	3
Oral		High	NA
None			

3. Written Procedure Step No. or Task Description	4. Dependence	5. Potential Error	6. Table No. & Item No.	7. Tabled HEP	8. Stress/Skill Fac.	9. Adjusted HEP	10. Comments
9. Set S.I pump Switch 1880 to "Auto"	-	K Omit resetting 2 SW1880 to "auto"	20-20 #4	.003 (.001-01)	-	-	-

Figure 11.(continued) Worksheet for the Development of the Modification of the Figure 10 Event Tree by Incorporating Some Human Factors Problems

Figure 12. Modification of the Figure 10 Event Tree by Incorporating Some Human Factors Problems

SECTION 3. PROBLEM EXERCISES

Work out the four problem exercises contained in this section. Fill out the supplied Problem Worksheets, construct the Event Trees, and calculate the $Pr[F]$ for each tree.

EXERCISE #3

READJUSTMENT OF BISTABLE AMPLIFIERS AFTER REACTOR TRIP

Background

In this exercise, a reactor trip has occurred. It has been determined that the trip was caused by a miscalibration of all three bistable amplifiers monitoring the output of the level sensors in the pressurizer. The specified trip point for high-level trip is 93%, but the amplifiers were tripping at 88%. A calibration technician has been assigned to readjust the three amplifiers and is working as rapidly as possible to minimize the downtime for the plant. After the three amplifiers are adjusted, the technician must retest the coincidence circuits to verify that the reactor trip signal will occur when any two amplifiers trip.

Task Description

No written procedure will be used for this task. The technician will perform the following operations from memory.

1. Obtain the reference voltage source which simulates the inputs from the level sensors in the pressurizer.
2. Adjust the reference voltage to a value of .93 on the digital readout on the simulator.
3. Connect the simulator to amplifier #1.
4. Apply voltage to amplifier #1.
5. Adjust trip to proper voltage level (.93). The point at which the trip occurs is indicated on a digital readout on the simulator.
6. Repeat steps 3, 4, and 5 for amplifiers #2 and #3.
7. Test the coincidence circuits.

The coincidence circuits will be tested in conjunction with an operator in the control room who will confirm the alarm trips when the calibration technician trips successive pairs of amplifiers. Under normal operating

conditions, the probability of his failing to note the status change is negligibly small.* The HEP for this two man task will therefore be disregarded, as will the recovery factor it affords. Upon completion of this test, the plant may be brought up to normal operation.

Problems to be Worked

Problem 3a. Assume that the technician is experienced and that he is responding to a direct order from his supervisor. Determine the probability that the recalibration task will be carried out correctly. Prepare an event tree outlining the various steps and their associated HEPs. Indicate the most likely errors that the technician may make. The recalibration task is defined as steps 1 through 5 of the procedure. The coincidence circuit test is not considered to be part of this problem.

Problem 3b. After making the above calculations, draw an event tree for a bounding analysis. State the assumptions you are making for both the upper and lower bounds, assuming an experienced technician for the best case and a novice for the worst case. An example of a bounding analysis is illustrated in Figure 13.

Performance Shaping Factors

1. No written procedure is used.
2. The technician is responding to an oral instruction from his shift supervisor.
3. Because of the time pressure, assume a moderately high level of stress.
4. The correct adjustment of all three amplifiers is completely dependent on the initial adjustment of the simulator—there are no alerting cues in this situation. The technician expects to find all the amplifiers out of adjustment by a considerable amount. Therefore, if he adjusted the simulator incorrectly, there would be no reason for him to become suspicious when each of the amplifiers required a large adjustment.

* Item 1, p. 11-15 of the Handbook, states, "Confirming status change after an operation, such as changing the status of an MOV, is an active task. The operator has initiated the change and ordinarily will watch the indicator lights for confirmation of the response. Under normal operating conditions, the probability of his failing to note the status change is negligibly small and will be disregarded."

Best-Case Analysis: For each success path S through the tree, use the lower bounds of the HEPs and upper bounds of the HSPs. Sum the terminal values at each S and subtract from 1.0 to obtain the lower bound of the overall failure probability.

Worst-Case Analysis: For each failure path F through the tree, use the upper bounds of the HEPs and lower bounds of the HSPs. Sum the terminal values at each F to obtain the upper bound of the overall failure probability.

Assume all HEPs = .01 (.005 to .05).

- Lower bound of system failure probability (using HEP of .005, HSP of .995)

$$\begin{aligned}
 &= 1 - [S_1 + S_2 + S_3 + S_4 + S_5 + S_6] \\
 &= 1 - [ab + aBc + AdeG + AdeGh + ADij + ADiJk] \\
 &= 1 - .99995 = .00005
 \end{aligned}$$

- Upper bound of system failure probability (using HEP of .05, HSP of .95)

$$\begin{aligned}
 &= F_1 + F_2 + F_3 + F_4 + F_5 \\
 &= aBC + AdE + AdeGH + ADI + ADiJK \\
 &= .00499 + .005
 \end{aligned}$$

- Nominal system failure probability (using HEP of .01, HSP of .99)

$$= .0002 \text{ (using either equation)}$$

Figure 13. An Example of a Bounding Analysis with Its Associated Event Tree

5. Assume that the simulator is designed so that it will not operate if it is incorrectly connected to the amplifiers. Disregard any errors in hook up, since the technician will have to correct them in order to perform the task.
6. Assume that the simulator has been calibrated properly.

EXERCISE #4

CORE SPRAY SYSTEM TEST

Background

This exercise consists of conducting a monthly test of the core spray pumps of the Emergency Core Cooling System (ECCS). It involves changing and restoring valves and recording the performance of the pumps.

Task Description

The procedure that is relevant to this exercise is taken from a longer set of actual procedures. It is reproduced almost verbatim in Figure 14. There are certain points relevant to this procedure that should be kept in mind during the analysis. These points include:

1. Certain valves appear under different designations within the procedure. For example, MOV1402-4A in step 2 appears as 1402-4A in steps 3.b and 4. This is one indication of a less-than-optimum written procedure.
2. Although this is a test procedure, there is no checkoff provision. The operator's signature at the end of the procedure does not constitute checkoff as defined in the Handbook.
3. No credit for human redundancy should be given for valve positioning. The supervisor checks the flow rate and pressure and to see that the operator signed the form. He does not inspect the valve restorations themselves. Valve restorations are the only part of the procedure that affects the post-test availability of the system.
4. Instead of providing a valve and control restoration list or a post-test restoration procedure, the procedure as written includes only a blanket statement to the effect that all control switches should be returned to their normal operating positions.
5. There is always the possibility that the operator will not use the written procedure (except to fill in the required flow and pressure values) but will rely on his memory instead. The current issue of the Handbook provides an HEP for this possibility but

CORE SPRAY SYSTEM TEST

1. Verify that the ECCS Fill System is in service and vent the Core Spray System. (The tasks for step 1 of this procedure have been omitted here to facilitate the analysis.)
2. Set up the following valve alignment:

<u>Valve No.</u>	<u>Alignment</u>	<u>Normal Position</u>
MOV1402-3A	open	open
MOV1402-24A	closed	open
MOV1402-25A	closed	closed
MOV1402-38A	open	open
MOV1402-4A	closed	closed
Valve 1402-6A	open	open
MOV1402-3B	open	open
MOV1402-24B	closed	open
MOV1402-25B	closed	closed
MOV1402-38B	open	open
MOV1402-4B	closed	closed
Valve 1402-6B	open	open

3. a. Start the core spray pumps, 1402A and 1402B.
b. Open valves 1402-4A and 1402-4B.
c. After 15 minutes, record the pump flow from flow indicators FI 1450-4A and FI 1450-4B, and record the pump discharge pressure from pressure indicators PI 1450-1A and PI 1450-1B.

<u>Pump</u>	<u>Indicator</u>	<u>Flow</u>	<u>Indicator</u>	<u>Pressure</u>
1402A	FI 1450-4A	_____	PI 1450-1A	_____
1402B	FI 1450-4B	_____	PI 1450-1B	_____

Note: Flow rates should be 4500 gpm, and minimum discharge pressure should be 230 psig.

4. Close valves 1402-4A and 1402-4B, and stop pumps 1402A and 1402B.
5. Return all control Switches to NORMAL operating position.

Unit No. _____ Date/Time _____
Operator _____ Shift Supervisor _____

Figure 14. Abbreviated Procedure for a Core Spray System Test

fails to provide an estimate of the probability of an error of omission given that the operator relies on his memory. Use the value .05 (.01 to .1). (See Note 2, p. 3 of this document.)

Problems to be Worked

Problem 4a. Starting with step 2 of the procedure, derive an estimate of the unavailability of the system after the monthly test. Assume that the core spray system will not be available unless all valves and controls are restored to their normal operating positions after the test.

Problem 4b. Assume that the test is performed routinely every three months and that an operator is assigned to check the status of the valves and controls of the core spray system at monthly intervals between the tests. If this inspection is done without error, assume the recovery factor will be 1.0 for the ECCS. Determine the unavailability of the system given the two intervening inspections using the appropriate equations from Chapter 6 of the Handbook, as revised and presented in the Introduction section of this document.

Performance Shaping Factors

1. The test will be conducted by a single operator.
2. Written procedures not requiring checkoff are available.
3. The procedures should be considered as a long list.
4. Level 2 tagging is used.
5. The test is routine, placing no unusual demands on the operator.
6. Upon completion of the test, the operator will sign the test form and give it to the shift supervisor. The supervisor will check the flow rate and pressure reading on meters in the control room and will verify that the operator has signed the form.
7. All like-numbered switches for channels A and B are located next to each other. Because of their locations, the fact that they are in the same procedural step, and the fact that they can be identified easily, the manipulations of the control room switches for MOV1402-4A and MOV1402-4B are considered to be completely dependent. Similarly the manipulations of pump switches 1402A and 1402B in the control room

are considered to be completely dependent. These pump switches are of the type that is spring-loaded to return to the normal operating position after activation.

8. In general, valves prefixed MOV are motor-operated valves of the type that is operated from the control room by momentary activation of switches labelled with the same MOV designation used on the valves themselves. All other valves are rising-stem, locally operated manual valves with position indicators on the valves.

EXERCISE #5

EMERGENCY PROCEDURES: STATION BLACKOUT

Background

In this exercise, a station blackout has just occurred. All auxiliary power has been lost except d.c. battery power. When this condition happens, several annunciators and associated alarms indicate the nature of the problem. However, the most salient cue in the control room is the automatic change-over from a.c. to d.c. lighting.

The operations hierarchy at this plant is as follows: Shift Supervisor, Control Room Operator, Assistant Control Room Operator, First Auxiliary Operator, Second Auxiliary Operator (A02), and General Maintenance Operator. The A02 reports to the Control Room Operator or the Shift Supervisor. He is the second most junior member of the Operations Staff. His level of experience can be critical.

The specific concern in this exercise is the determination of adequacy of response of the A02. His duties are asterisked in the set of procedures shown in Figure 15. Assume that it is critical that the A02 initiate his tasks within five (5) minutes of the blackout in order to preclude damage to safety-related equipment.

Even though a loss of auxiliary power is not an immediately life-threatening situation, the plant does follow an emergency procedure. Knowledge of this, plus his own lack of experience, will place the A02 under some level of stress. (Oak Ridge National Laboratory surveys suggest that operators consider this to be one of the three most stressful response situations encountered in nuclear power plant operations. The operators estimate that the highest level of stress they will be under is a moderately high level of stress.)*

This particular plant has an entry- and access-control system that enables the computer to keep track of the approximate locations of all plant personnel.

* P.M. Haas and T.F. Bott, "Criteria for Safety-Related Nuclear Power Plant Operator Actions: A Preliminary Assessment of Available Data," USNRC Report NUREG/CR-0901, July 1979.

A. Symptoms

1. All normal lighting lost; dc lighting on
[others omitted here for brevity]

B. Immediate Actions

1. Attempt to energize 4160 V buses
2. Initiate emergency feed per p. 2
3. Secure letdown by closing CV-1333 and 1334

C. Follow-up Actions

1. If 4160 V buses cannot be energized
 - a. Protect secondary plant and reduce dc power demand per p. 3
 - b. Verify RCS temp $>50^{\circ}\text{F}$ margin to saturation
 2. If 4160 V buses are energized, follow OP 1672.3 (Partial Power Loss)
-

p. 2 -- Manual OTSG Feed

1. Proceed directly to Steam Line Penetration Room and manually open MS Supply MOVs CV-3226 and CV-3213 to Emergency FW Pump Turbine.
- *2. Proceed to N. Piping Penetration Room; secure Seal Return by manually closing CV-1337. Begin Emergency Feed to A OTSG by manually opening either Emergency FW Valve CV-3202 or CV-3250.
- *3. Proceed to Emergency FW Pump Room; open either FW valve (in adjacent Piping Room) CV-3215 or CV-3219.
- *4. Contact Control Room; modulate Feed to B OTSG by throttling CV-3215 or CV-3219, modulate Feed to A OTSG by throttling either discharge crossover valve (in Pump Room) CV-3436 or 2317 to maintain stable temp. $\text{TH} < 570^{\circ}\text{F}$.
- *5. Monitor Emergency FW Pump Suction and Discharge Pressures; notify Shift Supervisor if Suction Pressure falls below 10 psig. (Disch. press. should be >1000 psig.)

* Duties of the A02

It requires that a badge be inserted and a personal identification number be entered into a control console for passage from one room to another. In the event of a loss of power, this control system fails with the doors open to egress but locked to entry, in which case access is afforded by using keys. Master keys are provided that permit the opening of any door in the operator's field of action. There is a set of keys designated for each operator position. They are passed on to the next person at shift change. It is assumed that each person will carry his keys with him when out of the control room for any reason. If he does so, the operator will be able to make his way through the plant should a station blackout occur while he is outside the control room. Based on direct observations it was determined that it takes the A02 30 seconds to find his master key and unlock a door, remove his key, and enter.

The physical layout of the part of the plant area relating to this exercise is shown in Figure 16. The North Piping Penetration Room (NPPR) is one floor below the tagging office and the control room. The Emergency Feed-water Pump Room (EFPR) is one floor below the NPPR. From the control room, the A02 must pass through one controlled entry door to reach the NPPR.

From there, he must pass through two such doors, one of which is an exit, to reach the EFPR. During an interview the operator estimated that, coming from the control room, the A02 will be able to make it to the NPPR "within two minutes, anyway." Assume the estimate to be two minutes.

Task Description

As can be seen from the procedure (Figure 15), the A02 is responsible for performing steps 2 through 5 of page 2. Step 2 should be initiated within five minutes into the blackout.

It is assumed that the A02 knows his duties in the case of a station blackout—he need carry no written procedures with him to perform his tasks. If he is not in the control room at the time of the blackout, the A02's first duty is to proceed toward the control room immediately or to contact the control room by telephone. It is likely that he will be paged before he has time to get there and will be given his instructions. In any event, it is assumed that the control room operator or the assistant control room operator will tell the A02 where to go and what to do.

* Key controlled doors

Figure 16. Layout of Plant Area Relevant to Exercise 5.
(Only valves called out in the procedure are shown although there are several valves in each room.)

Problems to be Worked

Analyze the activities of the A02 considering the following two scenarios.

Problem 5a. The blackout occurs while an experienced A02, i.e., one having more than six months experience, is in the control room.

Problem 5b. The blackout occurs while a novice A02, i.e., one who has less than six months experience, is in the tagging office.

For each situation, determine the probability of the A02's failing to perform all of his assigned tasks successfully. Include the probability that the A02 may freeze and never initiate the task. Develop an event tree for each A02 using the handbook Chapter 20.

In addition, for each situation, make an assessment of the time elapsed from the onset of the emergency to the A02's initiation of the first task.

Performance Shaping Factors

1. Written procedures are not carried by the A02. He has been trained to perform his tasks without them.
2. The A02 is considered to be under a moderately high level of stress.
3. In the emergency, the A02 will stop on his way to the controlled access area long enough to throw on a lab coat, shoe covers, and gloves before entering. He will not take time to undress completely and put on coveralls.
4. The site operator's estimate of the transit time for an experienced A02 from the control room to the NPPR is two (2) minutes. He also estimates no significant time difference for the novice operator coming from the tagging office. (Consider the possibility that the operator may be underestimating the performance time through ignorance, possible halo effect, or a desire to make a good impression on the interviewer. Data from Oak Ridge National Laboratory suggest that operator estimates of response times should be doubled, especially when decision-making is involved.*

*P.M. Haas and T.F. Bott, Criteria for Safety-Related Nuclear Plant Operator Actions: A Preliminary Assessment of Available Data," USNRC Report NUREG/CR-0901, July 1979.

5. All manual valves are of the large, turning wheel type (about 12 inches in diameter). They are fairly well isolated from other valves in the same room and are clearly labelled as to their valve numbers and functions.
6. Where the procedures call for the manipulation of one valve or another, e.g., CV-3202 or CV-3250, whatever the A02's response is, it will be treated as one event on the event tree.
7. Step 4 in the procedure requires that two valves be throttled. The A02 is in contact with the control room by telephone. He modulates the position of the valves based upon the instructions given by the control room operator who is monitoring a display. One likely error is that the control room operator might misread his display. This would lead to the valve's being left in an incorrect position. Since the A02 is not at fault here and since the evaluation involves his ability to complete his assigned tasks within the time constraints, disregard this type of error.
8. The measured time for the A02 to open a door with the master key is 30 seconds.
9. In both cases (experienced or novice), the A02 and the rest of the operations staff see their tasks as one complete job—that of supplying emergency feedwater to steam generators A and B. Therefore, it is assumed that the performance of the A02's tasks are completely dependent with respect to errors of omission.
10. Reversal errors involve closing a valve that should be open and vice versa. They will be disregarded in the analysis, since the A02 is in almost constant contact with the control room.
11. Step 5 in the procedure, monitoring the emergency feedwater pump suction pressure, is an activity that is not required until almost two hours into the blackout. Therefore, it should not be included in the emergency procedure event trees.

EXERCISE #6

RISK ASSESSMENT FOR VALVE RESTORATION FOLLOWING MAINTENANCE

Background

An activity common to many maintenance operations is the restoration of the subsystem after the maintenance has been completed. The scenario^{*} presented relates to maintenance that has been performed on a safety-related item of equipment. The procedure requires that a number of locally (manually) operated valves be manipulated prior to the maintenance in order to isolate the subsystem. Upon completion of the maintenance these valves must be restored to their original position.

The principal means of ensuring proper valve alignment before and after maintenance is the use of tags, logs, and other administrative controls. In addition, in some plants, the valve status is displayed on an Engineered Safety Feature (ESF) panel. (Reminder: see Note 3, page 4 of this document.)

Task Description

While specific procedures and policies differ from plant to plant, Figure 17 presents an assumed flow of events associated with the maintenance of safety-related equipment for this particular problem.

Problem 6a. A single locally operated ESF valve that has an associated position indicator on the ESF panel is not restored after the maintenance. Determine the probability that the operator will detect the deviant valve position.

The following questions should be considered for Problem 6a.

1. What sort of tagging/logging procedure (what level) is required by the plant?
 - What percentage of the time is the procedure actually followed?
 - What are the restoration requirements?

^{*}This scenario is not a representation of a specific plant. It addresses a generic problem common to all NPPs.

Before maintenance is performed:

- isolation of the subsystem must be approved by the shift supervisor
- each component affected must be issued a tag, which is entered into a log book
- maintenance personnel perform maintenance acts; operators perform status changes of tagged items

After maintenance is performed:

- shift supervisor verifies (or has someone verify) that the maintenance was performed
- the log book identifies which tags relate to that maintenance act
- the tags are removed as their respective components are restored
- tags are then returned to the control room, where they are checked against the log book to determine whether all of them have been removed
- position indicators on ESF panel are checked to ensure proper valve alignment

Figure 17. General Flow of Operator Actions before and after Maintenance is Performed

2. What are the type and location of the indicator?
 - How is position/state of the component displayed?
 - Is the display isolated?
 - Is the display labelled clearly?
3. How many indicators are being considered?
4. How often is the ESF panel scanned/inspected for deviations?
 - Is the scan/inspection always performed on schedule?
 - What are the requirements of the scan/inspection?

Performance Shaping Factors for Problem 6a.

1. The isolation and maintenance were performed correctly.
2. Level 1 tagging control is assumed. (Note that a Level 1 tagging system does not preclude errors of commission.)
3. The position indicator is a standard "red for open, green for closed" backlit display located on the ESF panel. It is clearly labelled and visible.
4. The ESF panel is scanned formally at the beginning of each shift. Using a checklist, a man inspects the position of each component on the panel.
5. The deviant indicator on the ESF panel is the only factor in the control room that alerts the operator to the position of the valve.

Problem 6b. Assume that there is no position indicator for the misaligned valve. The only recovery factor is a walk-around inspection performed once per shift.

What is the probability that the incorrect valve status will be detected within 30 days or less?

Performance Shaping Factors for Problem 6b.

1. There are three shifts per day.
2. There are three inspectors available per shift and each inspector is equally likely to be assigned to the walk-around inspection.
3. There is one walk-around inspection per shift.
4. There is zero dependence between inspectors.

5. The valve in question is a rising-stem valve with no direct indication of what its status should be.

YOU ARE NOW READY TO PROCEED TO THE QUESTIONNAIRE (ITEM 4)

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APPENDIX B

CANDIDATE SOLUTIONS FOR
HUMAN RELIABILITY ANALYSIS PROBLEMS
(Workbook Exercises 3 through 6)

Based, in part, on
An Appendix to the NREP Chapter on
Human Reliability Analysis Methodology

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An Approach to Exercise #3

In this exercise, the supervisor gives a direct order to the operator to perform a task which he then checks to see was performed. In this case, the HEP for the operator's unrecovered failure to initiate the task is negligible (Table 20-18, p. 20-28, #6).

For our initial analysis we will assume that an experienced technician performs the tasks. The tasks to be performed are as follows (along with their unmodified HEPs):

<u>Task</u>	<u>HEP</u>	<u>Table</u>
"A" - adjust simulator (involves one digital readout)	.001 (.0005 to .005)	20-5, (p. 20-11, #2)
"B" - adjust amplifiers	Negligible	20-5, (p. 11-15*)

Adjustment of the amplifiers involves turning a control until a change in a status indication is obtained, such as a lamp turning on or off. Although the HEP for this task is usually negligible, we are assigning a value of .001 because of the stress level involved. This value is somewhat arbitrary--it is a reasonably small number that reflects our feeling that, under stress, even very well-practiced, easy tasks are subject to disruption. By the same reasoning, for the first task, we take the nominal HEP of .001 (.0005 to .005) and double it to .002 (.001 to .01) to allow for the effects of stress; for the second task we take the value of .001 (.0005 to .005) as the HEP for adjustment of each of the three amplifiers.

* Item 1, p. 11-15 of the Handbook, states, "Confirming status change after an operation, such as changing the status of an MOV, is an active task. The operator has initiated the change and ordinarily will watch the indicator lights for confirmation of the response. Under normal operating conditions, the probability of his failing to note the status change is negligibly small and will be disregarded."

Note that the adjustment of all three amplifiers is completely dependent on the adjustment of the simulator--there are no alerting cues in this situation. The technician expects to find all the amplifiers out of adjustment by a considerable amount. Therefore, if he adjusted the simulator incorrectly, there would be no reason for him to become suspicious when each of the amplifiers required a large adjustment.

The event tree for the recalibration consists of just two branches, as shown in Figure 1. (The success probability for branch b is raised to the third power because there are three operationally similar amplifiers.)

Using the above modified HEPs, the failure probability is $1 - (.998 \times .999^3) \approx .005$.

Regarding the most likely error that would be made, the error in setting up the simulator would be limited to misreading a digital display. One of the most common errors would be that of confusing an 8 for a 3, resulting in the trip point's being set for 98% instead of 93%.

To do a bounding analysis, we assume an experienced technician for the best case and a novice for the worst case. Therefore, for the novice, we will double the above HEPs given for the experienced personnel. For Task "A," the HEP for the experienced technician is .002 (.001 to .01); for the novice it is .004 (.002 to .02). For Task "B," the corresponding values are .001 (.0005 to .005) and .002 (.001 to .01). For the best case, we use the lower limits of the HEPs for the experienced technician, and for the worst case, we use the upper limits of the HEPs for the novice, in both cases using the HEPs that have been modified for stress. Thus, the lower bound is

$$1 - (.999 \times .9995^3) \approx .0025$$

and the upper bound is

$$1 - (.98 \times .99^3) \approx .05.$$

Error	HEP	Table
A = Adjust simulator incorrectly	.002 (.001 to .01)	20-5
B = Adjust at least 1 amplifier incorrectly	.001 (.0005 to .005) (per amplifier)	20-5

Figure 1. Event Tree of Readjustment of Three Bistable Amplifiers after Reactor Trip.

An Approach to Exercise #4

In approaching a solution to this problem, let us define the possibilities for human error. The only errors we will describe are those associated with the restoration of all switches to their normal operating positions since failure to restore any given switch(es) is the definition of system unavailability. The system event tree is shown in Figure 2; a discussion of the events appears below.

1. The operator could fail to use the written procedures in performing this test. Since we have no information dealing with the administrative controls at this plant, we do not know how likely or unlikely it is that this happen. Therefore, we use the nominal value of .05 (.01 to .1) for this probability (Table 20-22, p. 20-31, #6).
2. The operator could forget to close MOVs 1402-4A and 1402-4B. The problem states the rationale for assuming complete dependence between the switches for these valves, so we will treat them as a unit. If the procedures are used, the HEP for this task is .01 (.005 to .05), the probability of omitting an item from a long list that does not require checkoff (Table 20-20, p. 20-29, #5). If the procedures are not used, the HEP is .05 (.01 to .1), as discussed in Section #1, p. 3. This estimate does not include any recovery factors. Since we are assuming complete dependence between the two switches (making the conditional HEP of the second switch 1.0, given an error on the first one), the HEP of .05 is the probability that both will be overlooked.
3. The operator may fail to stop pumps 1402A and 1402B. These pumps are also completely dependent and will be treated as a unit. The task called for here is in the same procedural step as that calling for the closing of MOVs 1402-4A and 1402-4B. Because of this less-than-optimum written procedure, some level of dependence exists between the two sets of switches for errors of omission. We have no information on the relative positions of the switches for the MOVs and pumps. Certainly they are all in the control room, but they could be separated by several yards. If so, the operator could be distracted or interrupted between performing one task and the next and could

$$S_T = S_1 + S_2 \approx .961$$

$$F_T = F_1 + F_2 + F_3 + F_4 + F_5 + F_6 \approx .0391$$

Error	HEP	Table*
A = Failure to use the written procedures	.05 (.01 to .1)	20-22 (p. 20-31, #6)
B = Failure to close MOVs 1402-4A and 1402-4B, given that the procedures are used	.01 (.005 to .05)	20-20 (p. 20-29, #5)
B' = Failure to close MOVs 1402-4A and 1402-4B, given that the procedures are not used	.05 (.03 to .3)	see text
C = Failure to stop pumps 1402A and 1402B, given that the procedures are used	.005 (.003 to .03)	see text
C' = Failure to stop pumps 1402A and 1402B, given that the procedures are not used	.03 (.02 to .2)	see text
D = Failure to open MOVs 1402-24A and 1402-24B, given that the procedures are used	.02 (.01 to .1)	see text
D' = Failure to open MOVs 1402-24A and 1402-24B, given that the procedures are not used	.05 (.01 to .1)	see text

Figure 2. Event Tree for Restoring Core Spray System to Normal Operating Condition after Test.

fail to perform the second task. So the level of dependence is not complete, but still is considerable; assume high dependence between closing the MOVs and stopping the pumps. Use the same nominal HEP for stopping the pumps as was used for closing the MOVs. To reach an actual estimate of the probability of an error here, the conditional HEP for the second task (stopping the pumps) will reflect modifications made to this nominal value based on the dependence model given in Table 20-2, p. 20-7. The resulting values assume success in closing the MOVs. It is not necessary to consider the possibility of pump stop errors if the MOVs are not closed since forgetting to close the MOVs already results in system failure as defined in the problem. The nominal HEP for stopping the pumps is .01 if written procedures are used and .05 if the task is done from memory. Reference to Table 20-2 shows that these HEPs become, respectively, .005 and .03 when high dependence exists. If we retain the same relative uncertainty bounds for the conditional as for the basic HEPs, the full expressions of the HEP become .005 (.0025 to .025) (rounded to .005 (.003 to .03)) for the case in which procedures are used and .03 (.015 to .15) (rounded to .03 (.02 to .2)) for the case in which procedures are not used.

4. The operator could fail to open MOVs 1402-24A and 1402-24B. This task is not specified in the procedure but is covered in the blanket order to return all control switches to their normal operating positions. We assume that, since in the 12 tasks called for in step 2 only these two tasks had to be changed, the operator will not refer to step 2 to perform this task but will rely on his memory. Given that he used the procedures in the first place, we would not expect this HEP to be as low as that for the case in which the MOVs were called out for restoration by their labels, nor would we expect this HEP to be as high as that for the case in which the operator relied completely on his memory. Thus, the HEP should be greater than .01 and less than .05. The Handbook offers no explicit guidance for this particular situation, so we suggest doubling the .01 HEP. Using the same relative uncertainty bounds, the derived HEP is .02 (.01 to .1), given that he used the procedures initially but did not use them as a restoration checklist. For the case in which the operator relied

only on his memory, we used the same HEP of .05 (.01 to .1) as was used for the other cases of not using the written procedures. The probability of failure for the system, as defined, is equal to one minus the sum of the two success paths, $1 - (.917 + .044) \approx .04$. This, then, is the value of U , the probability that the system will be unavailable if called on between the tests due every 3 months. To investigate the effects of two intervening inspections on the probability of system unavailability, assume that one such inspection is made 1 month after the test, that one is made 2 months after the test, and that the HEP for each inspection is .05 (.01 to .1), Table 20-9, p. 20-14, #3. Thus, a time line like the one shown below can be said to represent these events.

In terms of the variables defined in the Introduction to these exercises,

$$p = .04 \quad \bar{T} = 2160 \quad h_1 = h_2 = h_3 = 720 \quad C_1 = C_2 = .05$$

and

$$d_{\bar{T}} = 720 + (.05 \times 720) + (.05 \times .05 \times 720) \approx 757.8$$

Therefore,

$$U = (.04 \times 757.8) \div 2160 \approx .014 .$$

Thus, the incorporation of the two monthly checks reduces the system unavailability by a factor of about $.04 \div .014 \approx 2.86$.

An Approach to Exercise #5

The solution of this problem requires quite a bit of troubleshooting on the part of the analyst, especially with respect to the time requirements. In both cases (experienced and novice operators), the A02 (and the rest of the operations staff) sees his tasks as one complete job: that of supplying emergency feedwater to steam generators A and B. Therefore, we will assume that the performances of the A02's tasks are completely dependent with respect to errors of omission. Errors of commission are defined below for each task.

1. Close CV-1337 -- This is a manual valve. Errors of selection and reversal* are possible.
2. Open CV-3202 (or CV-3250) -- This is a manual valve. (Remember we are considering "either...or" commands to require one manipulation.) Errors of selection and reversal* are possible.
3. Open CV-3215 (or CV-3219) -- This is a manual valve. Errors of selection and reversal* are possible.
4. Throttle CV-3215 (or CV-3219) -- This is a manual valve. Errors of selection and reversal* are possible. Though not in the same procedural step as the order to open the same valve, this instruction to throttle CV-3215 is still considered to be completely dependent on the previous CV-3215 instruction with respect to errors of selection.
5. Throttle CV-3436 (or CV-2317) -- The manipulation of this manual valve is called out in the same procedural step as that for CV-3215. However, this is the crossover discharge valve for the A steam generator; whereas, CV-3215 is the main feedwater valve for the B steam generator. They are not considered to be dependent with respect to errors of commission.

There is a possibility that the entire task will not be initiated. For the first case, this would involve an experienced A02's forgetting to perform his primary responsibility and the two senior staff members' forgetting to

*Reversal errors involve closing a valve that should be open and vice versa. These will be disregarded in the analysis since the A02 is in almost constant contact with the control room and receives feedback from them.

order the task. Given that the task is called out in the procedures and that all three people have considerable operating experience, their joint probability of failing to recall the need for these is negligibly small and will be disregarded here. (This points out the favorable effects of human redundancy.)

From Table 20-14 (p. 20-21, #2), the estimated basic HEP for errors of selection in the operation of manual valves is .005 (.002 to .02). This tabled HEP assumes that the valves are among similar-appearing valves in the same position as themselves. This does not hold true for this case, so a lower HEP should be used. Also, these valves are the main valves controlling major subsystems. They are labeled clearly as to function and valve number and can be easily recognized by their locations. This prominence makes them less susceptible to errors of selection, especially since instructions pertaining to their manipulations are given referring to their functions. Based on these considerations, we designate the lower bound of the tabled value, or .002 (.001 to .01), as the estimated BHEP for the experienced A02 for errors of selection. This BHEP must now be modified to reflect the effects of a moderately high level of stress. According to Table 20-23, p. 20-32, #3, this becomes .004 (.002 to .02). The event tree for the experienced A02 is shown in Figure 3.

In addressing the question of whether an experienced operator (in the control room at the time of the blackout) could respond in time, consider all the time estimates given for the following events.

<u>Event</u>	<u>Time</u>
Decision and travel time from control room to NPPR	4 minutes
Entry into NPPR	<u>0.5 minute</u>
Total time to initiation	4.5 minutes

We see that this best-case scenario barely provides enough time to initiate the tasks on schedule. Now let's look at a worst-case scenario.

For the second case, given that the A02 is a novice, there is some probability that he himself will not remember his responsibilities during a

$S_1 \approx .98$ without recovery

Since all error limbs are fully recovered,

$S_T = 1.0$

Event	HEP (Bounds)	Table
A = Failure to initiate task	Negligible	See text
B = Select wrong valve for CV-1337	.004(.002 to .02)	See text
C = Select wrong valve for CV-3202	.004(.002 to .02)	See text
D = Select wrong valve for CV-3215	.004(.002 to .02)	See text
E = Select wrong valve for CV-3215 (complete dependence)	0.0	20-2 (p. 20-7, #1)
G = Select wrong valve for CV-3436	.004(.002 to .02)	See text

*R stands for Recovery Factor in this case. Feedback from the control room would alert the A02 to having made a mistake. He could correct it on the spot.

Figure 3. Event Tree for Experienced A02 Responding to Station Blackout.

station blackout. He may freeze in the Tagging Office and make no response, he may completely forget his duties and call for instructions, or he may pause before going to the control room because he is confused. The probability of his freezing and making no response is highly unlikely because of his training, but we assign it a token probability of .0001 because of the moderately high stress level. We assign the two senior staff members a joint probability of failing to order the tasks done of .00001. If the A02 merely waits in the Tagging Office or exhibits uncertainty in responding, the probability is still negligibly small that he will fail to receive proper instructions. He may call or go to the control room himself, be paged by the control room, or be prompted to contact the control room by someone in the Tagging Office.

The estimated BHEP for errors of selection of .005 (.002 to .02) (Table 20-14, p. 20-21, #2) is modified the same way it was for the experienced operator. The BHEP for the task itself is now .002 (.001 to .01). However, as seen in Table 20-23 (p. 20-32, #9), the effects of moderately high stress are more pronounced for a novice than for an experienced operator. The estimated HEP for the novice under the stated conditions is .008 (.004 to .04). The event tree for the novice operator is shown in Figure 4.

The time estimates for the novice operator are listed below with their corresponding events.

<u>Events</u>	<u>Time</u>
Decision and travel time to control room (collect keys, receive instructions)	3 minutes
Travel time, control room to NPPR	6 minutes
Entry into NPPR	<u>0.5 minute</u>
Total time to initiation	9.5 minutes

In the operator interviews, it was determined that it would take a novice no appreciably greater amount of time to reach the NPPR than it would an experienced man. We judge that this is an overly optimistic assumption because it fails to account for the greater probability of indecision on the part of the novice. This plus the fact that the novice was out of the control room at

$S_1 \approx .968$ without recovery

Since all error limbs are fully recovered,

$S_T = 1.0$

Event	HEP (Bounds)	Table
A = Failing to initiate task (joint probability)	10^{-9}	See text
B = Select wrong valve for CV-1337	.008(.004 to .04)	See text
C = Select wrong valve for CV-3202	.008(.004 to .04)	See text
D = Select wrong valve for CV-3215	.008(.004 to .04)	See text
E = Select wrong valve for CV-3215 (complete dependence)	0.0	20-2 (p. 20-7, #1)
G = Select wrong valve for CV-3436	.008(.004 to .04)	See text

*R stands for Recovery Factor on this case. Feedback from the control room would alert the A02 to having made a mistake. He could correct it on the spot.

Figure 4. Event Tree for Novice A02 Responding to Station Blackout.

the time of the accident leads us to assume that he could hope to reach the NPPR in no fewer than 9.5 minutes. This is clearly unacceptable in terms of system requirements.

An Approach to Exercise 6

Problem 6a

Two of the Performance Shaping Factors described in this problem contribute to the estimated low probability (10^{-5}) of an unrecovered failure to restore the valve. First, the plant has a Level 1 tagging system as defined in Table 15-3, p. 15-11 of the Handbook. Second, there is a pair of indicator lights in the control room indicating whether this locally operated valve is closed (green light) or open (red light). The detection of a control room indication of an inappropriate valve position during a shift inspection of the panels while using a checklist constitutes a recovery factor for an error of omission or commission in valve restoration after maintenance.

Considering the restoration of a specific component after maintenance on it or on related equipment, the question of interest is the detection of the deviant indicator corresponding to the misaligned component.

The event tree associated with this solution of the problem is shown in Figure 5 and the events are defined in Table 1.

Problem 6b

This problem illustrates the degrading effect of eliminating the valve position indicator lights from the ESF Panel. The only recovery factor in such a system is the walkaround inspection conducted during each shift.

For the conditions assumed in this problem, Table 8-2 (p. 8-12 #3) lists an estimated probability of .89 for detecting a deviant condition in 30 days or less.

Figure 5. Event Tree for Detection of Failure to Restore ESF Valve after Maintenance.

Table 1. Definitions of Events in Figure 5.

<u>Event</u>	<u>HEP (Bounds)</u>	<u>Source</u>
A = the failure to remove the tag and restore the valve. This is an error of omission. It is the same as failing to initiate the restoration task.	.001 (.0005 to .005)	Table 20-15 (p 20-23, #3)
B = the failure to initiate the shiftly inspection. The operator for any given shift may entirely forget to perform the check of the ESF panels. This is a failure of administrative control since this check is a standard plant procedure.	.001 (.0005 to .005)	Table 20-22 (p 20-31, #2)
C = failure to use written procedures. In this case, after deciding to perform the inspection, the operator chooses not to use the available written procedures.	.01 (.005 to .05)	Table 20-22 (p 20-31, #3)
D = the failure to use the checklist properly. Given that the operator has decided to perform the check of the ESF panels, he may fail to use the check-off provision of the checklist properly; i.e., checking then signing for one display at a time.	.5 (.1 to .9)	Table 20-21 (p 20-30, #1)

Table 1 (Cont.)

<u>Event</u>	<u>HEP (Bounds)</u>	<u>Source</u>
E = failure to check the status of the indicator in question, given that the checklist is used improperly. If a checklist with provision for checkoff is not used properly, no credit for the checkoff provision is assumed. Since the entire ESF system is checked, a long list is assumed.	.01 (.005 to .05)	Table 20-20 (p 20-29, #5)
G = failure to check the status of indicator in question, given that the checklist is used properly. This is the probability that any one item from a long list of items will be omitted when using a checklist with check-off provision.	.003 (.001 to .01)	Table 20-20 (p 20-29, #2)
H = failure to detect an improper status cue of an indicator lamp. This is a reversal error in which the operator looks at the indicator to check its status but does not perceive that its status is incorrect. The general HEP for an error of commission is used.*	.003 (.001 to .01)	Table 20-25 (p 20-34, #3)
J = failure to check the status of the indicator in question, given that the written procedures are available but not used.	.05 (.01 to .1)	See page 3 of the problem set.

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