UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 10 1984

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 140, "HANDBOOK OF HUMAN RELIABILITY ANALYSIS WITH EMPHASIS ON NUCLEAR POWER PLANT APPLICATIONS"

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Reference (1) "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications -- Final Report," NUREG/CR-1278, August 1983.

(2) "A Procedure for Conducting a Human Reliability Analysis for Nuclear Power Plants -- Final Report," NUREG/CR- 2254, May 1983.

(3) "Reactor Safety Study -- An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," NUREG-75/014, 1975.

(4) Memorandum, "Request for Endorsement of Proposed Research," (RR-RES-80-13), September 1980.

(5) Memorandum, "Endorsement of Data Analysis Research," (RR-RES-80-25), February 27, 1981.

(6) Memorandum, "NRR Research Needs in PRA Methodology," November 30, 1982.

(7) "Conference Record of the 1979 IEEE Standards Workshop on Human Factors and Nuclear Safety: The Human, the Key Factor in Nuclear Safety," Institute of Electrical and Electronic Engineers (IEEE), Inc., December 1979.

(8) "Conference Record of the IEEE Standards Workshop on Human Factors and Nuclear Safety: The Man-Machine Interface and Human Reliability, An Assessment and Projection," Brookhaven National Laboratory, September 1981.

(9) "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications -- Draft Report for Interim Use and Comment," NUREG/CR-1278 (Draft), October 1980.

(10) "Peer Review Study of the Draft Handbook for Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278," Sandia National Laboratories, SAND82-7056, January 1983.

(11) "Critical Appraisal of the Draft Report (NUREG/CR-1278) -- Handbook of Human Reliability Analysis with Emphasis on NPP Applications," SRS/ASG/1317, Systems Reliability Service, United Kingdom Atomic Energy Authority, Warrington, England, April 1981.

(12) "Peer Review Comments on NUREG/CR-1278," Sandia National Laboratories, SAND82-1196, December 1982.

Introduction

This research information letter transmits the results of research on a handbook (Ref. 1 and Enclosure) for conducting human reliability analysis (HRA) segments of probabilistic risk assessments (PRAs) at nuclear power plants (NPPs). The primary purpose of the handbook is to present methods, models and human error probability (HEP) data enabling persons having a general understanding of human reliability concepts and terminology to make quantitative and qualitative assessments of the likelihood of human errors in NPPs that could affect the availability and operability of engineered safety features and components. A second purpose of the handbook is to enable the user to recognize NPP equipment design, operational and administrative policies and practices, and other human factors problems that affect human error likelihood so that improvements in these areas can be considered. More specifically, the handbook compiles into a single document information from over 300 sources concerning state-of-the-art techniques, models, procedures and estimated HEP data necessary to carry out HRAs specified by current NRC PRA procedures guidelines (NUREG/CRs-2300 and 2728).

This research is responsive to requirements established by the Reactor Safety Study (Ref. 3), RES Request for Endorsement (Ref. 4), NRR Endorsement of Research (Ref. 5), NRR Request for Research (Ref. 6), IEEE Workshops (Refs. 7 and 8), TMI Action Plan (NUREG-0660, Task II.C., Reliability Evaluation and Risk Assessment), and by RES/NRR reliability evaluation specialists' experiences to date in PRAs. These experiences indicate that a significant risk factor is human error -- notwithstanding the quality and redundancy of plant hardware. Furthermore, PRAs for the most part, consider only human errors of omission. Only minimal consideration is given to human errors of commission that could also have a significant impact on predictions of risk.

This research was conducted as part of the Human Reliability Research Program described in NUREG-0985, under the direction of the Human Factors and Safeguards Branch, Division of Risk Analysis. The overall objective of the Human Reliability Research Program is to develop a comprehensive technical support system for human risk analysis segments of NRC reliability evaluation programs, especially those programs employing PRA methodologies. The handbook (Ref. 1) is an initial milestone of that research program.

The handbook was developed over a period of 6 years (1978-83) by Sandia National Laboratories (SNL), sub-contractors, consultants and reviewers. Sub-contractors included Human Performance Technology (HPT), Inc. of Thousand Oaks, CA, Technology for Energy Corporation (TEC) of Chattanooga, TN and Systems Applications Inc. (SAI) of New York, NY. Consultants and reviewers included human reliability specialists from U.S. civilian government and military agencies, utilities, industry and academia and from nine foreign countries.

This research was initiated in 1978 with SNL to compile, into a single document, information on existing methods, models and estimated HEP data which could be used for conducting HRAs at NPPs. An initial draft of the handbook was prepared by SNL for review by participants in a 1979 IEEE Workshop at Myrtle Beach, SC (Ref. 7). Comments and suggestions received from workshop participants were considered, and where appropriate, incorporated in a second draft of the handbook (Ref. 9) which was published by the NRC in October 1980. Between 1980 and its publication as a final report in August 1983, the draft handbook underwent a series of technical reviews to assess its adequacy, completeness and usefulness for supporting HRAs. First was a review of the handbook by participants in a 1981 IEEE Standards Workshop at Myrtle Beach, SC (REF. 8). Second, a draft handbook exercise project (Ref. 10) was conducted by HPT, Inc. involving 29 human reliability experts, from the U.S., Europe, South Africa and Japan, who solved NPP human performance problems using HRA techniques, models and HEP data from the draft handbook. Third, a formal review (Ref. 11) of the draft handbook involving 13 European human reliability experts was conducted by the United Kingdom Atomic Energy Activity (UKAEA) under the sponsorship of the Electric Power Research Institute (EPRI). Fourth, informal reviews (Ref. 12) of the draft handbook were also conducted among 60 human reliability specialists from the U.S., Europe and South Africa. Finally, the draft handbook is known to have been used as a reference document in at least 20 U.S. PRAs, and eight PRAs at foreign NPPs. The final research product (Ref. 1) incorporates findings from the aforementioned exercises, peer reviews, etc., and therefore, contains state-of-the-art (1982-83) techniques, models and estimated HEP data for conducting HRA segments of PRAs at NPPS.

Results

The handbook (Ref. 1) consists of 23 chapters and 11 appendices organized into four major sections. The first section presents basic definitions of terms, guidelines for viewing the human in a system context, discussion of factors that influence human performance in a system, and principles of good human factors design. The second section presents analytic methods for identifying tasks and task elements to be included in HRAs, developing event trees using a Technique for Human Error Rate Prediction (THERP), relating HRAs and PRAs, identifying potential sources of HEP data, computing uncertainty bounds, and conducting sensitivity analyses. The third section presents a series of procedures developed from the scientific literature for modeling the influences of several shaping factors on human performance. Included are interdependence of behavior steps in human action sequences, information displays, manual controls, oral and written instructions, management and administrative controls, stress, staffing and experience levels, and accident recovery. The fourth section presents tables of estimated HEP data

and case studies employing some of the procedures described in earlier sections of the handbook. In summary, and most importantly, the handbook brings together in a single document information on contemporary procedures and error probability data for carrying out HRA segments of PRAs utilizing the THERP method.

A workbook (Ref. 2) serves as a companion document to the handbook. It illustrates how handbook techniques, models, procedures and estimated HEP data can be used in performing HRAs, and provides several examples that can be used as training aids for persons who wish to perform a systematic HRA.

Evaluation

The handbook (Ref. 1) is currently a one-of-a-kind reference document for conducting HRAs. The state of the art in HRA is barely beyond its infancy. Until recently, many systems analysts did not attempt to quantify the effects of human performance in system reliability or safety studies. Even today, some systems analysts omit human performance considerations, or they make gross assumptions about the probability of human error. Experience in military, space, and commercial man-machine systems indicates that the human has a major role in both accident propagation and mitigation. Despite some limitations in the coverage and accuracy of certain human performance estimates, use of the techniques, models, procedures and estimated HEP data from the handbook by persons having a general understanding of reliability concepts can lead to improved risk assessments at NPPs.

The handbook in its present form provides contemporary models, techniques, procedures and estimated HEP data that should enable users to perform HRAs either for PRA purposes or to identify human factors problems at NPPs that are serious enough to warrant changes in equipment or procedures. The handbook can be used to perform HRAs for operating plants or for plants in any stage of design or development.

Although the handbook is oriented toward human errors in the operation of engineered safety equipment, the models, procedures, and estimated HEPs are relevant or adaptable to all aspects of NPP design and operation where there is an interaction of people and plant systems and equipment.

The handbook addresses explicitly only the kinds of tasks that have been studied in PRAs to date. These include tasks performed during normal operating conditions and after abnormal events. Despite this limitation, the user should be able to apply much of the material to other tasks since there can be considerable similarity in the human factors aspects of different NPPs and NPP systems despite differences in equipment and other engineering considerations.

Chapter 20 of the handbook presents estimated HEP data, their uncertainty bounds, and other related information addressing a variety of actions performed by personnel at NPPs under normal, transient and accident conditions. HEP estimates, etc., should be used with caution since they are primarily derived data. In some cases, they are extrapolations from performance measures only

marginally related to NPP operations (e.g., military weapons development, space program, oil refining). In other cases they represent the authors' best judgment based on their experience in other complex man-machine systems and their background in experimental and engineering psychology. Chapter 20 tables contain, for example, human error probability data (i.e., point estimates, uncertainty bounds) related to:

- o diagnosing NPP control room abnormal events.
- o taking rule-based actions after diagnosis of abnormal events.
- o preparing written materials (e.g., procedures).
- o executing administrative controls.
- o recalling oral instructions.
- o selecting unannunciated displays.
- o recording quantitative information from unannunciated displays.
- o operating manual controls.
- o selecting locally operated valves.
- o detecting malfunctioning valves.
- o tagging and locking systems.
- o detecting errors made by other personnel.
- o responding to multiple annunciators.
- o reading annunciated legend lights.
- o scanning unannunciated deviant displays.

This research program resulted in a handbook (Ref. 1 and Enclosure) for systematically carrying out HRAs at NPPs. Since August 1983, it has been distributed to over 600 human factors professionals and other interested individuals throughout the world, and is being used in PRAs currently in progress at six U.S. NPPs and three foreign NPPs (Taiwan, Italy, Switzerland). The handbook is designed for use by persons with some knowledge of human reliability methodologies. To this end, RES has set up an HRA course as part of a curriculum in PRA using the handbook and companion workbook (Ref. 2) as instructional material. Finally, the handbook is intended as a living document to be updated as more and better HEP data and human performance models (diagnosis, recovery, decision making) become available from NRC's Human Reliability Research Program and other sources. In this regard, while we feel that the handbook is a very worthwhile and useful product and a very important source of information on contemporary human performance modeling techniques, we recommend that it be used with caution least its use lead to unwarranted assumptions about the precision with which human error probabilities can presently be estimated. Validation of the methods, procedures and data presented in the handbook, through operational experience, will continue to be a high priority of this office. Therefore, we urge handbook users to provide us with feedback on any problems they encounter, or comments and suggestions they have, as the result of applying handbook techniques, models, procedures and estimated HEP data in solving practical problems of HRA.

We recommend that the handbook be used:

- o by persons having a general understanding of reliability concepts, in NRC and industry sponsored PRAs or other reliability assessments, to achieve improved estimates of human error likelihood in NPP operations.

- by persons with a general understanding of reliability concepts, to assist in identifying and reducing man-man and man-machine safety problems at NPPs.

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o by persons with a general understanding of reliability concepts, to assist in identifying and reducing man-man and man-machine safety problems at NPPs.

/S/
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