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Developing an Emergency Procedures Writers' Guide: A Case Study

Idaho National Engineering Laboratory

Lee T. Ostrom, Ph.D.; EG&G, Idaho; Idaho Falls, ID.
Susan G. Hill, Ph.D.; EG&G, Idaho; Idaho Falls, ID.
James A. Close; EG&G, Idaho; Idaho Falls, ID.
James D. Lash; EG&G, Idaho; Idaho Falls, ID.
William C. Hemming; EG&G, Idaho; Idaho Falls, ID.

Abstract

The Nuclear Regulatory Commission's (NRC) Three Mile Island Task Force identified the need for incorporating human factors and technical writing guidance into the development of function-oriented emergency operating procedures (EOPs). The NRC recommended that this guidance be contained in plant specific EOP writers' guides which should be developed by the plant for use by the plant's EOP developers (NUREG-0737 Supplement, 1982). Based on industry success with post-Three Mile Island procedure philosophy, Management of the Department of Energy's Advanced Test Reactor (ATR) facility made the decision to restructure their EOPs using the post-Three Mile Island guidelines and incorporating human factors principles into the process. To further enhance the procedures, ATR Management wanted to ensure the lessons learned by the NRC while inspecting commercial reactor facilities' EOPs were incorporated. To meet these goals a multi-disciplinary team was assembled and tasked with the development of the writers' guide and procedures. The process of developing the writers' guide included a needs assessment, gathering procedure writing information, deciding on the EOPs' format, writing the writers' guide, and then revising the writers' guide based on the outcome of the verification and validation of the procedures and operator feedback. The resulting EOP writers' guide contains state-of-the-art human factors guidance for writing procedures.

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Introduction

The purpose of this paper is to discuss the development of the EOP writers' guide for the ATR. An overview of procedure development is presented for completeness. In certain instances procedure writing information is presented. Please see Hill et al. (1990) for a more thorough discussion of the human factors principles of writing procedures.

Background

Almost immediately following the March 28, 1979 accident at Three Mile Island-2, the Nuclear Regulatory Commission (NRC) initiated a Special Inquiry Group to investigate the causes and consequences of the accident (NUREG-0600, 1979). This group found numerous problems with the procedures that were being used at that time. Included in these deficiencies were:

- Lack of consistency between nomenclature used in procedures and that used on panel components.
- Instructions for control actions seldom provided an indication of the correct (or incorrect) system response.
- The procedures placed an excessive burden on operator short-term memory.
- Charts and graphs were not integrated into procedure text.
- It was not always clear which procedures pertained to which situations.
- There was no formal method for getting operator inputs into procedure updates.
- Procedures were deficient in assisting the operators in diagnosing events.
- Procedures were directed toward responding to specific events. They were not oriented toward restoring lost or degraded safety functions in the plant.

- Training on procedures was not closely associated with the procedures.

Since that time the body of knowledge available to write and implement emergency procedures has greatly increased. The NRC and Institute for Nuclear Power Operations (INPO) have published numerous documents on writing procedures. The NRC's Three Mile Island Task Force identified the need for incorporating human factors and technical writing guidance into the development of function-oriented emergency operating procedures (EOPs). Function-oriented EOPs are written to address a broad range of conditions and recovery actions necessary to maintain a facility in a safe condition. Function-oriented EOPs provide the operator guidance on how to restore and maintain critical safety functions (CSFs). These are a limited set of safety functions which are the most important in maintaining the barriers to the release of radioactive material from a nuclear reactor core in the event of an accident. In contrast, event-oriented EOPs are written to address single or specific events. Event-oriented procedures require the operator to diagnose the specific event causing the disturbance of operation in order to correctly select the procedure that will mitigate the consequences of the event. The NRC recommended that the guidance for writing EOPs be contained in plant specific emergency procedure (EP) writers' guides which should be developed by the plant for use by the plant's EP developers (NUREG-0899, 1982).

In 1989 the NRC published the results of the Emergency Operating Procedures Inspection Program (NUREG-1358). During this inspection program the NRC inspected 29 commercial nuclear power plants (NPPs) of both the pressurized water reactor (PWR) and boiling water reactor (BWR) types. This inspection program found there were still numerous problems with EOPs. Most of these problems stemmed from deficiencies in the writers' guide, EOP production, verification and validation, and training on the procedures.

The problems with the writers' guide included:

- Guidance for formatting certain types of steps was lacking or vague in the writers' guide.

- The writers' guide was written after the EOPs.

- Readability standards for EOPs were not addressed in the writers' guide.
- Human factors principles were not always consistently applied in the writers' guide.
- The writers' guide was independently developed, with little input from prospective users.

Other problems encountered included:

- A team approach was not always utilized in their development.
- Care was not taken when EOPs were copied to ensure they were readable and complete.
- The EOPs were also not always verified and validated correctly.
- In some cases verification and validation (V&V) were omitted.
- Training was not always done correctly.

ATR Procedure Development Process

Operations management for the ATR facility at the Idaho National Engineering Laboratory saw the need for reformatting their EOPs. The ATR is a Department of Energy (DOE) test reactor facility that performs many experimental functions. ATR management wanted to ensure the new procedure development process produced technically correct and usable EOPs and incorporated all lessons learned by the NRC during its inspections of at commercial nuclear power plants (NPPs). To accomplish this a multi-disciplinary team of human factors, trainers, operators, procedure writers, and reactor safety personnel was assembled and tasked with developing an ATR plant specific EP writers' guide. Each speciality on the team had a purpose. The human factors personnel supplied human factors guidance on writing procedures. The training personnel considered how the procedures would be received by the operators and developed EOP training materials as the procedure

development process proceeded. They were also involved in deciding the trade off between level of detail in the procedures and training. Operations personnel supplied technical and operational information about the reactor facility. Procedure writers supplied information concerning the current method of procedure generation and technical writing guidance. They also supplied information as to how commercial reactor facilities wrote procedures and supplied guidance on the development of the procedure network. Reactor safety personnel coordinated the effort, provided input as to the facility's needs, and served as an interface between all writers' guide/procedure development personnel and the facility management. Reactor safety personnel also called in other specialists as needed.

In developing formal EOPs for the ATR the following occurred:

1. A needs assessment was conducted

2. Information on writing procedures was obtained.

3. A rough draft of the writers guide was produced.

4. The procedure format was determined.

5. The writers' guide was modified to reflect the procedure format.

6. Procedure writing began.

7. Development was begun on the procedure training materials.

8. As procedures were completed they were validated and verified. The V&V also involved evaluating how well the transitions between procedures worked.

9. In conjunction with the V&V, operators began to receive training on the EOPs.

10. The procedures and writers' guide were modified according to the outcome of the V&V and operator feedback.

11. The operators received training on the completed, new procedures.

12. The writers' guide was put in final form.

Please note in many cases these steps were performed in parallel.

Needs Assessment

The first step in developing the plant specific EP writers' guide was to conduct a needs assessment. This phase sought to determine if facility personnel had a preference for procedure format (text or flowchart), the level of detail of the procedures, and style information. It also sought to determine where the EOPs would be in the overall facility procedure hierarchy. To help answer these questions the expertise of the multi-disciplinary team was called upon. The team contained operations specialist with both commercial, pressurized water reactor and boiling water reactor backgrounds. Traditionally, PWR commercial reactors use text-formatted EOPs and BWR commercial reactors use flowchart-formatted EOPs. This varied background allowed the ATR to fully explore which type of EOP format was best suited to the facility, based on the existing state of emergency procedures, training, and need.

Obtaining Procedure Writing Information

A literature search was conducted at about the same time the needs assessment was conducted in order to obtain as much information concerning the writing of procedures as was available. Although this is a very important topic, there was no single "best" source of information located. Also, most of the information on writing procedures is classified as "good practice" and has not been proven by experimentation. Most of the procedure writing information has been developed by the commercial nuclear industry and the NRC.

The sources of information for the writers' guide included existing ATR procedures and writers' guide, NRC guidelines and requirements (NUREG-0899, 1982; NUREG/CR-5228, 1989; NUREG/CR-4613, 1987; NUREG 0737, 1982; NUREG/CR-4617, 1987; NUREG-1981, 1987), nuclear industry work group guidelines (INPO 83-007, 1983), and academic sources (Bailey, 1982). In July of 1990 the Department of Energy issued an order on Conduct of Operations (DOE Order 5480.19, 1990) that provides guidance on writing operations procedures. Because NRC and INPO guidance was used in developing the ATR emergency procedures, they meet the requirements of the DOE order.

Rough Draft of Writers' Guide Produced

After procedure writing information was obtained a rough draft of the writers' guide was produced. This draft was to be used to help determine the final format of the procedures. The draft contained information concerning writing both flowchart-formatted and text-formatted procedures. The examples used in the rough draft were of a general nature and were not samples of plant-specific procedures.

Procedure Format

Using the results of the needs assessment, the rough draft of the writers' guide, and commercial experience, a decision was made concerning the format of the EOPs. To ensure higher acceptance by the operators, text-formatted procedures were adopted applying a commonly used PWR-NPP dual-column style. The dual-column format also distinguishes the EOPs from other plant procedures. Figure 1 is an example of this format with an overly simplistic, but brief example. This format incorporates two primary columns. The first column is the "INSTRUCTIONS" column. It contains the actions the user performs under expected conditions. The right-hand column is the "RESPONSE NOT OBTAINED" column. This column contains the contingency actions the user performs if the actions in the "INSTRUCTIONS" column cannot be successfully performed. This structure equates to the logic: IF NOT the action in the "INSTRUCTIONS" column, THEN follow the action specified in the "RESPONSE NOT OBTAINED" column. It was also decided that abnormal operating procedures (AOPs) would be single-column text-formatted procedures. Even though dual-column format was selected for the EOPs it was decided to retain the information concerning flowchart formatted EOPs in the writers' guide for future reference.

Once the procedure format was selected the emergency procedure network (EPN) was developed. The EPN provides predefined and prioritized symptom-based response strategies that guide the operator in the management of emergency transients. Event-related recovery and function-related strategies are combined to guide diagnosis and restoration of the safety state independent of event sequence. The optimal end state is the state in which personnel injury, radiation release, and equipment damage are minimized and plant conditions are stable, with equipment operating in long term alignments.

EMERGENCY PROCEDURE NETWORK

Document No.	Title	Date Issued
FRP-L.1	LIGHT BULB CHANGE	2/28/91

STEP	INSTRUCTIONS	RESPONSE NOT OBTAINED
1.	Verify lampcord unplugged Indication: MALE ELECTRICAL CONNECTOR NOT IN RECEPTACLE	1. Unplug lampcord.
	CAUTION Light bulb may break if handled in a rough manner.	
2.	Remove old bulb.	2. IF: Old bulb cannot be removed, THEN: Buy new lamp.
3.	Install new bulb.	3. IF: New bulb cannot be installed, THEN: Buy new lamp.
4.	Plug in lampcord.	4.
5.	Test by TURNING ON Switch (LAMP-1).	5. IF: Lamp does not come on, THEN: Verify power to switch.
	END OF PROCEDURE	

FIGURE 1: Example of a Dual-Column Procedure.

The network is entered through E-0, an entry procedure, whose purpose is to: limit damage; bring the plant to an initially stable condition; obtain status of important safety parameters; diagnose and direct to appropriate function restoration procedures and/or optimal recovery procedures and to critical safety function status trees (CSFSTs) or to appropriate abnormal function restoration procedures, which are designed to restore the critical safety functions. The optimal recovery procedures are event-related procedures that provide direction for reaching the optimal state.

Procedure Writing

After the format was decided upon, the procedure writing phase began. The procedure writers were experienced operator examiners with both commercial and navy nuclear reactor experience. The procedures were written using the guidance from the writers' guide. During the procedure writing process it was found that guidance for writing certain parts of procedures was lacking. The team approached these areas and decided on a solution that was acceptable to all parties. The writers' guide was then modified to reflect these changes. For example, for certain sequence of steps in the "INSTRUCTIONS" column of a dual-column procedure there would not be corresponding steps in the "RESPONSE NOT OBTAINED" column. This resulted in several pages of only a single column of the procedure containing text. It was obvious that if the single-column format could be used in these places the total number of pages of the procedure could be reduced. It was important; however, that the procedure be written so that the user was well informed the transition from dual-column to single-column format was going to occur. This would ensure the user would transition smoothly. In this instance, the team agreed that a note at the beginning of the sequence of steps telling the user about the transition to single-column format and another note at the end of the transitioned section telling the user the procedure was returning to dual-column format would provide the user with adequate information.

In numerous other instances operators at the ATR expressed a preference for a different step format. These preferences were considered and included if they had merit or if there was no good human factors practice that required a different approach. An example of

operators' preference was the formatting of logic statements. In the first draft of the procedures the logic statements looked like so:

IF containment pressure high, **THEN** go to step 18.

From operator feedback, the logic statement format was changed to:

IF: Containment pressure high,
THEN: GO TO step 18.

This formatting change was accepted by all members of the procedure development team and produced procedures easier to use visually.

Some changes to the writers' guide based on the input from the procedure writing process were based on the attributes of the word processing package. The package used allowed for macros, graphics boxes, and text boxes. The writers' guide was modified to reflect the use of this package and examples were made using it to ensure the writers' guide and procedures had the same look and feel. During this process it was also evident that the writers' guide needed plant specific examples to ensure the procedure writers used the guidance correctly. When the examples were not plant specific the procedure writers had a difficult time relating the example to their needs. By making the examples plant specific the procedure writers could take the example and easily adapt it to other, similar steps. All modification to the writers' guide were analyzed to ensure they did not violate human factors principles.

Initial validation

The ATR wanted to ensure complete operator acceptance before the procedures went into actual use. Each month the shifts evaluated the draft EPs using table-top discussions. Using the expertise of the operators in this manner allowed the procedure writers to receive feedback to effectively modify the EPs.

Verification and Validation

The purpose of verifying procedures is to ensure they are technically correct according to the design basis documents and to ensure they are consistent with the writers' guide. The purpose of validating the procedures is to ensure they are usable. Validation can be performed through either table-top exercises, walking through procedures on plant equipment, and/or simulator scenarios. The ATR chose to use primarily simulator scenarios and walk throughs to ensure procedures were adequate. Table top validation was also used, but to a lesser degree. By using the operators in the validation process the training program benefited in that the operators became fully acquainted with the intent of the procedure and took ownership in them also. Again feed back from the V&V was used to modify and fine tune the procedures and writers' guide.

Final Document

The final document contains the results of the entire development process and contains state-of-the-art procedure writing information. The ATR EP writers' guide has 5 main sections and 3 appendices. Section 1 explains the EPN. Section 2 discusses information common to both single-column and dual-column text procedures. Section 3 discusses information specific to single-column procedures. Section 4 discusses information specific to dual-column procedures. Section 5 discusses the CSFSTs. The appendices contain a glossary, a list of common ATR acronyms, and information concerning writing flowchart procedures.

Discussion

The writers' guide which was developed for the ATR contained information necessary to develop both text-formatted and flowchart-formatted function- and event-oriented EPs which were in accordance with currently accepted human factors principles. However, for the EPs it was decided to use text-formatted procedures. Flowchart formatted procedure information was retained for future reference.

Many lessons were learned during the development process. The need for including operations personnel into the development of the writers guide was very evident. Personnel with a broad range of operational

experience using different types of procedures greatly enhances the procedure development process. Such personnel bring to the process information concerning the positive aspects of various procedure formats and their limitations. Having training personnel involved from the start of the development process ensured feedback from the operators was incorporated into the EPs and writers' guide and allowed the operators to be informed of the coming changes. This aided in operator acceptance of the new procedures. It was evident that the EP writers' guide needed to have plant specific examples. Using plant specific examples helped the procedure writers adapt the example to their needs.

In summary, a need for emergency operating procedures which were in accordance with human factors principles was identified. The DOE and NRC, as well as the commercial nuclear industry, have developed guidance in order to fulfill that need. In the development of a plant specific EP writers' guide, a team approach aids in tailoring the document to the specific needs of the plant. Having operator feedback helps to produce better looking procedures and gives the procedure developers greater perspective as well as fostering ownership of the procedures.

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Biographies

Lee T. Ostrom, Ph.D., CSP
EG&G, Idaho
Idaho National Engineering Laboratory
P.O. Box 1625
M.S. 2405
Idaho Falls, ID 83415

Dr. Lee Ostrom is a Senior Scientist with the Human Factors Research Unit (HFRU) at the INEL. Dr. Ostrom's Ph.D. in Industrial Engineering is from Texas Tech University. He worked as a safety and health professional for PPG, Industries from 1981 to 1985.

Susan G. Hill, Ph.D.
EG&G, Idaho
Idaho National Engineering Laboratory
P.O. Box 1625
M.S. 2405
Idaho Falls, ID 83415

Dr. Susan Hill is a Senior Scientist with the HFRU at the INEL. Dr. Hill's Ph.D. in Industrial Engineering is from Virginia Polytechnic Institute and State University. She has over 10 years of experience and training in human factors in a broad range of areas including military systems, industrial ergonomics, and process control.

James A. Close
EG&G, Idaho
Idaho National Engineering Laboratory
P.O. Box 1625
M.S. 7121
Idaho Falls, ID 83415

Mr. James (Jim) Close is an Engineering Specialist in the ATR Reactor Safety Analysis Unit at the INEL. He has over 24 years experience at the INEL in the field of nuclear engineering, primarily performing systems and safety analyses. Mr. Close earned a BS in Engineering Physics from the University of Arizona and continued his education with graduate studies in physics and nuclear engineering through the University of Idaho.

James D. Lash
EG&G, Idaho
Idaho National Engineering Laboratory
P.O. Box 1625
M.S. 7100
Idaho Falls, ID 83415

Mr. James (Jim) Lash is a Nuclear Operations Engineer in the ATR Operations Training Unit at the INEL. He worked for two years as a Senior Reactor Trainer at a commercial BWR NPP. He was also in the U.S. Navy Nuclear Program as a reactor operator.

William C. Hemming
EG&G, Idaho
Idaho National Engineering Laboratory
P.O. Box 1625
M.S. 2409
Idaho Falls, ID 83415

Mr. William (Bill) Hemming is an Engineering Specialist in the Regulatory and Technical Assistance Unit at the INEL. Mr. Hemming has been a Certified Operator Licensing Examiner for 7 years. He was a Certified Senior Reactor Operator Instructer from 1980 to 1984 in commercial PWR NPPs. He was also in the U.S. Navy Nuclear Power Program from 1971 to 1979.