NUREG/CR–5455
SI–92–101
Vol. 1

Development of the NRC's Human Performance Investigation Process (HPIP)

Summary

Manuscript Completed: October 1993
Date Published: October 1993

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NRC FIN B5876

ABSTRACT

The three volumes of this report detail a standard investigation process for use by U. S. Nuclear Regulatory Commission (NRC) personnel when investigating human performance related events at nuclear power plants. The process, called the Human Performance Investigation Process or HPIP, was developed to meet the special needs of NRC personnel, especially NRC resident and regional inspectors. HPIP is a systematic investigation process combining current procedures and field practices, expert experience, NRC human performance research, and applicable investigation techniques. This blending of experience and proven techniques results in an intuitive, easy to learn and use system that helps NRC personnel perform better field investigations of human performance problems. The results of these field investigations (the identification of the root causes of human performance problems) assist both NRC field and headquarters personnel in their understanding of the human performance issues that cause events at nuclear power plants.

ACKNOWLEDGEMENTS

We would like to thank all of the NRC personnel who helped by providing their ideas, support, review, or other assistance. We would like to especially thank Ann Ramey-Smith, the initial project manager. HPIP would have never existed without her persistence in getting this system developed and shepherding it through the testing and approval process. Also, we would like to thank Dolores Morisseau, the current project manager, for her helpful guidance of the project through the final revisions and implementation. Finally, we would like to recognize the invaluable input to the system testing provided by NRC Region I. They willingly volunteered to pilot test the system in the field. Their feedback provided improvements in the process and training that made HPIP an even better system.

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EXECUTIVE SUMMARY

The three volumes of this report detail a standard investigation process for use by U. S. Nuclear Regulatory Commission (NRC) personnel when investigating human performance related events at nuclear power plants. The process, called the Human Performance Investigation Process or HPIP, was developed to meet the particular needs of NRC personnel, especially NRC resident and regional inspectors, for the identification of root causes of human performance problems. HPIP combines current procedures and field practices, expert experience, NRC human performance research, and the best applicable investigation techniques. This blending of experience and proven techniques results in an intuitive, easy to learn and use system that helps NRC personnel perform better field investigations of human performance problems. The results of these field investigations assist both NRC field and headquarters personnel in their understanding of the human performance issues that cause events at nuclear power plants. The improved understanding of human performance problems during events will also lead field personnel to identify the need for detailed human factors investigations by human factors-trained personnel.

The three volumes of this report consist of:

Volume I: A concise description of the need for the human performance investigation process, the process' components, the methods used to develop the process, the methods proposed to test the process, and conclusions on the process' usefulness.

Volume II: A field manual for use by investigators when performing event investigations. Volume II includes the HPIP Procedure, the HPIP Modules, and Appendices that provide extensive documentation of each investigation technique.

Volume III: More detailed documentation of the development effort and the pilot training program.

There are six tools that comprise a flexible procedure for identifying the root causes of human performance problems. These six tools are the investigation techniques:

- Events and Causal Factors Charting
- SORTM - A guide to HPIP Modules
- Barrier Analysis
- HPIP Modules
- Change Analysis
- CHAP - Critical Human Actions Profile

The techniques and the process are summarized in Volume I, Section 2 and thoroughly explained in Volume II. Some of these techniques are familiar to those who have been trained in root cause analysis. Events and Causal Factors Charting, Barrier Analysis, and Change Analysis are part of the Incident

Investigation Team (IIT) training and have been used extensively in the Department of Energy Weapons Complex and at nuclear power plants. Also, Events and Causal Factors Charting, Barrier Analysis, and Change Analysis have all been adopted for use in the Institute of Nuclear Power Operation's Human Performance Enhancement System. The HPIP Modules and CHAP were derived from previously existing systems, and have been tailored to the NRC's needs. SORTM was developed especially for this process.

In developing HPIP, a large portion of the effort focused on identifying the NRC's particular needs. In individual and group interviews and five meetings with NRC headquarters and field personnel, 154 people helped assess user needs and provided feedback. Three of these five meetings were held at regional headquarters to provide field personnel the opportunity to shape the process. One hundred and twenty-three regional personnel, 60 of whom were Senior Resident or Resident Inspectors, participated in these sessions and provided excellent input to the development of the system criteria (Volume III), the HPIP Flow (Volume I, Figure 3.1), and the investigation techniques chosen as tools for the process (as previously listed).

Much of the remaining development effort was spent assessing and developing human performance and root cause analysis techniques to be incorporated into HPIP. This work included conducting a computerized literature review, interviews with human performance and root cause analysis experts, and meetings on root cause analysis (details of which are presented more fully in Volume III).

The initial version of HPIP was pilot tested to get additional feedback from the eventual users. The testing included: review by headquarters personnel, a usability workshop, review by a senior human factors expert, 2 pilot training sessions followed by trial use by trained regional personnel. The feedback from this testing further attuned the system to the user's needs, assuring that the implemented version of HPIP is readily accepted in the field.

HPIP provides NRC personnel a process with which to obtain the information needed to better understand the root causes of human performance related incidents. This understanding will be helpful in evaluating the utilities' plans for improving performance and in setting the NRC's research and policy goals in the coming years.

1. WHY DEVELOP AN IMPROVED HUMAN PERFORMANCE INVESTIGATION TECHNIQUE?

1.1 Change of Emphasis - Need for a New Technique

The entire nuclear industry has gone through a transition from a period of plant construction to a period of plant operations. As the industry went through this transition, the NRC likewise changed its regulatory emphasis. Today, with new nuclear construction complete, the NRC is focusing on the safety of operation and maintenance of nuclear plants. This change in focus has caused the NRC's regulatory efforts to be less oriented toward engineering design basis studies and more toward operating experience and the human element of plant performance. Therefore, plant performance indicators, performance-based inspections, and licensee events now receive special attention.

As increased attention is paid to human performance, its contribution to plant safety becomes more evident. Yet, despite the realization of the importance of human performance to plant safety and the NRC's emphasis on operational safety, not all personnel performing event investigations have formal training or experience in investigation of the human contribution to events.. However, in the NRC Regions, resident inspectors or other regional personnel frequently review human performance when investigating the causes of an event (either individually or as members of Augmented Inspection Teams) and when assessing the adequacy of the corrective actions proposed in a utility's event report.

Certainly if all NRC personnel involved with the review of events and human performance could receive weeks of training in event investigation and human factors, understanding of the causes of these events would increase. This improved understanding could lead to new ways to improve plant safety and identify unsafe trends. However, this much training would represent an extensive investment in NRC staff time.

Another option is the development of a standard human performance investigation process to be used by field personnel when investigating events. To be successful this process would have to:

- Help investigators more accurately pinpoint the root causes of human performance related events, thereby leading to a better understanding of human performance problems in the nuclear industry.
- Be easily understood by the user and require very little initial training (perhaps no more than one day).
- Be easily understood by management.
- Be compatible with future database applications to statistically analyze trends.
- Not require significantly more work by the investigators in the field.

Although these requirements are ambitious, they were the goals used in developing the Human Performance Investigation Process (HPIP).

2. THE DEVELOPMENT OF HPIP

2.1 Development Strategy and Implementation

The initial goal of the HPIP development process was to create a human performance root cause analysis process that would help personnel in the field more accurately determine the causes of nuclear plant events that involve human performance issues. To do this, the development team performed five basic steps:

1. Analyzed the user needs by conducting interviews with Senior Resident Inspectors and personnel from the Offices of Nuclear Reactor Regulation (NRR), Analysis and Evaluation of Operational Data (AEOD), and Nuclear Regulatory Research (RES) and by discussing the development and potential investigation techniques at quarterly regional resident inspector meetings in Regions I, IV, and V.
2. Developed criteria for ensuring that the proposed investigation process meets the user's needs.
3. Identified, collected, and reviewed methods of analyzing root causes and human performance. Various experts in government, industry, and research were interviewed. Also, a detailed literature search using national computerized bibliographical databases was conducted to find additional potential human performance root cause analysis systems. Methods from the nuclear, chemical, and aerospace/transportation industries from the U.S. and abroad were considered.
4. Selected the best methods available that met the user's needs and developed new methods as needed. Wove the techniques into a flexible process that is documented in an investigation procedure.
5. Developed the investigation process documentation (Volume II) and pilot training program material.

The results of this development effort are described in Section 3. Additional details for each of these five steps are provided in Volume III.

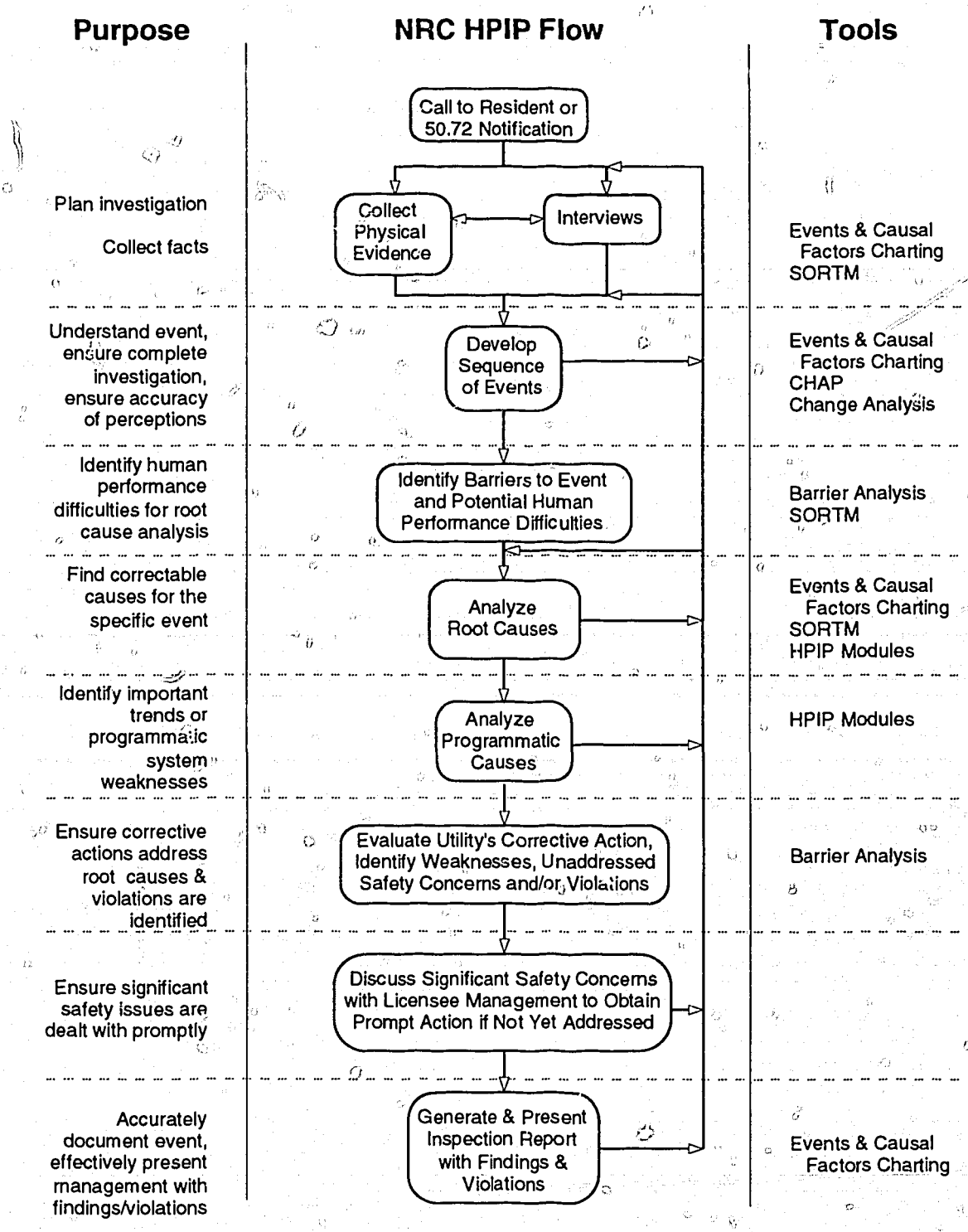
3. CONTENT OF HPIP

3.1 System Overview

The Human Performance Investigation Process is a systematic method for NRC investigations of nuclear power plant events that involve human performance issues. HPIP can be flexibly applied by the investigator by choosing to use only the investigation techniques, forms, etc., that are needed. The HPIP Flow Chart (Figure 3.1) graphically portrays the process and consists of three parts:

- The ***NRC HPIP Flow***, which displays the steps used to investigate an event (center column of the diagram).
- The ***Purpose*** of each major section of the process (left column of the diagram).
- The ***Tools*** which are the investigation techniques required to perform each major section of the process (right column of the diagram).

FIGURE 3.1: NRC Human Performance Investigation Process.



HPIP provides a procedure to lead the investigator through using the techniques while performing an in-depth investigation of human performance contributors to an event. Each investigation technique is supported by an in-depth descriptive guide that is provided in the appendices to Volume II and briefly described in Volume I, Section 3.2. Also provided in Volume II and described in Volume I, Section 3.2 are six investigation modules (Procedures, Training, Verbal Communications, Organizational Factors, Human Engineering, and Supervision) for determining the root causes of human performance problems. Each module provides references to NRC and commercial documents that provide additional information on specific human performance subjects.

3.2 Description of HPIP Tools & Modules

This section briefly outlines the HPIP Tools (investigation techniques) and Modules that are referred to in Figure 3.1. Volume II provides the detailed explanation of these techniques. Section 3.3 briefly outlines the integration of these techniques into the Human Performance Investigation Process.

3.2.1 Events and Causal Factors Charting

An events and causal factors chart (E&CF Chart) is a graphic presentation of the sequence of events that led to an accident / incident and the causal factors for those events. An example E&CF Chart is shown in Figure 3.2. An E&CF Chart helps the investigator understand the event's progression, identify holes and inconsistencies in the information, and explain the event to others.

3.2.2 SORTM

SORTM is a simple paper-and-pencil expert system that provides basic questions similar to those that an expert human performance investigator would be expected to ask during an event investigation. These questions are presented as a Yes / No logic tree in Figure 3.3. SORTM ensures consistency in the breadth of contributors that are considered during an investigation. The answers to SORTM's questions lead the investigator to those human performance areas most likely to have contributed to human error during the accident / incident. SORTM, therefore, helps the investigator allocate investigation effort to those areas where the causes of human error are most likely to be identified.

3.2.3 Barrier Analysis

Barrier Analysis is a formal method of identifying the events that, if avoided, would have prevented the accident / incident from occurring or would have significantly mitigated its consequences. A barrier to an event can be any physical boundary, natural occurrence, human action, or administrative control that could keep an event from occurring. Because the emphasis of HPIP is

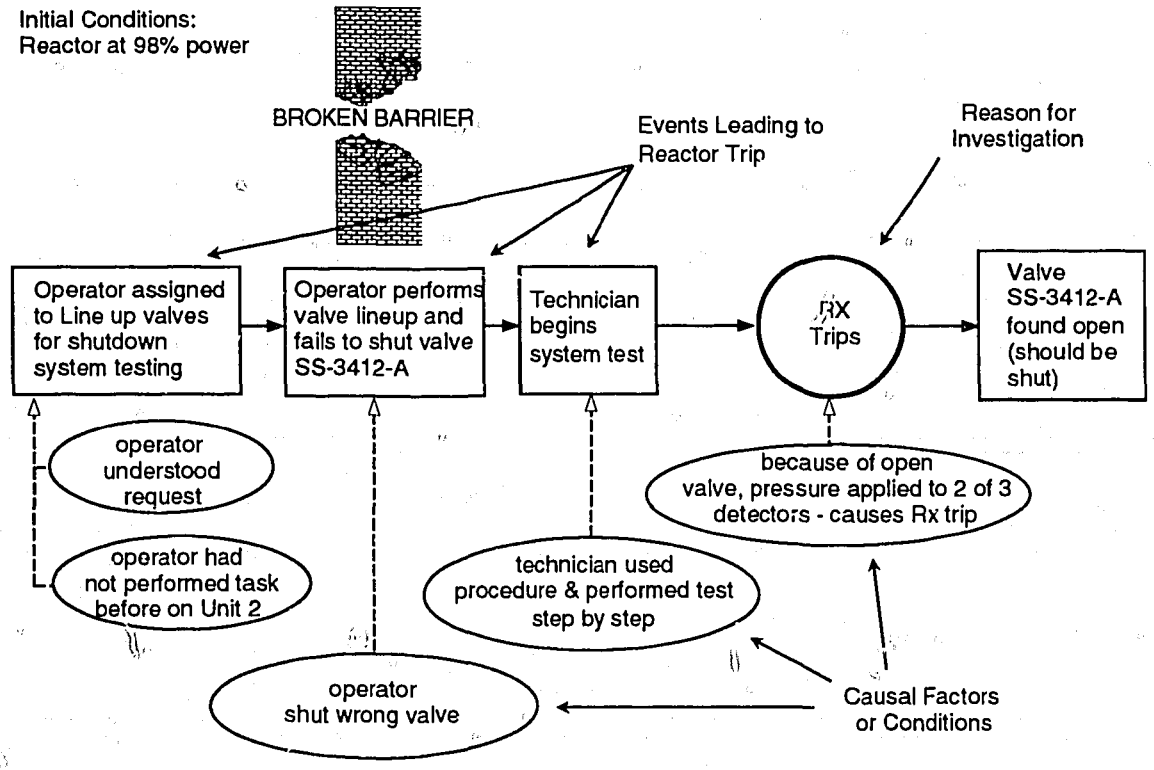
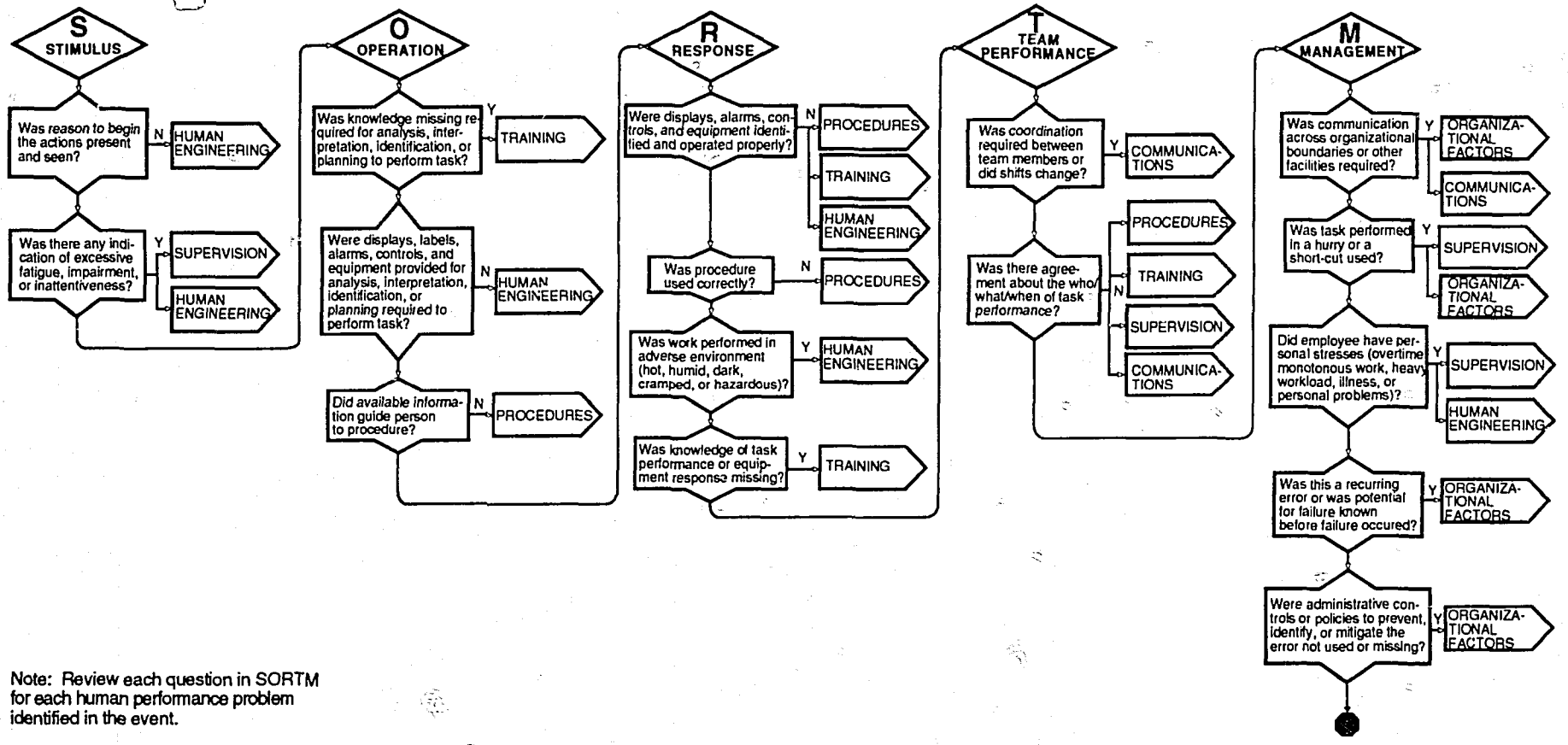


FIGURE 3.2: Example Events & Causal Factors Chart with a Broken Barrier

identifying the causes of human performance problems, the discussion of barrier analysis in these volumes concentrates on human action and administrative control barriers. Barriers are easily displayed on an events and causal factors chart as in Figure 3.2.

3.2.4 Change Analysis

Change Analysis is a systematic process for identifying changes in the process that may have contributed to an event. A form (Volume II, Appendix F, Form F.A) is used to record the factors that influenced performance and the differences between the old way that the task was performed successfully and the new way that the task was performed when the event occurred. This method can be particularly helpful in identifying inappropriate changes in administrative controls. It also can be helpful in analyzing an event where the causes of the problems have not successfully been identified using other techniques.



Note: Review each question in SORTM for each human performance problem identified in the event.

FIGURE 3.3: SORTM - Guide to HPIP Modules

3.2.5 CHAP

The Critical Human Action Profile (CHAP) is an operationally oriented investigation technique roughly based on the human factors technique of task analysis. An investigator using CHAP identifies and records all the critical human actions. A critical human action is one that, if performed correctly, could have prevented the event from occurring or could have significantly reduced the event's consequences. CHAP provides several techniques to help an investigator identify the critical human actions. The list of critical human actions can then be analyzed using SORTM or, if special expertise is needed, the list can provide a starting point for investigation assistance by a human performance expert. CHAP does not have to be used for every investigation but should be used when identification of the causes of the event is difficult or controversial, when extremely complete documentation of the event is required, or when assistance from human performance experts is needed.

3.2.6 HPIP Modules

The HPIP Modules (Volume II, Sections 11 - 16) are used to identify the root causes of problem areas identified by SORTM. Each module has a figure that shows the types of problems to be considered. Figure 3.4 is an example of a module figure. To help the investigator identify the correct root cause(s) on the figure, the module provides a list of questions. These questions are written to be answered by an investigator with very little or no human factors training. However, the modules also contain a list of references (both NRC headquarters' contacts and documentation) to provide more information on frequently encountered problem areas so that the investigator can find additional information to learn more about a particular type of problem.

3.3 Outline of HPIP Steps

HPIP is more than just a collection of investigation techniques. The techniques have been woven together into a tightly coupled, but flexible, investigation system as shown in Figure 3.1. This system is documented in an investigation procedure (Volume II, Sections 2 - 10) for use by investigators in the field. The following sections outline the procedure's steps.

3.3.1 Step 1 - Planning After Notification

Once the investigator is notified of an event and decides to gather additional information, a strategy for the investigation needs to be developed . Two techniques contribute the most to the development of this strategy - Events and Causal Factors Charting and SORTM. Using the information initially available, the investigator can develop a preliminary events and causal factors chart. For each of the causal factors that contributed to the event, the investigator can then rapidly consider the applicable questions from SORTM. This will help the investigator determine the initial thrust of the investigation by developing a preliminary understanding of what happened to cause the event, by developing

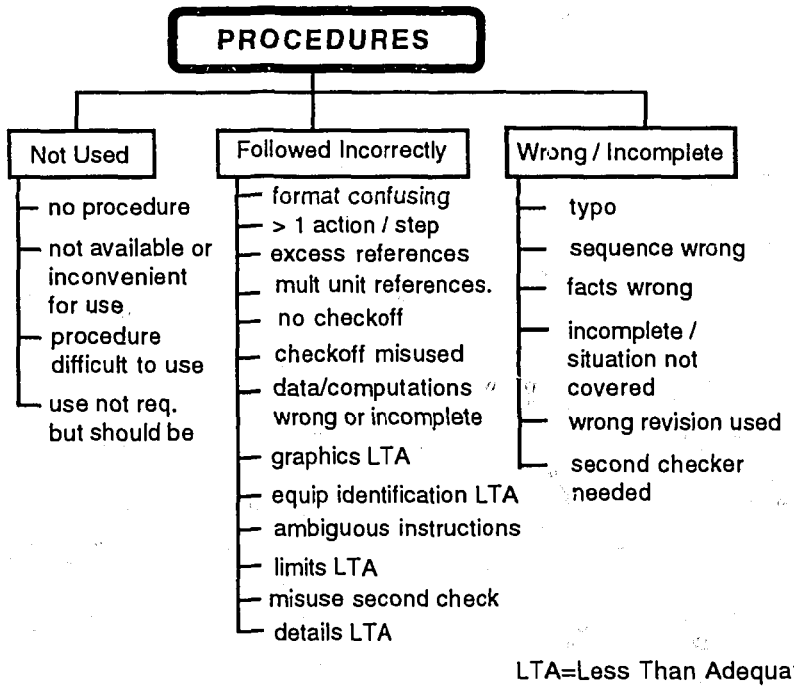


FIGURE 3.4: HRIP Module Procedures Figure
(Adapted from Paradies and Busch, Root Cause Tree User's Manual, Revision 1, 1990)

questions to fill holes in currently available information, and by identifying conflicting perceptions or facts that need resolution.

3.3.2 Step 2 - Interviewing Personnel and Collecting Physical Evidence

Once an investigator has planned the initial phase of the investigation, the next step is to collect information through interviews and analysis of physical evidence. Interviewees should include those involved in the event, their supervision, and the appropriate technical, training, and management personnel. Having an interviewee help construct an Events and Causal Factors Chart can be a good way to gain valuable information during an interview. Questions from SORTM that are applicable to the interviewee should be incorporated into the interview questions.

3.3.3 Step 3 - Developing the Event's Sequence

Through interviewing and analyzing physical evidence, the investigator collects the information necessary to fully develop the event's sequence and identify the problem areas requiring root cause analysis. To do this, an investigator develops a detailed Events and Causal Factors Chart.

3.3.4 Step 4 - Identifying Barriers and Potential Human Performance Difficulties

Using Barrier Analysis and SORTM, the investigator identifies the broken barriers and corresponding human performance problem areas that allowed the event to occur. For particularly difficult events, the investigator may also need to use Change Analysis or CHAP to collect additional information and identify human performance problems.

The results of collecting information, developing the event's sequence, and identifying barriers are a complete understanding of what occurred during the event and the identification of the problem areas. In the next step, these problem areas are analyzed for their root causes by using the HPIP Modules.

3.3.5 Step 5 - Analyzing Root Causes

Once an investigator has used SORTM to identify specific problem areas that need further analysis, the investigator should complete the HPIP Modules for those areas. Answers to the HPIP Modules' questions help the investigator pinpoint the event's root causes. These root causes are then used in the next several steps to determine if programmatic causes exist and to evaluate the utility's root cause analysis and corrective action proposal.

3.3.6 Step 6 - Analyzing Programmatic Causes

The specific causes for a particular event may be symptoms of a more pervasive problem. For example, if one event is caused by one set of valves not having label plates, other events may occur because of similar labeling problems with different valves. Therefore, a specific root cause may indicate a program-wide weakness (Programmatic Causes). These programmatic causes can be verified by investigating the pervasive nature of the problem. This can be done by statistically analyzing a plant-specific database, by performing a limited scope study of the problem in the particular plant, or by relying on the investigator's experience with the plant's problems. Once the programmatic causes are identified, they also can be used to evaluate the adequacy of the utility's corrective action plan.

3.3.7 Step 7 - Evaluating Utility's Corrective Actions & Identifying Weaknesses, Unaddressed Safety Concerns, and/or Violations

In addition to the investigator's previous training and experience, the results of an HPIP analysis (the accident/incident's specific and programmatic root causes) can be used to review a utility's proposed corrective actions and identify potential violations of regulations. The Events and Causal Factors Chart will help the investigator completely understand what happened so that violations can be identified. The Barrier Analysis, root cause analysis, and analysis of programmatic causes will allow the investigator to check a utility's proposed corrective actions to see if they are complete. For example, if a utility didn't propose a complete and effective corrective action, did the utility explain

why corrective action wasn't needed, was inappropriate, or was not feasible; if the event has been identified as a repeat of a similar past event, are the corrective actions proposed different from the corrective actions previously tried, and why didn't those corrective actions succeed?

3.3.8 Step 8 - Discussing Significant Safety Concerns with Licensee Management

Although this step is shown as step 8, the investigator should in fact discuss significant safety concerns with licensee management as soon as they are known. The investigator should work with the licensee and NRC management to ensure the appropriate safety measures are taken.

3.3.9 Step 9 - Generating and Presenting Inspection Reports

All of the information and analysis performed up to this point allows the investigator (1) to write a clear, complete event report describing what happened, why it happened, and what needs to be corrected to prevent the event (or a similar event) from occurring again, and (2) to evaluate the adequacy of the utility's proposed corrective actions. The Events and Causal Factors Chart can be particularly helpful in providing an organized display of the information collected and presenting the information to management.

4. HPIP PATH FORWARD

4.1 Testing and Revising HPIP

The HPIP development team tested the investigation process in the field to ensure that HPIP met the development goals of:

- helping the investigator more accurately pinpoint the root causes of human performance related events;
- being easily understood by the user and requiring very little initial training;
- being easily understood by management; and
- not requiring significantly more work by the investigators in the field.

Lessons learned from this testing were used to verify that the system works as planned and to improve the process where needed. The basic steps in this testing and revision effort were:

1. Presenting the investigation process to headquarters personnel for review and conducting a workshop on the usability of the process.
2. Having an independent senior human factors expert review the system for technical excellence and ease of use. (Letter Report from Dr. Charles O. Hopkins to Dolores Morisseau, NRC, "Review of NRC Human Performance Investigation Process," Contract Number NRC-04-90-078, August, 1991.)

3. Conducting a pilot course for headquarters and regional personnel and receiving feedback from the trainees on the pilot training.
4. Having the trained personnel test the system by using it during actual investigations and providing the development team with feedback.
5. Presenting reports on the development and use of HPIP at three industry conferences.
6. Collecting all the system critiques and user feedback and developing recommendations for revisions to the system for approval by the NRC project manager.
7. Publishing the revised investigation process results for use.

An additional step was planned: Having members of the development team accompany NRC staff on a limited number of investigations and observe first-hand the use of the system. However, events conducive to these observations did not occur in Region I (the selected test region) during the testing phase. Therefore, because the feedback from Region I trainees using HPIP in their investigations/inspections was positive, HPIP was revised to incorporate their comments into the process.

4.2 Testing Results

The testing of HPIP provided a basis for a series of recommendations for improving HPIP. This testing showed that resident and senior resident inspectors accepted the system. The testing also showed that HPIP is usable in the field after one day of training and helps investigators find root causes that otherwise would not have been identified. These findings were summarized in a letter report from Charles Hehl, NRC-RI, to Brian Sheron, NRC-RES, "Human Performance Investigation Process," October 11, 1991.

The recommendations for improving HPIP are based on the results of the testing. All but one of the recommendations are fine tuning of the process. The recommendation that goes beyond fine tuning is based on the large number of requests by the trainees for additional HPIP training. To respond to this request without adding additional *initial* training, two optional HPIP workshops are recommended as follows:

1. The first workshop would provide advanced training on HPIP techniques and a review of the trainees' initial experience using HPIP. It would be a four to eight hour workshop held about six months after the initial HPIP training.

2. The second workshop would be an advanced human performance evaluation workshop to provide: refresher training on the HPIP techniques; additional training on specific, job related human performance evaluation information; and interesting, current human performance investigation findings from every region's investigations. The second workshop would be a two to four hour workshop held periodically (not more than every six months) at the regional resident inspector meetings.

5. CONCLUSIONS

Because there is a need for improved understanding of the role of human performance in operational safety, techniques are needed to help field personnel better identify the root causes of human performance related events. HPIP integrates several techniques to meet the need. HPIP has been carefully developed with the capabilities and experiences of the potential end users in mind. The testing of HPIP was designed to further refine the system and ensure its usability in the field. HPIP represents a major step forward in providing NRC personnel, both in the field and at headquarters, with the information needed to better understand the root causes of human performance problems. This understanding will help in the evaluation of the utilities' plans for improving performance and in setting the NRC's research and policy goals in the coming years.