EPRI

Incident Investigation and Reporting

Technical Report

Incident Investigation and Reporting

1002077

Final Report, May 2003

EPRI Project Manager
B. Damsky

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Beare Ergonomics

Quality Training Systems

ORDERING INFORMATION

Requests for copies of this report should be directed to EPRI Orders and Conferences, 1355 Willow Way, Suite 278, Concord, CA 94520, (800) 313-3774, press 2 or internally x5379, (925) 609-9169, (925) 609-1310 (fax).

CITATIONS

This report was prepared by

Beare Ergonomics
6243 Parallel Lane
Columbia, MD 21045

Principal Investigator
A. Beare

Quality Training Systems
6418 Dry Barley Lane
Columbia, MD 21045

Principal Investigator
S. Lutterodt

This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

Incident Investigation and Reporting, EPRI, Palo Alto, CA: 2003. 1002077.

REPORT SUMMARY

This report presents a model procedure for incident investigations based on an examination of programs at fourteen utilities believed to have good and effective procedures. The model was compiled by an expert who also drew on materials from other industries. An outline presents the basic procedure while the main text discusses in more detail alternate methods that may be preferable for a specific utility.

Background

EPRI's 1996 report, Field Operation Power Switching Safety (TR-106465), was a milestone that sparked interest across the industry in switching safety. That report led directly to the first switching safety conference held the next year. Since then, the conference has become an annual event with a strong and growing attendance focused on exchanges of incidents and findings from individual utilities as well as EPRI research. The keystone of this project has been a combination of surveys with analysis. Done properly, this approach will yield insights for improved practices. This report covers the latest work on the subject: work related to how incidents are investigated and reported. The proper study of incidents is crucial to understanding and correcting error-prone procedures.

Objectives

- To document a range of approaches for investigating and reporting operating incidents.
- To identify useful approaches and job aids that may not be widely used.
- To develop model procedures, job aids, and report formats and forms.
- To identify candidate "best practices."

Approach

EPRI arranged for fourteen cooperating utilities to participate in a survey and for the data gathered to be analyzed by experts in the field of accident prevention and accident analysis. The source of all individual data remains confidential to encourage full and complete disclosure.

The project team made an effort to collect supporting documentation, including procedures and forms used for reporting incidents and samples of completed incident reports from participating utilities. The team also surveyed literature on root cause analysis and other topics related to incident investigation, reporting, and learning from incidents. This survey provided valuable background and confirmed that the team was not overlooking useful material from other industries.

This report is concerned with investigating and reporting more or less routine operational incidents and human errors by and for the operations department. Investigating incidents involving injuries or death is usually conducted by the safety department using more standardized procedures designed to fulfill various regulatory/reporting requirements. Data were not collected on the methods used for investigating injuries.

Results

Some of the more important components of this report include

- A model procedure for incident investigations presented in outline form that makes the components clear.
- A discussion of the model procedure's components, their significance, and the pros and cons that might lead an individual utility to adopt a variant procedure.
- An introduction to root cause analysis supplemented by a significant bibliography of standard publications and Internet resources for those who wish to pursue the subject.
- A useful checklist summarizing best practices found in the study.

EPRI Perspective

Safety and reliability have never been more important for a utility. This report represents the first step toward understanding what is clearly a complex set of issues. It will help utilities design individual programs that will benefit their companies and safeguard their employees.

Keywords

Safety practices
Switching
Substations
Power system operation
Power system control

ABSTRACT

This report presents a model procedure for incident investigations based on an examination of the programs at fourteen utilities believed to have good and effective procedures. The model was compiled by an expert in such investigations and he drew on materials from other industries as well. An outline presents the basic suggestion while the text gives a more detailed discussion of alternate methods which may be preferable for a specific utility.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

Background

EPRI's Switching Safety and Reliability project has from its inception focused on the prevention of operating errors/incidents and, more generally, on any and all means to increase the safety and reliability of switching operations. Project participants have recognized that incident investigation and reporting is an important tool in attaining that goal. In particular, there is a broad consensus that:

- Effective investigation is required for proactive identification and effective correction of operational deficiencies.
- Investigation and reporting of operational incidents aids "organizational learning."
- Incident investigation and reporting is recognized by many reliability-oriented organizations (e.g., NRC, DOE) as a critical part of a "Safety Culture."
- There are many inconsistencies between – and sometimes even within – utilities as to what is investigated, how it is investigated, and how the findings of investigations are reported and followed-up.

Accordingly, investigation of how utilities and other organizations conduct and report incident investigations was voted a research priority by the project steering committee following the Switching Safety and Reliability Conference, that took place in Atlanta in 2001.

The steering committee recognizes that sharing of information, particularly lessons learned from operating experience, is a feature of other industries that place a high value on reliability (e.g., the nuclear industry), and has sought to promote such sharing among utilities. The committee has long believed that standardization, or at least greater similarities in investigation and reporting of operating incidents and their causes, could facilitate better sharing of information within the industry, to the potential benefit of all its members.

Project Goals

The goals of the present investigation were to:

- Document a range of approaches to investigation and reporting operating incidents
- Identify useful approaches and job aids that may not be widely used
- Develop model procedures, job aids, & report formats/forms
- Identify candidate "best practices"

This report is concerned with the investigation and reporting of more or less routine operational incidents and human errors by and for the Operations Department. Investigation of incidents involving injuries or death is usually conducted by the Safety Department using more standardized procedures designed to fulfill various regulatory/reporting requirements. Data was not collected on the methods used for investigating injuries.

Participants

The report is based on information collected by a survey conducted by telephone and e-mail, and supplemented with examination of reporting forms and other documentation as available.

Fourteen utilities supplied information and sample materials for this study. Participating utilities were selected from volunteers at the Atlanta conference, or from contacts that had been made in conducting the Near-Miss study (EPRI Report 1001956.) All participants were current members of EPRI's Substation Operations and Maintenance target. Participating utilities are listed in Appendix A. In this report, materials from individual utilities are identified by a randomly assigned letter (A - N).

This sample is entirely self-selected and is not in any way a "scientific" or representative sample of electric utilities in general. In particular, contributing utilities are all large companies with a longstanding interest in measures that contribute to safe and reliable operations. Although we are aware of utilities with strong programs who did not participate in the study, the authors believe that several of the utilities in the present sample are among the best of US utilities in regard to investigation and reporting.

In only one case (K, which is a transmission company) was the scope of procedures explicitly limited to certain voltage levels. However, none of the project contacts were from distribution operations departments. Four (E, I, J and L) of the14 utilities supplying information for this study reported that different procedures were used for investigating switching incidents that occur in the Control Center as opposed to those that occur in a substation or other field location.

Differences in investigative procedures among functional groups within the same utility were not addressed by the data collected. However, the authors feel that such differences may be problematic in that they may impede communication of lessons learned between operating units and may also represent a duplication of effort in training of investigators, construction and maintenance of incident databases, etc.

Research Approach

The approach was the same as used in the study *Collecting and Using Near-Miss Information*, EPRI TR 1001956. The approach included:

- Written and telephone survey
- Collection of supporting documentation, including procedures and forms used for reporting incidents and samples of completed incident reports from participating utilities
- Survey of literature on Root Cause Analysis and other topics related to incident investigation, reporting, and learning from incidents. This literature was identified via searches of The University of Maryland System library catalogs and Amazon.com books using keywords "incident," "investigation," and "root cause"

- Brief review of selected web sites dealing with Root Cause Analysis identified with a search on keyword "root cause." (See Appendix B for an annotated list of websites.)

The research allowed us to evaluate current utility practice in relation to the published expertise of other industries. The practices reported by participants were evaluated in relation to these established criteria and using participants' own assessments in order to arrive at a set of "best practices" for the investigation and reporting of electric operations incidents.

Organization of this Report

The remainder of this report is organized in nine sections and six supporting appendices.

1. The Rationale for Performing Investigations
2. What is Investigated
3. Who Investigates
4. The Incident Investigation Process
5. Incident Investigation Reports
6. Follow-up
7. Job Aids for Incident Investigation
8. Proposed Best Practices
9. References

Appendix A Participating Utilities

Appendix B Internet Resources

Appendix C Root Cause Analysis

Appendix D Model Procedure for Investigations

Appendix E Incident Investigation Checklist

Appendix F Guidelines for Conducting Interviews

Appendix G Guidelines for Developing Recommendations

A Note on Nomenclature

Because utilities vary significantly in the names of departments, committees, and job titles, generic names titles are used throughout this report.

2
THE RATIONALE FOR PERFORMING INVESTIGATIONS

The introductory chapter to Hale's book *After the Event–From Accident to Organisational Learning* (Hale, 1997, pp. 1-9) (References are detailed according to author and date in Section 10 of this report.) describes two basic approaches to the investigation of what are called "events."

1. The traditional judicial approach, whose aim is to identify who is to "blame," i.e., those individuals who, through their inaction or inappropriate actions, caused or contributed to the mishap

2. An approach designed to support organizational learning and process improvement, whose goal is to determine the causes of the incident so that steps may be taken to prevent it or something like it from happening again.

For proponents of the second approach, incident investigation and reporting is considered an important part of a continuous improvement orientation. An incident is a negative quality indicator that points to things that can be improved. It can be seen as a useful learning experience.

In the case of facilities that make, use, or store hazardous chemicals, the value attached to the opportunity of learning from incidents is reinforced by law. OSHA's Process Safety Management Standard (OSHA, 1992) requires both reporting and analysis of accidents and near misses which resulted in, or could have resulted in, "serious harms" to persons, property, or the environment, either onsite or offsite. The investigation must produce a report that includes a description of the incident, the factors that contributed to it, and recommendations for preventing its recurrence. In addition, the company is required to establish a system to address the incident report findings and recommendations, and to document all corrective actions (Baram, 1997, p.165).

As the power of incident investigations for discovering ways to improve safety, reliability, and other indices of quality has been demonstrated, the idea of employing incident investigation ***primarily*** as a tool for improving the organization, and only secondarily for apportioning blame, has become widely accepted in many industries. Virtually every utility participating in this study subscribes to this notion, though perhaps few would state it as strongly as does James R. Thomen in his book *Leadership in Safety Management*: "Incident investigations are designed to discover and correct the weaknesses in the organization which permitted the incident to occur." (p. 241)

Organizations can also benefit from investigating, understanding, and circulating reports of even minor incidents, even if nothing "new" is learned. One of the effects of reporting incidents that resulted from failure to follow established practices and procedures is to reinforce the value of these practices to employees. Trevor Kletz, an authority on chemical process safety, puts it this way in his book *Learning from Accidents*:

> We learn more from stories, true or fictional, than from statements of principal and exhortations to follow them. Stories describe models we can follow in our own lives and can help us to understand what motivates other people. They instigate action more effectively than codes and standards and have more effect on behavior. (Kletz, 2001, p. 100)

The value of incident investigation and reporting as a tool for organizational learning – as demonstrated in other safety-critical industries – has been an important motivator in this research of methods for investigating switching incidents.

3
WHAT IS INVESTIGATED

The first issue to address is what counts as an "incident" or – in other words – what types of occurrences merit investigation. The discussion focuses first on the types of event that are included in the definition of an incident, starting with the categories used in an earlier study. The section goes on to discuss how different types of incidents may merit different levels of investigation.

Definition of Incident

Categories Used in Earlier Survey

To obtain information about how utilities define an incident, the questionnaire for the *Survey of Switching Practices* (EPRI report 1000123) contained the item shown in Figure 3-1.

How does your utility define an "operating error" or "incident"?

Personal injury……☐

Damage to equipment……☐

Loss of service to customers……...☐

Violations of operating procedures……☐

Mis-operation of equipment……☐

Other (describe): _____

Figure 3-1
Item Soliciting Information on Types of Incidents Investigated from *Survey of Switching Practices*

The survey responses indicated that the majority of utilities investigated incidents falling into at least four and usually all five of the categories identified in the questionnaire item. The reader will note that the categories used in the survey were not mutually exclusive. For example mis-operation of equipment could lead to damage to equipment or loss of service, or neither; opening a breaker other than the one on the switching instruction could be considered a violation of an operating procedure (the switching procedure), or mis-operation ("unauthorized operation") of the breaker and could lead, likewise, to loss of service or other adverse effect depending on the circumstances.

All of the participants in the present study, with one exception, provided lists or copies of procedures or policy documents indicating the kinds of incidents that warrant an investigation. The exception - Utility J - reported that incidents to be investigated were determined on a case-by-case basis, within the general categories of loss of load, customer outages and safety issues.

Although there are differences in terminology between utilities, many of their responses appear to "map into" the five general categories of the earlier survey.

Personal Injury: All utilities in the study investigate these. The investigation is usually conducted by the Safety Department, which is responsible for all injury reports. For this reason, "Injuries" was seldom a category listed in documents supplied by operational groups.

Damage to Equipment: Equipment damage was mentioned explicitly by only two of the participants (utilities F and M), though others (D, H, I) mentioned "equipment failure."

Loss of Service to Customers: This was mentioned explicitly by only four utilities (A, E, J, and K). It is, however covered under other general categories by virtually all respondents. For example, Utility C defines an "event" as any unscheduled outage of one or more system components, a definition that clearly includes outage to customers. Loss of service is also clearly covered under the general categories of "unplanned," "undesired," or "unexpected event" used by utilities D, G, and L.

Violation of Operating Procedures: This was mentioned explicitly by only five utilities (A, B, G, H, and I), but is covered under more general definitions by several others.

Mis-operation of Equipment: This was explicitly mentioned as "inadvertent operation" of equipment by B, K, M, and N, and explicitly called a "switching error" by E, M, and N. Utility C's definition of "outage" at the level of system components rather than continuity of service to customers includes (inadvertently) opening a breaker on one end of a two-terminal line, even if it did not result in any loss of load.

Altogether, less than a third of the present sample explicitly uses the categories of incidents that were employed in the Survey of Switching Practices, but in many cases, the same types of occurrences were covered by more general statements or simply by differences in terminology. For example, utilities may investigate any activities that "put the system at risk" (utilities A and H) or any "unplanned or undesired event" or "unexpected event" (D, G, and L). An event falling into any of the five categories used for the *Survey of Switching Practices* would be covered under these global criteria.

Note also that some utilities that provided lists of events to investigate preface these lists with the phrase "... include but not limited to..." which leaves room for them to investigate any instance of events-not-as-planned. Because deviation from expectations is incompatible with the high reliability required for power delivery operations and the safety-critical tasks that they require, "events-not-as-planned" may be the most sophisticated approach to defining investigation-worthy incidents.

Near Misses

Utilities G, H, and I mentioned "near misses" as a category of "incident," rather than a distinct separate category. For the present study, we did not ask how near misses were defined, but it is apparent that some utilities may not recognize the near-miss category (i.e., an event that has no overt effect on personnel or the system) at all. For example, Utility N's list of investigatable events includes "circuit breakers, disconnects, switches, etc., left in abnormal position." A different utility might consider these near misses if they were discovered before having adverse consequences. As another example, Utility L's Operations Department does not draw a distinction between a near miss and other types of "operating errors" in switching operations. If the dispatcher orders a breaker closed, but the substation operator checks it out and says he cannot do it because there are grounds applied on the bus, it is investigated and reported as an operating error. This incident might be called a near miss by a different company, and another might not even record it since the system of double checks worked as intended to prevent any effect on the electrical system.

Additional Categories

Utility N provides detailed lists of events that are categorized, respectively, as operating errors or switching errors (see Section 8). An example listed is unintentional relay operations, and these are also explicitly named as incidents to be investigated by Utility I. These would likely be covered by the "unintentional operation" phrasing in the criteria of several other utilities.

Utilities A and M listed events that had the potential to generate "adverse publicity" or "draw media attention" as cause for performing an investigation. Some also mentioned that any event that involved non-utility personnel or equipment would be investigated.

A Note on The Desirability of Consistency

Comparison of processes or outcomes (benchmarking) is a popular tool for process improvement, and the error or incident rate is rightly considered an indicator of quality. Indeed, as we indicated in Section 2, one of the explicit purposes of incident investigation is to reduce incident rates and improve the quality and reliability of operations.

However, comparisons may be misleading. In general, utilities' incident reporting systems are designed primarily for internal use, even though they may also be used to collect information to satisfy external reporting requirements. Thus for their incident investigation and reporting systems, utilities define incidents in ways that are familiar and useful to them. These definitions can – and do – vary widely from one utility to another.

It is difficult to compare incident rates in a meaningful way if one utility counts apples and oranges, and another counts apples and pears, and a third counts all three. For example, a utility that only counts events that have a "real" effect on the system (e.g., an outage) as an "incident" might find that its "incident rate" was lower than those of utilities L and N who count what many would consider near misses as "real" errors.

Some standardization of what counts as an error or incident is needed to allow the electric operations industry to derive maximum benefit from incident statistics. The point is not that comparisons of error rates are meaningless, but that they should be evaluated with caution, and a knowledge of what kinds of events are included.

Despite this caution in comparing incident rates, there is much to be learned from the content of incident reports and a comparative study of the incident investigation processes used by different utilities as provided in the present report. The differences in definitions will be examined in more detail in a future report.

Levels of Investigation

The description of how different utilities define incidents to be investigated does not adequately address the question of what is investigated, since many utilities use different levels of investigation for different types of events.

Two Levels of Investigation

Investigations can differ considerably in the detail and depth of analysis performed and the documentation produced. In this report, such differences are referred to as "levels" of investigation. The person or group assigned to the investigation generally varies according to the level of detail of the investigation.

Within the range of incidents investigated exclusively by Operations, 10 of the 14 participants reported that there were essentially two levels of investigation, depending on the seriousness or potential seriousness of the event.

- First level or initial investigation. These investigations, which are normally conducted by the first-line supervisor or manager, are undertaken for all incidents that fall within the company's definition.
- Second level or more detailed investigations. These investigations, which require a higher level of effort, are usually reserved for investigation of high or potentially high-consequence incidents. However, they are occasionally performed for simple events that keep occurring in spite of attempts at correction.

There are two reasons for employing two levels of investigations. First, utility operations are conducted with a well-defined system of procedures that have evolved over nearly a century. Doing things "by the book" works. Many, perhaps the majority of incidents involving switching, can be traced to oversights in performing or preparing the written plans by which most switching is performed. Such "human errors" are usually easily discovered by interviewing the people involved or comparing what actually happened to the documentation of what was planned.

The second reason is that in-depth investigations are more expensive. Discovering the causes and effective solutions for preventing the recurrence of high-consequence events is an effective use of resources, while preventing low-consequence events may not be worth the cost. Moreover, management knows it will be expected to do something in response to high-consequence

incidents. More rigorous formal investigations tend to identify more contributing factors for a given incident, which provides a greater number of opportunities for correction (Ferry, p. 144). A more rigorous investigation is also more likely to identify the "true" causes, which in turn will produce remedies more certain to be effective.

Thresholds for More Detailed Investigations

For some utilities the level of investigation employed may be determined by a quantitative threshold: outage to X number of customers, or Y dollars of equipment damage. Utility C has quantitative criteria that trigger higher level investigations, such as equipment damage in excess of $75,000 or customer outage costs in excess of $100,000. Other such quantitative criteria can include:

- Other costs associated with the event
- Lost revenue in excess of $X
- Load-not-served in excess of a certain amount
- Reserve capacity falls below Y MW

Other utilities base their triggers on judgments of seriousness. For example, opening the wrong breaker would not normally trigger a second-level investigation, actions that compromised a clearance would. Other qualitative criteria can include:

- Outage to a major customer
- System disturbance affecting neighboring utilities
- Other disturbances as required by regulators, power pool, system operating authority, etc.
- A near-miss that endangered employees or the public
- Repetition of events whose causes were supposedly corrected by recommendations enacted following an earlier investigation
- Events with contributing factors beyond the control of the parties directly involved in the incident (e.g., inaccurate drawings, poorly maintained equipment, deteriorated or missing signage, etc.) which may indicate systemic problems beyond the control of the immediate supervisor or that could require significant resources to correct.

The authors suggest that where the formal thresholds are quantitative, the system should allow discretion to perform more detailed investigations of events not meeting the established criteria at the request of the initial investigator, responsible manager, or a review committee. "Little" incidents often have the same causes as those having major consequences (Ferry, p. 9 and Kletz, p. 13) and by finding and fixing them an event having more significant consequences may be avoided.

A problem in determining the level of investigation based only on the quantitative outcome derives from the fact that the causes for "minor" and "significant" incidents can be the same. Consider the following example:

> An operator opened the wrong breaker at an isolated tap due to an incorrect switch number on the switching order. There are four breakers at this tap, all feeding lines to substations. All of the substations have redundant feeds. However, the redundant feed to the substation supplying a critical customer, a pharmaceutical plant engaged in round-the-clock production of very expensive medications, was already open for work on the breaker. Investigation revealed that the switching order was executed exactly as written: the incorrect switch number appeared to be a simple typo, the transposition of two characters.

Using the consequence of the event as the threshold for more detailed investigation in this example, the depth of investigation would depend on which of the incorrect breakers was opened. For two of the incorrect breakers, this error would have no very important consequences. The investigation would probably be a rather cursory affair conducted by the immediate supervisor or manager, who would probably conclude the switching instructions should have received review by several people and they *should* have recognized the typo and corrected it before issuing the instructions. The conclusion would likely be that existing policies requiring such review were adequate, but the involved individuals did not follow them with sufficient diligence. However, if the critical customer were dropped, a more intensive investigation involving a team would likely be performed. The team would probably look a little harder at the adequacy of the existing procedures for pre-dispatch review, and would also probably consider ways of providing additional protection for the critical customer.

Incidents of Increased Severity

For incidents of increased severity, additional levels of investigation are normally used. The most detailed and thorough investigations are undertaken if an incident results in injury or death. In such cases, the safety department will usually lead the investigation, drawing on the Operations Department for additional expertise as necessary. In most cases, Safety will also investigate any electrical contacts, whether there is an injury or not. Safety may also investigate "safety violations" which could include violations of tagging policies, which are frequently a part of a company's safety manual. Some utilities have a serious accident investigation team that performs such investigations; among the study participants, K has such a team, and L has used outside consultants for the same purpose.

Even more rigorous investigations may be conducted following major system disturbances that involve widespread outages, impacting neighboring utilities and the public. Such incidents typically involve a cadre of independent outside investigators that may be appointed by national, state, or local authorities.

4
WHO INVESTIGATES

The question of who conducts the investigation is closely related to the level of investigation. In this section we discuss first the individuals who are normally responsible for the initial investigation and then situations in which teams are involved. The benefits of team investigations – and more generally of a structured organizational approach to investigations – are discussed. Finally, the training provided for investigators is described briefly.

Role of the Initial Investigator

For most participating utilities the initial investigation is performed by the first-line supervisor or, sometimes, the unit manager (Utilities A and K). This individual is the first, and usually the only, investigator of low-consequence and low-complexity incidents. The investigation involves interviews of the people involved and review of the documentation related to the activity in progress (switching instructions, work orders, drawings), and usually inspection of the site of the incident.

Note that the initial *investigation* is different from the initial *reporting* of the incident, which is often done by the personnel involved.

For example, in Utility B, the persons involved are expected to write a brief description of what happened and submit it to their supervisor. Other than log entries, this is usually the first document describing the incident. The supervisor then interviews the people involved, and writes a report that typically includes the original hand-written document and any additional details gained from interviews, inspection of the scene, and review of documentation relating to the work being performed. This report may or may not include recommendations for corrective actions, or descriptions of corrective actions that have already been initiated. The supervisor's report is then forwarded to his manager or the control center for review and approval. The responsible manager at that level may conduct a further investigation (e.g., additional interviews, etc.) or accept the report from the supervisor. For incidents with only minor consequences, the investigation and reporting process ends at that level, though a sanitized summary version of the report is prepared for distribution.

For low-consequence and low-complexity incidents, such as the omission of a step in the execution of a switching order or accidental activation of a relay during testing, the immediate supervisor or manager is usually the only investigator. But four of the 14 participants offer exceptions to the above generalization.

1. Utility C employs a 2-page "apparent cause" form for reports of all incidents; those meeting threshold criteria are followed up by a more detailed root cause investigation. The supervisor or employee reports the incident, but the apparent cause report is completed by a loss prevention specialist rather than the supervisor or employee.

2. Utility I has "lead investigators" in its several operating departments who conduct all investigations and may convene a team for high-consequence or high-complexity events.

3. Utility J maintains a team whose members conduct all investigations in their Operations Department. Investigations may be conducted by one or more team members.

4. In Utility L, for incidents occurring in substations, the supervisor's role is limited to notification of the incident and collection of related documentation for use by a standing committee that is convened to conduct the investigation within 24 hours of the incident. All operating errors are investigated by the team, which attempts to determine the "root cause or causes" for every incident, (i.e., a single level of investigation). Incidents occurring in the Control Center are usually investigated by a single person, who is a member of a small cadre of persons who conduct such investigations.

Investigative Teams

Although teams are involved in all investigations in some utilities (e.g., Utility L as just described), formation of an investigative team is normally associated with a higher level of investigation.

Composition of the Team

For the majority of participating utilities the teams are formed on an ad-hoc basis, with a leader from the affected department and additional members selected for their technical expertise. The team leader may be a manager or his designee, or a member of a cadre that has been trained in more advanced techniques of investigation and analysis (Utilities C, F, and I).

For about half (6) of the utilities, a Safety representative is normally included in the team: for the others, Safety may be included on an as-needed basis. The Safety representative may have more training in investigative techniques than other team members. Additional members include subject matter experts in the operations or equipment involved in the incident, and representatives of all departments involved. Utility F routinely includes a union representative on the team, others (D, H) may include a union representative if needed (e.g., disciplinary action may result from the investigation). Utility C includes someone involved in the event on the root cause analysis teams, which they feel adds to the credibility of the results.

Benefits of Using Teams

Two principal strengths of the team approach lie in its use of the specialized expertise of several people, and the team's employment one or more of the formal techniques of root cause analysis. Although in principle such techniques may be employed by individual investigators, they are

time consuming and first level investigators may not have training in their use. Teams are convened for more complicated or high-consequence events where such techniques are more likely to be required. Team investigations for 4 of the 14 participating utilities use adaptations of commercially available root cause analysis systems. Methods for determining causes of incidents are discussed in Section 5 and a more detailed description of root cause analysis is provided in Appendix C.

A third strength of the team approach stems from sheer numbers: several heads are better than one, in that different members are not likely to have identical prejudices and blind spots. In his book on the Apollo root cause analysis system, Gano emphasizes that teams are more likely to identify the true causes and more effective fixes for them because their members bring a diversity of perspectives as well as technical knowledge to their task. The value of diverse perspectives among the members of a team is also recognized by Ferry, the author of *Modern Accident Investigation and Analysis,* and Trevor Kletz. Kletz strongly recommends that the team include a person form outside the organization or unit that experienced the incident. Individuals from the same operating unit (or dedicated team of investigators) may be at risk for developing a shared set of prejudices and blind spots, whose effects may be countered by the inclusion of an outsider.

Finally, a team may have both the ability and the authority to consider broader remedial measures.

The benefits of a team approach are illustrated by the following example which builds on the earlier example in which an operator opened the wrong switch because there was an incorrect switch number – presumably a typo – in the switching instructions.

Two obvious questions are raised by the incident:

- How did we dispatch an order with a typo in it?
- Why didn't the dispatcher or the operator realize it was not the right switch?

A team would probably employ some charting method that would help the investigators focus on why the field switchman operator did not recognize the typo, as well as on why the typo was not discovered prior to dispatching.

Both individuals and teams would likely look for compliance with existing policies & practices as well as examining these practices for potential improvements. For example, the investigator might conclude that if the line to be switched were included in the order as well as the breaker number, the switchman would be more likely to have noticed the discrepancy and stopped before any harm was done. A difference might be that the team would likely devote more time to the consideration of additional preventive measures. They would be more likely to entertain the idea that, yes, we have procedures that should catch such errors before they are dispatched, but is there something *else* can be done to prevent this kind of incident? For example, where planned switching placed a critical customer in a radial feed situation, might it be prudent to place warning tags on the remaining feeder?

In principle, the single investigator could have gone down the same path as the team. In practice, he or she is all too likely to stop at the most obvious explanation, or not feel entirely free to propose additional measure that would increase the expense of conducting operations, as would the additional tagging. The team has an advantage in this regard because the importance attached to the incident has shown the cost of *not* doing something different.

Training Provided to Investigators

In most utilities, the people who have received the most training in incident investigation are members of the Safety Department. Most managers have received some training, but are not as experienced as safety personnel. Supervisors also receive some training, though it is often only a module on incident investigation that is given as a part of a safety management course. Half of the participating utilities (A, B, D, E, J, M, and N) reported that the people who are the first and often the only investigators (supervisors and managers) had received little training in conducting an investigation.

Utility A attempts to compensate for this by providing a well-structured procedure and job aids, as does H. Utility M usually includes a safety professional on its incident investigation teams, in part to supply the investigative expertise that the other members (managers and subject matter experts) lack.

Teams from C, and individuals from F and G who will be team leaders, have received extensive training in commercially available root cause analysis systems. Utilities I and K have in-house training programs for root cause analysis, and K's managers have also received human performance event training provided by the Institute for Nuclear Power Operations (INPO). The cadre who investigate Operations events for L have taken comprehensive incident investigation courses.

Organizational Status of the Investigator(s)

The organizational status of those responsible for investigations may have a substantial effect on their effectiveness. The situation varies from one utility to another. Four of the participating utilities (Utilities C, I, J, and L) have a cadre of people who conduct all or most of their investigations.

The authors believe that the existence of a formal organization – whether a committee or a department – contributes to the effectiveness of the investigation process. In the first place it indicates a level of management support that confers status on the personnel and their activities. Given this status, the investigators are empowered to be more searching in their investigations and more sweeping in their recommendations. Moreover, an established group that is involved in numerous investigations may be able to see trends and patterns in the events that are investigated. The individual or local investigator only sees an individual event and may have more difficulty in identifying systemic causes.

5
THE INCIDENT INVESTIGATION PROCESS

This section covers the main steps in the investigation process up to, but not including, the preparation of the incident report; this is covered in Section 6. The section starts with a review of the documented procedures that are used by participants in this study.

Written Procedures for Investigations

Eight utilities supplied procedures or policy documents governing the conduct of investigations. Three of the participating utilities (E, J, and N) do not have written procedures for conducting investigations. The remaining three utilities in the study have procedures but did not supply copies for review.

The structure and detail of procedures governing investigations varies considerably, as shown in the table on the next page. In the table, procedure sections are shown in bold, specific contents in plain type. Utility O did not participate in the present study but its procedures were reviewed for the study of *Near Miss Investigation and Reporting;* their procedure is included in the table because it is particularly informative, and is written as a guide for execution.

The procedures reviewed usually describe the first level of investigation. As described in Section 4, additional levels are usually available for injury cases or major system impacts.

Inspection of the table shows that procedures vary a great deal in their structure and content. Although they contained guidance on the expected product of the investigation such as report forms or an outline of the expected report, which state or imply the information to be collected, many of the procedures reviewed presented relatively little direction about the steps required to actually perform the investigation itself. For example, the document supplied by B is essentially a policy document saying little more than certain events must be investigated and a report submitted.

The detail desirable in a written procedure depends largely on the training that can be assumed for investigators, which varies a great deal. One participating utility provides very minimal guidance, but investigations are done by managers with training in various aspects of investigation. Experience is also a determinant; a utility that has designated individuals or standing teams that conduct all investigations needs to provide less guidance than one in which investigators are inexperienced.

The authors of this report believe that written procedures are useful for promoting consistency in what is investigated, how it is investigated, and how the results of investigation are reported. A more detailed procedure leaves fewer things to chance or custom. Where each investigation is likely to be done by a different person or team, more complete guidance should be provided, and supplemented by appropriate job aids. The outline of a model procedure is presented and discussed in detail in Appendix D.

Table 5-1
Procedure Sections

Procedure Section	Utility[1]								
	A	B	D	G	H[2]	K	L	M	O
Purpose	●	●	●		○			●	●
Explicit goal of prevention		●			●				●
Scope (units to which procedure applies)	●	●	●	●		●		●	
Criteria for Reporting									
Events to investigate and report	●	●	●	●	●	●,○	●	●	●
Timeliness	●	●	●	●	●	●	●	●	●
Levels of investigation			●	●	●				
Responsibilities	●	●	●	●	●	●	●	●	
Investigator qualifications									
Team composition	□		●	●		□	□		●
Investigation Guidelines				○					
Discussion of causes	○					●,○			●
Report Preparation Guidelines	●			○	○	●		○	●
Use/Distribution of reports	●	●				●		●	●
Management review/approval	●					●			●
Assignment/tracking of follow-up					●			●	●
Follow up analyses (Committee review for trends)	●					○			
References (to governing or supporting documents)				●	●		●		
Training Requirements					●				
Report Outline or Forms	●		●	○	○	●		●	●
Other Job Aids	●		●	●	●	●		●	●

1. Utilities C, F, and I have procedures governing investigation and reporting but did not supply copies for review.
2. Much of the investigation-related information for H comes from their incident report form and accompanying instructions, rather than the (draft) Accident/Incident Reporting procedure: the training requirement comes from the superordinate company-wide Safety procedure, which deals with injuries.

□ One “investigator” is specified (usually the immediate supervisor or manager), but may involve other people as appropriate.

○ Described in an attachment or separate document.

Overview of the Investigation Process

Most investigations are performed in the same way, whether by an individual or a team. The major steps involved are:

- Identifying and collecting relevant materials
- Determining the facts of the case
- Determining the causes of the deviation or undesired outcome
- Proposing recommendations for avoiding similar incidents in the future
- Preparing a report of the incident (discussed in Section 6)

One participating utility (G) provides a checklist for performing the investigation and preparing the report as a job aid. A model investigation checklist is presented as Appendix E and shown in outline form in Section 8 of this report.

Identifying and Collecting Relevant Materials

The first step in the investigation is to identify the individuals involved and any material that may be relevant to the investigation. In the case of an accident (physical damage to persons or property), the investigator should secure the scene and document the damage with measurements, drawings, or photographs. Securing the scene means leaving everything as it was at the time of the event so it can be inspected thoroughly. This is not necessary for most switching incidents and, in any event, the safety department will usually lead the investigation if an injury was involved.

Some utilities will stop a job in progress when an error is discovered. However, if there is no injury or equipment damage, most utilities will issue revised orders to correct the error and return the system to the desired state as soon as possible.

The investigator should also collect any other "evidence" related to the incident. In the case of switching incidents this will include written switching orders, logs, work orders or other job instructions, notes on the locations of tags, recordings of communications between the field crew and the dispatcher, the tools used by relay technicians if applicable (for example, if contacts were shorted out), and additional materials as dictated by the nature of the incident.

Determining the Facts

The central, indispensable element of all investigations is the interview. Some utilities supply guidelines for conducting interviews. A set of such guidelines is presented in Appendix F.

The investigator should interview all individuals involved in the incident to establish the basic facts of when and where the incident occurred, who was involved, what work was in progress, what happened that was not supposed to, and, if known to the participants, how the unintended action or event happened. Usually the people involved know what happened, and have an idea of why it did.

As a part of the interview process, the investigator may ask employees involved in the incident what they could or should have done differently or may ask for their suggestions for correcting or mitigating the influence of any contributing factors that have been identified.

Because people forget details rapidly, and may distort their recollections of events by filling in gaps and trying to resolve inconsistencies so that their memories form a coherent story, interviews should be conducted as soon after the event as is practical. If several individuals are involved, they should be interviewed separately before they have had a chance to compare notes on the event. Individuals may be re-interviewed to corroborate information obtained in one interview but not another, or to resolve conflicting versions of events offered by different interviewees.

The investigator will usually conduct a walk-down inspection of the part of the job in which the incident occurred, and may perform a walk-through of the incident with the personnel involved. If site conditions (bad lighting, degraded or missing labels, difficult access, inoperable equipment, omissions in the station operating instructions or other documents) are reported to have contributed to the incident, the investigator should evaluate them and document any deficiencies found. For incidents that arise because of an error in the control room, a simulator may be used to "reenact" the event as an aid to identifying its causes or contributing factors.

The investigator should also review documentation of the work in progress, particularly working documents such as switching instructions. The documents establish what was supposed to happen, i.e., the expected performance that was not obtained. The review should determine if the documentation was accurate, complete, and used properly. For example, the checkoff on the switching orders may not be properly filled in, the station log may not contain the "as left" status of equipment involved in the incident, etc. Handwritten documents should also be evaluated for legibility and such common slips as transposed characters.

For switching incidents, tapes of conversations with the dispatcher (or between dispatchers) should be reviewed to determine if communications were clear, complete, and in accordance with company protocol.

Any deficiencies in the documentation or communications should be documented for evaluation as contributing factors to the present incident. For example, errors in switching orders are sometimes traced to inaccuracies, omissions, or illegibility in the documents from which they were developed. Deficiencies in documentation or communications generally warrant further investigation, even if they did not contribute directly to the incident under investigation.

This information from the interviews and document review is used to develop a factual narrative of the incident, usually beginning with a description of the work in progress and continuing through the incident itself. In some cases the narrative may include any actions performed to restore the system to its desired state. For a complex event the investigators may produce a timeline of events, though a timeline, in the sense of the sequence of events, is implicit in the narrative.

Determining Causes

The term "root cause" is widely used, but sometimes with different meanings. We start by examining the meaning and then look more broadly at different levels of causes and different approaches to determining the cause of an incident. The discussion in this section is supplemented by the description of different root cause analysis techniques in Appendix C.

Searching for Root Causes

In their responses to the survey, representatives of most participating utilities claimed to be searching for the "root cause." There are many definitions of root cause. A common one is:

> Root cause(s) are the fundamental factor(s) that, if corrected, would have prevented the incident even if all (or most) of the other causes still existed.

A more formal definition from the DOE *Root Cause Analysis Guidance Document* is given below.

> *Root cause.* The cause that, if corrected, would prevent recurrence of this and similar occurrences. The root cause does not apply to this occurrence only, but has generic implications to a broad group of possible occurrences, and it is the most fundamental aspect of the cause that can logically be identified and corrected (DOE, p.3).

The definition of root cause contains many elements. The first is that it is the controlling factor, so fixing it will fix the problem. A second is that the same cause can affect many other events with similar consequences. A third idea contained in most discussions of root cause is that it may be, and often is, far removed from the events it causes. A fourth idea contained in such discussions is that, because actions typically have local effects, root causes are more likely to be found in conditions rather than actions (though the *condition* of an overextended staff can be caused by the *action* of reducing budget). This is an extension of the second and third ideas listed above.

Four of the 14 utilities in the study use adaptations of commercially available root cause analysis techniques. Utilities A and F use TapRooT®, C uses Apollo©, and G uses a system available from the American Society of Safety Engineers (ASSE). Utilities I and K use techniques developed in house on the basis of published materials from vendors and other sources. For example, some of K's techniques are derived from Human Performance Event training materials published by the Institute for Nuclear Power Operations (INPO). The TapRooT® and Apollo© techniques are described briefly in Appendix C.

Levels of Causes

More sophisticated investigators recognize that there are many levels of causes as exemplified in the hierarchy of causes from Utility O:

> *Immediate Cause* (only one) – The *specific* thing that went wrong that was *directly and immediately responsible* for triggering the incident.
>
> *Contributing or Indirect Causes* (frequently several) – The circumstances or actions which *enabled or set up* the situation for the immediate cause to occur, or which *contributed* to the damage or injury (such as not wearing PPE).
>
> *Root Cause* (one) – The fundamental factor that, if corrected, would have prevented the incident even if all (or most) of the other causes still existed.

Only two of the procedures provided by participating utilities include any discussion or definitions of different levels of causes. Many experienced investigators recognize that "root cause" is elusive in most human performance events. Such events frequently involve multiple interrelated causes or causal factors (see Appendix C for an illustration). These may be found by

the application of formal root cause analysis techniques such as event and causal factors charting (also described briefly in Appendix C), but such techniques are usually used only in the analysis of complex or high consequence events by a team, rather than the investigation of run-of-the-mill switching errors.

Typical Approaches used to Determine Causes

For most investigations three approaches are used, usually in combination:

1. **Focus on identifying all contributing factors or causes.**
   Investigators tend to be practical people with a focus on usable results. They may realize that "root cause," the single factor whose correction guarantees that something similar will not happen again, is an academic abstraction whose real-life instances are difficult-to-impossible to identify. Most understand that the careful interviewing and inspection of the site and other materials may identify a number of contributing factors that can be addressed by management and whose correction may lessen the probability of recurrence, though not eliminate it entirely. Approaching a problem by attacking all identified contributing factors is an approach explicitly propounded by Gano in his book *Apollo Root Cause Analysis*.

2. **Dig until it seems unproductive to go further.**
   Most investigators probably try to do this. The willingness to dig deeper where warranted provides the most payoff in terms of future incidents avoided. Each cause or contributing factor identified has, in turn, its own set of causes. With time and resources such causal chains can expand almost indefinitely. The stopping point for an investigation is usually when the investigator is reasonably satisfied that he or she has identified sufficient causes, or when the causes identified cannot be controlled. Consider the following example:

   > An error occurred because a drawing was incorrect because it was not updated to reflect recent changes because of a large backlog in the responsible department, because of an increase in new construction coupled with a reduction in staffing because of cost cutting done because the value of the company's stock was slipping.

A local supervisor might stop with the first one or two of these 6 successively more fundamental causes. It is sufficient to explain the error and he or she may be able to ensure that his drawings, at least, are correct. In addition the supervisor may feel (correctly) that there is nothing to be done about the cost cutting.

While this approach is practiced by virtually all investigators, it has two liabilities. First, stopping with sufficient causes may overlook correctable contributing factors. Investigations by inexperienced investigators are more likely to succumb to this liability than are those conducted by more experienced ones. Second, the point at which it is "unproductive" to dig further can be influenced by the resources available to the investigator, and also his or her position in the management hierarchy. A committee convened by the Vice President of Operations to investigate a serious incident has more resources than the supervisor investigating a routine one, and it expects more factors to be controllable by its client.

3. **Search for "causes" that fit into predefined Root Cause Categories.**
   Several of the participating utilities provide job aids that are lists of root cause categories, or incorporate material from such lists in their report forms (See Section 8). Although we believe that such lists should not limit the range of causes that can be examined, they are useful in that they function to keep an investigator from too narrowly focusing on what appears to be the most obvious cause or causes. They can be a corrective for the tendency of the inexperienced investigator to stop looking when what is thought to be a sufficient cause has been found.

Searching for Causes of Switching Incidents

In most switching incidents where documentation, communications, site conditions, etc are all as they should be, the "cause" of the event usually lies in something the personnel involved did or did not do. Unintended actions or omissions can usually be traced to failure, usually through inadvertence, to scrupulously follow established practices and procedures. Such failure will often be identified by the responsible personnel themselves, sometimes with an explanation of why they behaved as they did.

When such deviations are identified, they are often the immediate cause of the incident, and are often cited as the primary or sole cause. In the tightly controlled environment of utility operations failure to follow established practices or procedures satisfies the first two elements of the definition of *root cause* very well. Deviations from accepted practice are almost always *sufficient* cause, in that the event would not have happened if such practices had been followed. Deviations from accepted practice are often cited as the "root cause" of an incident, even though they do not satisfy the third and fourth elements of the definition given earlier, namely the fact that root causes typically are found in *conditions* rather than *actions*. We believe this is a mistake because identification of the "root cause" signals the end of the inquiry, and this particular "root cause" also effectively limits management response to exhortations to follow the rules better.

Many investigations will be satisfied that deviation from accepted practice is "the" cause of the incident. However, the investigator should try to determine why the deviation occurred. In some cases it may be no more than a mental lapse ("loss of focus"). Such lapses may be unexplainable and uncontrollable random occurrences. However, they may sometimes be traceable to distractions, excessive workload, illness, or fatigue from excessive overtime, which are all factors that management can exert some influence over. In other cases the deviation may be the result of lax observance of expected practices, or a misunderstanding of requirements. Such findings imply that supervision or training was less than adequate. A local investigation of a low-consequence event may not do the digging required to reach such conclusions.

Because the goal of the investigation is prevention of similar incidents, investigations should try to determine not only the immediate causes of an incident but the less obvious ones as well. If mitigating factors are claimed, e.g., deficient labeling, incorrect or confusing drawings, etc., the investigation should verify their existence through the inspections of materials and documents described above.

All such irregularities should be documented as contributing factors, even if all concerned feel that the person involved "should have been" able to compensate for them. If any such pre-existing condition contributed to this event, the investigators should be concerned that the condition could contribute to future events. For example, the investigator should ask, "If this drawing is wrong, how many others are also wrong?" "Is this an isolated error, or a symptom of some inadequacy in our document control process?" If the investigators cannot answer these questions themselves, review of a sample of drawings should be one of the recommendations developed by the investigation.

Developing Recommendations

Development of recommended corrective actions is the next-to-last step in the investigation. The goal of this phase of the investigation is to effect changes in the organization that will prevent recurrence of similar incidents.

The point of conducting investigations is to find ways to correct any problems with the work practices, procedures, work environment, etc, that are revealed by the incident. The recommendations, or more accurately, the corrections, are the product that justifies the time and effort expended in the investigation. Wherever contributing factors are identified, recommendations for correcting them should be made.

Although three of the participating utilities provide guidelines for generating effective recommendations (shown in Section 8), most appear to leave what is acceptable up to the judgment of the investigator. In the authors' judgment, this is a mistake because correction of deficiencies is the goal of the entire investigation process, and effective recommendations are difficult to write.

Guidelines for developing recommendations are given in the books by Ammerman (pp. 71-78), Ferry (pp. 236-237), and Gano (pp. 93-95), and comprehensive guidance given in the DOE *Root Cause Analysis Guidance Document* is reproduced in Appendix G. Collectively, these sources identify six criteria for effective recommendations:

- Comprehensiveness: recommendations should address all causal factors identified.
- Specificity: specific and individually actionable recommendations should be developed to address each identified deficiency.
- Efficacy: recommendations should be such that they are likely to fix the problem, and prevent its recurrence.
- Practicality: recommendations should be realistic, within the control of the organization to implement, and cost-effective.
- Compatibility: recommended actions should not create other problems or undue burden, and should be compatible with existing practices and procedures.
- Sustainability: recommendations should be sustainable for the foreseeable future.

Recommendations not meeting all of the above criteria may not be effective if implemented, and are in fact unlikely to be acted upon.

It may be a good idea for the investigator to discuss proposed recommendations with the manager who will receive the report and may have to act on them. This helps ensure that the recommendations are both do-able and reasonably cost-effective. It also lets the manager know what to expect, ensures that the evidence required to secure the desired action is included in the report, and ensures that the recommendations will be acted upon.

A Note on Legal Aspects of Incident Investigation

In the utility business, those conducting investigations attempt to do so in the spirit of impartial fact-finding, with the expectation that any facts discovered will be used by the company to correct deficiencies and improve the reliability of its operations and the safety of its employees and the general public. The investigator seldom gives thought to legal requirements or the potential for legal consequences to follow from his findings. However, a company's legal or claims department may be concerned that information contained in an incident report contains information that could be used against the company.

It is not the purpose of this report to give legal advice. However, the following points should be considered, perhaps in consultation with the company's Legal Department.

1. Any incident involving damage to non-company property or the injury of non-company personnel may result in legal action against the company, and should be immediately brought to the attention of the Legal Department. It is also possible that legal action may be initiated by an injured employee, or the survivors of one that has been killed, if the responsible hazard was allegedly known to, but not corrected by company management.

2. It sometimes happens in the course of investigations that speculations, allegations, or evidence concerning unsafe conditions or practices is discovered. Where there is evidence, this should be duly reported and become part of the official record of the investigation. Where there is not supporting evidence, such allegations or speculations may still be recorded in the notes of the investigators, where they may be resurrected by legal "discovery" processes instituted years later, to the potential detriment of the organization (Ferry, p. 256). Thus one recommendation of this study (see retention of records in Section 7) is *not* to keep materials that are not included in the report unless required to do so.

3. The company should identify all circumstances in which an incident should be brought to the attention of the Legal Department and make such circumstances known to those responsible for incident investigation and reporting, preferably by incorporating the criteria in the procedures governing incident investigation.

4. From both the legal and moral perspectives, the best defense against incurring a legal action is to eliminate as far as possible those circumstances which might give rise to it. The authors believe that thorough investigation, coupled with prompt and effective implementation of corrections when investigation reveals the need for them, is a major component of any such effort. This belief is reinforced by the observations of Michael Baram, who is a faculty member at Boston University's Center for Law and Technology, writing about the chemical industry:

> "Common law doctrines in the U.S., which establish company liability for personal injuries and damage to private property, also promote organizational learning. For example, negligence doctrines impose liability on companies for injurious events caused by management failure to exercise due care in operating a process with hazardous attributes. Thus, a company's insufficient attentiveness to prior accidents or near misses can be used as evidence of lack of due care, and increase the likelihood that liability will be imposed. . . . As a result, regulatory requirements [in the chemical industry], liability doctrines and market forces converge and have the effect of making a rational company which poses accident risks quite attentive to incident analysis." (Baram, p.166).

Baram is writing about an industry where accidents can and have cost hundreds of millions of dollars and taken hundreds of lives. While similar regulations do not, to the authors' knowledge, exist for the electric utility industry, the common law doctrines he mentions apply with equal force.

The above discussion makes it clear that incident investigation reports could be a liability in some circumstances. Suppose a switching error drops a critical customer whose contract specifies a certain level of reliability, and the customer sues for breach of contract. If incidents of a similar nature were on record, the reports of the incidents contained sensible recommendations for preventing such errors, and the recommendations were not acted upon, the customer's lawyers might claim that the company was aware of the problem, and was negligent in not taking steps to correct it (Ferry, p. 259). An administrative judge, jury, or dispute arbitrator might well agree.

Some utilities that have implemented a formal incident reporting process have encountered resistance from their legal departments to documenting information that could put the company in jeopardy. The authors contend, to the contrary, that a record of aggressive attempts to identify and correct problems that surface during an incident could be presented as evidence of the company's concern and diligence in identifying and responding to problems. Such a record is far more likely to enlist the sympathies of a judge or jury than not investigating such incidents would be. The authors believe that the last sentence in the Baram quote above applies equally to the utility industry. A rational management should find that its best defense against potential legal actions arising from incidents is through investigation and aggressive follow through to correct any problems identified.

6
INCIDENT INVESTIGATION REPORTS

Preparation of the report is the last step in the investigation process. The report serves as the record of the incident and the subsequent investigation. It is also the primary vehicle for conveying lessons learned and recommendations for corrective actions. This section addresses report contents and format, the presentation of recommendations, and attachments to reports. The distribution of reports is discussed in Section 7.

Report Contents and Format

Because the incident report is the vehicle for communicating recommendations and the supporting arguments, it is important that it should be well written and convincing. It is particularly important that the narrative be complete, accurate, and easily understood, and that all the facts relevant to the recommendations be included. Guidelines for organizing materials and drafting the report are given in the books by Ferry and Ammerman. The books by Kletz and Ammerman also contain model reports. (See section 10 for references.) Here we summarize information about the types of reports prepared by utilities that participated in this study and go on to make our own recommendations.

Reports Prepared by Participating Utilities

A given incident may result in several different levels of reports which can vary greatly in their complexity and the formality of presentation. The investigator(s) usually prepare a report for management. From this report a "sanitized" version for distribution may be prepared by the investigator or someone else. Thus there are basically two kinds of reports, those intended for the responsible management that include all necessary details, including names of those involved, and reports intended for fairly wide distribution.

In the study, we found little consistency among participating utilities in the format of incident reports. The report formats of three of the participating utilities are shown in outline form in Figure 6-1.

Many initial investigations are reported via a standard form. An example is the form used by Utility D, the outline for which is on the left in the figure. More elaborate investigations may also be reported using similar forms. Though the blank forms are a single page, the report itself may be much longer. Where the report is submitted on a form, the form dictates its contents (and often the structure of the investigation as well). The forms reviewed generally had multiple narrative sections and resulted in multi-page reports if the narratives were extensive.

Report Form (D)	Simple (K)	Elaborate (G)
Incident Date and Type Person(s) Reviewing Incident Employee(s) Interviewed Summary of Incident Facts # of hr Worked in prior 48 Conclusions Recommendations	Reason for Improvement Problem Definition Process/Activity Description and Root Cause Analysis Date/Time Root Cause Solution(s)	Incident date/Time Location Investigation Start Date/Time Investigation Team Personnel Interviewed Scope Narrative Equipment Environment Workers Management System Direct Cause Indirect Causes Root Cause(s) Findings Recommendations

Figure 6-1
Sample Report Formats

Forms are "working" reports that convey pertinent information to management; in particular, they may name the individuals involved. The report that is eventually distributed will be edited to remove names, but may be otherwise identical.

The simple format used by Utility K is intended to produce a concise report limited to one or two pages. This report is intended for distribution. Before a finalized report is issued, each incident is presented to the operations review committee by the investigating manager and the persons involved in the incident.

The more elaborate format used by Utility G is intended to ensure that the investigation has not overlooked any possible contributing factors. The format requires the examination of potential contributing/root causes from the utility's list of root causes; it also requires that the investigators specifically address the multiple levels of causes that may be associated with the event.

Reports from utilities B and J are in a memo form that seems to follow no set format.

Recommended Report Contents and Outline

Based on a study of the literature and the experience of participating utilities, the authors recommend that, at a minimum, the contents of an incident report should include:

1. A narrative description of the incident itself and its consequences. This was a part of reports from all participants. The narrative may also include a description of actions required to compensate for conditions caused by the incident, such as switching to restore the system to its proper configuration. The DOE and NRC require this for nuclear facilities, and most people intuitively feel that the incident is not over until things are back to normal. Utilities J and M follow this philosophy.

2. Identification of one or more causes or contributing factors.

3. Recommendation for correcting the identified causes.

The reports of at least one participating utility allow inclusion of an optional section in an incident report to document deficiencies or irregularities discovered in the course of the investigation, even if they did not appear to be causally related to the incident under investigation. Examples of such incidentally discovered deficiencies include deteriorated labels or poor lighting. Examples of deviations from expected practice include unauthorized abbreviations in hand-copied switching instructions or communications not conducted in strict accord with company protocols. We believe that documentation of such non-causal deficiencies is in accordance with the overall goals of the incident investigation process, and recommend that all deficiencies discovered be documented in the investigation report.

A general report outline based on the features of the reports collected for this study is shown in Figure 6-2 below.

Incident Report Outline

Title (include location, date, and nature of the incident) e.g.,

Accidental relay activation at Orchard St SS, 10/16/02

Overview of the incident A capsule summary of the narrative, including:

- Where incident occurred
- Work in progress
- What happened
- Consequences
  - to system/customers
  - to employees, if any
- Restoration
- Recommendations to prevent recurrence (if any)

Narrative

- Location & Work in progress
- Events immediately preceeding the incident
- **Actions** involved in the incident
- Consequences of those actions
  - to system
  - to employees, if any
- Actions immediately following the incident
  - how error was discovered if not recognized immediately by personnel involved
  - actions to restore the system to desired configuration

Type of analysis performed

- Persons interviewed
- Records reviewed
- Observations at the scene if any
- Formal techniques employed if any (e.g., causal charting, etc)

Causal factors

- Facts supporting determination of immediate cause
- Immediate cause
- Facts and observations supporting determination of contributing causes
- Contributing causes or conditions identified
- Facts and observations & analyses supporting determination of root cause if discernable
- Root causes if discernable

Recommendations for corrective actions to prevent recurrence

Management Response

- Corrections already undertaken
- Management sign-off for recommended corrections
- Assignments and due dates for corrective actions
- Management comments (Optional)
  - These may include reasons for rejection or deferral of recommended corrections, or alternatives

Administrative Information

- Investigator(s)
- Other required administrative information

Figure 6-2
Model Report Outline

Presentation of Recommendations

The point of conducting investigations is to find ways to correct any problems with the work practices, procedures, work environment, etc., that are revealed by the incident. The recommendations, or more accurately, the corrections, are the product expected in return for the time and effort expended in an investigation.

A specific section of the report is usually provided for recommendations. For many utilities they are simply listed, sometimes with the notation that they have already been implemented.

In the reports of Level 2 investigations from Utility F, each recommendation is preceded by a listing of the findings that establish a need for it:

- Findings
- Significance
- Recommendation

This structure is a rhetorical device that basically lays out an argument in support of the recommendation. We believe this style of presentation is preferable to a simple listing because the reasons for the recommendations are more readily apparent than if findings, causes, and recommendations are listed separately.

Utilities A, C, and G list each recommendation with the name of the person responsible for implementing it and a due date. Utility C's reports are prepared by a team of investigators that negotiates with the managers who have the authority to authorize and fund any recommended corrections prior to the release of the final report. Recommendations in the final report are thus pre-authorized, and represent a firm management commitment. Recommendations are entered into a database and tracked by senior management to insure completion.

Utility C's approved recommendations are presented in a table format (see Figure 6-3) that again makes the connection between the problem and its corrective action readily apparent.

Cause	Recommendation	Person Responsible	Completion Date
Aeolian Vibration	*Review design practices re bus length and damping*	*John Doe*	*3/30/01*

Figure 6-3
Table of Recommendations, Responsibilities, and Due Dates

Utility A's reports are prepared by the responsible manager and approved by more senior management. In Utility G, the responsible manager often serves as head of the investigation team. Such management involvement in the investigation obviously is helpful in being able to assign responsibility for implementing recommendations. In both cases the list of corrections and due dates signifies that the manager has assumed responsibility for their completion.

Recommendations presented without assigned responsibilities and due dates (or an annotation that they have already been implemented) are simply recommendations that may or may not be acted upon. Recommendations with assigned responsibilities and due dates are a clear sign that management recognizes that there is a problem and is taking steps to correct it.

In addition to recommendations, or in lieu of them, the report may list actions that have already been taken by the report originator to address the problems within his span of control. For example, a substation technician did not disable an undercurrent relay whose input was from a transformer that he isolated for routine maintenance. The information that he should do this should have been in the substation operating manual, but was not. The supervisor's report might note that the manual had been corrected, and that he or she had instituted a review of the manuals for the other substations in his/her area of responsibility.

Report Attachments

Attachments are generally appended to an incident report only as needed to ensure complete understanding of the incident and to support conclusions and recommendations. The most common attachments for reports of switching incidents are:

- One-line diagrams
- Switching instructions
- Work plans

One-lines and switching orders are likely to be included in most reports of switching-related incidents. The one-lines establish a context for the narrative and the switching instructions or work plans document what was supposed to happen, but did not. Where relays were actuated or additional switching was required to correct an error, even preliminary reports may also contain a timeline or sequence of events. Sequence of event listings are a part of Utility M's procedure format, and are usually included in the reports from Utility J's investigation group.

Reports of more detailed investigations involving formal root-cause analyses generally include timelines, charts, or tables produced in the analysis (Events and Causal Factors, Apollo, or others, depending on the system). Utility A has a root cause chart (shown in Section 8) that is part of the report form for all operations incidents.

Investigations of serious injuries conducted by the Safety department usually include photos of the scene, but most reports produced by Operations do not, unless there is equipment damage. The inclusion of interview summaries in reports is unusual, and may be done primarily for legal reasons.

7
FOLLOW-UP

Incident investigations are often spoken of as an aid to "organizational learning". The possibility of discovering ways to improve organizational processes and procedures is, or should be, the primary reason investigations are performed, and most of the utilities contributing to this study subscribe to this idea. If the only product of the investigation is a report that is read by only a select few within the chain of command, little has been done to achieve this goal. Vigorous and systematic follow-up is required to realize the benefits that can be achieved through investigation and understanding of operating incidents.

This section covers topics relating to the follow-up of incident investigations, including: distribution of reports; management response to the recommendations; mechanisms to ensure follow up; retention of records; and compilation and review of incident reports. The section also discusses the relationship between employee discipline and the outcomes of incident investigations.

Distribution of Reports

Because incident investigation and reporting is considered a tool for organizational learning, fairly wide distribution of reports is essential for communicating lessons learned.

The process for distribution of reports is quite consistent among participating utilities. Complete reports (including names) are sent to management whose personnel were involved. Complete reports (usually without names) are also submitted to System Operations Review Committees or similar bodies where they exist. Reports may also be submitted to external agencies (e.g., NERC, FERC, DOE) if required by the nature of the incident, though this is rare. Reports of incidents involving injury investigated by the Safety Department are usually submitted in some form to several external agencies, but these reporting responsibilities are outside the scope of this report.

All of the 14 participants provide versions of reports to line level workers, though J reported it does so only occasionally. The mechanisms for distribution of reports include:

- E-mailing of reports to supervisory personnel, with the expectation that they will be shared with their work groups or used in safety meetings.
- E-mailing reports or a special synopsis of them to all members of the affected department (A, C, and L). Utility L's reports are delivered by Professor Switchright, a whimsical clip-art character who is the e-mail face of a senior investigator known to all persons in the department (see Figure 7-1). In addition to incident reports, Professor Switchright also distributes tips on error prevention, and asks operators to e-mail him error prevention tips they come up with.

- Entry into electronic databases that may be accessed by all employees (I, K, N).
- Paper or electronic safety bulletins.
- Especially critical incidents may also be distributed or "published" via presentations. The substation operations group of Utility B has recently taken a presentation of a critical system disturbance on the road to all of its field operators. Other utilities provide presentations on incidents as a part of ongoing training programs.

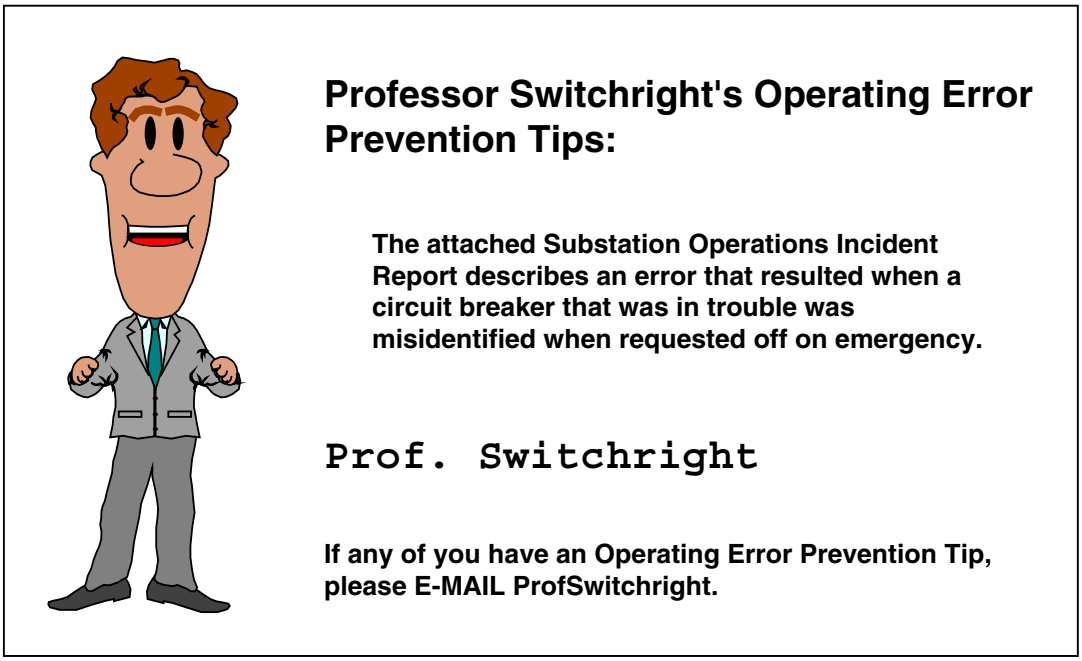


Figure 7-1
Utility L's Professor Switchright Delivers Incident Reports to all Members of Substation Operations

Reports intended for distribution are "sanitized" by removing names and are often condensed. For example, a multi page report may be turned into a single page for posting or distribution.

Several utilities send out the condensed reports and post a more detailed sanitized version on a site on the company intranet, so more information is available to anyone who wants it. Where there is an electronic database the report may be reformatted or abstracted to comply with the format used in the database. Two utilities in the study (C and N) appear to have truly sophisticated, fully searchable databases. Several others have databases that are little more than collections of reports in electronic form.

In his book *Learning from Accidents*, Kletz (2001, p. 313) recommends that incident reports should be kept in a special book in the control room where they can be reviewed and discussed by operators whenever they are interested. The idea is to heighten awareness of the many situations that can lead to such incidents. He states that the book should be compulsory reading for all newcomers.

We know of no utility that does this. However, Utility K has recently instituted a program that is similar in intent. Every month they post reports of incidents that have occurred in that month over the past few years on a website. To encourage review of the postings, they have instituted a lottery where any employee who sends an e-mail that he has read the month's postings is eligible for a prize. It is reported that response, in terms of the number of people who log on and review the reports, has been excellent.

Kletz further recommends that the book of incidents contain both the organization's own incidents and those of other companies as well. Although incidents drawing the attention of regional reliability councils or FERC are widely distributed, there is presently no mechanism for sharing such information about more "routine" incidents in utility power delivery operations that is analogous to the information bulletins in the nuclear and chemical industries.

Management Response

The necessary underpinning of incident investigation and reporting is recognition by management that incident reports provide important information about the quality of personnel, policies, procedures, and practices, and that this information can be used to improve performance in these areas. A management that does not believe this is unlikely to have committed the resources to conduct an investigation in the first place.

In many organizations the investigation itself is performed by the manager responsible for the work being performed when the incident occurred, with whatever delegation or assistance is deemed necessary. However, the literature reviewed for this report assumes the investigators are not themselves managers. This assumption derives in part from the belief that managers have neither the special expertise nor the time to conduct a really thorough investigation. It also assumes a degree of detachment on the part of the investigator that may allow him or her to more easily recognize deficiencies in the management system (or an individual manager) than would an individual who was a part of that system. In the discussion that follows the "management" referred to is the person to whom the report is submitted by the investigator. Such management has by definition the power to ask for clarification or additional details.

Review

Management's first responsibility is to review the report of the investigation for completeness. The report should provide a clear account of what went wrong and why it did so. Management should be left with no unanswered questions. The report should be convincing that each contributing cause identified in the report did in fact contribute to the incident.

The second item management should evaluate is the quality of the analysis. Specifically,

- Is evidence supplied for each causal factor identified?
- Is the evidence convincing?
- Is there any reason to suspect that there are causal factors that were not identified? This last is much easier said than done: it is very difficult to identify what is missing. The most likely kind of overlooked causal factor is a management deficiency. If employees did not do something that they were supposed to do, has the report at least looked into the possibility that:

  - Required skills were not provided (i.e., training was not provided or inadequate)
  - Expectations were not clearly communicated
  - Performance was not adequately monitored?

The third item to be reviewed is the recommendations for corrective actions:

- Do they meet all of the criteria for recommendations given in Section 5 (comprehensiveness, specificity, efficacy, practicality, compatibility, and sustainability)? Management is usually better able to evaluate practicality, compatibility, and sustainability than the original investigator(s) may have been, and such judgments are critical in the decision to accept or reject the proposed corrective actions
- Are equally or more effective alternatives available, or already in the pipeline for implementation?

At any time in the review process, the manager should feel free to request clarification or additional information. In particular, if the report contains recommendations for actions, the manager should ensure that the evidence for them is sufficiently complete and compelling to determine the appropriate priorities for action and funding, or to "sell" them to his or her superiors if they involve commitment of significant resources. As a practical matter, the larger the required commitment in terms of resources or priorities, the more compelling must be evidence supporting its necessity.

Acceptance of Proposed Recommendations

Management should formally accept or reject each of the proposed recommendations. However, there are two alternatives to immediate acceptance or rejection:

- Further evaluation to determine the extent of the problem. This in fact may be a recommendation from an investigator who has evidence for a problem but lacks the resources to determine its extent. For example, a supervisor investigating a low-consequence incident can document and correct errors in the documents that her employees use, but probably cannot determine if such errors are to be found in similar documents throughout the company. Calling for additional evaluation is neither an avoidance of a decision nor a "pocket veto;" it acknowledges the possibility of the problem, and the outcome of the evaluation should result in a clear acceptance or rejection of the recommendation.
- Referral of the problem and its fixes to an existing project or activity. For example, the manager could refer the potential document problems identified by the supervisor in the above example to those charged with conducting periodic reviews of all documents.

We believe that any rejection of recommendations should be justified. While a manager may interact as much as he or she likes with the person or team conducting an incident investigation, the authors believe that the investigator(s)should have the independence to "call-them as they see them" in regard to both causes and recommended corrections. The manager should not try to influence either the findings or the recommendations, other than to give advice on the kind of evidence needed to convince management of their validity and determine the appropriate priorities for action and funding. In particular, we believe that it is inappropriate for the manager to exercise a preemptive — and hidden — veto over either specific findings or specific recommendations."

Expected efficacy and cost-effectiveness or cost-benefit are likely to be the most frequent grounds for rejection. However, we believe that most such cost-benefit evaluations are essentially judgment calls. Although the cost of implementing a recommendation can be identified, both efficacy and benefit are difficult to quantify, and we believe a formal cost benefit analysis is seldom done for that reason.

A cost-benefit argument for rejection amounts to an acceptance of the risk of not (at least partially) correcting the problem. Making such judgments is a routine management function, but the decision and its rationale should be documented. The manager should include a justification for rejecting any recommendation, or substitution of an alternate correction, in the report that is passed to his or her superiors.

Additionally, we strongly believe that incident reports, including management responses to authorize and implement corrective actions, should be passed up the chain of command to senior management, and that reports should be widely circulated to those at all levels in the organization who may benefit from them. Most participating utilities do both.

Prioritization of Recommendations

Accepted recommendations should be prioritized and assigned to a person or organization for action by a realistic due-date. Prioritization is often difficult, because there are usually many "high priority" projects competing for limited resources, and seldom any money set aside for correcting problems not identified in the last budget cycle.

Prioritization is probably most often done on the basis of the manager's subjective cost-benefit analyses. Corrections will be assigned a high priority if the cost of *not* correcting the problem is judged to be high in relation to the costs of implementing the recommendation, or if the cost of implementing the recommendation is relatively small and the risk associated with not implementing it potentially high or simply unknown. High-consequence incidents have a decided advantage in the competition for resources because the cost of the status quo has already been demonstrated. Incidents with obvious safety implications also have an advantage because the possible consequences of inaction are both readily imaginable and very serious, even if they are unquantifiable.

Problems that can be resolved by changes to procedures or practices are easier to address than those that involve substantial capital outlay. For example, a recommendation to include the number *or* the name of the line to be switched in or out, in addition to the breaker number in switching instructions can provide the switchperson additional opportunities to detect errors in switching instructions before executing them. This involves little monetary outlay and the subjective cost-benefit assessment is likely to weigh strongly in its favor.

Hardware changes, on the other hand, may involve commitment of considerable resources. For example, relays whose testing or maintenance involves jumpering or lifting leads on poorly designed terminal blocks create a strong likelihood that there will be a number of "shorted contact" incidents every year. Changes in work methods or tools can help reduce the number of incidents and are usually cheap enough to accommodate within the operating budget (though changes in work methods will probably require training, which may itself be costly). However,

the only way to eliminate shorted contact incidents completely is to either provide bypass switches or replace the relays with models that do not require manipulation of live wires. Both of these solutions can be very expensive if substantial hardware changes are involved, and would likely require authorization and funding by senior management.

Mechanisms to Ensure Follow-Up on Recommendations

"Learning" by an organization is manifest only through changes in the way the organization conducts its business. Thus the implementation of recommendations resulting from incident investigations is the final, and arguably the most essential, component of the investigation and reporting process.

The normal means of insuring that recommendations from an investigation are implemented is to assign responsibility to particular individuals or organizations and track the expected action to completion. Participating utilities follow one of two approaches:

1. For three of the participants (A, E, and G) reports are prepared for (or by) and signed off by a manager who insures the follow-up actions are performed as necessary. Utility F's recommendations are also "signed-off" by a senior manager to ensure that what was agreed to in the action plan is completed.

2. Utilities B, C, F, G, L and M report that recommendations are entered into a database that is regularly reviewed by senior management.

Five of the participants (D, I, J, K, and N) said no formal mechanisms for insuring follow-up on recommendations were in place. Utilities I, K, and N have programs with many strong elements and commitment of significant resources. In the authors' estimation, the absence of a formal mechanism to ensure follow-up where necessary is a serious weakness in these programs.

The authors make the following recommendations concerning the sequence of actions to ensure follow up:

- Resources should be assigned to implement the corrections. Often this means assigning a department or individual to do it, with no assignment of additional funding.
- Realistic due dates should be determined and assigned.
- Authorized changes should be tracked to completion, as would any other assigned work.
- If the project is complex (e.g., system-wide replacement of certain styles of relays), management would normally institute some way of measuring the progress of the effort (e.g., defined milestones).
- Work should be scheduled so the most critical changes are implemented first. In the example above, those relays whose mis-operation could have the most serious consequences would be replaced first.
- Identifying a way to verify that the corrections implemented have the desired effects (e.g., monitoring incident reports for recurrence), and if they do not, determining why they do not.

Retention of Records

The investigation report is generally the final record of the investigation, and many of the materials collected in the course of the investigation are not preserved unless included in the final report. Materials that are routinely preserved include documents collected in the investigation (switching orders, etc), the initial reports of the incident, and reports to management. Because such materials may contain names and other information about personnel involved they should be treated as confidential.

In some situations it may be required that investigators keep all materials collected for possible future reference. This may be required if:

- Investigations are subject to review or auditing by a regulatory agency or a corporate headquarters.
- Management or a review committee may decide a more in-depth investigation is warranted for occurrences that keep recurring in spite of repeated attempts at correction.

None of the participating utilities maintain official files of material collected for investigations but not included in the reports. However, many of the contacts for this project reported that investigators often kept copies of other materials such as their personal notes, which may contain speculations subsequently discarded in the course of the investigation. While this is a good practice from the perspective and training of most engineers or operations personnel, such notes may be subject to "discovery" in legal proceedings initiated in response to incidents in which there was injury or serious damage to non-company property (Ferry, chapter 18). One of the reasons that the legal department often gets involved in such investigation is that the work products of the company's lawyers are generally protected from such discovery, while the products of other employees are not.

Investigators should check with their Legal Department as to the advisability of keeping materials that are not part of the official record of an investigation.

Periodic Review of Incident Reports

In the book *Learning from Accidents,*" Kletz describes the results of his investigation of 36 routine mishaps:

> During the three weeks we devoted more time to the investigation of the accidents than might be practicable in the ordinary way. Nevertheless the results showed that the investigations normally carried out were often superficial and that there was more to be learnt from the accidents than was in fact being learnt. In addition, conclusions could be drawn from the accidents as a whole that could not be drawn from individual incidents. Information bought at a high price was not being used. (Kletz, 2001, p 162).

In practice, a frequent outcome of investigations is that the incident is determined to have been caused by a failure to follow an established procedure or work practice, with no additional, and potentially more systemic, contributing factors identified in the report. If such failures are widespread, there may be a systemic problem that should be addressed by corrective actions. However, this fact is unlikely to be recognized or documented in the routine investigation of a single incident.

About half of the participants reported that there was a standing Operations Review Committee that met periodically to review reports produced since their last meeting. The committee reviews reports for "trends," which may include the frequency of events or possible commonalties among incidents which might not be recognized by local investigators. This function is also performed by Utility C's cadre of investigators, who meet as a group to review current reports on a monthly basis. If they believe it necessary, such committees can generally re-open an investigation, or instigate a more detailed investigation that encompasses a group of incidents, although in some cases this power seems to be exercised more by the influence of the committee or particular members than by explicit authority.

In the majority of utilities that did *not* have such a committee, the reports were collected and reviewed by a small group or an individual at the central office. In three cases (C, E, J), these groups also performed or participated in most investigations and have, de-facto, the power to perform more detailed investigations as they see fit. The groups that serve as the central repository of investigation reports, but do not participate in many of the investigations (B, M), usually have the power to request clarification of reports received, but not to expend resources on additional investigation.

In one utility (K), the Operations Review Committee meets frequently, and generally receives presentations on all events from the parties involved. Final reports are issued only after the incident is reviewed by the committee. This arrangement effectively makes the committee an active participant in, rather than a reviewer of, the investigation. It does, however, help the committee attain an overview of the nature of incidents occurring system wide.

The authors of this report believe that periodic review of reports by a committee is an excellent way of ensuring that someone has a big-picture view of the *nature* of the incidents that are occurring system-wide, not just the numbers of incidents (we may be assured that management is watching those). Those who have such committees tend to be the larger utilities that have more incidents system-wide. Committee review may not be required by a small utility that has few incidents, or by one that has several incidents a year that are all handled by the same investigators.

The Relation of the Investigation Process to Discipline

The word *discipline* means adhering to standards (every manager would like a well disciplined work force); the term is also used for sanctions applied to those who do not perform up to expectations. In any organization, discipline in the first sense is required: discipline in the second sense is a legitimate part of management's toolbox.

As we have indicated earlier in this report, many switching-related incidents are attributed to failure, whether inadvertent or willful, to properly follow established procedures or practices. Most participating utilities have a system of discipline for such infractions, but discipline was discussed in only one of the incident reports submitted for review. That report recommended against discipline, although the report documented deficiencies in the performance of several of the personnel involved.

In general, there appeared to be recognition that linking the investigation to discipline may complicate the fact-finding process. For this reason, where an investigation team performs a formal analysis it may be explicitly stated that it is not the purpose of the inquiry panel to recommend discipline.

All participating utilities reported that the investigation process was separate from discipline, and that it *should be*. Many emphasized that investigations should focus on "fact finding, not fault finding." However, investigations are conducted with the understanding that management may decide discipline is required after reviewing the facts contained in the incident report.

8
JOB AIDS FOR INCIDENT INVESTIGATION

Job aids provide easily accessible guidance to employees when performing their job functions, and help to ensure the quality and consistency of performance. Such aids may be especially valuable where investigations are concerned because investigations are not an everyday occurrence for most people called to perform them. Except for those who are part of a cadre of investigators (Utilities C, I, J, and L), training and practice are likely to be minimal.

The most basic job aid in conducting an investigation is a procedure that defines the process and its products. Procedures reviewed for this report have been discussed in Section 5. In addition, a model procedure is presented in Appendix D.

Other types of job aids provided by utilities participating in this study are shown in Table 8-1 below.

Table 8-1
Job Aids for Conducting and Reporting the Results of Investigations

Job Aid	Utility										
	A	B	D	G	H	I	K	L	M	N	O
Definitions of terms				●						●	●
Investigation checklist				●		●					●
Investigation process flowchart	●				●						
Guidelines for conducting interviews[1]				●							
Root cause analysis process				●							
Root cause flowchart	●										
Root cause categories				●			●				
Guidelines for corrective actions				●							●
Report outline or forms	●		●	●	○		●		●		●

○ A separate document referenced by the procedure.

[1] Guidelines are provided in Appendix F and are not discussed in this Section of the report.

Definitions of Terms

Definitions of terms related specifically to the investigation are useful, particularly if the terms are expected to be used in the report itself, if different categories of incidents are tracked separately, or if incidents are recorded in a database that is searchable by specific categories. The definitions of “operating” and “switching” errors below are from Utility N.

An **Operating Error** is defined as "a preventable action that results or potentially results in a hazard and/or the undesired operation of electrical equipment under the jurisdiction of a Dispatch authority." . . . Operating errors include but are not limited to the following:

- Incorrect wiring when diagrams and prints are correct.
- Digging into power cables or control cables without taking necessary precautions.
- Bumping switches, relays or other devices on control panels.
- Dropping tools, bridging contacts, etc.
- Failure to open correct knife switches during testing or maintenance.
- Inadvertent operation of equipment during relay or operational testing.
- Improper tagging of electrical equipment for the specified operating arrangement.
- Selector switches (i.e., reclosing, supervisory, high speed) left in abnormal position but found and corrected prior to the undesired operation of electrical equipment.
- Drilling/sawing on panels without taking necessary precautions.

A **Switching Error** is defined as "a preventable action during a switching procedure that results in a hazard and/or the undesired operation of electrical equipment under the jurisdiction of a Dispatch authority." Switching errors are a subset of operating errors and . . . include but are not limited to the following:

- Incorrect operation of a selector switch (i.e., reclosing, supervisory, high speed) that leads to an unintentional/improper operation, or non-operation of equipment.
- Operation of incorrect electrical equipment (i.e., circuit breaker, switch, disconnect, etc.).
- Operation of electrical equipment without authorization.
- Failure to cutout, disable or otherwise account for protective relaying.
- Improper switching sequence causing equipment damage, hazard to personnel or interruption of service.
- Failure to properly isolate or set-up equipment for the specific operating arrangement and a clearance or permit is issued.
- Circuit breakers, disconnects, switches, etc., left in abnormal position.

Figure 8-1
Definition of Terms

Investigations Checklists

Two utilities have checklists of steps to perform in the investigation and points to address subsequent report. Interestingly, both checklists came from procedures maintained by the companies' respective Safety Departments. The checklists summarize management expectations for the investigation and can be used to review the investigation for completeness prior to submission to management. Like a flowchart, the checklist format provides a concise summary of requirements in a way that may be clearer than normal administrative procedure language. An aid like this is very useful where reports will be prepared by a large number of different individuals who do it infrequently.

The checklist shown below is a composite based on the two checklists available for review. The figure shows the main check-off items. The complete checklist is presented in Appendix E.

Checklist for Investigations

A. Collect evidence

- ☐ Names and job titles of the individuals involved.
- ☐ Collect job documentation.
- ☐ Inspect the job site and note general conditions.

B. Interview involved employees (conduct interview according to company guidelines)

- ☐ Determine each individual's actions before, during, and after the undesired event.
- ☐ Inquire about possible contributing factors.
- ☐ Ask what the employee believes caused the undesired event.
- ☐ Ask what could be done to prevent such incidents in the future.

C. Analyze information collected

- ☐ Identify what happened (the action or omission) that was the **immediate** cause of the event (e.g., step omitted, wrong switch operated, contact shorted out, etc) Note: this is "what" happened, not "why" it happened.
- ☐ Identify the action(s), omission(s), or condition(s) that led to the immediate cause (this is the first "why").
- ☐ Review job documentation and communications for inadequacy/irregularities that may have contributed to the event: document any deficiencies.
- ☐ Review general conditions for factors that may have contributed to the event, and document deficiencies.
- ☐ If irregularities in documentation, communications, or conditions are found, perform additional information collection and analyses as necessary to determine the extent of such irregularities/deficiencies in related documents/practices/conditions.

D. Prepare a report of the investigation

- ☐ Provide a brief summary of the incident and its consequences.
- ☐ Provide a factual narrative of the incident incorporating all facts relating to causes and contributing factors.
- ☐ Provide a listing of identified causes.
- ☐ Provide recommendations for correcting identified causes and contributing factors.
- ☐ Provide a list of other deficiencies discovered in documents/practices/procedures/conditions that were not believed to be causally related to the incident.
- ☐ List actions already taken to correct deficiencies.
- ☐ Include administrative information as required by company.
- ☐ Include attachments a necessary to support understanding of incident and document deficiencies.

Figure 8-2
Checklist for Performing an Incident Investigation

Investigation Process Flowcharts

A flowchart is an economical way of presenting a lot of information in a way that is easily understood. A flowchart of the investigation and reporting process is especially useful where the notification, review, or distribution requirements for the report are complex.

The flowchart below (from utility A) is from a procedure that is intended to be used by managers at a number of control centers and regional field offices. It is expected that no one of the users is going to have to investigate enough incidents to become very experienced in the process. The flowchart helps ensure the whole process can be executed smoothly by users who may be essentially novices.

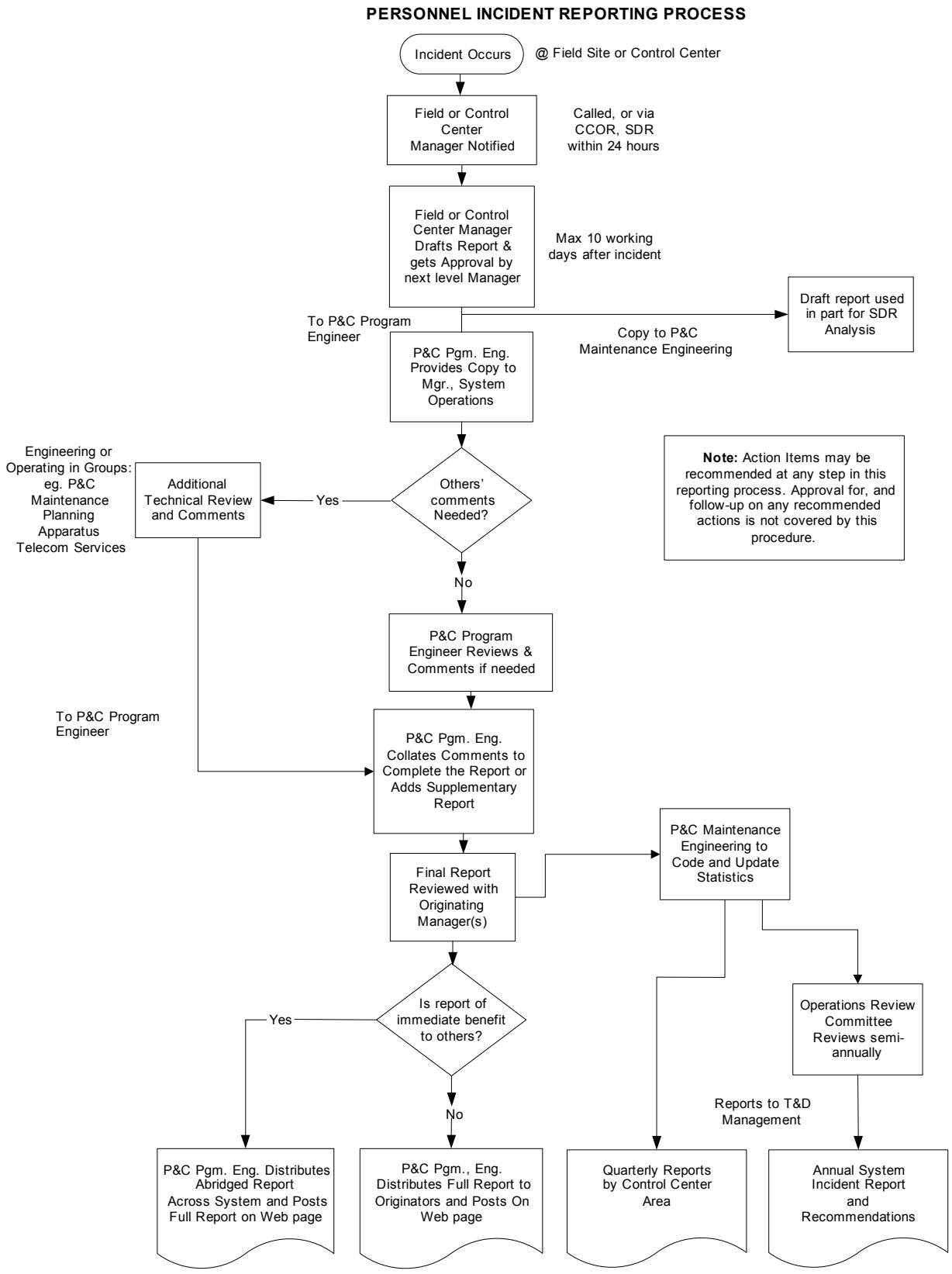


Figure 8-3
Investigation Process Flowchart

Root Cause Analysis Flowchart

Utility A uses the flowchart shown below as an aid to root cause determination.

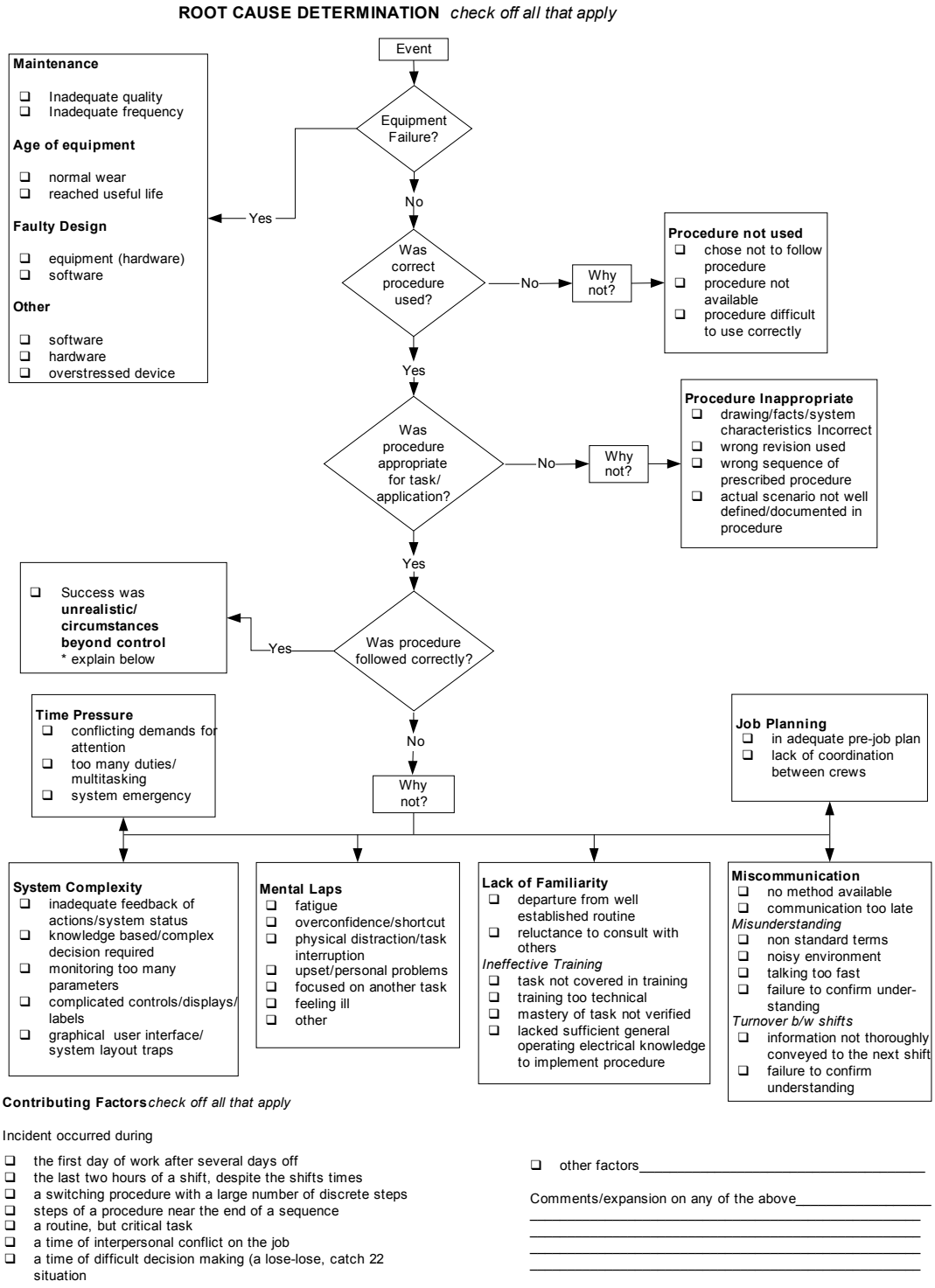


Figure 8-4
Root Cause Flowchart

The root cause flowchart lists most-likely root causes from which the investigator can make a selection. However, inspection of the chart shows that about half of the causes listed are really immediate causes rather than root causes. Checking any one of them should lead to another set of ***why's***. A good investigation will answer those questions rather than simply checking the box that best fits the situation. For example, if a necessary procedure wasn't used because it was not available, that is indeed a sufficient cause for an error. However, such a finding begs the question of why it was not available. If he or she is looking for a true root cause, the investigator should determine why it was not available, and then evaluate whether the reasons for its unavailability are indicative of some defect in the process of distribution. Similarly, if the pre-job plan was inadequate, not only its specific defects but the reasons for them should be determined and documented. Again, "inadequate plan" is a sufficient cause (and adequate enough if we intend to blame someone), but we need to know why it was inadequate before we have a plausible root cause that can be corrected so as to prevent others from suffering the same fate.

Root Cause Category Lists or Tables

Where the report is expected to identify root causes, some utilities provide a list of possible choices or categories. Such lists can be developed from INPO materials, lists given in the books by Ammerman and Ganor, or the lists of lower-level causes from TapRooT®. The most constrained of such lists is the one shown in Figure 8-5, from Utility K. The fact that there are only two categories is in effect a policy statement that all incidents that do not arise from failure of individuals to perform as expected are signs of deficiencies in the management system.

Root Causes

1. Insufficient support for the implementation functions (management system)

   Expectations

   Established Processes, Practices and Controls

2. Improper actions at the implementation level:

   Failure to follow procedures (includes failure to inform supervisor of extenuating circumstances or proceed under unknown circumstances)

Figure 8-5
Utility K's Root Cause Definitions

Utility G provides a more elaborate table (Table 8-2) of possible root causes as shown below. All of the labeled cells are subcategories of the four main factors listed in the top row, and each subcategory in turn contains a list of 3 more specific items (not shown). The investigator or team is supposed to evaluate each of the tabled factors for possible contribution to the event, and address them in the investigation report. Although they are more specific than the subcategory label, the items listed in the root cause table for each subcategory are themselves fairly broad categories. For example, the factors listed in the "Capabilities" cell are "mental/physical,"

"task difficulties," and "impairment factors." The investigator must still identify a specific cause within the listed subcategory so the ultimate causes may very well be something ***not*** explicitly listed in the table (e.g., intoxication, fatigue, and illness would all fall under "impairment factors").

Table 8-2
Table of Root Cause Categories used by Utility G

Tools/Equipment/ PPE	Work Environment	Worker/Job Procedure	Management Systems
In Use	Hazardous Conditions	Capabilities	Housekeeping
Availability	Job Task	Job Knowledge	Hazard Control
Design/Faults	Body Placement	Safety Skills	JSAs
	Environment	JSA/Safety Procedures	Incident Investigations
		PPE Usage	P.M.'s/Inspections
			Supervisors' Responsibility

This table is noteworthy for the inclusion of the Incident Investigation category (3rd from bottom under Management Systems). This refers the investigators to prior investigations of similar incidents, if any, and directs evaluation of the adequacy of controls enacted in response to them. Reviewing reports of similar incidents may also aid the investigators because prior investigations may well be a fertile source for hypotheses concerning causes involved in the incident under investigation (Ferry, p. 143).

One advantage of a table like this is that it helps to prevent premature closure or "tunnel vision." A potential disadvantage is that it may limit the search for causes to the items that are listed. A root cause table or flowchart should really be used as an aid to help the investigator consider all the possibilities. Their function is to encourage thinking, not substitute for it.

Guidelines for Corrective Actions

Three utilities provided written criteria (guidelines) for developing or evaluating proposed corrective actions. These are shown in Table 8-3.

Table 8-3
Guidelines for Corrective Actions

Utility O	Utility G	Utility C
Individually "actionable"	Is it specific?	Within my control to implement
Collectively tied to "fix" all of the causes	Is it feasible?	Meet my goals and objectives
Effective and Sustainable	Does it encompass the problem – now and in the future?	Prevent recurrence
	Is it practical, realistic?	
	Does it create other problems?	

No one of these lists is all-encompassing: each presents important ideas which do not appear in the others. But collectively they address the six criteria for recommendations discussed in Section 5.

1. Comprehensiveness (address all causal factors identified)
2. Specificity (specific, individually actionable)
3. Efficacy (effective, fix the problem, prevent recurrence)
4. Practicality (realistic, within my control to implement, cost-effective)
5. Compatibility (do not create other problems)
6. Sustainability (sustainable)

Good procedures should provide guidelines for producing practical and actionable corrections. Without some guidance you often get recommendations that are vague, impractical, and not likely to be implemented.

Report Outlines or Forms

Outlines

The most commonly provided job aid is an outline showing the sections of the expected report, including the appropriate sign-offs if required. Providing an outline of the eventual report helps assure consistency in reporting and helps to structure the investigation. A model outline was presented in Figure 6-2.

Forms

As noted earlier, many initial or first-level investigations are reported via a standard form. The form guides the initial investigation by the information it requires: in many cases gathering the information required essentially is the investigation. The forms reviewed generally had multiple narrative sections and resulted in multi-page reports if the narratives were extensive.

Figure 8-6 below shows a composite of parts of the form used by Utility C. This company uses an on-line form that enters data directly into a fully searchable database. The complete form is about two printed pages in length and has 19 questions to identify causal factors, 6 spaces for free-form text entries, and several fields for administrative information. The form is completed for all incidents by a member of Utility C's cadre of trained specialists. Note that the form has a field that allows the specialist to recommend that a more detailed root cause investigation be performed. Other utilities have paper forms that range from very simple to ones that are nearly as elaborate as Utility C's.

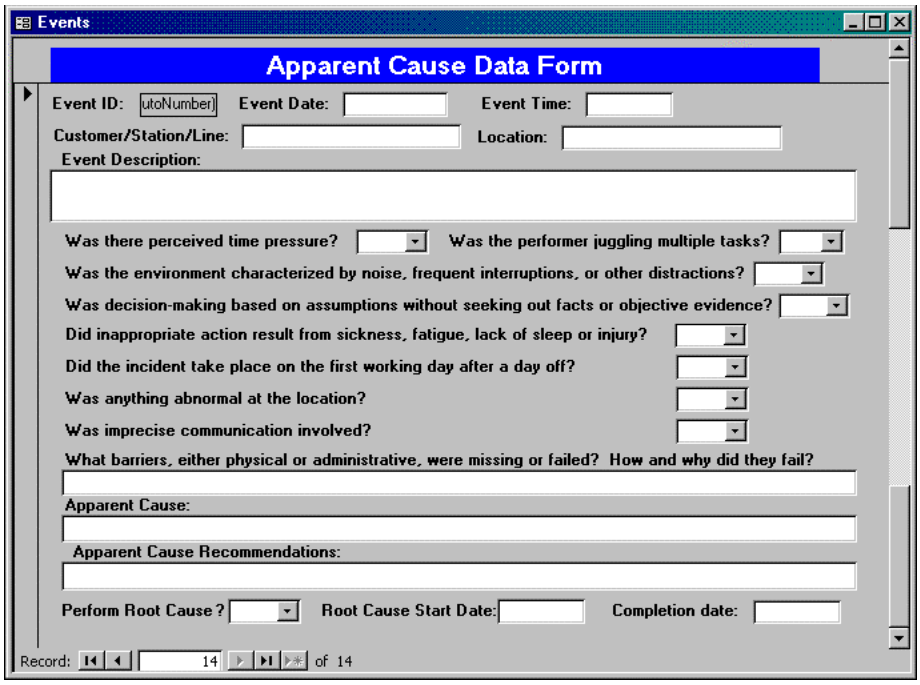


Figure 8-6
Electronic "Apparent Cause" Report Form Used by Utility C

9
PROPOSED BEST PRACTICES

In this concluding section of the report, we identify candidate best practices in investigation and reporting of operating incidents. The best practices are based in part on the practices of the utilities in the study and their own evaluation of what constitutes an effective process.

Summary of Utility Practices: Similarities and Differences

The project contacts for all participating utilities seemed similar in their appreciation of the value of incident investigation as a tool for discovering and correcting problems in the conduct of their operations. Participants were also similar in providing two levels of investigation for incidents that differed in consequence or potential consequence.

Beyond these encouraging commonalties, diversity seemed to be the rule. While most operated on the industrial model of the supervisor as the first (and often only) investigator, four had a cadre of investigators who conducted or participated in most investigations. Four had no written guidance (procedures) for the conduct of investigations, and the procedures of some of the others provided little detailed guidance. Most reported that they tried to determine the "root causes" of their incidents, yet several reported that their investigators had received little or no training in investigation or root cause analysis.

Only 2/3 reported having some mechanism for insuring that recommendations resulting from investigations were acted upon: four did not. Only three (1/4) provided explicit guidance for developing such recommendations. Collectively, the participants had developed a number of useful job aids, though the use of any single aid was generally confined to one or two.

To end this summary on an encouraging note, there appeared to be a widespread recognition that *potential* consequence, rather than damage actually incurred, was the appropriate marker for the severity of an incident. One-third (4) reported that they investigated near misses involving serious hazards in the same way as actual, consequential occurrences.

Qualities Desirable in an Investigation Process

The questionnaire used for the survey asked participants to list the qualities they thought were desirable in an investigation process. Responses included:

Management Support

- It is a commonplace that management support is required for the success of any program. In this case "support" means an honest recognition that in some cases the "fault" may lie in the design or execution of the procedures used or conditions established by management, as well as the actions or inactions of individuals. Incident investigation is widely recognized as one component of the process of continual improvement. Where management shares this view, commitment to correct any systemic problems that may be discovered follows naturally from its commitment to process improvement.

Goals

- Incident investigation should be recognized as a necessary and effective method to improve processes and communicate lessons learned.
- The goal of the program should be to prevent recurrence: find and fix systemic problems.

General Approach

- The process should be focused on finding facts, not assigning blame.
- The process should be fair and unbiased: the investigation process must be perceived as fair to get the most useful input.
- Published reports should protect the anonymity of those involved in incidents.

Factual Data

- Good procedures or standards should be applied so that the data is of good quality and comparable across investigations: to assure quality of problem identification and solutions, as well as to allow batch analyses.
- A consistent approach should be used so data is amenable to aggregation and meta-analyses.
- The process should incorporate detailed documentation of all the pertinent facts leading up to the incident.

Analysis and Reporting

- "Root cause" determination should focus on finding correctable problems: investigations should not ignore contributing factors.
- Investigation and reporting should be timely to gather facts from interviews and to get the word out if there are there are problems of which workers should be aware.
- The process should provide for dissemination of information on problems discovered before the final investigation is completed, if warranted by their potential for causing additional incidents.

Tracking and Follow-up

- The process should incorporate a good system-wide tracking system for collecting and easy reviewing of all event reports: Tracking to give warning of developing trends, easy reviewing of reports to encourage employees at all levels to review and think about incidents.
- The process must include adequate follow-up to correct procedural or other deficiencies uncovered: if the problems identified are not corrected, little has been gained from the investigation.

Candidate Best Practices

Certain themes are evident in the above comments and the data collected for this report. The following candidate best practices are derived from those that appear to be:

- common among utilities that have programs that we consider strong
- consistent with the literature reviewed
- likely to support the goals of institutional learning and the promotion of safety awareness among employees at all levels.

The candidate best practices fall into five categories:

1. Management focus

1.1. "A successful . . . program requires management involvement, assumption of responsibility, and commitment of necessary resources" (DOE p. 15).

1.2. Fair and unbiased investigations, focused on facts, not blame.

1.3. An organizational framework that supports investigations and follows up on the resulting recommendations.

2. Personnel qualifications

2.1. Provision of training for all persons expected to conduct investigations (e.g., supervisors) in investigative techniques and interviewing.

2.2. If practical, using a cadre of experienced investigators who have received training in investigative and root cause analysis techniques to conduct all low level investigations and lead all team investigations (the approach used by Utility C, elements of which are also followed by F, I, and L). Where teams are convened, only the leader should be from the cadre, with other members chosen to provide technical expertise and a variety of perspectives.

3. Appropriate procedural support

3.1. Provision of written procedures or guidelines for conducting investigations.

3.2. Provision of appropriate job aids for first-level investigations (process flowcharts, interviewing guides, checklists of factors to consider, etc).

3.3. Provision of clear criteria for determining when more elaborate investigation is warranted.

3.4. Specified report formats (one may be a form).

4. Mechanisms to ensure corrective actions are implemented

4.1. Publication of criteria for effective and acceptable corrective actions.

4.2. Management review and pre-authorization of proposed corrective actions.

4.3. Assignment of responsibility for correcting deficiencies uncovered, and tracking of approved corrections to ensure they are implemented.

5. Mechanisms to ensure that "lessons learned" really are

5.1. Dissemination of incident reports (or abbreviated versions of them) to all members of the organization who may benefit from any lessons learned.

5.2. Incorporate lessons learned from incidents into both initial and ongoing compliance or refresher training programs.

5.3. Provision of a good system-wide database for collecting and easy reviewing of all event reports, with access available to all personnel.

5.4. Review of all incident reports for trends or patterns in the incident data at regular intervals by a committee that is empowered to institute additional investigations as it sees fit.

Items 5.3 and 5.4 above are most applicable to larger utilities that have several incidents a year; the others are applicable to all utilities interested in process improvement.

10
REFERENCES

M. Ammerman. *The Root Cause Analysis Handbook–A Simplified Approach to Identifying, Correcting, and Reporting Workplace Errors*. Productivity, Inc., Portland: 1998.

B. Andersen, & T. Fagerhaug. *Root Cause Analysis: Simplified Tools and Techniques.* ASQ Quality Press, Milwaukee: 2000.

M. Baram. *Shame, Blame, and Liability: Why Safety Management Suffers Organisatonal Learning Disabilities*. Pp. 163-177 in Hale, B. Wilpert, & M. Freitag (eds). *After the Event–From Accident to Organisational Learning*. Elsevier Science, New York: 1997.

A. Beare & J. Taylor. *Field Operation Power Switching Safety.* EPRI, Palo Alto CA: 1996. TR 106465.

A. Beare & S. Lutterodt. *Switching Practices Survey: Toward Improved Safety and Reliability*. EPRI, Palo Alto CA: 1996. 1000123.

A. Beare & S. Lutterodt. *Collecting and Using Near-Miss Information: Enhancing Switching Safety and Reliability*. EPRI, Palo Alto CA: 1996. 1001956.

DOE. *Root Cause Analysis Guidance Document.* U.S. Department of Energy Office of Nuclear Safety Policy and Standards, Washington, D.C.: February 1992. DOE-NE-STD-1004-92.

T. S. Ferry. *Modern Accident Investigation and Analysis (2nd Edition).* Wiley, New York: 1988.

D. L. Gano. *Apollo Root Cause Analysis–A New Way of Thinking.* Apollonian Publications, Yakima, WA: 1999.

A. Hale. *Introduction: the Goals of Event Analysis.* Pp. 1-9 in A. Hale, B. Wilpert, & M. Freitag (eds). *After the Event–From Accident to Organisational Learning.* Elsevier Science, New York: 1997.

T. Kletz. *Learning from Accidents (3rd Edition).* Gulf Professional Publishing (Butterworth–Heinemann), Oxford: 2001.

OSHA. *Process Safety Management of Highly Hazardous Chemicals*. U.S. Occupational Safety and Health Administration, 29 CFR 1910.119, 1992.

M. Paradies & L. Unger. *Taproot: The System for Root Cause Analysis, Problem Investigation, and Proactive Improvement*. System Improvements, Inc., Knoxville, TN.

J. R. Thomen. *Leadership in Safety Management*. Wiley, New York: 1991.

A
PARTICIPATING UTILITIES

The following individuals contributed information about their companies' procedures and practices used in this report. The utilities are listed here in alphabetical order. The letters A through O by which participants are identified in the text were randomly assigned. This report would have been impossible without the knowledgeable and generous contributions of these industry leaders. We thank them very much.

Clinton Moses	American Electric Power
Bob Stone	BC Hydro
Wade Walter	Bonneville Power Administration
Lou Schmidt	Consolidated Edison Co. of New York
Eric Linker	Duke Energy
Chuck Fabo	FirstEnergy Corporation
Dean Mizumura	Hawaiian Electric Company
Chris Cooper	HydroOne
Pat Budler	Nebraska Public Power District
Bernard Silkowski	Northeast Utilities
Bob Cooper	Pacific Gas and Electric Company
John Flenniken	PacifiCorp
Michael Hall	Reliant Energy
Calvin Underwood	Tennessee Valley Authority
Mark Meyer	Western Area Power Administration

B
INTERNET RESOURCES FOR RCA TRAINING AND SOFTWARE

The companies listed below provide training and/or consulting in incident investigation and root cause analysis (RCA). This list is not intended to be exhaustive, but to provide a sampling of the variety of services and information available on the internet. Many of the sites listed below have RCA software packages, and several allow downloading of demo versions of their software for free trial: most are disabled after one or two weeks if you do not purchase a license.

The list is provided for information only. It does not imply endorsement on the part of EPRI or its contractors of the products or services offered by the listed companies.

1. ABS Consulting
   http://www.jbfa.com/rootcauseleader.html
   ABS provides training and consulting services in risk analysis and risk management, RCA, Failure Modes and Effects Analysis (FEMA) and Hazard & Operability Analysis, among others. Staff members include Alan B. Swain, the chief developer of Human Reliability Analysis, and Don Lorenzo, who has written a guide on error avoidance for the chemical industry. A free download of the company's Root Cause Leader software is available.

2. American Society of Safety Engineers (ASSE)
   http://www.asse.org
   ASSE provides training in incident investigation and reporting, and other topics related to safety and safety culture. ASSE is also the publisher of the journal *Professional Safety*, which frequently contains articles on investigation and related topics.

3. American Society for Quality (ASQ)
   http://www.asq.org/
   ASQ publishes books related to Quality Control (QC) and Total Quality Management (TQM).

4. Apollo Associated Services, Inc.
   http://www.apollo-as.com/
   Apollo© provides training on the Apollo© system of RCA. A free download of root cause analysis software is available.

5. Conger & Elsea, Inc.
   http://conger-elsea.com/
   Provides system safety and risk analysis consulting, traing and software, including training in RCA and MORT (Management Oversight and Risk Tree) analyses. Their (Mishap Analysis and Prevention System (MAPS) software package includes a number of RCA analytical techniques.

6 Decision Systems Inc.
http://www.rootcause.com
Decision Systems provides training in the company's Reason Root Cause Analysis system. The website includes some conference papers discussing criteria for evaluating root cause analysis systems A free download of Reason-4 RCA software demo is available through the website.

7. Failsafe Network, Inc.
http://www.failsafe-network.com
Failsafe provides RCA training & consulting services. The website has several papers available for downloading.
http://www.rootcauselive.com
This website is a part of Failsafe Network that provides an open forum for exchange of RCA information.

8. Orion Healthcare Technologies, Inc.
http://www.rcasoftware.com
The company specializes in RCA of medical errors. Free demonstration software for RCA is available through the website.

9. Outcome Engineering, LLC
http://www.outcome-eng.com
The company provides an interactive web-based training program called the Outcome Investigator designed to teach investigative skills. It also markets a 2-day onsite course in incident investigation. The courses are based on work the company has done for the Federal Aviation Administration.

10. Reliability Center, Inc.
http://www.reliability.com
Reliability Center provides consulting and training in all aspects of reliability. They offer an RCA software package called PROACT® RCA. Their website also offers a 31 minute online overview of the underlying concepts and benefits of the product.

11. System Improvements, Inc.
http://www.taproot.com
System Improvements offers training and consulting services in the use of their TapRooT® RCA system. The company also offers TapRooT® manuals and TapRooT® root cause tree software.

12. ThinkReliability, Inc.
http://www.thinkreliability.com
The company offers consulting services and training in RCA. The website offers a free "causemapping" template download for Microsoft Excel.

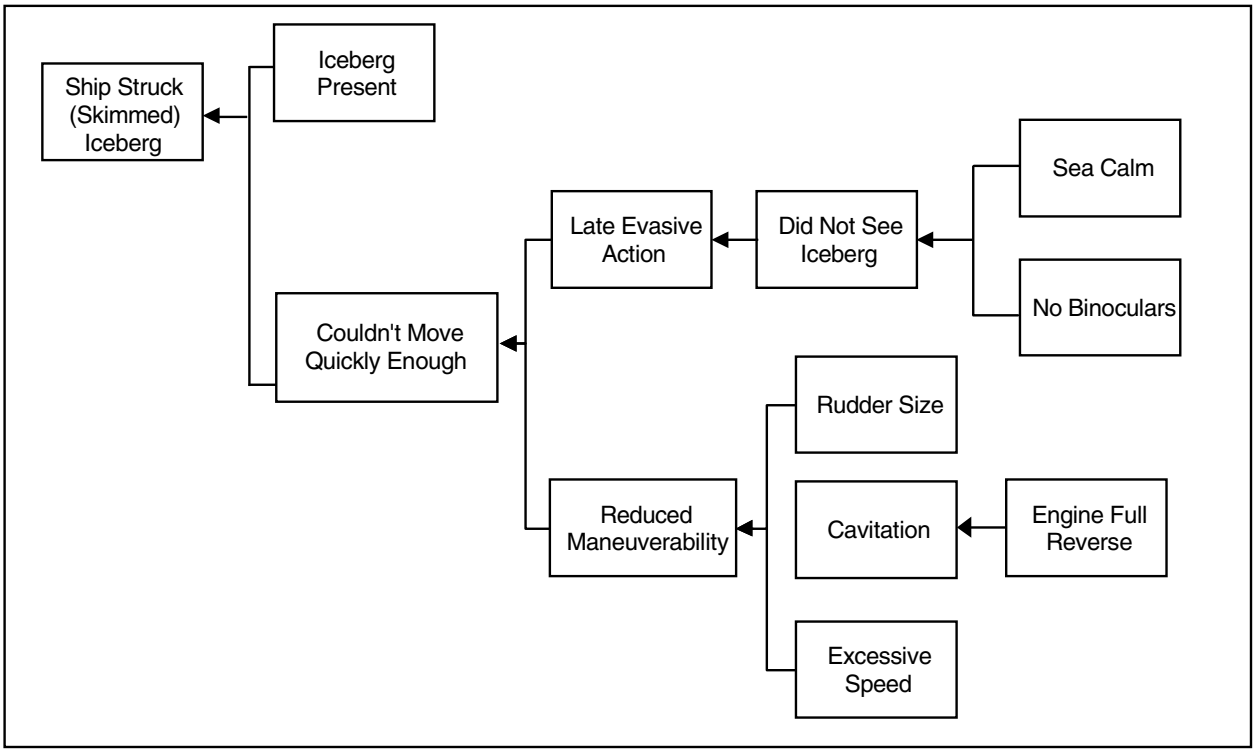
C
ROOT CAUSE ANALYSIS

Introduction

Most real-world events that require investigation are the result of a confluence of causes rather than a single, obvious cause. Detailed, formal analyses of the causes of events are usually called Root Cause Analysis (RCA). RCA is more likely to identify the actual, as opposed to the most immediately plausible, causes. In addition, RCA virtually always identifies more contributing causes than do more superficial investigations. Thus an RCA also identifies more opportunities for corrective actions, which in turn gives management more options as to how to approach the problem.

Complex Causal Chains

The chart below, which is a small section of a Cause Tree© (ThinkReliability.com) analysis of the Titanic sinking, illustrates several characteristics of the complex causal chains often uncovered by an RCA.



Examination of the chart shows that:

1. Multiple causal factors or contributing causes are identified rather than a single cause. The detailed analysis summarized by the chart seems to contradict the idea of a single basic or "root" cause.

2. Often some of the causal factors identified (sea calm in this example) are beyond any possibility of control.

3. However, some of the seeming "givens" may be correctable or avoidable. One could argue that the presence of the iceberg itself is the one item most nearly satisfying the simple-minded but common definition of root cause: it was after all the *sine qua non* of the accident. It was avoidable. White Star could have chosen a more southerly route. They in fact did make an adjustment to the originally planned route: just not quite enough.

4. Removing or altering *any* one of the contributing causes may disrupt the causal chain and greatly change the outcome.

5. In this example two of the cited factors, excessive speed and no binoculars, reflect management deficiencies. This is a typical finding.

6. Neither of these factors is *the* root cause (though many would argue that speed excessive for the conditions encountered may come close), but differences in either might have averted the accident.

7. In most cases identification of a causal factor suggests one or more corrective actions. For example, no one has claimed that the absence of binoculars for the lookouts was the root cause of the Titanic disaster. However, using binoculars almost certainly would have provided one or more minutes additional warning, which might very well have allowed the ship to miss the iceberg entirely.

8. Providing binoculars and maintaining a more prudent speed are easy and cheap corrective actions: redesigning the rudder is not. In this example it happens that the easier "fixes" are also likely to have a greater effect in preventing future occurrences than the more expensive redesign of the rudder.

9. While it is arguable that any one of the possible fixes identified could have averted *this* disaster if implemented alone, it is obvious that implementing all four of those discussed above would provide greater assurance of avoiding a similar occurrence in the future.

Using Charts to Display and Investigate Causal Chains

A variety of charting methods are used for performing formal root cause investigations. The chart of the Titanic sinking above exhibits several of the characteristics of any charting method that make charting a very robust technique, and a popular tool.

1. The chart itself is a powerful way of organizing and presenting information.

2. More importantly, it is a very powerful aid in collecting information. The chart helps us to discover additional questions that should be asked. All of the factors charted have additional causes. Some (e.g., excessive speed) fairly cry out for additional investigation (the complete chart displays these factors).

3. The chart has the ability to move us beyond preconceptions. Some things that most of us might not think could be important, were. If the seas had not been so calm, waves breaking against the iceberg would probably have made it visible at a greater distance.

4. Simply asking "why?" of each box in the chart will lead to the next level, if the resources to answer the question are available.

5. The same set of facts might be charted in a slightly different way by different analysts. It probably would not matter.

Charting Methods used by Participating Utilities

Three of the utilities participating in this study employ commercially available RCA methods, TapRooT® and Apollo©, that use charting, and the collection of the information required to construct the chart, as the principal analytic technique. These are described briefly below. The descriptions are for information only and do not constitute endorsement by EPRI or its contractors.

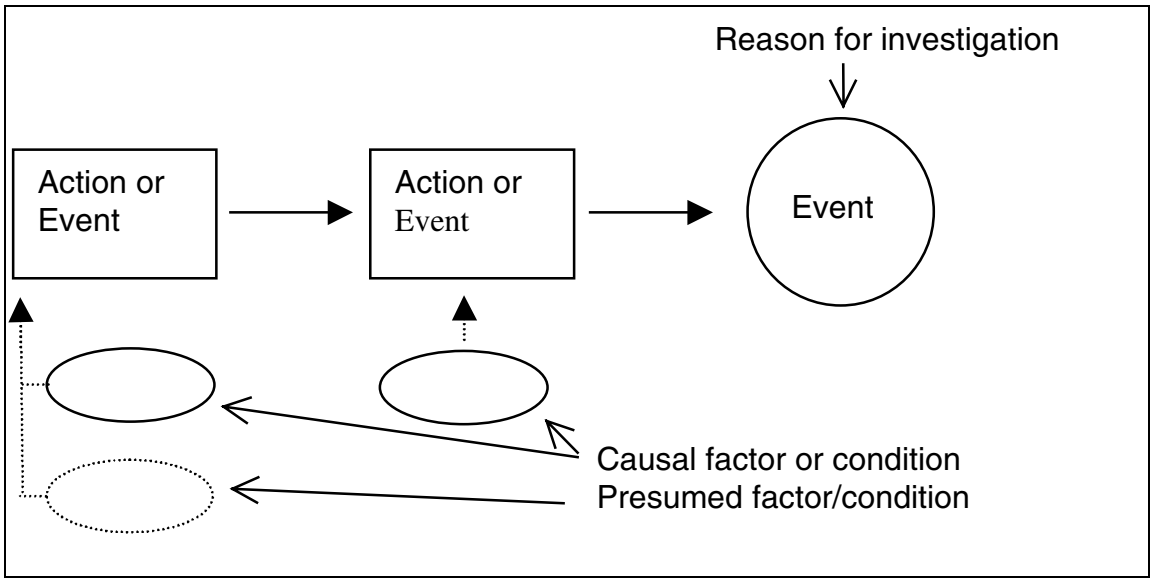
TapRooT®

TapRooT® is a proprietary RCA system offered by System Improvements, Inc., located in Knoxville, Tennessee. It is described in detail in the book *TaprooT: The System for Root Cause Analysis, Problem Investigation, and Proactive Improvement*, by Mark Paradies and Linda Unger.

The primary tool in TapRooT® is the construction of an Events and Causal Factors (ECF) chart. It is supplemented by use of a proprietary Root Cause Tree® that is used to identify probable root causes on the basis of a detailed listing of cause categories and sub categories.

Constructing an ECF Chart

The ECF chart is used to display and organize what is known, and to indicate what needs to be found out. It is also a convenient and effective way of presenting the results of an analysis. The principal elements of an ECF chart are shown in the figure below.



The chart begins as a timeline of events (actions) leading up to the event of interest. The timeline reads from left to right, and may terminate in the event, or may also depict recovery actions subsequent to the event. The event is depicted as a circle, and each action leading up to the event is depicted as a rectangle, connected to subsequent actions by a line. Actions of other individuals or groups involved may be depicted as parallel timelines. Actions or events should be based on evidence, but inferred actions or events may be included (indicated by dashed rather than solid outlines). Inferred actions should be verified by evidence, and removed from the chart if they are not.

Completing the ECF chart is an iterative process. Because it will be revised frequently, the TapRooT® manual recommends using Post-It™ notes or 3x5 cards to construct the chart.

When all events are in place, the team then fills in causal factors, which are indicated by ovals placed below each event and connected to it by lines. The causal factors may be actions or conditions. These too should be based on evidence, but inferred or presumed causal factors may be included, again subject to verification or removal.

The causal factors identified by the ECF chart are then used to enter the proprietary TapRooT® Root Cause Tree® to identify probable root causes.

The Root Cause Tree® has three levels:

1. Top level “basic cause” categories
   - Procedures
   - Training
   - Quality Control
   - Communications
   - Management System
   - Human Engineering
   - Immediate Supervision

2. Intermediate categories for each basic cause category: these are called Near Root Causes.
3. A list of causes within each Near Root Cause category that are called the Root Causes.

For example:

- Basic cause: procedures
- Near root cause: not used, followed incorrectly, wrong
- Root cause (under "not used"): no procedure, not available, difficult to use, not required to be used, but should be.

Most of the root causes provided in the root cause tables are conditions or the absence of required actions. Many of them are that some aspect of the situation (e.g., labels, lighting, crew briefing) is less than adequate (LTA). The LTA designation is very general, and the analysis team must fill in the specifics.

The root causes in the procedure example above are root causes by the definition that correcting them would probably have prevented the incident, and probably many others of a related nature. However, each fairly begs an additional "why?" The competent investigator should address the additional question and thus identify the deeper cause or causes, the deficiencies in the procedure system that allowed the condition to exist. The recommendations he develops should address both the causes from the table (e.g., "no procedure: provide one") and the condition that allowed them to exist, e.g., "Develop comprehensive criteria for identifying tasks for which written procedures should be provided."

Apollo©

Apollo© is a proprietary RCA method offered by Apollo Associated Services located in Friendswood, Texas. The system is described in the book *Apollo Root Cause Analysis–A New Way of Thinking,* by D. L. Gano.

Apollo© calls itself a problem-solving tool instead of an RCA method but has origins in RCA charting techniques. Features of the method include:

- Discussion of causality that explicitly requires *multiple* causes, both a precipitating *action* and an enabling *condition*, to bring about any effect.
- A brainstorming approach that separates generation of ideas (causes, possible solutions) from evaluation, thus facilitating creativity and *larger sets* of potential causes and fixes.
- Treating all causes identified, not just one or two, as opportunities for a solution.

The Apollo© technique focuses on "appreciative understanding" and uses brainstorming. The book also emphasizes conflict minimization within the team. Achieving these requires team leaders with skill (hence training) in small group facilitation.

A core team of trained investigators is recommended. Additionally, anyone likely to be added to the team (because of their specialized expertise or responsibility for the equipment/personnel experiencing the problem investigated) should be trained in the technique.

Gano states that reports should include cost/benefit information where possible (the author calls this return on investment – ROI). It helps sell the solution – and also the approach.

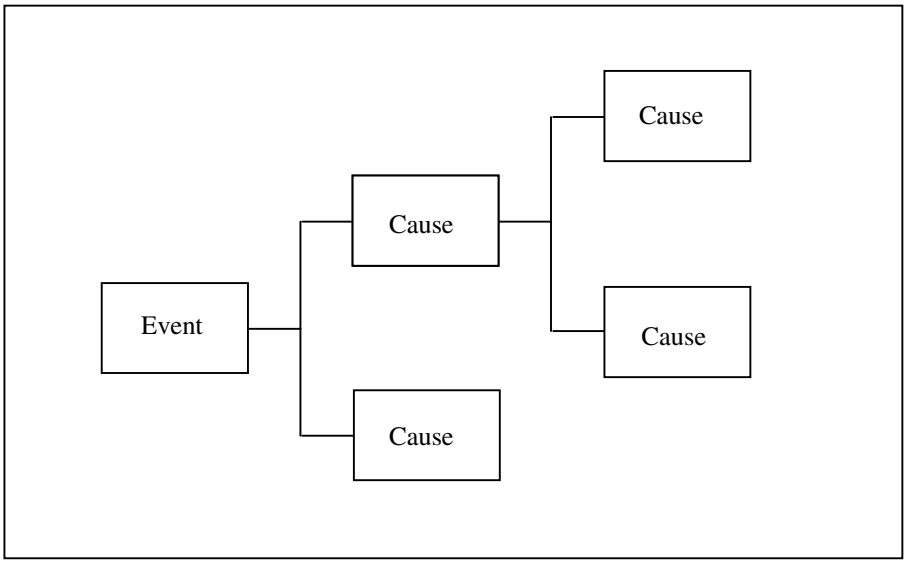
The book has valuable sections on collecting evidence and conducting interviews, and also has a sample report in a reasonable format.

Apollo© Precepts

1. Each cause is both a cause and itself an effect of some antecedent cause, ad infinitum. The event that precipitated the investigation is called the "*primary effect*."
2. There are two kinds of "causes:" actions & conditions. The pairing is important: you should look for at least one of each in the causation of any given effect.
3. One important benefit from construction of the chart is that it provides a common view of the event. It is also useful for presenting results, for example to management. The chart is always included in the investigation report.
4. Problem definition is important, but is subject to revision as the process progresses, and more causes are considered. Frequently the likely causes are redefined as the problem, not the precipitating event that is the occasion for the investigation.
5. Analysis can be done by an individual, but a team approach is encouraged. All stakeholders in the solution should be on the analysis team.
6. Diversity in the problem analysis team is desirable because the differing perceptions of members with diverse backgrounds expand the range and number of potential causes considered, and thus the number of potential solutions.
7. Each "cause" identified represents a potential avenue for solution.

Constructing an Apollo© Chart

The Apollo© chart is the primary tool of analysis. A generic Apollo© chart is shown below (it strongly resembles the Cause Tree chart shown at the beginning of this Appendix).



Because it will change continuously throughout the analysis, it is best to make the chart on a wall or white board using Post-It™ notes for events, causes, evidence, and potential solutions. The chart grows from left (the event) to right. The chart also tends to expand in a conical fashion because each "cause" has at least two more "causes." If the chart becomes unwieldy, it may be broken into several constituent charts.

To construct the chart:

1. Start with the event of interest, hypothesize causes backward from there in a chain (or rather a cone, since each effect must have at least two causes).

2. Brainstorm possible causes: put *all* possibilities on the table without judgment in the initial charting.

3. Continue until:
   - you reach your "level of ignorance:" simply don't know the next causes in the chain
   - causes adduced are plainly no longer relevant
   - causes adduced are plainly beyond the possibility of control

4. Record the *evidence* for each proposed cause (conventionally written below each cause).

5. If evidence is missing, go to appropriate sources and collect it, ***or***

6. Remove proposed causes that are not supported by evidence from further consideration.

Developing Solutions

1. Starting at the right side of the chart (the most distal causes) brainstorm possible corrections for *all* causes supported by evidence. This is called "*challenging the cause*."

2. Write possible solutions on the chart below their corresponding causes.

3. Evaluate proposed corrections by these criteria (Gano, p. 93):

- Prevent recurrence (of this specific problem)
- Within your power to control
- Meets your goals & objectives, which should include:
  - Does not create additional problems
  - Prevents similar occurrences (e.g., same equipment, different locations)
  - Provides reasonable value for its cost

Assignment of responsibilities for implementing fixes and tracking them to completion is essential to close the loop.

Additional RCA Methods

The charting methods described in the previous section are but two of the methods that are used for RCA. It is beyond the scope of this report to provide a catalog of such methods, but brief descriptions of dozens of additional methods may be found in the DOE's *Root Cause Analysis Guidance Document* and the books by Ammerman, Andersen, & Fagerhaug, and Ferry listed in the Reference Section.

D
MODEL PROCEDURE FOR INVESTIGATIONS

Introduction

As discussed in Section 5 of this report, a formal procedure for incident investigation is desirable to communicate management expectations and to promote consistency of results.

The model procedure outlined below is based on a composite of utility procedures reviewed for this project. It is more elaborate than any one of them on its own. It is presented in the expectation that the reader may use it as a menu for creating a procedure where none exists, or may incorporate those parts that offer increased specificity or control into his or her own utility's existing procedure. For those who do not have an established policy or program for incident investigation and reporting, it is also a guide to issues that should be thought through in advance.

The format and specific contents of any procedure developed from this model are certain to be different for each user. For example, the amount of detail needed would vary significantly if the procedure were intended for use by a well-trained cadre who conduct or lead the majority of investigations or by field supervisors who are expected to conduct investigations but are seldom called upon to actually do so. For the former, the procedure could be little more than an authorizing document; for the latter it should contain detailed "how-to" information that would be unnecessary for the cadre.

The major sections are presented in boldface type, with typical contents presented as bullets. Comments and explanation are presented in italics and a smaller font size.

Model Procedure

Procedure Number

To be effective, the procedure must be a part of the department or company-wide procedure system. It should have an "owner" who assumes responsibility for developing and maintaining it, and be subject to the same document control and maintenance as other procedures to ensure:

- Appropriate Quality Control during development
- Management review and authorization
- Periodic review and updating
- Control of revisions
- Control of distribution

Purpose

This section outlines the objectives to be attained by the procedure.

- Learn about problems so as to prevent similar (or worse) incidents in the future.
- Meet internal and external reporting requirements (e.g., injury, equipment, or outage reporting).
- Standardize information collected for database entry.
- Others as appropriate.

While the focus of this procedure is on investigation, understanding, and prevention of operating incidents by and for the Operations Department, the procedure may support other requirements, such as the collection of data on system disturbances required by NERC, regional reliability councils, or other external agencies.

The purpose section is a good place for an explicit statement that management considers conducting investigations to be an aid in improving policies and practices. It may also be an appropriate place to state that, although the purpose of investigations is to discover information that may aid in process improvement, individuals may be held accountable for deficient performance in accordance with existing policies.

Scope

- Applicability: organizational units to which this procedure applies (e.g., substations but nothing outside the fence, specified voltage levels, etc.).

The processes described in the procedure are intended to apply to all Operations Department activities, which may include maintenance activities as well. Where Operations has several sub-departments (transmission, distribution, substations, lines), we believe it is best if the same procedure is used by all, even if this entails separate carbon-copy procedures for each sub-department.

- Relation to other investigations (e.g., investigations of injuries conducted by the Safety Department).

If procedures are already in place to meet external reporting requirements (PUC, NERC, others), the scope section should contain appropriate references to them.

Definitions

- Definition of what is considered an incident.

The definitions may be general or include a list of types of incidents to investigate. A list is especially useful where some of the items of interest might be considered too trivial to bring to the attention of the department manager (e.g., a test switch discovered in an incorrect position or a lock not properly secured). Where such a list is given, it should be made clear that it is not exhaustive, and any unusual or unexpected happening should be reported and may be investigated at management's discretion.

- Definitions of all terms used in the procedure.

References

- Documents requiring or authorizing investigations described in this procedure.

This section may also include reference to policy statements regarding the importance placed by management on timely and complete investigation.

- Super-ordinate & related procedures, if any.
- Documents incorporated by reference.

Such documents might include those describing in detail how to perform a root cause investigation, guidelines for writing an investigation report, interview guidelines, etc.

- Forms and associated instructions, if separate from this procedure.

Responsibilities

This section lists the various individuals and organizations with responsibilities under the procedure and provides a broad statement of their role and responsibilities. The section does not recreate the actual procedure by stating in detail – and out of context – the actions performed by each position.

- Persons responsible for reporting of incidents.

A common model is that whoever recognizes a reportable occurrence or condition per the definition of reportable incidents reports it to the supervisor, who then determines the basic facts (who-what-where-when-what consequences) and notifies the manager responsible for initiating the investigation.

- Persons responsible for initiating and conducting investigations/reports.

This is generally the manager who has operational jurisdiction for the personnel, equipment, or activities involved in the incident, e.g., the Distribution Ops Manager, Transmission Ops Manager, or Maintenance Manager.

- Team composition (if applicable).
- Management responsibilities:
  - *Review & sign-off of findings & recommendations*
  - *May include committee review prior to release*
- Responsibilities of any Committee or Department established for the purpose of incident investigation and reporting.

Investigation Process Guidelines

The guidelines may be presented within the procedure itself or as one or more attachments. Alternatively, the procedure section may contain references to separate documents, for example investigation guidance documents produced by the Safety or Loss Prevention departments. There is little point in duplicating existing documents, and it is arguably desirable that investigation methods be similar for all units.

- Timeliness requirements:
  - *Initiate investigation immediately (i.e. within 24 hours)*
  - *Written report in x days*
- Guidelines for determining the appropriate level of investigation.

If the procedure describes several levels of investigation, the criteria for initiating each level must be stated. Generally, on the basis of the initial report, the responsible manager will determine whether the incident requires the formation of an investigation team or may be adequately investigated by the reporting supervisor. Possible criteria are identified in Section 3 of this report.

In addition, the system should allow discretion to perform more detailed investigations of events not meeting the trigger criteria at the request of the responsible manager, review committee, or initial investigator (the recommendation to perform a more detailed investigation may be a check-box on the initial report form)

- Guidelines for gathering information:
  - *Information & documents to collect*
  - *Preservation of evidence (documents & others)*
  - *Technical inputs as appropriate*
  - *Interview techniques*
- Guidelines/requirements for root cause analysis:
  - *Root cause definition*
  - *Techniques for root cause analysis*
- Guidelines/requirements for recommendations for corrective actions.

This may include discussing recommendations with the managers who will receive the report and may have to act on the recommendations presented. The intent is to let the manager know what to expect, and to ensure that the evidence required to secure the desired action is included in the report. Recommendations for prioritizing recommended corrective actions may also be included.

Notification Requirements

Many kinds of incidents require additional notifications, which are generally the responsibility of the manager receiving the initial report that an incident has occurred. Such notifications may include:

- Injuries or fatalities require notification of the Safety Department
- Fatalities usually require notification of local law enforcement
- Damage to non-company property may require notification of the Legal Department

  - Outages to critical customers may require notification of Customer Service or Major Accounts (where this is required, there should be a list of such customers)
  - The company Legal Department may require notification in any of the above circumstances
  - Most of the above, or any serious on potentially embarrassing incident may require notification of senior management

All such notification requirements should be explicitly stated in the procedure. The inputs of all persons or departments requiring notification should be solicited when developing the procedure to insure that their needs are met. The procedure should contain or reference a list of persons to notify and their phone numbers.

Reporting

- Information to include in reports:
  - *For management*
  - *For rank & file (format may be different, e.g., no names, general rather than specific follow-up with responsibilities & due-dates, etc.)*

Information to include may include formal citation of specific work practices or procedures if non-compliance with them is involved in the incident.

- Required or common attachments, such as operating orders, one-lines, event charts.
- How information is presented (includes report organization & formats):
  - *Formats for formal reports*
  - *Formats for bulletins*
  - *Formats for databases*

Follow-Up Requirements

- For incidents attributed solely to "human error."

Follow up generally includes publication of a report describing the incident and emphasizing how attention to established practices would have prevented it. Disciplinary actions are typically not discussed in such reports.

- For incidents resulting in recommendations for management actions to correct problems in processes or work procedures.

Management response should include:

- Management review and acceptance of recommendations, or
  - Proposal of alternatives that will accomplish the same goals, or
  - Documentation of reasons for rejection of proposed corrections

- Specific assignment of responsibility for actionable items,
- Assignment of due dates for completion,
- Tracking to closure.

Distribution and Use of Information

- Affected or potentially affected work groups (locally or company wide)
- Training
- Safety (if necessary because of the nature of the incident)
- System Operations Committee for periodic review & analysis of reports
- Entry to a data base

Training Requirements

- All employees

All employees and managers need to be aware of the investigation process & their responsibilities in relation to it.

- Management

The managers who are charged with implementing the process need to thoroughly understand the investigation process and the products it is intended to produce.

- Investigators

Personnel who will be responsible for performing investigations, including supervisors if they are expected to perform part or all of the investigation, should be trained in investigation techniques appropriate to the complexity of the investigations they are expected to perform.

Attachments

Any or all of the following may be presented as attachments to the procedure:

- Process flowcharts
- Guidelines for first responders
- Lists of organizations requiring notification of various kinds of incidents (including contact information such as phone numbers)
- Guidelines for conducting investigation
- Root Cause categories
- Root cause flowchart
- Criteria for developing recommendations
- Investigation or report QC checklist
- Report formats (outlines)

E
CHECKLIST FOR CONDUCTING AND REPORTING INVESTIGATIONS

An abbreviated checklist for conducting and reporting investigations was presented in Section 8 as an example of a useful job aid. An expanded checklist is provided in this appendix.

Checklist for Investigations

Collect Evidence

- List names and job titles of the individuals involved.
- Collect job documentation:
  - Switching instructions
  - Diagrams
  - Logs
  - Recordings of communications
  - Others as necessary
- Inspect the job site and note general conditions such as:
  - Time of day
  - Weather conditions
  - Housekeeping
  - Physical condition of labels and equipment
  - Lighting and visibility
  - Noise or other distractions
  - Design factors such as crowded, confusing, or inconsistent arrangement of controls, adequacy of labeling, etc.

Interview Involved Employees (Conduct Interview According to Company Guidelines)

- Determine each individual's actions before, during, and after the undesired event:
  - Actions leading up to the event
  - What happened that caused the undesired event
  - How the undesired event was recognized
  - Reaction to the undesired event
  - Actions to recover from undesired event
- Inquire about possible contributing factors:
  - Pre-job briefing/tailboard
  - Time pressures (e.g., delays in starting this job, more jobs waiting to be done)
  - Workload (e.g., time-sharing among several tasks, crew short-handed, etc)
  - Distractions
  - Procedures and/or job aids available and used properly
  - Anything unusual or "different" about the job
  - Time on shift
  - Employee morale or attitude
  - Employee training, experience, or supervision
- Ask what the employee believes caused the undesired event.
- Ask what could be done to prevent such incidents in the future.

Analyze Information Collected

- Identify what happened (the action or omission) that was the **immediate** cause of the event (e.g., step omitted, wrong switch operated, contact shorted out, etc) Note: this is "what" happened, not "why" it happened.
- Identify the action(s), omission(s), or condition(s) that led to the immediate cause (this is the first "why").
- Review job documentation and communications for inadequacy/irregularities that may have contributed to the event: document any deficiencies.
- Review general conditions for factors that may have contributed to the event, and document deficiencies.
- If irregularities in documentation, communications, or conditions are found, perform additional information collection and analyses as necessary to determine the extent of such irregularities/deficiencies in related documents/practices/conditions.

Prepare a Report of the Investigation

- Provide a brief summary of the incident and its consequences.
- Provide a factual narrative of the incident incorporating all facts relating to causes and contributing factors that:
  - Describes the details of what happened: Who? What? When? Where? Why?
  - Describes the events leading up to the incident, the sequence of events, and the aftermath
  - Is written in a way that an uninformed reader could understand what happened
- Provide a listing of identified causes:
  - Each identified cause supported by evidence
  - Immediate Cause
  - Identified more basic Causes or Contributing Factors
- Provide recommendations for correcting identified causes and contributing factors:
  - Each recommendation should meet company criteria for such recommendations
- Provide a list of other deficiencies discovered in documents/practices/procedures/conditions that were not believed to be causally related to the incident.
- List actions already taken to correct deficiencies.
- Include administrative information as required by company:
  - Management sign-off (and management comments if appropriate)
  - Names of investigator or team members
  - Other information as required
- Include attachments a necessary to support understanding of incident and document deficiencies.

F
GUIDELINES FOR CONDUCTING INTERVIEWS

Introduction

Interviewing is the means by which most information for the investigation of switching-related incidents is obtained. Many consider the interview the single most important source of information for investigations involving human performance.

Interviewing is a skill, and as such may benefit from training and practice. Although communications skills are central to the adequate performance of their jobs, many supervisors and managers may not have received training in interview techniques. This Appendix provides an outline of such techniques and other considerations for conducting effective interviews. It is based upon discussions of interviewing techniques in the books by Ammerman (pp. 49-61), Gano (pp. 136-143), and Ferry (pp. 35-41).

Interview Guidelines

Timing

Initial interviews should be conducted as soon as possible after the event because people:

- Forget details rapidly.
- Try to make a coherent story of their experience, which may lead them to
  - confuse inferences or assumptions with observations
  - supply details they in fact do not know.

  Note: This process is difficult to avoid if the experience is at all important to the person. It is a natural human thought process, whose goal is to make the experience more understandable to *them*. In the process of explaining an experience to themselves they often distort the facts recollected. And of course a person who feels at fault may deliberately distort his story to make himself look better.
- Discuss the event with others and such discussions may distort memory.

However, if the person to be interviewed is injured, his well being takes precedence over the need to interview quickly. Ferry (p. 36) states that an early hospital interview is preferable to an interview while awaiting the ambulance. Ferry also notes that an injured person's condition may affect the accuracy of his statements. A person traumatized by an injury may have poor recollection of events surrounding the injury; likewise, a person who is upset by a near miss may also not remember as well as one not so personally affected.

Preparation

To conduct an effective interview, the interviewer must be well prepared. Pre-interview preparations include:

- Review of what is known before the interview.
- Identification of any specific facts you want to collect or cross check.
- Preparation of a list of general or specific questions for the interviewee to ensure no important questions are forgotten.

Interviewer Self-Presentation

Several authors caution that the interviewer should avoid judgments during the interview process. In particular, they caution against finding fault or placing blame in an interview. This can be done with body language, facial expressions, tone of voice, or phrasing of questions, as well as with direct expressions. During the interview, the interviewer needs to be in control of *himself* to manage the impression he or she makes, including awareness and control of body language. The interviewer should be:

- Knowledgeable but not know-it-all
- Concerned
- Non-judgmental
- Focused on the problem, not blame

Guidelines for Conducting the Interview

The following are guidelines for the actual conduct of the interview:

Physical Arrangements

- Meet interviewees on their turf or a neutral location: the conference room next to the boss' office (or the boss' office itself) is not neutral ground.
- Sit on the same side of the table as the interviewee.

Conduct of the Interviewer

- Be prepared to listen with an open mind: suspend judgment and listen with a positive bias.
- Maintain eye contact (at least in American cultures).
- Don't be afraid to admit you don't know something or to ask for clarification.
- Take very good notes, and, if the interviewee agrees, tape record the interview.
- Use pauses ("dead air") to elicit additional information or give him or her time to reflect on a question or answer.

Getting Started

- Let the interviewee know the purpose of the interview & what you hope to achieve
- Emphasize that the purpose of the interview is to find facts, not assign blame
- Let the interviewee know what you already know.

Eliciting Information

- Allow the interviewee to tell what happened from beginning to end in his or her own words, without interruption.
- At least initially, use open-ended questions that require more than a yes-no response.
- Try to confine the interviewee to observations and discourage conclusions.
- Avoid leading questions, which imply a "correct" or expected answer. These can be very subtle: "Did you see the broken headlight?" may yield a different answer than "Did you see a broken headlight?" or "Did you notice anything unusual about the car?" Trial attorneys are expert at leading questions, but they are trying to support a conclusion they have already reached, not discover the truth.
- Paraphrase statements back to the interviewee to be sure you understand what has been said.

Closing the Interview

- Close the interview when all prepared questions are addressed. Consider asking what the interviewee would do differently or what he or she would recommend doing to solve the problem.
- Review your notes with the interviewee.
- Leave open the possibility of follow-up interviews.
- Ask if there is anything the interviewee expected to you ask about that you did not.
- If appropriate, ask for references to additional people who might have relevant information (e.g., to corroborate statements, etc).
- Give the interviewee your phone number and ask him or her to call you if he or she remembers anything else of importance.
- Close the interview on a positive note.
- Thank the interviewee for his or her participation.

Group Interviews

Published discussions of interviewing typically assume that the interview is a one-on-one process. Group interviews (multiple interviewees) are not a good idea because one person will typically do most of the talking, with the others simply agreeing. Moreover, hearing someone else's version of events may distort the memories of the other participants.

An investigation team should never use group interviews, but the first responder, often the immediate supervisor, may be confronted with a group (e.g., a work crew) and ask the group what happened. This exchange should be confined to a few essential facts, such as the job being done and the nature of the incident itself. If additional information is required, the first responder should ask to speak to each person individually to fill in the details.

Team Interviews

Where the interview of a single person is performed by a team, care must be taken to avoid intimidating the interviewee by numbers alone. Guidelines for team interviews include:

- There should be a single lead interviewer, who should
  - Introduce the other members of the team
  - Explain the purpose of their presence
  - Explain the purpose of the interview
  - Ask the majority of questions
  - Handle the closing of the interview
- Individual technical experts may handle the questions in their areas of expertise.
- All members of the team should manage their self presentation (tone of voice, body language, etc); a single "loose cannon" can sour the whole process.

The Boss as Interviewer

Many of the contributing utilities claim that they consciously try to separate the fact-finding process from blame and discipline. All the discussions of interviewing reviewed for this report assume that the interviewer is a member of an incident investigation team, whose role is that of fact finder. However, in many (most) cases, the initial interviewer will be the immediate supervisor or manager, who may also be judge, jury, and executioner if discipline is involved. Putting the interviewee at ease under this circumstance requires very good interpersonal skills on the part of the interviewer, and may not be possible. The following guidelines are suggested:

- Operations large enough to experience several incidents a year (e.g., a central control center) should consider having an individual or group of individuals other than the manager who are trained to conduct interviews.
- Where an investigation team has been convened, the responsible manager is often a part of, or leader of, the team. If possible, the person conducting the interview should be someone other than the interviewee's responsible manager.

Follow-Up Interviews

Follow-up interviews may be necessary to gather additional facts, resolve contradictions, or validate the testimony of other interviewees. Much of the work of gaining the interviewee's trust should have been accomplished in the first interview. The above guidelines on treatment of the interviewee apply to follow up interviews as well, though the follow-ups should be more focused on the small set of questions to be resolved. That resolution of loose ends or conflicting versions of events should be stated as an explicit goal of the follow-up interview.

The goal is always clarification of facts. Although the question may in fact be "Tom said X and you said Y: which is it?" approach this by asking the question that originally elicited the information again. The answer may be different if the interviewee has had some time to reflect on the incident. If there are specific contradictions to be resolved, leading questions may be used with caution, e.g., "Is it possible that X rather than Y happened?" You should also ask the opposite question of "Tom."

Make an effort to avoid confrontational questions if possible. They are generally counterproductive unless there is good reason to suspect the subject is deliberately lying.

Organizing Information from Multiple Interviews

Where events are complex and there are multiple witnesses, Ferry (p. 39 ff.) suggests making a chart to show differences and points of agreement in their testimony. The chart can identify points of disagreement or details that may have been mentioned by one witness but not others, and for which corroborative testimony is desirable.

G
GUIDELINES FOR DEVELOPING RECOMMENDATIONS

Introduction

Where deficiencies in processes or procedures are discovered, identification of effective corrections is the single most important product of the investigation and reporting process. Only a few of the participating utilities appeared to provide guidance for this critical step in the investigation process. However, as in other areas, without some guidance the recommendations presented may be so vague as to be inactionable, incomplete, or impractical. Recommendations suffering from any of these deficiencies are unlikely to be implemented, and unlikely effective if they are.

Guidance

The DOE *Root Cause Analysis Guidance Document* has treated development and implementation of corrective actions at a greater depth than other sources reviewed. The recommendations presented on pages 14-15 of that document are reproduced below with slight modification for the utility environment.

To begin, identify (one or more) corrective action(s) for each cause. Then apply the following criteria to the corrective actions to ensure they are viable.

1. Will the corrective action prevent recurrence?
2. Is the corrective action feasible?
3. Does the corrective action allow meeting primary objectives or mission?
4. Does the corrective action introduce new risks? Are assumed risks clearly stated? (The safety of other systems must not be degraded by the proposed corrective actions.)

If the corrective actions are not viable, re-evaluate the solutions.

Additional questions about corrective actions (DOE, p. 15).

- Do corrective actions address all of the causes?
- Will the corrective actions cause detrimental effects?
- What are the consequences of implementing the corrective actions?
- What are the consequences of *not* implementing the corrective actions?

- What is the cost of implementation?
- Will training be required as part of the implementation?
- In what time frame can the corrective actions reasonably be implemented?
- What resources are required for successful development of the corrective actions?
- What resources will be required for the continued effectiveness of corrective actions?
- What is the impact on other work groups?
- Is the implementation measurable (milestones, etc.)?
- Is the effectiveness of corrective actions measurable?

Once accepted by management, corrective actions should be treated in the same way as any other action items:

- Responsibility assigned. Those responsible for implementing corrective actions should be involved in the process of defining them.
- Prioritized in terms of importance.
- Scheduled.
- Tracked via a commitment tracking system.
- Implemented in a timely manner.
- Funded (for local corrections, the cost may be small or hidden in other budget items: for corrections of programmatic root causes – which presumably may have a larger span of effect – it may be much larger).

Program:
Transmission Substations

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

EPRI. Electrify the World

Printed on recycled paper in the United States of America

1002077

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com