keyed into a field and stored in a standard data base, where it can be interrogated to produce the familiar range of numerical and descriptive data such as bar charts and graphs. The disadvantage of the standard format for human error data is that there is usually insufficient space to allow free text descriptions of accidents to be entered in full. These descriptions are a rich source of data for the human error analyst. It is therefore recommended that the collection and storage systems for human error data provide these facilities. In order to search these free text descriptions, a database system which is capable of storing variable length records and performing text searches is desirable. Examples of database and text retrieval software which can be used for this purpose are Pagefinder® by Caere Systems (USA) and Idealist by Blackwell Software (Europe).

6.7. DATA INTERPRETATION

There is considerable overlap between the processes of data collection and interpretation as discussed in earlier sections of this chapter. The nature of the data collected will be strongly influenced by the assumed relationship between the observable characteristics of errors and their underlying causes. Similarly, the interpretation process will also be driven by the causal model.

The overall process of data interpretation and the development of suitable remedial strategies once a set of causes has been identified, is set out in Figure 6.4. The two-stage process of confirming the initial causal hypothesis is recommended to overcome the tendency to jump to a premature conclusion and to interpret all subsequent information on the basis of this conclusion.

In the following sections, a number of methodologies for accident analysis will be presented. These focus primarily on the sequence and structure of an accident and the external causal factors involved. These methods provide valuable information for the interpretation process and the development of remedial measures. Because most of these techniques include a procedure for delineating the structure of an incident, and are therefore likely to be time consuming, they will usually be applied in the root cause analysis of incidents with severe consequences.

In the case of incident reporting systems, the data interpretation process will be more concerned with identifying trends in recurrent causes for a large number of incidents than a detailed investigation of specific situations. These analyses could identify the repeated occurrence of failures arising, for example, from inadequate procedures, work systems, training, and equipment design. In addition, classifying errors using some of the concepts from Chapter 2, such as slips, mistakes, and violations, can be useful. Essentially, the interpretation process should be based upon an explicit causal model, which should specify the types of data to be collected by the incident reporting system. This causal

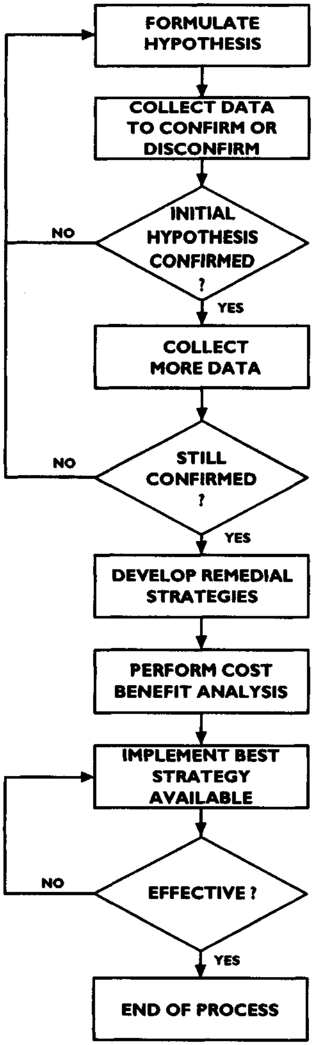

FIGURE 6.4. **Data Interpretation, Remedial Strategy Generation, and Implementation.**

model must not, however, be cast in concrete. If there is evidence that important causes are not being addressed by the existing causal model, then this must be updated and the new information generated by the revised model must be collected and incorporated in the interpretation process.

A specific example of a causal model is the root cause tree described in Section 6.8.4 and Figure 6.8. This is a very elaborate model which includes several levels of detail for both equipment and human causes of incidents. The root causes tree is a generic causal model, and may require tailoring for application to specific plants and processes (e.g., in the offshore sector) where other error causes may need to be considered.

6.8. ROOT CAUSE ANALYSIS TECHNIQUES

Root cause analysis techniques are formalized methodologies that are usually applied to incidents with severe consequences, for example, major financial loss or injuries to personnel. The ideal root cause analysis technique would include all the dimensions discussed in Section 6.5.2—event sequence and structure, human error tendencies, PIFs, and organizational causes. Unfortunately no incident analysis technique currently exists that comprehensively addresses all of these areas. However, several of the available techniques provide a highly structured approach for performing an investigation which will provide insights into incident root causes. These techniques are described in subsequent sections. The description of techniques is necessarily selective, since a large number are available. (See Ferry, 1988, and CCPS, 1992d, for an extended analysis of these techniques.)

6.8.1. Tree of Causes/Variation Diagram

The Tree of Causes investigative method was developed by the Institute National de Recherché et de Sécurité (Leplat, 1982). The underlying principle of the method is that an accident results from changes or variations in the normal process. These antecedent variations must be identified listed, and finally organized into a diagram in order to define their interrelationship. Unlike a fault tree, the method starts with a real accident and results in a representation which only includes the branches actually leading to the accident. Thus, no OR gates are represented. The construction of the diagram is guided by simple rules which specify event chains and confluence relationships. These correspond to AND gates in fault trees, in other words, event C would only have occurred if events A and B also occurred. Suokas (1989) used the tree of causes to describe the Spanish campsite disaster (see Example 6.1 and Figure 6.5).

Example 6.1. The Spanish Campsite Disaster (based on a description in Mill, 1992)

A tank truck was delivering propylene from Tarragon to Puertotollano, a road journey of 270 miles. Prior to the journey, the tank truck had frequently carried anhydrous liquid ammonia, which probably affected the strength of the high tensile steel storage tank. Another contributory factor to the accident was the fact that no pressure relief valve was fitted. At the loading bay, the tanker was filled with propylene. No metering facilities or overload cut-out devices were provided. The driver measured the weight of propylene at a scale at the exit to the site. The weight of propylene in the tank was 23 tons, which was 4 tons over the maximum allowed weight.

The driver of the tank truck decided to take the coastal route to Puertotollano, which passed close to several campsites. During the journey, the pressure in the tank built up and, because of the absence of a pressure relief valve, the weakened tank cracked. The propylene that was released ignited, and a flash fire burned near the tank. Eventually this ruptured and an explosion occurred close to a campsite, killing 210 people.

It should be noted that the completed diagram is not a diagram of causes as such, since variations are the active factors necessary to generate an accident in conjunction with other latent factors already present in the system. The method recognizes that there may be permanent factors in a system which need to be represented in order to improve the comprehensiveness of the diagram, and it is by representing these "state antecedents" that one moves toward a comprehensive description of causes. For example, in Figure 6.6 the situation "no relief valve in tank" could have arisen from "design error" as an antecedent cause. The goal of the method is to identify those changes which can be introduced to break the flow of events in the diagram.

The finished diagram is used to identify nodes representing inappropriate acts and abnormal physical states in the system, and to extract a list of factors involved in the accident with a view to improving the conditions for human decision-making and action, hence improving the work environment and system design. Also, the sequence of events is analyzed with the objective of breaking the causal relations among nodes by either making physical changes or providing operator feedback concerning a risky course of events. Both of these interventions act as barriers against the flow of events which could lead to an accident

Although the diagram is easy to construct and represents the incident process in an accessible manner, the method provides little guidance on how to collect all the relevant information or identify the main events involved. The method also relies heavily on the analyst's knowledge of the system conditions. Without this knowledge, it is necessary to perform a task analysis of the system in order to identify all the deviations. The root causes may remain undiscovered if the analyst is not experienced in incident investigation, as the method deals mainly with identifying direct causes, trigger events and prevailing conditions, but not the underlying causes which lead to these.

An extension of the tree of causes, called **variation diagrams** (Leplat and Rasmussen, 1984) was developed to answer some of these criticisms. In this method, the Rasmussen stepladder model of human error (see Chapter 2) is applied to analyze causal factors at each node of the tree. A detailed example of the use of this technique is provided in Chapter 7 (Case Study 1).

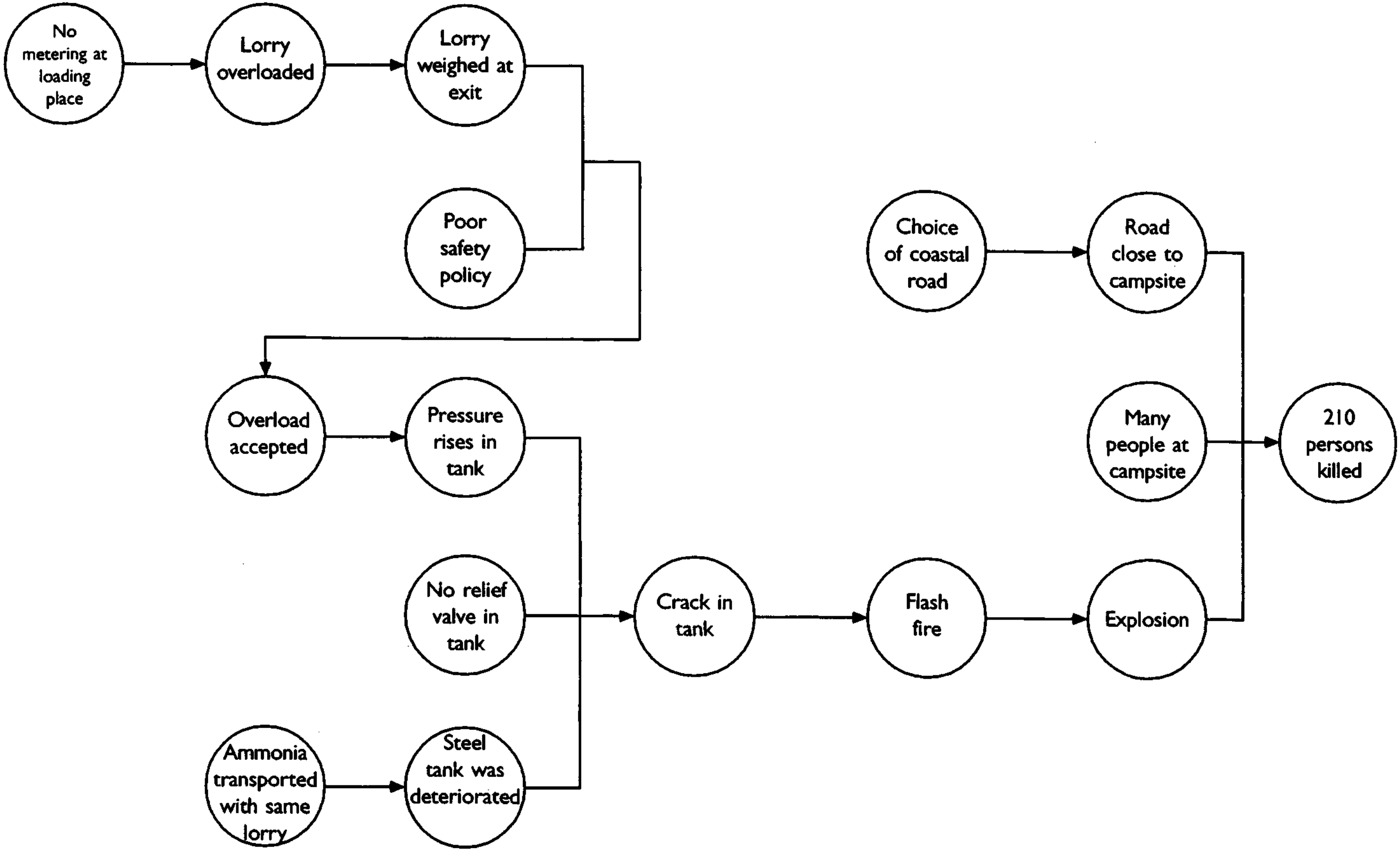

FIGURE 6.5· **The Spanish Campsite Disaster Described Using the Tree of Causes Diagram (from Suokas, 1989).**

6.8.2. The Management Oversight and Risk Tree (MORT)

The development of MORT was initiated by the U.S. Atomic Energy Commission, and is described in Johnson (1980). MORT is a comprehensive analytical procedure that provides a disciplined method for determining the causes and contributing factors of major accidents. It also serves as a tool to evaluate the quality of an existing safety program.

Management Oversight and Risk Tree is designed as an investigative tool with which to focus on the many factors contributing to an accident. A unique feature of the method is a logic diagram (see Figure 6.6) which represents an idealized safety system based upon the fault tree method of system safety analysis. The diagram comprises specific control factors and general management factors. Detailed consideration of the former is accomplished by reasoning backward in time through several sequences of contributing factors. This analysis ends when the question posed by the MORT statements is answered "yes" or "no." The analyst must focus upon the accident sequence when evaluating the specific control factors and, when evaluating the management factors, must consider the more global or total management controls. The diagram is supplemented by the MORT text which is a commentary on best concepts and practices found in the safety literature. It contains criteria to assist the analyst in judging when a factor is adequate or less than adequate. In summary, MORT provides decision points in an accident analysis which help an analyst detect omissions, oversights, or defects. Johnson (1980) claims that MORT considerably enhances the capability of the analyst to identify underlying causes in accident analyses.

However, MORT does not aid in the representation of the accident sequence which must first be determined before the method can be effectively used. Although MORT provides a comprehensive set of factors which may be considered when investigating an incident, it can easily turn an investigation into a safety program review as no guidance is provided on the initial investigative process.

MORT excels in terms of organizational root cause identification, as factors such as functional responsibilities, management systems and policies are well covered, but this strength of the method requires an accurate description of the incident process, and an experienced MORT analyst who is knowledgeable and well-practiced in the methodology.

6.8.3. Sequentially Timed Events Plotting Procedure (STEP)

The STEP procedure, described by Hendrick and Benner (1987), was developed from a research program on incident investigation methods. STEP is based on the multiple events sequence method and is an investigative process which structures data collection, representation, and analysis.

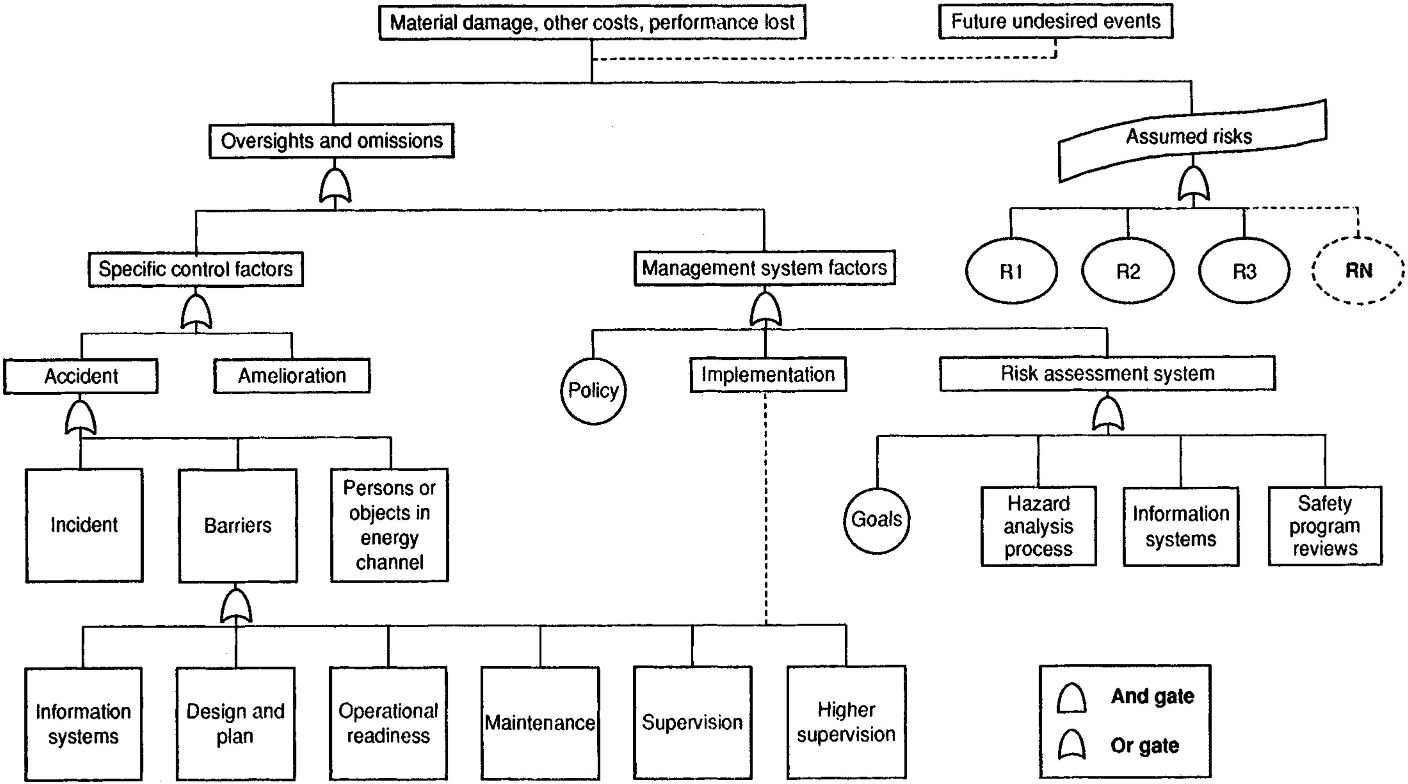

FIGURE 6.6. **Management Oversight and Risk Tree (Johnson, 1980).**

The method distinguishes among actors (referred to as "agents" in this book), actions, and events. Agents can be people, equipment, substances, etc., whereas actions are anything brought about by an agent. Events are the unique combination of one agent plus one action during the main incident process. The method's primary aim is to help the analyst identify the main agents and their actions and map the relations among these events along a flexible time line.

The main agents are identified based on a description of the incident and its end state. The initial state is determined by identifying the first event in the incident which is an unplanned change by an agent within the planned process. The method proceeds by developing an event sequence diagram which involves listing the agents down a vertical axis and establishing a time line on the horizontal axis. It should be noted that the time axis is not necessarily linear. Nevertheless, the actual time that events occur needs to be recorded. Each agent's actions are traced from the start of the incident to the finish. Agents which initiate changes of state in other agents are also identified. This reveals new agents not previously implicated in the incident. Events are positioned relative to one another along the time line and causal links are represented. Figure 6.7 provides an example of the structure of the STEP work sheet using the Spanish campsite disaster described in Section 6.8.1 and Figure 6.5. Case Study 1 in Chapter 7 provides a detailed example of a STEP analysis.

As the diagram develops, a necessary and sufficient test is applied to pairs of events, and checks for completeness and sequencing are made. One-to-many and many-to-one relations can be represented in the diagram. If data cannot be found to verify the relation between an event pair, then a technique called back-STEP can be used to explore gaps in understanding. Essentially back-STEP is a fault tree which uses the event with no other events leading to it as the top node. The analyst then develops possible event flows which could describe what happened during the gap in events in order to cause the top node.

When the diagram is complete, the analyst proceeds through it to identify sets of events that were critical in the accident sequence. These critical events are then subjected to a further causal analysis using other techniques such as **root cause coding**, described below in Section 6.8.4.

The method is well-structured and provides clear, standardized procedures on how to conduct an investigation and represent the incident process. Also it is relatively easy to learn and does not require the analyst to have a detailed knowledge of the system under investigation. However, the method alone does not aid the analyst in identifying root causes of the incident, but rather emphasizes the identification of the propagation of event sequences. This is an important aspect of developing a preventive strategy.

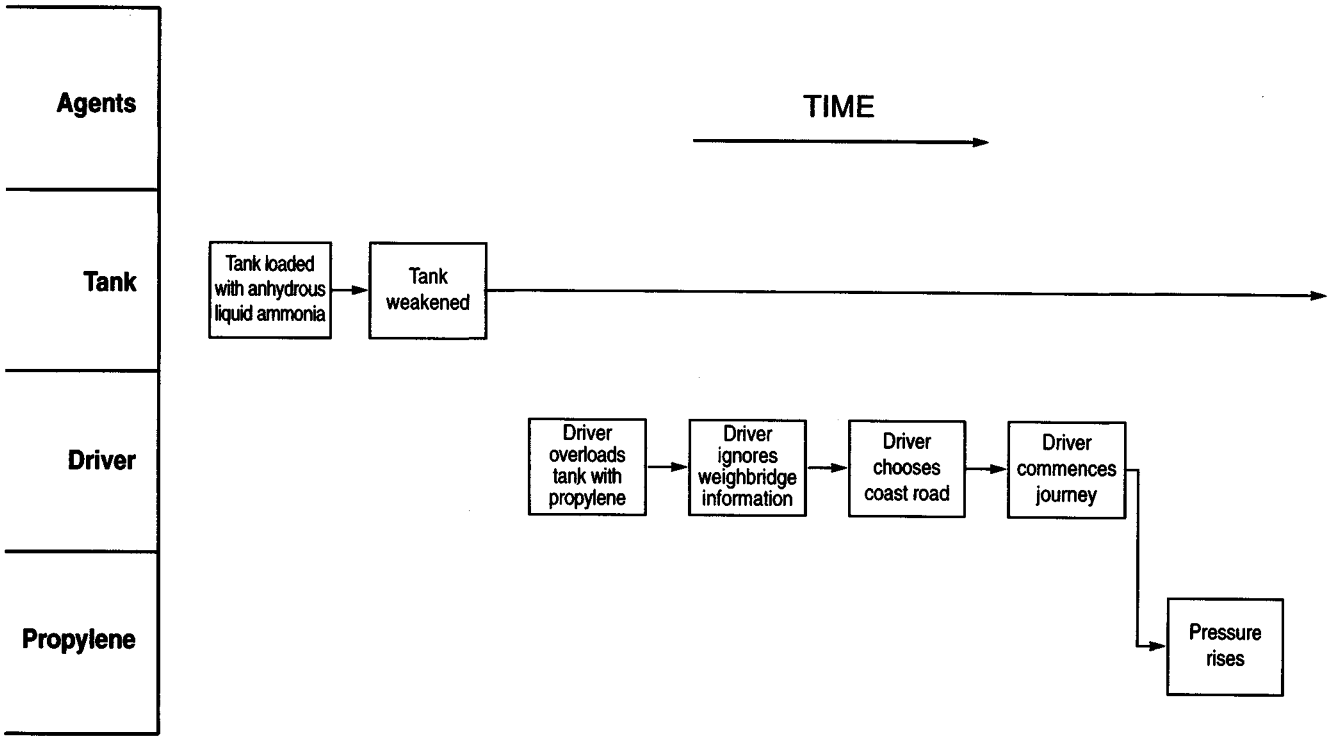

FIGURE 6.7. **STEP Diagram for the Spanish Campsite Disaster (page 1).**

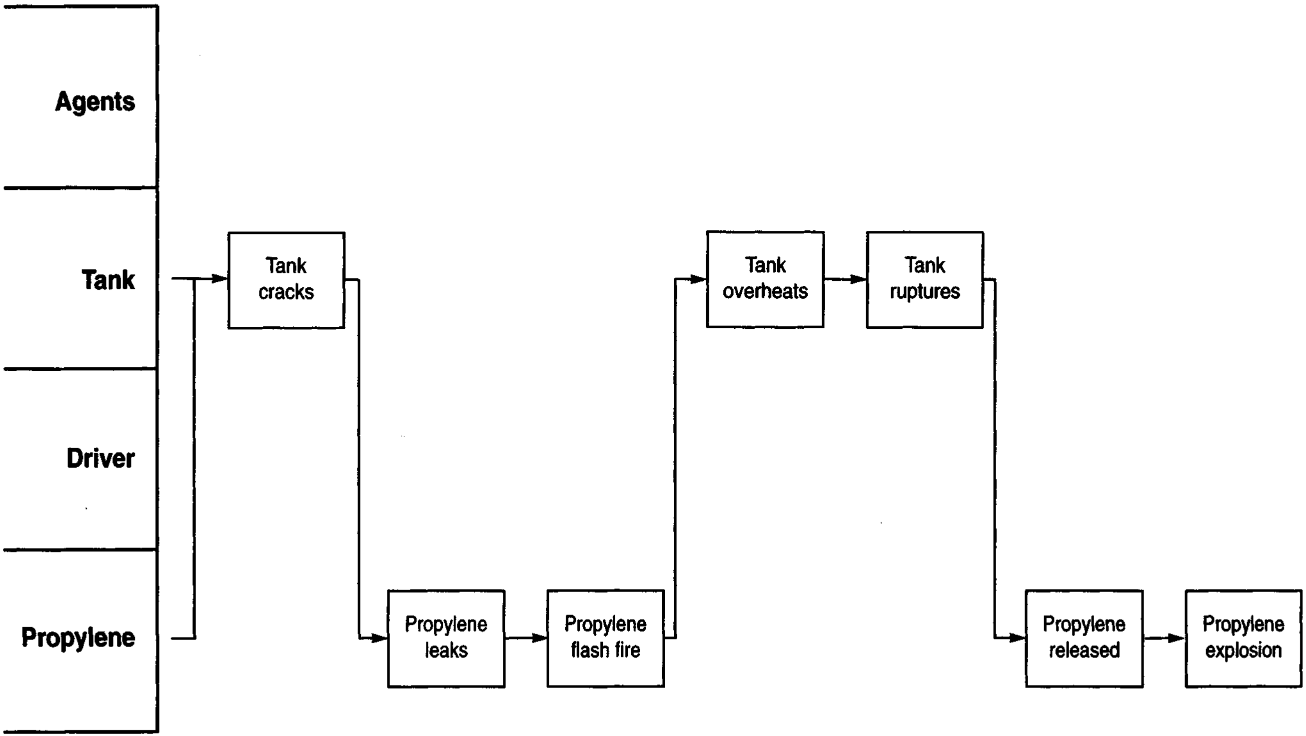

FIGURE 6.7. **STEP Diagram for the Spanish Campsite Disaster (page 2).**

6.8.4. Root Cause Coding

As discussed in the previous section, STEP, although an excellent method for representing the accident sequence, does not in itself provide direct insights into the causal factors underlying an incident. However, it can be used in conjunction with a technique called root cause coding to produce a comprehensive accident investigation framework. The most important aspect of root cause coding is a root cause tree (see Figure 6.8). This is a decision aid to assist the analyst in identifying the underlying causes of accidents at a number of different levels.

The root cause tree was originally developed in the U.S. nuclear industry and has close links with MORT. Armstrong (1989), and Armstrong et al. (1988) provide full descriptions of its development and construction. It consists of six levels covering equipment failures, quality failures, management systems failure and human error. The decision tree codes critical actions and events. By entering the top level of the tree, the analyst has to determine whether the critical event involved an equipment difficulty, operations difficulty or technical difficulty. Based on the answers to these general questions, the investigator branches down to more specific levels of the tree. These relate to: functional area, equipment problem category, major root cause (such as training and management system), near root cause (such as incorrect procedure, and training methods less than adequate), and finally root causes themselves (such as procedures design and training inadequate). This root cause coding allows the investigator to specify the underlying reason for a given critical event. Critical events in the STEP analysis are those which lead directly to critical outcomes or which influenced the course of subsequent events in a critical manner. The use of root cause coding in conjunction with STEP is illustrated in Chapter 7, case study 5.

6.8.5. Human Performance Investigation Process (HPIP)

The HPIP process is a hybrid methodology which combines a number of the techniques discussed earlier. The development of HPIP was supported by the U.S. Nuclear Regulatory Commission, and most of its early applications have been in the nuclear industry. A description of the approach is provided by Paradies et al. (1992). The structure of the incident investigation process is represented in Figure 6.9. The HPIP method was originally developed for use by investigators external to the plant (specifically NRC inspectors), and hence some steps would be modified for use by an in-plant investigation team in the CPI. The stages in the investigation process and the tools used at each of these stages are discussed below.

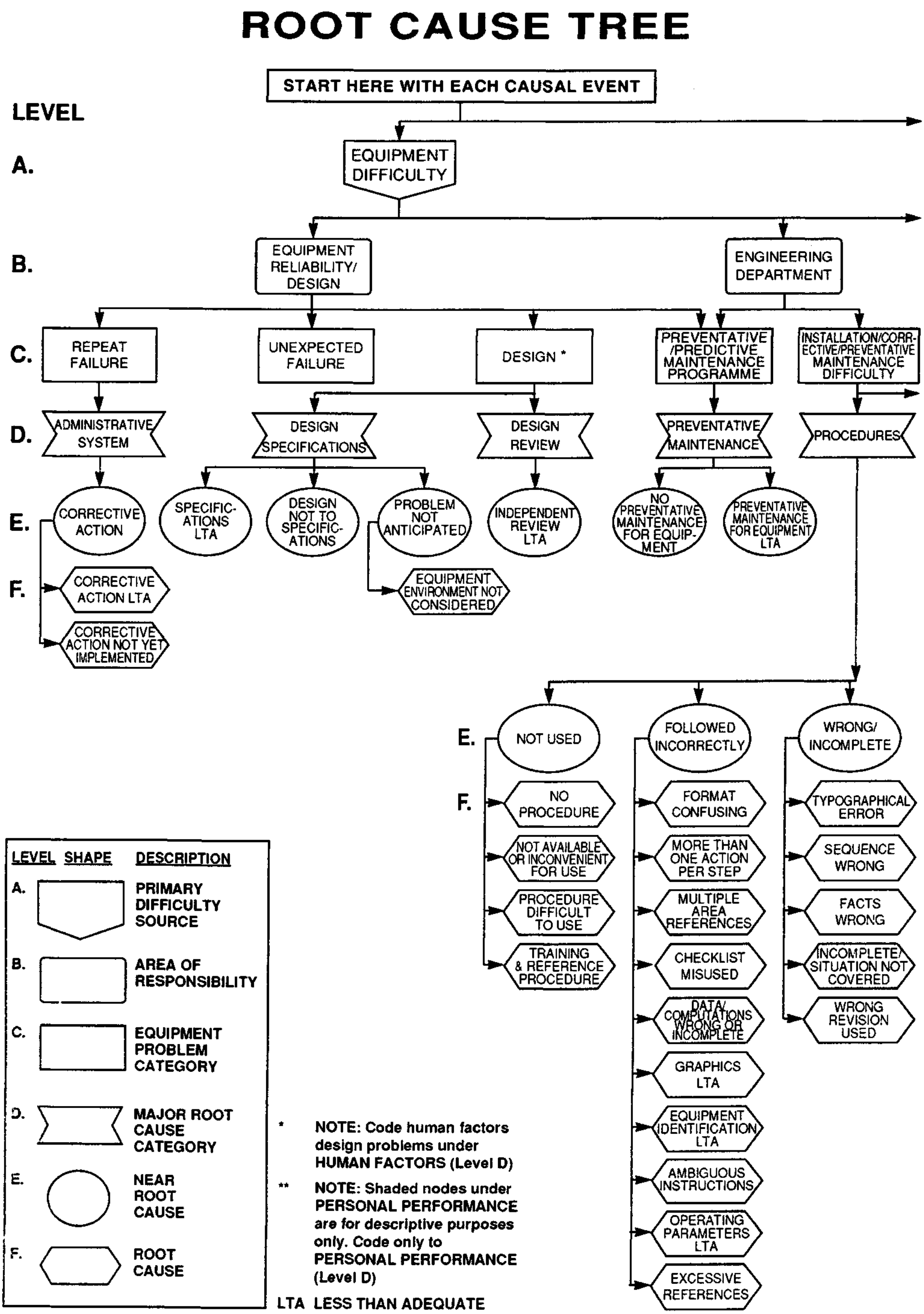

FIGURE 6.8. **Root Cause Tree** *(continues on next two pages).*

ROOT CAUSE TREE

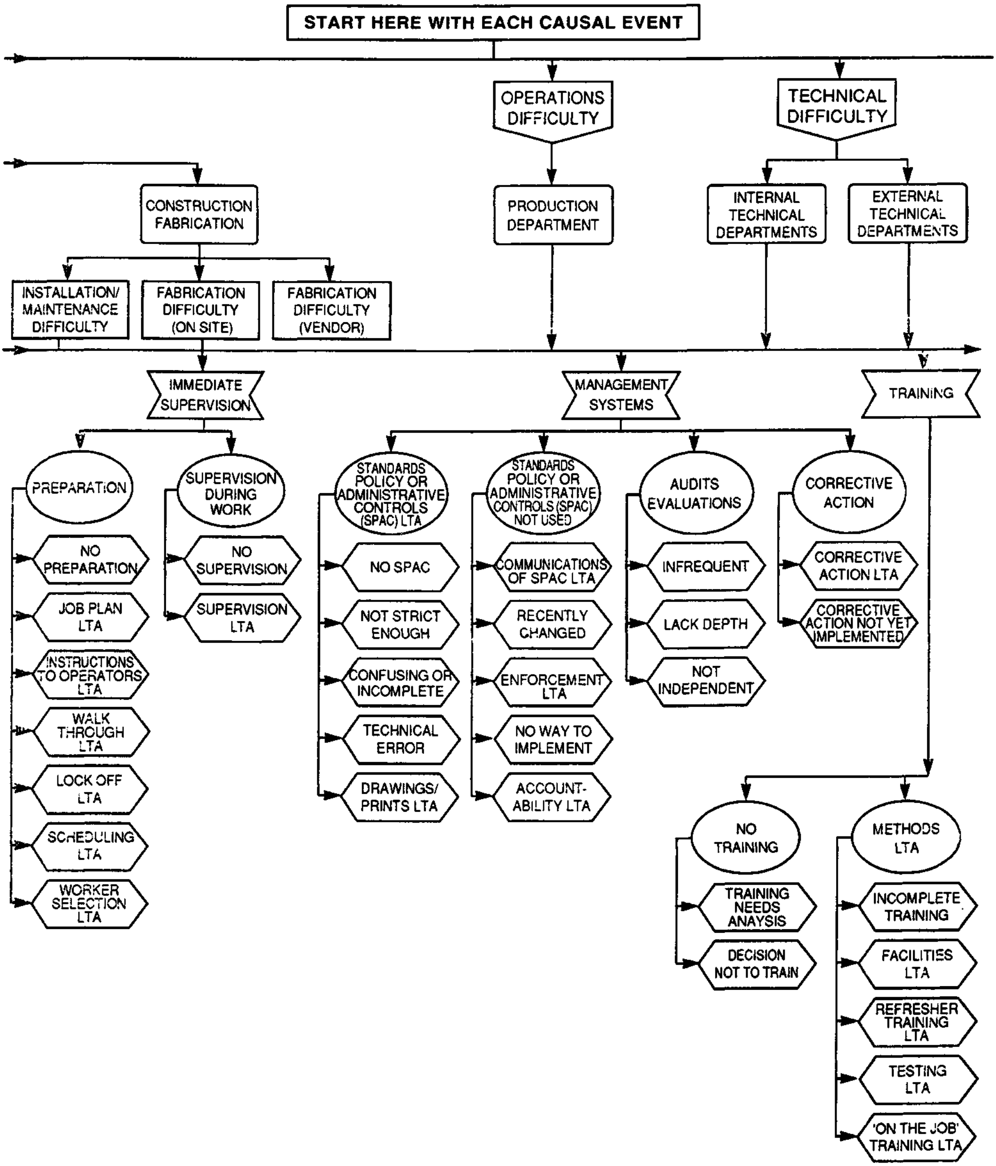

FIGURE 6.8. **Root Cause Tree** *(continues on next page).*

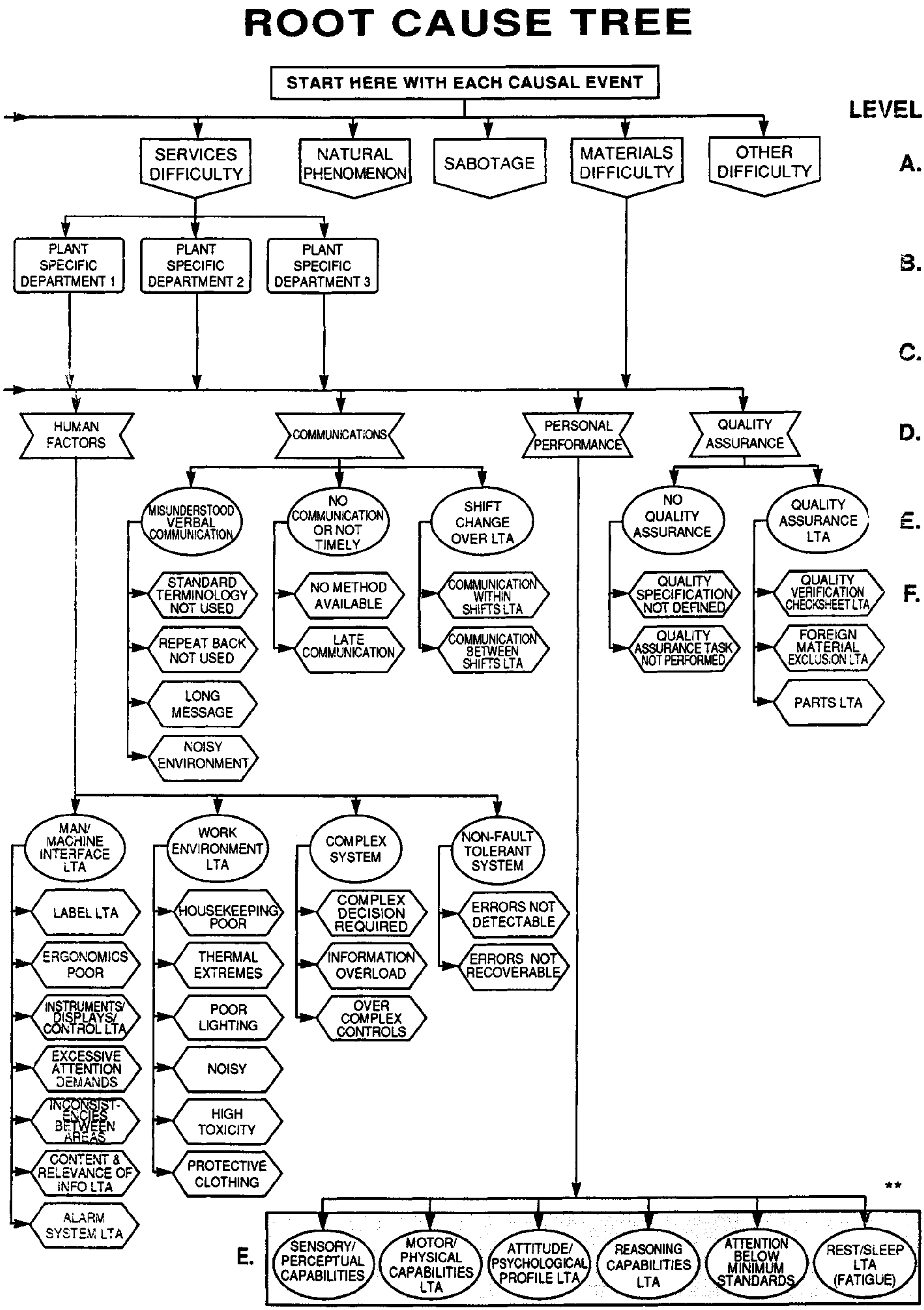

FIGURE 6.8. **Root Cause Tree.**

Plant Investigation

This involves collecting physical and documentary evidence and interviewing key witnesses. A preliminary representation of the accident sequence is developed using the Events and Causal Factors Charting (ECFC) method. This is an event sequence representation method similar to the Tree of Causes and related techniques, and was originally developed for use with the root cause tree described in the last section (see Armstrong et al., 1988). A worked example of the ECFC method is provided in Chapter 7, case study 1. Stimulus operation response team performance (SORTM) is a structured series of questions addressing the following aspects of the causal factors involved in the incident:

- Stimulus—the initiating events for the actions involved in the accident
- Operation—the mental and physical skills and information requirements
- Response—the nature of the individual actions
- Team performance—the team performance aspects of the incident
- Management factors

Develop Event Sequence

This is accomplished using the ECFC and the Critical Human Action Profile (CHAP), a task analysis-based method used to identify the most critical actions necessary for the performance of the task. Change Analysis is a technique for investigating the role of change in accident causation. It will be described in Section 6.8.6.

Analyze Barriers and Potential Human Performance Difficulties

During this phase of the analysis process, the barriers that have been breached by the accident are identified. These barriers could include existing safety systems, guards, containment, etc. This analysis is called barrier analysis. The causal factors from SORTM are also applied in more detail.

Analyze Root Causes

Using the ECFC representation of the incident, a series of detailed questions which address specific causal factors (e.g., poor procedures), are applied to evaluate direct and indirect root causes. These detailed questions are contained in a series of HPIP modules.

Analyze Programmatic Causes

This stage is used to evaluate indirect generic causes such as inadequate human factors policies in the plant or the company.

Evaluate Plant's Corrective Actions and Identify Violations

This stage is used to develop remedial strategies, based on the findings of previous stages. In the original HPIP framework, this stage is simply a check

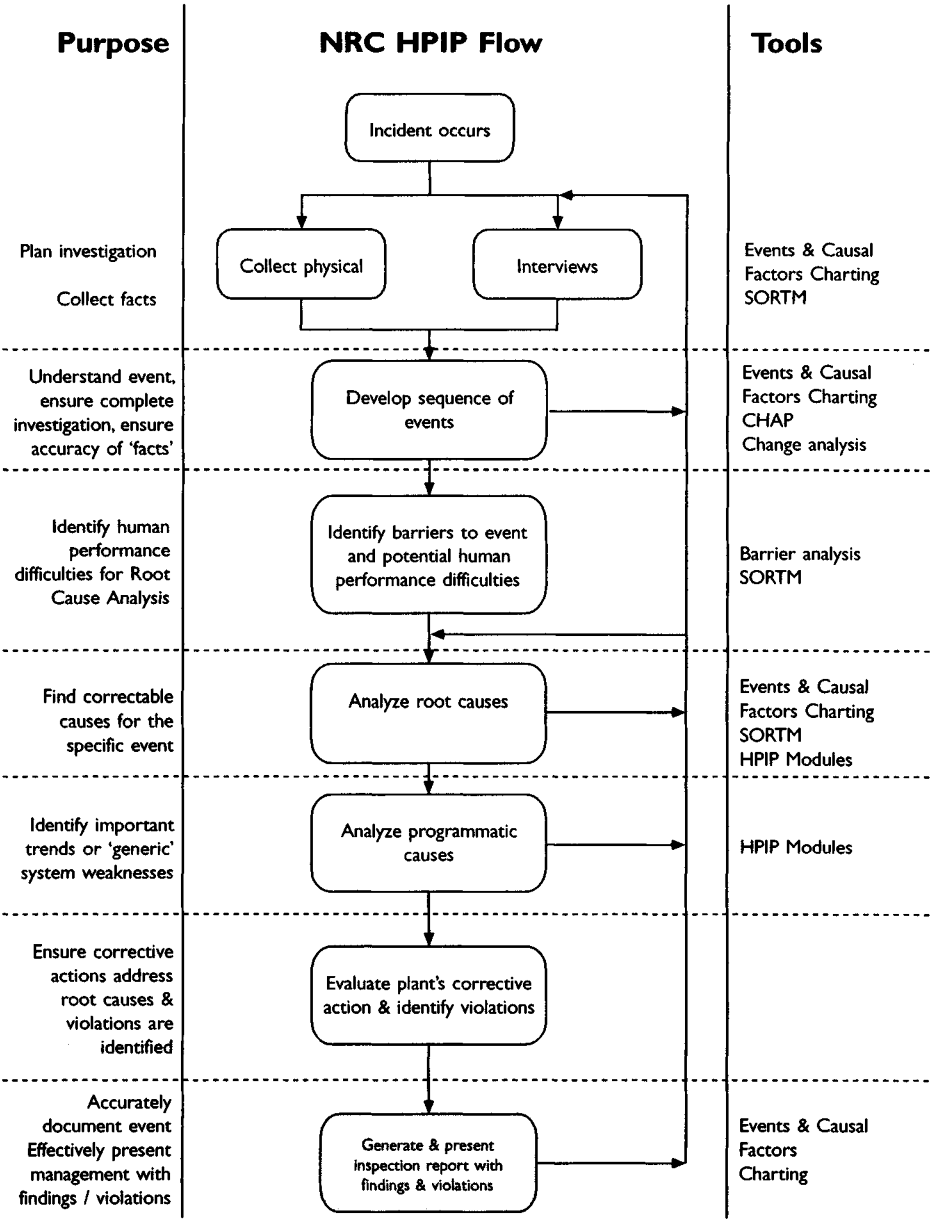

FIGURE 6.9. **HPIP Flow chart.**

performed by the regulatory authority to ensure that the plant response is adequate. This stage was included because each nuclear power plant has a resident inspector who would be expected to evaluate the response of this plant to the incident.

Generate and Present Inspection Report
The results of the investigation would be presented to management at this stage.

6.8.6. Change Analysis

In many accidents an important contributory cause is the fact that some change has occurred in what would otherwise be a stable system. The importance of change as an antecedent to accidents has lead to the development of a formal process to evaluate its effects.

The technique of change analysis was originally developed by Kepner and Tregoe (1981) as part of research sponsored by the Air Force. It was subsequently incorporated in the MORE technique described earlier. A comprehensive description of the process is provided in Ferry (1988). The main stages of the process are shown in Figure 6.10. The MORT process indicates that the

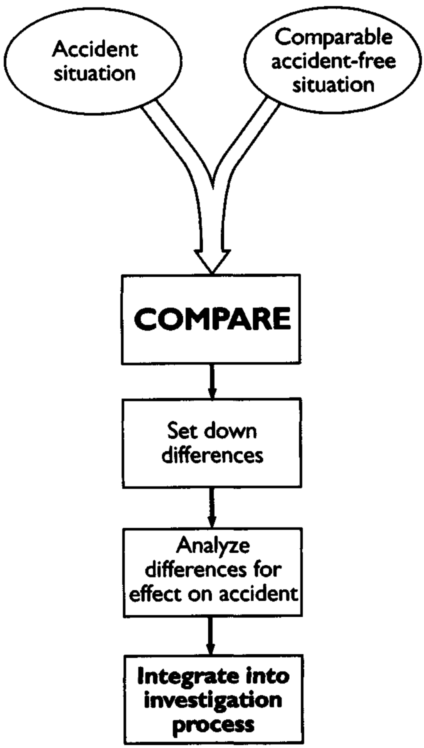

FIGURE 6.10. **The Six Steps of Change Analysis (Ferry, 1988).**

following types of change should be considered (these have been interpreted in the context of process safety):

Planned versus Unplanned Changes
Planned changes should be documented as part of a formal change monitoring process (for example via a quality assurance system). Unplanned changes should be identified during the accident investigation process.

Actual versus Potential or Possible Changes
Actual changes are those identified by a surface analysis of the incident sequence. Potential changes would be revealed by a more in-depth analysis.

Time Changes
These are changes in the system over time due to factors such as wear and deterioration of hardware, and also the erosion of human systems such as supervision and permits to work.

Technological Changes
Changes resulting from the implementation of new processes and plant.

Personnel Changes
These are changes in individuals or teams which may mean that normally assumed unwritten knowledge (e.g., about the particular operational characteristics of the plant) is not available.

Sociological Changes
These can arise from changes in values of process workers (e.g., an increased focus on production rather than safety, because of a fear of reduced pay or job losses) due to larger changes in society (e.g., reduced job security because of an economic depression).

Organizational Changes
These may give rise to lack of clarity with regard to who is responsible within an operating team.

Operational Changes
These are defined in MORT as changes in procedures without an associated safety review.

6.8.7. Evaluation of Root Cause Analysis Techniques

On the basis of the descriptions of incident analysis techniques in the previous section and the comprehensive reviews available in Ferry (1988) and CCPS

(1992d) it is clear that there is no shortage of methods to provide a framework for the detailed incident analysis that would form part of a root cause analysis system. However, despite the variety of techniques which are available, very few of these appear to effectively address the following areas:

- Incorporation of psychological models of human error into the investigation process
- Evaluation of effects of management influences and policy factors on error causation
- Consideration of how formal data collection incident investigation methods are to be introduced into a plant in order to ensure acceptance and long-term support by the workforce

Use of Psychological Models

With regard to this issue, it can be argued that a knowledge of the psychological processes underlying error may not be necessary in order to carry out effective incident analyses. If the direct causes of errors are identified, in the form of the PIFs that were present when the error occurred, then it may appear to be unnecessary to try to evaluate the actual mental processes that occurred.

However, a knowledge of the psychology of error from the cognitive engineering perspective provides unique insights. In the case study of a reactor explosion quoted in Section 1.8, one of the error mechanisms identified was the reversion, under stress, to a familiar set of operating instructions which were similar to those which should have been used, but which omitted a critical step. This "strong stereotype take-over" error mechanism (see Chapter 2) would not have occurred to the analysts without some knowledge of cognitive psychology. This would mean that an important error reduction strategy, the use of less confusing procedures, would have been neglected.

In general, the value of a psychological perspective in incident analysis is that it directs the analyst to search for causes that would not otherwise have been considered. This means that the development of preventative strategies will be better informed. In addition, an evaluation of causes from a psychological perspective can be useful when the "root cause" appears to be an otherwise incomprehensible failure on the part of an individual. A psychological analysis can break the "causal log jam" by providing an explanation.

Management and Policy Influences on Error and Accident Causation

As has been emphasized in Chapters 1, 2, and 3, the system-induced error view states that it is insufficient to consider only the direct causes of errors. The underlying organizational influences also need to be taken into account. However, most of the available techniques stop when an immediate cause has been identified, such as less than adequate procedures or poor equipment design. The questions of why the procedures were poor, or why the equipment was badly designed, are rarely addressed at the level of policy. Kletz (1994a) has described the importance of identifying these policy level factors, and including them in recommendations for corrective action.

With regard to evaluating these factors, it is recommended that structured checklists be used, such as those provided by the HFAM method described in Chapter 2. These checklists provide an explicit link between the direct causal factors and management policies. Figure 2.12 shows how these checklists could be used to investigate possible procedures deficiencies, and the policies that led to the deficiencies, as part of the incident investigation. Similar checklists can be used to investigate possible culture problems (e.g., inappropriate trade-offs between safety and production) that could have been implicated in an accident.

Workforce Support for Data Collection and Incident Analysis Systems
Few of the incident investigation and data collection systems reviewed provide any guidelines with regard to how these systems are to be introduced into an organization. Section 6.10 addresses this issue primarily from the perspective of incident reporting systems. However, gaining the support and ownership of the workforce is equally important for root cause analysis systems. Unless the culture and climate in a plant is such that personnel can be frank about the errors that may have contributed to an incident, and the factors which influenced these errors, then it is unlikely that the investigation will be very effective.

6.9. IMPLEMENTING AND MONITORING THE EFFECTIVENESS OF ERROR REDUCTION MEASURES

As shown in the flow diagram in Figure 6.1, the process of identifying underlying causes leads naturally to the development of error reduction strategies that will address these causes. Remedial strategies can be formulated to prevent a recurrence of the specific type of accident under investigation and/or can address more fundamental systemic causes possibly at the level of management or even policy systems. Although there is often pressure to be seen to be implementing measures which address the direct causes of accidents, it is obviously important, and in the long run highly cost effective, to remedy problems at a fundamental level. If these underlying causes are not addressed, it is likely that an accident of the same type will recur in the future.

Establishing the effectiveness of error reduction measures is difficult in an environment where there are a number of other changes occurring. Nevertheless, a properly designed reporting system should be able to detect changes in the incidence of particular types of error as a result of the effectiveness of the preventive strategy. One of the advantages of near-miss reporting systems is that they can provide a greater volume of evidence to allow the effectiveness of preventive measures to be evaluated.

6.10. SETTING UP A DATA COLLECTION SYSTEM IN A CHEMICAL PLANT

In previous sections of this chapter, the required characteristics of effective causally based data collection systems to reduce human errors and accidents have been described. In this final section, the stages of setting up such a system in a plant will be described.

Specify Objectives

The first stage of the process will need to specify the overall boundaries and objectives of the proposed system. For example, will the system perform both incident reporting and root cause analyses, what types of data will be stored, who will be involved in setting up and operating the system? In order to ensure that the system engenders ownership from its inception, a data collection group should be set up including representatives from all levels of the organization. This group should be provided with visible management support and adequate resources. The purpose of this group is to provide a stewardship function to ensure that the data collection systems are implemented and maintained.

Evaluate Potential Cultural Barriers to Data Collection

It is advisable at an early stage in the development process to determine if problem areas such as a negative view of human error or a blame and punishment culture exist in the organization. If these are identified as a problem, then appropriate measures such as culture change programs can be implemented. If these problems are not addressed at the design stage, then it is unlikely that any human error data collection initiative will be successful. Since cultural problems often have their long-standing origins in senior or middle management beliefs (see Section 6.5.1), the development of a supportive culture may not be an easy task. Nevertheless, it is wise to evaluate the extent of these problems and the possibility of developing a supportive culture within which the data collection process can operate. Otherwise, resources may be wasted in implementing a system which is technically adequate but which fails because of lack of support.

Specify Data Collection Methods and Responsibilities

Several types of data collection have been specified in earlier sections. It is important that the responsibilities for operating the various aspects of the system are unambiguously defined.

Specify the Analysis, Interpretation Framework, and the Type of Input Data Required

The purpose of this stage is to specify how underlying causes will be derived from plant data and the type and level of detail required to perform these analyses. During this stage data reporting and incident analysis forms will be developed, based on the underlying causal model together with a consideration of the practicalities of data collection (e.g., amount of time available, other competing priorities).

Develop Procedure for Identifying and Implementing Remedial Measures
This process will specify the methods for deriving error reduction strategies from the data collected, and the responsibilities for implementing these measures and monitoring their effectiveness.

Specify Feedback Channels
This phase of the program is designed to ensure that the information produced by the system is fed back to all levels of the workforce, including process operators, managers, supervisors, engineers, and senior policy makers.

Develop Training Programs
This phase will proceed in parallel to some of the earlier phases. In addition to launching the system, and raising the general level of awareness at all levels of the organization regarding the importance of human performance, the training program will provide the specific skills necessary to operate the system.

Implement Pilot Data Collection Exercise in Supportive Culture
In order to ensure that the data collection system has been thoroughly checked and tested prior to its launch, it is advisable to test it in a plant or plant area where there is likely to be a supportive culture. This will allow the effectiveness of the system to be addressed prior to a larger-scale implementation in a less controlled environment.

Evaluate Effectiveness on the Basis of Outputs and Acceptance
Once the system has been implemented on its chosen site, its effectiveness needs to be evaluated at frequent intervals so that corrective action can be taken in the event of problems. The first criterion for success is that the system must generate unique insights into the causes of errors and accidents, which would not otherwise have been apparent. Second, the system must demonstrate a capability to specify remedial strategies that, in the long term, lead to enhanced safety, environmental impact and plant losses. Finally, the system must be owned by the workforce to the extent that its value is accepted and it demonstrates its capability to be self-sustaining.

Maintain the Momentum

In order to maintain motivation to participate in the data collection process, the providers of information need to see that their efforts produce tangible benefits in terms of increased safety. This is particularly important in the case of near miss reporting systems, where the benefits of participation may be less obvious than with accident reporting systems. This type of feedback can be provided via regular newsletters or feedback meetings. Even if tangible improvements cannot be demonstrated in the short term, then it is at least necessary to show that participation has some effects in terms of influencing the choice of safety strategies. As with the data providers, data analysts also need to be motivated by seeing that their work is recognized and used effectively and that recommendations are implemented.

Since the resources for data collection systems will be provided by senior management it is essential that information from the system is fed back to policy makers at this level. It is also important that the system indicates the problem areas as well as the successes. Many organizations have drifted to a state where safety standards have fallen to below acceptable levels over time as a result of suppression of information feedback to senior managers. This may be carried out with good intentions, but its long-term effect can be disastrous.

6.11. SUMMARY

This chapter has adopted a broad perspective on data collection and incident analysis methods. Both qualitative and quantitative aspects of data collection have been addressed, and data collection approaches have been described for use with large numbers of relatively low-cost incidents or infrequently occurring major accidents.

Three major themes have been emphasized in this chapter. The first is that an effective data collection system is one of the most powerful tools available to minimize human error. Second, data collection systems must adequately address underlying causes. Merely tabulating accidents in terms of their surface similarities, or using inadequate causal descriptions such as "process worker failed to follow procedures" is not sufficient to develop effective remedial strategies. Finally, a successful data collection and incident investigation system requires an enlightened, systems oriented view of human error to be held by management, and participation and commitment from the workforce.