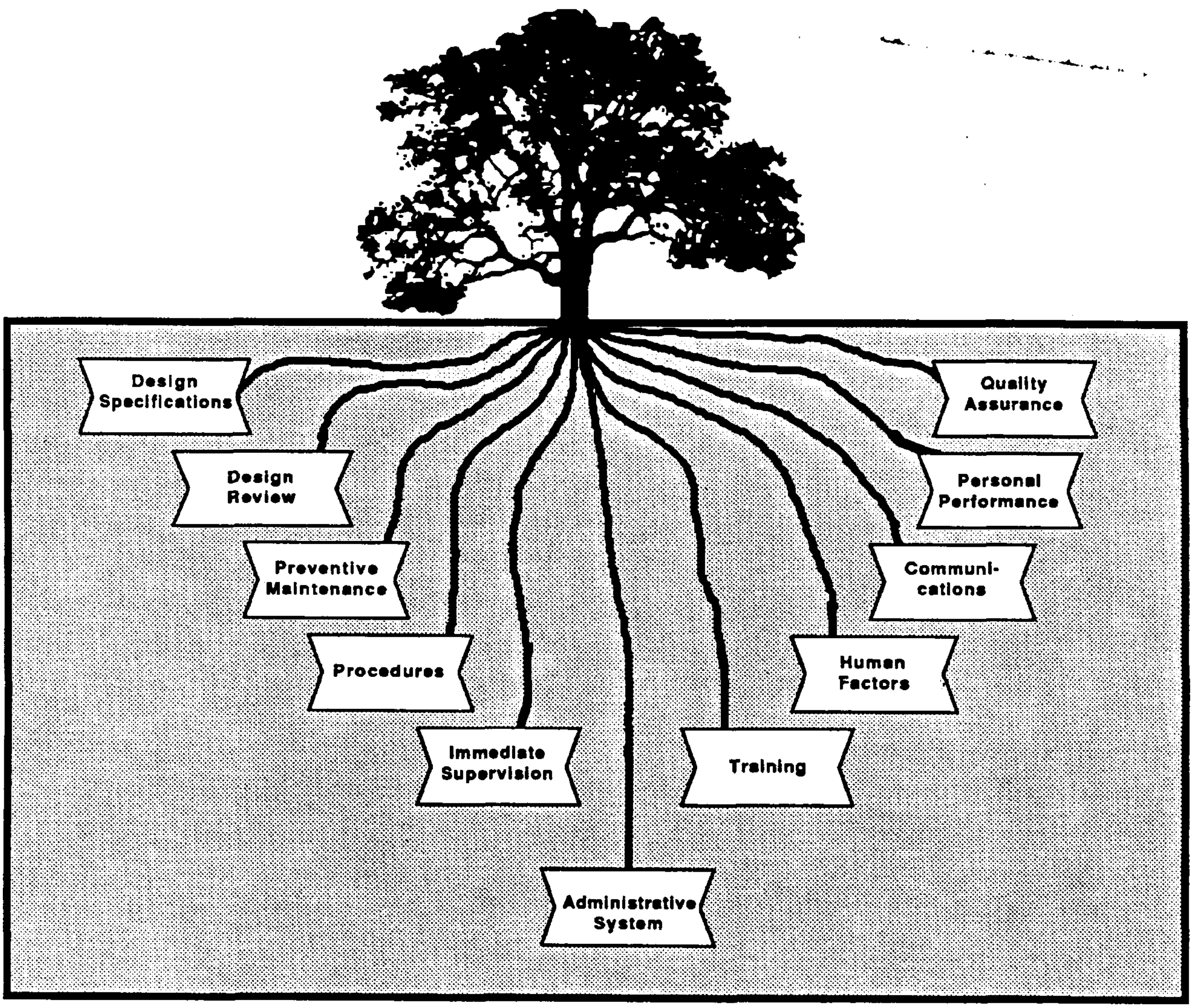
285

DPSTOM-81

Controlled by Receipt

Root Cause Analysis Handbook



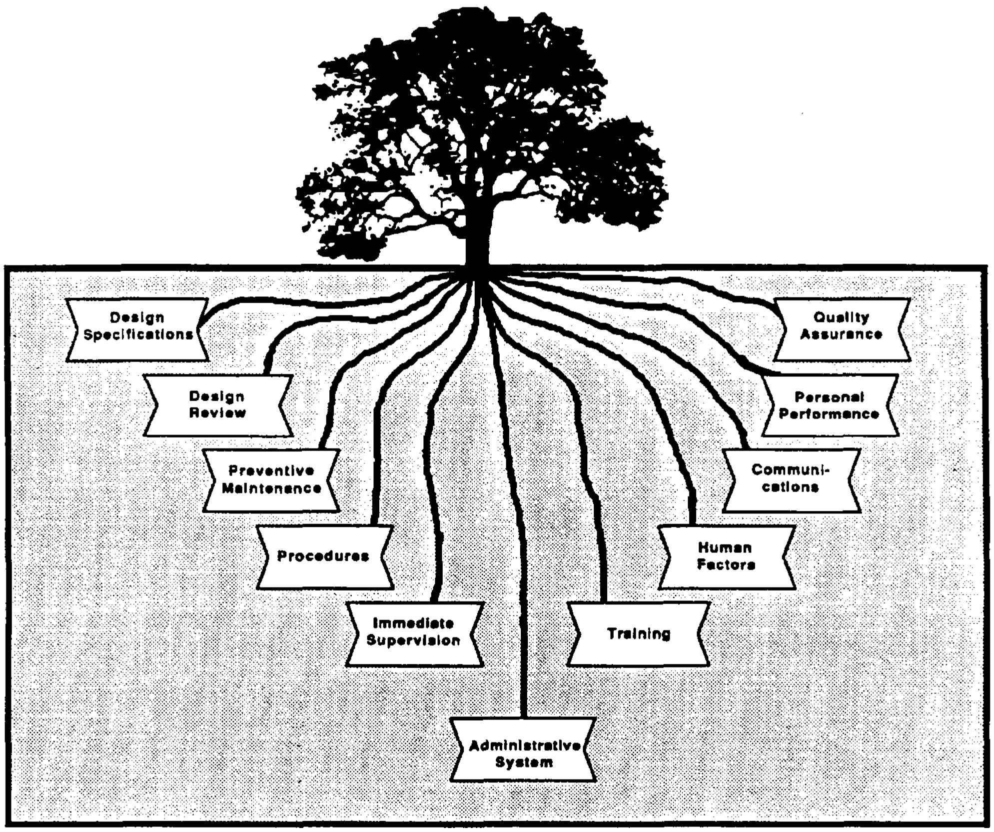
E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

DPSTOM--81

DE89 013806

Root Cause Analysis Handbook



M. E. Armstrong
W. L. Cecil
K. Taylor

Approved by:

R. F. Bradley, Superintendent
Non-Reactor Safety Evaluation Division

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

DISCLAIMER

Table of Contents

Introduction

The root cause analysis system presented in this handbook is designed for use in investigating and categorizing the root causes of incidents in Savannah River non-reactor facilities. Root cause analysis is simply a tool designed to help incident investigators describe WHAT happpened during a particular incident, to determine HOW it happened, and to understand WHY it happened. Only when investigators are able to determine WHY a failure occurred will they be able to specify workable preventive measures.

Traditionally, incident investigation systems have allowed investigators to answer questions about what happened during an incident and about how the incident occurred, but seldom have they been encouraged to determine why the failure occurred. Imagine an incident in which an operator is instructed close Valve A; instead, he closes Valve B. The typical investigation would probably result in the conclusion that "opeator error" was the cause of the incident. This is an accurate description of what happened. An operator committed an error by manipulating the wrong valve. If the investigators stop at this level of analysis, however, they have not probed deeply enough to understand the reasons for the mistake. Generally, mistakes do not "just happen." They can be traced to some well-defined causes. In the case of the valving error, we might ask if the procedure was confusing? Were the valves clearly labeled? Was the operator who made the mistake familiar with this particular task? These are all questions that should be asked to determine why the error took place.

When the investigation stops at the point of answering what and how, the recommendations for preventing recurrence of the incident may be deficient. In the case of the operator who turned the wrong valve, we are likely to see recommendations like "Remind all operators to be alert when manipulating valves," or "Emphasize to all personnel that careful attention to the job should be maintained at all times." Such recommendations do little to prevent future incidents. Investigations that probe more deeply into why the operator error occurred, are able to provide more specific, concrete recommendations. In case of the valving error, examples might include, "Revise procedure so that references to valves match the valve labels found in the field," or "Require trainees to have a Training & Reference procedure in hand when manipulating valves."

The root cause analysis system described in this handbook provides a structured approach for investigators trying to discover the WHYs (i.e., the true "root causes") of incidents. The methods presented here were pioneered by the Reactor Safety Evaluation Division (RSED) of the Savannah River Laboratory (SRL). After an extensive study of incident investigation systems used in both the utilities and in other industries, RSED combined what was considered to be the best of several systems. The result was a cause coding system for Reactor Incidents (RIs). For a complete description, see DPST-209, "User's Guide for Reactor Incident Root Cause Coding Tree, (Revision 5)." The Non-Reactor Safety Evaluation Division (NRSED) has expanded this sytem so that it better fits the needs of investigators in the site non-reactor facilities. This handbook describes the basic techniques of root cause analysis as they should be applied in the investigation of non-reactor incidents.

Definition of Root Cause

Although there is substantial debate concerning the the definition of a root cause, as defined in this system:

> a root cause is the most **basic cause** that can **reasonably be identified** and that management has **control to fix.**

This definition contains three key elements.

1) Basic Cause

The goal of the investigator should be to identify basic causes. The more specific we can be about the reasons why an incident occurred, the easier it is to arrive at recommendations that will prevent recurrence of the events leading up to the incident.

2) Reasonably Identified

Incident investigations must be completed in a reasonable time frame. It is not practical to keep valuable manpower occupied indefinitely searching for the causes of incidents. Root cause analysis, to be effective, must help investigators to get the most out of the time that they have allotted for the investigation.

3) Control to Fix

Investigators should avoid using general cause classifications such as "operator error." Such causes are not specific enough to allow those in charge to rectify the situation. Management needs to know exactly why a failure occurred before action can be taken to prevent recurrence. If the investigators arrive at vague recommendations such as "Remind operator to be alert at all times," then they have probably not found a basic enough cause and need to expend more effort in the investigation process.

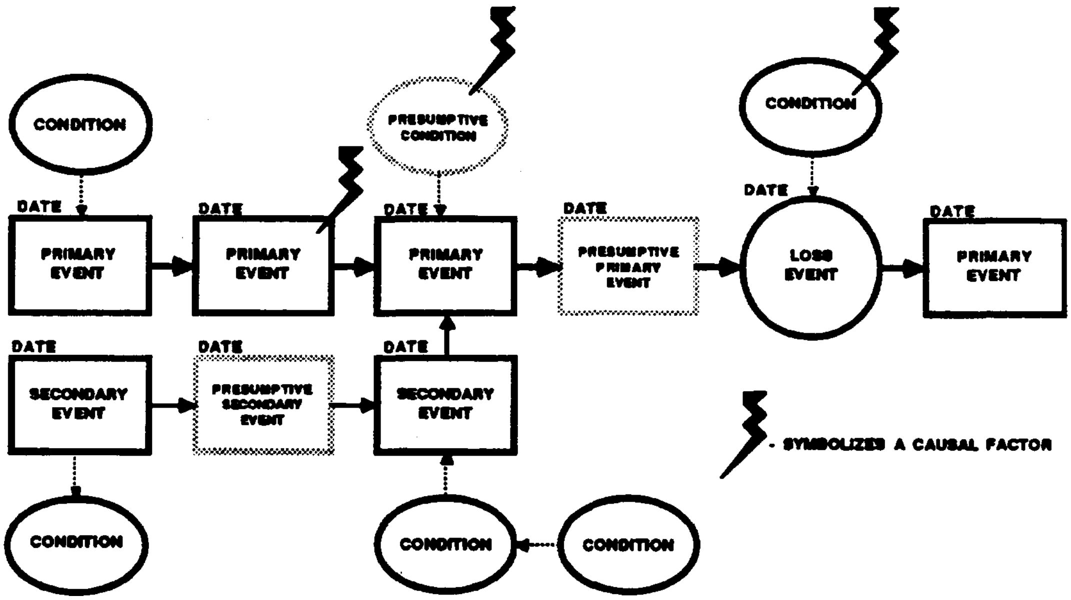
Description of Root Cause Analysis

Root cause analysis is basically a two step process involving 1) Events and Causal Factors (E&CF) Charting and 2) Root Cause Coding (see Figure I.1). The first technique, E&CF Charting, provides a way for investigators to organize and analyze the information gathered during the investigation and to identify gaps in knowledge as the investigation progresses. The E&CF chart is simply a sequence diagram that describes the events leading up to and following an incident as well as the conditions surrounding these events. The final step in E&CF Charting involves identifying the major contributors to the incident (i.e., causal factors). E&CF Charting is discussed in further detail in the "Events and Causal Factors Charting" section of this handbook.

The second technique, Root Cause Coding, involves the use of a "Root Cause Tree" to categorize the causal factors identified during E&CF Charting. Trending studies of the root causes of incidents coded over a period of time can provide valuable insight concerning generic areas for improvement. This is an added benefit of root cause analysis. Not only can we prevent specific incidents from recurring, we can combine the lessons learned from individual incidents to identify areas of weakness. This allows action to be taken before an incident occurs the first time. The cause coding process is discussed in more detail in the "Root Cause Coding" section of this handbook.

Figure I.2 illustrates the root cause analysis process. Preparation of the E&CF chart starts as soon as investigators begin to collect information about the incident. They start with a "skeleton" chart that is modified as more and more relevant facts are uncovered. Data collection continues until the investigators are satisfied with the thoroughness of the chart.

STEP 1: EVENTS AND CAUSAL FACTORS CHARTING



STEP 2: ROOT CAUSE CODING

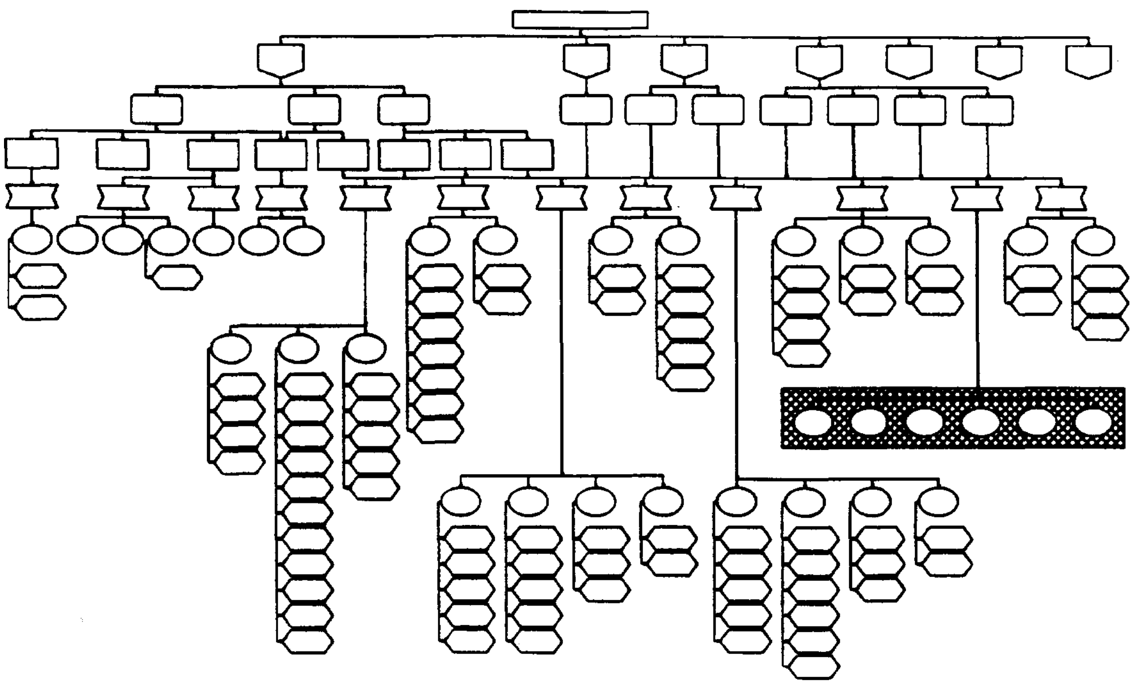


FIGURE I.1: TWO MAJOR STEPS IN ROOT CAUSE ANALYSIS

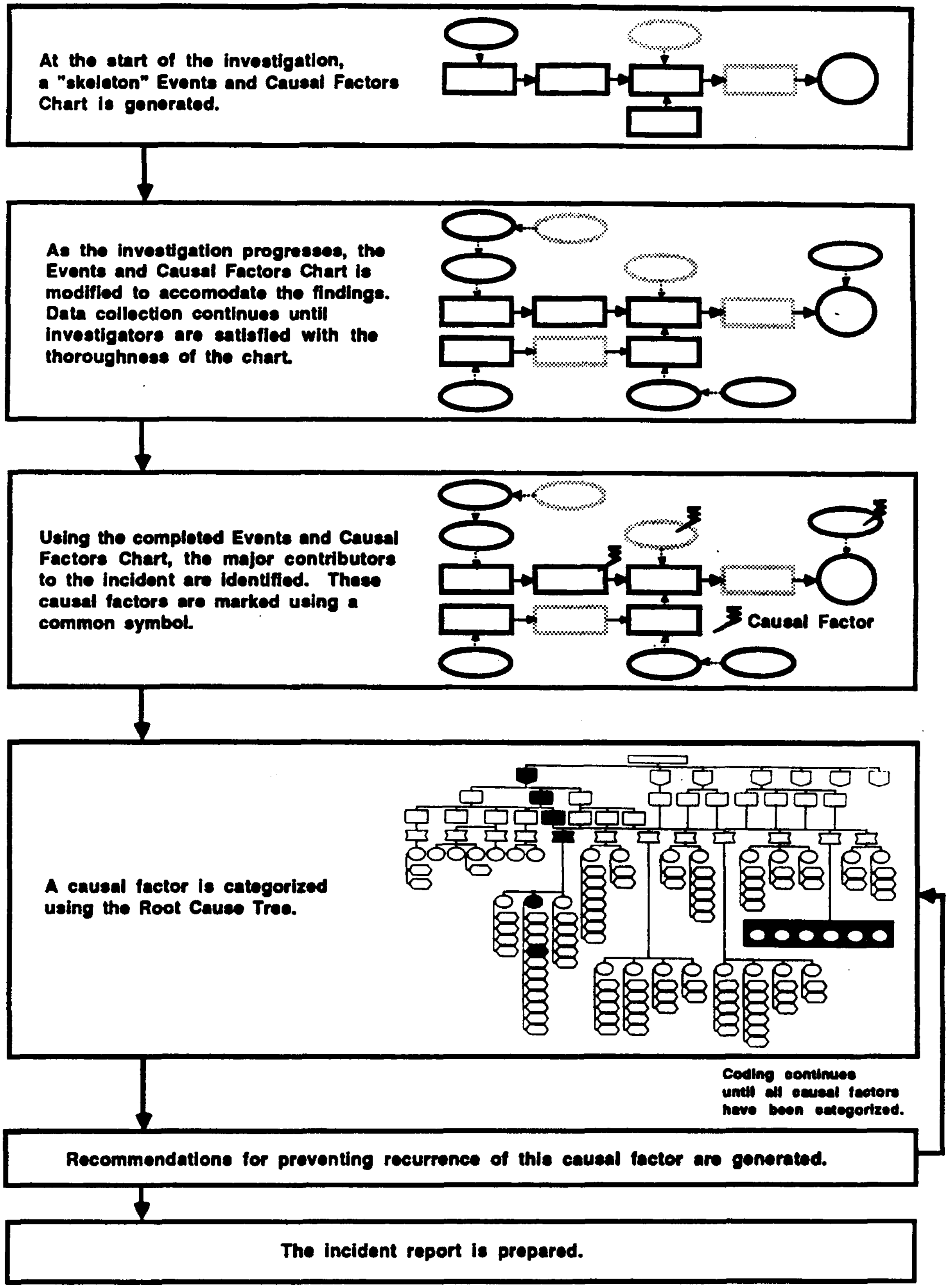


FIGURE I.2: ROOT CAUSE ANALYSIS PROCESS

When the entire incident has been mapped out, the investigators are in a good position to identify the major contributors to the incident. These are labeled as causal factors. Causal factors are those that, if eliminated, would have prevented or reduced the effects of the incident.

After all of the causal factors have been identified, the investigators begin Root Cause Coding. Each causal factor is categorized, one at a time, using the "Root Cause Tree." The tree structures the reasoning process of the investigators by helping them to answer questions about why particular causal factors occurred. After each causal factor is coded, the investigators attempt to arrive at recommendations that will prevent its recurrence. This process continues until all causal factors have been coded.

In many traditional investigations, the most visible causal factor is given all of the attention. The investigators are tempted to "jump to conclusions" about how to solve the problem. Rarely are incidents due to one causal factor. They are usually due to a combination of contributors. When only one salient causal factor is addressed, it is likely that the list of recommendations will not be complete. Consequently, the incident may repeat itself. In order to prevent the investigators from omitting important recommendations, root cause analysis requires that each causal factor be addressed separately. When recommendations are generated for each causal factor, one at a time, the probability of missing important details decreases.

The final step in the process is generation of an incident report. A thorough root cause analysis can greatly simplify the preparation of this document. The completed E&CF chart provides an excellent basis for an incident description. Root Cause Coding should leave the investigators feeling confident that they have discovered the reasons why the incident occurred.

Organization of the Handbook

The Root Cause Analysis Handbook is divided into five major sections. The "Introduction" presents a basic overview of the root cause analysis process. The "Events and Causal Factors Charting" section provides a step-by-step description of the E&CF Charting techniques. Examples of completed E&CF charts are included for reference. The "Root Cause

Coding" section explains the use of the "Root Cause Tree." Subsections under "Root Cause Coding" describe the major segments of the "Root Cause Tree." Detailed descriptions of the individual "nodes" on the tree are also presented. The "Database Management" section provides descriptive information for those interested in establishing a database to track root cause trends. Finally, a "References" section is provided for those interested in learning more about the items contained in this handbook. Questions and comments concerning this handbook should be addressed to the Non-Reactor Safety Evaluation Division of the Savannah River Laboratory.

Events and Causal Factors Charting

When an investigator or investigation team begins a root cause analysis, the first step is to prepare an Events and Causal Factors (E&CF) chart. An E&CF chart is simply a sequence diagram that allows investigators to graphically portray what took place during a particular incident. The E&CF Charting technique was originally developed by Ludwig Benner and his colleagues at the National Transportation Safety Board. The tool is designed to help investigators describe, chronologically, the events leading up to an incident and the conditions surrounding these events.

Benner (1975) suggests that an accident involves a sequence of events (i.e., happenings) that occur during the course of good-intentioned work activity but that culminate in unintentional personnel injury or damage to a system. Experience has shown that incidents are rarely simple and almost never result from a single cause. Instead, incidents develop from clearly defined sequences of events which involve performance errors, changes, oversights, and omissions. The incident investigator needs to identify and document not only these events themselves, but also the relevant conditions affecting each event in the incident sequence. The E&CF chart is an excellent vehicle for accomplishing this purpose.

The E&CF Charting method has been adopted by the Department of Energy (DOE) and used successfully as a focal point of analysis in a number of major DOE accident and incident investigations. The System Safety Development Center (SSDC) of EG&G Idaho, Inc., under DOE contract, has prepared a document that describes E&CF Charting and its role in determining the root causes of incidents. This document, titled Events and Causal Factors Charting (DOE 76-45/14, SSDC-14, Rev. 1), is included as an appendix in this section of the Root Cause Analysis Handbook. Additional copies are available from the SSDC, EG&G Idaho, Inc. It is recommended that the SSDC document be read in its entirety. The text clearly explains the basic principles of E&CF Charting. In addition, the appendices present several examples of completed charts. This section of the handbook is intended to provide a summary of the technique followed by some examples for reference.

The E&CF Chart: Definition of Components

The principles of E&CF Charting are quite basic. Figure ECF.1 presents a "generic" E&CF chart. Notice that the diagram is constructed from several different types of components. The most basic component of an E&CF chart is called an event. Events are simply the actions or happenings that occur during some sequence of activity. Events make up the backbone of the E&CF chart. Event statements describe specific occurrences (e.g., "4-12 shift operator filled Tank 123," or "Control room operator acknowledged level alarm for Tank 123"). They do not describe conditions, states, circumstances, issues, conclusions, or results.

When generating the E&CF chart for a particular incident, there may be the need to distinguish between primary events and secondary events. Primary events describe actions directly leading up to and following the inappropriate action, accident, or loss event. (NOTE: The loss event is the one that causes the negative consequence. This event is probably the reason an incident investigation is required.) Primary events form the basic sequence in the diagram. Secondary events are actions that impact the primary events, but which are not directly involved in the situation.

Another major type of component in the E&CF chart is the condition. Conditions are not specific activities but are circumstances pertinent to the situation. Conditions usually provide descriptive information (e.g., "Pressure was 1000 psig.,") as opposed to stating action (e.g., "Operator placed Valve ABC into open position").

Some events and conditions, although they may appear to be logical in the sequence of the diagram, cannot be substantiated with valid factual evidence. Such components are referred to as presumptive events and presumptive conditions. On the E&CF chart, events and conditions of this type are clearly distinguished from components based on fact.

After the E&CF chart has been completed, the investigators are in a good position to identify factors that influenced the course of events. These components are labeled causal factors. Causal factors, which may be in the form of events or conditions, are those items that are considered to be major contributors to the incident. Presumptive events and conditions that are identified as causal factors are labeled as presumptive causal factors.

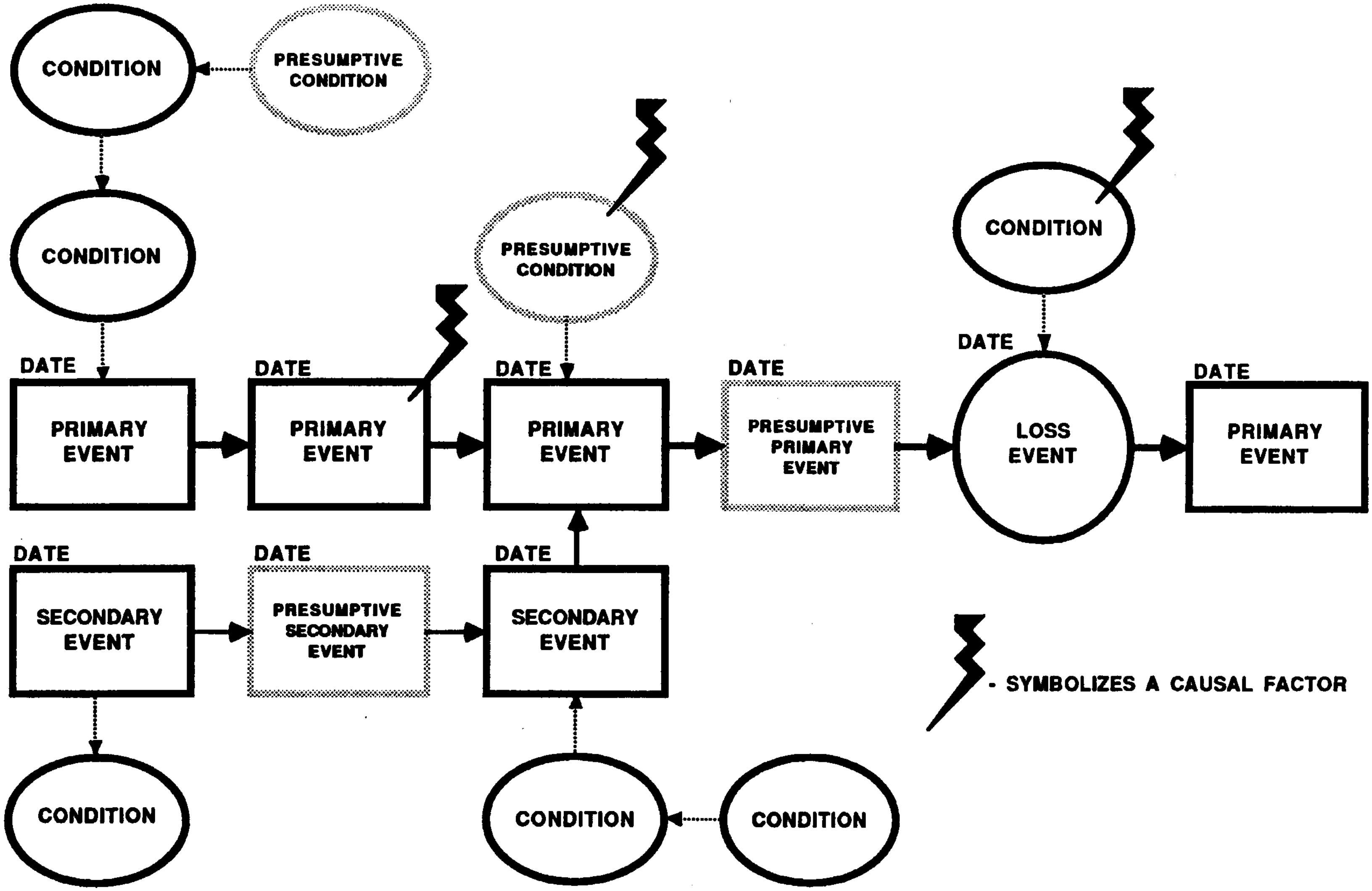


FIGURE ECF.1: GENERIC EVENTS AND CAUSAL FACTORS (E&CF) CHART

Arrows are used to link the basic components of the E&CF chart together. The arrows serve to complete the chart by illustrating the relationships between components. For summary definitions of the E&CF chart "building blocks," see Table ECF.1.

The E&CF Chart: Format

Traditionally, the format of E&CF charts has varied widely; however, DOE has adopted some general guidelines for developing E&CF charts for agency investigation reports. The underlying philosophy is that standardization will help to ensure comparability and consistency in accident reporting within the DOE complex. Common guidelines also will facilitate communication between personnel who routinely prepare incident reports and those who read these reports.

The guidelines for E&CF chart format are listed in Table ECF.2. They are not complex. The intent is only to provide some basic structure, not to inhibit investigators with too many complex, cumbersome rules.

Development of an E&CF Chart

There is no set method for developing an E&CF chart. Generally, as investigators gain experience, they develop strategies that work well for their particular purposes. Different strategies may be necessary given a specific investigation. The following recommendations are intended only as guidance.

The first step in developing the chart is generally to try to capture the sequence of primary events. These are the events directly involved with the loss event. Often, the easiest way to accomplish this is to start with the inappropriate action, accident, or loss event and work back through pre-incident events and forward through post-incident events. The primary events should be carefully and completely defined because they form the basis for the rest of the E&CF chart. Due to the importance of primary events in the E&CF chart, several criteria should be taken into account during their definition. These criteria, along with examples of appropriate and inappropriate event descriptions, are presented in Table ECF-3.

TABLE ECF.1: DEFINITION OF E&CF CHART COMPONENTS

COMPONENTS	DEFINITIONS
Events	Actions or happenings that occur during some activity
Loss Event	The inappropriate action resulting in the negative consequence; the event that necessitates the incident investigation
Primary Events	Actions DIRECTLY leading up to and following the loss event
Secondary Events	Actions that impact primary events but that are NOT DIRECTLY involved in the situation
Presumptive Events	Actions, not based upon valid factual evidence, that are assumed because they appear logical in the sequence of events
Conditions	Circumstances pertinent to the situation; usually provide descriptive information
Presumptive Conditions	Circumstances, not based upon valid factual evidence, that are assumed because they appear logical in the sequence of the chart
Causal Factors	Components that influence the course of events; major contributors to the incident
Presumptive Causal Factors	Causal factors, not based upon valid factual evidence, that are logically assumed to be major contributors to the incident

TABLE ECF.2: GUIDELINES FOR E&CF CHART FORMAT

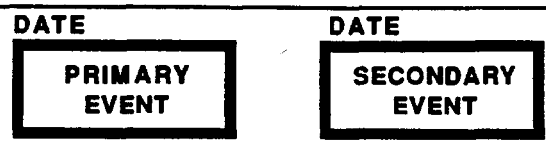
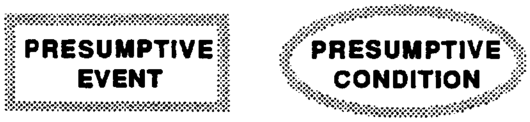
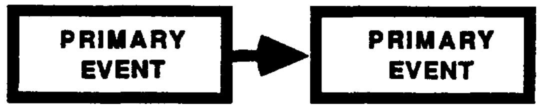
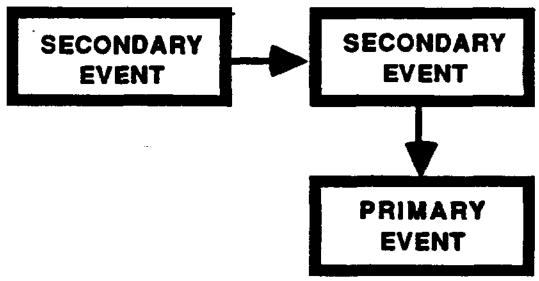
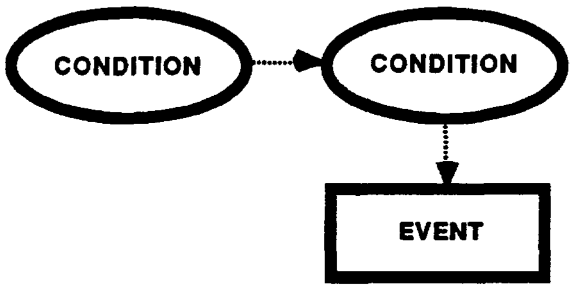
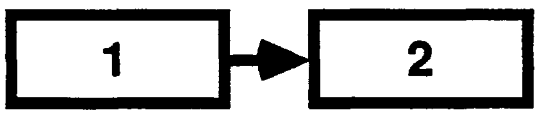
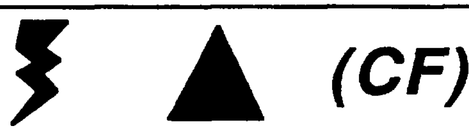
Primary and secondary events should be enclosed in rectangles. All events should be dated.	
Conditions should be enclosed in ovals.	
Events and conditions not based upon valid factual evidence should be clearly indicated by dashed line rectangles and ovals.	
The primary sequence of events should be depicted in a straight horizontal line with events joined by bold printed connecting arrows.	
Secondary events should be depicted on horizontal lines at different levels above and below the primary sequence of events. Secondary events should be joined to each other and to primary events by solid connecting arrows.	
Conditions should be connected to each other and to both primary and secondary events by dashed arrows.	
Events should be arranged chronologically from left to right.	
Causal factors should be identified using a common symbol. Examples of symbols that have been used in the past are presented here.	

TABLE ECF.3: CRITERIA FOR EVENT DESCRIPTIONS

AN EVENT SHOULD:	GOOD EXAMPLE	BAD EXAMPLE
Be an occurrence or happening.	**Pipe wall ruptured.**	**Pipe wall had a crack in it.**
Be described by a short sentence with one subject and one active verb.	**Mechanic checked front end alignment.**	**Front end alignment was checked and brakes were adjusted.**
Be precisely described.	**Operator turned Valve 32 to "OPEN" position.**	**Operator opened valve.**
Consist of a single, discrete occurrence.	**Pipe wall ruptured.**	**Internal pressure rose and pipe wall ruptured.**
Be quantified when possible.	**Plane descended 350 feet.**	**Plane lost altitude.**
Be derived directly from the event and conditions preceding it.	**Mechanic adjusted camber on both front wheels.** **IS PRECEDED BY** **Mechanic found incorrect camber.** **IS PRECEDED BY** **Mechanic checked front end alignment.**	***<u>NOTE</u>*** ***When an event is not derived directly from the preceding event, this is usually an indication that one or more steps in the sequence have been omitted.***

As the primary events are identified, secondary events and conditions will most likely be discovered as well. These should be added to the "skeleton" chart as they are uncovered. Presumptive events and conditions should be clearly identified as such by enclosing them with dashed lines. Every effort should be made to substantiate presumptive events and conditions with factual evidence. Allowance of presumptive components on the chart should not provide an excuse for a less than thorough investigation.

As the investigation reveals more and more information, the investigators should begin to "flesh out" the E&CF chart. At this time, any gaps, either in chronological sequence or logic, should become apparent. These gaps should point the investigators to the need for more in-depth analysis. Construction of the E&CF chart should continue until the investigators feel reasonably certain that they have created a thorough chart containing the appropriate level of detail.

After the E&CF chart is complete, the investigators are in an excellent position to identify factors which were major contributors to the incident. Determination of these causal factors requires judgment on the part of the investigators. There are no definitive rules to follow when identifying causal factors. Any component on the E&CF chart that is considered to have significantly influenced the course of events can be identified as a causal factor. Events can be labeled as causal factors. A given action, or lack of action, may have contributed to the incident. A causal factor can also be in the form of a condition. Certain states or circumstances may have influenced the course of the incident. Further, presumptive events and conditions may be identified as causal factors.

It is important to remember that most incidents do not have a single cause. Usually a number of factors contribute to an incident. The evaluation should not stop after the first causal factor is discovered. The investigators should continue until all major contributors to the incident have been identified. Each of the causal factors should be marked on the chart using a common symbol.

Identification of causal factors is the final step in creating the E&CF chart. After this has been done, the investigators continue to the second step of the root cause analysis process, Root Cause Coding. Root Cause Coding involves categorizing the causal factors for trending purposes. A description of this process is presented in the "Root Cause Coding" section of this handbook.

A Simple Example: The Dump Truck Accident

Perhaps the easiest way to understand E&CF Charting is through a basic example. The following scenario was created by EG&G Idaho, Inc. to demonstrate E&CF Charting concepts. Consider the following incident.

> Ajax Construction Company was awarded a contract to build a condominium on a hill overlooking the city. Prior to initiation of the the project, a comprehensive safety program was developed covering all aspects of the project. Construction activities began on Monday, October 4, 1976, and proceeded without incident through Friday, October 8, 1976, at which time the project was shut down for the weekend. At that time, several company vehicles, including a 2 1/2 ton dump truck, were parked at the construction site. On Saturday, October 9, 1976, a nine-year-old boy, who lives four blocks from the construction site, climbed the hill and began exploring the project site. Upon finding the large dump truck unlocked, he climbed into the cab and began playing with the vehicle controls. He apparently released the emergency brake, and the truck began to roll down the hill. The truck rapidly picked up speed. The boy was afraid to jump out and did not know how to apply the brakes. The truck crashed into a parked auto at the bottom of the hill. The truck remained upright, but the boy suffered serious cuts and a broken leg. The resultant investigation revealed that, although the safety program specified that unattended vehicles would be locked and the wheels chocked, there was no verification that these rules had been communicated to the drivers.

An E&CF chart depicting this particular incident is shown in Figure ECF-2.

Primary Events

The most basic part of the scenario is captured in the sequence of primary events. These events are presented in chronological order with each event logically following the one before it. Each event description is surrounded by a rectangle. Related events are connected to one another by solid, bold arrows. All events are labeled with the date of occurrence.

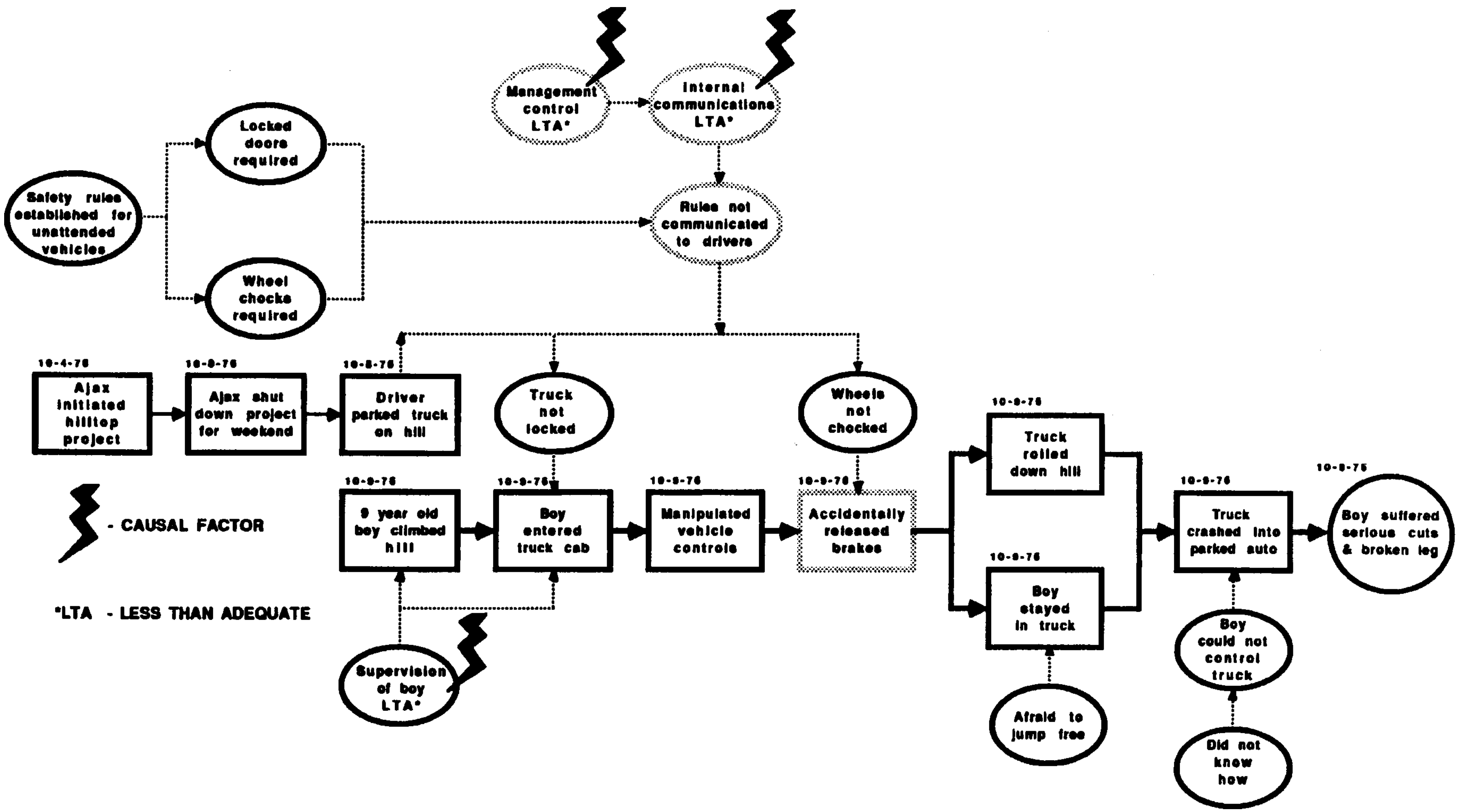


FIGURE ECF.2: E&CF CHART FOR DUMP TRUCK ACCIDENT

From EG&G Idaho, Inc. (1978), DOE 76-45/14, SSDC-14, REV. 1

The first event, "9 year old boy climbed hill," is characterized by a single subject (i.e., 9 year old boy) performing one action (i.e., climbing hill). This is the case for event descriptions throughout this sequence of primary events. In two of the primary event descriptions, the subject is implied. For example, the implied subject of "Manipulated vehicle controls," is, of course, the 9 year old boy.

Also occurring in this primary sequence are two simultaneous events (i.e., "Truck rolled down hill" and "Boy stayed in truck"). These events are represented by parallel rectangles. The fourth event in the primary sequence is enclosed by a dashed rectangle. The dashed line is an indication that this event cannot be based upon solid, factual evidence. It is likely that the young boy could not remember, or would not admit to, releasing the emergency brakes. The investigators of this incident considered this event likely enough to include in the E&CF chart; however, they clearly identified it as presumptive in nature.

Secondary Events

Directly above the sequence of primary events, the investigators have chosen to display a sequence of secondary events. These events are also time-sequenced and enclosed in rectangles; however, the connecting arrows are not bold-faced. Secondary events are connected by ordinary solid arrows. These events were designated as secondary events because, although they were not directly involved in the incident, they impacted the primary events. In this example, the secondary events deal with the circumstances that resulted in the truck being parked on a hill (i.e., "Ajax initiated hilltop project" and "Ajax shut down for the weekend"). The final secondary event involves a company driver parking a truck on the hill and feeds directly into two key conditions surrounding the incident (i.e., "Truck not locked" and "Wheels not chocked").

Conditions

The list of components presented earlier defined a condition as a circumstance pertinent to the situation. A condition, which is surrounded by an oval, usually provides descriptive information. This is the case with the two conditions describing the state of the dump truck (i.e., "Truck not locked" and "Wheels not chocked"). These are simple descriptive statements, not actions.

Conditions can also address circumstances, issues, results, or even conclusions. Key issues arising in this scenario include the youngster's supervision, his emotional state just prior to the crash, and his inability to drive a truck. This information is also captured in condition ovals. Notice that conditions are connected to events and to other conditions by dashed arrows.

There are several presumptive conditions presented in this scenario. These conditions are enclosed in dashed lines because they cannot be backed up with solid, factual evidence. For example, "Rules not communicated to drivers" is a presumptive condition because the investigators could not be absolutely certain that this statement was true; yet, it seemed logical given the circumstances.

Other conditions, which are not presumptive, feed directly into these presumptive conditions. This is acceptable. One of the major benefits of E&CF Charting is that it helps the investigating team to see gaps in logical sequence. Sometimes it is necessary to display presumptive events and conditions so that the sequence remains logical. **Allowance of presumptive events and conditions in the E&CF chart should not, however, be used as an excuse for less than thorough investigations**. Every effort should be made to uncover valid, factual information to substantiate components that are initially shown on the chart as presumptive.

Causal Factors

The SSDC did not go so far as to specifically mark the causal factors involved in this incident. However, three causal factors, all conditions, are apparent. In Figure ECF.2, these are marked with a common symbol, the lightning bolt. "Supervision of boy Less Than Adequate (LTA)" is an appropriate causal factor because the boy would not have been at the construction site if he had been properly supervised. Further, the boy would not have been able to get into the truck if it had been locked, and the truck would not have rolled if the wheels had been chocked. These conditions describe <u>what</u> happened during the course of the incident; however, the incident investigators should be more interested in <u>why</u> the truck was left in this condition. Therefore, the reasons why the truck was left unlocked and unchocked are the more appropriate causal factors. In this case, "Management control LTA" and "Internal communication LTA" are judged to be causal factors.

Typically, causal factors are not prioritized. Certainly some causal factors are more serious than others; however, to prevent future similar incidents, all causal factors must be addressed.

As mentioned previously, the identification of causal factors requires a great deal of judgement on the part of the investigators. There is no "magic formula" for choosing the correct causes. E&CF Charting is simply a tool to help ensure that the investigators have all of the facts and that they approach the investigation in a step-by-step, logical fashion.

E&CF Charting: An Example from Savannah River

Another sample E&CF chart, this one portraying a Savannah River incident, is presented in Figure ECF.3. As with the chart describing the dump truck accident, this chart follows all prescribed format guidelines. Primary events are presented chronologically, enclosed in rectangles, and connected to each other with bold solid arrows. The investigating team did not identify any secondary events. Conditions are enclosed in ovals and connected to other conditions and to events with dashed arrows. All events are appropiately dated.

This chart is particularly interesting because of its complexity. It describes the activities of several operators and supervisors over the period of two shifts. As shown in the chart, the investigating team identified six causal factors that they believed to have contributed to the incident. These causal factors will be discussed further in the "Root Cause Coding" section of this handbook. Not all E&CF charts are as basic as the one describing the dump truck accident and not all are as complex as the example from Savannah River. It is up to the investigators to decide how detailed the investigation, and thus the E&CF chart, should be.

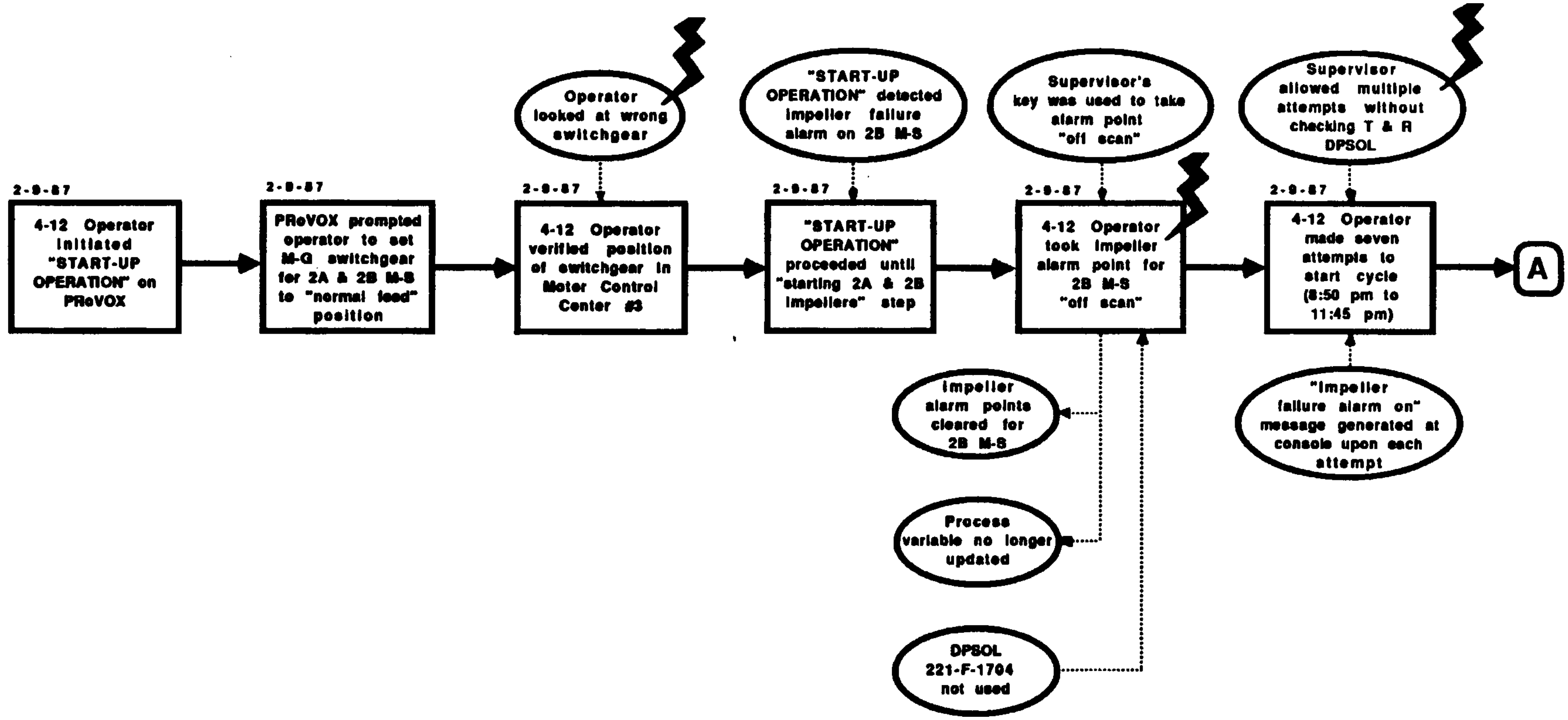


FIGURE ECF.3: E&CF CHART FOR SAVANNAH RIVER INCIDENT (PAGE 1)

"Operating 2nd Pu Cycle Without Impellers Turning On 2B Mixer-Settler (M-S)"

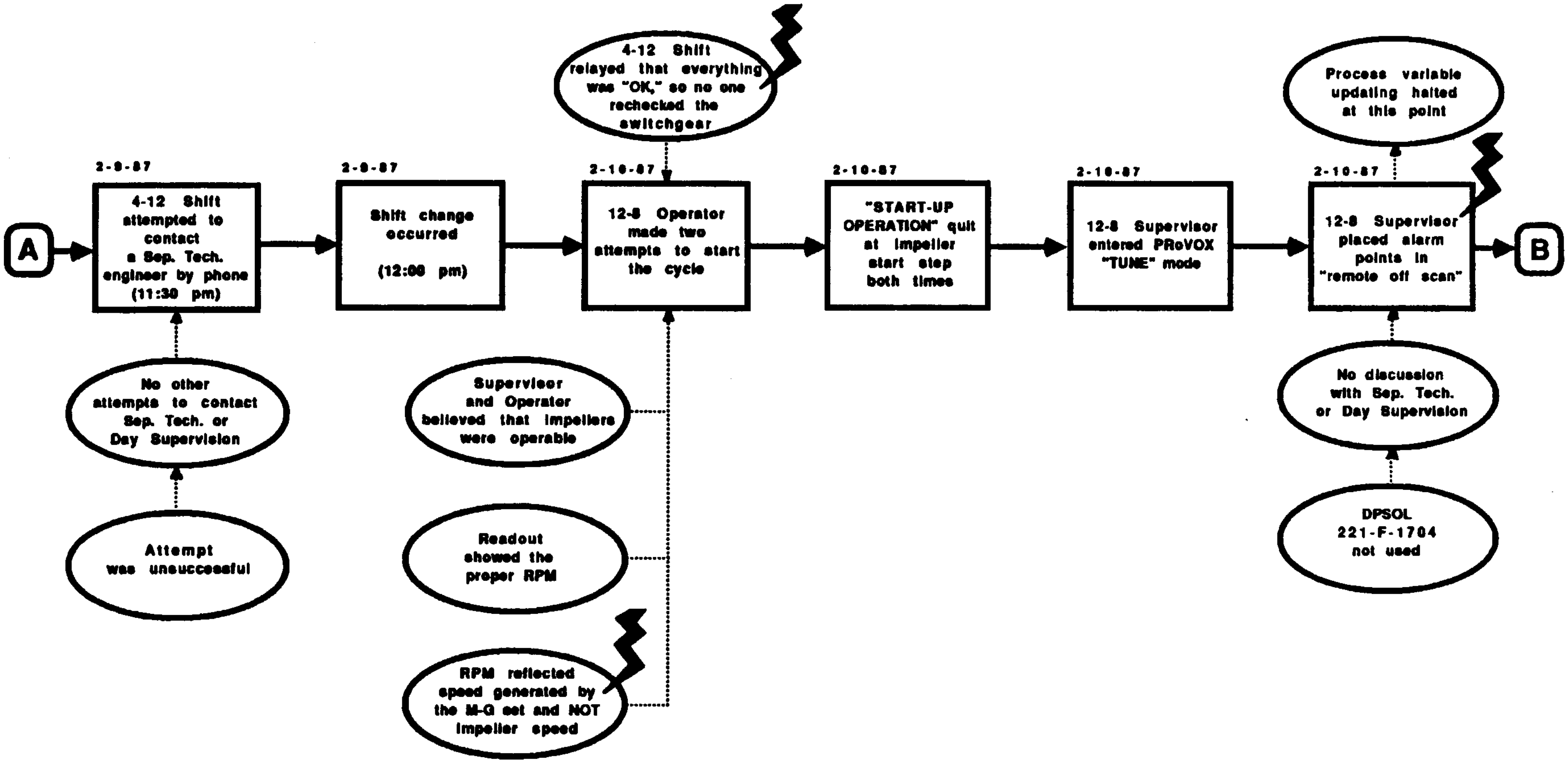


FIGURE ECF.3: E&CF CHART FOR SAVANNAH RIVER INCIDENT (PAGE 2)

"Operating 2nd Pu Cycle Without Impellers Turning On 2B Mixer-Settler (M-S)"

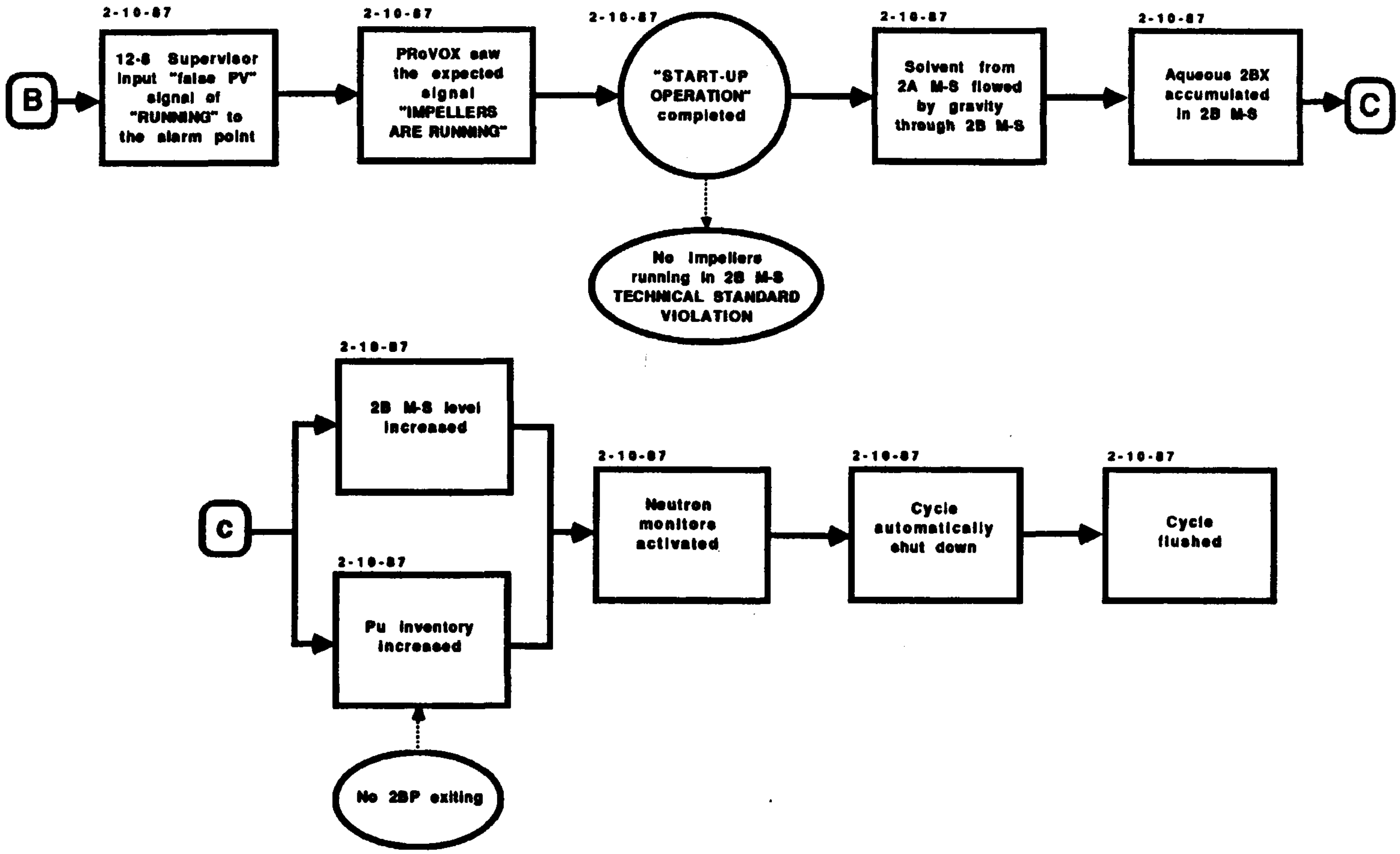


FIGURE ECF.3: E&CF CHART FOR SAVANNAH RIVER INCIDENT (PAGE 3)

"Operating 2nd Pu Cycle Without Impellers Turning On 2B Mixer-Settler (M-S)"

Practical Application of E&CF Charting

The instructions for preparing an E&CF chart presented in this handbook should serve as basic guidelines. Strict adherence to these guidelines is not necessary. The combined experience of many incident investigators has led to the identification of several "rules of thumb" to follow when developing an E&CF chart. These guidelines, applied judiciously, should help to achieve high quality incident investigations. Further discussion of these elements can be found in the SSDC document included in this section of the handbook.

(1) Start early.

Start the E&CF chart as soon as you begin to collect facts about the incident. Construct a "working chart." This will only be a skeleton of the final product, but it will serve to ensure that valuable information is not forgotten or lost during the investigation. To help prevent false starts, it is acceptable to create a "rough draft" E&CF chart to establish how an incident might have happened. Care should be taken, however, to avoid locking the investigating team into a preconceived scenario of the the incident occurrence.

(2) Follow format guidelines.

Use the guidelines for format described in this document. This will help you to get started and to stay on track as you reconstruct the events and conditions surrounding the incident. Keep the proper perspective as you apply the guidelines. They are intended to assist you in simple application of the investigative tool. They are not "hard and fast" rules that must be applied without exception. They have grown out of experience and fit well for most situations. If you believe that you have a truly unique situation and need to deviate from the guidelines, then feel free to do so.

(3) Proceed logically with available data.

Naturally, events and conditions are not going to emerge in the sequence in which they occurred during the incident. Initially, the E&CF chart will have many unresolved gaps. The job of the investigating team is to probe deeply enough to get the facts needed to fill these gaps. It is usually easiest to use the incident or loss event as the starting point and to reconstruct the pre-incident and post-incident sequences from that anchor point.

(4) Use an easily updated format.

As more and more information is learned about the incident, the working E&CF will need to be updated. It is of extreme importance to choose a format that can be easily modified; otherwise, the chart will become too cumbersome to be of any value. In the past, investigators have attempted to redraw the chart repeatedly. This approach is both time consuming and frustrating for those involved in the investigation. Chalkboards and magnetic display boards have also been used. The technique that has proven to be most effective involves the use of the yellow self-adhesive stickers (e.g., "Post-It Notes" or "Clingers") and a large sheet of paper (e.g., flipchart paper or newsprint). A single event or condition is written on each sticker and affixed to the paper. As a more complete picture of the incident emerges, the stickers can be added, deleted, or rearranged. Using the large sheet of paper as a base allows the investigators to take the chart with them if they need to move between conference rooms, offices, or locations involved in the incident. Once the working chart has been completed, a final version can be drawn for inclusion in the incident report. Experienced incident investigators have discovered that the working chart is not only useful for establishing the incident sequence, but it illuminates "gaps" in knowledge, points to areas for further inquiry, and makes report writing relatively straight-forward.

(5) Use other investigation techniques when appropriate.

E&CF Charting provides a way for investigators to organize the data collected during the incident investigation. There are numerous techniques for collecting the data that goes into the chart. Some of these are discussed in documents listed in the "References" section of this handbook. The more skill that the investigators have in collecting incident data, the better the E&CF chart. The investigator should make every effort to build his or her knowledge of investigative techniques.

(6) Select the appropriate scope for the E&CF chart.

One of the first things to consider when creating the E&CF chart is how large or small the scope should be. For example, in the dump truck scenario presented earlier, the investigators chose to limit the chart to events immediately preceeding the accident. They could have probed much deeper into issues such as supervision of the child, development of the corporate safety program, or how the doctors in the emergency handled the boy's broken leg. Apparently, the decision was made to limit the E&CF chart to those things directly under the control of company managment. It is necessary, on a case-by-case basis, to decide upon the appropriate depth and sequence length of the E&CF chart.

(7) Provide an executive summary of the E&CF chart.

Condense the working E&CF chart into an executive summary chart for publishing in the incident report. The working chart will contain much detail, so it is of the greatest value in guiding the investigation. The primary purpose of the E&CF chart in an incident report is to provide a concise, easy-to-follow representation of the incident sequence for the report readers.

Advantages of E&CF Charting

The benefits of E&CF Charting for incident investigation are numerous. Several of the most obvious advantages are listed below.

(1) Organization of data

The chart provides a way to organize the data gathered during the incident investigation. Often, important data is lost or forgotten as the investigation progresses. If the investigation is being conducted by a team, different investigators may collect different pieces of information. The E&CF chart helps to ensure that everyone involved has the benefit of the total group's knowledge.

(2) Guides the investigation

The technique is excellent for group investigations. The E&CF provides a common reference for everyone involved. While inexperienced investigators can use the method to structure their investigations, experienced investigators can use the chart as a way to avoid drawing conclusions before they have all of the relevant facts. E&CF Charting forces investigators to think about causal factors, one at a time, instead of considering the incident in global terms.

(3) Allows validation of the incident sequence

An E&CF provides a good reference during interviews of those directly involved in an incident. The investigators can ask interviewees if the chart is correct. Interviewees have a graphic representation of what the investigators think happened during the incident. They can easily point out descrepancies.

(4) Allows identification of causal factors

Many times incident investigators are tempted to think of an incident in global terms. They ask themselves what they can do to "fix the problem." Using the global approach, we often address only parts of the problem. An E&CF chart allows us to see the entire incident, broken down into its components. Each part can be assessed separately, and solutions can be recommended for individual causal factors. This lessens the probability that some important contributor to the incident will be overlooked.

(5) Simplifies organization of incident report

Generally, a graphic representation of an incident is more easily interpreted than a narrative representation. Readers of an incident report can glance at an E&CF chart and quickly familiarize themselves with the incident. Gaps in logic that might not be so visible in a narrative report, are far more apparent when presented in chart form. E&CF Charting has proven to be a clear and concise aid for report readers whose goal it is to understand the causes of the incident.

Summary

The E&CF Charting technique is simply a tool designed to help incident investigators describe the events leading up to and following an incident as well as the conditions surrounding these events. The technique provides a structured approach to collecting and analyzing the facts pertaining to an incident.

The charting technique, in and of itself, does not ensure an adequate incident investigation. The investigators must be knowledgeable about the processes, facilities, and personnel involved in the incident. They must know the right questions to ask as well as who to ask. Finally, they must be willing to probe to the levels necessary to determine WHAT happened during the incident, to describe HOW it happened, and to understand WHY.

DOE 76-45/14
SSDC-14
REV.

EVENTS AND CAUSAL FACTORS CHARTING

SYSTEM SAFETY DEVELOPMENT CENTER

EG&G

DOE

EG&G Idaho, Inc.

P.O. Box 1625
Idaho Falls, Idaho 83401

August 1978

UNITED STATES
DEPARTMENT OF ENERGY
DIVISION OF OPERATIONAL AND ENVIRONMENTAL SAFETY

Available from:

System Safety Development Center
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho 83401

DOE 76-45/14
SSDC-14
UC-41
REV. 1

EVENTS AND CAUSAL FACTORS CHARTING

Prepared By

J. R. Buys
J. L. Clark

Work Performed At
EG&G IDAHO, INC.
IDAHO OPERATIONS OFFICE
Under Contract No. E-76-C-07-1570

August 1978
(Second Printing - May, 1980)

ACKNOWLEDGMENTS

Special acknowledgment is extended to the staff of the System Safety Development Center and to reviewers throughout the Department of Energy complex for their helpful suggestions and guidance, and to Della Kellogg for her editorial assistance.

CONTENTS

FIGURES

1. INTRODUCTION

The goal of the Department of Energy (DOE) to build and maintain a comprehensive safety management program includes an accident investigation process that utilizes state-of-the-art investigative and analytical methods. Accidents are investigated to identify the causes of their occurrence and to determine the actions that must be taken to prevent recurrence. It is essential that the accident investigators probe deeply into both the events and the conditions that create accident situations, and also the managerial control systems that let them develop so that the root accident causes can be identified. Identification of these root causes necessitates understanding the interacting of events and causal factors through a time-sequenced chain of activity from an initiating event through the final loss producing occurrence. Vital factors in accident causation emerge as sequentially and/or simultaneously occurring events, which interact with existing conditions, are traced out to reconstruct the multifactorial path to unacceptable loss. A meticulous trace of unwanted energy transfers [a basic Management Oversight and Risk Tree (MORT) concept in accident causation] and their relationships to each other and to the people, plant, procedures, and controls implicated in accident occurrence further reveals a well-defined sequence in accident development.

Ludwig Benner[1] suggests two basic foundation principles which are helpful in defining and understanding these sequences of events, conditions, and energy transfers.

(1) Accidents are the results of a set of successive events that produce unintentional harm (i.e., personal injury, property damage, etc.).

(2) The accident sequence occurs during the conduct of some work activity (i.e., a series of events directed toward some anticipated or intended outcome other than injury or damage).

The key points, then, are that an accident involves a sequence of events (happenings) that occur in the course of good-intentioned work activity but that culminate in unintentional (not willful) injury or damage. Implicit here, too, is the existence of contributing causative factors, such as existing conditions, energy flows, failed barriers, etc., as well as identifiable beginning and ending points in the accident sequence.

Benner and his colleagues at the National Transportation Safety Board (NTSB) pioneered the use of sequence diagrams or charts as analytical tools in accident investigation. Their work led to the development of the Events and Causal Factors (E&CF) chart (or diagram), which depicts in logical sequence the necessary and sufficient events and causal factors for accident occurrence. It can be used not only to analyze the accident and evaluate the evidence during investigation, but also can help validate the accuracy of preaccident systems analyses.

The E&CF sequence charting technique is an integral and important part of the MORT-based[2] DOE accident investigation process. It is used in conjunction with other key MORT tools, such as MORT tree analysis, change analysis, and energy trace and barrier analysis, to achieve optimum results in accident investigation. E&CF charting has been used successfully as a focal point of analysis on several ERDA and DOE accident and incident investigations with excellent results. The fundamentals of this valuable MORT tool are discussed in this monograph.

2. NATURE OF ACCIDENT INVESTIGATION

Experience has shown that accidents are rarely simple and almost never result from a single cause. Rather, they are usually multifactorial and develop from clearly defined sequences of events which involve performance errors, changes, oversights, and omissions. The accident investigator (or the investigating board or committee) needs to identify and document not only the events themselves, but also the relevant conditions affecting each event in the accident sequence. To accomplish this, a simple, straightforward approach can be utilized which breaks down the entire sequence into a logical flow of events from the beginning of accident development to the end (which may be defined either as the loss event itself or as the end of the amelioration and rehabilitation phase). This flow of events need not lie in a single event chain but may involve confluent and branching chains. In fact, the analyst/investigator often has the choice of expressing the accident sequence as a group of confluent event chains which merge at a common key event, or as a primary chain of sequential events into which causative factors feed as conditions that contribute to event occurrence, or as a combination of the two.

Construction of the E&CF chart should begin as soon as the accident investigator begins to gather factual evidence pertinent to the accident sequence and subsequent amelioration. The events and causal factors will usually not be discovered in the sequential order in which they occurred, so the initial E&CF chart will be only a skeleton of the final product and will need to be supplemented and upgraded as additional facts are gathered. Even though the initial E&CF chart will be very incomplete and contain many information deficiencies, it should be started very early in the accident investigation because of its innate value in helping to:

(1) Organize the accident data.

(2) Guide the investigation.

(3) Validate and confirm the true accident sequence.

(4) Identify and validate factual findings, probable causes, and contributing factors.

(5) Simplify organization of the investigation report.

(6) Illustrate the accident sequence in the investigation report.

With all its virtues as an independent analytic technique, E&CF charting is most effective when used with the other MORT tools that provide supportive correlation. Causal factors on the E&CF chart should be checked by comparison with the prime deficiencies identified by MORT chart based analysis.

Critical changes revealed through change analysis interface with key events and causal factors in the E&CF chart in establishing sequence chains. A meticulous trace of unwanted energy transfers and their interrelationships facilitates:

(1) Questioning and testing of accident hypothesis.

(2) Use of barrier analysis to examine possible energy flow interruptions.

(3) Identification of energy channels which lead directly to injury or damage or contribute to their occurrence.

An appropriate combination of the major MORT analytic tools, including E&CF charting, provides the core for a good investigation.

3. DESCRIPTION OF TECHNIQUE[3]

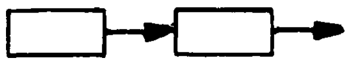
Several examples of E&CF charting which illustrate different construction methods of varying complexity, sophistication, and clarity are shown in Appendices A through H. As can be seen from these appendices, strict adherence to specific rules for developing sequence diagrams has not been followed in the past, nor is such adherence necessary now. In applying the technique as an analytical tool, people have generally used whatever seemed to work best for them and that is still a valid approach. There is, however, adequate justification for adopting some general guidelines for developing E&CF charts for DOE investigation reports.

First, they will help achieve the goal of increased comparability and consistency in accident reporting within the DOE complex. Additionally, there is such a wide variety of operational activities within DOE and such a wide range of experience and technical expertise among the personnel who conduct accident investigations that the unifying influence of common guidelines for individual analysts is needed for meaningful communications. It is intended that these guidelines be as simple as possible while preserving the effectiveness of the E&CF chart as a key analytical tool. It is further intended that investigators be provided with helpful guidelines without inhibiting their use of this tool by imposing too many or too complex rules. Consistent with these intentions, then, the following guidelines are suggested for use in constructing E&CF charts for accident analyses and inclusion in investigation reports.

3.1 Suggested Format

3.1.1 Events should be enclosed in rectangles,  , and conditions in ovals. 

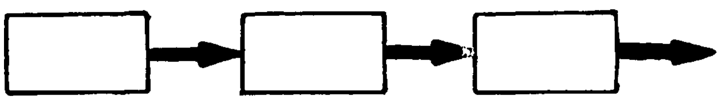
3.1.2 Events should be connected by solid arrows.



3.1.3 Conditions should be connected to each other and to events by dashed arrows.

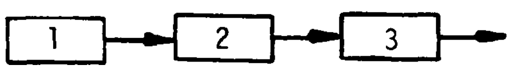
3.1.4 Each event and condition should either be based upon valid factual evidence or be clearly indicated as presumptive by dashed line rectangles and ovals.

3.1.5 The primary sequence of events should be depicted in a straight horizontal line (or lines in confluent or branching primary chains) with events joined by bold printed connecting arrows.



3.1.6 Secondary event sequences, contributing factors, and systemic factors should be depicted on horizontal lines at different levels above or below the primary sequence (see Figure 1).

3.1.7 Events should be arranged chronologically from left to right.



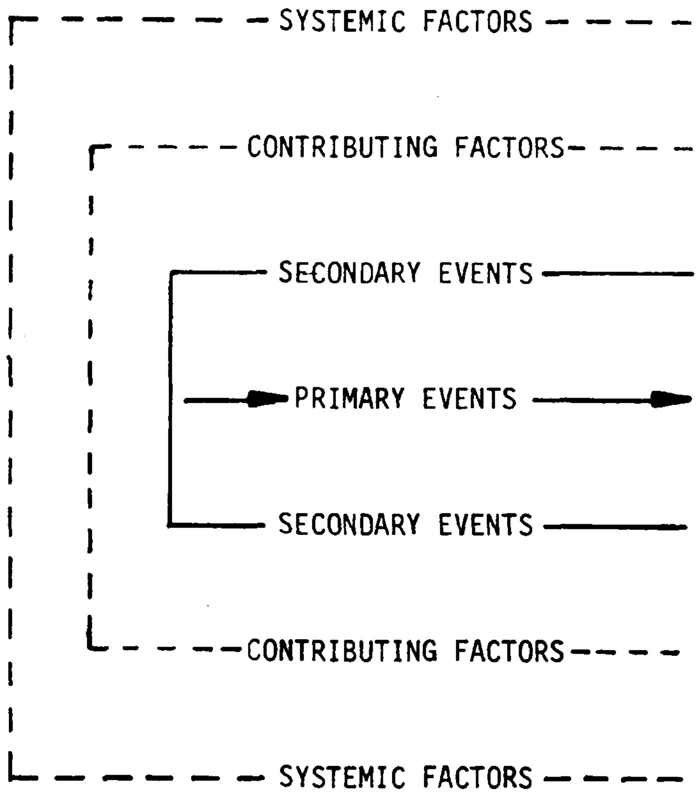


Fig. 1 Events and causal factors relationships.

3.1.8 Events should track in logical progression from the beginning to the end of the initiation-preaccident-accident-amelioration sequence and should include all pertinent occurrences. This necessitates that the beginning and the end be defined for each accident sequence. Analysts frequently use the accident as the key event and proceed from it in both directions to reconstruct the preaccident and postaccident E&CF sequences.

3.2 Suggested Criteria for Event Descriptions

3.2.1 Each event should describe an occurrence or happening and not a condition, state, circumstance, issue, conclusion, or result; i.e., "pipe wall ruptured", not "the pipe wall had a crack in it".

3.2.2 Each event should be described by a short sentence with one subject and one active verb; i.e., "mechanic checked front end alignment", not "mechanic checked front end alignment and adjusted camber on both front wheels".

3.2.3 Each event should be precisely described; i.e., "operator pulled headlight switch to 'on' position", not "operator turned lights on".

3.2.4 Each event should describe a single, discrete occurrence; i.e., "pipe wall ruptured", not "internal pressure rose and pipe wall ruptured".

3.2.5 Each event should be quantified when possible; i.e., "plane descended 350 feet", not "plane lost altitude".

3.2.6 Each event should be derived directly from the event (or events in the case of a branched chain) and conditions preceding it; i.e., "mechanic adjusted camber on both front wheels" is preceded by "mechanic found incorrect camber" which is preceded by "mechanic checked front end alignment" - each event deriving logically from the one preceding it. When this is not the case, it usually indicates that one or more steps in the sequence have been left out.

3.3 Typical Application

Application of the suggested format and event description criteria for constructing a typical E&CF chart of a simple accident is illustrated in the following example.

3.3.1 Accident Description. Ajax Construction Company was awarded a contract to build a condominium on a hill overlooking the city. Prior to initiation of the project, a comprehensive safety program was developed covering all aspects of the project. Construction activities began on Monday, October 4, 1976, and proceeded without incident through Friday, October 8, 1976, at which time the project was shut down for the weekend.

At that time, several company vehicles, including a 2-1/2-ton dump truck, were parked at the construction site. On Saturday, October 9, 1976, a nine-year-old boy, who lives four blocks from the construction site, climbed the hill and began exploring the project site. Upon finding the large dump truck unlocked, he climbed into the cab and began playing with the vehicle controls. He apparently released the emergency brake and the truck began to roll down the hill. The truck rapidly picked up speed. The boy was afraid to jump out and did not know how to apply the brakes. The truck crashed into a parked auto at the bottom of the hill. The truck remained upright, but the boy suffered serious cuts and lacerations and a broken leg. The resultant investigation revealed that, although the safety program specified that unattended vehicles would be locked and the wheels chocked, there was no verification that these rules had been communicated to the drivers.

3.3.2 Discussion (see Figure 2). You will note that events are in time-sequenced order, that each follows logically from the one preceding, and that dates are indicated when known. Events are enclosed in rectangles and the conditions in ovals. Event statements are characterized by single subjects and "active" verbs. (In some events, the subject is implied only.) The primary sequence of events is identified by bold printing the connecting arrows. Other events are connected by solid arrows and conditions by dashed arrows. The "rules not communicated to drivers", "internal communications LTA", and "management control LTA" conditions and the "accidentally released brakes" event are enclosed in dashed ovals and a dashed rectangle, respectively, to indicate that the information is presumptive. The sequence was terminated at the accident but could have been extended to include amelioration (i.e., rescue, emergency action, medical services, rehabilitation, etc.). Further application of these principles are shown in the generalized E&CF charts in Appendix A.

4. BENEFITS OF THE TECHNIQUE

Use of the E&CF charting technique by the accident investigator provides benefits in: (1) meeting the general purposes of accident investigation, (2) conducting the investigation, and (3) writing the investigation report.

4.1 General Purposes of Investigation Served By E&CF Charting

The primary purpose of accident investigation is to determine what happened and why it happened in order to prevent similar occurrences and to improve the safety and efficiency of future operations. When serious accidents occur, they are often symptomatic of systemic deficiencies which also downgrade performance and production. When the accident is used as a window through which to view the existing management system, these deficiencies are revealed and benefits are derived which go far beyond correction of the immediate causes of the accident. The emphasis, then, should be placed on discovering all cause-effect relationships

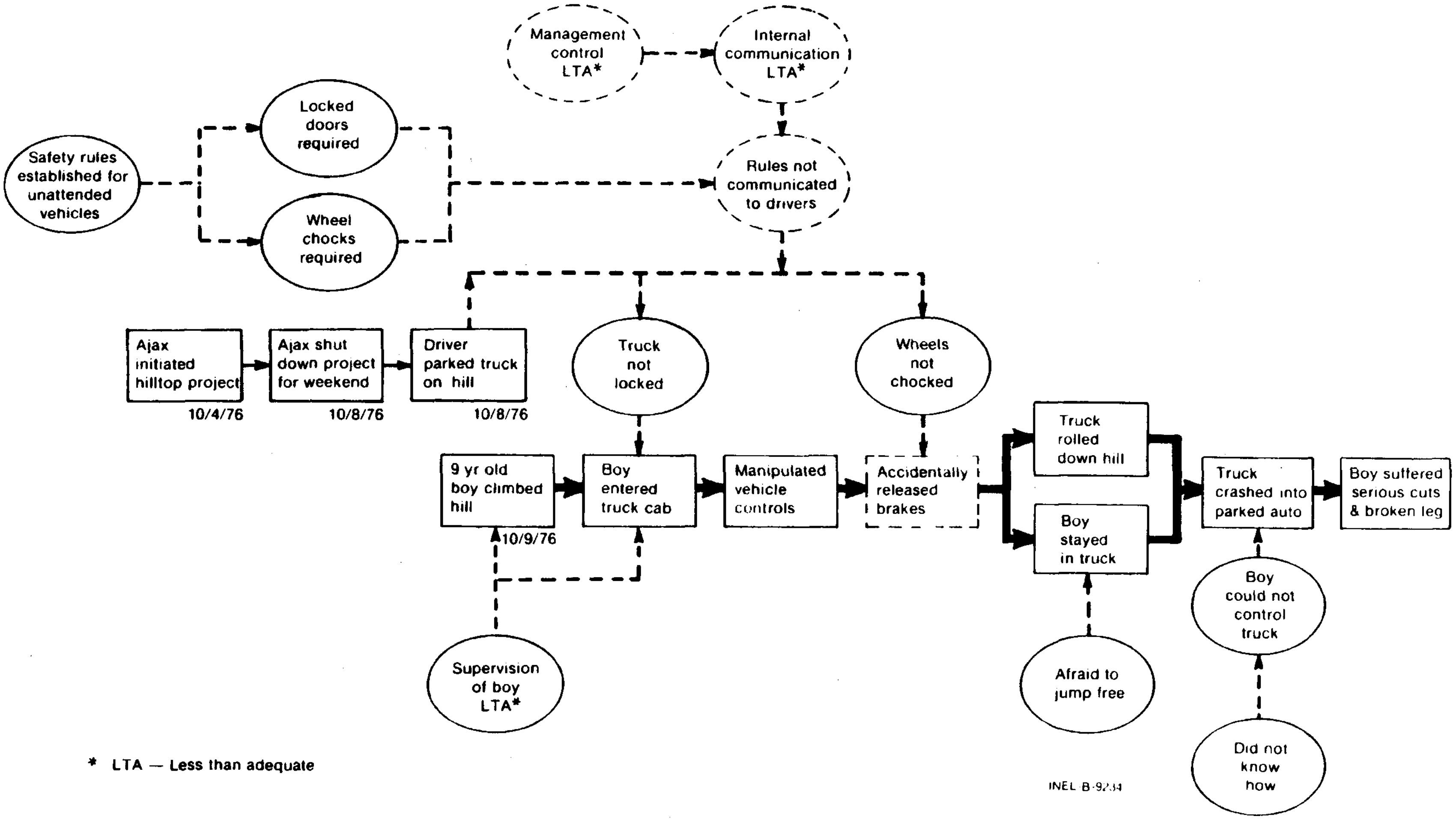


Fig. 2 Events and causal factors chart example

from which practical corrective actions can be derived to upgrade total performance. The intent of the investigation, then, is not to place blame, but rather to determine how responsibilities can be clarified and how loss-producing errors can be reduced and controlled. Accurate E&CF charting can help satisfy these purposes in the following ways:

(1) Provide a cause-oriented explanation of the accident.

(2) Provide a basis for beneficial changes to prevent future accidents and operational errors.

(3) Help delineate areas of responsibility.

(4) Help assure objectivity in the conduct of the investigation.

(5) Provide an organization of quantitative data (e.g., time, velocity, temperature, etc.) related to loss-producing events and conditions.

(6) Provide an operational training tool.

(7) Provide an effective aid to future systems design.

4.2 Role of E&CF Charting in Conducting the Investigation

E&CF charting contributes the following useful aids to conducting accident investigations in a professional manner:

(1) Aids in developing evidence, in detecting all causal factors through sequence development, and in determining the need for in-depth analysis.

(2) Clarifies reasoning.

(3) Illustrates multiple causes. As previously stated, accidents rarely have a single "cause". Charting helps illustrate the multiple causal factors involved in the accident sequence, as well as the relationship of proximate and remote, and direct and contributory causation.

(4) Visually portrays the interactions and relationships of all involved organizations and individuals.

(5) Illustrates the chronology of events showing relative sequence in time.

(6) Provides flexibility in interpretation and summarization of collected data.

(7) Conveniently communicates empirical and derived facts in a logical and orderly manner.

(8) Links specific accident factors to organizational and management control factors.

4.3 Use of the E&CF Chart in Preparing the Report

The purpose of the investigation report is to convey the results of the investigation in clear and concise language. The investigation report constitutes a record of the occurrence by which the investigation is measured for thoroughness, accuracy, and objectivity. The report should also fully explain the technical elements of the causal sequences of the occurrence and describe the management systems which should have prevented the occurrence. Use of E&CF charting has been effective in satisfying these report objectives. Specific advantages provided are as follows:

(1) Provides a check for completion of investigative logic. Even the most elementary types of sequence charting can reveal gaps in logic and help prevent inaccurate conclusions.

(2) Provides a method for identification of matters requiring further investigation or analysis. Significant event blocks with vague or nonexistent causal factors can alert the investigator to the need for additional fact-finding and analysis.

(3) Provides a logical display of facts from which valid conclusions can be drawn.

(4) Provides appropriate and consistent subject titles for "discussion of facts" and "analysis" paragraphs.

(5) Provides a method for determining if the general investigative purposes and specific objectives have been adequately met in terms of the conclusions reached.

(6) Provides a method for differentiation between the analysis of the facts and the resultant conclusions.

(7) Presents a simple method for clearly describing accident sequences and causes to a reading audience with divergent backgrounds. Without the use of sophisticated or exotic methodology, the accident causes can be easily communicated to readers with a wide variety of experience and technical expertise.

(8) Provides a source for the identification of organizational needs and the formulation of recommendations to meet those needs. The charting technique provides the basis for a systematic trace of the logic from a statement of the facts through the analysis, conclusions, judgments of needs, and recommendations.

(9) Provides a method for evaluating the factual basis of possible recommendations.

(10) Finally, the technique has shown to be useful in solving various unanticipated problems associated with preparing the final report for specific accident investigations. For example, the clear identification of events and conditions as factual or presumptive assists in complying with the DOE report format, which requires explicit separation of facts, analysis, and conclusions into separate and distinct report sections. Also, the clear and logical development of the accident events and causal factors facilitates agreement among report reviewers on accident causation and minimizes negative reaction from those persons and organizations whose performance deficiencies contributed to accident occurrence. They may not like what the report says, but they will agree that it is fair and accurate.

5. PRACTICAL APPLICATION

How can an investigator best apply E&CF charting to reap the benefits outlined in this monograph? The experience of many people participating in numerous accident investigations has led to the identification of seven key elements in the practical application of E&CF charting to achieve high quality accident investigations.

(1) Begin early. As soon as you start to accumulate factual information on events and conditions related to the accident, begin construction of a "working chart" of events and causal factors. It is often helpful also to rough out a fault tree of the occurrence to establish how the accident could have happened. This can prevent false starts and "wild goose chases" but must be done with caution so that you don't lock yourself into a preconceived scenario of the accident occurrence.

(2) Use the guidelines suggested in this monograph. They will assist you in getting started and staying on track as you reconstruct the sequences of events and conditions that influenced accident causation and amelioration. Remember to keep the proper perspective in applying these guidelines. They are intended to guide you in simple application of a valuable investigative tool. They are not hard and fast rules that must be applied without question or reason. They have grown out of experience and fit well in most applications, but if you have a truly unique situation and feel that you must deviate from the guidelines for clarity and simplicity, do it.

(3) Proceed logically with available data. Events and causal factors usually do not emerge during the investigation in the sequential order in which they occurred. Initially, there will be many holes and deficiencies in the chart. Efforts to fill these holes and get accurate tracking of the event sequences and their derivation from contributing conditions will lead to that deeper probing by investigators which will uncover the true facts involved. In proceeding logically, using available information to direct the search for more, it is usually easiest to use the accident or loss event as the starting point and reconstruct the preaccident and postaccident sequences from that vantage point.

(4) Use an easily updated format. As additional facts are discovered and as analysis of those facts further identify causal factors, the working chart will need to be updated. Unless a format is selected which displays the emerging information in an easily modified form, construction of the chart can be very repetitious and time-consuming. Successive redrafts of the E&CF chart on large sheets of paper have been done; magnetic display boards or chalkboards have been used; but the technique that has consistently proven most effective and most easily updated is use of 3" x 5" index cards on which brief event or condition statements are written. A single event or condition is written on each card. The cards are then taped to a wall or a large roll of heavy paper, or are placed on a large flat surface, in order of the sequence of events as then understood. As more information is revealed, cards can be rearranged, added, or deleted to produce a more complete and accurate version of the working chart. Once the card-based working chart has been finalized, the E&CF chart can be drawn for inclusion in the investigation report. Several investigators have testified of the value of this approach, commenting that it made their investigations more expeditious and thorough. They further stated that use of the index

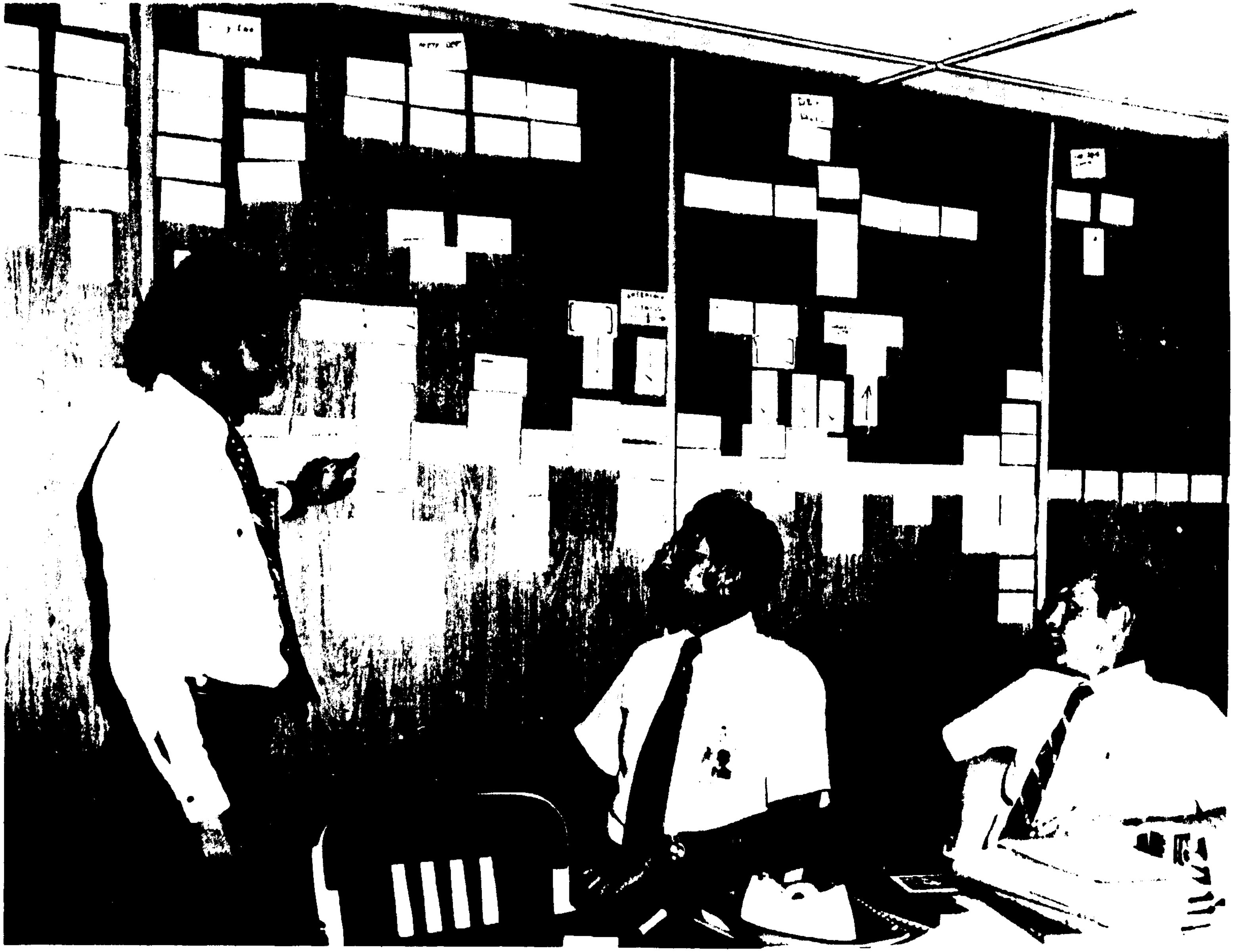


Fig. 3 Events and causal factors wall display.

cards for the working chart not only was useful in establishing the accident sequence and identifying key events and conditions, but it also illuminated deficiencies in knowledge, pointed out areas for further inquiry, and finally made the report writing relatively straightforward. Figure 3 shows a typical accident investigation committee employing this approach.

(5) Correlate use of E&CF charting with that of other MORT investigative tools. The optimum benefit from MORT-based investigations can be derived when such powerful tools as the E&CF charting, MORT chart based analysis, change analysis, and energy trace and barrier analysis are used to provide supportive correlation.

(6) Select the appropriate level of detail and sequence length for the E&CF chart. The accident, itself, and the depth of investigation specified by the appointing authority in his letter of appointment to investigating committee members will often suggest the amount of detail desired. These, too, may dictate whether ending the E&CF chart at the accident or loss-producing event is adequate, or whether the amelioration phase should be included. The way the amelioration was conducted will also influence whether this should be included and in how much depth it should be discussed. Certainly, if second accidents occurred during rescue attempts or emergency action, or if there were other specific or systemic problems revealed, the E&CF chart should cover this phase. However, the investigators and the appointing authority involved will have to decide, on a case-by-case basis, what is appropriate depth and sequence length on each accident investigated.

(7) Condense the working E&CF chart to make an executive summary chart for the report. The E&CF working chart will contain much detail so it can be of greatest value in shaping and directing the investigation. Normally, significantly less detail is required in the E&CF chart in the investigation report, for its primary purpose is to provide a concise and easy-to-follow orientation to the accident sequence for the report reader. When a detailed E&CF chart is felt to be necessary to show appropriate relationships in the analysis section or an appendix of the report, an executive summary chart of only one or two pages should be prepared and included in the report to meet the above stated purpose.

In summary, the seven key elements in practical application of E&CF charting on accident investigation are:

(1) Begin early.

(2) Use the guidelines.

(3) Proceed logically using available data.

(4) Use an easily updated format.

(5) Correlate with other MORT investigative tools.

(6) Include appropriate detail and sequence length.

(7) Make a short executive summary chart when necessary.

Finally, the use of E&CF charting has proven to be a valuable tool for accident investigators and a clear and concise aid to understanding of accident causation for the report readers. Use it for greater effectiveness in accident investigating and reporting.

6. REFERENCES

[1] Ludwig Benner, Jr., "Accident Investigations: Multilinear Events Sequencing Methods", Journal of Safety Research, 7, 2 (1975).

[2] W. G. Johnson, MORT - The Management Oversight and Risk Tree, SAN 821-2, February 12, 1973.

[3] Based on Outlines and Charts Developed by Henry Wakefield and Ludwig Benner of the National Transportation Safety Board and Staff Members of the EG&G Idaho, Inc. System Safety Development Center.

[4] W. G. Johnson, The Accident/Incident Investigation Manual, ERDA-76-20, Prepared for the Division of Operational Safety, Energy Research and Development Administration, August 1, 1975.

[5] W. G. Johnson, "Sequences in Accident Causation", Journal of Safety Research, 5, 2 (1973).

[6] Report of the Investigation Board on the X-Ray Exposure at the Pantex Plant, Albuquerque Operations Office (September 27, 1974).

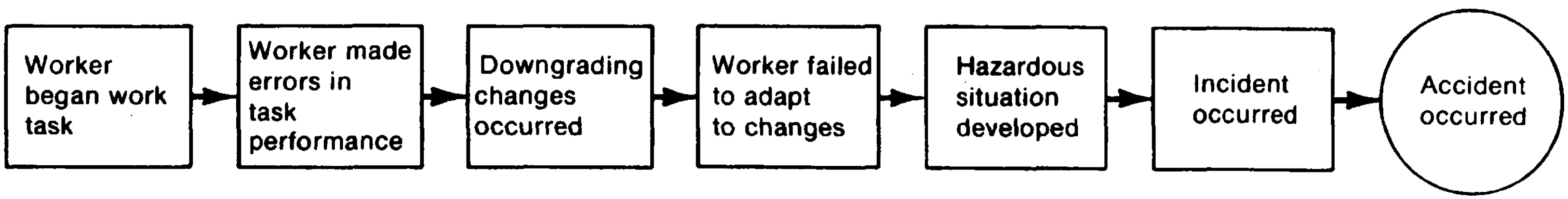
[7] Raymond L. Kuhlman, Professional Accident Investigation - Investigative Methods and Techniques, Institute Press, 1977.

[8] Report of the Investigation Board on the Accident at Drill Hole U2EC Peninsula, Area 2, Nevada Test Site, Nevada Operations Office (October 23, 1975).

[9] Report of Investigation of Near-Fatal Accident at the Central Facilities Vehicle Maintenance and Repair Shop, Idaho National Engineering Laboratory, EG&G Idaho, Inc. (April 25, 1977).

APPENDIX A

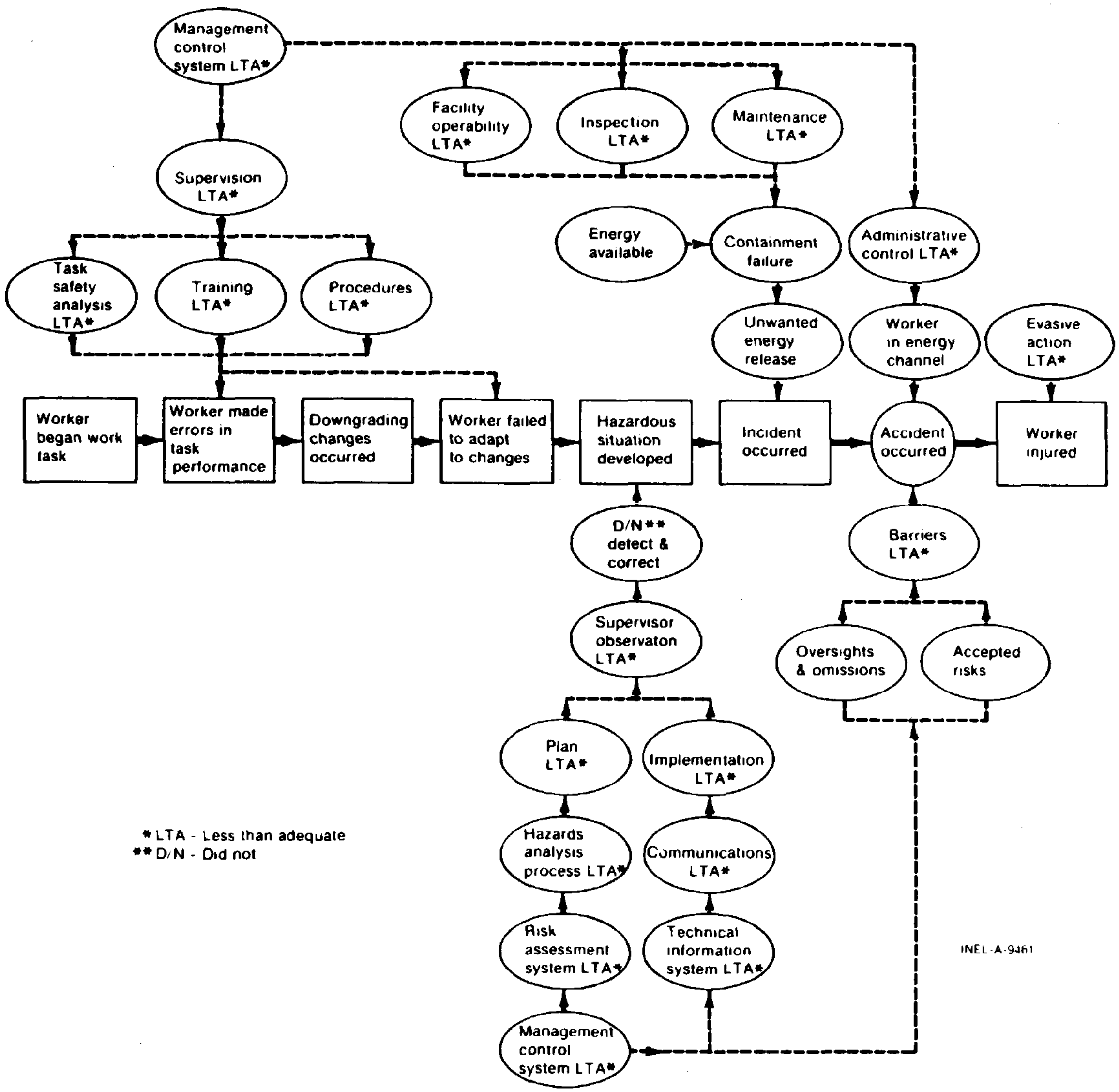
GENERALIZED EVENTS AND CAUSAL FACTORS CHART



INEL-A-9460

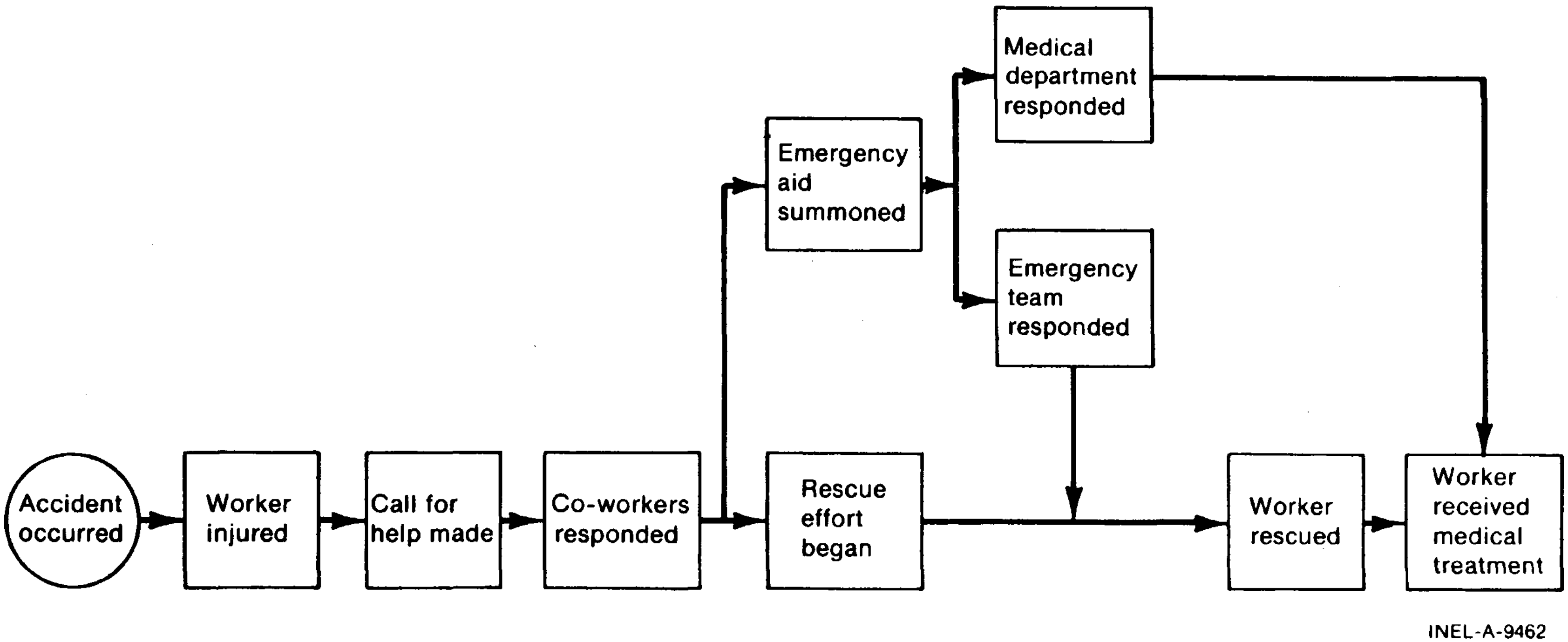
Preaccident Events

APPENDIX A (cont.)



Preaccident Events and Conditions

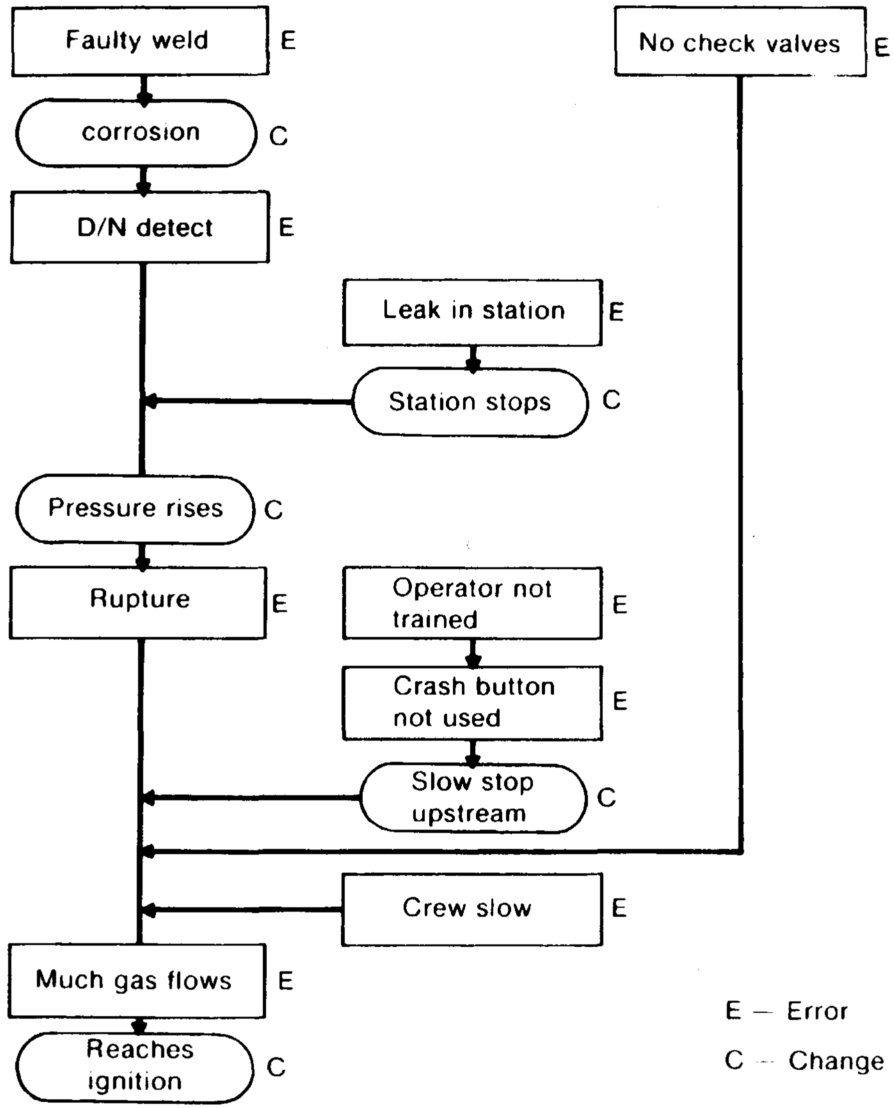
APPENDIX A (cont.)



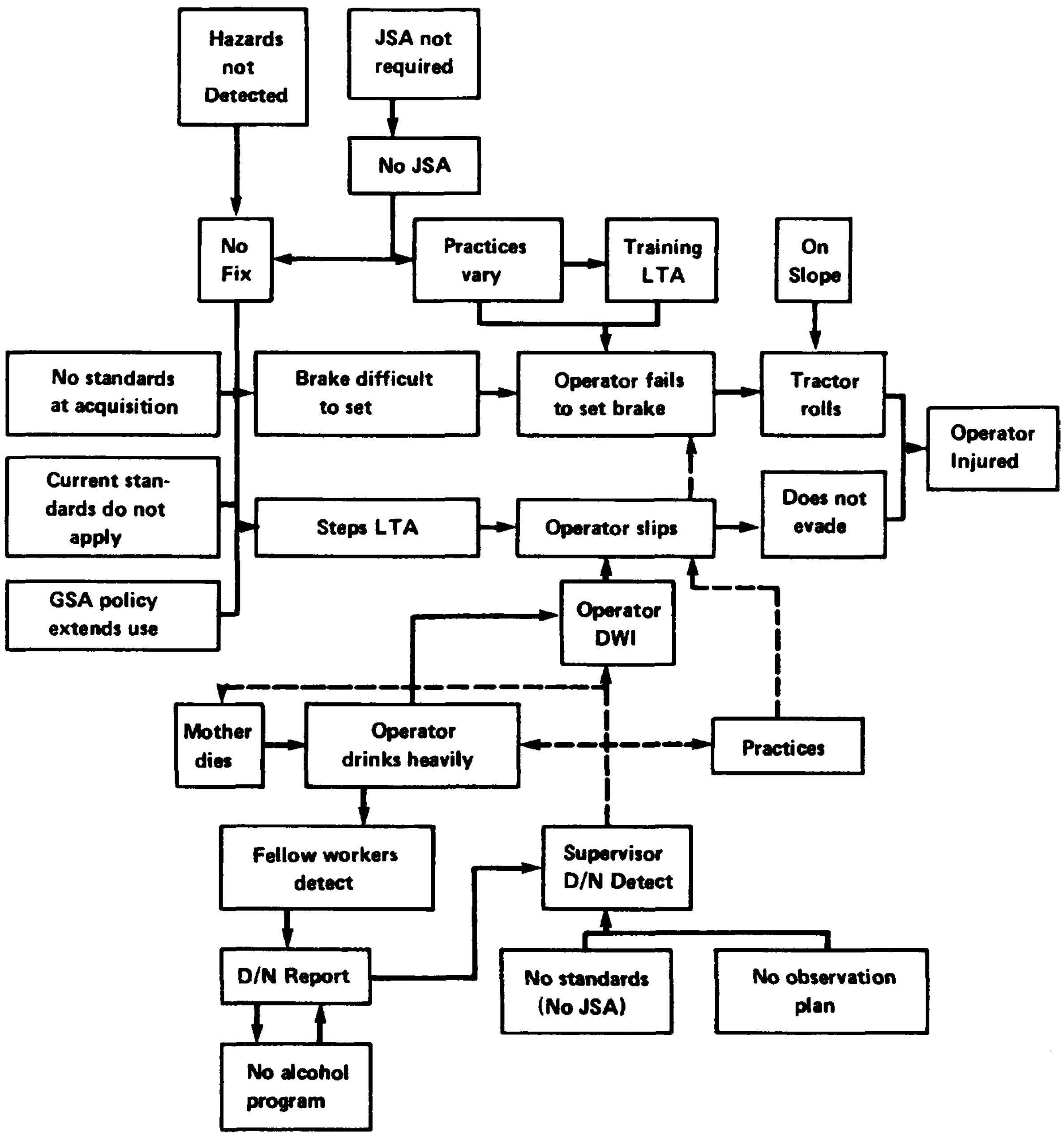
Postaccident Events

APPENDIX B

GAS PIPELINE ACCIDENT[5]

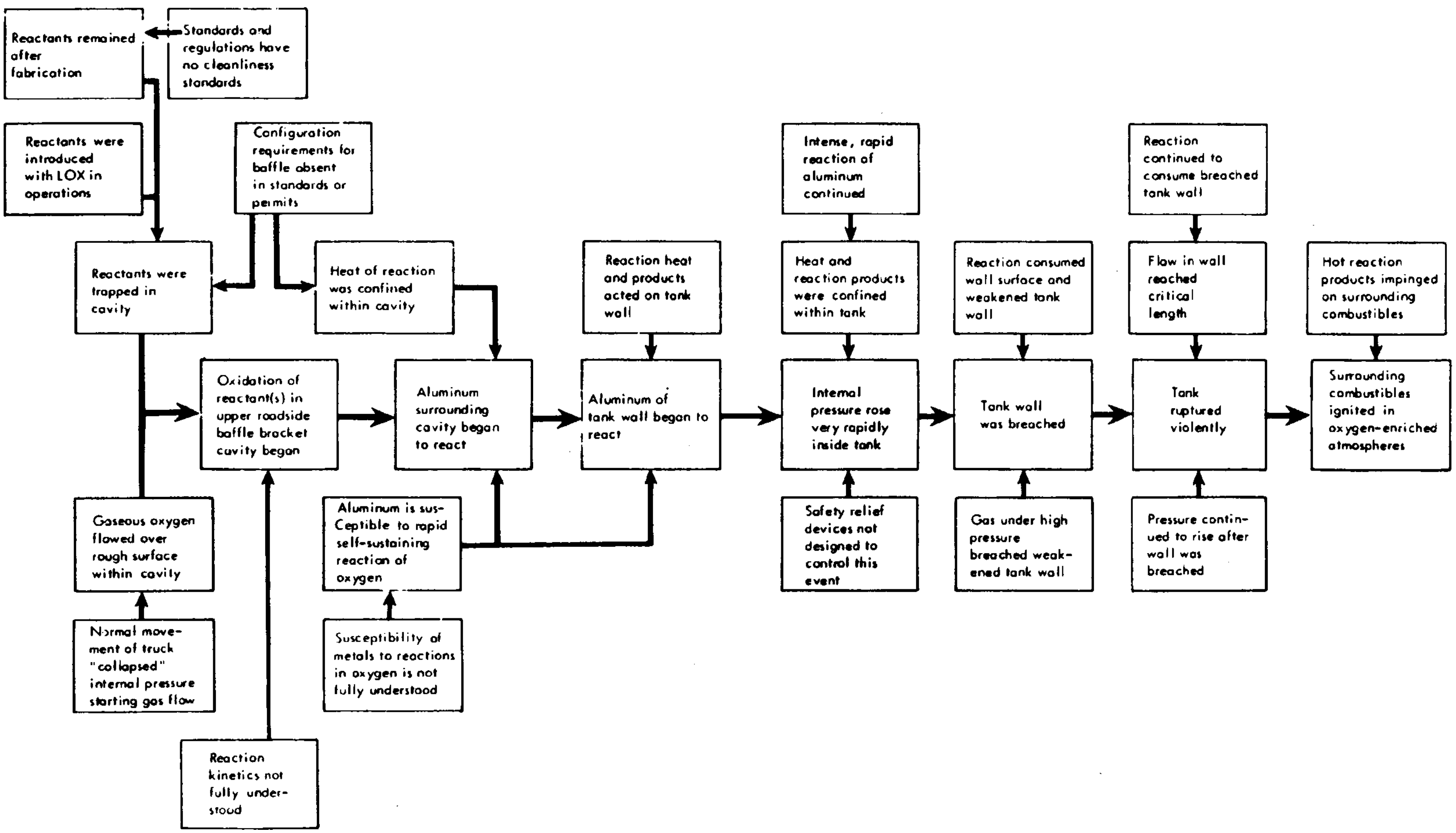


INEL-A-9415


Hazards not Detected
JSA not required
No JSA
No Fix
Practices vary
Training LTA
On Slope
No standards at acquisition
Brake difficult to set
Operator fails to set brake
Tractor rolls
Operator Injured
Current standards do not apply
Steps LTA
Operator slips
Does not evade
GSA policy extends use
Operator DWI
Mother dies
Operator drinks heavily
Practices
Fellow workers detect
Supervisor D/N Detect
D/N Report
No standards (No JSA)
No observation plan
No alcohol program

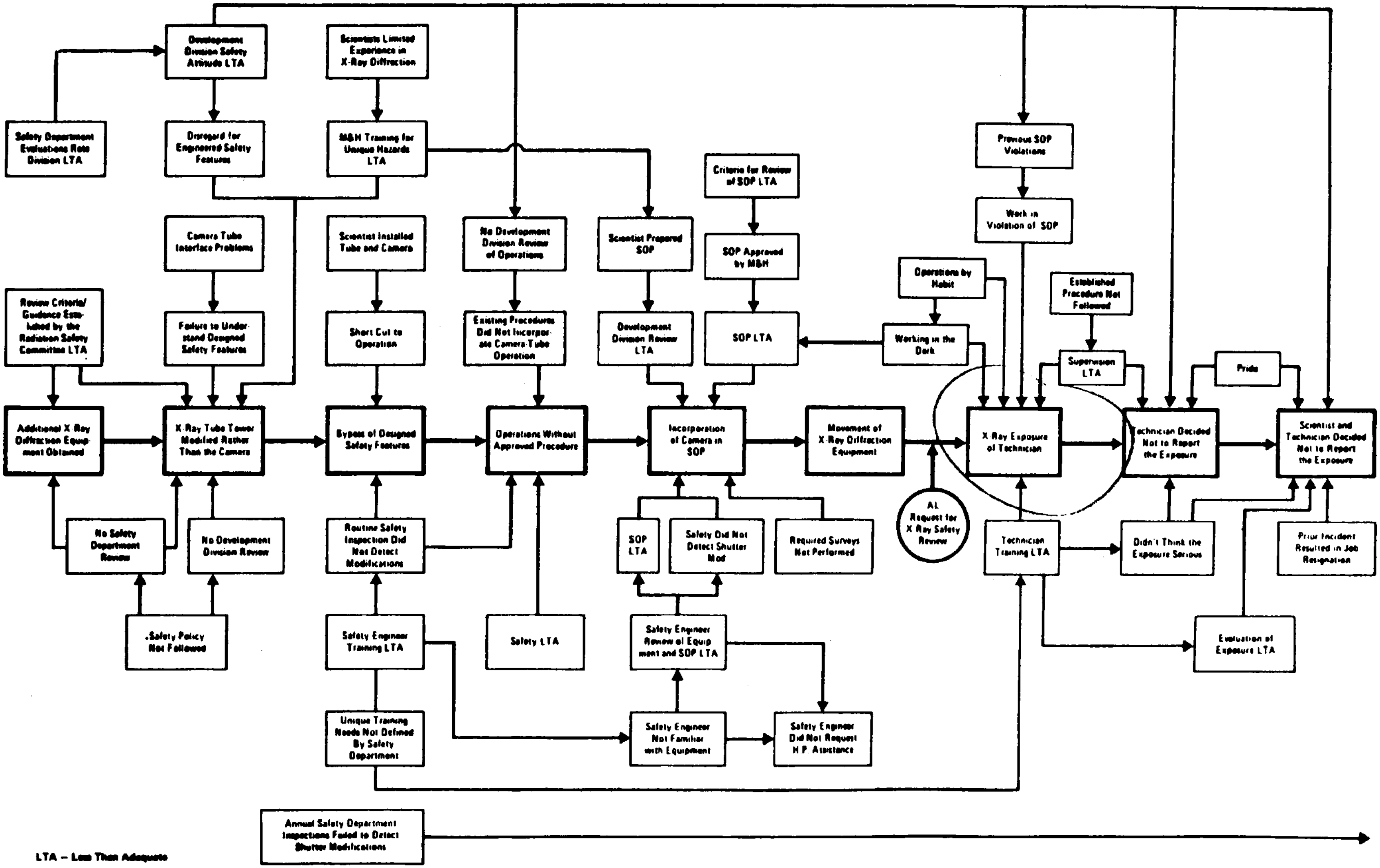
APPENDIX D

LOX TANK EXPLOSION[4]



APPENDIX E

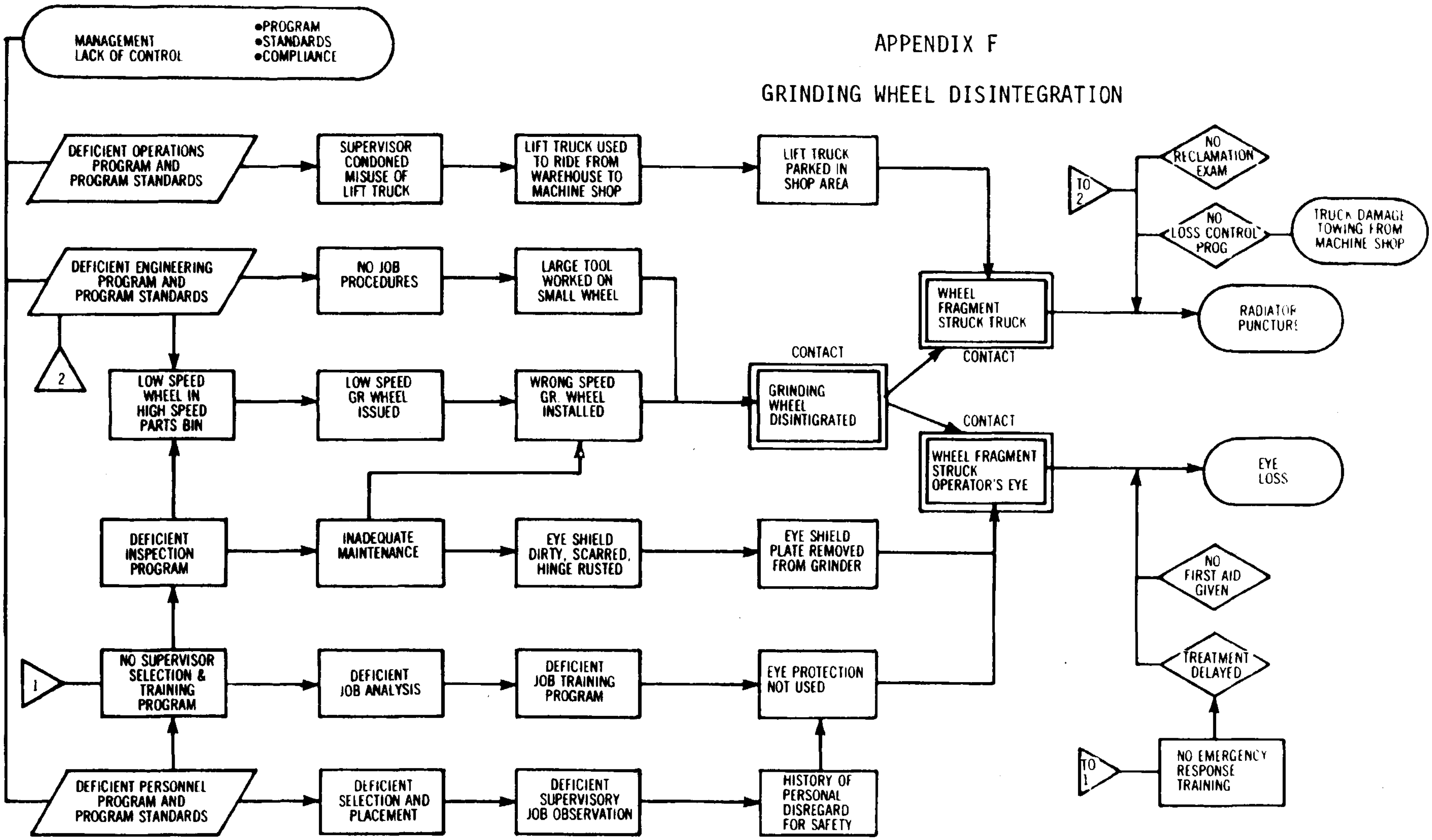
X-RAY EXPOSURE ACCIDENT[6]



LTA – Less Than Adequate

APPENDIX F

GRINDING WHEEL DISINTEGRATION



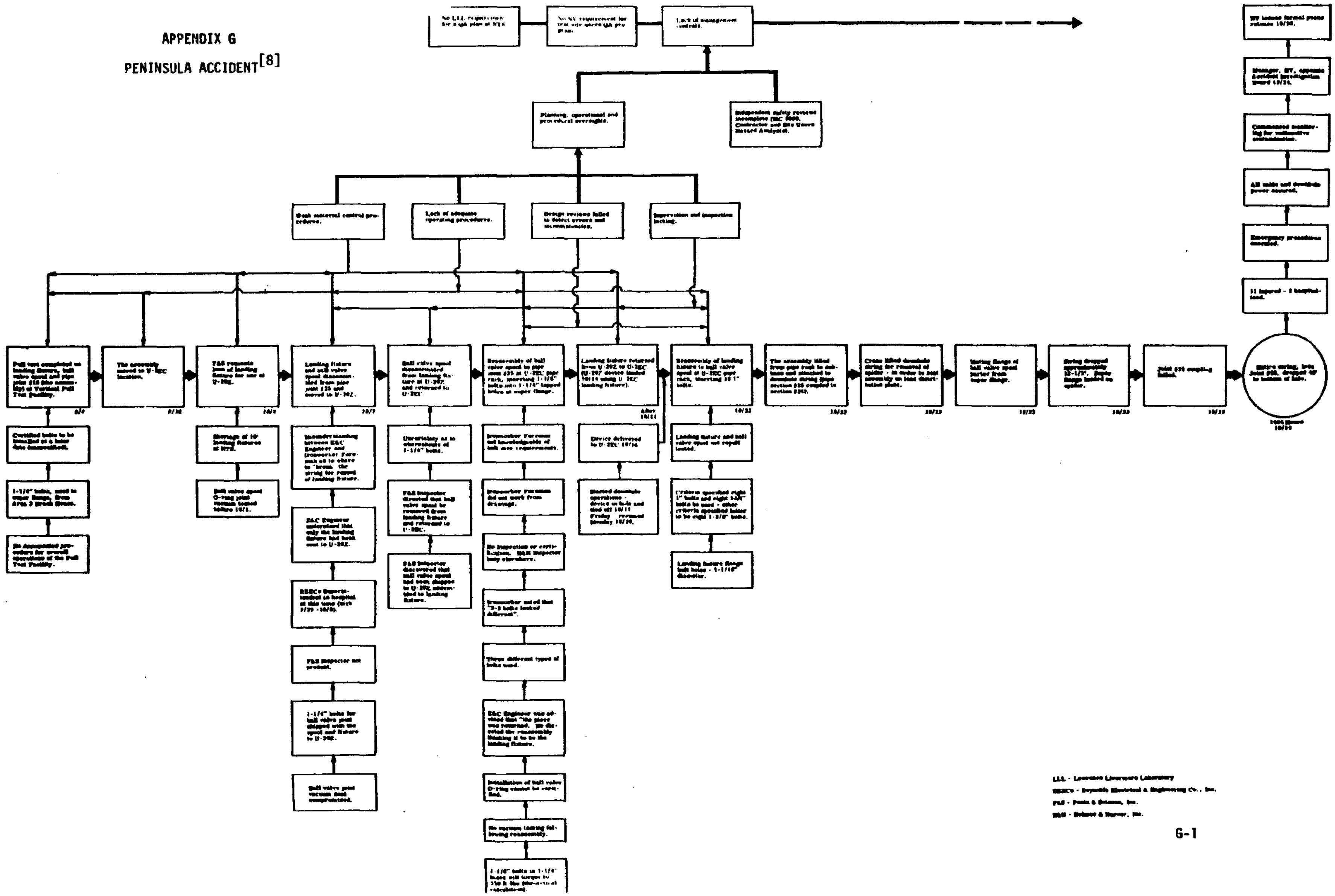
Chart

Outline

- A. Contact between grinding wheel and mower blade resulted in wheel fracture
  - 1. Grinding wheel accelerated to high speed.
    - a. New wheel not run-in after installation.
      - Installed by operator not familiar with run-in procedure.
        - Standards did not prohibit change of wheels by other than maintenance people.
        - Run-in procedure not published.
          - Task analysis not performed.
            - Deficient supervisor training program.
        - Excessively worn wheel not detected by inspection.
          - Not identified as critical part.
          - No inspection schedule established
            - Supervisor not trained on planned inspection program.
              - Lack of program standards.
      - Grinder spindle speed had been increased to maintain wheel surface speed as wheel wore down.
        - Operator not aware of speed adjustment procedure.
          - Deficient operator training program.
            - Inadequate selection and placement program.
          - Deficient job orientation on transfer.
            - Inadequate selection and placement program.
          - Deficient job analysis.
            - Inadequate supervisor selection and training program.
        - Wheel replacement procedure not published.
          - Not identified as critical job.
            - Inadequate program.
        - Tool room issued wheel to operator.
          - Standards did not differentiate between parts to be issued to maintenance and tools and parts which could be issued to equipment operators.
            - Inadequate program.
    - b. Low speed grinding wheel installed on high speed grinder.
      - Low speed wheels mixed with high speed wheels in parts bins.
        - Stock shifted in reorganization.
        - Returns to stock not repackaged to show identification.
          - Lack of standard for marking return of issued parts.
        - No marking or identification of wheel type.
      - Low speed and high speed wheels have same spindle size.
        - Purchase not coordinated with safety department.
          - Lack of program standards for purchasing.
        - Intentional condition to permit use of excess high speed wheel stock.
          - Lack of compliance with ANSI B7.1
  - 2. Mower blade not supported by tool rest.
    - a. Tool rest not reset to 1/8" clearance when new wheel installed.
      - Operator did not understand importance of tool rest and wheel guard position.
        - Inadequate training.
          - No task analysis.
          - No standard job procedure.
        - No supervisory key point typing program.
          - Inadequate supervisory training and qualification.
      - Tool rest clearance not checked by supervisor or technically qualified inspector.
        - Inadequate inspection program.
        - Supervisor not trained on inspection programs.
          - Inadequate program.
      - Tool rest clearance standard not enforced in company.
        - Standards enforcement lax in product development.
        - Standard not considered significant in production area.
          - Inadequate compliance.
    - b. Holders for large work not available within plant.
      - Benefit not evaluated for quality or safety.
      - No safety evaluation of benefit for production line.
        - Inadequate program.
- B. Grinding wheel fragments not contained by wheel guard or eye shield
  - 1. Wheel guard not in proper position.
    - a. No tongue over upper opening.
    - b. Guard not movable to control upper opening.
      - Inadequate purchasing standards.
      - No safety approval of purchase.
        - Inadequate program.
    - c. Guard turned past 65° position.
      - Operator not aware of guard position standards.
      - Maintenance not aware of guard position standards.
        - Inadequate compliance with ANSI B7.1
          - Inadequate program.
  - 2. Eye shield removed from grinder.
    - a. Eye shield dirty and greasy.
    - b. Eye shield heavily scratched.
    - c. Eye shield hinge rusted and frozen.
      - Inadequate maintenance schedule.
      - Inadequate supervisor action.
        - Inadequate program.
- C. Grinding wheel fragment struck operator's eye.
  - 1. Operator not using personal eye protection.
    - a. Protective goggles hanging near grinder.
    - b. Protective goggles dirty and scratched.
      - Inadequate worker action to maintain goggles.
        - Lack of standard.
      - Inadequate supervisor action on care of equipment.
        - Inadequate supervisor selection and training.
          - Inadequate program.
    - c. Operator had history of disregard for use of personal protective equipment.
      - Workers frequently observed operator without eye protection.
      - Workers did not report violation of standards to supervisor.
        - Deficient compliance program.
        - Inadequate training.
          - Inadequate program.
      - Deficient supervisory job observation.
        - Inadequate supervisor selection and training.
          - Inadequate program.
  - 2. No first aid administered after injury.
    - a. Supervisor and work section people not trained in first aid.
      - Inadequate program.
    - b. Injury aggravated by failure to flush foreign material from eye.
  - 3. Medical treatment delayed by confusion following the accident.
    - a. No emergency response plan.
    - b. No emergency action training of managers and supervisors.
      - Inadequate program.
- D. Grinding wheel fragment punctured mowing tractor radiator.
  - 1. Tractor moved into shop area.
    - a. Tractor mis-used as personal transport to shop.
      - Supervisor condoned general mis-use.
        - Lack of compliance with standards.
  - 2. Tractor damaged in towing from shop.
    - a. Tow chain wrapped around steering mechanism rods.
    - b. Brake not released before attempting towing.
      - Inadequate planning for control of damaged equipment.
        - Inadequate investigation program.
      - Steering rods bent.
      - Steering rods discarded and replaced.
        - No program for examination and reclamation of accident damages.
          - Inadequate investigation program.
    - c. Transmission damaged by towing tractor backwards after steering rods damaged.
      - Inadequate planning for control of damaged equipment.
        - Inadequate investigation program.

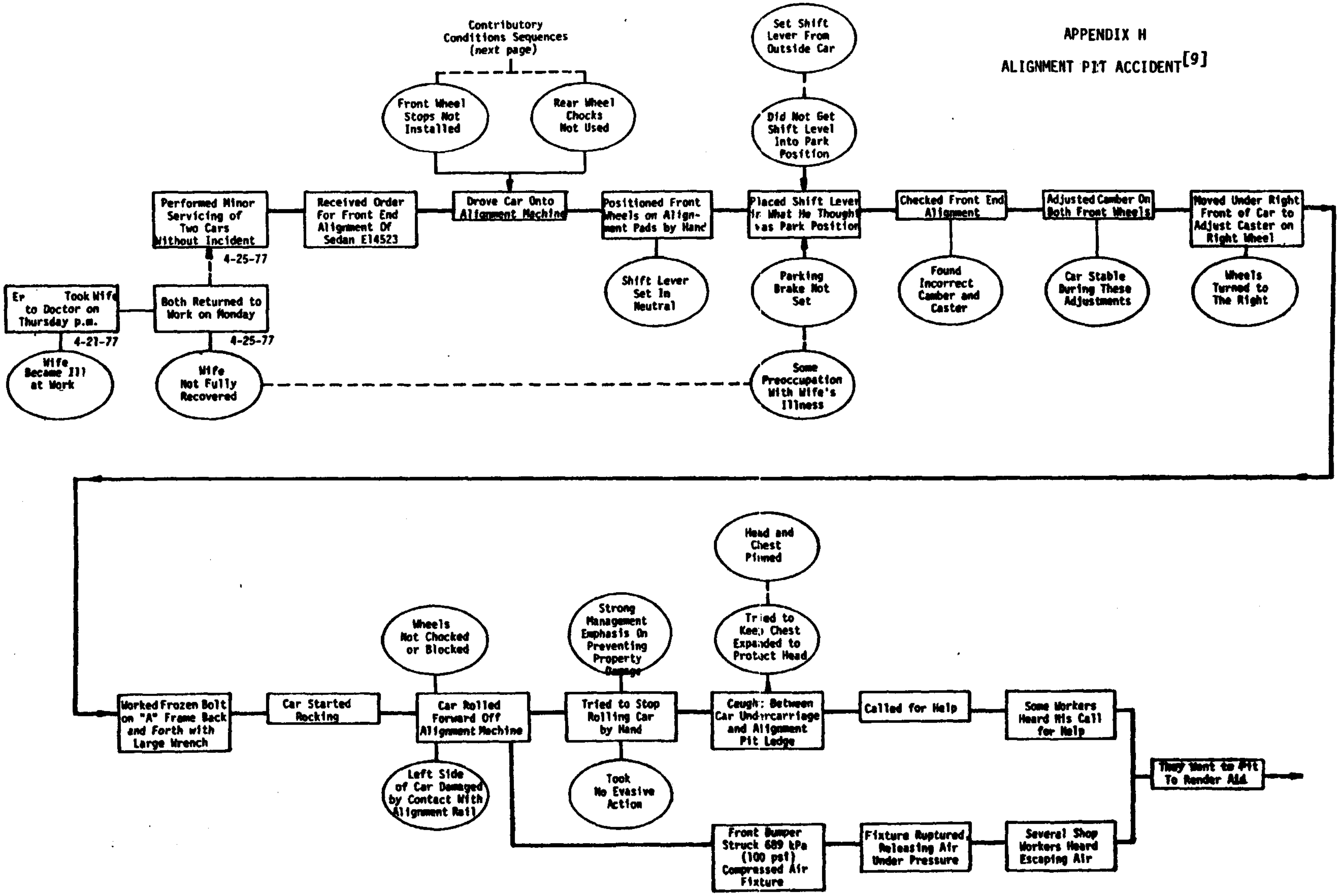
APPENDIX G

PENINSULA ACCIDENT[8]



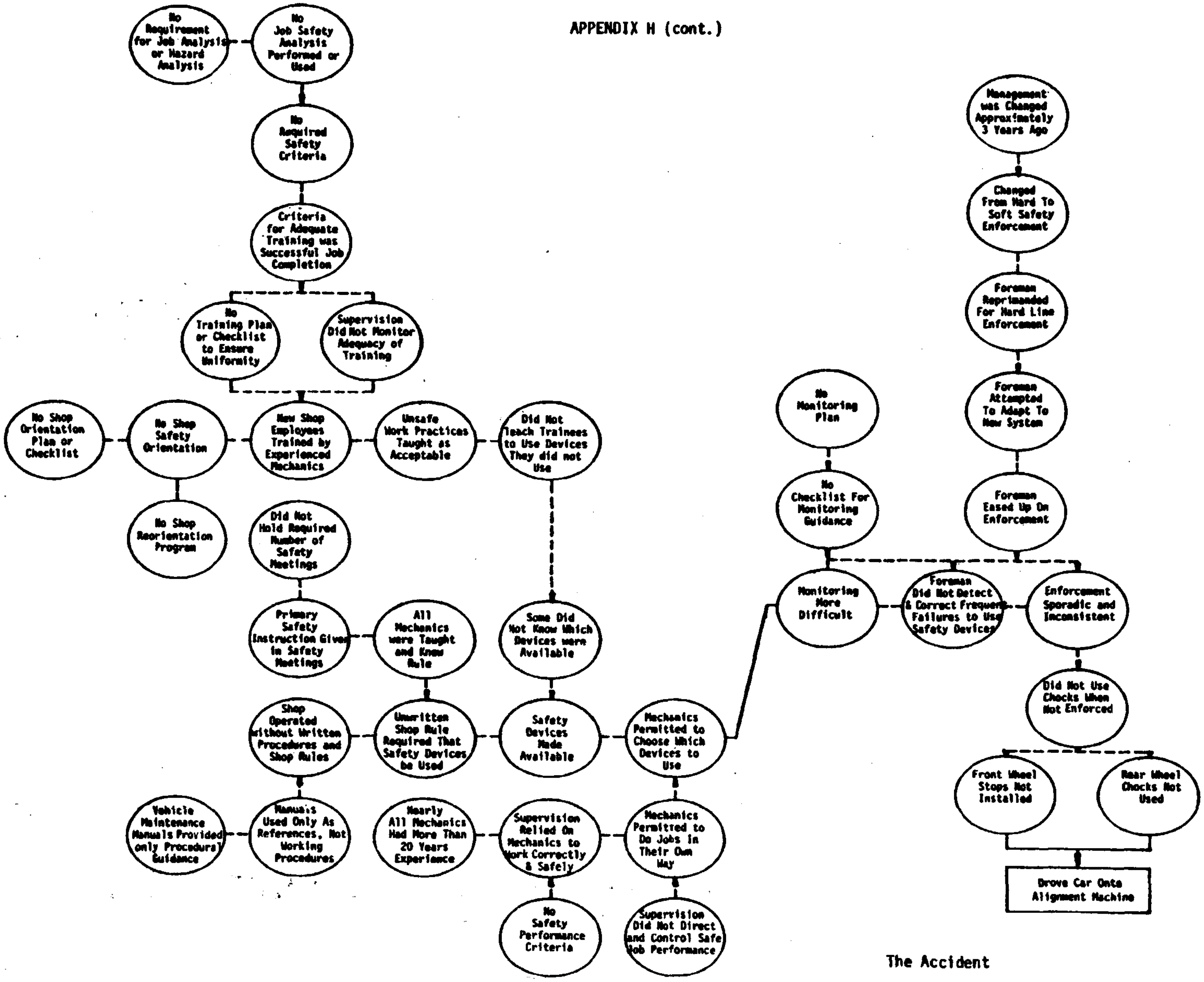
APPENDIX H

ALIGNMENT PIT ACCIDENT[9]

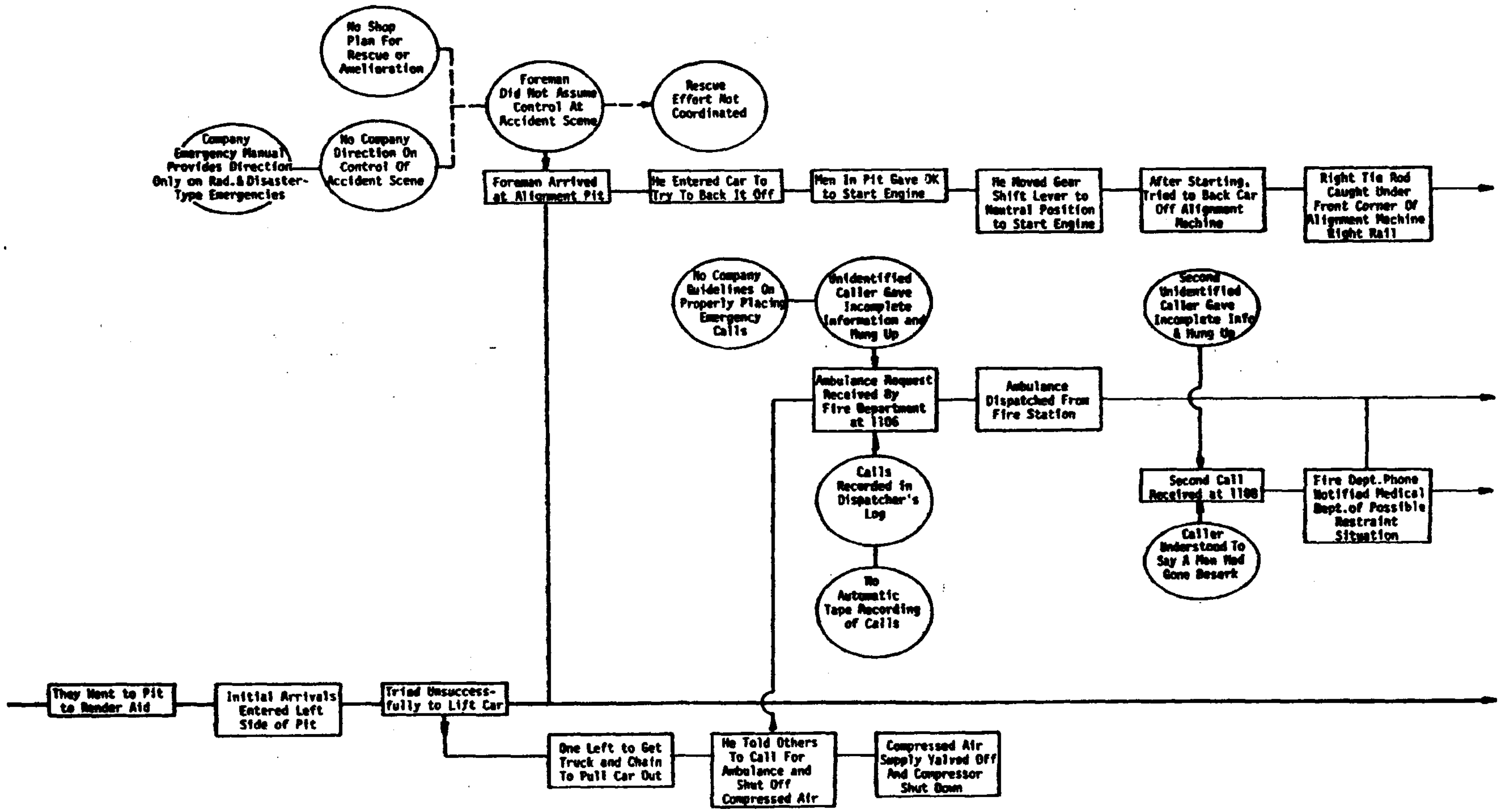


The Accident

APPENDIX H (cont.)

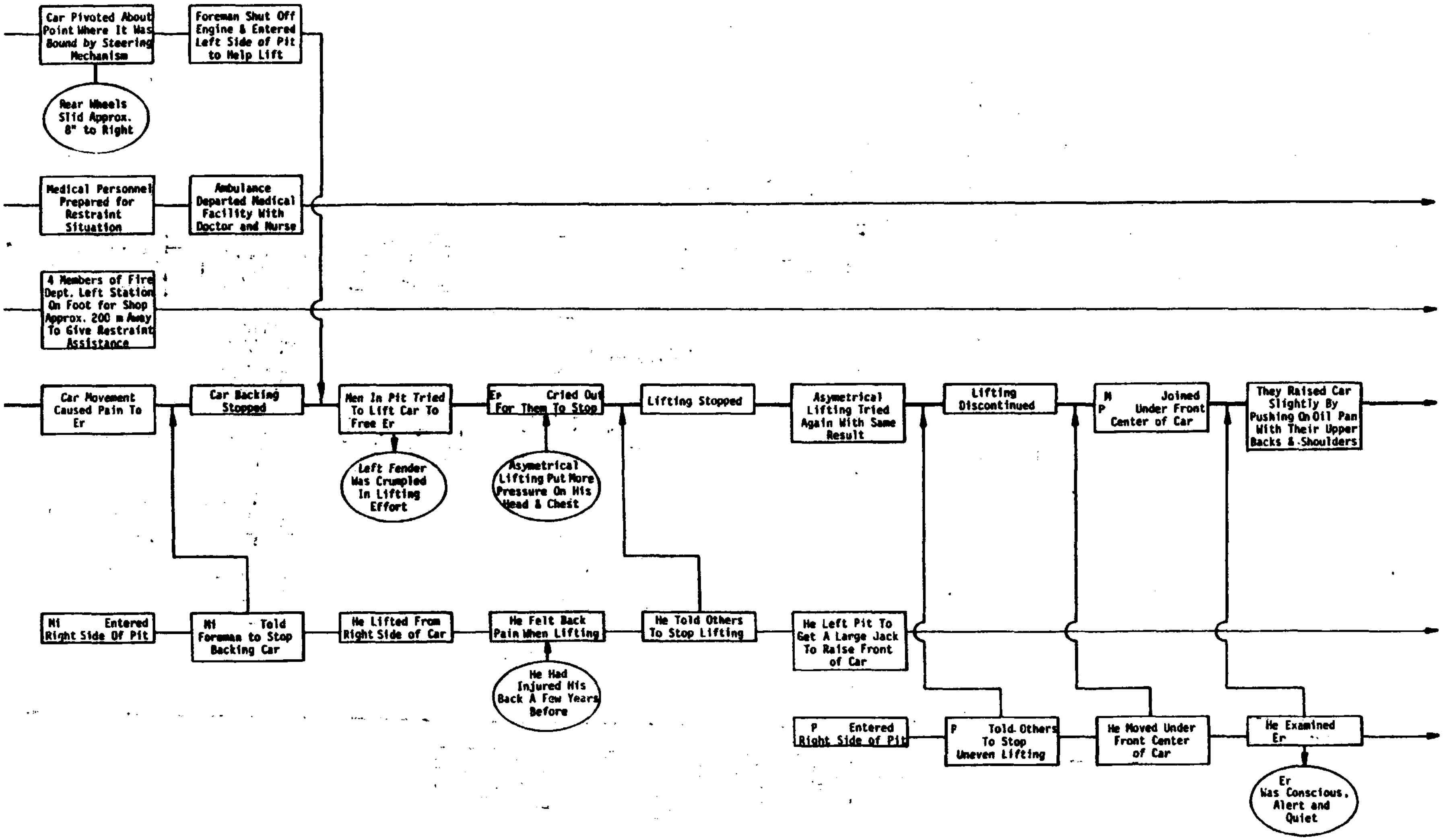


The Accident

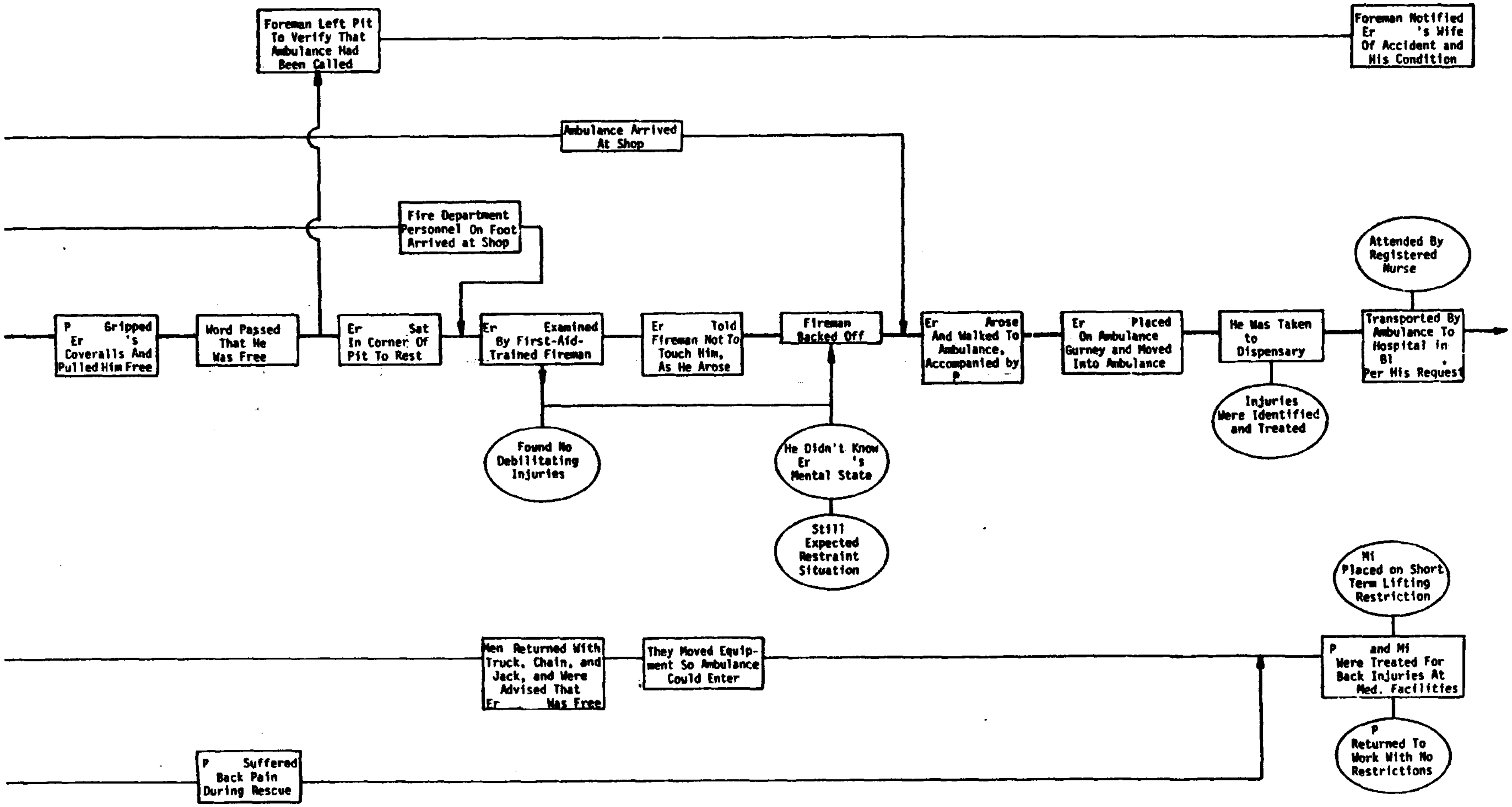


Amelioration

APPENDIX H (cont.)

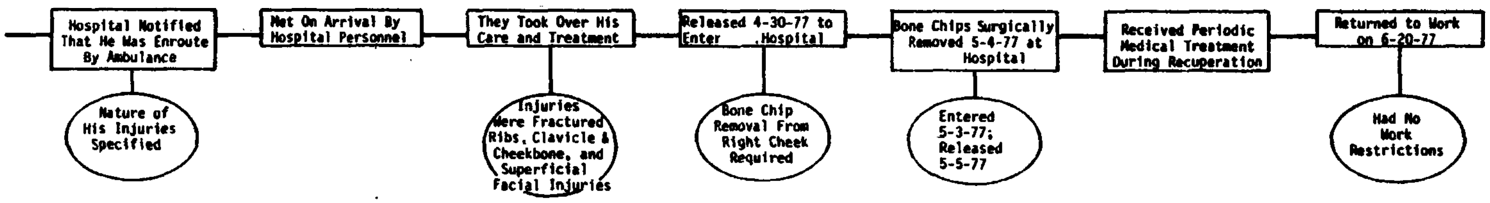


Amelioration



Amelioration

APPENDIX H (cont.)



Amelioration

Root Cause Coding

Once the investigator has created an Events and Causal Factors (E&CF) chart describing the incident, the next step in the root cause analysis process is to determine the root cause(s) for each causal factor identified in the chart. As defined in this handbook, a root cause is the most basic cause that can reasonably be identified and that management has control to fix. Root Cause Coding is simply a tool to help the investigator determine the underlying problems (i.e, root causes) associated with each causal factor. As defined in the "Events and Causal Factors Charting" section of this handbook, a causal factor is a major contributor to the incident. Generally, a causal factor will be an event that occured during the incident or a condition surrounding an event. A causal factor, as presented in the E&CF chart, is a description of WHAT happened to cause the incident. Before the investigator can recommend workable preventive measures, he or she needs to know WHY the causal factor occurred. Root Cause Coding helps the investigator to examine, in a systematic way, possible reasons for the causal factor.

The Cause Coding Process

For simplicity, a tree format was chosen for use in Root Cause Coding. The tree structures the reasoning process of the investigators. It ensures consistency across all investigations by requiring everyone to use the same process for categorizing causal factors. As can be seen in Figure RCC-I.1, the "Root Cause Tree" is actually a decision tree divided into many different sections called nodes. Starting at the top of the tree, the investigator codes each causal factor identified in the E&CF chart, ONE AT A TIME, by working down through the tree as far as known information will allow. For each causal factor, an investigator determines which top level node is applicable. Based on this decision, the investigator moves down to the next level and selects another applicable node. Only lower level nodes branching from the node chosen on the previous level can be considered for coding a causal factor. Paths through the "Root Cause Tree" flow only in a downward direction. By following the branches of the tree, nodes that do not apply to a given causal factor are not considered. This saves considerable time and effort during the coding process.

Figure RCC-I.2 shows the tree format and demonstrates how to follow a path from the top of the tree to lower levels. The arrows show examples of possible paths. When Root Cause Coding, the investigator always starts at the top of the tree with a given causal factor and proceeds down through the tree as far as possible given the information available. **Movement through the tree is always from the top down.** If information is not available to answer questions at the lowest level of the tree, the investigator can stop at a higher level. In Figure RCC-I.2, the path at the far left stops short of the lowest level.

The Root Cause Tree

At first glance, the "Root Cause Tree" appears to be quite unbalanced. The left side is far smaller than the right. Basically, the tree is divided into two major parts. Nodes on the left side of the tree are used to code causal factors dealing with equipment failure. The right side of the tree is used for coding causal factors related to personnel error. This division is illustrated in Figure RCC-I.3. The two parts of the tree are not mutually exclusive. Many equipment problems can be traced back to mistakes made by personnel. For example, a pump malfunction may be the result of the maintenance mechanic failing to follow the required procedure. In order to deal with scenarios like this, the two sides of the tree intersect at nodes dealing with personnel involved in the fabrication, installation, or maintenance of equipment. This allows coding from the "equipment side" of the tree to extend over to the "personnel side."

In addition to dividing the tree according to "Equipment" and "Personnel" nodes, it has also been divided into six major levels (i.e., Level A through Level F). Each level on the tree corresponds to a particular class of nodes. When coding a causal factor, Level A nodes require the investigator to make only broad distinctions. Level F nodes require that very specific questions be answered. The nodes on each level are shape-coded to help the investigator differentiate between levels. Table RCC-I.1 provides a description of the different levels of the tree.

Level A is the most general level of the tree. When coding a causal factor, the investigator is first asked to make broad distinctions concerning the type of difficulty involved. He or she might initially determine that a particular causal factor involved an "Equipment Difficulty," an "Operations Difficulty," or a "Technical Difficulty." Based on answers to these general

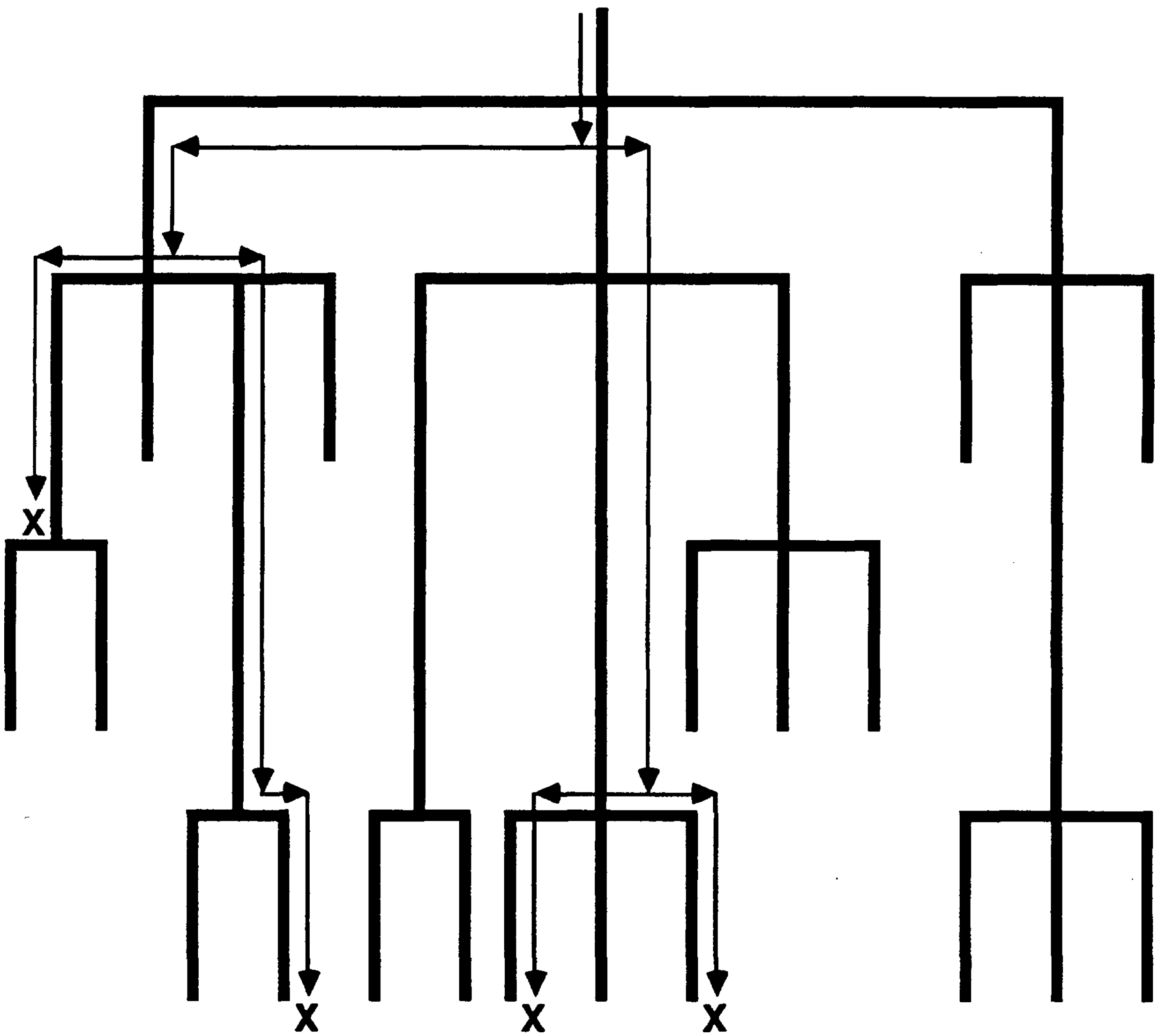


FIGURE RCC-I.2: USE OF TREE FORMAT

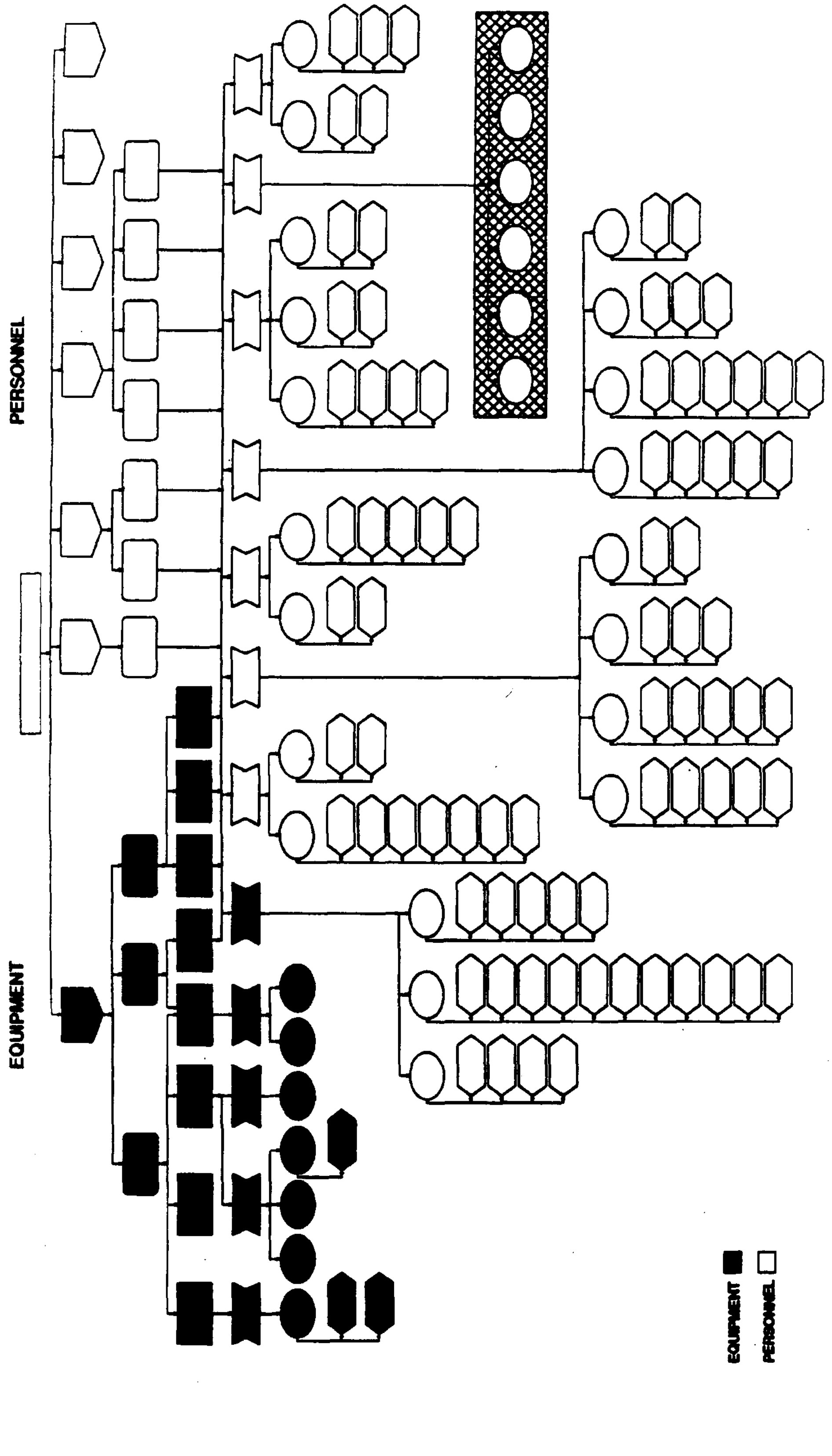
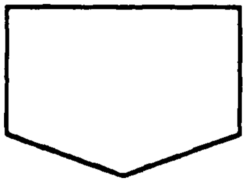
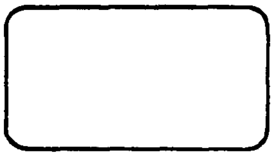
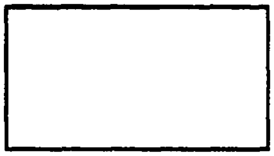
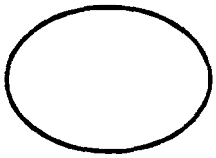


FIGURE RCC-I.3: EQUIPMENT AND PERSONNEL SECTIONS OF THE ROOT CAUSE TREE

TABLE RCC-I.1: LEVELS OF THE ROOT CAUSE TREE

LEVEL	SHAPE	DESCRIPTION
A		PRIMARY DIFFICULTY SOURCE
B		AREA OF RESPONSIBILITY
C		EQUIPMENT PROBLEM CATEGORY
D		MAJOR ROOT CAUSE CATEGORY
E		NEAR ROOT CAUSE
F		ROOT CAUSE

questions, the investigator branches down to more specific levels of the tree. Level B addresses the question of who was responsible for the incident. Here, the investigator determines the functional area of the organization involved in the causal factor. Examples of Level B nodes include, "Equipment Reliability/Design," "Production Department," "Savannah River Laboratory," and "Health Protection Department." Level C nodes address causal factors dealing specifically with equipment failure. These nodes can only be reached by going through the "Equipment" side of the tree. Examples include, "Unexpected Failure," "Design," and "Fabrication Difficulty (Vendor)."

When the investigator reaches Level D, he or she is required to categorize the causal factor using major root cause categories. Examples of Level D nodes include, "Design Review," "Procedures," "Administrative System," "Human Factors," and "Training." Using Level D nodes, the investigator begins to get specific about the nature of the causal factor. Nodes on Level E are known as near root causes. These are major subdivisions of the major root cause categories. Finally, Level F contains basic root causes. Level F, the lowest level of the tree, requires that the investigator answer very detailed questions about the causal factor. Examples of nodes located at the bottom of the tree include, "Wrong Revision [of procedure] Used," "Noisy Environment," or "Labels Less Than Adequate." The goal of Root Cause Coding is to allow the investigator to be as specific as possible about the underlying reasons for a given causal factor. If possible, the investigator should attempt to code to the Level F nodes.

Notes

The segment of the tree under the major root cause category "Personal Performance" is only to be coded to Level D. The shaded nodes on Level E are intended to provide guidance concerning the types of issues that would be considered personal performance problems. Due to the sensitivity of this segment of the tree, causal factors are coded only to Level D, "Personal Performance," and no further.

Many of the nodes are followed by the abbreviation LTA. This means that the item being described is "Less Than Adequate."

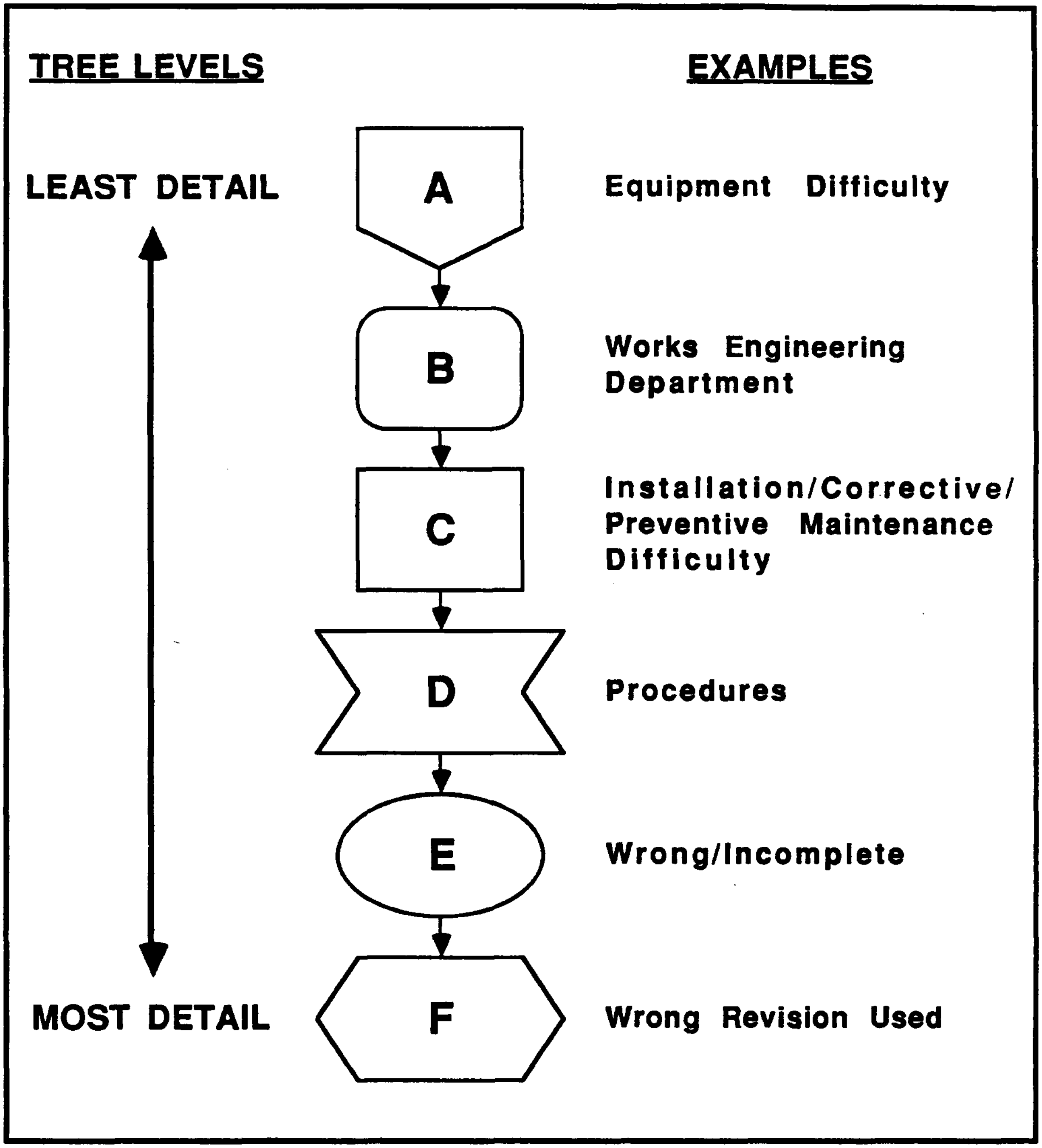
Root Cause Coding: A Simple Example

The best way to explain the mechanics of Root Cause Coding is to demonstrate with a simple example. Consider the following incident:

> An extraction process was in operation. Feed and solvent were pumped into a mixer-settler where the extraction process took place. During the operation, the operator on duty noticed that the flow rate for the solvent stream decreased rapidly and went to zero flow. The operator halted feed to the process and shut the operation down per procedures. Investigation into the cause of the incident revealed that the event was caused by a pump failure. The bearings in the pump seized, causing the pump to fail. It was determined that the bearings seized because they were improperly installed during routine maintenance. Therefore, the causal factor identified in the E&CF chart was "improper installation of the bearings during maintenance." When questioned, the maintenance personnel and their supervisor stated that they had followed the written procedures for the task. When the procedure was examined by investigators, it was found to be outdated. A newer revision should have been used, but it was never made available to the maintenance personnel.

Starting at the top of the "Root Cause Tree," the investigators determined that the source of the difficulty was an equipment problem. The first node coded was "Equipment Difficulty." Next, the area of responsibility was determined. Maintenance for the pump was the responsibility of mechanics in the Works Engineering Department. Therefore, the second node coded was "Works Engineering Department." The problem involved pump maintenance. Therefore, the third node determined to be applicable was "Installation/Corrective/Preventive Maintenance Difficulty." The reason for the improper installation of the bearings involved the procedure used. The fourth node coded was "Procedures." An outdated procedure was used so the fifth node coded was "Wrong/Incomplete." The wrong revision of the procedure was used; therefore, the last node coded (i.e., the root cause) was "Wrong Revision Used." Table RCC-I.2 illustrates the path followed through the "Root Cause Tree."

TABLE RCC-I.2: PATH CODED FOR SIMPLE EXAMPLE



Dual Coding of Nodes

Sometimes it may be appropriate to code a causal factor under more than one root cause node. This is referred to in the handbook as DUAL CODING. DUAL CODING is used whenever more than one root cause is responsible for the occurrence of a causal factor. A fairly common example of DUAL CODING occurs when an operator fails to follow a procedure. Operators are taught that they are always to follow procedures. This is policy. Therefore, a failure to follow procedures represents a breakdown in the administrative system that requires procedure use. When coding this causal factor, the investigator would DUAL CODE the action under "Procedures - Not Used" and "Standards, Policies, or Administrative Controls (SPAC) Not Used."

The causal factor in the pump example could also be DUAL CODED. The procedure administration system failed to provide the proper revision of the procedure to maintenance personnel. This causal factor could be DUAL CODED under "Wrong Revision Used" and under "Standards, Policies, or Administrative Controls (SPAC) LTA."

Root Cause Coding: An Example from Savannah River

The Savannah River incident described in the Events and Causal Factors section of the handbook contained six causal factors. On the following pages, these six causal factors will be root cause coded to demonstrate how coding is conducted for an actual incident investigation. The causal factors are summarized in Table RCC-I.3. The following is a brief description of the incident and how it occurred.

> The 2nd Plutonium Cycle was operated without the 2B mixer-settler (M-S) impellers turning. The incident was initiated when operating personnel failed to place a motor-generator (M-G) switchgear into the "normal feed" position and bypassed a configured interlock designed to prevent cycle operation without the impellers turning.

On the pages that follow, the causal factors identified in the E&CF chart are described. Following the description of each causal factor, the root causes are presented, and an explanation of the coding process is given. DUAL CODING principles are demonstrated for Causal Factors 1, 2, 3, and 6.

TABLE RCC-I.3: CAUSAL FACTORS FOR SAVANNAH RIVER EXAMPLE

CAUSAL FACTOR	E&CF CHART SYMBOLS
# 1	Operator looked at wrong switchgear
# 2	2-9-87 4-12 Operator took impeller alarm point for 2B M-S "off scan"
# 3	Supervisor allowed multiple attempts without checking T & R DPSOL
# 4	RPM reflected speed generated by the M-G set and NOT impeller speed
# 5	4-12 Shift relayed that everything was "OK," so no one rechecked the switchgear
# 6	2-10-87 12-8 Supervisor placed alarm points in "remote off scan"

CAUSAL FACTOR #1: Operator looked at wrong switchgear.

The Distributive Control System (DCS) prompted the operator to set the Motor-Generator (M-G) switchgear for both the 2A and 2B Mixer-Settlers (M-S) to the "normal feed " position. When the operator went to the motor control center to verify the switchgear position, he looked at the wrong switchgear.

Root Cause #1: <u>Labels Less Than Adequate</u>

Operations Difficulty
Production Department
Human Factors
Man-Machine Interface LTA
Labels LTA

Labels in the motor control center were not clear enough for the operator to be absolutely certain that he had identified the correct switchgear.

Root Cause #2: <u>Ergonomics Poor</u>

Operations Difficulty
Production Department
Human Factors
Man-Machine Interface LTA
Ergonomics Poor

The motor control center has a number of large switchgears which are similar in appearance. The applicable switchgear was not in clear sight of the operator, but was hidden behind some other features in the room. The operator verified the position of one of the more conspicuous switches in the motor control center.

Root Cause #3: **Incomplete Training**

Operations Difficulty
Production Department
Training
Methods LTA
Incomplete Training

The investigation revealed that the operator who went to verify the position of the switchgear had probably not been required to use this particular switchgear in the past. If he had been shown the switchgear as part of his training, it is unlikely that he would have forgotten its location.

Figure RCC-I.4 and Table RCC-1.4 show the path taken through the "Root Cause Tree." The problem was an "Operations Difficulty" involving an operator in the "Production Department." The poor labeling and the hidden switchgears are "Human Factors" problems involving a less than adequate "Man-Machine Interface." The root causes coded were "Labels LTA" and "Ergonomics Poor." The fact that the operator probably had never been required to use the switchgear in the past is a "Training" problem. The methods of training were not adequate; therefore, the root cause was coded as "Incomplete Training."

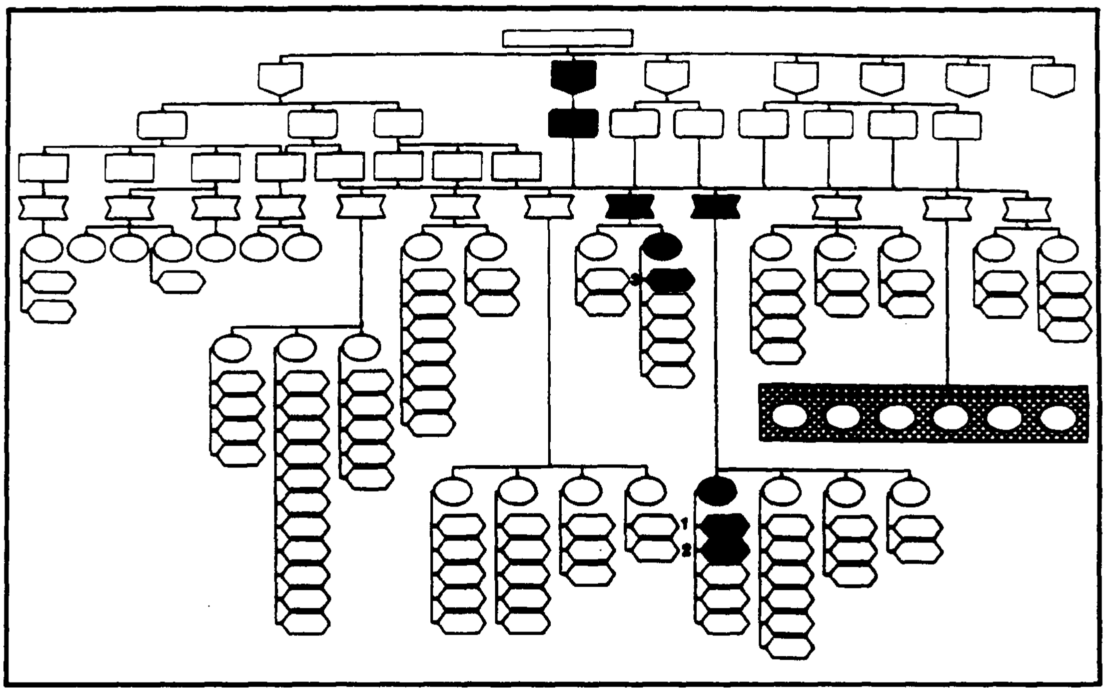


FIGURE RCC-I.4: CAUSAL FACTOR #1 PATHS THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.4: CAUSAL FACTOR #1 ROOT CAUSE CODES

	ROOT CAUSE		
LEVEL	# 1	# 2	# 3
A	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT
C			
D	HUMAN FACTORS	HUMAN FACTORS	TRAINING
E	MAN-MACHINE INTERFACE LTA	MAN-MACHINE INTERFACE LTA	METHODS LTA
F	LABELS LTA	ERGONOMICS POOR	INCOMPLETE TRAINING

CAUSAL FACTOR #2: Operator took impeller alarm point for 2B M-S "off scan."

After an initial attempt to initiate the automatic "Start-up Operation," the DCS operator took the impeller alarm point for the 2B M-S "off scan." This resulted in the suppression of both the visual and auditory failure alarms on the DCS console. For the operator to carry out this action, the supervisor was required to turn a key on the console, thereby, "approving" modification of the system.

Root Cause#1: **<u>Supervision Less Than Adequate</u>**

Operations Difficulty
Production Department
Immediate Supervision
Supervision During Work
Supervision LTA.

The supervisor allowed the DCS operator to modify a system parameter without using the required DPSOL. The procedure is a Use Every Time (UET) DPSOL and requires the approval of the Technology Department and Area supervisors prior to system modification.

Root Cause #2: **<u>Procedure Not Used - Inconvenient For Use</u>**

Operations Difficulty
Production Department
Procedures
Not Used
Not Available Or Inconvenient For Use

It has become accepted practice not to use the UET DPSOL. Although normal operations do not require routine parameter changes, trouble-shooting often results in modifications. Completing the DPSOL for a number of these changes results in a substantial amount of paperwork and many signature approvals. Technology Department and Area supervision must be reached each time a change is to be made. Technology Department supervisors are not available on non-day shifts. Due to these inconveniences, the DPSOL has been used in consistently.

Root Cause #3: Standards, Policies, Or Administrative Controls (SPAC) Not Used - Enforcement LTA

Operations Difficulty
Production Department
Administrative System
SPAC Not Used
Enforcement LTA

It has become accepted practice not to use a UET DPSOL. In the case of DCS operation, SRP's policy of operating by procedure has not been enforced by the management system.

Root Cause #4: Instruments/Displays/Controls LTA

Operations Difficulty
Production Department
Human Factors
Man-Machine Interface LTA
Instruments/Displays/Controls LTA

The absence of alarm signals may have led operating personnel to believe that the problem no longer existed, even though a message indicating impeller failure was generated at the DCS consoles and printer during each start-up attempt. During the course of the incident, personnel disregarded the impeller failure message numerous times, indicating that the signal by itself was not sufficient to convince them that the failure was real.

Figure RCC-I.5 and Table RCC-I.5 show the path taken through the "Root Cause Tree." The problem was an "Operations Difficulty" involving the "Production Department." The supervisor allowed the DCS parameters to be modified without use the required DPSOL. This involves "Immediate Supervision" under "Supervision During Work." The root cause was coded as "Supervision Less Than Adequate." The fact that the UET DPSOL was not used involves a "Procedures" problem. The procedure was "Not Used" because it was inconvenient. Therefore, the root cause coded was "Not Available Or Inconvenient For Use." The fact that it has become accepted practice not to use a UET DPSOL involves a problem with the "Administrative System." The policy of operating by procedures was violated indicating that "Standards, Policies, Or Administrative Controls were Not Used." The root cause was "Enforcement Less Than Adequate." Failure to heed the impeller failure message suggests a problem with the display. This is a "Human Factors" problem involving "Man-Machine Interface LTA." The root cause was "Instruments/ Displays/Controls LTA."

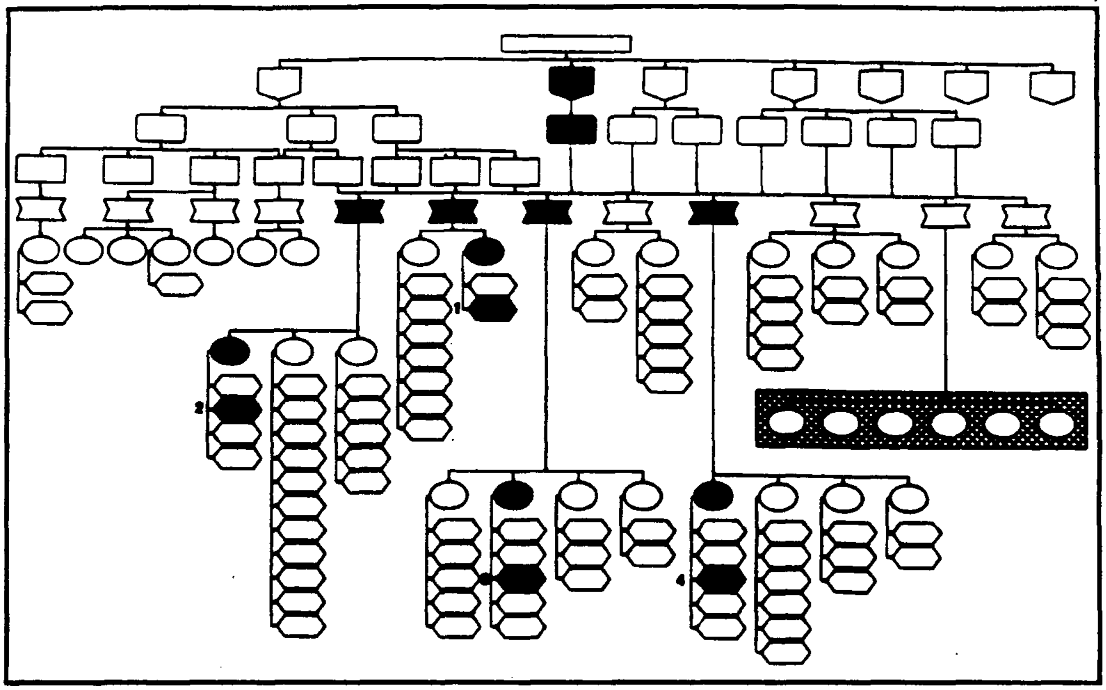


FIGURE RCC-I.5: CAUSAL FACTOR #2 PATHS THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.5: CAUSAL FACTOR #2 ROOT CAUSE CODES

	ROOT CAUSE			
LEVEL	**# 1**	**# 2**	**# 3**	**# 4**
A	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT
C				
D	IMMEDIATE SUPERVISION	PROCEDURES	ADMINISTRATIVE SYSTEM	HUMAN FACTORS
E	SUPERVISION DURING WORK	NOT USED	SPAC NOT USED	MAN-MACHINE INTERFACE LTA
F	SUPERVISION LTA	NOT AVAILABLE OR INCONVENIENT FOR USE	ENFORCEMENT LTA	INSTRUMENTS/ DISPLAYS/ CONTROLS LTA

CAUSAL FACTOR #3: Supervisor allowed multiple start-up attempts without checking T&R DPSOL.

The DCS operator made multiple attempts to start the system. Each time, the supervisor was required to acknowledge the attempt by turning a key on the DCS console. The supervisor did not refer to the appropriate Training and Reference (T&R) procedure for information on how to interpret the impeller failure messeges presented by the DCS.

Root Cause #1: **Supervision Less Than Adequate**

Operation Difficulty
Production Department
Immediate Supervision
Supervision During Work
Supervision LTA

The supervisor allowed multiple start-up attempts even though the DCS generated impeller failure messages on the console and at the printer.

Root Cause #2: **Training**

Operation Difficulty
Production Department
Training

The supervisor did not have sufficient knowledge of the system to recognize the problem.

Root Cause #3: **T and R Procedure**

Operation Difficulty
Production Department
Procedures
Not Used
Training and Reference Procedure

The supervisor did not refer to the T&R procedure for assistance in interpreting the impeller failure message.

Figure RCC-I.6 and Table RCC-I.6 show the path taken through the "Root Cause Tree." The problem was an "Operations Difficulty" involving the "Production Department." The supervisor allowed multiple start-up attempts when impeller failure messages were being generated. This involves "Immediate Supervision" under "Supervision During Work." The root cause was coded as "Supervision Less Than Adequate." The fact that the supervisor did not have sufficient knowledge of the system to recognize the problem indicates a problem with "Training." This is a case where no further information regarding the indivdual's training was available. The causal factor was coded only to "Training" because further nodes could not be coded based on the known information. The T&R "Procedure" was "Not Used" because it is a "Training And Reference Procedure" and is not required to be used at all times.

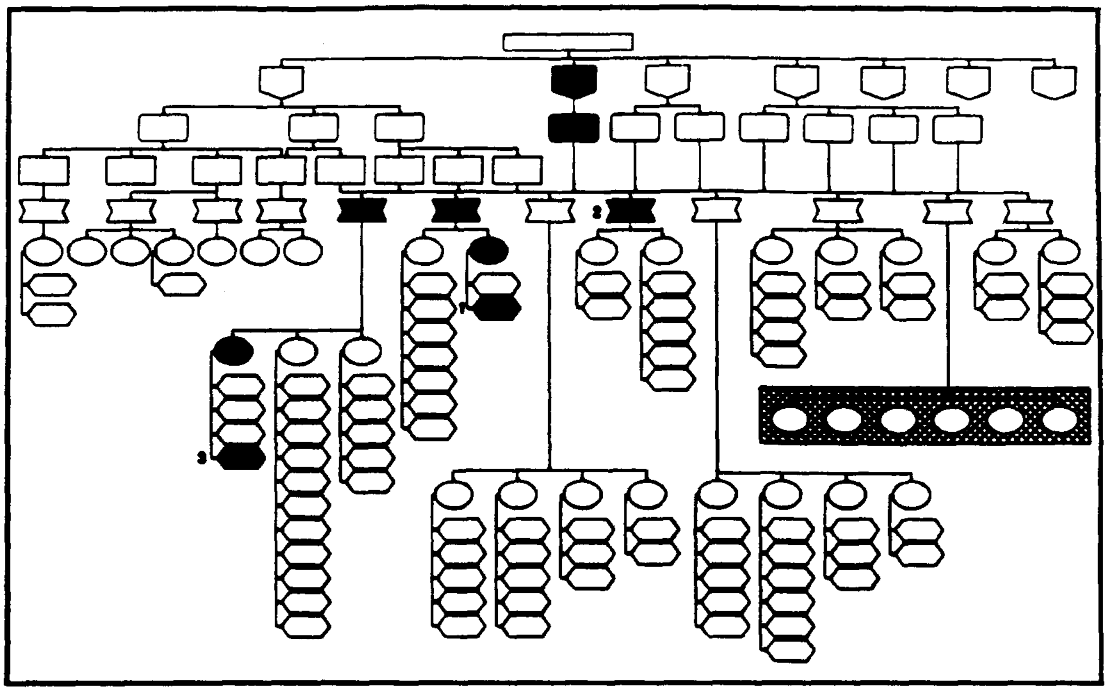


FIGURE RCC-I.6: CAUSAL FACTOR #3 PATHS THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.6: CAUSAL FACTOR #3 ROOT CAUSE CODES

	ROOT CAUSE		
LEVEL	# 1	# 2	# 3
A	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT
C			
D	IMMEDIATE SUPERVISION	TRAINING	PROCEDURES
E	SUPERVISION DURING WORK		NOT USED
F	SUPERVISION LTA		TRAINING AND REFERENCE PROCEDURE

CAUSAL FACTOR #4: No recheck of switchgear was made at shift change.

At the shift change the DCS operator did not recheck the M-G switchgear position in the motor control center because the previous shift indicated that everything was "OK." This is accepted practice.

Root Cause #1: **<u>Communication Between Shifts Less Than Adequate</u>**

Operations Difficulty
Production Department
Communications
Turnover LTA
Communication Between Shifts LTA

Erroneous information was passed from one shift to the next. The later shift failed to follow the DCS prompts requiring the switchgear position to be verified.

Figure RCC-I.7 and Table RCC-I.7 show the path taken through the "Root Cause Tree." The problem was an "Operations Difficulty" involving the "Production Department." Improper information being given from one shift to the other. This falls under the "Communications" segment of the tree. Shift turnover was less than adequate; therefore, the causal factor was coded under "Communication Between Shifts LTA."

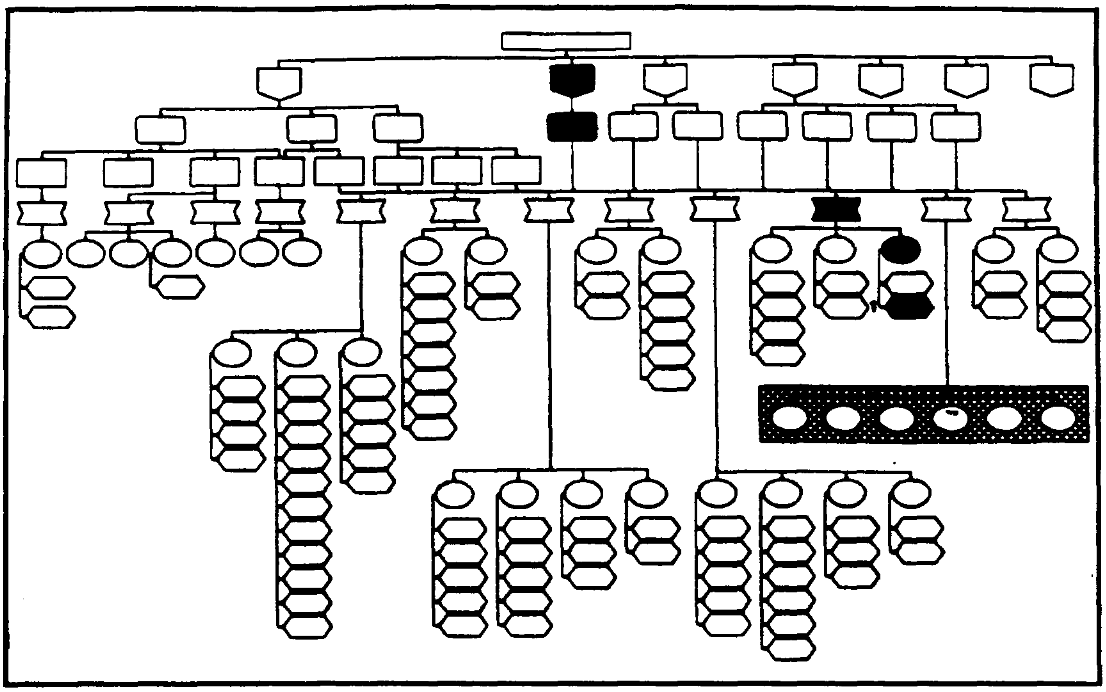


FIGURE RCC-I.7: CAUSAL FACTOR #4 PATH THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.7: CAUSAL FACTOR #4 ROOT CAUSE CODE

LEVEL	ROOT CAUSE #1
A	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT
C	
D	COMMUNICATIONS
E	TURNOVER LTA
F	COMMUNICATION BETWEEN SHIFTS LTA

CAUSAL FACTOR #5: RPM reflected speed generated by the M-G set and NOT impeller speed.

The supervisor and operator on the later shift believed that the impellers were operating because they saw a readout showing the proper speed (RPM). The readout reflected the speed (RPM) generated by the M-G set and not the speed of the impellers.

Root Cause #1: **<u>Instruments/Displays/Controls Less Than Adequate</u>**

Operations Difficulty
Production Department
Human Factors
Man-Machine Interface LTA
Instruments/Displays/Controls LTA

The speed (RPM) indication resulted in an erroneous assumption by the operating personnel. They believed that the speed reading reflected the impeller speed and discounted other cues that indicated otherwise.

Figure RCC-I.8 and Table RCC-I.8 show the path taken through the "Root Cause Tree." The problem was an "Operations Difficulty" involving the "Production Department." The personnel believed the instruments were reading out impeller speed when actually it was something else. This is a "Human Factors" problem under "Man-Machine Interface LTA." The display caused an erroneous assumption to be made; therefore, the root cause was coded "Instruments/Displays/Controls LTA."

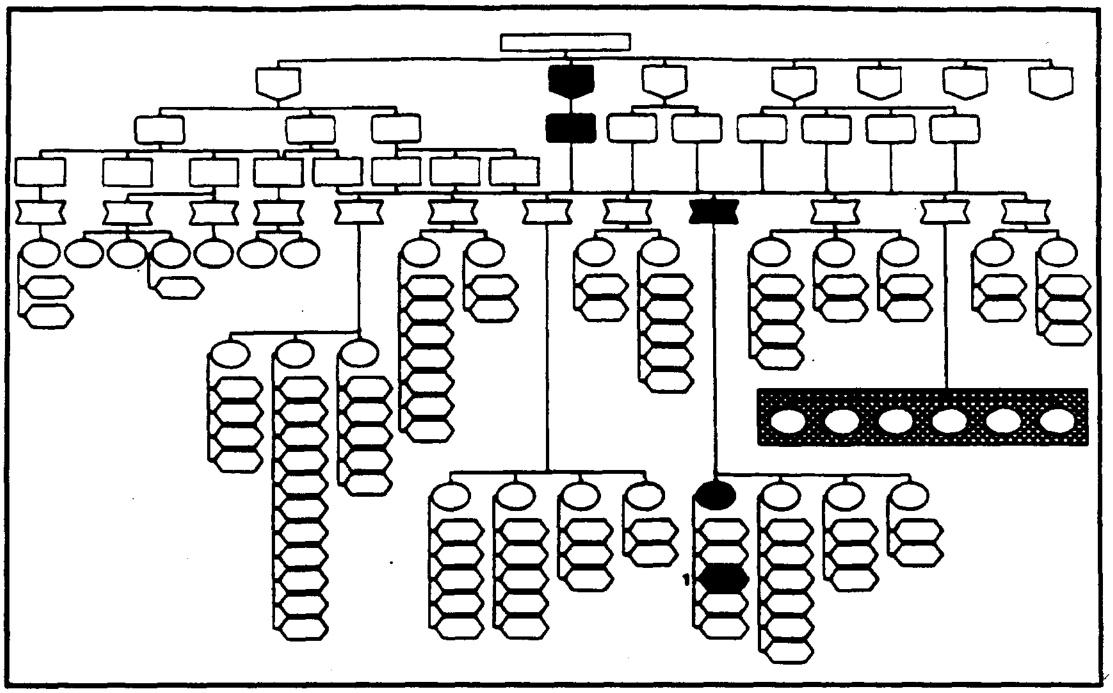


FIGURE RCC-I.8: CAUSAL FACTOR #5 PATH THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.8: CAUSAL FACTOR #5 ROOT CAUSE CODE

LEVEL	ROOT CAUSE # 1
A	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT
C	
D	HUMAN FACTORS
E	MAN-MACHINE INTERFACE LTA
F	INSTRUMENTS/ DISPLAYS/ CONTROLS LTA

CAUSAL FACTOR #6: Later shift supervisor placed DCS alarm points in"remote off scan."

The supervisor on the later shift went into "Tune" mode and placed the alarm points "remote off scan." This allowed start-up without the 2B M-S impellers.

Root Cause #1: <u>Procedure Not Used - Inconvenient For Use</u>

Operations Difficulty
Production Department
Procedures
Not used
Not Available Or Inconvenient For Use

Taking the alarm points "remote off scan" requires the use of a UET DPSOL. This procedure, which requires signatures of both Technology Department and Day supervision, was not used because these persons were not available at the time

Root Cause #2: <u>Standards, Policies, Or Administrative Controls Not Used - Enforcement Less Than Adequate</u>

Operations Difficulty
Production Department
Administrative System
SPAC Not Used
Enforcement LTA

It had become accepted practice to modify parameters without completing the required UET DPSOL. This inconsistent enforcement makes it appear to operating personnel that they are not required to use the DPSOL in all situations.

Figure RCC-I.9 and Table RCC-I.9 show the path taken through the "Root Cause Tree." This causal factor was coded in the same manner as Causal Factor #2.

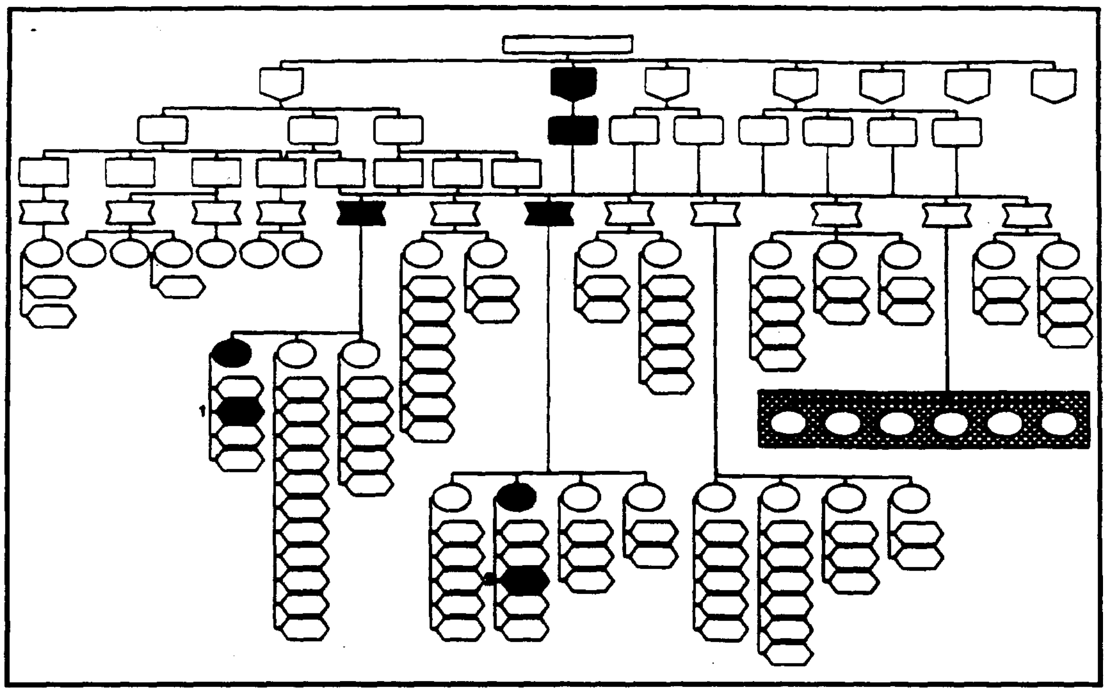


FIGURE RCC-I.9: CAUSAL FACTOR #6 PATHS THROUGH THE ROOT CAUSE TREE

TABLE RCC-I.9: CAUSAL FACTOR #6 ROOT CAUSE CODES

LEVEL	ROOT CAUSE #1	ROOT CAUSE #2
A	OPERATIONS DIFFICULTY	OPERATIONS DIFFICULTY
B	PRODUCTION DEPARTMENT	PRODUCTION DEPARTMENT
C		
D	PROCEDURES	ADMINISTRATIVE SYSTEM
E	NOT USED	SPAC NOT USED
F	NOT AVAILABLE OR INCONVENIENT FOR USE	ENFORCEMENT LTA

This example of root cause coding is more complicated than many and less complex than others. It does a good job; however, of showing the type of information that can be obtained when a logical, thorough root cause analysis is performed.

Explanation of Nodes

On the following pages, all of the nodes on the "Root Cause Tree" are defined. In many cases, examples are presented. To simplify description of the nodes, the "Root Cause Tree" is divided into segemnts. The segments are as follows.

1) Primary Difficulty
2) Equipment Difficulty
3) Area of Responsibility
4) Procedures
5) Immediate Supervision
6) Administrative System
7) Training
8) Human Factors
9) Communications
10) Personal Performance
11) Quality Assurance

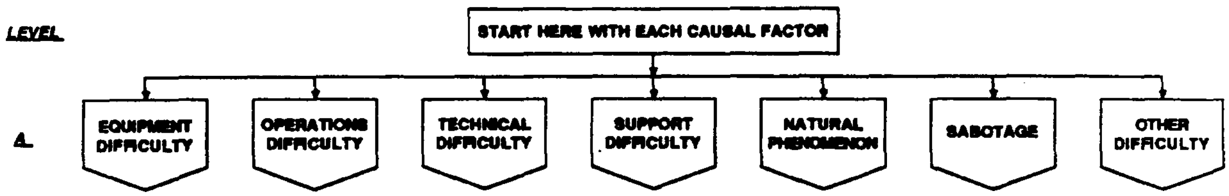
The segments are presented in the yellow tabbed sections that follow. At the beginning of each section is an explanation of the segment of the tree to be discussed. Following the explanation of the segment, the nodes are defined. Node definitions are presented in the form of questions. These questions will help the investigator to determine whether or not a node is appropriate for coding a particular causal factor. Notes offering more information about a node are given where appropriate.

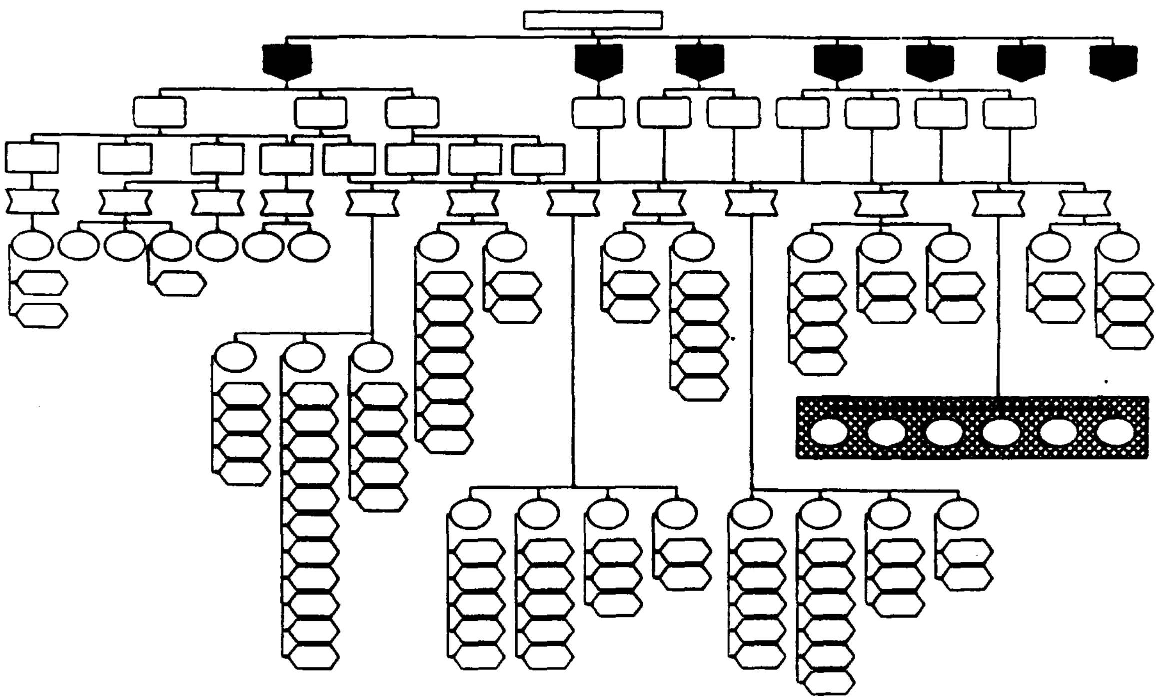
Primary Difficulty Source

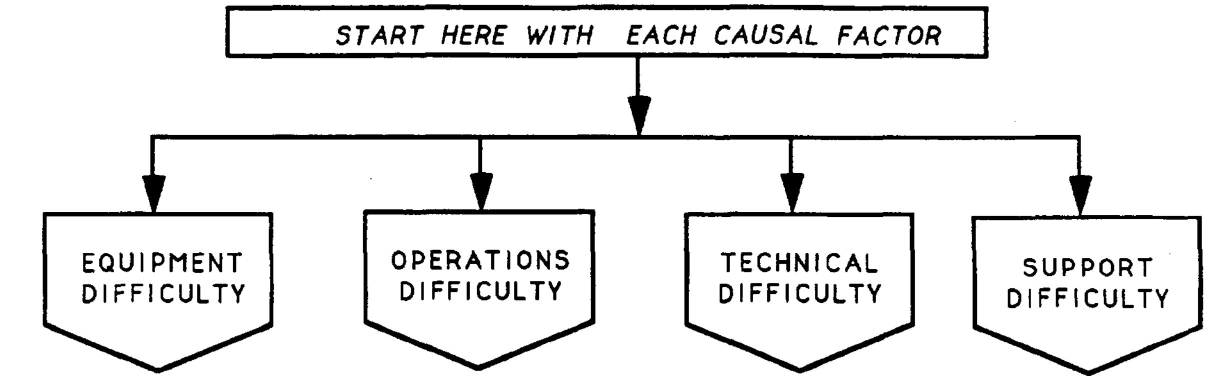
Level A is the most general level of the "Root Cause Tree." It is divided into seven nodes, each describing a broad source of difficulty. Nodes in this segment of the tree include: "Equipment Difficulty," "Operations Difficulty," "Technical Difficulty," "Support Difficulty," "Natural Phenomenon," "Sabotage," and "Other Difficulty." The first four of these high level nodes branch to lower levels of the tree. The last three nodes stand alone.

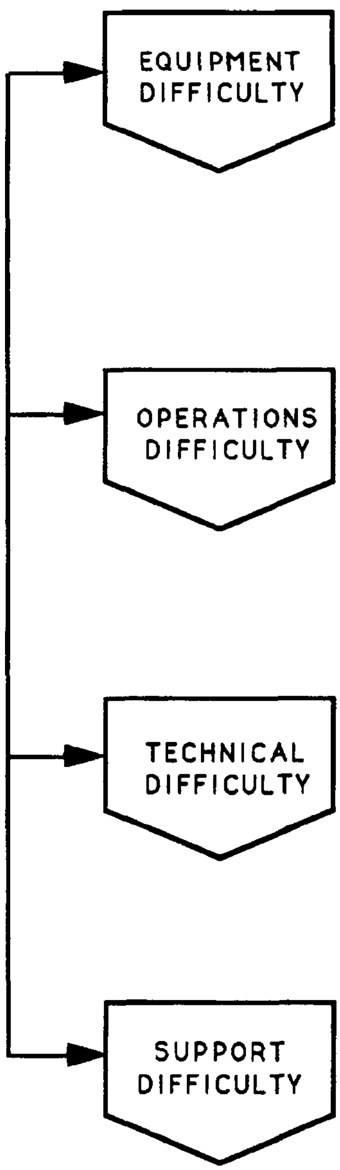
When preparing to categorize a causal factor, the first question that the investigator should ask is "What type of problem was involved?" Selection of the most appropriate Level A node is the first step in defining the path to be followed through the tree. For a complete explanation of this segment of the tree, see the pages that follow. Questions are provided to help the investigator determine which Level A nodes are appropriate for a particular causal factor.

Primary Difficulty Source









EQUIPMENT DIFFICULTY

Was the event initiated by an equipment problem?
Was the event first recognized because of an equipment failure or malfunction?

OPERATIONS DIFFICULTY

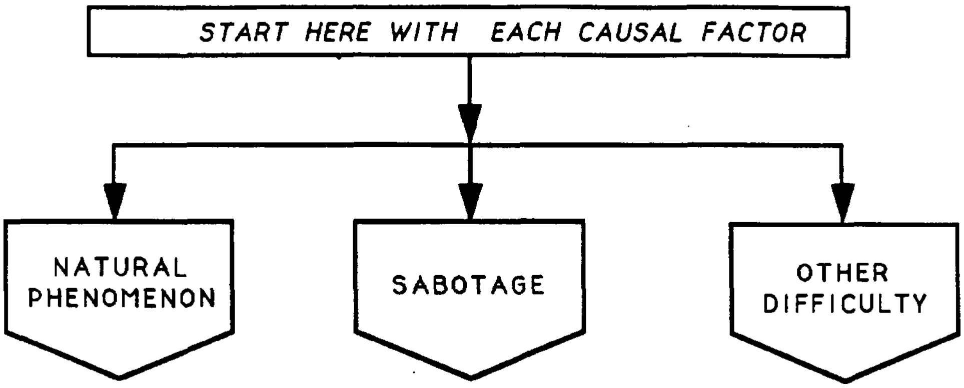
Was there an operations problem associated with the causal factor?
NOTE: If someone from an Operations Department outside of the primary organization is involved in the difficulty, then code under "Support Difficulty." For example, if a Separations Department operator is involved in a Raw Materials incident, then the "Support Difficulty" node should be used.

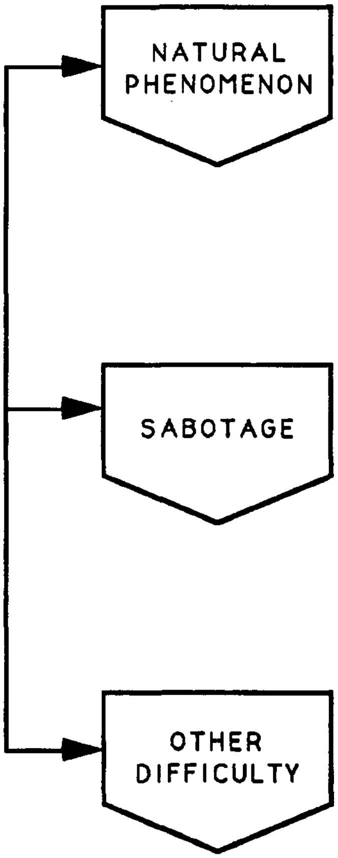
TECHNICAL DIFFICULTY

Could adequate technical support, surveillance, or coverage by personnel in the Technology Department or the Savannah River Laboratory have prevented occurrence of the causal factor?
NOTE: If someone from a Technology Department outside of the primary organization is involved in the difficulty, then code under "Support Difficulty." For example, if a Separations Technology Department engineer is involved in a Raw Materials incident, then the "Support Difficulty" node should be used.

SUPPORT DIFFICULTY

Did support personnel (i.e., employees in the Health Protection, Laboratories, Power, or other Support Departments) contribute to the causal factor?





NATURAL PHENOMENON: Was a tornado, hurricane, earthquake, lightning, or other natural phenomenon at fault?

SABOTAGE: Were malicious acts responsible for the event?
Did malicious lack of action contribute to the causal factor?

OTHER DIFFICULTY: Any cause that cannot be coded elsewhere on the tree should be coded using this category.
NOTE: **If sufficient detail is not available to determine even the most basic cause, then this category should be used.**

Equipment Difficulty

Incidents are sometimes due to problems with equipment. For example, gauges may show incorrect readings, motors may cease to function, or parts may loosen. Causal factors involving equipment failure, malfunction, design, or misuse should be coded using the "Equipment Difficulty" segment of the "Root Cause Tree."

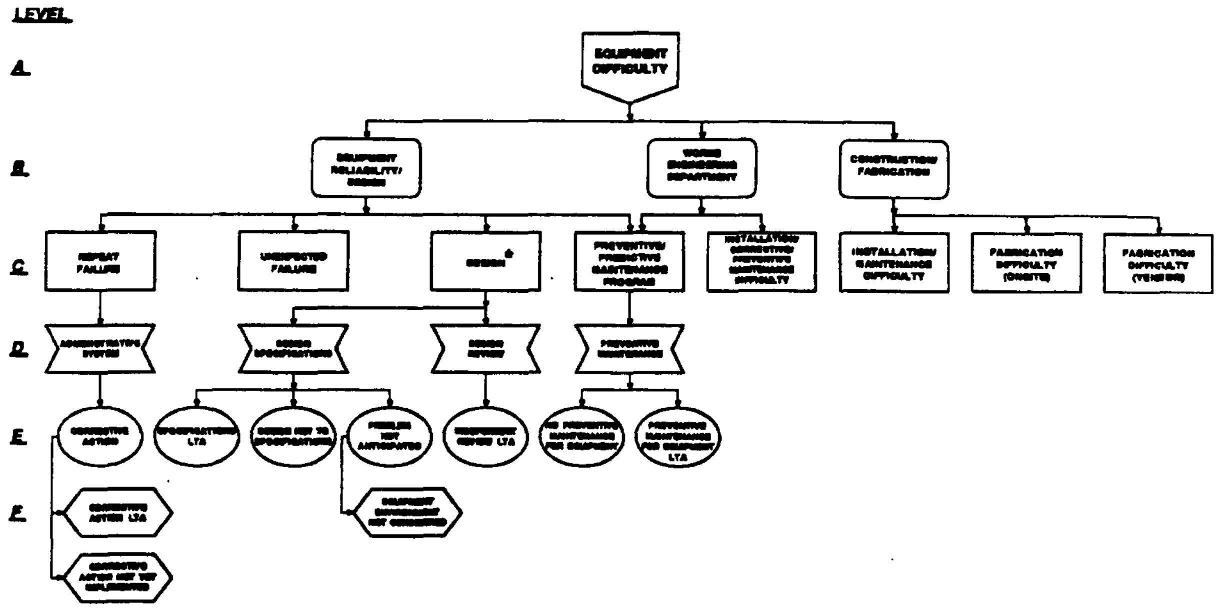
After the investigator has determined that a causal factor should be coded as "Equipment Difficulty," the next step is to determine the functional area of the organization responsible for the problem. "Equipment Difficulty," on Level A, branches to three Level B nodes. These are "Equipment Reliability/Design," "Works Engineering Department," and "Construction/Fabrication."

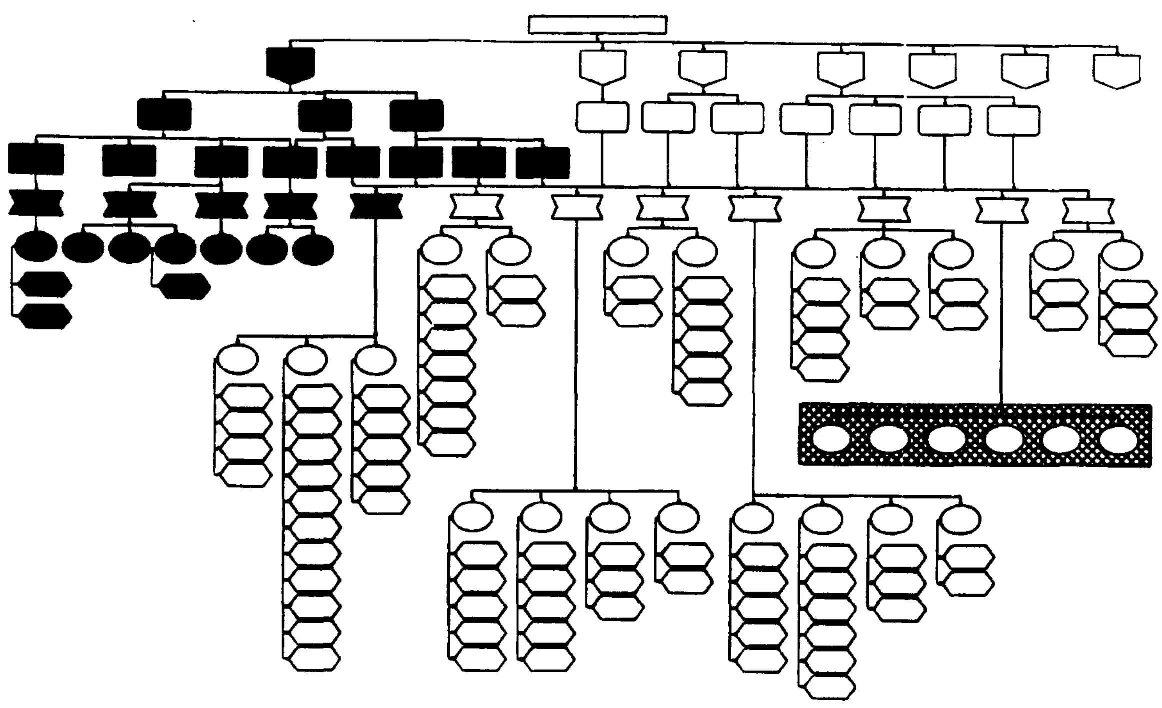
Once the area of responsibility has been determined, the specific type of equipment problem must be identified. Level C nodes are used for this purpose. Level C nodes are found only on the "equipment side" of the tree. Four of these nodes, "Repeat Failure," "Unexpected Failure," "Design," "Preventive/Predictive Maintenance Program," branch from "Equipment Reliability/Design" on Level B. Two nodes branch from the "Works Engineering Department" node. These are "Preventive/Predictive Maintenance Program" and "Installation/Corrective/Preventive Maintenance Difficulty." Level C nodes branching from "Construction/ Fabrication" include "Installation/Maintenance Difficulty," "Fabrication Difficulty (Onsite)," and "Fabrication Difficulty (Vendor)."

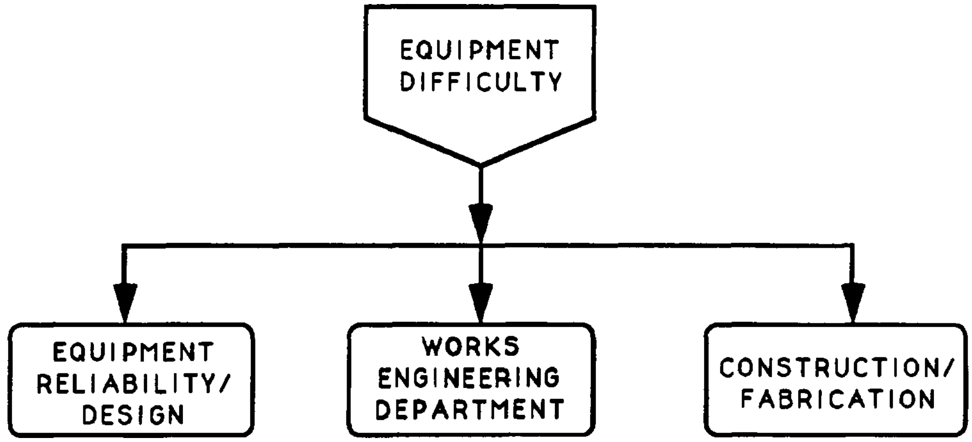
When the equipment problem category has been coded, the investigator attempts to further categorize the causal factor into the applicable major root cause category. From this point, near root causes, and finally root causes, are coded. Equipment failure, design, and preventive maintenance problems are coded down through specific branches on the left side of the tree. These nodes describe problems that are strictly related to equipment or programs. Installation, corrective/preventive maintenance, and fabrication difficulties usually deal with some type of human error; therefore, these nodes branch to the personnel side of the tree. Near root causes that can be coded for personnel related difficulties are discussed later in this section of the handbook.

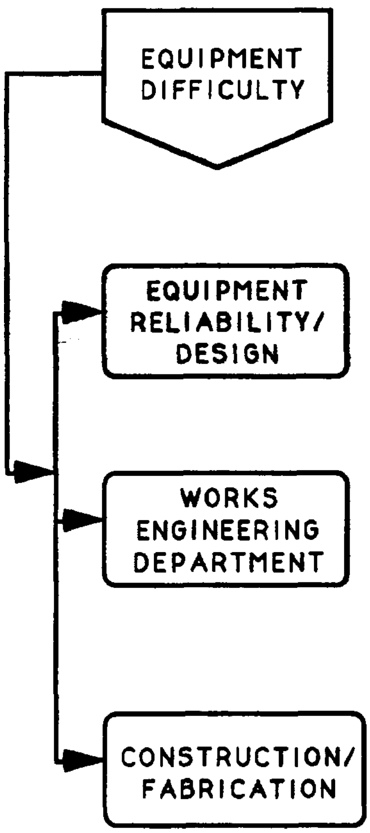
Definitions for all of the nodes under "Equipment Difficulty" are located on the following pages. Examples are included for reference.

Equipment Difficulty







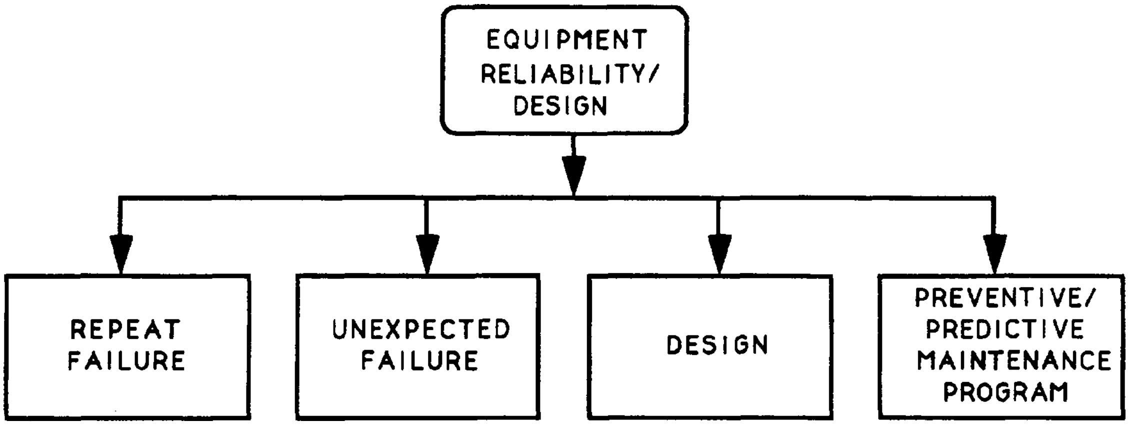


EQUIPMENT DIFFICULTY: Was the event initiated by an equipment problem? Did equipment failure or malfunction contribute to the difficulty?

EQUIPMENT RELIABILITY/DESIGN: Was the equipment difficulty or malfunction a repeat or unexpected failure (reliability problem)? Was the difficulty caused by a design error?

WORKS ENGINEERING DEPARTMENT: Were Works Engineering personnel responsible for the equipment difficulty or otherwise related to the causal factor?

CONSTRUCTION/FABRICATION: Was the causal factor related to construction, fabrication, or vendor activities?



EQUIPMENT RELIABILITY/ DESIGN

Was the equipment difficulty or malfunction a repeat or unexpected failure (reliability problem)?
Was the difficulty caused by a design error?

REPEAT FAILURE

Was the equipment malfunction a failure known to have occurred in the past?
Has management had reasonable time to implement corrective action for the previous failure(s)?

UNEXPECTED FAILURE

Was the failure unpredictable, unforeseen, or unexpected for the piece of equipment?
Was the failure unanticipated from past experience, industry norms, or expected equipment life?
Was failure of the equipment a known and assumed risk, judged acceptable if failure occurred?

NOTE: All failures can be said to be "unexpected" in that the exact time of failure cannot be predicted. The "Unexpected Failure" category should be used only when the cause of failure cannot be coded elsewhere.

Continued on next page

Continued from previous page

DESIGN

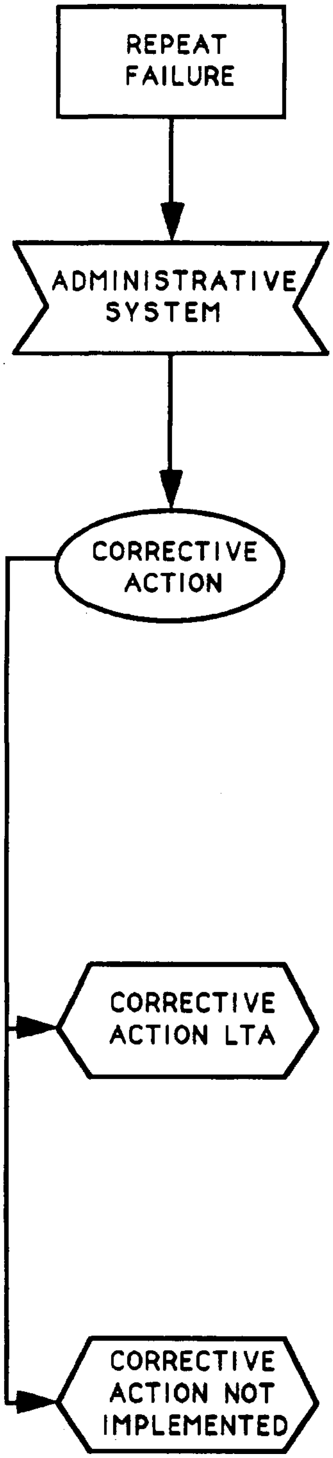
Did the error or difficulty occur due to the design or the design review process?

NOTE: Code all human factors design problems under "Human Factors." If a particular event continues to recur because of design deficiencies, DUAL CODE under "Corrective Action LTA" or "Corrective Action Not Yet Implemented."

PREVENTIVE/ PREDICTIVE MAINTENANCE PROGRAM

Could a reasonable preventive maintenance program have prevented the equipment difficulty or malfunction?
Was there no preventive maintenance for the equipment?
Was the preventive maintenance inadequate?

NOTE: This category should be used only if sound preventive maintenance, as defined by industry, SRP, or vendor experience and recommendations, is not being performed for a piece of equipment. It is not reasonable to expect preventive maintenance to prevent all malfunctions or to expect it to be performed on every piece of equipment.



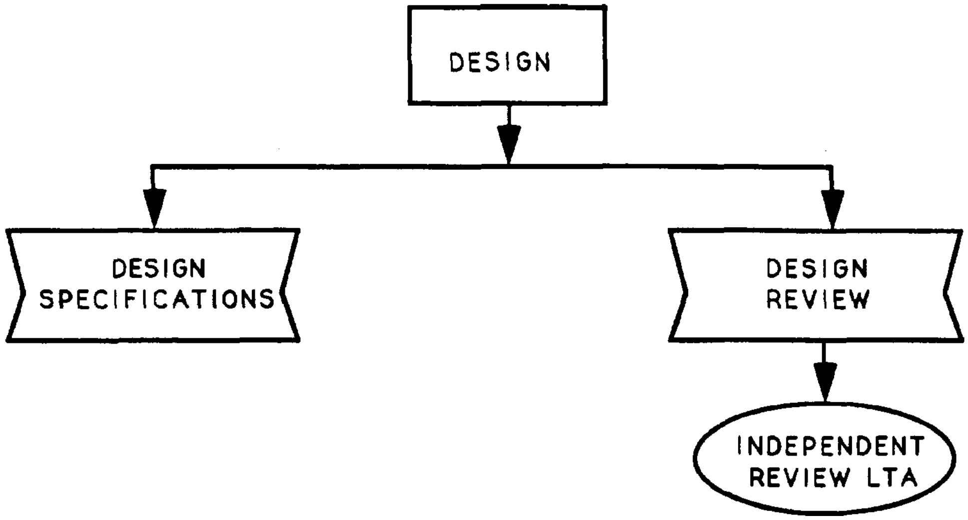
Was the equipment malfunction a failure known to have occurred in the past?
Has management had reasonable time to implement corrective action for the previous failure(s)?

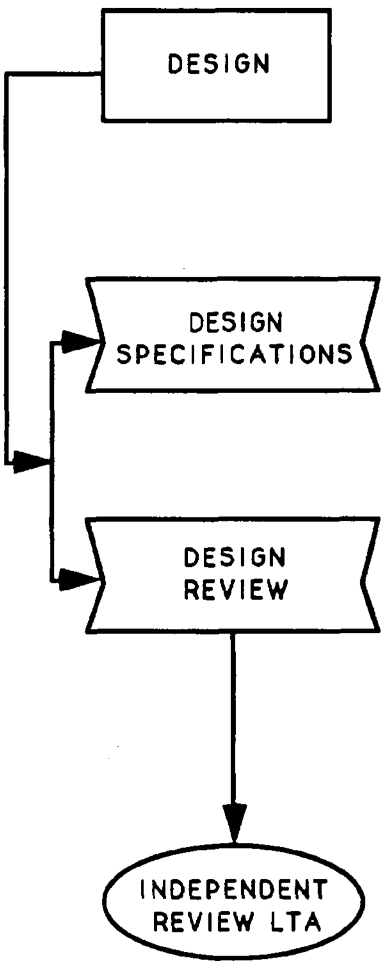
Did a known equipment reliability problem exist for the equipment?
Could management assignment of resources have been reasonably expected to prevent recurrence?

Could adequate and timely corrective action have been taken based on previously known equipment malfunctions or reliability problems?
NOTE: Incident investigators should maintain a list of recurring failures for which previous corrective action was less than adequate to prevent recurrence or for which a recommended solution had not been implemented before recurrence. This list will require continuous updating but should be used to standardize the coding of events in this category.

Was the failure a repeat failure, having occurred at least twice before?
Had supervision and management been made aware of the previous failures?
Was any corrective action taken?
Was corrective action implemented but unsuccessful?
NOTE: If a design or procedure improvement had been identified to prevent recurrence of the failure, but had not yet been implemented, code as "Corrective Action Not Yet Implemented."

Had a design or procedure improvement been identified to prevent the failure from occurring but not been implemented before the failure recurred?





Did the error or difficulty occur due to the design or design review process?

NOTE: Code all human factors design problems under "Human Factors." If a particular event continues to recur because of design deficiencies, DUAL CODE under "Corrective Action LTA" or "Corrective Action Not Yet Implemented."

Was an equipment malfunction caused by inadequate design specifications, nonconformance to design specifications, or unanticipated operational problems during design?

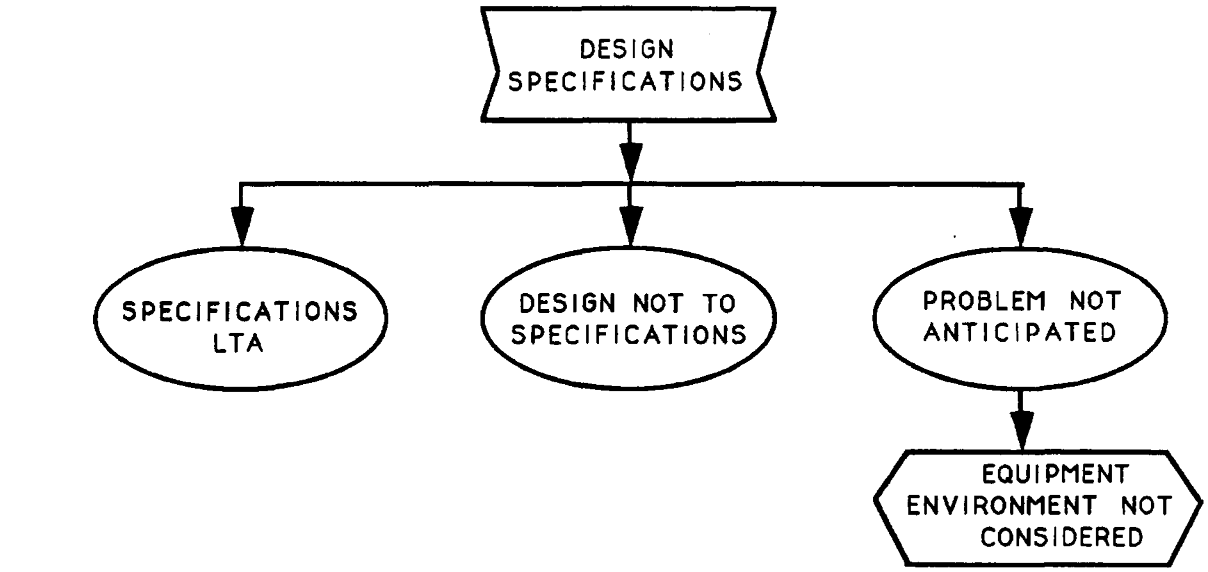
NOTE: Equipment malfunctions should only be coded as design errors if the problem could have been reasonably anticipated, based on operational experience or common sense.

Did the design review process fail to detect design errors?

NOTE: The cause of an equipment malfunction should only be coded as a "Design Review" error if the reviewer could have been reasonably expected to detect the error. The reviewer is usually not as familiar with a design as the designer. If the design review process is inadequate or an obvious error went undetected, then this category should be used.

Was a design review error caused by failure to have adequate independent review by someone other than the designer?

Was there sufficient control of the independent review process to ensure that the correct people reviewed the design and design changes at the proper time during the design process?



DESIGN SPECIFICATIONS

Was an equipment malfunction caused by inadequate design specifications, nonconformance to design specifications, or unanticipated operational problems during design?

NOTE: Equipment malfunctions should only be coded as design errors if the problem could have been reasonably anticipated, based on operational experience or common sense.

SPECIFICATIONS LTA

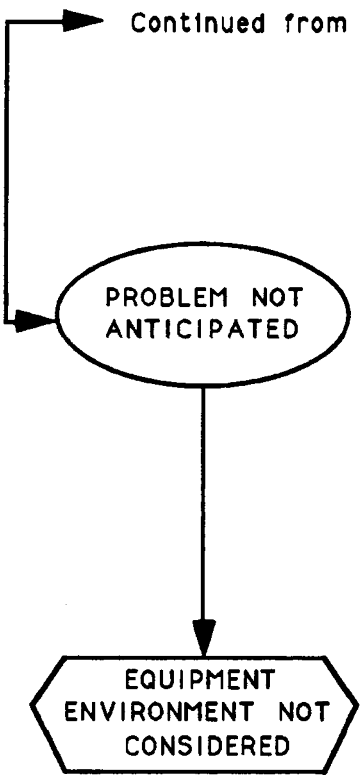
Was an equipment malfunction caused by incorrect or inadequate design specifications or basic data?
Were design standards (e.g., mechanical or DuPont standards) incorrect?

DESIGN NOT TO SPECIFICATIONS

Did the design meet specifications?
NOTE: Also consider DUAL CODING under "Design Review" because the design review process can, in many cases, detect designs that do not meet specifications.

Continued on next page

Continued from previous page



PROBLEM NOT ANTICIPATED

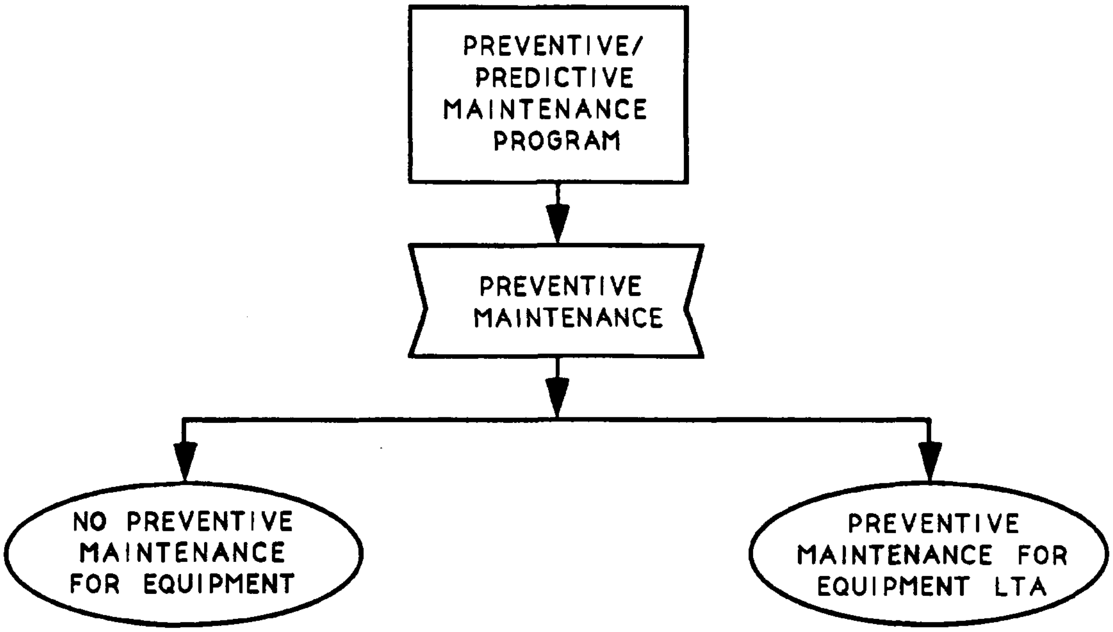
Did the designer anticipate and design equipment to withstand or adjust to problems that might occur during the equipment's service life?

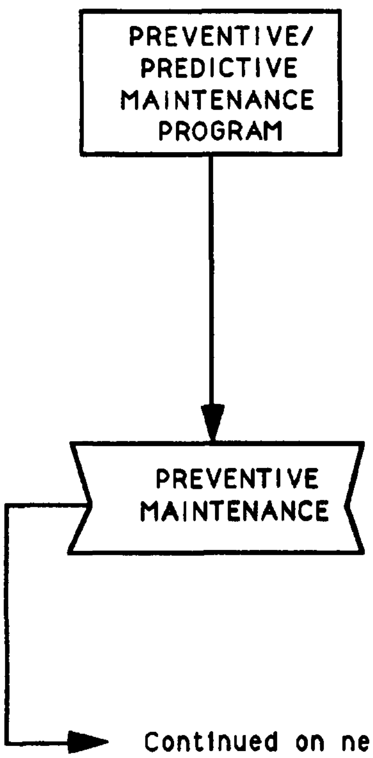
NOTE: **Also consider DUAL CODING under "Design Review" because the design review process can, in many cases, detect designs that do not anticipate potential problem areas. This is especially true if the design reviewer is more familiar with the plant than the the designer.**

EQUIPMENT ENVIRONMENT NOT CONSIDERED

Was a potential design problem not anticipated because the designer failed to consider the equipment environment?

Example: Was carbon steel recommended for use in a nitric acid environment?





Could a reasonable preventive maintenance program have prevented the equipment difficulty or malfunction?
Was there no preventive maintenance for the equipment or was the preventive maintenance inadequate?

NOTE: **This category should be used only if sound preventive maintenance, as defined by industry, SRP, or vendor experience and recommendations, is not being performed for a piece of equipment. It is not reasonable to expect preventive maintenance to prevent all malfunctions or to expect it to be performed on every piece of equipment.**

Was an equipment malfunction caused by inadequate or lack of preventive maintenance?
Did industry or SRP experience indicate that the equipment needed preventive maintenance?
Was that preventive maintenance provided?

Continued on next page

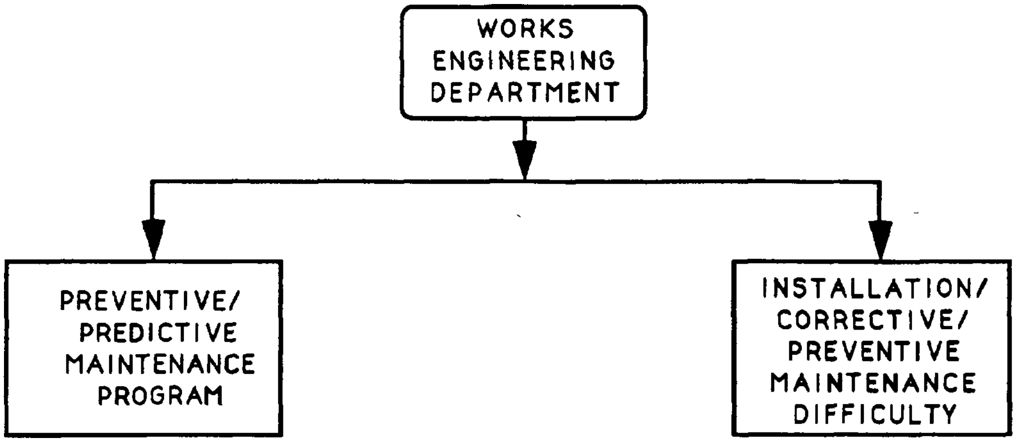
Continued from previous page

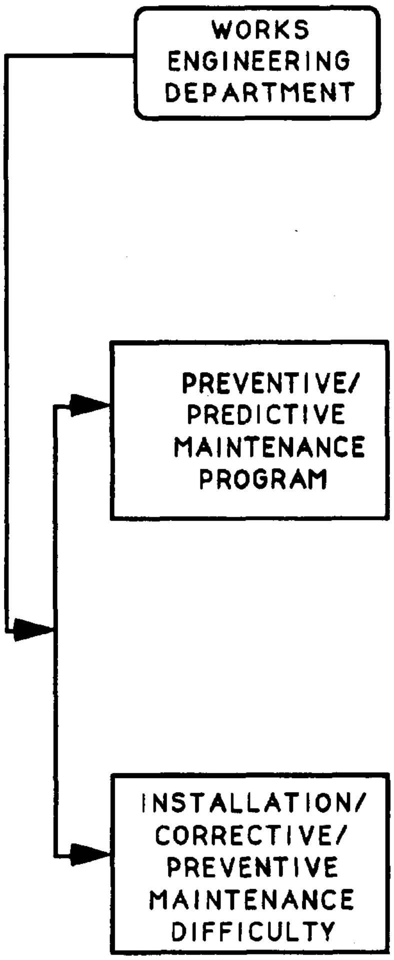
NO PREVENTIVE MAINTENANCE FOR EQUIPMENT

Was an equipment malfunction caused by failure to carry out scheduled preventive maintenance?
Should there have been preventive maintenance on the particular equipment or component that failed?
Did the vendor recommend performing preventive maintenance?
Did SRP or known industry experience indicate that the equipment required routine preventive maintenance to prevent failure?

PREVENTIVE MAINTENANCE FOR EQUIPMENT LTA

Was preventive maintenance scheduled too infrequently, considering vendor recommendations and operating experience?
Was preventive maintenance performed on some components but not others?





WORKS ENGINEERING DEPARTMENT

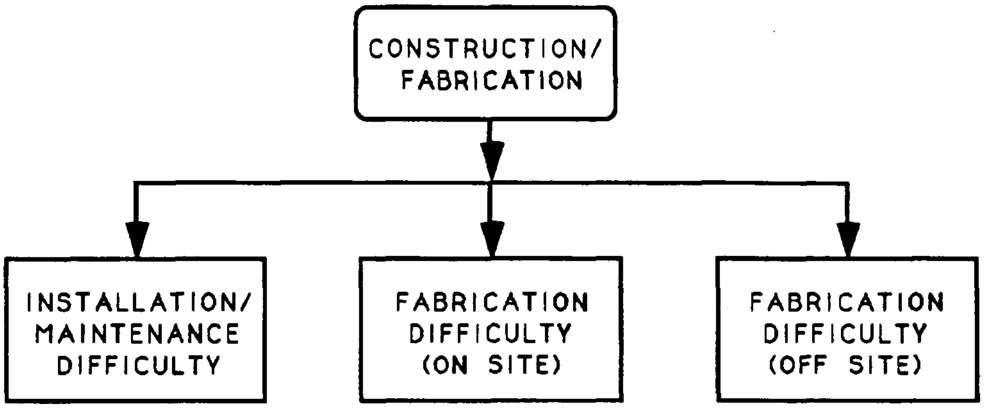
Were Works Engineering personnel responsible for the equipment difficulty or otherwise related to the causal factor?

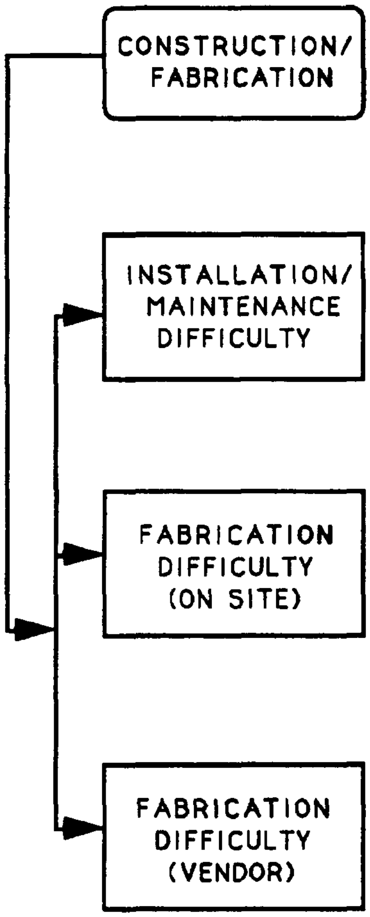
PREVENTIVE/PREDICTIVE MAINTENANCE PROGRAM

Could a reasonable preventive maintenance program have prevented the equipment difficulty or malfunction?
Was there no preventive maintenance for the equipment?
Was the preventive maintenance inadequate?
NOTE: This category should be used only if sound preventive maintenance, as defined by industry, SRP, or vendor experience and recommendations, is not being performed for a piece of equipment. It is not reasonable to expect preventive maintenance to prevent all malfunctions or to expect it to be performed on every piece of equipment.

INSTALLATION/CORRECTIVE/PREVENTIVE MAINTENANCE DIFFICULTY

Did the difficulty occur during installation of project work or during equipment modifications?
Was there a corrective maintenance error while repairing or correcting an equipment malfunction?
Was an error committed while performing scheduled preventive maintenance?





Was the causal factor related to construction, fabrication, or vendor activities?

Did the difficulty or error occur during installation of project work, equipment modifications, or during maintenance on existing systems?

Was an error made during fabrication of equipment by onsite personnel?
Did onsite personnel fail to build equipment per the specifications?

Was a fabrication error made off-plant by a vendor during manufacture of equipment?
Did the vendor fail to build the equipment per the specifications?

Area of Responsibility

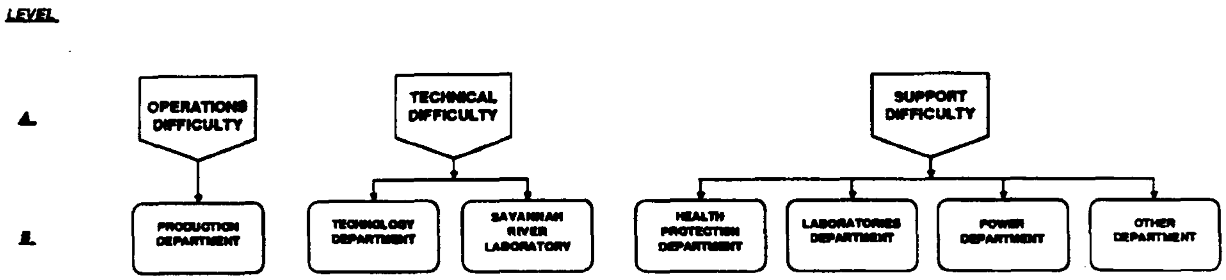
The general nodes on Level A of the "Root Cause Tree" branch to more specific nodes on Level B. Level B nodes describe areas of responsibility. After using Level A nodes to describe the primary source of difficulty for a particular causal factor (e.g., "Operations Difficulty"), the next step is to determine the functional area or department in the organization that was responsible for the problem.

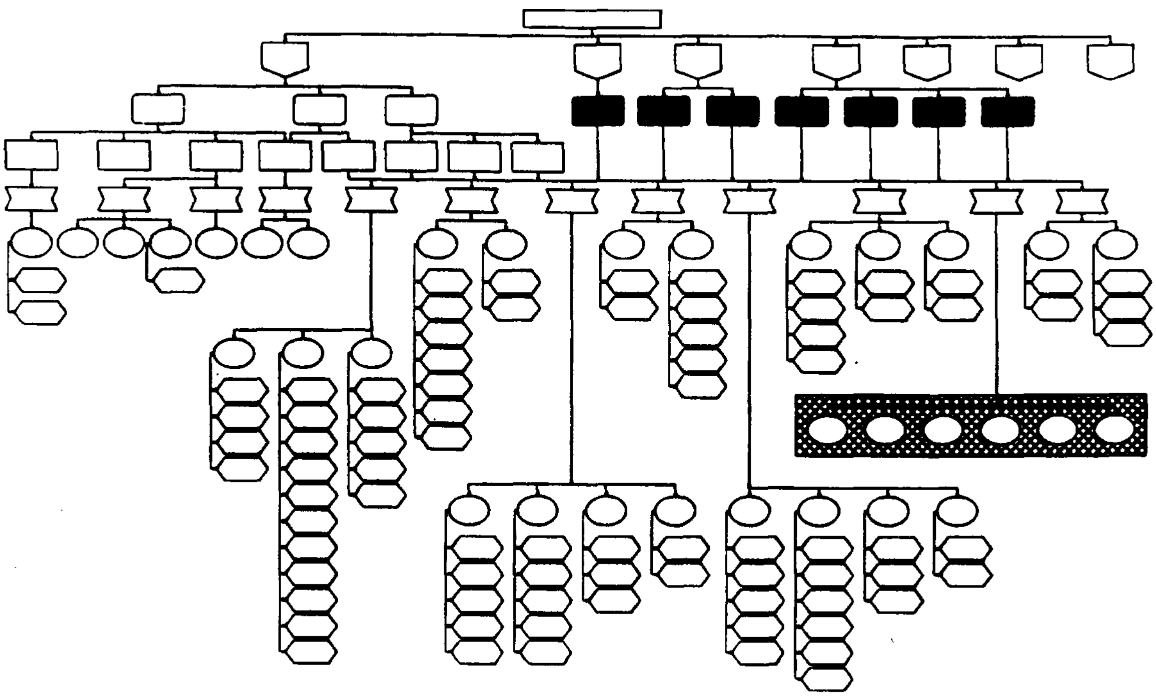
The Level A "Equipment Difficulty" node branches to three Level B nodes that describe functional areas related to equipment (i.e., "Equipment Reliability/Design," "Works Engineering Department," and "Construction/Fabrication"). For ease of explanation, these nodes are discussed under "Equipment Difficulty" in this section of the handbook.

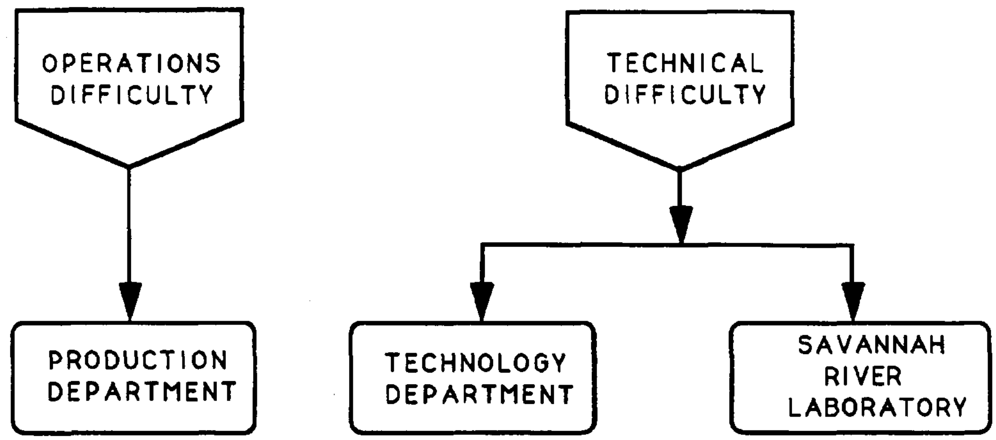
The remaining nodes in Level B refer strictly to departments in the organization. The Level A node "Operations Difficulty" branches more specifically in Level B to the "Production Department." "Technical Difficulty" branches to "Technology Department" and "Savannah River Laboratory." "Support Difficulty" branches to four Level B nodes: "Health Protection Department," "Laboratories Department," "Power Department," and "Other Department." References to generic departments make the "Root Cause Tree" adaptable for use in any non-reactor organization on the site.

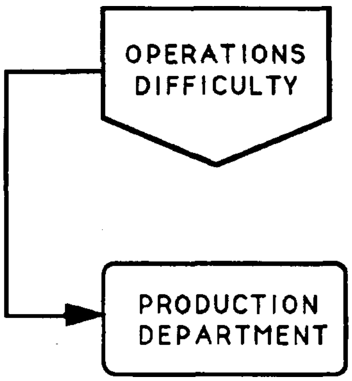
An expanded diagram of the Level B nodes associated with responsible departments are presented on the pages that follow. Questions are provided to help the investigator determine which nodes are applicable for a particular causal factor.

Area of Responsibility





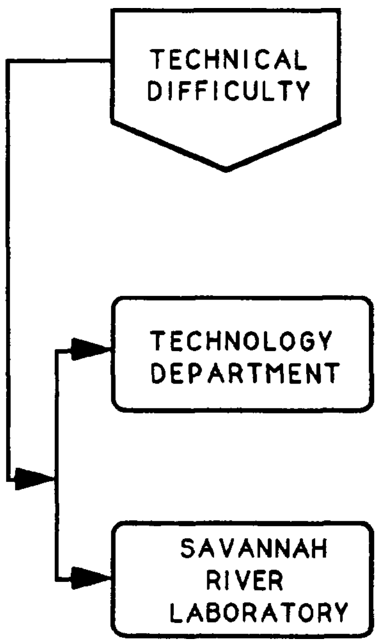




Was there an operations problem associated with the causal factor?

NOTE: If someone from an Operations Department outside of the primary organization is involved in the difficulty, then code under "Support Difficulty." For example, if a Separations Department operator is involved in a Raw Materials incident, then the "Support Difficulty" node should be used.

Were personnel from the Production Department involved in the difficulty?

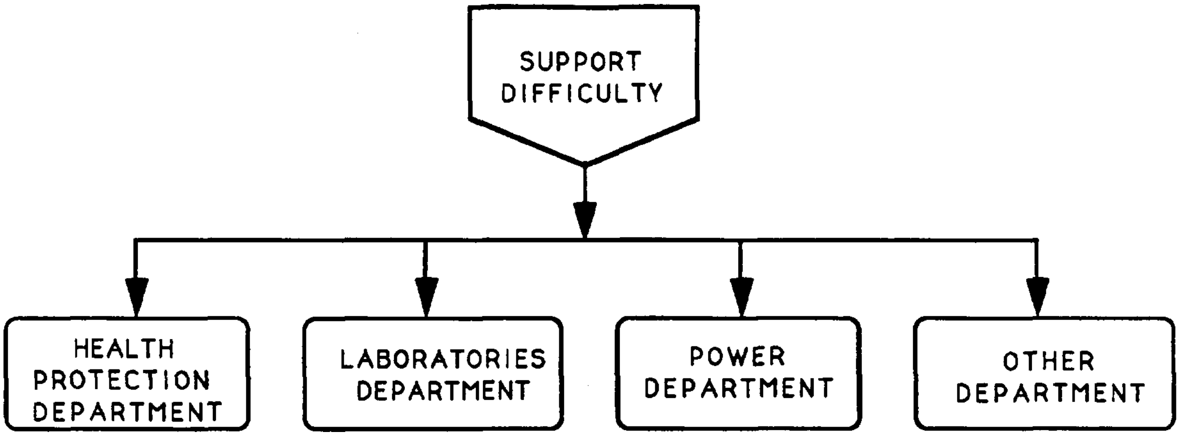


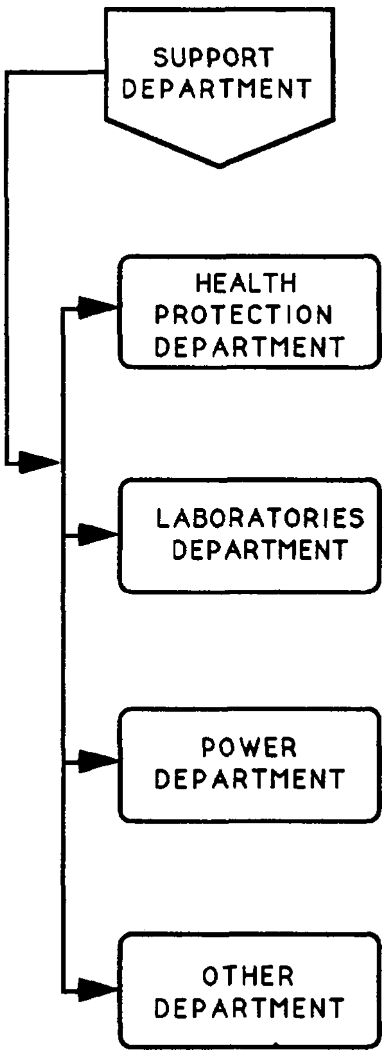
Could adequate technical support, surveillance, or coverage by personnel in the Technology Department or the Savannah River Laboratory have prevented occurrence of the causal factor?

NOTE: If someone from a Technology Department outside of the primary organization is involved in the difficulty, then code under "Support Difficulty." For example, if a Separations Technology Department engineer is involved in a Raw Materials incident, then the "Support Difficulty" node should be used.

Were Technology Department personnel involved in the difficulty or otherwise related to the problem?

Did Savannah River Laboratory personnel contribute to the causal factor?





SUPPORT DEPARTMENT: Did support personnel (i.e., employees in the Health Protection, Laboratories, Power, or other Support Departments) contribute to the causal factor?

HEALTH PROTECTION DEPARTMENT: Were Health Protection Department personnel involved in the difficulty?

LABORATORIES DEPARTMENT: Were Laboratories Department employees involved in the difficulty?
Did an incorrect lab analysis contribute to the problem?

POWER DEPARTMENT: Were personnel from the Power Department involved in the difficulty?

OTHER DEPARTMENT: Did personnel from a Support Department (other than Health Protection, Laboratories, or Power) contribute to the causal factor?

Procedures

One of the most frequent complaints voiced by incident investigators centers around the failure of personnel to correctly perform written instructions. Whenever a human error occurs, the tendency is to state that the cause of the incident was "operator failure to follow procedure." This is really only a description of what happened during the incident. Unfortunately, it is a description that is aimed very directly and negatively toward the operator. The resulting recommendation is usually quite predictable (i.e., "Instruct personnel always to follow procedures when performing their jobs."). This strategy for preventing recurrence is of limited effectiveness. Personnel are already aware that procedure compliance is mandatory. Reminding them again and again will probably not improve their overall performance.

The question that should be addressed is, "Why did the operator, mechanic, or supervisor fail to follow a given procedure?" Based on a review of relevant literature and numerous incident reports, it appears that there are many reasons why people commit errors when following written procedures. At times there are problems inherent in the procedure itself, in the procedure administration system, or in the method of using the procedure. The "Procedures" segment of the tree addresses these issues. Once these types of problems are identified, it is usually an easy matter to arrive at specific, implementable recommendations.

When a causal factor involving procedure noncompliance is identified, nodes in the "Procedures" segment of the tree should be considered. "Procedures," a major root cause category, branches to three near root causes: "Not Used," "Followed Incorrectly," and "Wrong/Incomplete."

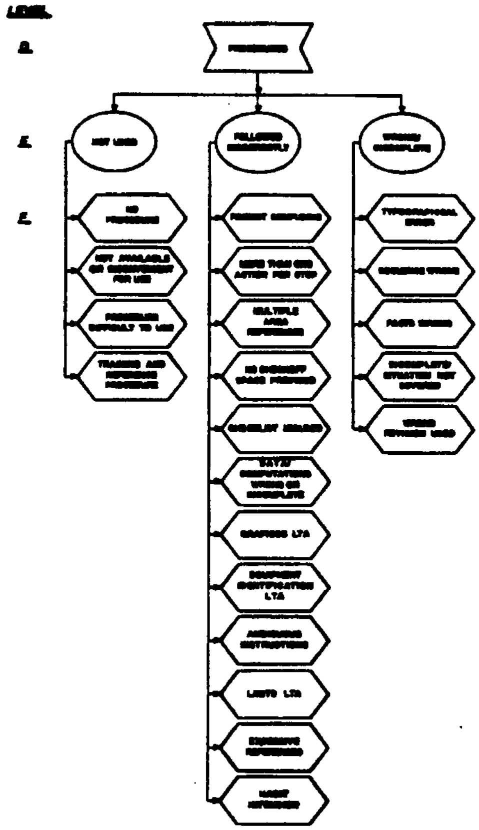
The first near root cause, "Not Used," addresses situations in which a task was carried out without benefit of written instructions. There are a number of reasons, other than personnel neglect or carelessness, why a procedure might not be used to carry out the job. This node branches to four root causes: "No Procedure," "Not Available or Inconvenient for Use," "Procedure Difficult to Use," and "Training and Reference Procedure."

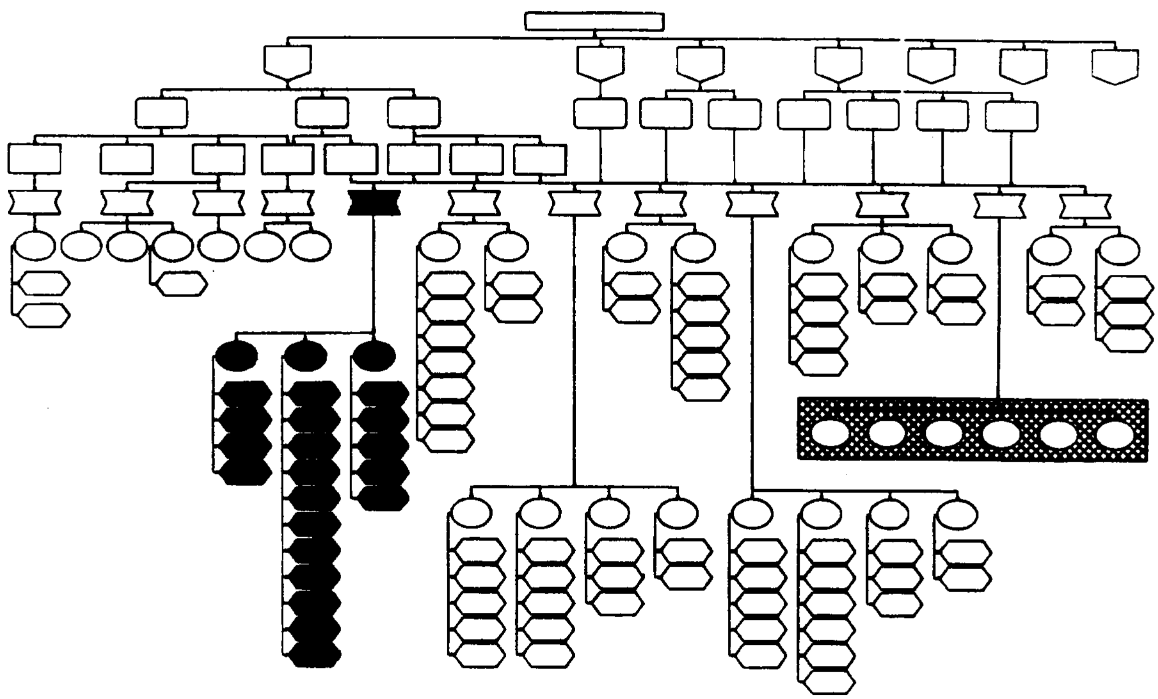
"Followed Incorrectly," the second near root cause branches to twelve root causes: "Format Confusing," "More Than One Action Per Step," "Multiple Area References," "No Checkoff Space Provided," "Checklist Misused," "Data/Computations Wrong or Incomplete," "Graphics Less Than Adequate," "Equipment Identification Less Than Adequate," "Ambiguous Instructions," "Limits Less Than Adequate," "Excessive References," and "Habit Intrusion." These nodes should be considered for situations in which an error occurred despite the fact that a procedure was used to carry out the work.

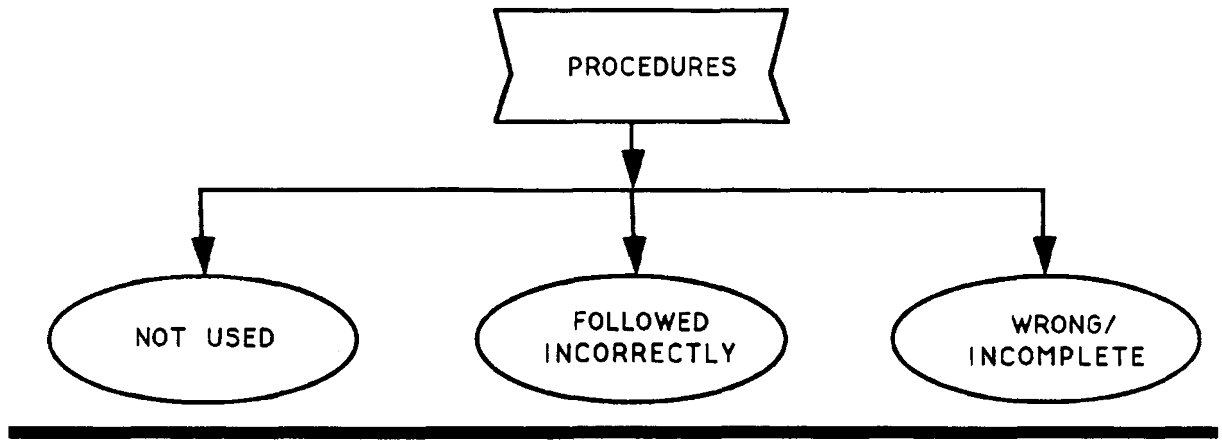
The final near root cause, "Wrong/Incomplete," branches to five root causes: "Typographical Error," "Sequence Wrong," "Facts Wrong," "Incomplete/Situation Not Covered," and "Wrong Revision Used." Each of these nodes addresses a procedure inadequacy.

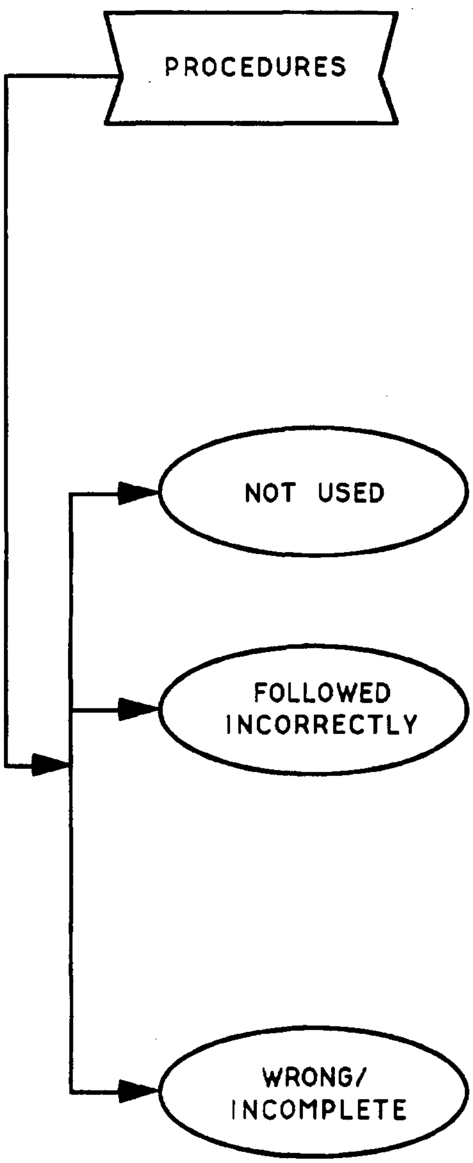
A more in-depth explanation of the "Procedures" segment of the tree can be found on the pages that follow. Specific node definitions, and in some instances, examples, are presented.

Procedures









PROCEDURES

Was the difficulty in any way related to written procedures?

NOTE: Some causes coded using the "Procedures" segment of the tree should be DUAL CODED under "Human Factors." This is the case when better human factors design, man-machine interface, or environmental conditions could have prevented the error. Not all problems with poorly human factored designs can be overcome by providing detailed procedures.

Also, causes may be DUAL CODED under "Training" if it is determined that additional training was needed to successfully complete the procedure.

NOT USED

Was a procedure used to do the job?

NOTE: If a procedure was a available but not used, the event should be DUAL CODED under "Standards, Policies, or Administrative Controls (SPAC) Not Used" because the policy of using procedures for all work was not followed.

FOLLOWED INCORRECTLY

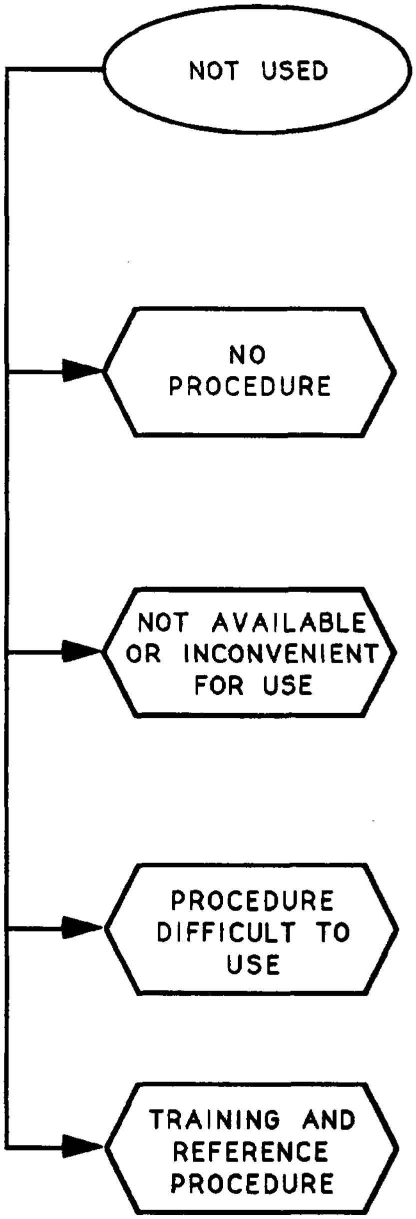
Was an event caused by an error made while following or trying to follow a procedure?

NOTE: Some errors in following procedures should also be coded under "Standards, Policies, or Administrative Controls (SPAC) Not Used." For example, an error may be made because several steps of a procedure are carried out and then checked off. If the policy is to read one step, perform the instruction, and then check it off before moving to the next step, then an SPAC has been violated. "Human Factors" and "Training" segments of the tree should also be considered.

WRONG/INCOMPLETE

Was the procedure incorrect?

Did the procedure fail to address a situation that occurred during performance of the applicable task?



NOT USED

Was a procedure used to do the job?

NOTE: If a procedure was a available but not used, the event should be DUAL CODED under "Standards, Policies, or Administrative Controls (SPAC) Not Used" because the policy of using procedures for all work was not followed.

NO PROCEDURE

Did a procedure exist for the job or task being performed?

NOT AVAILABLE OR INCONVENIENT FOR USE

Was the procedure readily available?
Was there a copy of the procedure in the designated file or rack?
Was there a "master copy" of the procedure available for reproduction?
Was procedure use inconvenient because of working conditions (e.g., radiation zones, tight quarters, plastic suits)?

PROCEDURE DIFFICULT TO USE

Considering the training and experience of the user, was the procedure too difficult to understand or follow?
Was the procedure designed for the "less practiced" user?
Was there sufficient information to identify the appropriate procedure?

TRAINING AND REFERENCE PROCEDURE

Was the procedure classified for training and reference?
Based upon the significance or difficulty of the job, should the procedure have been classified as a "Use Every Time" procedure?

NOTE: Designations for "Training and Reference" (T&R) and "Use Every Time" (UET) procedures may vary depending upon the organization involved. For example, several organizations on the site refer to UET procedures as Category 1 procedures.

FOLLOWED INCORRECTLY

Was an event caused by an error made while following or trying to follow a procedure?

NOTE: Some errors in following procedures should also be coded under "Standards, Policies, or Administrative Controls (SPAC) Not Used." For example, an error may be made because several steps of a procedure are carried out and then checked off. If the policy is to read one step, perform the instruction, and then check it off before moving to the next step, then an SPAC has been violated. "Human Factors" and "Training" segments of the tree should also be considered.

FORMAT CONFUSING

Did the layout of the procedure make it difficult to follow?
Did the format differ from that which the operator was accustomed to using?
Were the steps of the procedure logically grouped?

MORE THAN ONE ACTION PER STEP

Did any steps in the procedure have more than one action or direction to perform?
Did some steps in the procedure state one action, which in practice, actually requires several steps to perform?
"Change the pump" is one instruction, but it involves numerous actions (e.g., line breaks, electrical lockouts, wiring disconnections).

MULTIPLE AREA REFERENCES

Did references to the different processes and areas contribute to the event?

NOTE: This node was created because of errors made by site personnel using certain Reactor DPSOLs. These DPSOLs, designed to be used in all of the reactor facilities, contain instructions like "Trip pump if pressure reaches 65 psig (LKC) or40 psig (P)."

NO CHECKOFF SPACE PROVIDED

Was an error made because each separate action in a step did not have a checkoff space provided? For example, a list of valve alignments lacking checkoff spaces for individual valves could easily result in one or more valves being omitted.

CHECKLIST MISUSED

Was a checklist misused? A familiar scenario involves the user doing several steps at one time instead of doing one step at a time and checking it off as completed before progressing to the next step.

NOTE: If a given checklist is required by policy to be used in a step-by-step manner, consider DUAL CODING under "Standards, Policies, or Administrative Controls (SPAC) Not Used."

DATA/ COMPUTATIONS WRONG OR INCOMPLETE

Was the error made because of a mistake in recording or transferring data?
Were calculations made incorrectly?

NOTE: It is unreasonable to expect extensive calculations to be carried out accurately by hand. In such cases, independent checking systems should be implemented.

continued on next page

continued from previous page

GRAPHICS LTA

Was an error made because graphcis or drawings were of poor quality?
Were the graphics or drawings unclear, confusing, or misleading?
Were graphics, including datasheets, legible? Repeated attempts at reproduction can degrade graphic quality to the point of illegibility.

EQUIPMENT IDENTIFICATION LTA

Was the equipment identification too generic?
Did equipment identification or labeling in the field agree with the identification in the procedure? For example, the procedure might refer to the circulation pumps, while the labels on these pumps might read "CP ABC" and "CP EFG."

AMBIGUOUS INSTRUCTIONS

Were the instructions in the procedure unclear, uncertain, or interpretable in more than one way?
Was the language or grammar unclear/complex?

LIMITS LTA

Were limits or permissible operating ranges expressed in absolute numbers instead of in a ± format? Instead of requiring mental arithmetic (e.g., 7.50 ± 0.75), limits should be expressed as ranges (e.g., 6.75 minium, 8.25 maximum).

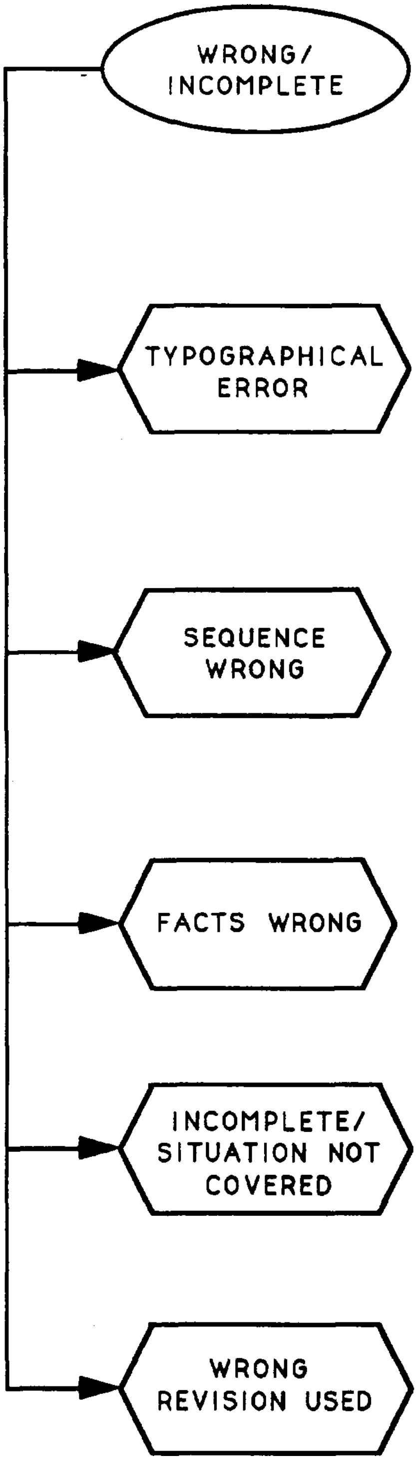
EXCESSIVE REFERENCES

Did the procedure refer to an excessive number of additional procedures?
Did the procedure contain numerous steps of the type "Calculate limits per DPSOL XYZ."?
Was the procedure difficult to follow because of excessive branching to other procedures?
Did the procedure contain numerous steps of the type "If X, then go to DPSOL ABC. If Y, then go to DPSOL EFG."?

HABIT INTRUSION

Was the procedure user required to carry out an action different from those he was accustomed to doing?
Did the procedure user revert to some well-rehearsed action?
Was a special or temporary procedure in place at the time?
Was a recently revised procedure being used?
Were the most recent revisions to the procedure clearly marked?

NOTE: Consider DUAL CODING under "Human Factors" if less than adequate man-machine interface or poor environment contributed to the problem.



Was the procedure incorrect?
Did the procedure fail to address a situation that occurred during performance of the applicable task?

Was a typographical error in the procedure responsible for the event?

Were the instructions/steps in the procedure out of sequence?

Was specific information in the procedure incorrect?

Were details of the procedure incomplete?
Was sufficient information presented?
Did the procedure address all situations likely to occur during the completion of the procedure? For example, a step might instruct the operator to start a certain pump during an emergency situation but fail to address what to do if the pump fails.

Was the wrong revision of a procedure used?
NOTE: The wrong revision of a procedure may be used for a number of reasons (e.g., delays in printing, improper placement in the field, failure to discard old revisions when new ones are issued).

Immediate Supervision

Immediate supervision is the first line supervision in a facility. For the purposes of this handbook, personnel directly in charge of operators, specialists, maintenance personnel, technicians, and other line workers are considered immediate supervision. Causal factors involving the responsibilities and duties of immediate supervision should be coded using the major root cause category "Immediate Supervision."

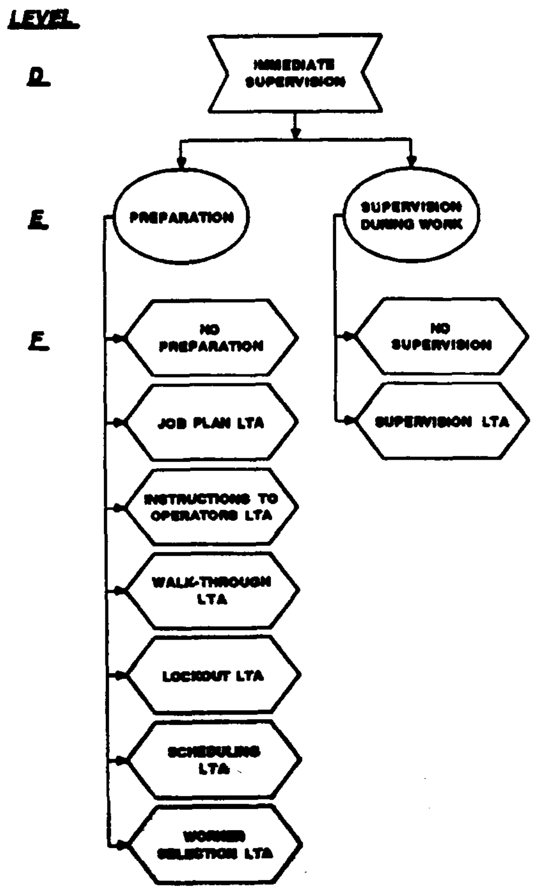
Responsibilities of first line supervision include providing preparation for work that is to be performed and providing supervision of line workers during performance of this work. Near root causes branching from the "Immediate Supervision" node are "Preparation" and "Supervision During Work."

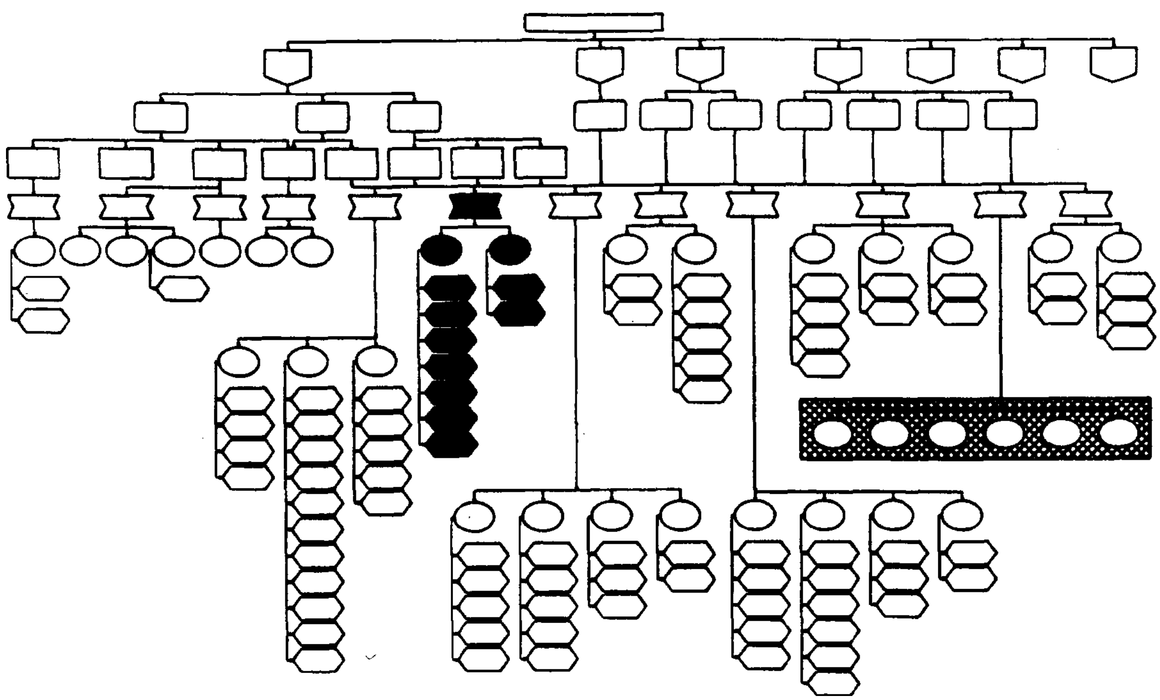
The near root cause, "Preparation," includes all aspects of preparation needed before a job can be performed. The root causes associated with this node are "No Preparation," "Job Plan Less Than Adequate," "Instructions To Operators Less Than Adequate," "Walk-Throughs Less Than Adequate," "Lockout Less Than Adequate," "Scheduling Less Than Adequate," and "Worker Selection Less Than Adequate."

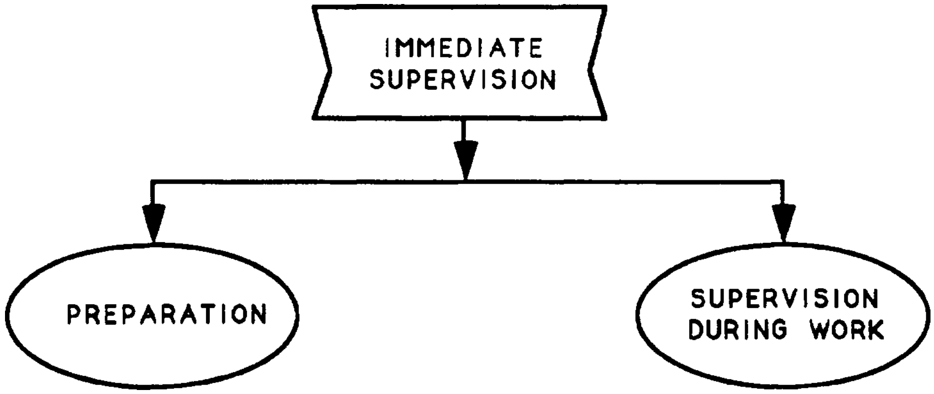
"Supervision During Work," the second near root cause branching from "Immediate Supervision," addresses the issue of whether adequate supervision was provided during performance of the work. The two root causes branching from this node are "No Supervision" and "Supervision Less Than Adequate."

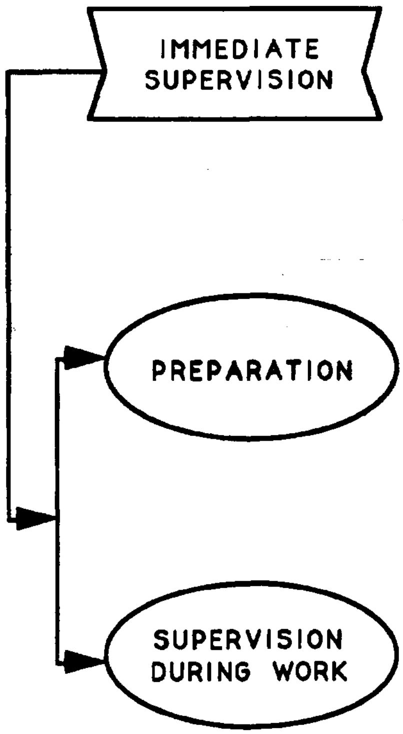
More in-depth explanations of the nodes in the "Immediate Supervision" segment of the "Root Cause Tree" are found on the following pages. In some cases, examples are presented for clarification.

Immediate Supervision









IMMEDIATE SUPERVISION: Was an event caused by inadequate or lack of immediate (first line) supervision during job preparation or performance?

PREPARATION: Did immediate supervision fail to provide adequate preparation (including capable workers), job plans, or walk-throughs for a job?
Were potential interruptions or special circumstances identified before the work began?

SUPERVISION DURING WORK: Did immediate supervision fail to provide adequate support, coverage, oversite, or supervision during job performance?
NOTE: One must judge what level of supervision was necessary based on the importance of the job in relation to safety and production.

PREPARATION

Did immediate supervision fail to provide adequate preparation (including capable workers), job plans, or walk-throughs for a job?
Were potential interruptions or special circumstances identified before the work began?

NO PREPARATION

Did immediate supervision fail to provide any preparation (instructions, job plan, walk-through, etc.) for the work to be performed?

JOB PLAN LTA

Did immediate supervision provide an incorrect, incomplete, or otherwise inadequate job plan for performance of the work?

INSTRUCTIONS TO OPERATORS LTA

Did immediate supervision provide incorrect, incomplete, or otherwise inadequate job instructions prior to the beginning of work?
Were the duties and tasks to be performed explained and clear to workers?

WALK-THROUGH LTA

Did immediate supervision perform an adequate walk-through (show locations of equipment, how to operate equipment, proper sequence of steps, etc.) with workers before starting the job?

LOCKOUT LTA

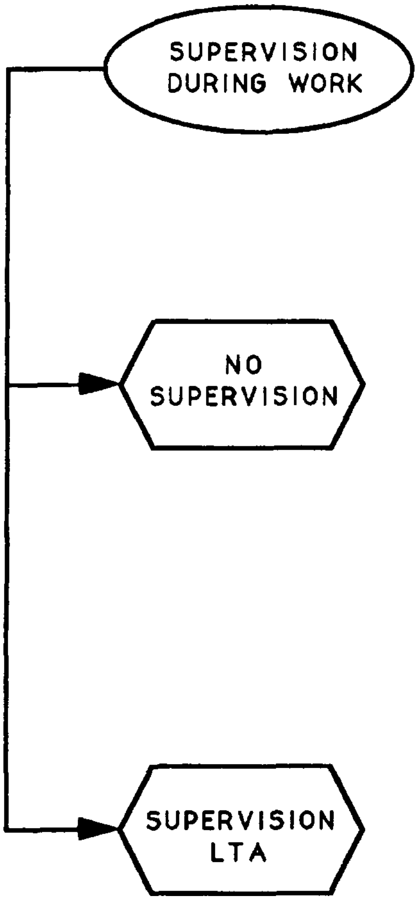
Was the error the result of an incorrect lockout or failure to lock out all necessary equipment or parts before doing a job?

SCHEDULING LTA

Was scheduling of periodic testing or surveillance inadequate?
Were too many concurrent tasks assigned to workers?
Were duties not well-distributed among personnel?

WORKER SELECTION LTA

Did immediate supervision fail to select capable workers to perform the job?
Were sufficient numbers of trained or experienced workers assigned to the task?
NOTE: Examples of inadequate worker selection include choosing workers who are fatigued due to excess overtime, workers with substance abuse problems , or workers who are not trained for a particular job.



Did immediate supervision fail to provide adequate support, coverage, oversite, or supervision during job performance?

NOTE: One must judge what level of supervision was necessary based on the importance of the job in relation to safety and production.

Did immediate supervision fail to follow the job or provide any support, coverage, or oversite during the job?

Did immediate supervision provide inadequate (some but not sufficient) oversite, coverage, or support during performance of the job?
Was an appropriate level of in-task supervision provided?
Was contact with workers too infrequent?
Did direct supervisor involvement interfere with supervisory overview role?

Administrative System

The administrative system is concerned with the standards, policies and administrative controls that management uses to operate a facility safely and efficiently. Nodes in the major root cause category "Administrative System" should be considered when coding causal factors related to these controls.

Problems that are blamed on "poor management" can in many instances be attributed to breakdowns in the administrative system. The administrative system establishes the standards, policies, and administrative controls that govern facility operation. Audits and evaluations determine how well these controls are working. When a breakdown in the system does occur, it is essential that appropriate corrective action plans be set into motion. Nodes under the major root cause category "Administrative System" should be considered the event of problems in any one of these areas. Near root causes falling under "Administrative System" are "Standards, Policies, Or Administrative Contols (SPAC) Less Than Adequate," "SPAC Not Used," "Audits/ Evaluations," and "Corrective Action."

The first near root cause, "SPAC Less Than Adequate," addresses inadequacies in the specific controls. The root causes associated with this node are "No SPAC," "Not Strict Enough," "Confusing Or Incomplete," "Technical Error," and "Drawings/Prints LTA."

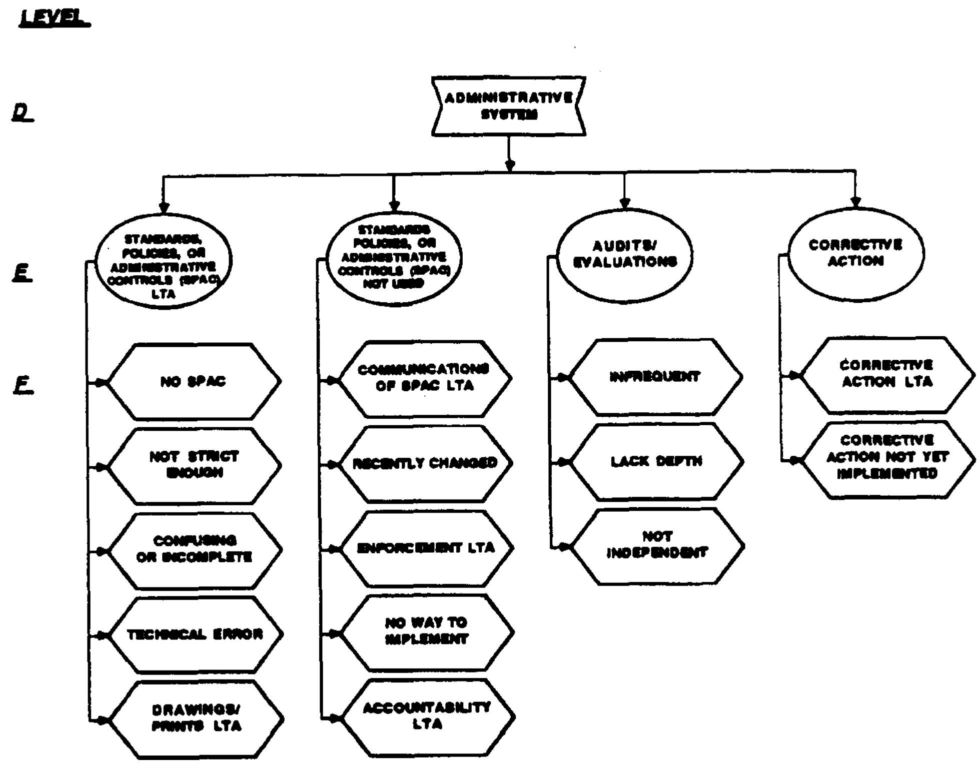
The second near root cause, "SPAC Not Used," deals with reasons why established SPACs are not used. The five root causes branching from this node are "Communication Of SPAC Less Than Adequate," "Recently Changed," "Enforcement Less Than Adequate," "No Way To Implement," and "Accountability Less Than Adequate."

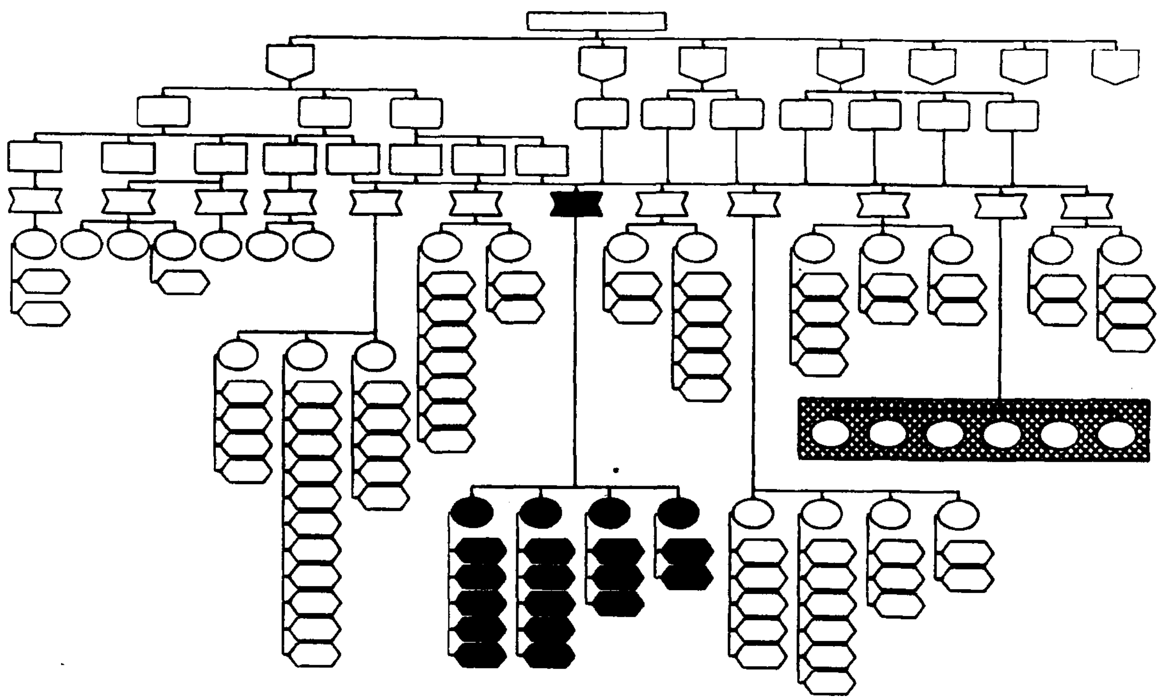
"Audits/Evaluations," the third near root cause, branches to three nodes. These nodes are "Infrequent," "Lack Depth," and "Not Independent." These nodes are used when a potential causal factor could have been detected by an audit or evaluation but was not because of deficiencies in the audit or evaluation.

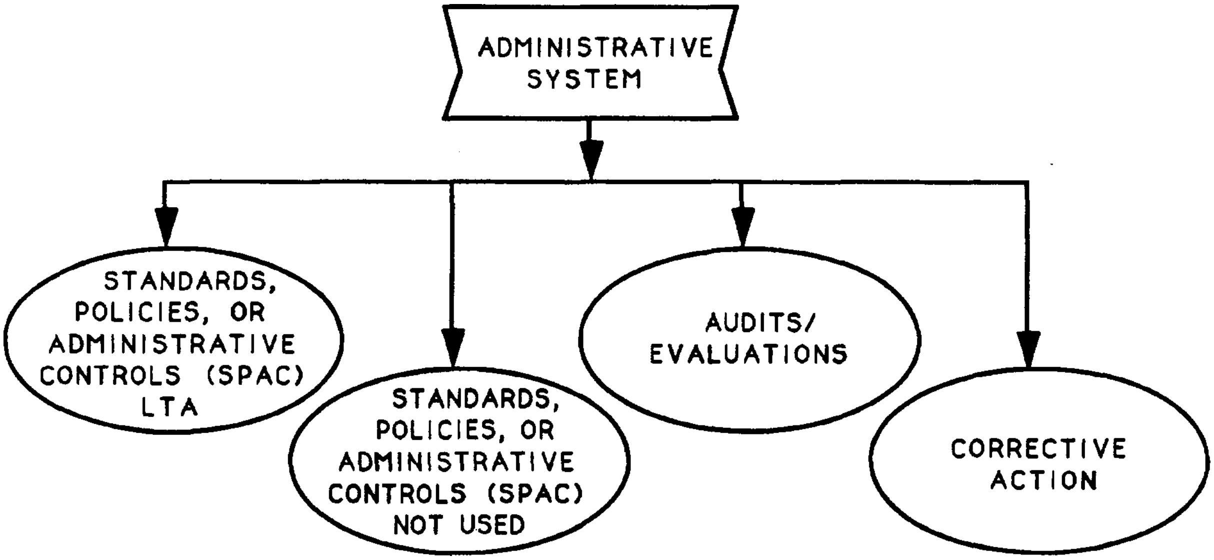
The last near root cause branching from "Administrative System" is "Corrective Action." The root causes associated with this node are "Corrective Action Less Than Adequate" and "Corrective Action Not Yet Implemented." Problems associated with failure to take corrective action concerning a known problem, or implementation of a deficient corrective action, are addressed here.

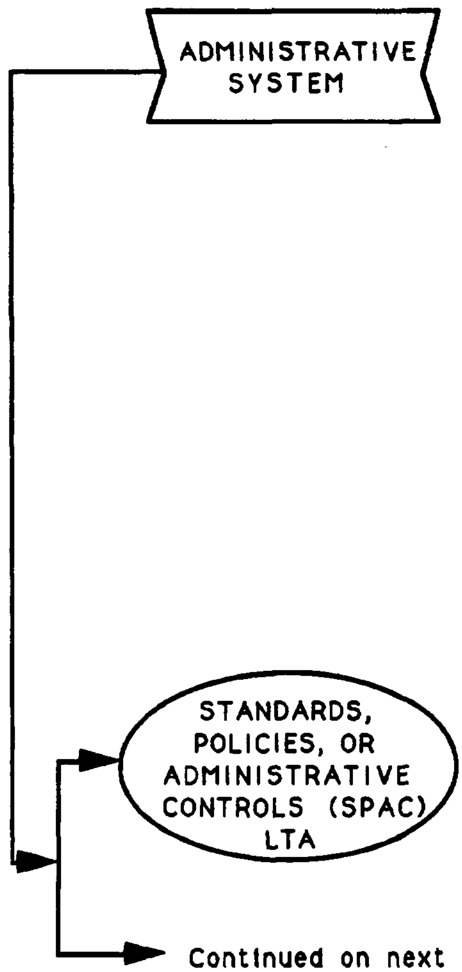
A more in-depth explanation of the "Administrative System" segment of the tree is found on the following pages. Specific node definitions and applicable examples are presented.

Administrative System









Did the error result because of inadequate standards, policies or directives, or because of organizational ineffectiveness?

Was the error due to administrative control deficiencies or failure to employ existing policy?

Was implementation of policy or directives less than adequate?

Was an event caused by inadequate audits or failure to perform audits or evaluations?

Was an event caused by inadequate corrective actions or failure to implement corrective actions for known malfunctions or deficiencies?

NOTE: The "Administrative System" node is related to problems with administrative controls, the organization, or the system by which work is controlled and accomplished. This segment represents problems that upper level management has both control and the responsibility to correct. It is intended to reflect weaknesses in the work control system, not errors committed by management.

Was the event caused by inadequate standards, policy, or administrative controls (SPAC) including drawings prints?

Were the SPACs confusing, incomplete, unclear, ambiguous, not strict enough, or otherwise inadequate?

Continued on next page

Continued from previous page

STANDARDS, POLICIES, OR ADMINISTRATIVE CONTROLS (SPAC) NOT USED

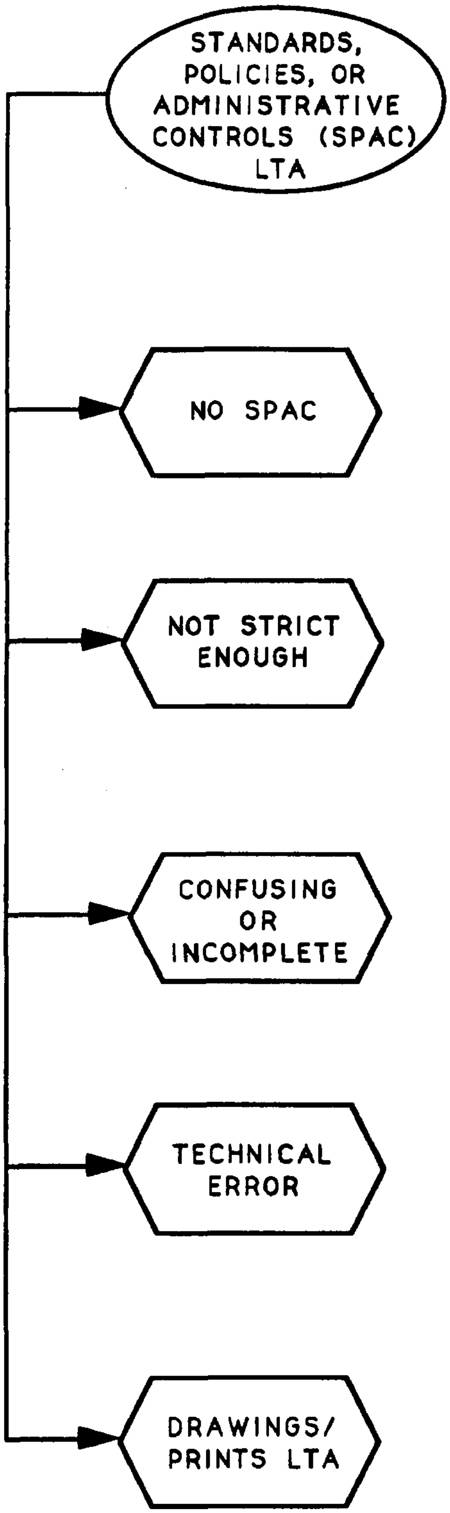
Were SPACs or directives not used, adhered to, or followed?
NOTE: Reasons for failing to follow directives may not be known, but whatever the reason, it is the administration's responsibility to correct the problem.

AUDITS/ EVALUATIONS

Was the event caused by failure to provide independent audits or evaluation programs?
Did inadequate audit or evaluation programs contribute to the problem?
NOTE: This category should be used only if it is reasonable to expect an audit or evaluation system to be in place for the affected equipment or system. Certainly, everything can not be audited, but important safety related systems and the effectiveness of those systems should be audited or evaluated periodically. Before using this node, the investigator must consider whether would be reasonable for an auditor to be able to detect the type of error that caused the incident.

CORRECTIVE ACTION

Was an event caused by failure to provide corrective action for known deficiencies or failure to implememt recommended corrective actions before known deficiencies recur?
NOTE: Known deficiencies are any deficiencies other than equipment failures, such as human performance related deficiencies, procedure deficiencies, or administrative control system deficiencies. Repeat equipment failures occurring because of inadequate or unimplemented corrective actions are coded under "Repeat Failure" category.



STANDARDS, POLICIES, OR ADMINISTRATIVE CONTROLS (SPAC) LTA

Was the event caused by inadequate standards, policy, or administrative controls (SPAC) including drawings prints?
Were the SPACs confusing, incomplete, unclear, ambiguous, not strict enough, or otherwise inadequate?

NO SPAC

Did an SPAC exist to control the particular type of work or situation involved in the incident?
Was the work or situation significant or involved enough to warrant some type of SPAC to ensure adequate job quality and work control?

NOT STRICT ENOUGH

Were the existing SPACs strict enough to provide adequate job quality or work control?
Did leniency allow violation of the intent, if not the letter, of the SPAC?

CONFUSING OR INCOMPLETE

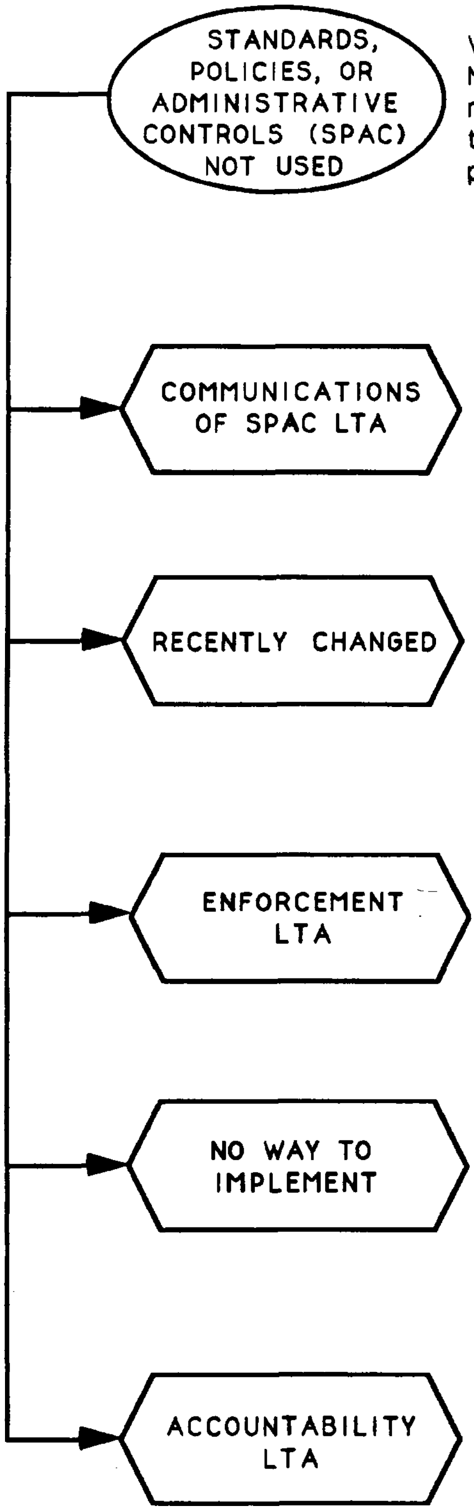
Were the SPACs confusing, hard to understand or interpret, or ambiguous?
Were the SPACs incomplete or not specific enough?

TECHNICAL ERROR

Did a technical error or incorrect facts exist in the SPACs?

DRAWINGS/ PRINTS LTA

Were drawings or prints incorrect or not updated?
Did drawings or prints reflect "as built" conditions?



STANDARDS, POLICIES, OR ADMINISTRATIVE CONTROLS (SPAC) NOT USED: Were SPACs or directives not used, adhered to, or followed?
NOTE: **Reasons for failure to follow directives may not be known, but whatever the reason, it is the administration's responsibility to correct the problem.**

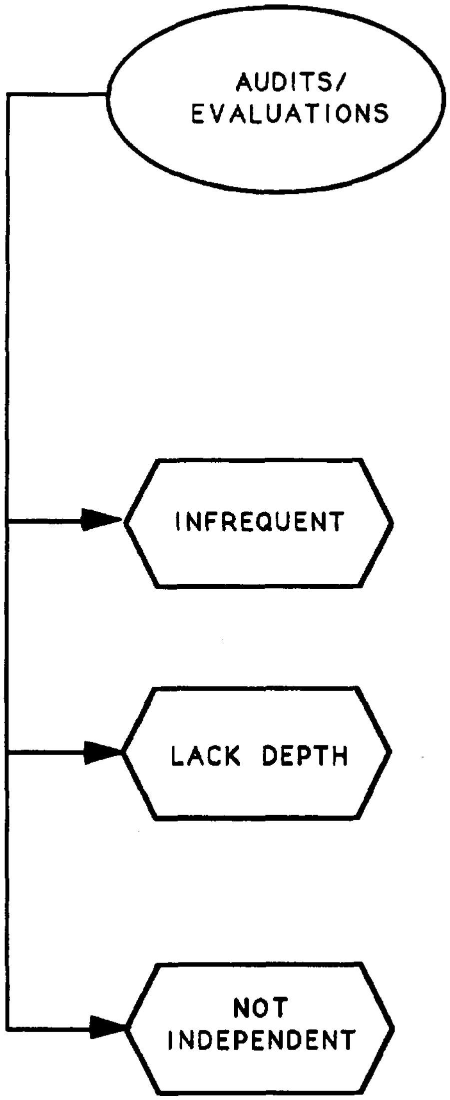
COMMUNICATIONS OF SPAC LTA: Were standards, directives, or policy not communicated from management down through the organization?
NOTE: **Inadequate communication can refer either to failure to communicate the SPAC formally (training, directives, or oral communication) or failure to support the SPAC through involvement, concern, example, or vigor.**

RECENTLY CHANGED: Have standards or directives been recently changed?
Did information concerning changes fail to reach all levels of the organization?
Has some confusion been created by the changes?

ENFORCEMENT LTA: In the past, has enforcement of the SPAC been lax?
Have failures to follow the SPAC in the past gone uncorrected or unpunished?
Has noncompliance been accepted by supervision?

NO WAY TO IMPLEMENT: Was an SPAC not followed because a method of implementation was not provided or because no practical way of implementing the SPAC existed?

ACCOUNTABILITY LTA: Did the event occur because no one was accountable, responsible, or answerable for a specific job or action?



AUDITS/EVALUATIONS

Was the event caused by failure to provide independent audits or evaluation programs?

Did inadequate audit or evaluation programs contribute to the problem?

NOTE: **This category should be used only if it is reasonable to expect an audit or evaluation system to be in place for the affected equipment or system. Certainly, everything can not be audited, but important safety related systems and the effectiveness of those systems should be audited or evaluated periodically. Before using this node, the investigator must consider whether would be reasonable for an auditor to be able to detect the type of error that caused the incident.**

INFREQUENT

Were audits or evaluations performed too infrequently to detect system or equipment deficiencies?

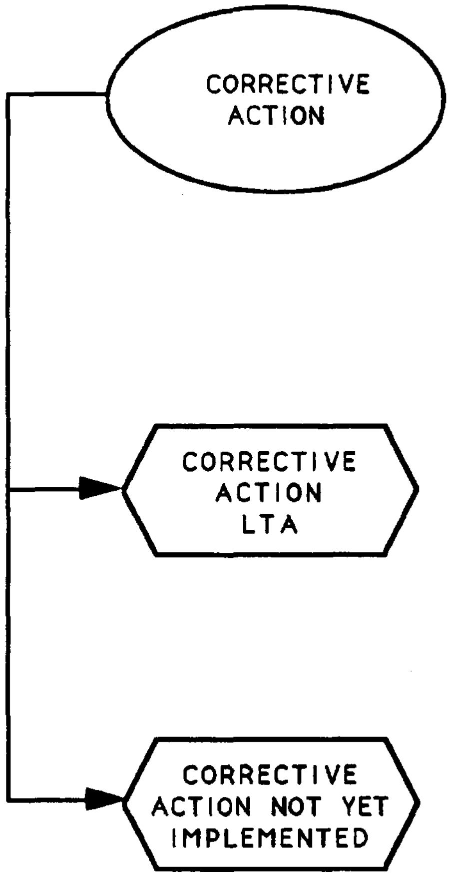
LACK DEPTH

Are audits and evaluations performed thoroughly enough to detect system deficiencies?

NOT INDEPENDENT

Was an event caused by failure to provide independent audits or evaluations?

Were audits or evaluations carried out by someone other than the custodian of the system involved?



CORRECTIVE ACTION: Was an event caused by failure to provide corrective action for known deficiencies or failure to implement recommended corrective actions before known deficiencies recur?

NOTE: **Known deficiencies are any deficiencies other than equipment failures, such as human performance related deficiencies, procedure deficiencies, or administrative control system deficiencies. Repeat equipment failures occurring because of inadequate or unimplemented corrective actions are coded under the "Repeat Failure" category.**

CORRECTIVE ACTION LTA: Was corrective action taken for known deficiencies? Were implemented corrective actions unsuccessful in preventing recurrence?

CORRECTIVE ACTION NOT YET IMPLEMENTED: Was recommended corrective action for a known deficiency not implemented (due to delays in funding, delays in project design, normal length of implementation cycle, tracking deficiencies, etc.) before recurrence of the deficiency?

Training

Training is the control of an individual's internal learning process through external means. It is a method for educating personnel in the skills necessary to perform desired tasks (e.g., use of a specific tool, operation of a process, flying an airplane). The function of training is to manipulate the learner's outside environment in order to initiate and regulate the basic internal learning process. There are different types of learning and different stages of learning that that one must progress through before mastering a subject. Training methods should take advantage of our knowledge of the learning process.

One of the most important elements of a training program is the identification of the need for training. Before a training program can be developed for a particular job, that job must be defined. It must be broken down into individual tasks, task elements, task sequences, and timelines. Task or task/timeline analyses are very common methods for accomplishing this goal. For purposes of the "Root Cause Tree," task analysis is defined as follows:

> **Task analysis is the process of identifying and describing parts of a job and analyzing the resources necessary for successful work performance.**

Timeline analysis, a related technique, involves the laying out of task elements along a line marked off in units of time.

Once the job has been defined, the people and the specific skills needed to perform the job can be selected. For specific jobs such as those at the Savannah River site, training is almost always required. The training methods selected depend on many things; however, they should be chosen with two principle goals in mind, namely, to facilitate the required learning for the trainees and to verify that the trainees have in fact learned the required job skills.

There are numerous effective techniques for training people. Classroom instruction, on the job training, use of simulators and mockups, and programmed instruction are some of the most commonly used methods. From our knowledge of human learning, we do know that certain techniques such as repetition, proper feedback and reinforcement, performance testing, and periodic test and retraining are important.

When coding causal factors suspected of being related to training, the investigator should consider the nodes in the "Training" segment of the "Root Cause Tree." This major root cause category branches to two near root causes: "No Training" and "Methods Less Than Adequate."

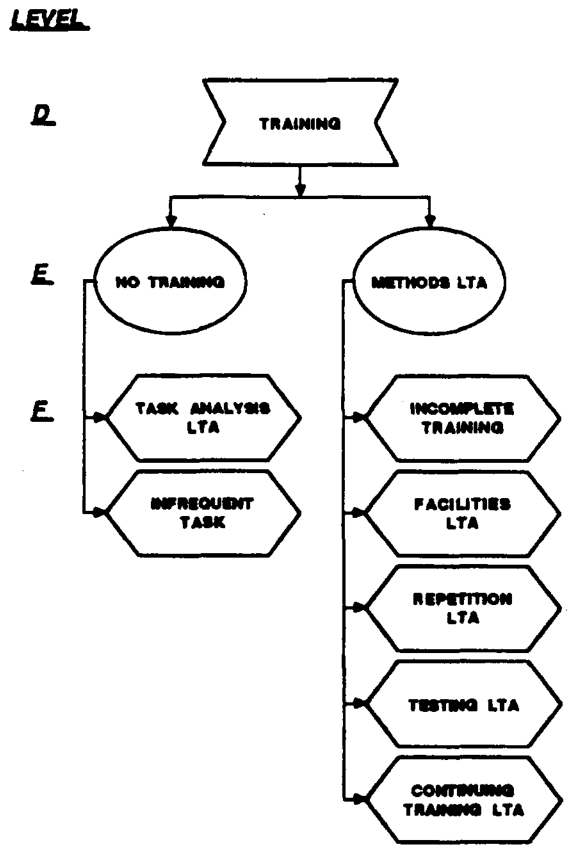
The first near root cause, "No Training," branches to two root causes. These are "Task Analysis Less Than Adequate" and "Decision Not To Train." No training program can be initiated properly unless the training requirements have been identified and well thought out. A systematic task/training analysis which identifies skill requirements, manning requirements, the need for job aids, and the need for special tools and equipment is essential in designing an adequate training program. The root cause, "Task Analysis Less Than Adequate," should be used for causal factors involving this issue.

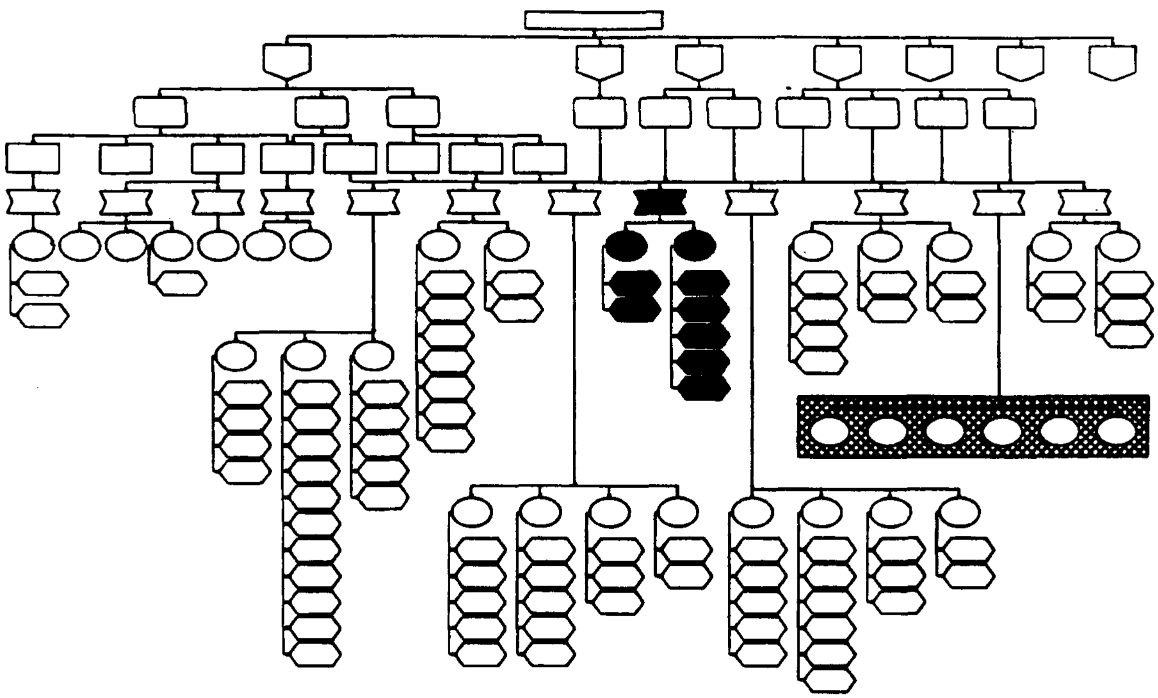
Sometimes, the designer of the training program has to make a decision about whether the likelihood of the task is remote, whether the task is of little consequence, whether the task requires only common knowledge, or whether the cost of training is prohibitive. "Decision Not To Train" should be coded as the root cause when such a decision results in a causal factor.

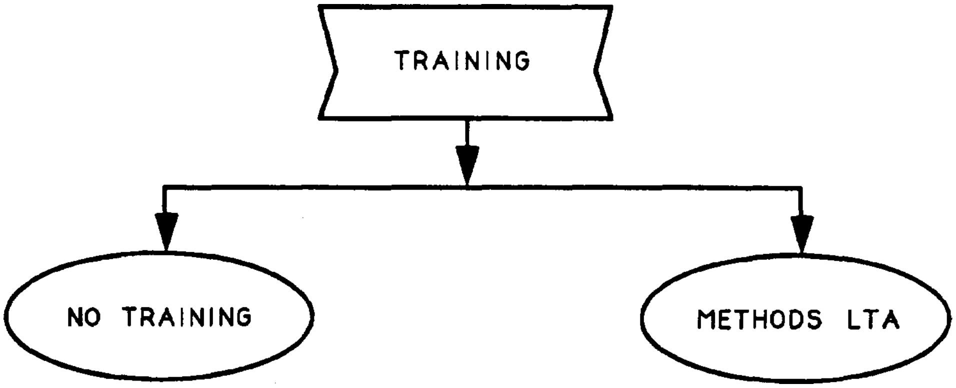
The second near root cause, "Methods Less Than Adequate," branches into five root causes: "Incomplete Training," "Facilities Less Than Adequate," "Repetition Less Than Adequate," "Testing Less Than Adequate," and "Continuing Training Less Than Adequate." These root causes should be considered when the causal factor appears to be the result of inadequate training technique.

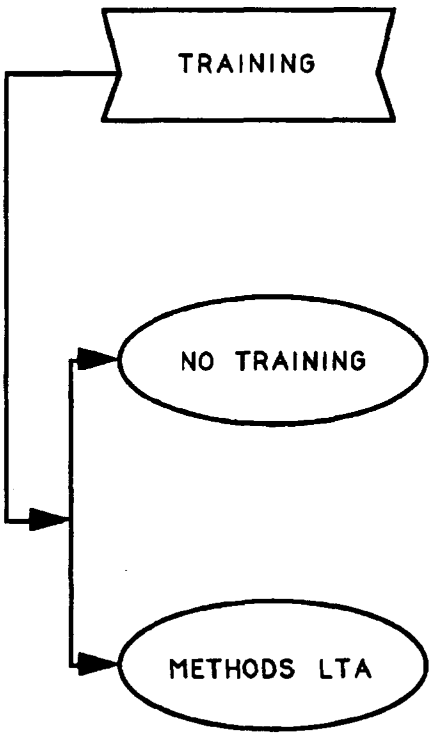
A word of caution is in order here. Many times inadequate training is given as the reason for a multitude of problems that are really due to other factors. Training can only do so much in the way of overcoming poor design, improper instructions, inadequate procedures, etc. Dual coding of training with nodes in other segments of the tree should always be considered. The following expansion of the "Training" segment of the "Root Cause Tree" furnishes questions and thoughts to use when considering nodes dealing with the training of personnel.

Training


LEVEL
D
E
F
TRAINING
NO TRAINING
METHODS LTA
TASK ANALYSIS LTA
INFREQUENT TASK
INCOMPLETE TRAINING
FACILITIES LTA
REPETITION LTA
TESTING LTA
CONTINUING TRAINING LTA



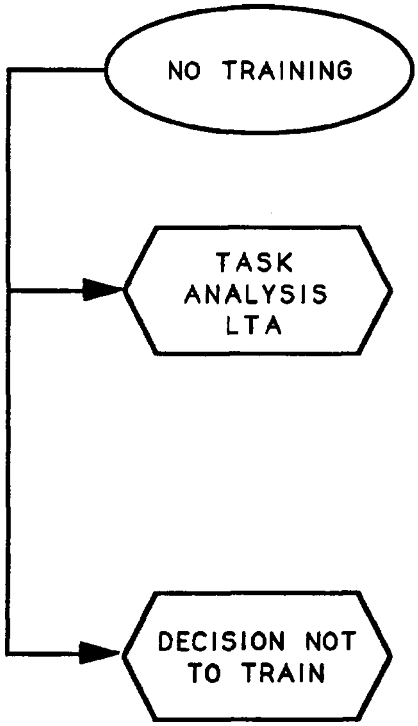




Was an event caused by a lack of training?
Was the training incomplete or otherwise inadequate?
NOTE: Some causes coded under "Training" should be DUAL CODED using "Human Factors" or "Procedures." Problems that involve poor design or inadequate procedures cannot be expected to be completely resolved by providing detailed training.

Was there a complete lack of training on a particular system, job, or subject?
NOTE: This usually indicates an inadequate analysis of the training requirements, or a consious decision not to train.

Were training methods (e.g., testing, repeat training, facilities, thoroughness) adequate?



Was there a complete lack of training on a particular system, job, or subject?

NOTE: This usually indicates an inadequate analysis of the training requirements, or a consious decision not to train.

Was training not offered because an inadequate task analysis failed to recognize the need for training?

NOTE: Task analysis is the process of listing all tasks or jobs that personnel perform as well as the requirements or knowledge necessary to perform these tasks.

Was training not offered for an infrequent task?

Was training thought to be unneccessary for the particular task?

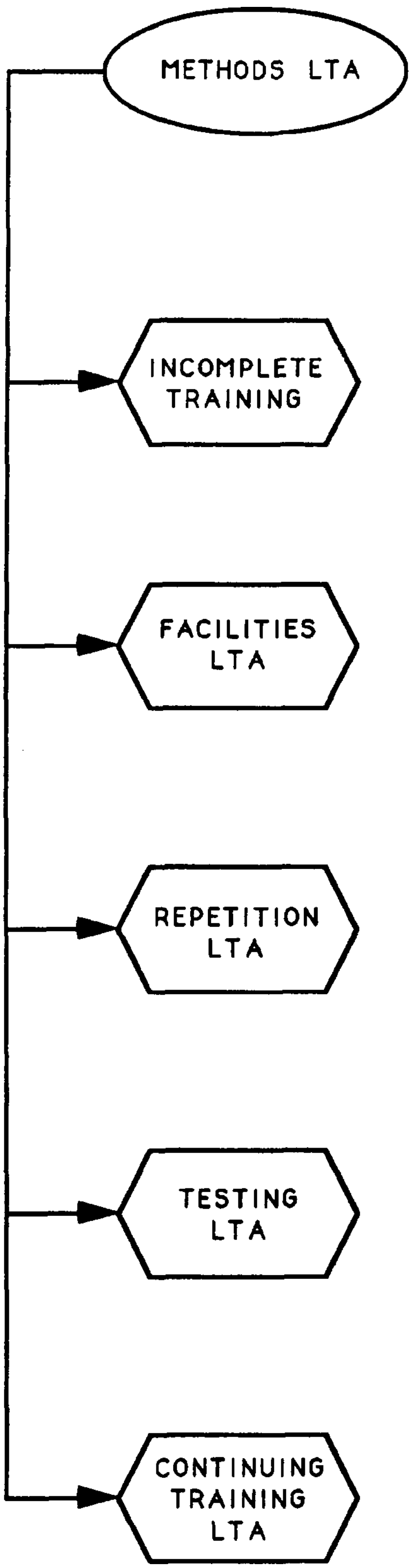
Was a decision made not to train because task occurs very infrequently?

Was the task thought to be of little consequence?

Was the task thought to be of common knowledge or common sense?

Was a decision made not to train because the task was thought to be of little risk?

Was a decision made not to train because of prohibitive expense?



Were training methods (e.g., testing, repeat training, facilities, thoroughness) adequate?

Was training such that it failed to address all of the necessary aspects of a system or subject?
How do you know the training was incomplete?

Were training facilities or tools (e.g., classrooms, shops, mockups, visual aids) adequate?
Were appropriate criteria used to determine adequacy?
Are models and mock-ups current?

Was training repeated sufficiently for the information to be learned?
How many times, and in how many ways, was the information presented to trainees?
NOTE: Periodic retraining is to be coded under "Continuing Training LTA."

Was testing sufficient to demonstrate that learning was accomplished?
What type of testing was performed?

Was continuing training or retraining of personnel too infrequent, insufficient in depth, or otherwise inadequate?
Did an individual forget how to carry out the task because it is done so infrequently?

Human Factors

The "Human Factors" segment of the "Root Cause Tree" deals with errors made due to poor human factors engineering. Human factors engineering is the process of applying knowledge about the capabilities and limitations of humans to the design, development, production, and control of manned systems. The goal of human factors engineering is to reduce the likelihood of human error in the operation and maintenance of these systems. Put in simple language, human factors engineering is applying what is known about people to develop the systems that people are required to use to do their jobs.

Human factors are all of the considerations that affect the performance of humans within a system. These factors are commonly divided into three categories: 1) anatomical, 2) physiological, and 3) psychological. Anatomical considerations might involve reach distances, viewing angles, and stature with respect to the placement of equipment. Physiological factors might include the effects of temperature, light, or noise on performance. Examples of psychological considerations include the mental workload placed on the individual and the effect of stress on job performance.

Incident investigators should always consider the system as a possible cause of human error. An individual may commit an error caused by a human factors deficiency. Take for example, an operator who misreads a gauge. Perhaps the gauge is mounted too high or low to be read correctly. Glare from surrounding lights may make the gauge difficult to read. Causal factors like these should be coded using the "Human Factors" segment of the tree.

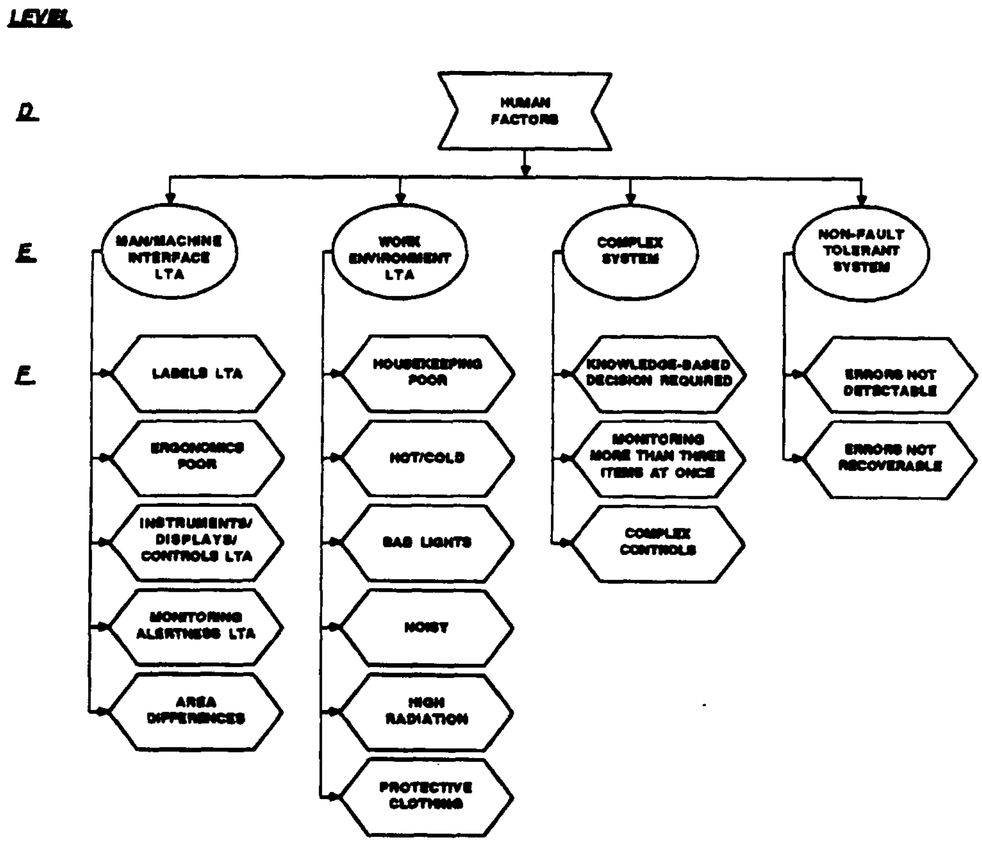
The major root cause category, "Human Factors," branches to four near root causes. These are "Man/Machine Interface Less Than Adequate," "Work Environment Less Than Adequate," "Complex System," and "Non-Fault Tolerant System."

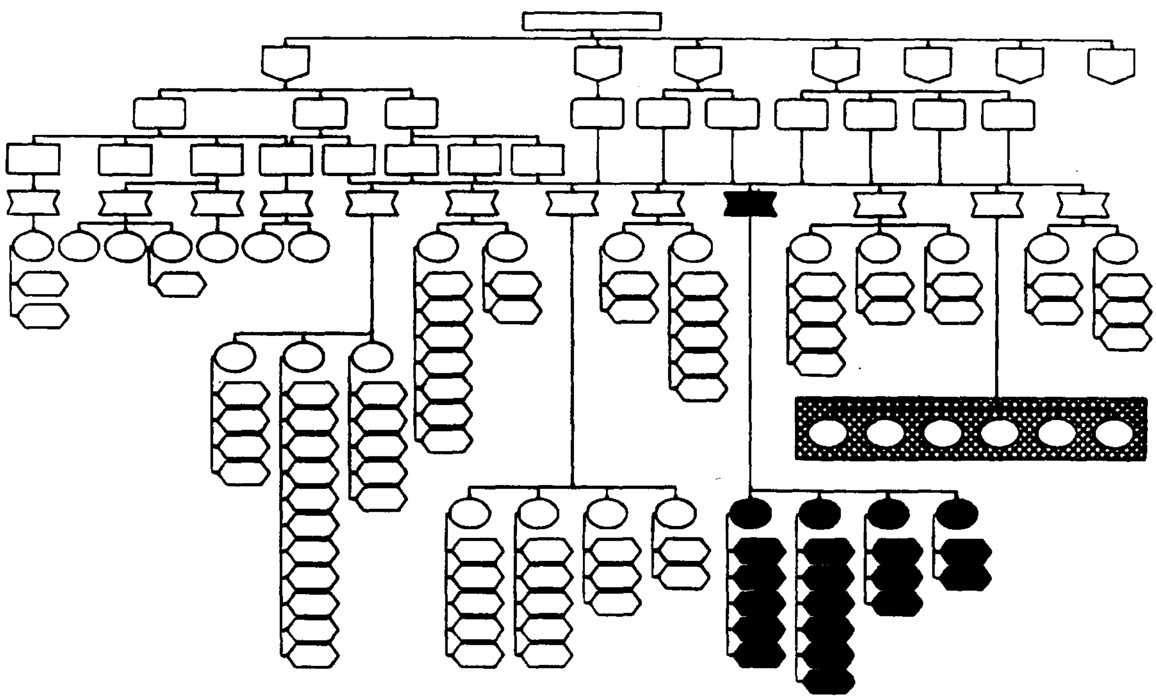
The first near root cause, "Man/Machine Interface Less Than Adequate," branches to five root causes. Areas to be considered include "Labels Less Than Adequate," "Ergonomics Poor," "Instruments/Displays/Controls Less Than Adequate," "Monitoring Alertness Less Than Adequate," and "Area Differences." Ergonomics, as defined in this handbook, deals with the arrangement and placement of equipment. The second near root cause, "Work Environment," branches to six root causes: "Housekeeping Poor," "Hot/Cold," "Bad Lights," "Noisy," "High Radiation," and "Protective Clothing."

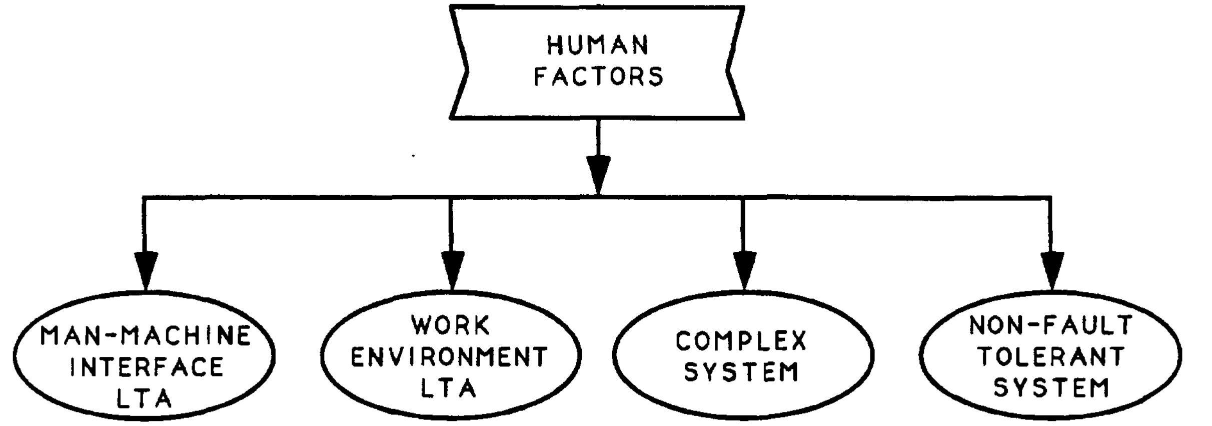
"Complex System," the third near root cause in this segment of the tree, branches to three root causes. Areas to be considered include "Knowledge-Based Decision Required," "Monitoring More Than Three Items At Once," and "Complex Controls." Finally, "Non-Fault Tolerant System," branches to two root causes. These are "Errors Not Detectable" and "Errors Not Recoverable."

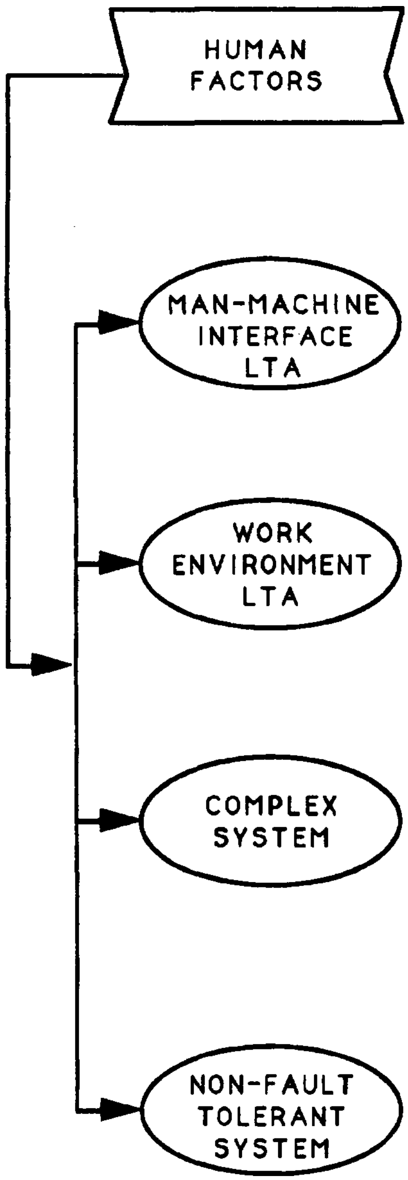
Detailed definitions of each of the nodes in the "Human Factors" segment of the tree are presented on the pages that follow. Examples are included for reference. Causal factors coded using nodes in this segment of the tree are often DUAL CODED.

Human Factors









Was the error made because of poor human factors engineering?
NOTE: **All human factors design problems are coded here rather than under "Design." Always consider DUAL CODING human factors problems under "Procedures" and "Training." The best mix of human factored designs, procedures, and training is difficult to judge; however, the three are interrelated.**

Was the event caused by poor coordination or interaction of personnel with the equipment, systems, facilities, or the instrumentation with which they work?
NOTE: **Examples of poor man-machine interface include inadequate design layout, readability, and accessibility; presentation of distracting information; inadequate accuracy of displays; and inadequate precision of controls.**

Was the work environment conducive to good human performance? Items like housekeeping, lighting, and noise should be considered.

Was an error caused by the system or equipment controls being complex or complicated?
Was a knowledge-based decision required?
Were too many variables acting at once, causing confusion or indecisiveness?
NOTE: **If adequate training could have reduced the chance of error by teaching personnel how to best use the complex system, then DUAL CODING under "Training" is appropriate.**

Were errors undetectable?
Did the system design prevent discovered errors from being corrected before a failure or event occurred?

MAN-MACHINE INTERFACE LTA

Was the event caused by poor coordination or interaction of personnel with the equipment, systems, facilities, or the instrumentation with which they work?

NOTE: **Examples of poor man-machine interface include inadequate design layout, readability, and accessibility; presentation of distracting information; inadequate accuracy of displays; and inadequate precision of controls.**

LABELS LTA

Did labeling fail to clearly identify equipment?

Did labeling incorrectly identify equipment?

Were the labels hard to read, incorrect, or misleading? For example, two labels, identical except for 1 or 2 letters and located side by side, are very difficult to distinguish from one another.

ERGONOMICS POOR

Did poor arrangement or placement of equipment contribute to the event?

Did poor coordination of human characteristics with the physical environment, facilities, or equipment contribute to the event?

Did an individual have to bend down or assume an awkward position to complete a task? For example, locating equipment in hard to reach places or placing instruments at above eye level increases the probability of human error.

NOTE: **Consider reach distances, viewing distances and angles, overall layout of equipment, and amount of space the individual has to move about in.**

INSTRUMENTS/ DISPLAYS/ CONTROLS LTA

Did inadequate or unclear instrument gauges or displays contribute to the incident?

Did inadequate equipment controls contribute to the incident?

NOTE: **Problems with gauges include difficult to read scales, lack of metrics, and the use of conversions. Other problems include confusing groupings of controls and controls that operate contrary to normal expectations.**

MONITORING ALERTNESS LTA

Could the error be attributed to loss of alertness due to the excessive length of a monitoring task?

NOTE: **Human performance studies indicate that alertness during monitoring decreases over time. Due to this "vigilance decrement," continuous monitoring, with little or no control action, should be limited to 30 minutes.**

AREA DIFFERENCES

Did differences in equipment or equipment controls between different processes or areas contribute to the event? Personnel may often change assignments from one facility to another, and slight differences between the areas can cause human performance errors.

WORK ENVIRONMENT LTA

Was the work environment conducive to good human performance? Items like housekeeping, lighting, and noise should be considered.

HOUSEKEEPING POOR

Did poor housekeeping conditions contribute to the event?

HOT/COLD

Was an event caused by excessive exposure of personnel to a hot or cold environment?

BAD LIGHTS

Was an event caused by bad lighting conditions - too much, too little, or glare producing?

NOISY

Was an event caused by diminished human performance due to excessive noise?

NOTE: Communication errors due to noise should be coded under "Noisy Environment."

HIGH RADIATION

Did high radiation contribute to the event by making personnel rush work to reduce exposure?

Were personnel hindered by the required protective clothing?

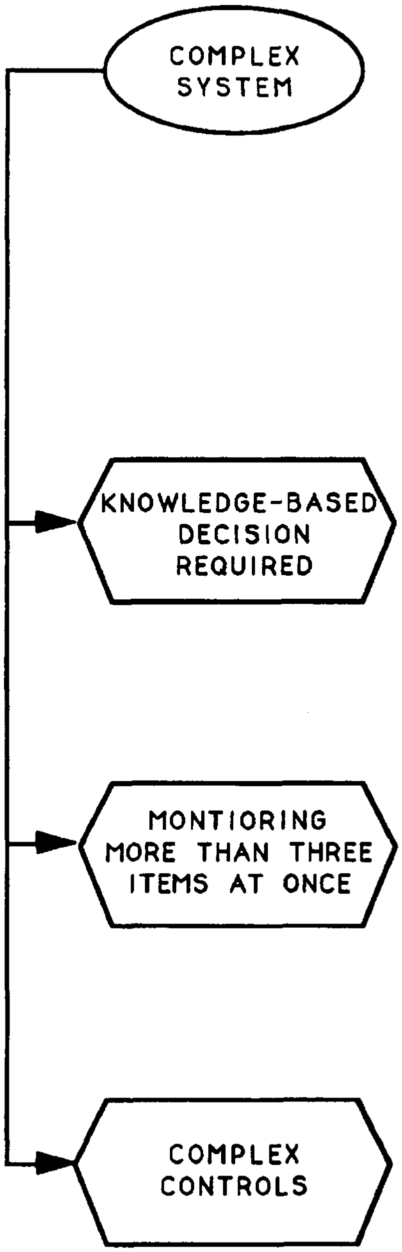
NOTE: Consider DUAL CODING those events involving difficulties with clothing worn for radiation protection under "Protective Clothing".

PROTECTIVE CLOTHING

Did protective clothing (e.g., plastic suit, gloves, respirator) contribute to the difficulty?

Were personnel required to wear protective clothing for an uncomfortable length of time?

Were personnel required dress in and out of protective clothing an excessive number of times?



COMPLEX SYSTEM

Was an error caused by the system or equipment controls being complex or complicated?
Was a knowledge-based decision required?
Were too many variables acting at once, causing confusion or indecisiveness?

NOTE: **If adequate training could have reduced the chance of error by teaching personnel how to best use the complex system, then DUAL CODING under "Training" is appropriate.**

KNOWLEDGE-BASED DECISION REQUIRED

Was an error caused by a situation or system being complex and requiring a decision based on specific knowledge for a successful outcome?
Could better design have been reasonably expected to eliminate the error?

NOTE: **Knowledge-based decisions require thought based on understanding and knowledge of a system, the interactions of the system's parts, and variables affecting the system. These decisions are not reflexive in nature. They are not based simply on trained or developed reaction to rules. Knowledge-based decision making usually results in more errors than rule-based decision making.**

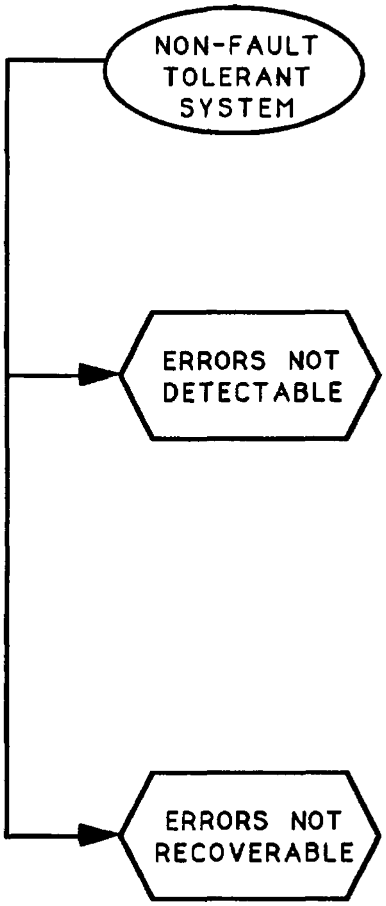
MONTIORING MORE THAN THREE ITEMS AT ONCE

Were personnel required to monitor more than three items or variables at once, causing overload or failure to notice necessary information?

NOTE: **Experience has shown that the probability of error increases when personnel are required to monitor more than three variables at once.**

COMPLEX CONTROLS

Were the system or equipment controls so complex that they contributed to or caused the event?
Could the system have been designed with simpler controls so that the chance of error was reduced?



NON-FAULT TOLERANT SYSTEM

Were errors undetectable?
Did the system design prevent discovered errors from being corrected before a failure or event occurred?

ERRORS NOT DETECTABLE

Were errors detectable (by way of alarm or meter readings, etc.) during or after occurrence?
NOTE: **It is unreasonable to expect all systems and equipment to have alarms; however, important safety related equipment should have reliable error detection systems.**

ERRORS NOT RECOVERABLE

Were errors recoverable if discovered before a failure occurred?
NOTE: **Important safety related equipment should be designed so detected errors can be alleviated before system failure occurs.**

Communications

Communication is the act of exchanging information. For communication to be effective, the information must be complete and remain unchanged as it is passes from person to person. Communication, as defined in the "Communications" segment of the "Root Cause Tree" refers to the exchange of either spoken or written messages. The messages may be transmitted and received in many different ways (e.g., face-to-face, by telephone, by radio, over a video display terminal, or through written notes left in logbooks, on erasable boards, or on notepads).

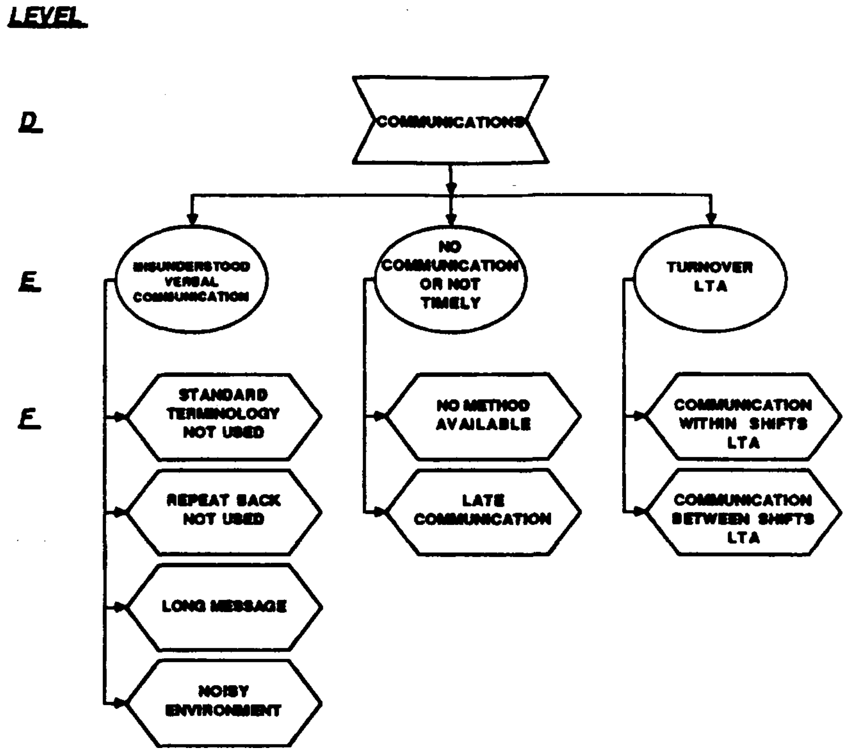
When coding causal factors dealing with faulty communication, the investigator should consider nodes in the "Communications" segment of the tree. This major root cause category branches to three near root causes: "Misunderstood Verbal Communication," "No Communication or Not Timely," and "Turnover Less Than Adequate." Problems with communication through formal documentation (e.g., written procedures, policies, and drawings) should be coded under other, more appropriate Level D nodes (i.e., "Procedures" and "Administrative Systems").

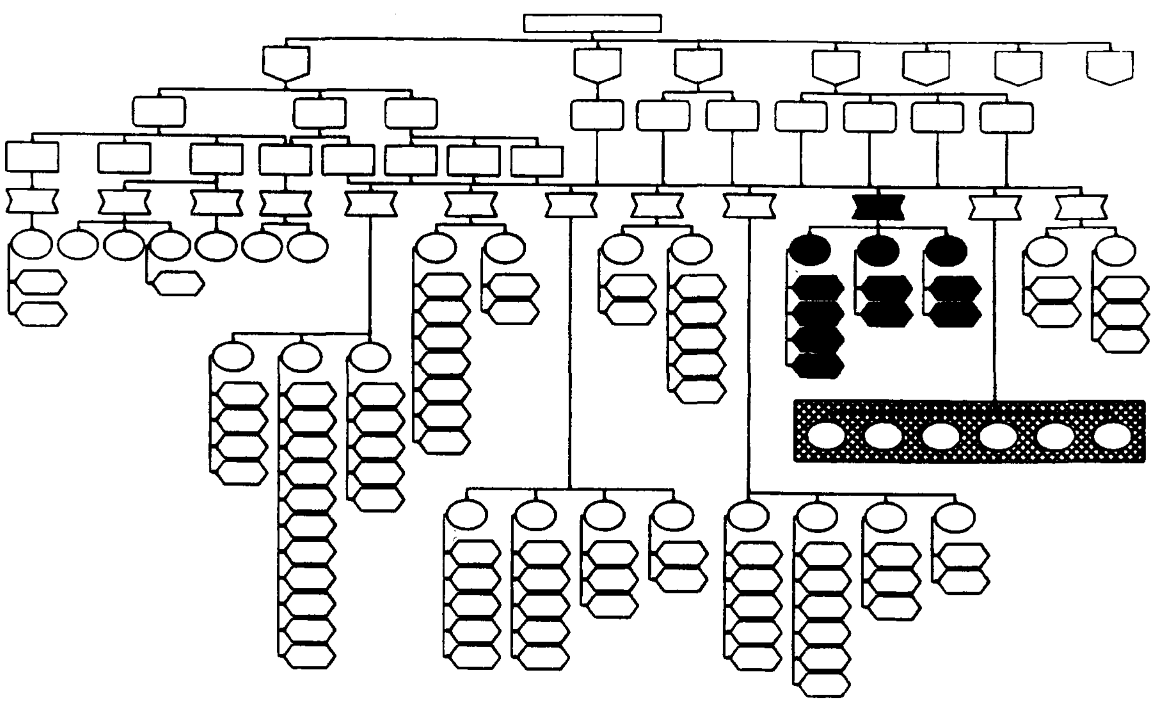
The first near root cause, "Misunderstood Verbal Communication," branches to four root causes. These are: "Standard Terminology Not Used," "Repeat Back Not Used," "Long Message," and "Noisy Environment." Problems with verbal conversations between operators, between operators and supervisors, and between supervisors and managers should be coded using this node.

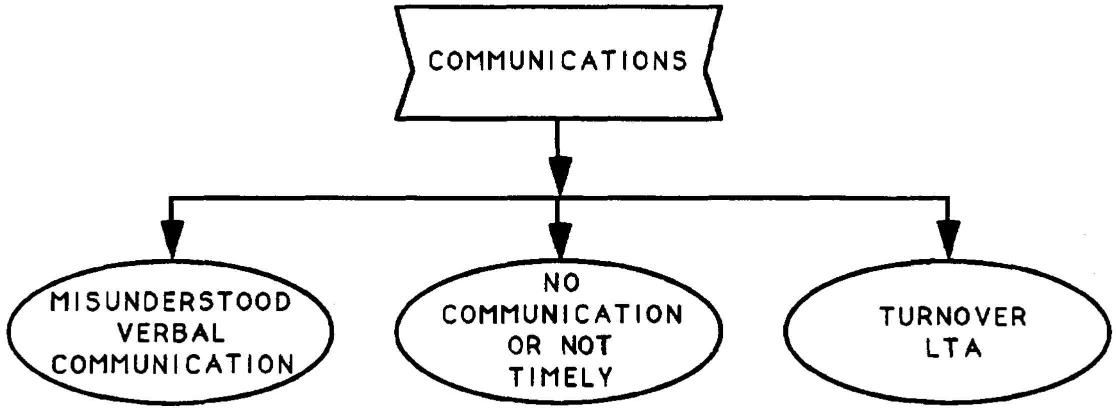
The second near root cause, "No Communication or Not Timely," branches to two root causes: "No Method Available" and "Late Communication." The final near root cause, "Turnover Less Than Adequate," also points to two root causes: "Communication Within Shifts Less Than Adequate," and "Communication Between Shifts Less Than Adequate."

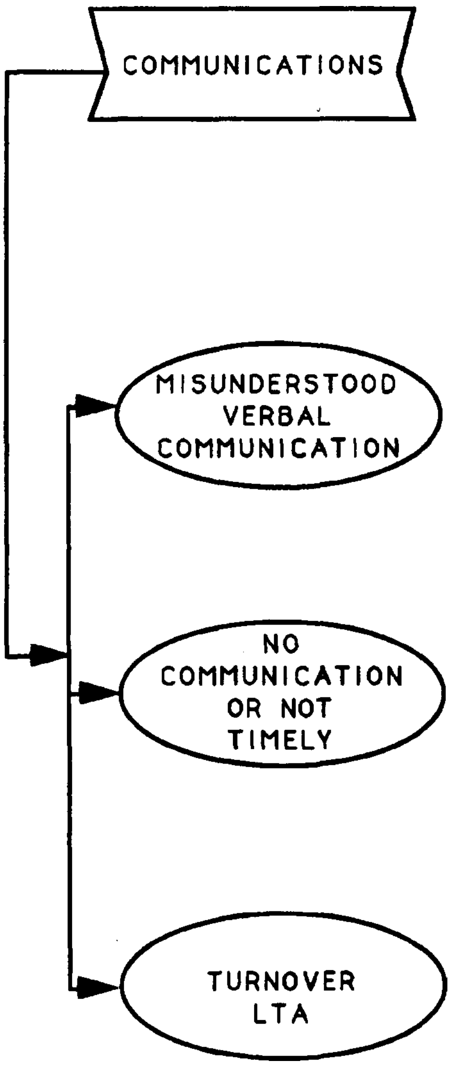
An expansion of the "Communications" segment of the "Root Cause Tree" is presented on the following pages. Questions are provided for use when considering nodes in this segment.

Communications









Was an error caused by misunderstood comunication or lack of communication?

NOTE: Communication is defined as the act of exchanging information. This node addresses many modes of communication (e.g., face to face, telephone, radio, video diplay terminal, short written messages, log entries). It does not address the more formal methods of communication involving written procedures, specifications, etc.

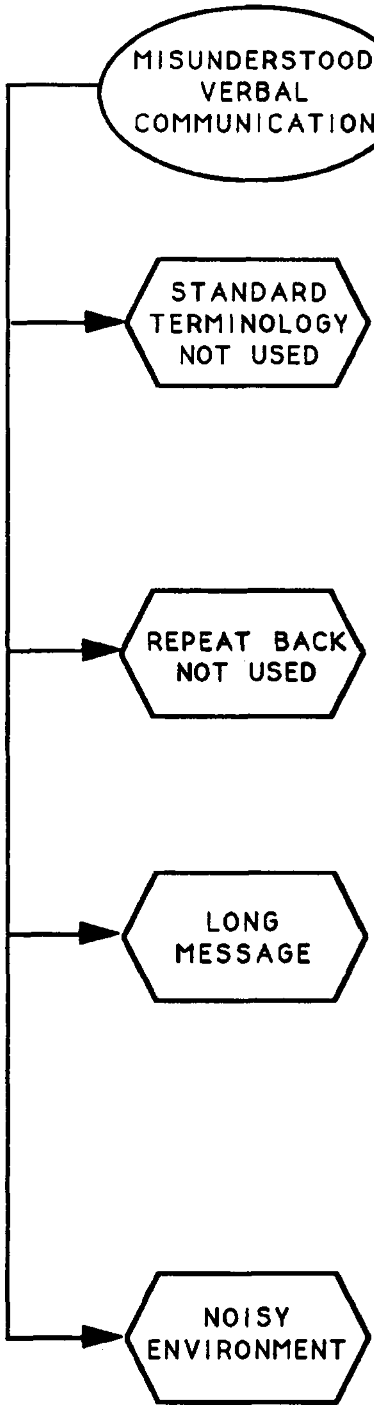
Was an error caused by the misunderstanding of verbal communication between personnel?
Was there an error in verbal communication between operators? Between operator and supervisor? Between supervisor and management?

Was the problem caused by a failure to communicate?
Did the communication take place too late?
What obstacles hindered or delayed communication?

NOTE: Each individual involved should be questioned regarding messages he or she feels should have been received or transmitted. Determine what means of communication was used (i.e., the technique)? Persons on all sides of a communication link should be questioned regarding known or suspected problems.

Was there incorrect, incomplete, or otherwise inadequate turnover during a shift or between shifts?

NOTE: Turnover is an area that can be fruitful for the investigator. Many turnover problems have been associated with incidents in the past.



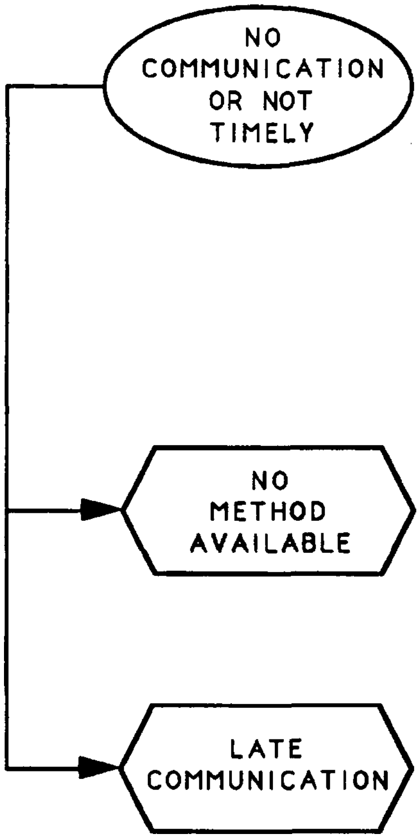
Was an error caused by a misunderstanding of verbal communication between personnel?
Was there an error in verbal communication between operators? Between operator and supervisor? Between supervisor and management?

Was standard or accepted terminology used?
Did one piece of equipment have two or more commonly used names?
NOTE: **The same word or phrase can mean different things to different people. Two persons can both feel that communication is accurate when, in fact, it is not because of inconsistent nomenclature. Regional or non-standard speech may also present a problem.**

Was a communication error caused by failure to repeat back a message to the sender for the purposes of verifying that the message was heard and understood correctly?
Note: **Consider DUAL CODING under "No Standards, Policies, or Administrative Controls" if the importance of the communication should have required a repeat back system, but no such system existed.**

Was a message or instruction misunderstood because it was too long?
Should the message have been written instead of oral?
Could the message have been shortened or broken up?
NOTE: **A person can only retain a given amount of information. Some people have better memories than others. However, it is certain that a short, concise message can be retained and forwarded much easier than a long, convoluted message. Long messages should be broken down into a series of short messages.**

Was a message or instruction misunderstood by the listener because of noise interference?
NOTE: **Communication can be greatly disrupted by ambient sound levels, general noise, whines, buzzes, and the like. Human speech communication takes place in a narrow frequency band between 600 and 4800 Hz. This is known as the speech interference zone. Sounds can mask frequencies of speech in this zone, thereby making communication very difficult.**



NO COMMUNICATION OR NOT TIMELY

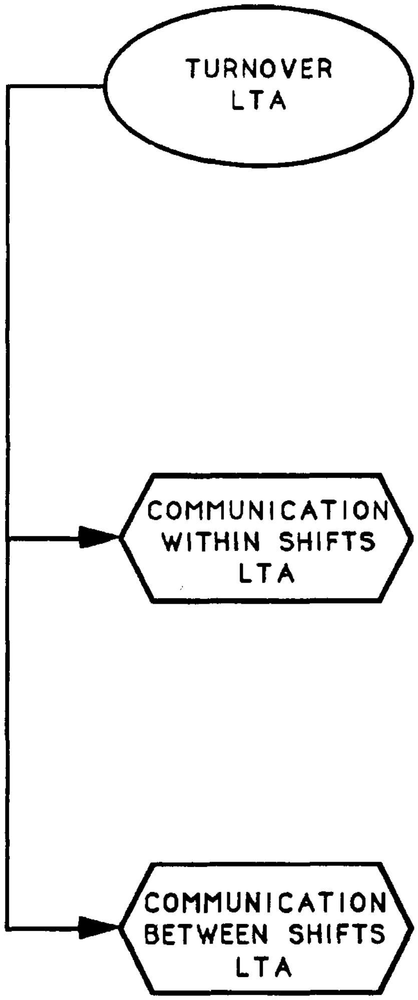
Was the problem caused by a failure to communicate?
Did the communication take place too late?
What obstacles hindered or delayed communication?
NOTE: Each individual involved should be questioned regarding messages he or she feels should have been received or transmitted. Determine what means of communication was used (i.e., the technique)? Persons on all sides of a communication link should be questioned regarding known or suspected problems.

NO METHOD AVAILABLE

Did a method or system exist for communicating the necessary message?
Was the communication system out of service or otherwise unavailable at the time of the incident?

LATE COMMUNICATION

Was communication provided too late because events happened too fast to allow time for communications?
NOTE: Late communications can be disastrous. *Remember Pearl Harbor!*



TURNOVER LTA

Was there incorrect, incomplete, or otherwise inadequate turnover during a shift or between shifts?

NOTE: **Turnover is an area that can be fruitful for the investigator. Many turnover problems have been associated with incidents in the past.**

COMMUNICATION WITHIN SHIFTS LTA

Was there incorrect, incomplete, or otherwise inadequate communication between workers during a shift?

Could a more effective method of communication have been used?

NOTE: **This situation usually involves the relief of one worker by another.**

COMMUNICATION BETWEEN SHIFTS LTA

Was there incorrect, incomplete, or otherwise inadequate communication between workers during a shift change?

NOTE: **Turnover between shifts is usually more formal than within-shift turnover. Use of log-out and log-in procedures is very helpful. Detailed instructions and other important status information should be exchanged.**

Personal Performance

Most schemes for coding the causes of incidents or accidents specify a category to address human error (e.g., "human performance," "pilot error," "human caused error," or "human error"). Studies have shown human error to be the general cause of 20% of failures associated with consumer products, 50-60% of failures associated with nuclear power plants, 74% of aircraft failures, and 85% of automobile/highway system failures (Lawrence Livermore National Laboratory & Essex Corporation, Undated). Alan Swain, an expert in the field of human reliability, divides human error into two broad categories: 1) situation caused errors and 2) human caused errors (Swain, 1980). Situation caused errors are related to work station design. In other words, some aspect of the system or work environment causes the human to make a mistake. Human caused errors reflect problems within people (e.g., low motivation, poor skills, carelessness). Research conducted to evaluate these types of error has shown that approximately 85% of all human errors are situation caused.

The distinction between human caused error and situation caused error becomes very important during the root cause coding process. Many of the incidents in site non-reactor facilities involve human error; however, much of this error is situation caused. We find human errors that are attributable to poor human factors design, improper instructions, inadequate training, confusing procedures, lack of communications, and other system problems. Most of the nodes on the "Root Cause Tree" address aspects of the system or situation that may have caused these human errors. The "Personal Performance" segment of the tree reflects human qualities and conditions (e.g., physical and mental well being, attitude, mental capacity, attention span, degree of rest, and substance abuse). Causal factors coded using this segment of the tree are similar to Swain's human caused errors. If the investigator is unable to code a causal factor under other Level D nodes (e.g., "Human Factors," "Training," "Communications"), then "Personal Performance" can be used. This segment of the tree is valid when not overused and is primarily oriented toward inadequate job performance by an individual.

"Personal Performance" is exclusive of other Level D nodes. When attempting to code a given causal factor, it is important to consider all other Level D nodes before choosing "Personal Performance." The investigator needs to determine whether system problems were involved before "blaming " an individual for the incident. When the other Level D nodes are used correctly, "Personal Performance " should account for only a small percentage of causal factors coded. This segment of the tree is very sensitive. When the investigator uses this category, he is, in effect, saying that one of the reasons why the incident occurred is that the person or persons involved did not exhibit minimum essential requirements for the job.

Defining the shortcomings of an individual is a very sensitive process and should be handled confidentiallly. When documenting the root cause analysis, the investigator should document the path taken through the "Root Cause Tree" only to the "Personal Performance" node on Level D. Six Level E nodes are listed to provide the investigator with an understanding of the types of problems that might be categorized under the more broad "Personal Performance" node. These include: "Sensory/Perceptual Capabilities Less Than Adequate," "Motor/Physical Capabilities Less Than Adequate," " Attitude/Psychological Profile Less Than Adequate," "Reasoning Capabilities Less Than Adequate," "Attention Below Minimum Standards," and "Rest/Sleep Less Than Adequate (Fatigue)." These Level E nodes are "shadowed" on the tree to indicate that they are for reference purposes only. In no case should one of these Level E nodes be presented in the incident report. Table RCC-PP.1 presents the these Level E nodes along with some descriptive symptoms.

The primary goal of the investigator conducting a root cause analysis is to indentify and categorize causal factors so that recommendations for preventing recurrence can be identified and implemented. An important point to remember about using the "Personal Performance" node is that it should always be followed up by a specific action item aimed at solving the personal performance difficulty for the individual in question. Due to its confidential nature, this action item should not be documented in the incident report. Action items might include counseling, medical leave, reassignment to a more appropriate job, constructive discipline, or in extreme cases, termination.

It is understood that investigators are not going to be experts in diagnosing the underlying causes of personal performance problems. They can only identify obvious symptoms, such as those shown in Table RCC-PP.1. If the investigator has any doubts about coding "Personal Performance" as the causal factor, then assistance should be sought from appropriate sources (e.g., Supervision, Medical, NRSED, etc.).

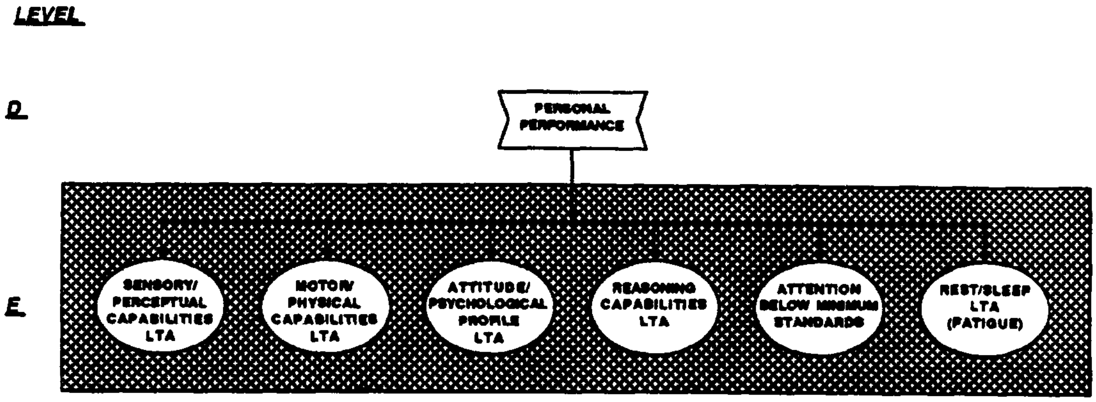
It should also be noted that general personnel action items (e.g., "Remind all operators to ... ") are not suitable for addressing a personal performance difficulty . Although general reminders can be useful to assure that everone is aware of supervision's standards, they do not solve the performance problem of a specific individual.

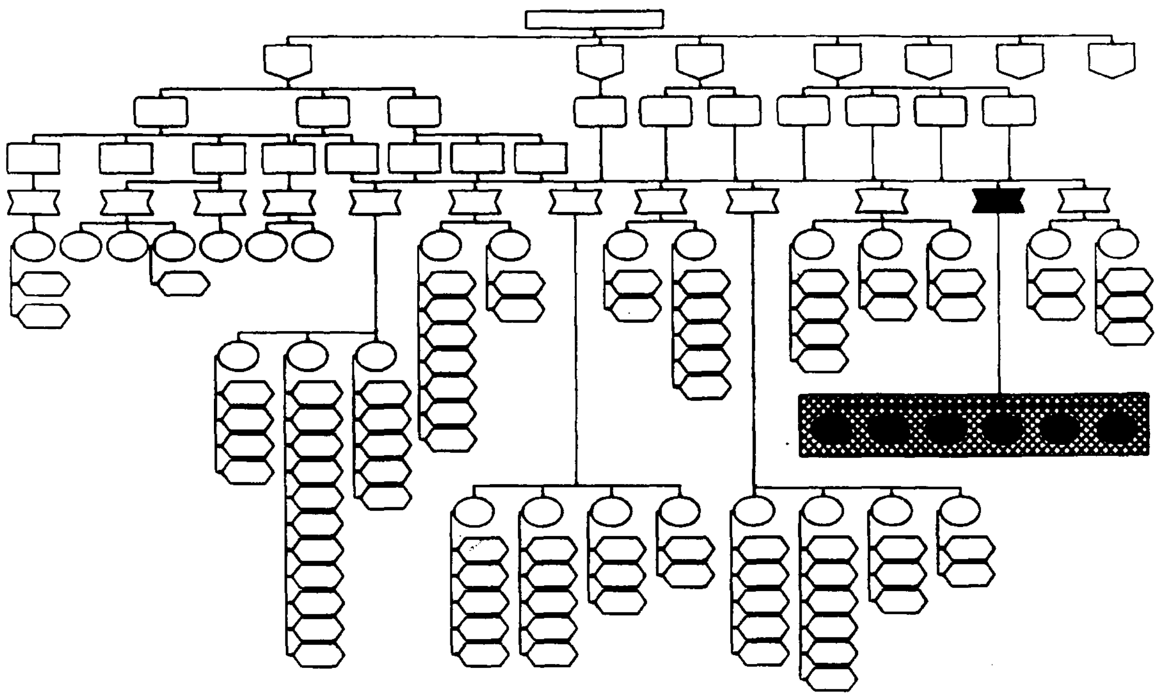
For a complete explanation of this segment of the tree, see the pages that follow. Questions are provided to help the investigator determine whether or not the "Personal Performance" node is appropriate for a given causal factor.

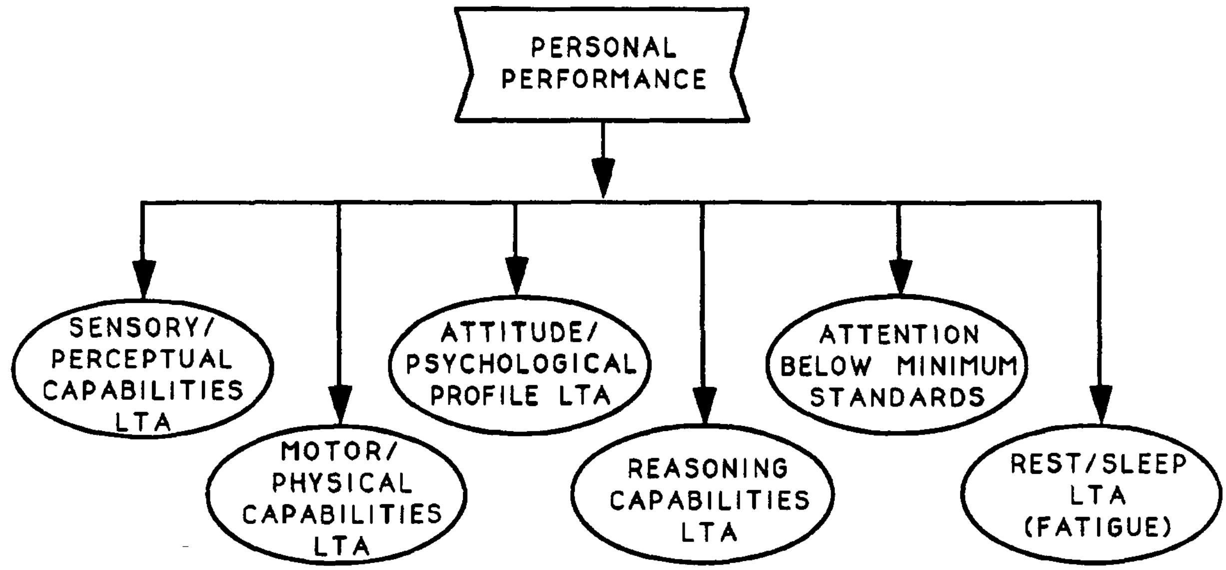
TABLE RCC-PP.1: PERSONAL PERFORMANCE SUBCATEGORIES

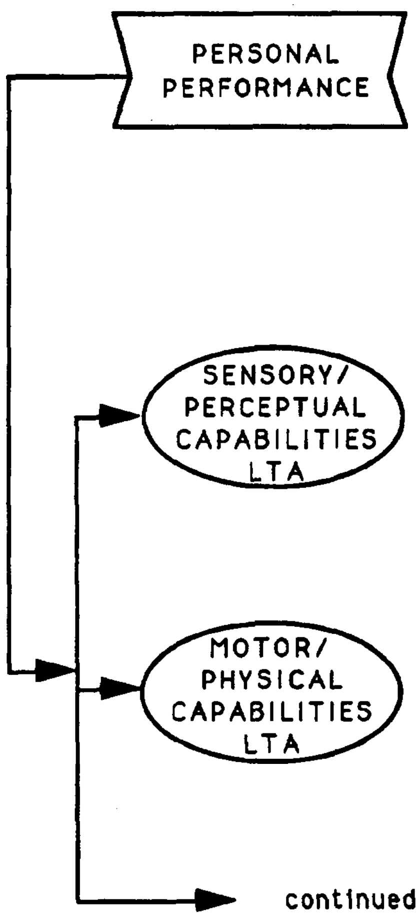
PERSONAL PERFORMANCE					
SUBCATEGORIES					
SENSORY/ PERCEPTUAL CAPABILITIES LTA	MOTOR/PHYSICAL CAPABILITIES LTA	ATTITUDE/ PSYCHOLOGICAL PROFILE LTA	REASONING CAPABILITIES LTA	ATTENTION BELOW MINIMUM STANDARDS	REST/SLEEP LTA (FATIGUE)
SYMPTOMS	SYMPTOMS	SYMPTOMS	SYMPTOMS	SYMPTOMS	SYMPTOMS
• COLOR BLINDNESS • TUNNEL VISION • INADEQUATE HEARING • INADEQUATE VISUAL ACUITY	• INADEQUATE COORDINATION • INADEQUATE STRENGTH • INADEQUATE STATURE • INADEQUATE REACTION TIME	• HORSEPLAY • NOT AT WORK LOCATION • DOES NOT PERFORM EXPECTED WORK • MALICIOUSNESS • INABILITY TO OPERATE UNDER STRESS • POOR PSYCHOLOGICAL HEALTH • USE OF DRUGS/ ALCOHOL • INSUBORDINATION • INABILITY TO WORK WELL OR COMMUNICATE WITH OTHER PEOPLE • IGNORES SAFETY RULES	• LOW CAPACITY • FREQUENTLY MAKES WRONG DECISIONS • INABILITY TO THINK PROBLEMS THROUGH • DOES NOT PROCESS INFORMATION WELL	• CHRONIC INATTENTION • ACUTE INATTENTION • FREQUENT DAYDREAMING • EASILY DISTRACTED • VIGILANCE FREQUENTLY BELOW MINIMUM ACCEPTABLE STANDANDS	• ASLEEP ON DUTY • TOO TIRED TO PERFORM JOB

Personal Performance









"Personal Performance" addresses human qualities and conditions such as physical and mental well being, attitude, mental capacity, attention span, rest, substance abuse, etc.

Was the problem caused by some factor inherent to an individual?

Was the problem due to less than adequate vision (e.g., poor visual acuity, color blindness, tunnel vision)?

Was the problem due to some defect in hearing (e.g., hearing loss, tone deafness)?

Was the problem due to some other sensory defect (e.g., poor sense of touch or smell)?

Can the causal factor be attributed to trouble with inadequate coordination or inadequate strength?

Was the problem due to inadequate size or stature of the individual involved?

Did other physical limitations (e.g., shaking, poor reaction time) contribute to the problem?

continued on next page

continued from previous page

ATTITUDE/ PSYCHOLOGICAL PROFILE LTA

Was the problem due to a poor attitude on the part of an individual?
Did the individual involved show signs of emotional illness?
NOTE: Symptoms like the following are often warning signs of poor attitude or mental illness: 1) Horseplay, 2) Absence from work location, 3) Failure to perform expected work, 4) Maliciousness, 5) Poor performance under stress, 6) Poor psychological health, 7) Use of drugs or alcohol, 8) Insubordination, 9) Failure to work well or communicate with others, and 10) Disregard for safety rules.

REASONING CAPABILITIES LTA

Was the problem caused by inadequate intellectual capacity?
Does the person frequently make wrong decisions?
Does the individual have trouble thinking problems through?
In general, does the person have difficulty processing information?

ATTENTION BELOW MINIMUM STANDARDS

Was the problem caused by lack of attention?
Does the person exhibit chronic (longstanding) lack of attention?
Does the individual show acute (severe) lack of attention?
Does the individual involved in this causal factor frequently "daydream?"
Is the person distracted easily?
Is the person's ability to maintain vigilance frequently below minimum acceptable standards?

REST/SLEEP LTA (FATIGUE)

Was the worker involved in the causal factor asleep on duty?
Was the person too tired to perform job?
NOTE: This node addresses problems associated with an individual's rest and sleep practices outside of the job. Problems with workers who are forced to work unreasonable amounts of overtime should be coded using the "Immediate Supervisor" or "Administrative System" segments of the tree.

Quality Assurance

Quality assurance is defined as all those planned and systematic actions necessary to provide confidence that an item or facility will perform satisfactorily in service. Such activity is tremendous in scope and requires the participation of everyone at the Savannah River site. The quality assurance function is normally broken down into eighteen to twenty subcategories. Important quality items include: general organization and responsibilities; planning; document control; traceability; records; and quality improvement. Quality assurance is also concerned with the proper control in procurement; design; inspection; measuring, and test equipment; installation and maintenance; and control in audits and surveillance.

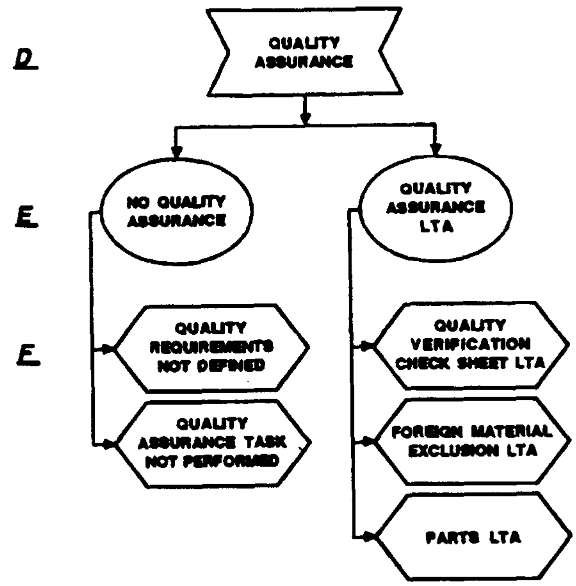
The quality assurance (QA) function at Savannah River is presently undergoing change. As these changes occur, the "Quality Assurance" segment of the tree will no doubt be updated many times. Consequently, at this point, the number of "Quality Assurance" nodes has been kept to a minimum. Many very important items addressed by the QA function are already represented by nodes in segments of the "Root Cause Tree" other than "Quality Assurance." QA is very important in the control of procedures, training, and administrative systems. The fact of the matter is that quality must be maintained throughout all of the activities at the site. Most of the nodes on the tree deal with some aspect of quality.

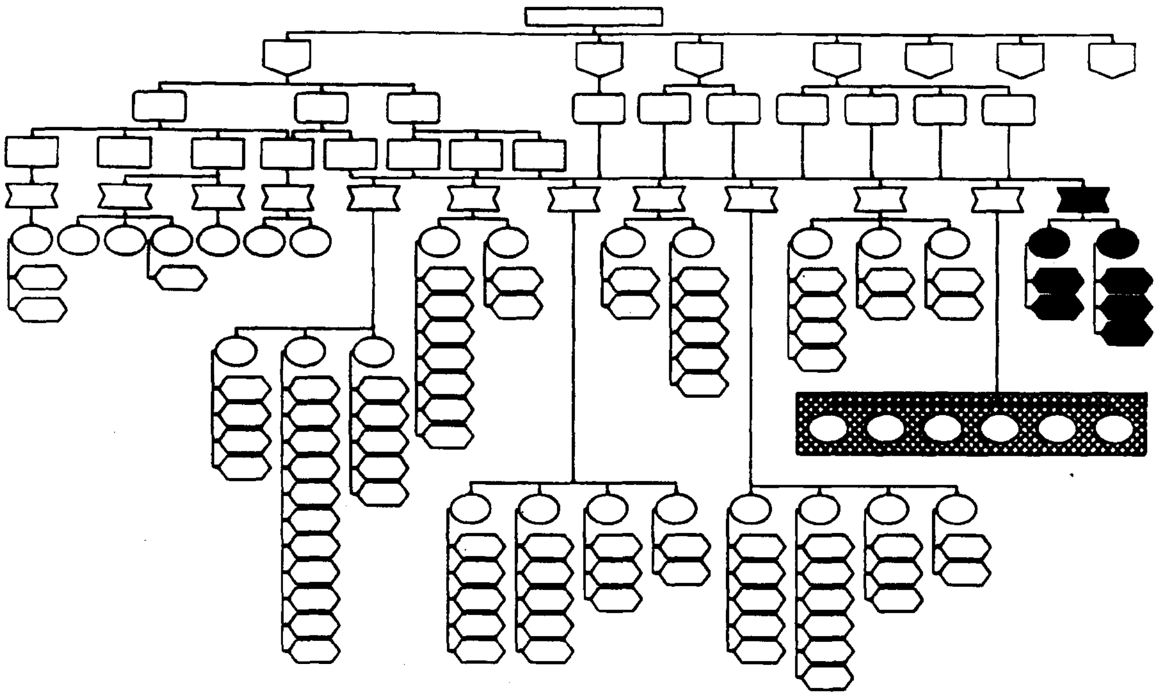
On the present "Root Cause Tree," the major root cause category "Quality Assurance," branches to two near root causes. These are "No Quality Assurance" and "Quality Assurance Less Than Adequate." "No Quality Assurance" is further broken down into two root causes, "Quality Requirements Not Defined" and "Quality Assurance Task Not Performed." "Quality Assurance Less Than Adequate" branches to three root causes. These are "Quality Verification Checksheet Less Than Adequate," "Foreign Material Exclusion Less Than Adequate," and "Parts Less Than Adequate." As stated previously, this segment of the tree will be expanded as the quality assurance function expands.

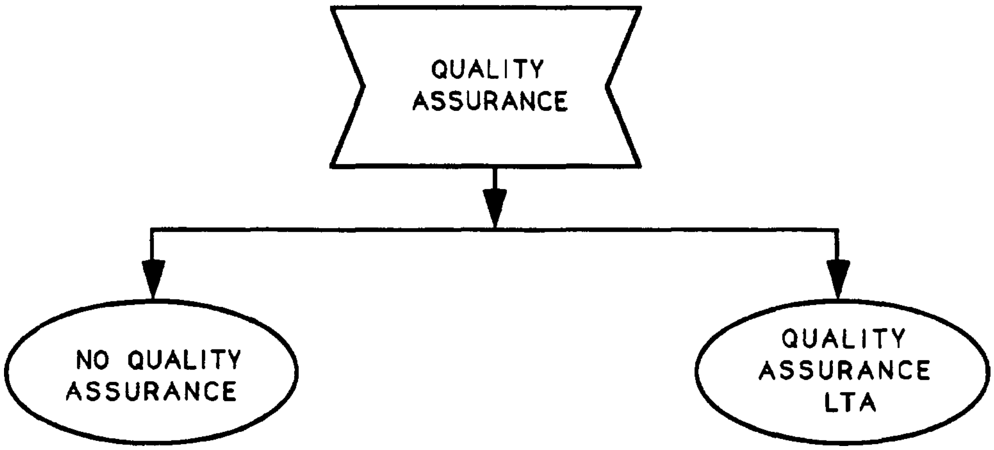
A more detailed explanation of the "Quality Assurance" segment of the tree is presented on the pages that follow. Descriptions and examples are included to assist the investigator in determining the applicability of "Quality Assurance" nodes.

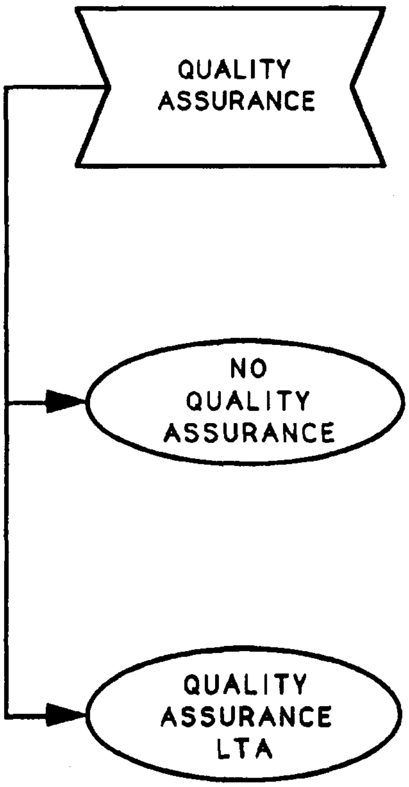
Quality Assurance

LEVEL





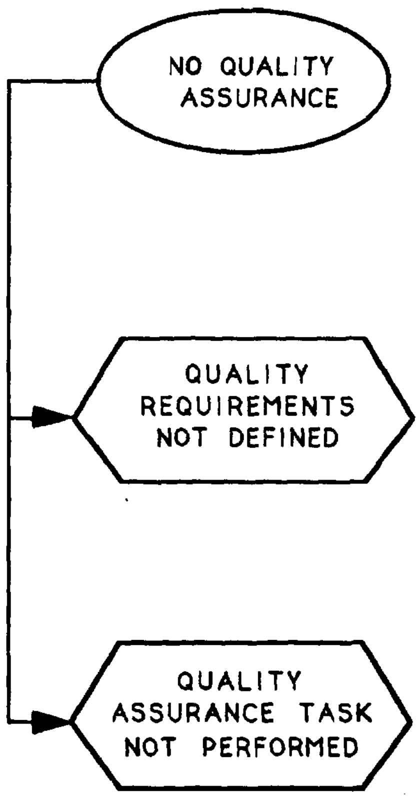




Was the causal factor the result of poor quality assurance? **NOTE: Consider less than adequate QA audits, surveillances, or independent in-process inspections. Also evaluate procurement control, design control, materials control, process control and monitoring, inspection, control of measuring equipment, and installation and maintenance control.**

Was no quality assurance performed because of inadequate definition of requirements or the failure to carry out existing requirements?

Was there a malfunction or difficulty because specific quality control or functional testing was not adequate or comprehensive enough to detect possible errors?



Was quality assurance not performed because of inadequate definition of requirements or the failure to carry out existing requirements?

Were quality assurance requirements not identified or dissimenated?

Did the difficulty occur because of failure to carry out established quality assurance requirements?

****This section of the handbook will be completed at a later date.****

References

Events and Causal Factors Charting

Benner, L. Jr. (1975). "Accident investigations: Multilinear events sequencing methods." Journal of safety research. 7, 2.

EG & G Idaho, Inc. (1978, August). Events and causal factors charting (DOE 76-45/14 or SSDC-14, Rev. 1). Idaho Falls, Idaho: System Safety Developement Center.

Root Cause Analysis

Busch, D. A., and Paradies, M. W. (1986, December). User's guide for reactor incident root cause coding tree (Rev. 5) (DPST-87-209). Aiken, SC: E. I. du Pont de Nemours & Co., Inc., Savannah River Laboratory.

Procedures

Brune, R. L., and Weinstein, M. (1982, September). Procedures evaluation checklist for maintenance, test and calibration procedures used in nuclear power plants (USNRC Report NUREG/CR-1369-Rev. 1). Albuquerque, NM: Sandia National Laboratories.

Brune, R. L., and Weinstein, M. (1980, May). Development of a checklist for evaluating maintenance, test and calibration procedures used in nuclear power plants (USNRC Report NUREG/CR-1368). Albuquerque, NM: Sandia National Laboratories.

Brune, R. L., and Weinstein, M. (1981, March). Development of a checklist for evaluating emergency procedures used in nuclear power plants (USNRC Report NUREG/CR-1970). Albuquerque, NM: Sandia National Laboratories.

Brune, R. L., and Weinstein, M. (1983, April). Checklist for evaluating emergency operating procedures used in nuclear power plants (USNRC Report NUREG/CR-2005-Rev. 1). Albuquerque, NM: Sandia National Laboratories.

Division of Human Factors Safety (1982, August). Guidelines for the preparation of emergency operating procedures (USNRC Report NUREG/CR-0899).

EOPIA Review Group (1982, July). Emergency operating procedures writing guideline. (INPO 82-017). Atlanta, GA: Institute of Nuclear Power Operators.

Folley, J. D., and Munger, S. J. (1961, October). A review of the literature on design of informational job performance aids (ASD-TR-61-549). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division.

Gunning, R., and Mueller, D. (1981). How to take the fog out of writing. Santa Barbara, CA: Gunning-Mueller Clear Writing Institute, Inc.

Joyce, R. P., Chenzoff, A. P., Mulligan, J. F., and Mallory, W. J. (1973, December). Fully proceduralized job performance aids (Vol. 1 Draft specification for organizational and intermediate maintenance) (AFHRL-TR-73-43(I)). Wright-Patterson Air Force Base, OH: Air Force Human Resources Laboratory.

Joyce, R. P., Chenzoff, A. P., Mulligan, J. F., and Mallory, W. J. (1973, December). Fully proceduralized job performance aids (Vol. 2 Handbook for JPA Developers (AFHRL-TR-73-43(II)). Wright-Patterson Air Force Base, OH: Air Force Human Resources Laboratory.

Paramore, B., Petersen, L. R., and Banks, W. W. (1986, February). How adequate are your procedures? Paper presented at the Reactor Training Coordination Program, Chattanooga, TN.

Strunk, W., Jr., and White, E. B. (1979). The elements of style (3rd ed.). New York: Macmillan Publishing Co., Inc.

Administrative System

E. I. du Pont de Nemours & Company, Atomic Energy Division. (1985, January). The administrative and procedural controls system for the Savannah River Plant nonreactor nuclear facilities parts I and II (DPW-83-112). Wilmington, DE.

Training

Bailey, R. W. (1982). Human performance engineering: A guide for system designers. Englewood Cliffs, N. J.: Prentice Hall.

Cascio, W. F. (1982). Applied psychology in personnel management. (2nd ed.). Reston, VA: Reston Publishing Company, Inc.

Hollnagel, E. (1982). Training simulator analysis method (N-1-82). Roskilde, Denmark: Riso National Laboratory.

Salvendy, G. (1987). Handbook of human factors. New York: John Wiley & Sons, Inc.

Woodson, W. E. (1981). Human factors design handbook. New York: McGraw-Hill.

Human Factors

Bailey, R. W. (1982). Human performance engineering: A guide for system designers. Englewood Cliffs, N. J.: Prentice Hall.

Eastman Kodak Company. (1983) Ergonomic design for people at work. (Vol. 1 and 2). Belmont, California: Lifetime Learning Publications.

Huchingson, R. D. (1981). New horizons for human factors in design. New York: McGraw-Hill.

McCormick, E. J. and Sanders, M. S. (1982). Human factors in engineering and design. (5th ed.). New York: McGraw-Hill.

Salvendy, G. (1987). Handbook of human factors. New York: John Wiley & Sons.

Woodson, W. E. (1981). Human factors design handbook. New York: McGraw-Hill.

Communications

Salvendy, G. (1987). Handbook of Human Factors. New York: John Wiley & Sons, Inc.

Personal Performance

Lawrence Livermore National Laboratory & Essex Corporation (Undated). Introduction to human factors engineering: DOE workshop.

Swain, A. D. (1980). The human element in systems safety: A guide for modern management. Albuquerque, NM: A. D. Swain.

Quality Assurance

Deming, W. E. (1982). Quality, productivity, and competitive position. Cambridge, MA: Massachusetts Institute of Technology Center for Advanced Engineering Study.

E.I. du Pont de Nemours & Company, Atomic Energy Division. (1987). The Savannah River Plant Quality Assurance Manual. DPW-83-111-3. Wilmington, DE.

Harris, D. H. and Chaney, F. B. (1969). Human Factors in quality assurance. New York: Wiley.

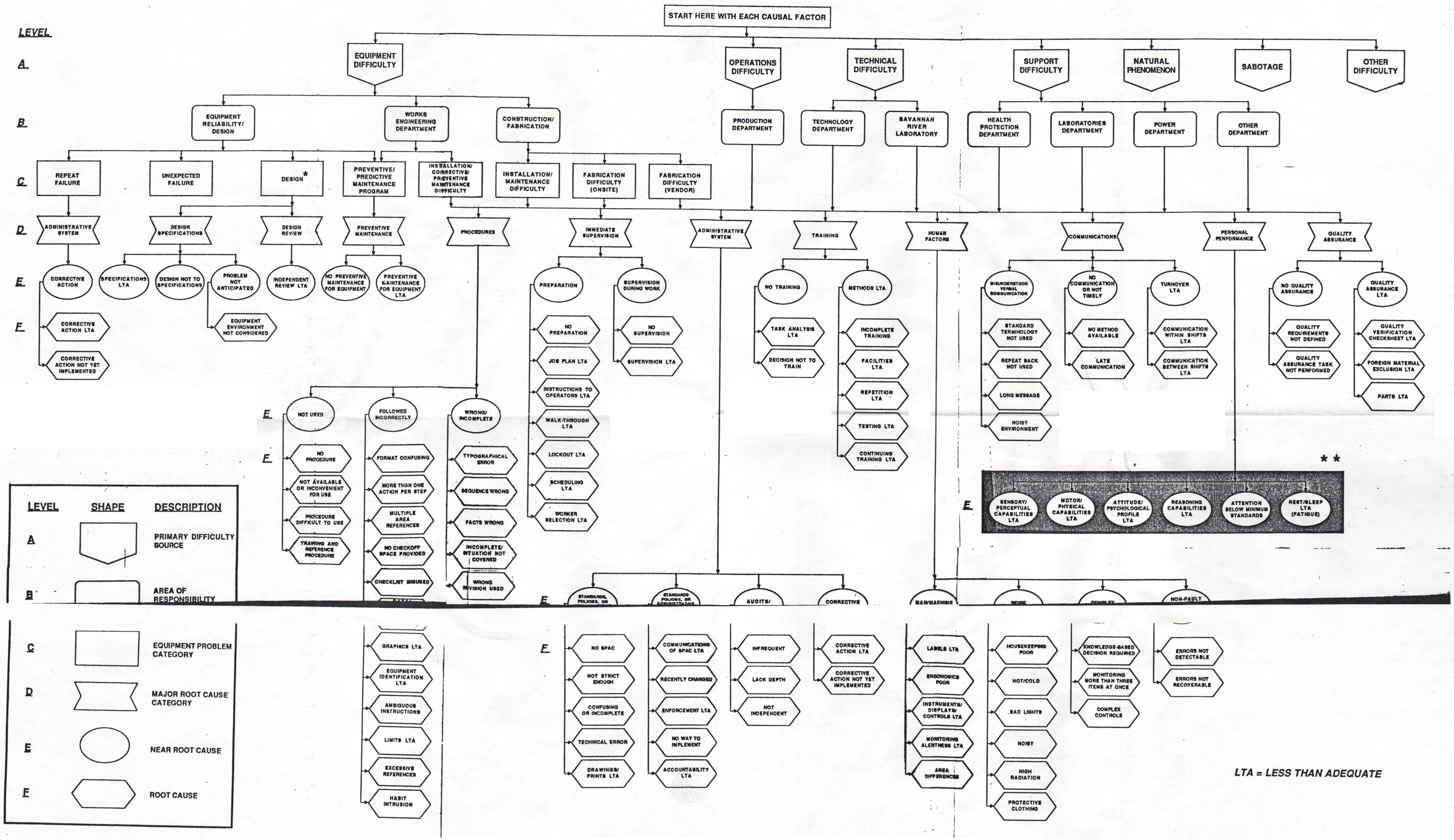
Greene, J. H. (1987). Production and inventory control handbook. New York: McGraw-Hill.

OTHER SSDC PUBLICATIONS IN THIS SERIES

SSDC-1	Occupancy-Use Readiness Manual
SSDC-2	Human Factors in Design
SSDC-3	A Contractor Guide to Advance Preparation for Accident Investigation
SSDC-4	MORT User's Manual
SSDC-5	Reported Significant Observation (RSO) Studies
SSDC-6	Training as Related to Behavioral Change
SSDC-7	ERDA Guide to the Classification of Occupational Injuries and Illnesses
SSDC-8	Standardization Guide for Construction and Use of MORT-Type Analytic Trees
SSDC-9	Safety Information System Guide
SSDC-10	Safety Information System Cataloging
SSDC-11	Risk Management Guide
SSDC-12	Safety Considerations in Evaluation of Maintenance Programs
SSDC-13	Management Factors in Accident and Incident Prevention (Including Management Self-Evaluation Checksheets)

ROOT CAUSE TREE

FIGURE RCC-I.1: ROOT CAUSE TREE



* NOTE: Code human factors design problems under HUMAN FACTORS (Level D)
** NOTE: Shaded nodes under PERSONAL PERFORMANCE are for descriptive purposes only. Code only to PERSONAL PERFORMANCE (Level D).