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ACCIDENT/INCIDENT INVESTIGATION MANUAL

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Foreword
(to the DOE Accident Investigation Manual)

The Department of Energy must assure that environment, safety, and health concerns are included logically throughout the life-cycle of its programs, facilities, and products. The potential risks and diversity of hazards are great whether the activity involved is construction, research, development, demonstration, or production. Considering the advanced technologies associated with these activities, the Department must have a comprehensive and systematic environment, safety, and health program to reduce risks to an acceptable level.

One fundamental element of such a program is the thorough investigation of accidents and incidents in order to obtain the maximum in corrective actions. Thorough investigations of "near-misses" which had the potential for serious consequences also are needed to aid in the prevention of major losses.

In addition, public attention to the safety of the nation's energy policies and programs demands that our accident investigations meet the highest standards of performance. This applies not only to the actual investigation, but also to the clear and logical presentation of the facts, analysis, and conclusions in the written report.

This manual presents state-of-the-art investigative and analytical methods for application to this critical part of the Department's system safety program. Since the investigation report represents a yardstick by which the investigation is measured as to thoroughness, accuracy, and objectivity, we encourage our investigators to be totally professional. This is the best way to prevent the recurrence of accidents, improve management and staff functions, and increase safety in the Department's programs and operations.

William A. Vaughan
Assistant Secretary
Environment, Safety, and Health

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The contributions of the following are gratefully acknowledged in the writing of this manual: Bill Johnson, who started it all with the first edition he prepared for the ERDA in 1976; Bob Nertney and other members of the SSDC staff who have been involved in the development and teaching of the concepts, principles and methods discussed herein, Ray Kuhlman of ILCS, Tom Kerr of NASA, Bill Albers of DOE, Bob Meibaum of EG&G, and Dennis Burling, David Haynes and other members of the Ontario Hydro Health and Safety Division, from whose writings we have liberally drawn; Claire Reno and Fauneen Ringer for editorial and scheduling support; Helen Askew, Carol Jess, and Camille Koplin for word processing services; Lorraine Bate for preparing the graphics, and reviewers from within and outside of the DOE, who took the time and expended the effort to review and comment upon this work.

PREFACE

The first edition of this Manual was prepared by W. G. Johnson for the Energy Research and Development Agency (ERDA) and was published in August 1975. It has become a standard for accident investigation throughout ERDA and its successor, the U.S. Department of Energy (DOE), and has served as a basic text for training in systematic accident investigation, not only in ERDA and DOE, but in other government agencies and university programs as well.

In the intervening years since that initial publication, methods and techniques that were new at that time have been further developed and proven, and Johnson's basic concepts and principles have been further defined and expanded. Experience in using the manual in conducting high quality, systematic investigations has identified areas for additional development, and has generated need for yet higher levels of investigative excellence to meet today's safety and loss control needs.

This revision is intended to meet those needs through incorporating developments and advances in accident investigation technology that have taken place since Johnson's first accident investigation manual was written.

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ACCIDENT/INCIDENT INVESTIGATION MANUAL

I. INTRODUCTION

In the Foreword to the first edition of this Accident/Incident Investigation Manual, Robert C. Seamans Jr., then Administrator of the U.S. Energy Research and Development Administration (ERDA), spelled out clearly and distinctly the need for and purpose of this manual. To indicate the current applicability of his remarks, DOE is substituted for ERDA in quoting his Foreword.

> "[DOE] must assure that safety is built into its own programs and products as they are developed, and that its facilities are operated safely. With the tremendous range of hazards associated with the various energy technologies, and the inherent risk involved in any research, development, and demonstration, fulfilling this mandate will require a comprehensive, modern safety program.
>
> One fundamental element in such a program is the thorough investigation of accidents and incidents that do occur in order to obtain the maximum in corrective actions. This is especially important in [DOE] since the frequency of serious occurrences in our operations is relatively low.
>
> In addition, the increasing public concern in the energy technologies makes it imperative that [DOE] accident investigations meet the highest standards of performance. This includes not only the actual investigation, but also the clear and logical presentation of the facts, analysis, and conclusions in the written report.
>
> This manual represents an attempt to apply the state-of-the-art in investigative and analytical methods to the [DOE] investigation process.
>
> Since the investigation report represents a yardstick by which the investigation is measured as to thoroughness, accuracy, and objectivity, we encourage our investigators to 'Tell it the way it is.' This is the best way to prevent [recurrence of] accidents, improve management and staff functions, and increase safety in [DOE] programs and operations."

By "telling it the way it is," and by taking the most effective corrective actions on identified accident causes, each participant in the investigative process may effectively stay focused on the mandates of accident investigation.

The primary purpose of accident investigation for DOE is to prevent similar occurrences and to discover potential hazards, thus improving the safety of DOE and contractor operations. The intent is not to place blame but to determine how responsibilities may be clarified and supported, and errors reduced. The emphasis should be on discovering all cause-effect relationships from which practical corrective actions can be derived.

Collateral purposes of investigation are to determine the nature and extent of the event and its programmatic impact; to assist in the improvement of policies, standards, and regulations; to satisfy the public's "right to know"; and to dispel any mystery associated with the occurrence. Additional benefits (other than prevention) include impressing employees with management concern, improving general performance, and improving supervision and management abilities. The purposes do not include enforcement proceedings, liability determination, or controlled research, all of which require supplementary or separate investigations.

By adhering to the proper purposes of accident investigation and by avoiding traditional misconceptions which impede or prevent true fact-finding and evaluation of causal factors, accident investigators are able to fulfill their roles as essential parts of the accident prevention and loss control effort.

The primary intent of this manual is to aid investigators and investigative boards in training for, conducting, and reporting the results of thorough investigations of major accidents. Additionally, the same principles and methods involved in major accident investigations can be appropriately tailored for investigation of less serious accidents and incidents. Hence, this manual provides usable guidelines for investigation of all accidents or incidents, regardless of the seriousness of their consequences or potential. Furthermore, it provides guidance for preparing for accident management and investigation, appointing investigators and investigative boards, reviewing their activities and reports, and taking action on their findings and recommendations.

The first chapter defines the concepts and principles underlying MORT-based accident investigation and describes the accident investigation process. Chapter II deals with the first phase of that process, preparing to investigate; and Chapter III, with initiation of the investigation. Chapter IV discusses the activities that are involved in conducting the investigation; i.e., (a) managing the investigation, (b) collecting information, (c) analyzing the collected facts, and (d) integrating factual finding and analytical results. Chapter V describes effective means of reporting findings and recommendations.

Concepts and Principles

An accident investigation is an appropriately detailed, systematic search to uncover the "who, what, when, where, why, and how" of a loss-producing event and to determine what recommendations and corrective actions are needed in order to prevent a recurrence. The thoroughness, depth, scope, and focus of the investigation are influenced by the magnitude of loss; the objectivity and independence of the investigators, appointing official, and reviewers; and by the basic concepts of accident causation held by these people and the organizations they represent. Loss level, participant independence, and particularly, concepts held affect the facts that are sought, the observations made, the perceptions believed, the conclusions drawn, and the corrective actions recommended. Sound concepts and principles of accident causation and development, therefore, form the essential foundation upon which effective accident investigations are built.

Fundamental to these concepts and principles are a comprehensive accident definition and a meaningful and practical accident model.

Accident Definition and Accident Model. The MORT (Management Oversight and Risk Tree) definition of an accident is:

1. An unwanted transfer of energy or exposure to a harmful environment
2. Because of a lack of barriers and/or controls
3. Producing injury to persons, property, or process
4. Preceded by sequences of planning and operational errors which:
   a. Failed to adjust to changes in physical or human factors
   b. Produced unsafe conditions and/or unsafe acts
5. Arising out of the risk in a well intentioned activity
6. Interrupting or degrading the activity.

The related accident model is shown in Figure 1. Every activity has some level of inherent risk. If thorough and informed planning has been done, the activity risks will have been identified and evaluated. Management decisions will have been made and carried out to (a) eliminate those unacceptable risks which cannot be reduced to an acceptable level through appropriate controls, (b) acceptably control those which can be controlled, (c) transfer

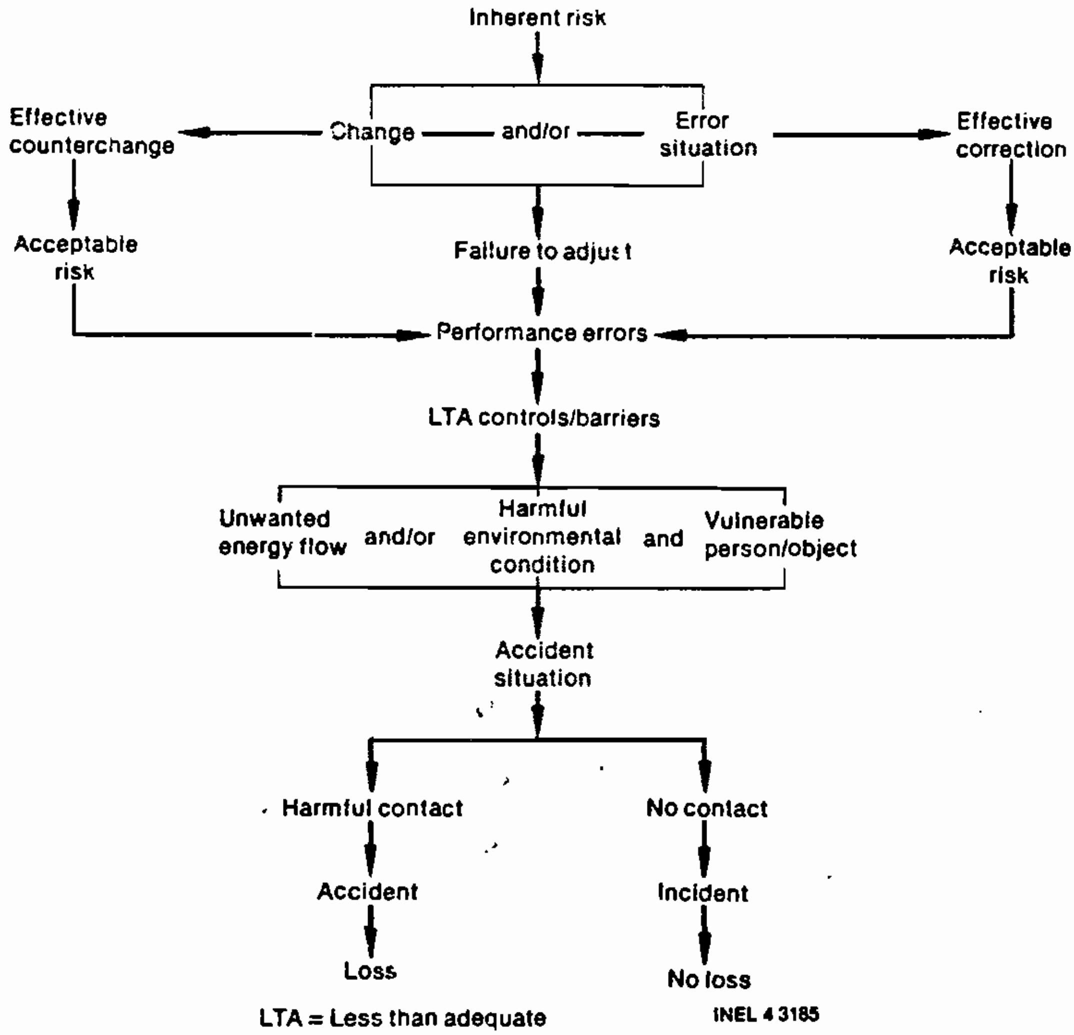

Figure 1. Accident Model.

those which can be economically transferred, and (d) accept those residual risks which have an acceptably low consequence and probability of occurrence (or which have uniquely overriding considerations which justify their acceptance). If planning or preparation has not been sufficiently comprehensive, or if faulty risk perceptions have overridden "real risk" identification and evaluation, oversights and omissions in the risk assessment process result in work situations which are error-prone or error provocative. These may produce accidental losses of a magnitude and frequency that was not anticipated. Inherent risks built into the work activity that are not designed or engineered out lead to error situations. If not recognized and adjusted for, these situations may contribute to performance errors and initiate a sequence of events and conditions which culminate in accidental loss. This accident sequence may also be started when an activity with acceptable inherent risk experiences unanticipated or inadequately controlled changes which degrade safety of the activity. Safety is defined as control of accidental loss, so anything that degrades safety will ultimately result in accidents and losses, unless it is recognized, adapted to, and effectively corrected or counter-changed to restore an acceptably safe work situation. Even when effective correction and counter-change have achieved acceptable risk, the accident sequence may still develop from the residual risks. As Johnson states, "What can happen, will happen, the only uncertainty is when."

When inherent risk, failure to adjust to error situations, and/or safety-degrading changes exist, the resulting performance errors produce or interact with controls and barriers that are inadequate to separate vulnerable persons or objects from unwanted hazardous energy flows and harmful environmental conditions. This creates accident situations. If harmful contact occurs between vulnerable recipients and hazardous energies or environments that exceed the recipients' threshold for damage, an accident results, with corresponding loss. If contact between the hazardous energy or environment and the vulnerable target does not occur, or if the hazardous contact is below the damage threshold of the target, a no-loss incident results. If the potential for loss is great, the no-loss incident should be investigated with as much rigor and thoroughness as a major accident in order to prevent recurrence with major loss.

The MORT accident definition and the accident causation model are seen to embrace basic concepts of: (a) energy sources and flow, and harmful environments which constitute hazards; (b) vulnerable persons or objects which are subject to injury or damage from contact with the hazards; (c) needed, but missing barriers and controls which should prevent the damaging contacts; (d) sequences of errors and changes which produce situations in which the harmful contacts can occur; (e) inherent risks of contact which exist in all work processes and work activities and which require proper identification, evaluation, and management to prevent the contacts and minimize their consequences; and (f) resulting unacceptable losses which consist of such things as interrupted productive processes, downgraded system performance, physical damage or personal injury, adverse public or programmatic impact, and loss of facilities, products, or services. Each of these will be addressed in turn.

Energy Flows and Harmful Environments. Energy is the capacity to do work. If the work done is productive, the energy is considered as desirable, beneficial, and controlled. If the work done is unintentionally destructive, the energy is seen as undesirable, harmful, and uncontrolled or inadequately controlled. If needed energy exchanges which are essential to life processes are disrupted by such harmful environmental conditions as oxygen-deficient atmospheres or exposure to the elements in excess of body tolerance, the effect is again destructive or injurious, and exposure to the hazardous environment is the causative factor. This exposure, also, is unwanted and harmful and must be adequately prevented or controlled.

Both energy sources and hostile environments represent hazards which are potential sources for accidents and will cause harm to the vulnerable people or objects they contact. It becomes meaningful, then, to specify accident types by the hazard sources, or energies and environments, involved; so there are chemical accidents, electrical accidents, radiation accidents, mechanical accidents, thermal accidents, inert gas accidents, etc.

The unwanted energy flows or environmental conditions can have their origins either within the system or external to it. All systems, processes, and activities have some inherent hazards. Hazardous energies, energy flows, or environmental conditions exist within most systems to produce beneficial work and products. A loss of control of system energy can lead to undesired access of people or objects to the energy sources, energy flow channels, or environmental conditions, or permit escape of these hazardous system elements or materials into undesired channels or areas where harm can result. In both cases, system safeguards (controls and barriers), which should prevent contact between the needed system energies and environments and the vulnerable people and objects, failed or were inadequate, misused, or not used. Hazard sources outside of the system usually consist of acts of nature or of persons, equipment, or materials beyond the direct control of system personnel. However, they can be anticipated, planned for, protected against, controlled within practical and reasonable limits, and properly responded to when contact does occur, to reduce exposure and minimize losses.

Vulnerable Targets. Anything vulnerable to injury or damage from contact with an energy flow is a potential target for harm and loss. To be of real concern, of course, the potential target must be of value to the organization or activity, so that its reduced capability or loss would downgrade performance or efficiency. Vulnerable targets are usually persons and objects of value and must be protected from contact with hazards by adequate controls and barriers.

Controls and Barriers. The harmful effects of energy transfers and environmental conditions are commonly handled by one or more of a succession of measures. They fall into 11 general categories.

1. Limit the energy (or substitute a safer form)
2. Prevent the energy buildup
3. Prevent the energy release
4. Provide slow energy release
5. Separate the energies and potential targets in time and space
6. Place barriers on the energy source
7. Place barriers on the person or object
8. Place barriers between the energy source and potential target
9. Raise the threshold for harm of the target
10. Ameliorate after exposure to limit the harm
11. Rehabilitate and restore to service.

Generally, the earlier the imposition of a control or barrier on the list, the better; and the bigger the hazard, the greater the need for early interruption and multiple controls and barriers.

Controls and barriers are additionally classified as (a) those used to contain wanted hazardous environments and energy flows, (b) those used to prevent, control, or minimize the impact of unwanted energy flows or environmental exposures, and (c) those used to prevent or control actions of persons or objects which may bring them into contact with harmful energy flows or environmental conditions. Obviously, many controls and barriers can fulfill all of these functions at the same time.

There are many varieties of controls and barriers that can be used in many different ways. Usually, they are characterized by their function, location, and type. They function (a) to control wanted work activities and the use of wanted and needed energies and environmental conditions, (b) to prevent unwanted energy flows and environmental release and exposures, (c) to prevent unwanted entry into hazardous areas, and (d) to limit the effects of unwanted energy flows and environmental exposures. Controls and barriers can be established at the initial conceptual phase of the life cycle of a system or activity and continually be subjected to review. They can be located on the hazard or the potential target, between them, or in such a way as to separate them in time and space. Types of controls and barriers are physical, procedural, administrative, supervisory, engineered, informational, warning, etc.

In MORT terminology, controls can be distinguished from barriers, in that controls generally relate to organizational and system functioning and barriers, to placement at specific locations in time or space. Controls include (a) adequate technical information, (b) system, facility, equipment, or process design and operability, (c) maintenance, (d) inspection, (e) supervision, (f) employee activity, and (g) management system services, including upper level supervision and management, safety and loss control, quality assurance, etc. Barriers are placed on or between hazards and potential recipients to provide adequate separation for protection of persons and objects. It should be apparent that there are no fine distinctions between controls and barriers, and rightly so, for barriers are, in fact, a type of control. So, one should be concerned about meshing the control and barrier concepts, or breaking them apart, when it is helpful to do so. The important thing to keep in mind is that some measures must be taken to keep energy and vulnerable targets from coming into contact (with resulting harm and loss). The control/barrier concept enables a person to identify what those measures should be, and when and where they should be applied.

Inasmuch as desired controls/barriers are sometimes not practical, or they fail, or they are not used or are misused, it is rarely acceptable to rely on a single control/barrier for protection of persons and valuable objects. Rather, multiple controls/barriers are required to give the desired level of assured protection. The number and sequence of controls/barriers required for any hazard, or set of hazards in a given system, activity or work situation depends upon (a) the reliability of the controls/barriers used and (b) the degree of protection or safety required. It is a judgment that requires proper planning, preparation, identification, evaluation, and incorporation of needed controls/barriers to prevent accidents; or to determine the adequacy of controls/barriers that were, or should have been, in place when an accident occurred. In either case, preplanning or postinvestigating, a meticulous trace of energy flows and environmental conditions that makes visible the number of practical opportunities for interrupting possible harmful interactions between hazards and people/objects with controls/barriers has proven to be invaluable. It is highly recommended for use in accident/incident investigations and will be discussed further in the Analyzing Facts section of this manual under Barrier Analysis and MORT Analysis.

The meticulous energy trace (coupled with barrier analysis) can and should also be used effectively in operational and process audits, appraisals, and inspections to identify and evaluate potential hazardous interactions in ongoing activities. Modifications and changes in designs, hardware, procedures, controls, people, and work situations and activities produce consequent variations in existing hazards that require safety-related counter-changes in controls/barriers to maintain the desired level of safety. Failure to do this is often found as a causative factor in accident investigations.

Sequences in Accident Causation. Accidents rarely are simple and almost never result from a single cause. Rather, they are usually multifactorial and develop through well defined sequences of changes and errors. Even in a well controlled work environment, the most serious loss-producing events involve numerous error and change sequences, either in series or parallel. Frequently, complexity is added by multiperson and multiorganizational involvements. Since serious accidents are often very complex, there are both many chances to err or to change, and many opportunities to intervene or interrupt the accident sequences. It seems essential, then, that accident investigation strategies and methods be used which can recognize and handle these complex accident sequences and enable the investigator to diagnose and recommend fixes for the root accident causes from which they developed. The conventional, simplistic approach of endeavoring to identify the unsafe act or the unsafe condition that is the cause of the accident leads the investigator to identify only symptoms of problems or deficiencies and results in investigations which are shallow and more fault-finding than fact-finding; this simplistic approach leads only to treatment of symptoms and recurrence of accidents, rather than a cure of root causes and lasting fixes.

Accidents occur during work activities and must be evaluated within the context of the work situation, the work site ingredients, and the upstream processes which shaped them and contributed to the accident causation sequence. As shown in Figure 2, the work situation is composed of people, plant and hardware, procedures and management controls, and the interfaces which ideally tie them together into a well coordinated, smooth functioning, effective production of beneficial work. If there are significant deficiencies, errors, or unwanted changes in any of the major people-plant-procedures work ingredients, or in their interfaces or relationships, the stage is set for an accident. Some deficiencies, errors, and unwanted changes which contribute to work accidents develop during normal work activities; others are built into the system or are set in motion during the upstream processes which establish the work situation. The work process schematic, Figure 3, depicts the elements of the upstream processes which prepare the work situation and work activity, as well as the feedback loops which provide the performance data necessary to correct and refine those processes. If deficiencies are built into the system through oversights, omissions, and accepted risks in the work-situation-shaping upstream processes, they will be manifest as problems and accidents during the work activity. Likewise, observed deficiencies in work activities mirror similar deficiencies in the functioning of the management system which shaped the work situation, and are, generally, the results of management oversights (wrong actions) and omissions (failure to take appropriate action). Oversights and omissions and resulting deficiencies can occur anytime in a system or work activity life cycle and anywhere in the system or organization. Those at one organizational level, life cycle phase, or part of the system often affect those at other levels, phases, or system parts. Usually, the higher the level or the earlier in the upstream process these oversights and omissions occur and go undetected, the greater their potential consequences.

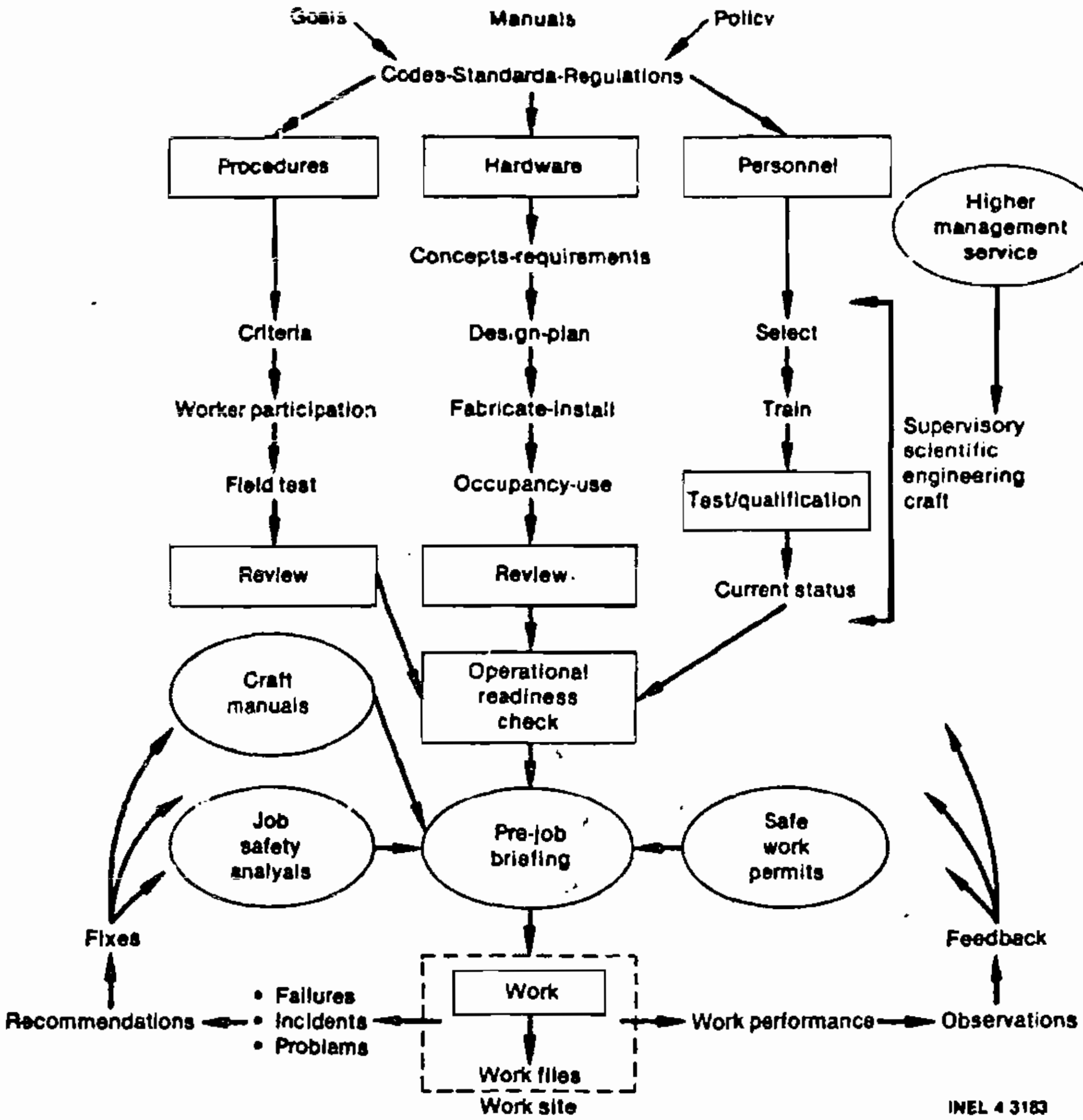

Figure 3. The Work Process.

but we must find out how and why they happened and direct efforts to prevent their recurrence. We must key our thinking and our efforts to prevent, control, and minimize future accidental losses. This is a key to good business and good safety. Additionally, we do not need to wait until we have a serious accident and a devastating loss before we search out our loss control problems and the causes from which they stem. Almost all serious accident investigations reveal numerous precursors which should have triggered in-depth inquiries into the causal factors and ultimate consequences of inaction. Had the precursor incidents been properly investigated, causal factors identified, and needed specific and systemic fixes made and maintained, many of our costly accidents would not have occurred. Incident investigations can be costly, but the savings from prevention of future accidents and losses far offset the investigative costs—it is a simple matter of intelligent economics. Further, the employment of good investigative protocol and preparation and the use of systematic and efficient investigative methods by trained and skilled investigators makes incident investigations eminently cost-effective and sensible.

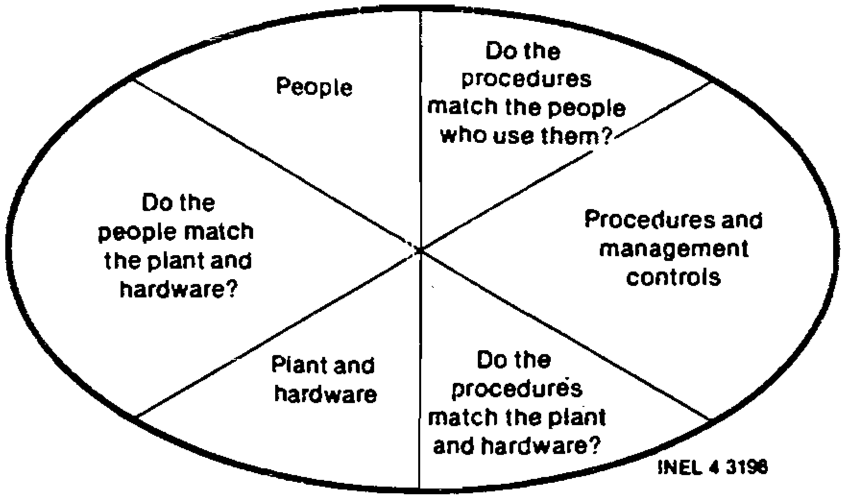

Figure 2. Intersystem Relations.

Inherent Risks. Risk is the mathematical expected loss: the probability of an accident multiplied by the quantified consequences of the accident. Risk is an inescapable factor in any human activity. Because of their omnipresence, risks of harmful contacts with hazards must be properly identified, evaluated, and managed to prevent the contacts and minimize the definable consequences. This identification-evaluation-management process should be designed and carried out to take the original inherent work risks and determine their acceptability, apply needed controls, and ensure that the remaining residual risks have been reduced to an acceptable level.

Two management system malfunctions often prevent the risk assessment and management process from being adequately effective in control of accident risks:

1. Oversights and omissions due to lack of knowledge, inadequate assessment, uncertainties, or misperceptions of true risk levels

2. Risk acceptance at an inappropriately low level in the chain of command, without the knowledge or participation of higher levels of management.

The two are obviously tied together. Management has to define the criteria for risk acceptance and forward risk information for higher level decisions. If this is not done, there will be risk acceptance based on misperceptions, uncertainties or inadequate knowledge, or made by default through oversights and omissions, or made at too low a level at the job site.

Proper evaluation of accepted or assumed risk (as defined by MORT) is specific, identified, analyzed, quantified to the maximum practicable degree and accepted by the right level of management. Too often, however, serious risks are "assumed" in an offhand manner with, at best, a cursory assessment of the risk, and with a widely accepted justification that it is a "calculated risk" necessary to get the job done. There is nothing wrong with the notion of "calculated risk," except that it usually wasn't really calculated. In fact, that which is often identified as an "assumed risk" rarely meets the MORT definition, but rather consists of unrecognized and unevaluated hazards and uncertainties in the assessment-decision process. These are based on oversights and omissions, and all too frequently and conspicuously are found in serious accidents.

Unacceptable Losses. Accidental losses interrupt or degrade desired system performance and often have repercussions well beyond the work site. These losses appear in a multitude of forms—injuries, damage, other costs, performance lost, degraded programs, public impact, etc. It is not enough to identify the losses that have occurred, This manual is written to help you achieve the high quality accident and incident investigations that are essential to effective safety and loss control programs.

The Investigation Process

The investigation process begins well before an accident or incident occurs and continues until the recommended fixes have been completed and confirmed. It proceeds in a step-by-step sequence but with several steps overlapping or progressing concurrently and with some steps iteratively feeding each other in a cyclic manner.

Figures 4 and 5 portray the investigation process in consistent but different flow chart formats. The process begins with the establishment of operational and investigative requirements. The environmental, safety, and health (ES&H) requirements for DOE are published in the series of DOE 5480 Orders. These are amplified and further specified through Field Office implementation directives and Contractor safety manual chapters, directives, standard practices, and procedures. They are additionally defined and specified in DOE Program Offices orders and directives.

This entire chain of ES&H requirements provides acceptable accident management at all levels in DOE. Figure 6 shows the relationship of the three basic elements of accident management: prevention, response (emergency action), and investigation. Advance preparation to ensure operational readiness in each of these accident management activities is essential to establish and maintain an effective safety and loss control program. Involvement of safety/loss control specialists early in operational development and modification cycles, as well as throughout ongoing operations, enhances the identification, evaluation, and control of risks and hazards. This is necessary to prevent unacceptable accidental losses. Preplanning and advance evaluation of the effectiveness of emergency action and intervention in the postaccident phase of accident management ensures greater success in limiting existing losses and preventing additional losses during this improvement-growth phase. Advance preparation for accident investigation by line and ES&H management gives greater insurance of preservation of vital evidence. This can enable the accident investigators to identify the root causes of accidental losses and recommend practical fixes to prevent recurrence. Systematic, comprehensive accident/incident investigations generate findings and recommendations that feed back into advance preparation for accident prevention and emergency response. This lifts the overall level of operational readiness of the operating organization. Advance preparation for accident investigation will be discussed further in Chapter II.

Once the accident or incident has occurred, accident response is initiated to rescue the injured, limit the damage, control or prevent further loss, and collect and preserve evidence. Concurrently, needed notifications are made to set in motion the investigator selection and appointment process.

As shown in Figure 7, effective accident investigation can be accomplished either by independent investigators or by monitored self-investigators. In fact, preliminary investigation is almost always performed by in-house line managers/supervisors and/or safety personnel, who generally work to criteria established by an independent group. In addition, almost without exception, minor accidents are investigated only by the cognizant manager/supervisor, with followup by the local safety person or group. When a more objective investigation is required, it is usually accomplished by experienced investigators who are free from control, undue influence, and other dependence upon the organization and activities under investigation. When investigators have no vested interest in the outcome, they often weigh information and analytical results in a more open, evaluative manner and arrive at more rational, reasonable, and accurate conclusions and recommendations. Independent investigators, serving together as an investigative board, are always required for DOE Type A and Type B investigations. Individual investigators usually perform lesser level investigations. (Appendix A defines the criteria for DOE types of accident investigations.)

The appointed investigators conduct the accident/incident investigation on a full time basis, by managing investigative activities, collecting and analyzing factual evidence, integrating factual findings and analytical results to arrive at valid conclusions and report them, with corresponding recommendations, to the appointing authority. The appointing official then specifies appropriate report review and distribution, and action assignments for recom-

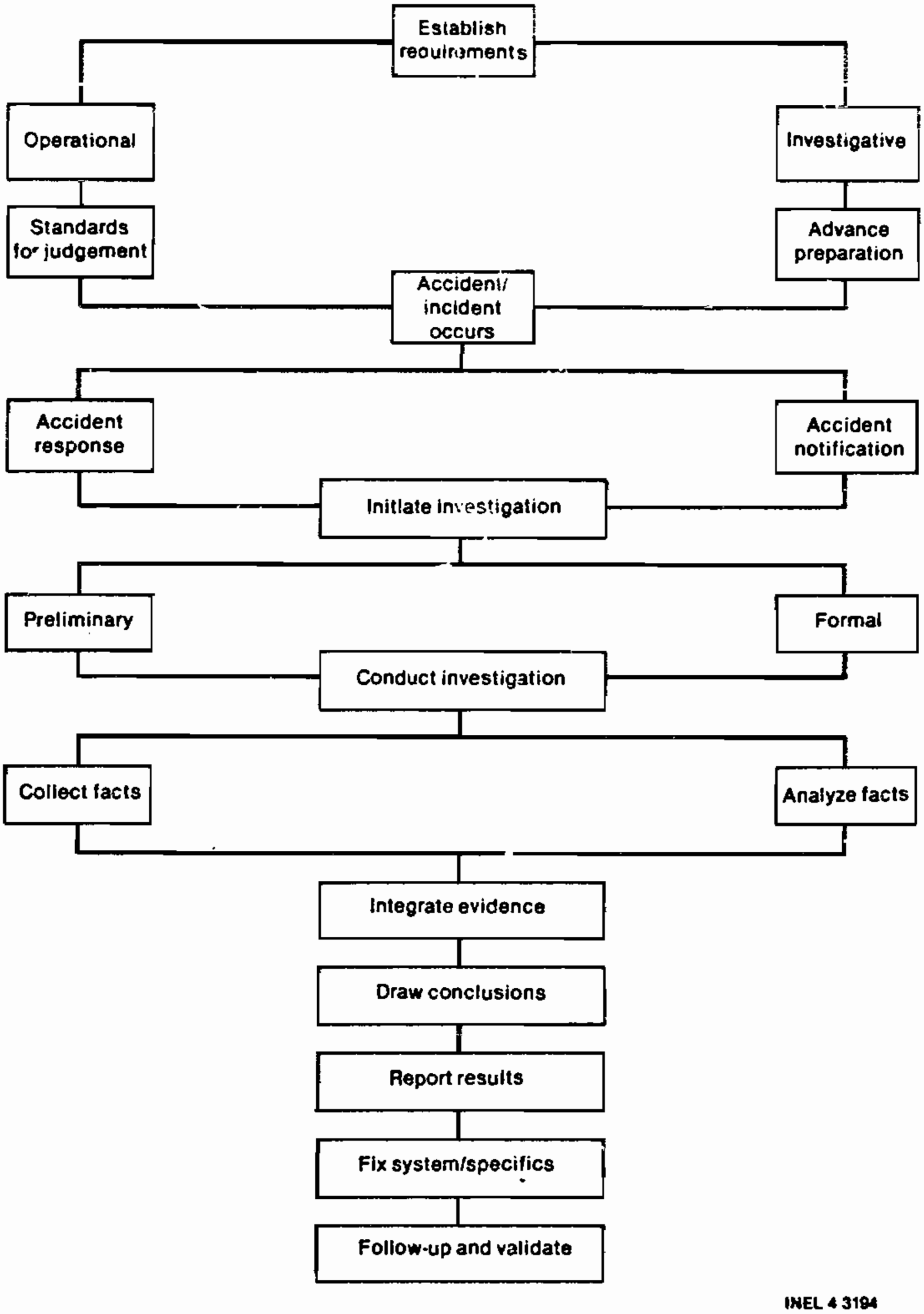

Figure 4. The investigation process.

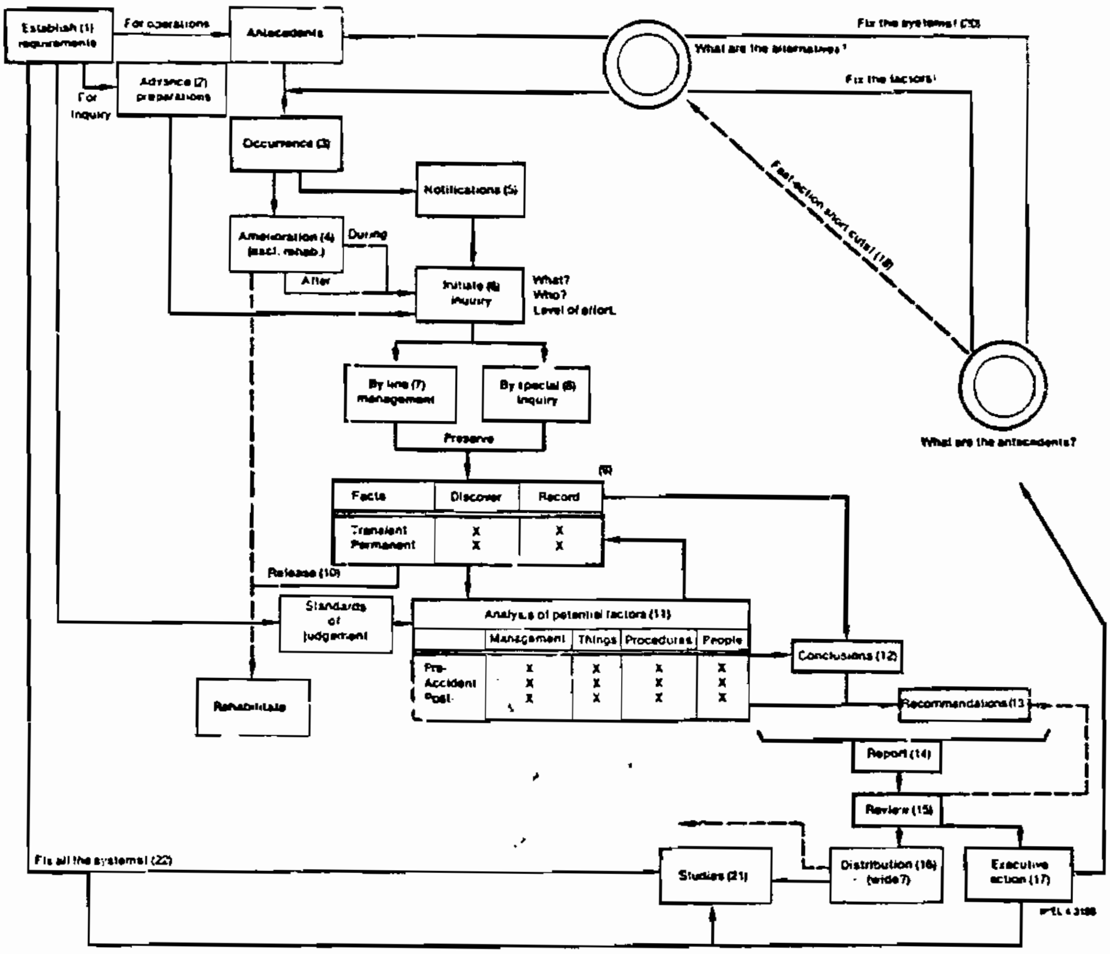

Figure 5. Accident/Incident Inquiry Process.

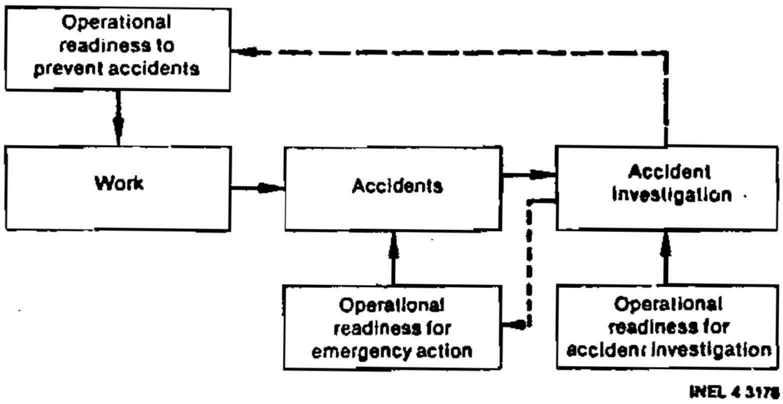

Figure 6. Accident Management.

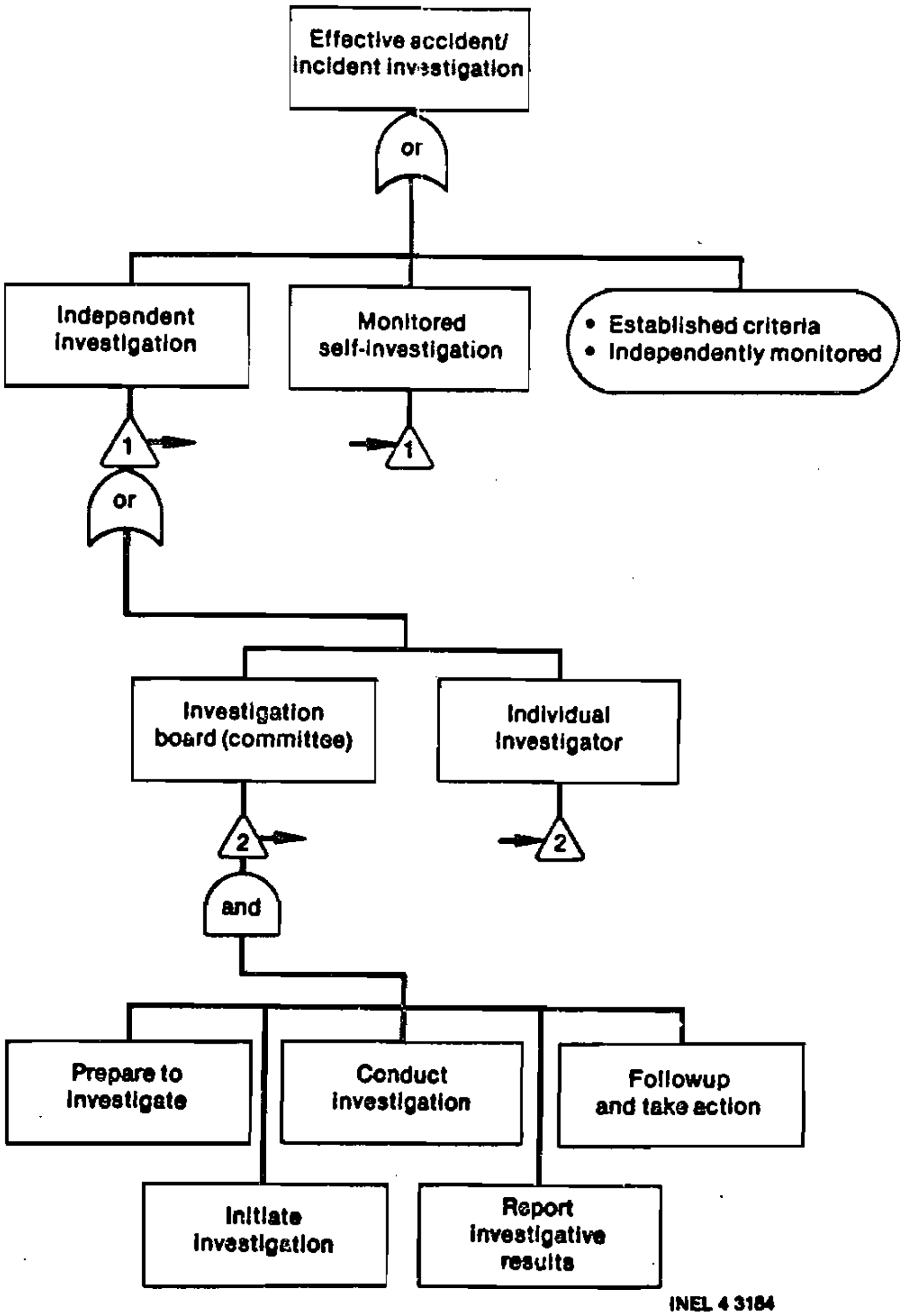

Figure 7. Effective Accident/Incident Investigation.

mended system and specific fixes. The official also arranges for followup, validation, and close out of corrective action. He may also direct or recommend further studies or inquiries to evaluate system problems beyond the scope of the accident investigation.

Figure 8 summarizes the sequential flow of activities and relationships in carrying out the accident/incident investigation process for a Type A or Type B investigation.

Appendix B is a more detailed outline of the postaccident sequence of investigation-related activities.

Headquarters or Field office	Preliminary investigators*	Investigation board	Contractor
1. Advance plans →	→	→	1. Implement advance plans
			Event Occurs
2. Notification ←	←	←	2. Amelioration (acute) 3. Notification
	1. Go to the scene 2. Get needed assistance 3. Review personnel safety 4. Observe amelioration		4. Secure the scene 5. Preliminary witness statements 6. Early photos 7. Preserve transient evidence
3. Receive ←	5. Receive 6. Evaluate magnitude 7. Collect transient evidence	←	8. Preliminary synopsis
4. Decide category 5. Appoint →	→	1. Briefed by authority →	9. If incident, appoint board
		2. Go to scene 3. Meet with management	10. Assign top level liaison
	8. Preliminary synopsis	4. Receive ←	11. Preliminary synopsis
6. Provide logistics →	9. Advise →	5. Plan ←	12. Provide logistics
7. Provide consultants →	10. Assist →	6. Assign tasks 7. Collect facts	13. Provide information, witnesses and evidence
8. Check on progress →	→	8. Analyze	14. Continue non-duplicative investigation
		9. Release scene when feasible ←	15. Continue rehabilitation
		10. Agree on facts, conclusions, recommendations	
9. Review report ←	←	11. Write report	
10. Distribute report			
11. Direct action and follow to completion →	→	→	16. Take action and report

*May be successively the roles of contractor safety engineers (field and headquarters) and DOE safety engineers (area, field, and headquarters).

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Figure 8. Sequential Investigative Activities and Relationships.

II. PREPARE TO INVESTIGATE

The quality and efficiency of accident/incident investigations will mostly depend on the advance preparation and planning done before an occurrence. Requirements and criteria need to be defined in advance and communicated to those who will need to use them. In the chaotic circumstances often present after an accident, those responding need to know their responsibilities and priorities for carrying out tasks. Guidance is needed on preserving evidence, securing the accident scene, and restoring the scene to service within a reasonable time. Selection, training, and designation of investigation participants needs to be planned and prepared in advance to identify and appoint investigators. Investigative materials and necessary support functions should be specified in advance and be available when needed by investigators. Procedures, guidelines, and methods need to be developed and ready for use in accident response and investigation, so that oversights and omissions can be prevented, performance errors minimized, and postaccident hazards and risks controlled.

Figure 9 identifies the three essentials of advance preparation for investigation that will be discussed in this chapter: (a) definition of requirements and criteria, (b) planning of accident response, and (c) planning of investigation activation.

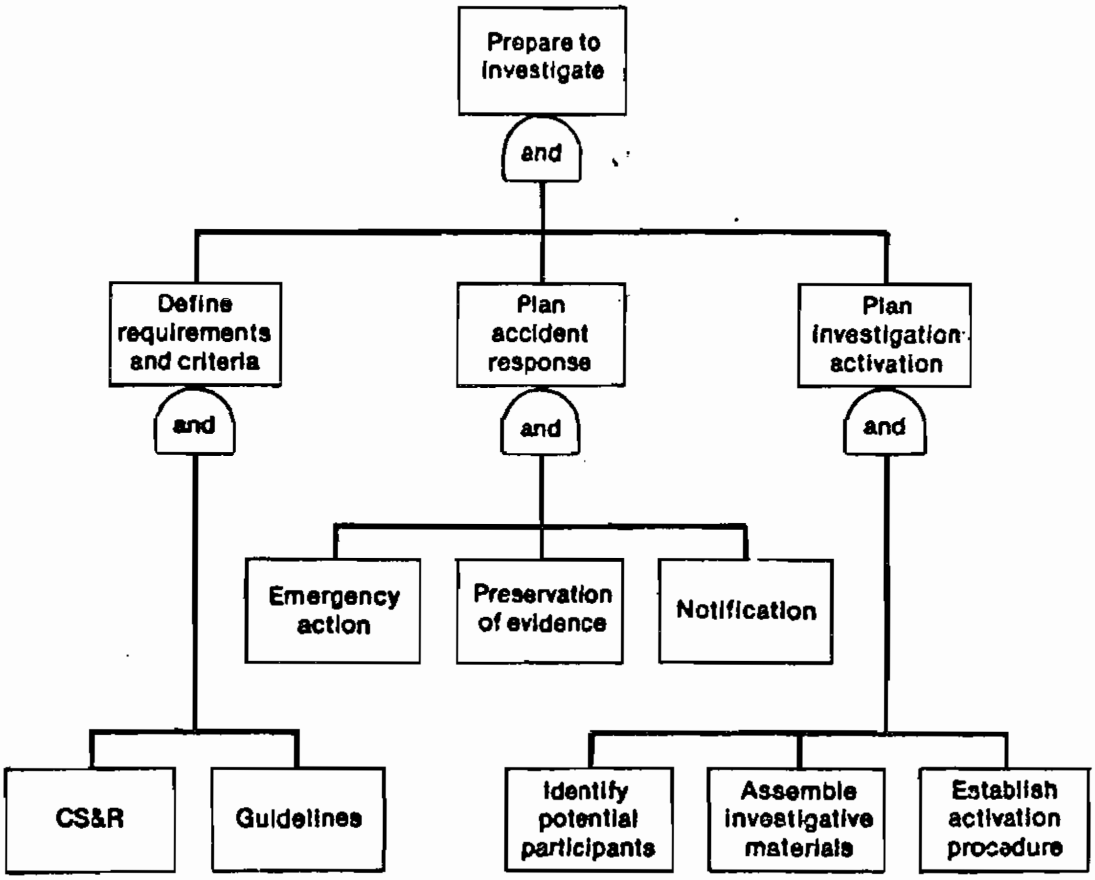

Figure 9. Preparing to Investigate.

Define Investigation Requirements and Criteria

Investigation requirements and criteria flow out of investigation policy and objectives, and form the basis for preaccident planning. They are spelled out in codes, standards, and regulations (CS&R) and are amplified, clarified, and simplified in nondirective guidelines. Figure 10 suggests the relationship between and the need for both CS&R's and guidelines, and identifies the common investigative requirements and criteria that they should address.

Codes, Standards, and Regulations. Basic DOE requirements for accident/incident response and investigation are spelled out in DOE Orders from Headquarters Program offices and the ES&H Office. The primary directive is DOE Order 5484.1. Further amplification is found in DOE Field Offices implementing directives. In addition, first line operating organizations, either DOE or contractor, should establish their own requirements and criteria to identify operation of their organizations in response to an accident or incident. These organization-specific directives, of course, must be consistent with DOE Orders and Field Office implementing directives. They need to relate the higher, generalized requirements to the specifics of particular organizations and operations, and the unique combinations of hazards, risks, and controls that are found there. They need to address (in appropriate

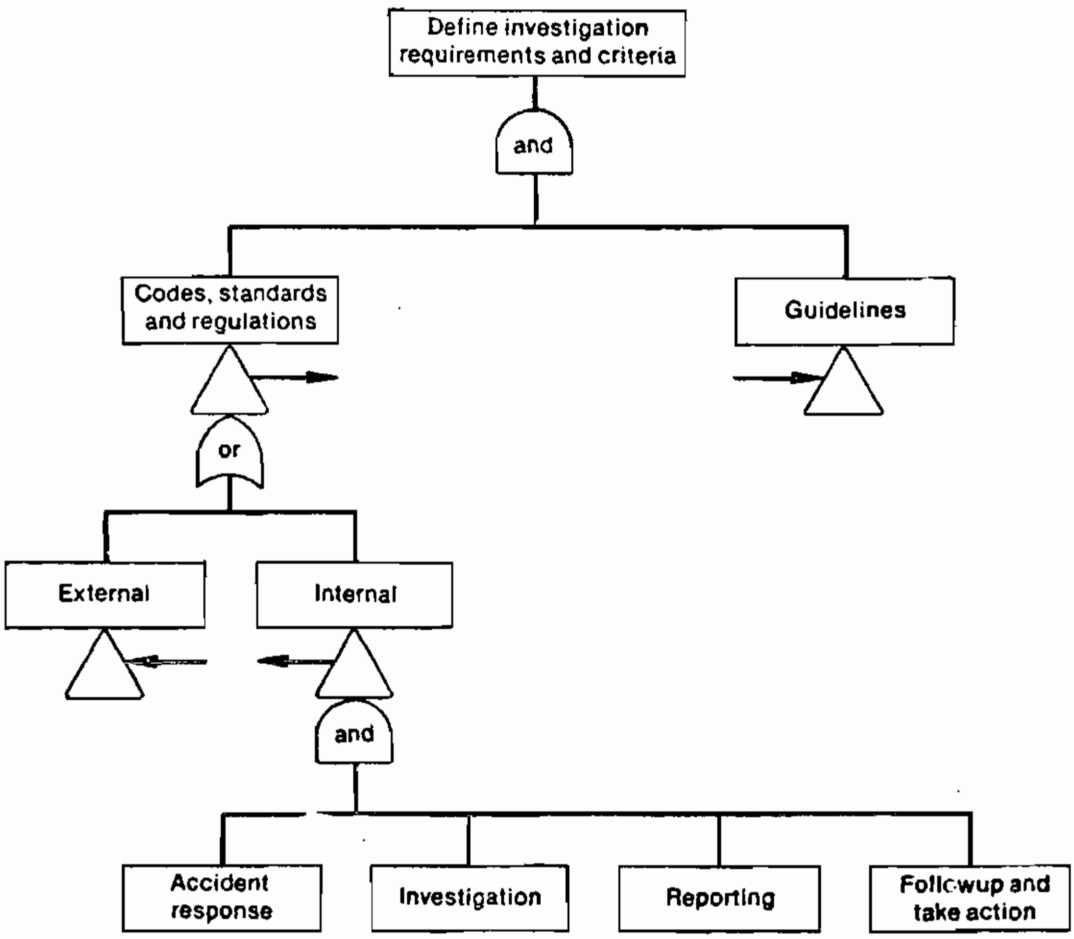

Figure 10. Define Requirements and Criteria.

details the specific responsibilities and activities that make up that organization's approach to accident response and investigation for internal (as well as external) reporting requirements and criteria, and in-house action assignments and followup. The directives need to define: (a) how and when alarms are sounded; (b) who is to respond; (c) when, how, and with what equipment; (d) who is to be in charge of response, rescue, and recovery activities; (e) who is to gather the accident data, make preliminary loss estimates, and notify appropriate officials; (f) who is to secure the accident scene, control access, and gather and preserve evidence; (g) who is to make information releases and with whom they need to be coordinated; (h) who is to perform initial preliminary investigations; (i) how and by whom internal accident incident investigation boards are to be appointed and convened; (j) what facilities, materials, support, and liaison are to be provided to investigative teams; (k) and how and from whom support is to be obtained. Also to be defined are: how to ensure that investigators remain free and independent to evaluate accident evidence objectively, so existing system deficiencies can be identified and needed corrections made; when and to whom accident reports are to be submitted, and in what form or format they are to be structured; who is to review the report before final acceptance, and what review criteria are to be used; how action assignments in response to investigative findings and recommendations are to be made, by whom and to whom; and who is to follow, verify, and close out completed action assignments, and how it is to be accomplished. These and other organization- and operation-specific requirements and criteria need to be defined and communicated to the people responsible for taking or directing action in response to accidents and incidents.

Guidelines. Nondirective guidelines need to be provided to management, supervision, employees, and accident incident investigators in preparing for and responding to accidents and incidents. This manual is the primary DOE guideline for investigation and attendant activities. It should be supplemented, as appropriate, by locally developed guidelines that provide information and methods tailored to organizational and operational needs. Guidelines, like requirements and criteria, need to address accident response and investigation, investigation reporting, and action-taking and followup in sufficient detail to enable proper management of accident investigative activities.

Plan and Prepare for Accident Response

Accident response is a critical phase in accident management. It is the phase in which the required emergency action is taken to save life and limit loss, and it is also the initial postaccident opportunity to preserve fragile evidence and gather the information required for official notifications and investigative decisions. As indicated in Figure 11, emergency action considerations, particularly lifesaving and life-protecting activities, always take first priority, even if property or evidence are destroyed, distorted, or broken in the process. Trade-offs invariably have to be made during accident response, but if they are properly evaluated beforehand, the likelihood of right decisions will be enhanced and adverse side effects will be minimized. This becomes significant when it is remembered that the preservation of evidence is essential to both the collection of factual information and the accurate and complete interpretation of its meaning. It is evident that advance preparation and planning are necessary to ensure proper coordination of emergency action, evidence preservation, and accident notification activities.

Emergency Action. Figure 11 identifies five primary areas that need to be addressed in every emergency action plan: (a) summon help, (b) respond to the emergency, (c) rescue victims, (d) limit the losses, and (e) prevent further loss.

Simple, easy-to-use procedures for summoning help and warning of accident situations need to be established. Reporting responsibilities need to be defined, and training in alarm system activation needs to be specified and performed. Those experiencing or discovering an accident need to know how, when, where, and to whom to report it to summon emergency help. Those responding to an accident need to know what they can do and what they cannot do, what actions fellow workers can take, and what actions require skilled and qualified emergency response professionals. Emergency personnel must also know who should direct and coordinate emergency response and rescue operations; what equipment, materials, and protective gear are required (how and where they are obtained and what training or qualifications are required for their use); and what risks, hazards, or peculiarities of this operation, process, or facility exist, and what specialized knowledge, skills, procedures, and equipment are needed to safely handle them. They must also know what means are needed and are available to control and limit present injuries and losses, and to prevent emergency teams, rescuers, and investigators from causing addi-

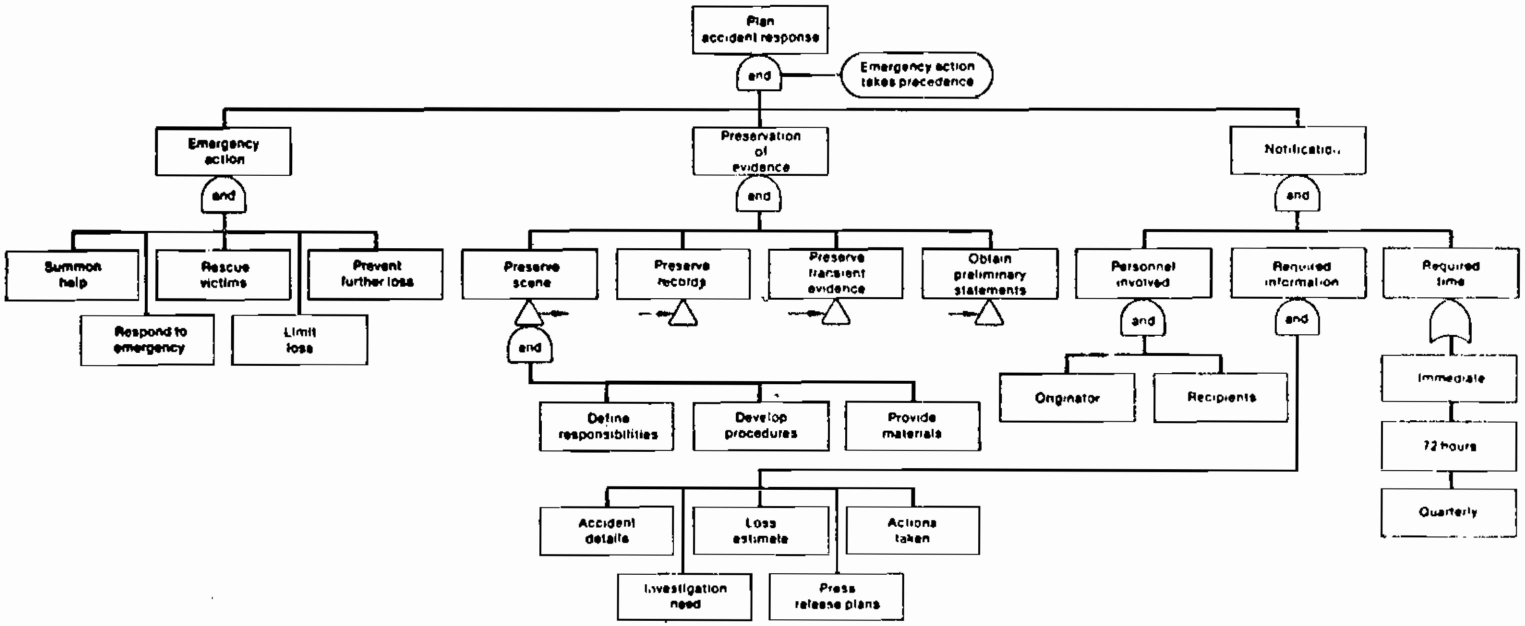

Figure 11. Plan Accident Response.

tional injury or loss, or becoming casualties themselves. Too often, second accidents result from good-intentioned emergency response and rescue actions, or existing injuries or losses are aggravated by improper, inadequate, or ill-advised actions. Usually, these additional or aggravated losses result from impromptu, on-the-scene actions, and could have been prevented by proper preaccident evaluation, planning, and preparation for emergency response. For greatest effectiveness, this preparation for accident response should include evaluation of the effects of various intervention actions on the probable loss outcome, using time-loss analysis or a similar analytical approach.

Preservation of Evidence. The primary tasks of accident investigators are the collection and evaluation of factual evidence to arrive at valid conclusions and recommendations to prevent accident recurrence. The investigators' task can be made easier and more effective if early time preservation of evidence is included in accident response preparation and planning. Preservation of evidence will always be overridden by life saving considerations and sometimes by risk reduction and programmatic considerations, such as purposely running a failing piece of equipment to destruction in the process of gathering vital programmatic data. By accepting the secondary precedence of preservation of evidence, much can be done concurrently with emergency action tasks, or soon thereafter, to preserve the accident scene and relevant records and transient evidence. Witnesses should be identified and preliminary statements gathered. Also, if the emergency response people are familiar with the need and methods for evidence preservation, they can often conduct their activities in a way that will enhance, rather than degrade, preservation of important accident evidence.

Preserving the accident scene involves securing the area by roping it off or barricading it and placing appropriate warning signs. Guards should be established to control access and limit entry to emergency teams, investigators, and others with authorization and need to enter. The reasons are obvious: to prevent people from trampling through the scattered accident debris, prevent the removal or relocation of equipment or materials, keep out souvenir hunters and others who may carry off valuable evidence, control access to those involved in accident management and investigation, protect people from exposure to hazards still remaining at the site, prevent activation of equipment or systems that may lead to a second accident, etc.

Preservation of relevant records requires that procedures be established and responsibilities be defined. Hardware and software need to be provided for identification, collection, preservation, processing, and storage or impoundment of recorded information. Some records at the site may be kept for only a day or a week, so those that may be pertinent to the accident need to be found as soon as possible. Records kept at central locations or other places remote from the scene of the accident need to be identified in accident response and investigation plans and guidelines, so they will not be overlooked or forgotten.

Some valuable evidence literally evaporates, some is purposely carried off, some is inadvertently carried off or destroyed at the scene (sometimes by emergency response personnel), and positions of things are changed. These and many other actions or events can lead to loss, distortion, or breakage of fragile evidence, so it needs to be quickly and carefully collected and recorded in order to preserve it for examination. Investigators should be liberal in their collection of samples and recording of information. They can always throw away what they don't need, but if they fail to collect or record it, it may be lost forever. They should go to the field equipped with an adequate collection of recording materials and supplies. If the organization's preparation for accident response and investigation has been properly set up, much will have been done by knowledgable people at the accident site. Investigators should not rely on this being done; they should follow up themselves.

A properly equipped investigator's kit, or "Go Bag" of supplies and equipment, prepared in advance for use when an accident occurs and an investigation team is activated, is invaluable. Every organization should have these kits made up and ready for use. They should be appropriately tailored for the most probable on-site accidents. Appendix C contains several lists of proposed investigator kits.

The earlier that preliminary statements can be obtained from witnesses after an accident, the more accurate and credible these statements are likely to be. This suggests, then, that collection of preliminary witness statements should be built into the emergency response system and carried out by line management and supervision before the arrival of the investigation team. Once more, investigators should be cautioned that it may not have been completely done before their arrival, so they should be sure to follow up. Preliminary statements not only preserve early impressions and observations by people at the scene at the time of the accident, but also have the added benefit of helping the team select the best witnesses for interview. Preliminary statements can be written on concise, easy-to-use forms which fully identify the individual witness, his job and work place, his point of observation, and his observations relative to accident and events, activities, conditions, equipment, materials, and environmental factors. Detailed factual evidence can be obtained in followup interviews with witnesses in areas suggested by the preliminary statements.

Early preservation of evidence can be initiated through adequate preparation and preplanning for accident response, and can be accomplished by management and supervision, emergency service personnel, and on-site investigators during the execution of emergency actions. The third element of planned accident response, notification of accident occurrence, is a separate task, but it is fed by the findings of those persons involved in initial evaluation of accident effects.

Notification. DOE Order 5484.1 Chapter I contains official accident notification requirements for DOE and contractor organizations. Local directives are needed to specify responsibility for making these official notifications, as well as defining notification procedures report contents, and format. Further, they should identify required recipients for the notifications, both in-house and outside. In addition to notification of company and DOE officials, the criteria, procedures, and responsibility for notification of others (family, employee, news media, community officials, etc.) need to be defined and assigned. The immediacy or time frames for notifications also should be identified and followed. DOE Order 5484.1 and Field Office implementing directives specify immediate notification by telephone to the designated DOE Field Office or Headquarters emergency operations center for those most serious accidents and occurrences which require Type A investigations. Immediate is interpreted as being as soon as sufficient information has been obtained to indicate the general nature and extent of accidental losses. Teletype notification within 72 hours to the designated Field Office or Headquarters operational safety office, with copies to cognizant programmatic, legal, and public affairs offices, is specified for accidents/occurrences requiring Type B investigations and for immediate notification confirmation. The required information includes: (a) accident details, such as time, date, location, general nature of accident/occurrence and its major consequences; (b) loss estimates of consequences, programmatic and public effects, injuries, property damage, and other real or potential losses; (c) actions taken for emergency control and amelioration, status of actions to initiate investigation, and comments on possible or probable causes of the occurrence; (d) press releases made or planned; and (e) the need for a DOE investigation and, if appropriate, the names and titles of proposed investigation board members, advisors, and consultants. Accidents and occurrences of a lesser nature and consequence are reported quarterly to the designated DOE recipient office using the specified forms.

Plan Investigation Activation

The threefold nature of preparation for investigation, as depicted in Figure 9, consists of: (a) definition of investigative requirements and criteria; (b) planning for accident response, including emergency action, preservation of evidence, and appropriate notifications of accident occurrence; and (c) planning for activation of the investigation. These three aspects of investigative preparation generally take place sequentially, but there are some common activities and overlap in the latter two, as well as some early time planning and preparation for investigation activation that precedes specific accident response planning. However, the better these two planning phases are coordinated and correlated, the better the actual accident response and investigation activation sequences are likely to flow, and the more effective and correct the specific activities are likely to be.

Figure 12, Elements of the Investigative Process (from Ray Kuhlman's *Professional Accident Investigation*) clearly ties the planning sequence together, showing preaccident definition of objectives, policy, and planning. These shape the requirements which establish an accident investigation classification system, as well as emergency response essentials and notification of cognizant officials who make investigation activation decisions. These decisions determine: (a) who is to be appointed to perform various investigative tasks; (b) when and how those appointments are to be made; (c) and what materials, aids, and instructions are needed by the appointees to provide the type of investigation and report desired by the appointing official and required by defined investigative criteria.

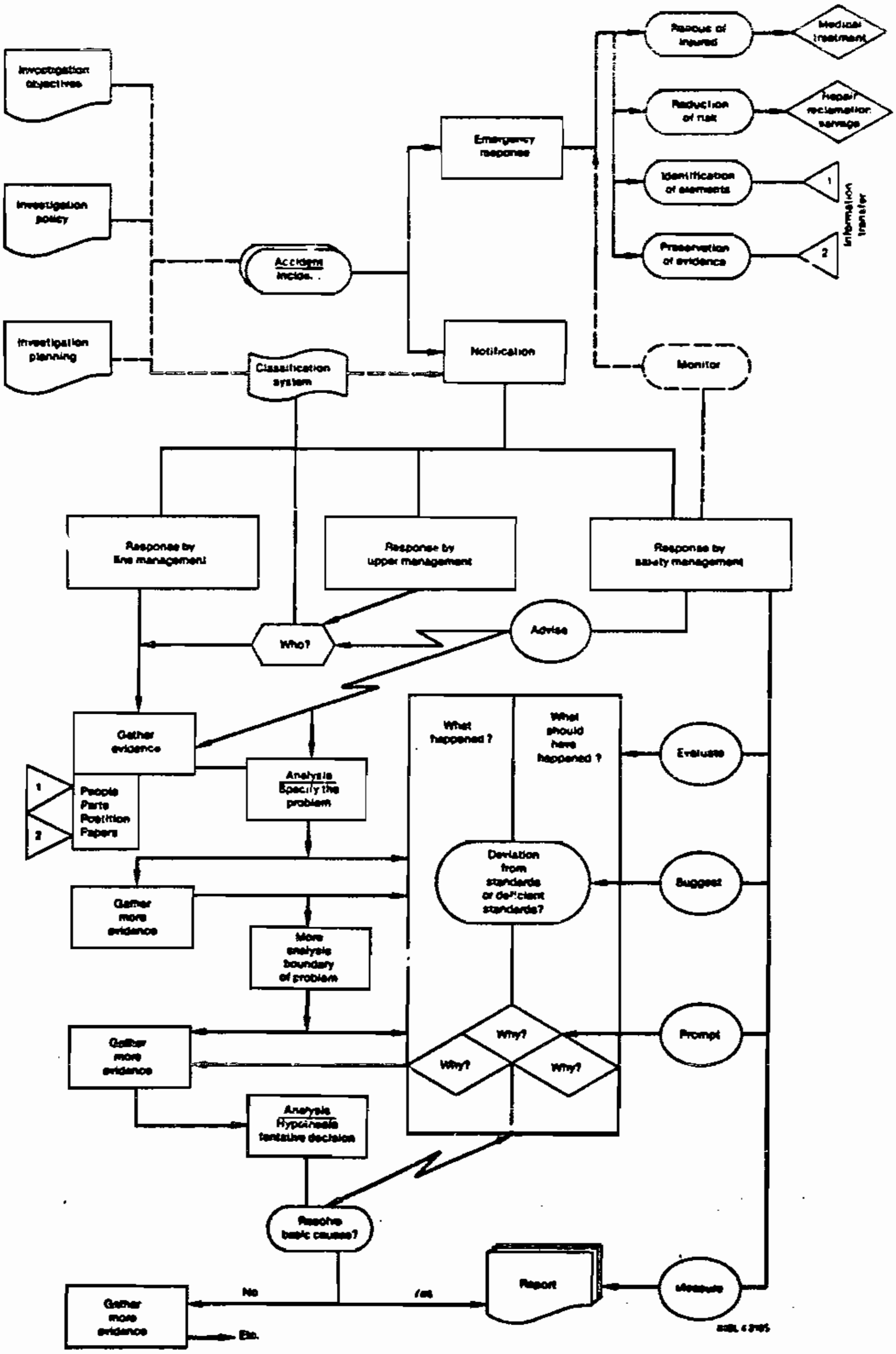

Figure 12. Elements of the Investigation Process.

Planning for investigation activation then involves: (a) identifying potential participants, (b) assembling investigative materials, and (c) establishing activation procedures, as indicated in Figure 13. Since appointing officials for investigation boards may be selected from and by DOE Headquarters, Field Offices, or contractor organizations, each level needs to plan for investigation activation. Generally, the more serious the accident, and the bigger the actual or potential losses, the higher the level of the appointing authority. Within DOE, Type A investigation boards are appointed by DOE Headquarters or Field Office officials, Type B boards by the DOE Field Office head, and Type C boards or lone investigators by the DOE or contractor organization official whose operations are involved in the occurrence. Additionally, Type A investigation boards consist entirely of DOE or other federal personnel, but Type B boards may contain DOE contractor personnel at the discretion of the Field Office head.

Identify Potential Participants. Potential investigation participants may be investigators or board members; specialists and advisors who assist board members in collection, protection, examination, and evaluation of evidence; and reviewers who evaluate the quality and completeness of the investigation report and recommendations. These investigative participants must be suitably qualified for the tasks they are to perform, and they must be available to perform them. If a potential investigative participant is the best qualified and prepared to perform a specific investigative function but is not available at the time he is needed, the appointing official and his advisers had better look elsewhere for another suitable candidate for that assignment. The availability aspect then necessitates the establishment and maintenance of potential participant lists at all levels from which appointing officials are selected. The need for suitable, as well as available, participants requires appropriate measures be in place to develop and identify a cadre of persons with the qualifications to conduct objective and meaningful investigative activities in whatever phase they participate.

Three basic characteristics determine a person's suitability as a potential investigative appointee:

1. Does he possess the necessary capabilities? Can he do it?

2. Does he have sufficient motivation? Does he want to do it?

3. Does he have sufficient independence and objectivity? Can he both see it and tell it as it is?

In order to determine whether a prospective appointee has the requisite capabilities for performing an effective investigation or review, one must look at his education and training, his experience, his present work assignment, and his current knowledge and skill within his area of expertise. Each of these should be considered within three general areas of capability: managerial, technical, and investigative (particularly possessing knowledge, skill, and experience in the specific type of investigation he will be expected to conduct or review). If a single investigator is to do the investigation by himself, he must have an adequate balance of these capabilities for the task involved. If an investigation board or a group of individual reviewers is to be used, the required balance of needed capabilities is achieved by appropriate selection of capable specialists or experts within each area. The effective lone investigator, then, must possess a combination of capabilities, whereas, the effective board or group of individual reviewers will combine a balance of specialists, each possessing a specific, needed capability. This, in fact, is one of the benefits of using appointed boards for investigations and is a primary reason that investigation boards are required on major accident investigations. Additional strengths derived from the use of investigation boards are (a) fostering of independence and diversity of views and experience, (b) counteracting of biases and inaccurate perceptions, and (c) built-in validation and confirmation processes that enhance the quality and completeness of the total investigative process. Shortcomings of investigative boards may be (a) members who are inexperienced in investigation and analysis, and (b) interpersonal factors that may slow or complicate the investigative work.

Regardless of other capabilities an investigator, consultant, or reviewer may possess, some training in investigative principles and methods is critical for top performance. Recognizing the need for investigative capability on every major accident investigation board, DOE requires that at least one member of each Type A and Type B investigation board be a Trained Investigator. One becomes certified as a Trained Investigator by completing the DOE Accident Investigation Workshop. This two-week course helps potential investigators develop proficiency in: (a) conducting high quality in-depth accident investigations, and (b) writing clear, concise, effective investigation reports.

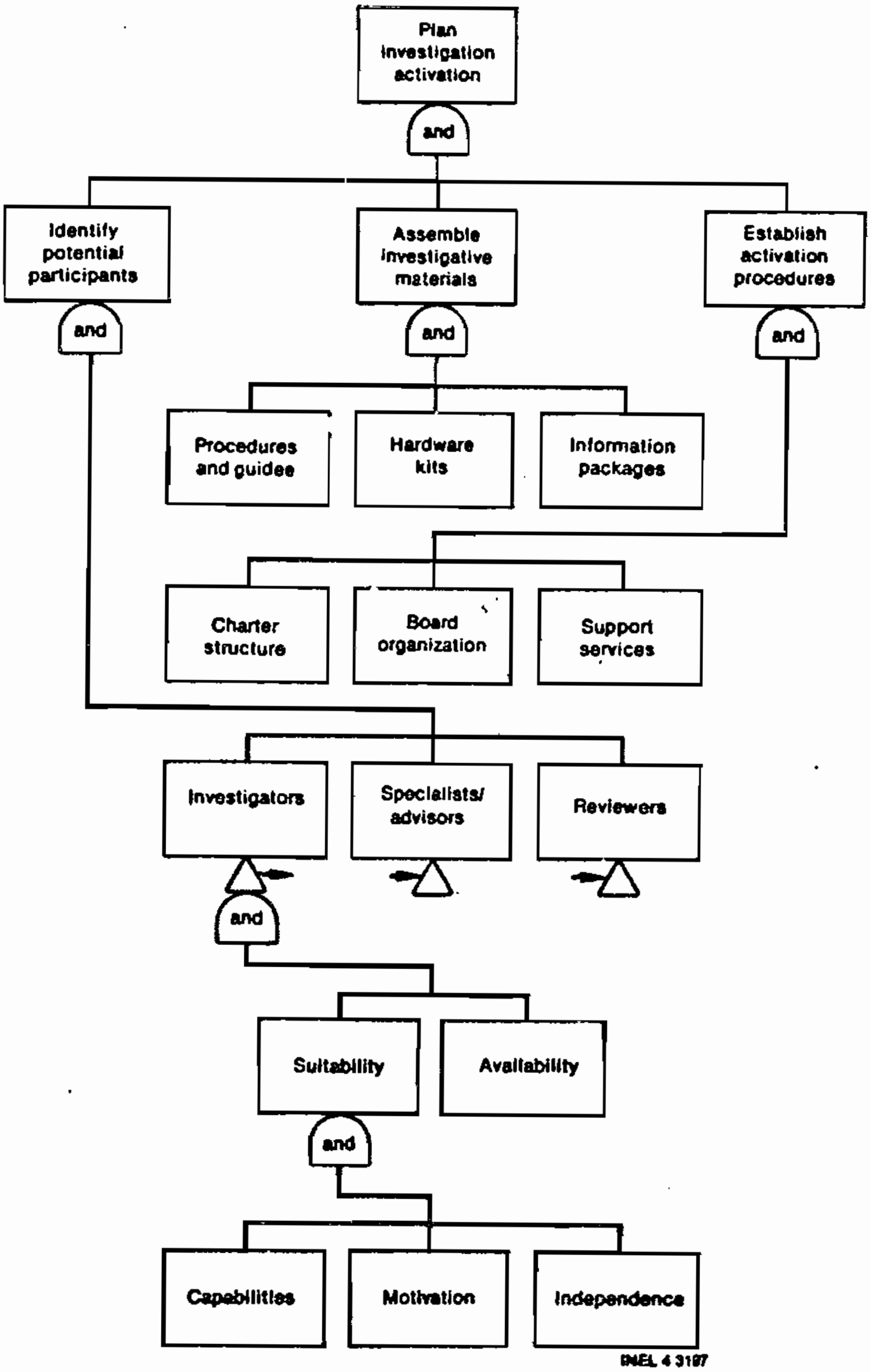

Figure 13. Plan Investigation Activation.

Trained Investigators are provided with structured opportunities to learn and use.

1. Basic accident investigation (AI) concepts and principles

2. DOE investigative and reporting requirements and guidelines

3. MORT/AI program developments, services, and resources

4. Important considerations (a) in advance preparation for accident investigation and (b) in structuring the investigating board and managing the investigation

5. Current best methods for collection of accident-related information and evidence

6. State-of-the-art investigative analytical methods for evaluating and integrating gathered facts

7. System risk evaluation methods to determine whether the accident should have been expected and how actions should be directed to prevent recurrence

8. Appropriate and available experts and specialists for gathering, evaluating, and understanding accident-related evidence

9. Standardized structure and format for the investigation report and recommendations letter

10. The total integrated accident investigation process

11. Experiences in the accident investigation process, including review and followup, lessons learned, and suggestions for process improvement.

Upon completion of the AI workshop, the Trained Investigators are certified for three years. They need to complete an AI refresher course every three years (four years. if they serve on a major AI board during that interval). The Trained Investigators normally find themselves cast in two specific roles on the investigation board as a result of their AI training and certification: (a) chief advisor to the board chairman on investigative matters, and (b) trainer of other board members on basic investigative principles and methods.

In addition to training of board members, consultants and reviewers, other potential participants in accident response and investigation should receive appropriate advance training in:

1. Initial reporting and notification of accident occurrence

2. Preservation of the accident scene and accident evidence

3. Collection and preservation of information

4. Participation in various roles in the investigation, i.e., liaison, providing of witnesses, documents, facilities, support, etc.

5. Specialized training pertaining to the particular requirements related to accident investigation at this facility or organization.

Effective accident investigation performance is affected not only by capability, but also by motivation No matter how capable an investigator is, his performance effectiveness can still fall short if motivational factors interfere. This can exist when: (a) his perceived value of the investigation is too low to justify his best efforts or the time and energy invested; or (b) it is perceived to be a meaningless drill, rather than a meaningful task, providing worthwhile benefits; or (c) the perceived conflicts it imposes with his time and workload, his interests and biases, and his working and personal relationships are unacceptable. The better the match between the potential investigator's motivational factors and the investigation tasks to which he is appointed, the higher the likelihood that he will be an effective contributor.

In considering the final criterion, independence for desirable investigator characteristics, those involved in selection and appointment should look at personal traits, management level, and functional position of the potential participant and his susceptibility to biasing influences which could impede or prevent the person's clear recognition and evaluation of facts and findings.

Additionally, a successful investigator should be able to work effectively with others, be knowledgeable in his specialty, be able to gather facts unemotionally and evaluate them objectively, be able and confident in making logical judgments, and be free from commitments, obligations and vested interests in the involved organization, people, and activities, on and off the job.

The investigator's management level and functional position should be appropriate for the investigation being conducted. His effectiveness and ability to get the information and cooperation he needs may also be affected by the level and position of the appointing official. The investigator needs to be independent of undue influence (vested interests) and control to be capable of evaluating accident evidence objectively. He must also possess sufficient clout to get what is needed in dealing with the involved organizations. All of these are related to the management levels of the appointing official and investigator.

Present and past functional assignments lend credibility to the investigator's observations and findings, but those assignments need to be sufficiently removed from the involved people, activity, and organization, so that his objectivity, independence, and ability to work with those involved are not adversely affected.

The appointing authority should avoid any attempt to interfere with the board's collection, evaluation, and finding of facts. If the appointing authority presses for predetermined inclusions, conclusions, omissions, or recommendations, the investigators' chances of being objective are greatly diminished. The appointing official can further enhance objectivity by ensuring: (a) that a superior and subordinate are not appointed to the same investigation board; (b) that employees directly related to the operation or the accident do not serve on the investigation board; and (c) that all involved know that appointees work directly for the appointing authority and have no other assignments or responsibilities for the duration of the investigation.

Assemble Investigative Materials. If investigative materials (including procedures and guides, hardware and software, and information packages) have been assembled in advance and are provided to the investigation board when it is appointed, the investigators can be more immediately productive in their efforts. Complete investigation kits or "go-bags," containing the needed investigative materials, may be assembled and tailored to special organizational needs by using the lists of contents suggested in Appendix C.

Establish Activation Procedures. Established activation procedures at all levels which appoint boards of investigation will facilitate the process of initiating an investigation after an accident or high potential incident has occurred. The board charter structure, board organization, and needed board support services need to be identified in advance and procedures established for activating them. The procedures should be keyed to the needs of the organization and the types and nature of accidents they are likely to investigate. They should be broad enough to adapt to whatever investigative needs may arise, yet specific enough to provide needed guidance to appointing authorities and their advisors in appointing investigators and providing them with the instructions, authority, and support they need to effectively accomplish their investigative tasks. DOE Order 5484.1 provides basic criteria for appointment of board members and advisors. The next chapter in this manual, "Initiate Investigation," discusses the details of structuring the charter, organizing the board, and providing support services. The details should be built into investigation activation plans and procedures.

III. INITIATE INVESTIGATION

When proper advance planning and preparation for accident response and investigation have been done, the occurrence of an accident or incident becomes a trigger to implement the advance plans. Line management and their safety advisers will ensure amelioration is underway as first priority, make immediate notifications, and secure the accident scene from disturbance and uncontrolled entry. They will also preserve evidence, collect transient evidence and preliminary statements, and cooperate with the independently appointed board of investigators, thus providing them with appropriate liaison and support services.

After evaluation of the accident notification information and consultation with DOE Headquarters, Field Office, and contractor personnel, as appropriate, the designated appointing authority will initiate the accident/incident investigation by specifying the investigation and appointing the investigation team, as indicated in Figure 14.

Specify Investigation

The investigation is specified concisely in the investigation board letter of appointment. It is emphasized in board briefings by the appointing authority, and in subsequent communications with the board, as initial specifications are explained, expanded, or revised. Key investigation elements that require specification are:

1. Type of investigation (DOE Type A, B, or C).

2. Level of appointed board (DOE Headquarters, Field Office, contractor, or contractor sub-element).

3. Scope of investigation (definition of how much of the accident-producing system the investigators should examine). Generally, the scope should be defined broadly enough to include the upstream processes which produced the accident situation and the management system which should have controlled it. It should also be limited enough to be manageable by the appointed board. Provisions should be made for expanding the scope or appointing others to subsequently or concurrently look at special concerns beyond the defined investigative scope, when emerging evidence warrants. Examples of special concerns that may be uncovered during accident investigations are (a) accident contributions that arose early in the system life cycle at other locations or organizations, (b) problems requiring research for resolution, and (c) general studies or inquiries of larger system involvement and widespread or extensive problems.

4. Requirements and constraints on the board (definition of the board's authority, responsibility and accountability). The appointing official defines for the investigators what he expects of them and what they can and cannot do. He should also specify for them what they should do if they encounter problems in getting things they need or getting the investigative job done.

5. Funding and resources for the investigation (specification of the source or sources for needed funding and resources for both direct board needs and those of others involved in the investigation). Others in the investigation would be consultants, advisors, witnesses, support people, etc. Basically, the appointing official defines who pays the investigation bills.

6. Support and liaison for the investigation team (designation of who provides these services). Usually, the organization experiencing the accident or the next higher management level, i.e., Field Office, will provide senior staff liaison to handle requests for documents, witnesses, tests, etc. That same organization will also ordinarily provide support services such as work space, offices, clerks, typists, transportation, protective gear, photographers, etc.

7. Schedules and commitments (specification of when oral or written progress reports and final reports are due and in what format they should be submitted). Generally, the format is specified

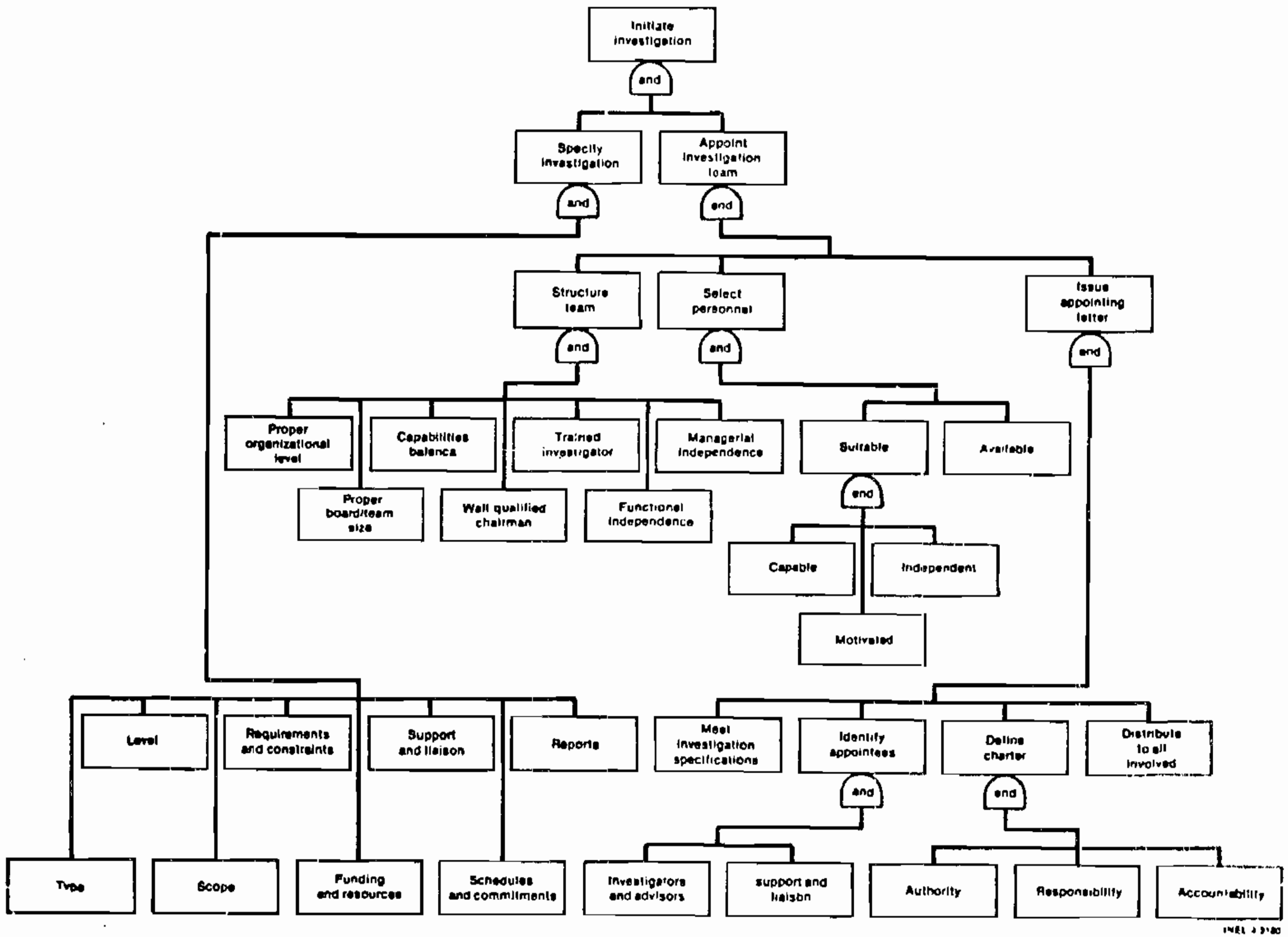

Figure 14. Initiate Investigation.

in DOE Order 5484.1, but local requirements may differ for less serious occurrences. The appointing official should specify what is to be done if desired schedules or commitments cannot be met as intended. Provisions made for extensions of time to accurately complete the report should be specified.

8. Reports (specification of type and nature of required reports). Experience has shown that appointing officials should be reluctant to ask for oral reports only, because qualified investigators using the investigative methods discussed in this manual will always find more than anticipated, and the findings will almost always warrant a written report. Too often when only an oral report is specified, sketchy notes are taken, and the investigation must be repeated to gather the details necessary for the written report.

Appoint Investigation Team

Concurrently with definition of the investigation specifications, the investigation team (consisting of board members and advisors/consultants/specialists) is appointed by complying with the DOE-specified team structure, selecting team personnel, and issuing the appointing letter.

Structure the Investigation Team. DOE Order 5484.1 specifies the structure of Type A and Type B investigation boards and teams. Individual organizations should specify local requirements for lower level accident investigation team structures. DOE Order 5484.1, which establishes basic criteria and can serve as a pattern for local team structuring, forms the basis for the following guidance.

1. Type A and Type B investigation boards/teams are appointed by DOE officials.

2. Type A investigation boards consist of DOE and other federal employees only.

3. Type B investigation boards may contain DOE contractor employees, as well as DOE personnel.

4. Type C investigations are conducted by DOE contractors when their operations are involved, and by DOE personnel when federal operations are involved.

5. Boards of investigation should consist of three to five members, one of whom is appointed as chairman.

6. The board/team chairman should be a competent manager who is qualified to manage the investigation team, direct investigative activities, and conduct necessary, often complex, coordination with involved organizations and officials.

7. All appropriate competencies (managerial, scientific, technical, professional, and investigative) should be considered in appointing boards and teams.

8. Consultants, advisors, and specialists who are experts in pertinent areas or who are familiar with the operations or management of the program involved in the accident should be appointed, as necessary, to assist the board. These persons may be contractor personnel.

9. At least one member of each board should be a Trained Accident Investigator, currently certified by DOE. One person should not serve in the dual roles of chairman and Trained Investigator on the board. It is very helpful to have the chairman a Trained Investigator.

10. A superior and his subordinate should not serve on the same board.

11. Employees directly related to the operation or activity involved in the accident should not serve on the board.

12. Investigators should work for and report to the appointing official and board chairman only for the duration of the investigation. They should have no other assignments or responsibilities in their regular work group until the investigation is completed and they are released by the appointing authority or board chairman.

Select Investigative Personnel. By drawing upon lists of Trained Investigators, other rosters of prospective board/team members having suitable capabilities, and contacts (with advisors and officials at appropriate levels) the appointing authority can select a board chairman, board members, and consultants/advisors to conduct an accident investigation. There will be trade-offs in making the best selections, which should be addressed by the appointing official and those assisting him. Following are some practical considerations:

1. Managerial level of the chairman and members should be considered. Appointing top level people reflects the organization's concern and gets faster action during the investigation and the implementation of corrective actions. In addition, they will generally handle the invesrigation better, and they are not easily awed or fooled during the investigation.

2. Desirable personal qualities include an open and logical mind, thoroughness, and ability to maintain perspective and independence. Personal qualities to be avoided are a "know-it-all" attitude, "prima donnas," preconceived biases, preoccupation with normal work, and reluctance to be away from home or regular work.

3. Members who are remote from the accident site delay progress and review. Evidence and testimony may change. Members may short-cut investigation to return home.

4. Vested interests have bias. This is a danger with those too close to the site, program, or operation.

5. When possible, the NASA approach (one member for each aspect, such as energy, structure, human factors, operations, control systems, etc.) could be valuable.

6. The chairman should have a high level of managerial skill as well as a strong technical background.

7. Line personnel needed for recovery should not be assigned to investigation.

8. Avoid using people just because they are available.

9. Exclusive selection of outside investigators may be construed to imply that local DOE staff is incompetent.

10. A physician can be valuable in every serious injury accident investigation, and in most property damage accidents where human error may be a contributor. It is better to have him serve as a consultant or advisor, rather than as a board member.

11. Legal advisors are usually effective in fact collection and evaluation and in report writing and review. They can be helpful in witness interviewing; but remember that they are trained in the adversarial approach and may tend to interrogate, rather than interview.

12. Since limited numbers of people are available, a gross scoring system may be a wise compromise for selection. A possible system could produce such an analysis as follows:

Chairman	Relation	Management Exp.	Investigation	Discipline	Expertise	Analytic
Chairman	Distant	+ +		+ +		
Member	Close	+		+	+ +	
Member	Safety		+ +	+	+	+ +
Member	Distant	+		+ +	+ +	
Member	Distant	+	+	+	+ +	

Organizationally, the chairman is located at a remote or distant facility. He fulfills the added dictum of managerial skill and is from the discipline concerned.

The other members represent a mixture of attributes which should, in themselves, contribute to a well-rounded board foundation. The safety representative may be the Trained Investigator.

Managerial skill and investigative experience are the tie breakers.

13. Since DOE imposes no limits on appointed consultants and advisors, a lengthy list of disciplines and subject matter can be considered for complex events which approach a wide variety of technical boundaries; for example:

Sciences and Engineering Disciplines	Cross-Classified by Subject Matter
Physics	Bubble chambers
Chemistry	Reactors
Metallurgy	Test and qualification
Chemical engineering	Accelerators
Nuclear engineering	Critical facilities
Mechanical engineering	Structures
Electrical engineering	Control system
System engineering	Transportation
Operations research	Chemical processing
Reliability and quality assurance	Explosives
(R&QA)	Crane operation
Medical	Heavy construction
Human factors	Radiation
Health physics	Chemical laboratories
Mine engineering	Coal liquefaction
Geophysics	Extraction technology
	Reclamation technology
	Geothermal and solar development
	Electric power transmission and distribution

14. Persons with substantial training in disciplines and specialties involved should be on the board.

15. Specialists with current work experience in the problem at hand should be consultants or members of the board.

16. For an accident/incident with high public interest, select a board member with experience in dealing with the press, i.e., one who is able to effect an honest evaluation of press or public concern.

17. Any accident/incident involving radiation or complex processes engenders personal trauma and

fear. The involvement of a medical doctor or other appropriate specialist who can evaluate traumatic effects is beneficial.

18. For radiation or other problems, there is a tremendous wealth of expertise within DOE. Do not hesitate to use it.

19. When speed is warranted (and it often is), notify appointees by direct contact, phone or other means, before arrival of the letter of appointment.

20. It may be advisable to appoint the board chairman first and have him participate in selection of other members and advisors.

21. Tailor board selection as much as possible to meet the specific needs of each investigation.

Issue Appointing Letter. The letter of appointment establishes the investigative team. It states the purpose, type, and scope of the investigation; specifies the board members, advisors, and liaison persons; indicates board responsibilities, authority, and accountability; and gives special instructions to the board, including milestones to be met. It is distributed to all of the people involved, not just the appointees, but those for whom they work, and those with whom they will work on the investigation.

As far as possible, the appointing letter should spell out the investigation specifications discussed in a previous section. It does this concisely and usually requires followup with a board briefing or other communication by the appointing official, or his designee, to provide needed explanation.

Appointees are identified in the letter of appointment by name, job, and organization, and are differentiated as board members, consultants, and advisors, and liaison and support people. Additionally, the board chairman and designated Trained Investigator are identified by their investigative roles.

The board charter is defined concisely in the letter so that all recipients of the letter will know the board's authority and constraints, and its basic responsibilities and accountabilities to the appointing official.

The appointing letter is usually addressed to the chairman of the board, but sometimes appointing authorities choose to address it to the Chief Executive or Manager of the organization experiencing the accident. In either event, all appointees and their managers, and all key management persons with whom they interface will receive copies.

Figures 15 and 16 are typical letters or memoranda of appointment for Type A and B accident/incident investigations. They should be helpful to appointing officials in composing appointing letters.

FIELD OFFICE LETTERHEAD
Chief Executive
Contractor Organization
Address

Dear (Name):

(Building) Fire—(Date of Occurrence)

I am appointing a (contractor organization) accident investigation board to investigate the fire which occurred in the (Building) on (date). The following employees have been selected to serve on this board:

(Name), Chairman
(Name), Trained Accident Investigator
(Name)
(Name)

I have selected (Name), (DOE Field Office), to provide liaison between (Field Office) and the investigation board. He is to officially represent (Field Office) in maintaining cognizance of the progress of the investigation, but he is not a member of the board.

Your investigation is to be conducted in accordance with DOE Order 5484.1, and the report is to be submitted to me by (Date). The report should fully explain the technical elements of the causal sequence and describe the management systems which should have, or could have prevented the occurrence. Appropriate recommendations for improvement of the management systems will be required. The DOE Accident/Investigation Manual is to be used for guidance in conducting the investigation and preparing the report.

Very truly yours,

Manager

Figure 15. Typical letter of appointment—Type A or B Accident investigation.

FIELD OFFICE LETTERHEAD

Chairman of Committee
Job Title
Address

SUBJECT: INVESTIGATION OF (BUILDING) ELECTRICAL FIRE

Dear (Name):

You are hereby appointed as Chairman of a committee to investigate the electrical fire and related injuries which occurred (Date) at the (Location). The following personnel are appointed as members of the Committee:

(Name), Trained Accident Investigator (Organization)

(Name), Electrical Safety Engineer (Organization) (Secretary)

(Name), Electrical Configuration Control Engineer (Organization)

(Name), Engineering Technician, Nuclear Fuel Cycle and Waste Management Division (Organization)

In addition, the following personnel are designated as consultants to the Committee as needed:

(Name), Electrical Construction Engineer (Organization)

(Name), General Foreman (Organization)

(Name), Physician (Organization).

(Name), Attorney.

The Committee is chartered to conduct a Type B investigation as outlined in DOE Order 5484.1. In this capacity, the Committee works for and reports to the Manager (Field Office). The Director, Operational Safety Division (Field Office) will act as the DOE consultant and liaison for me with the Committee.

The Committee should investigate the causes of the accident and its amelioration and provide specific recommendations for corrective action. The report should be submitted to me by (Date).

Very truly yours.

Manager

cc: Manager, Organization
Manager, Organization
Manager, Organization
Committee Members

Figure 16. Typical letter of appointment—Type B accident investigation.

IV. CONDUCT INVESTIGATION

After an accident occurs, the advance plans for response and investigation are set in motion: (a) emergency action is taken to rescue the injured and reduce the risk of further loss; (b) accident elements are identified and evidence preservation is begun; (c) appropriate notifications are made; (d) preliminary investigation is begun and preliminary witness statements collected; (e) the accident is type classified and the need for a formal investigation is determined; (f) the appropriate appointing official is designated; (g) the investigation specifications are defined; (h) the investigating board chairman, trained investigator and members, and the consultants, advisors, liaison, and support persons are selected and designated; (i) the appointing letter is issued and the board notified and briefed by the appointing official; (j) the investigation kits are provided to the board; and (k) the travel orders are processed. At that point, the Investigation Team is ready to go to the site and begin conducting the investigation in accordance with the requirements and guidelines specified by the appointing authority.

Advance plans for conducting the investigation are then implemented, modified, and adapted to meet the specific investigation needs. Though standard policies, plans, and guidelines for investigation have been established and defined, the methods of application vary with the nature of the accident under investigation. For general application and continuity of investigative effort, the investigation is divided into several, usually sequential steps, all of which have to be properly managed and coordinated, as shown in Figure 17. These investigative phases are:

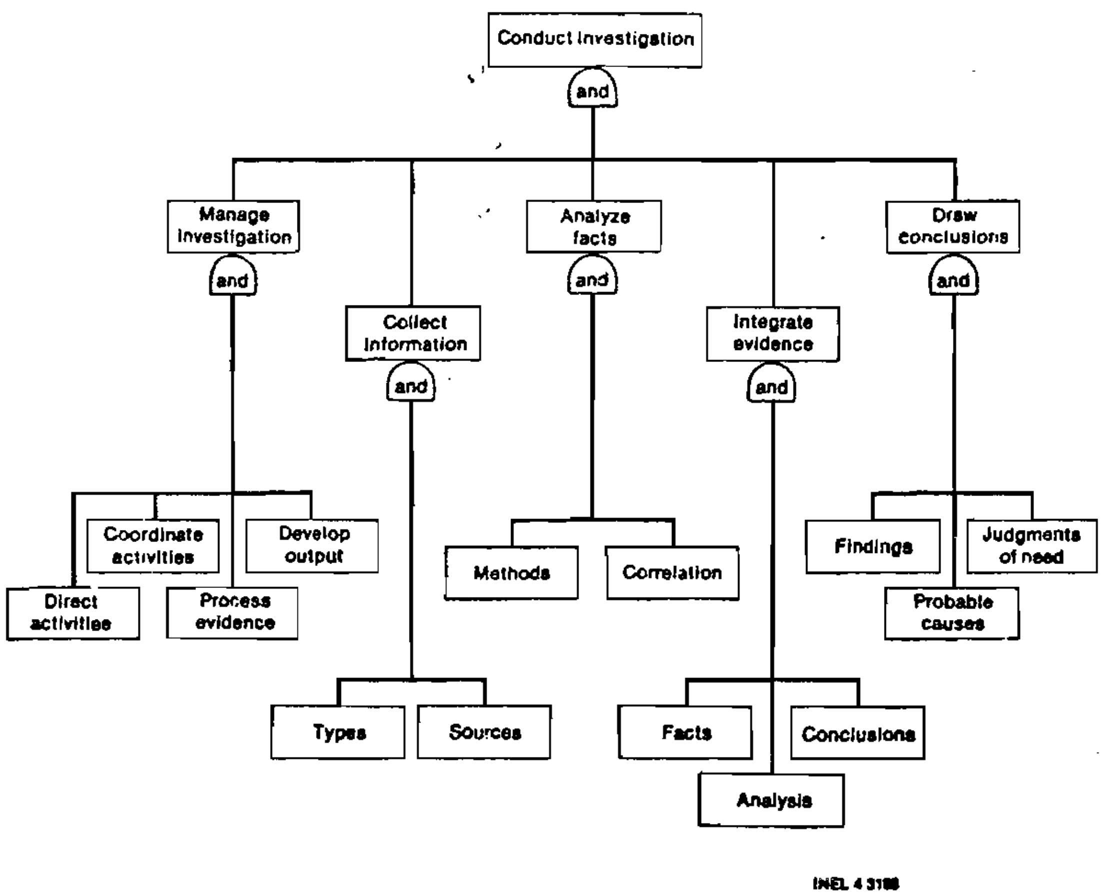

Figure 17. Conduct Investigation.

1. Taking critical initial actions

2. Collecting relevant, factual information

3. Analyzing the collected information

4. Integrating the factual findings and analytical results

5. Reaching valid and meaningful conclusions

6. Establishing reasonable recommendations for preventive action

7. Reporting investigation results to the appointing authority for action.

Although generally sequential, these phases are not distinct and discrete. There is much overlapping and even some readjustment of sequence in actual investigations. As shown in Figure 18, for example, as soon as investigators begin to accumulate factual accident information, they should begin to analyze what they have collected. This analysis leads back to the search for more facts to fill any gaps. Then a series of fact-finding and analysis iterative cycles develops and continues through those phases of the investigation. Figure 18 shows similar overlap and combination among investigation phases. Those phases are discussed separately in this chapter.

Starting properly by taking critical initial actions (Phase 1) is very important. Significant evidence can be lost while the board is trying to get organized. The following suggestions should assist in beginning an orderly investigation:

1. Assemble the board for field organization briefing on the occurrence and scope of investigation.

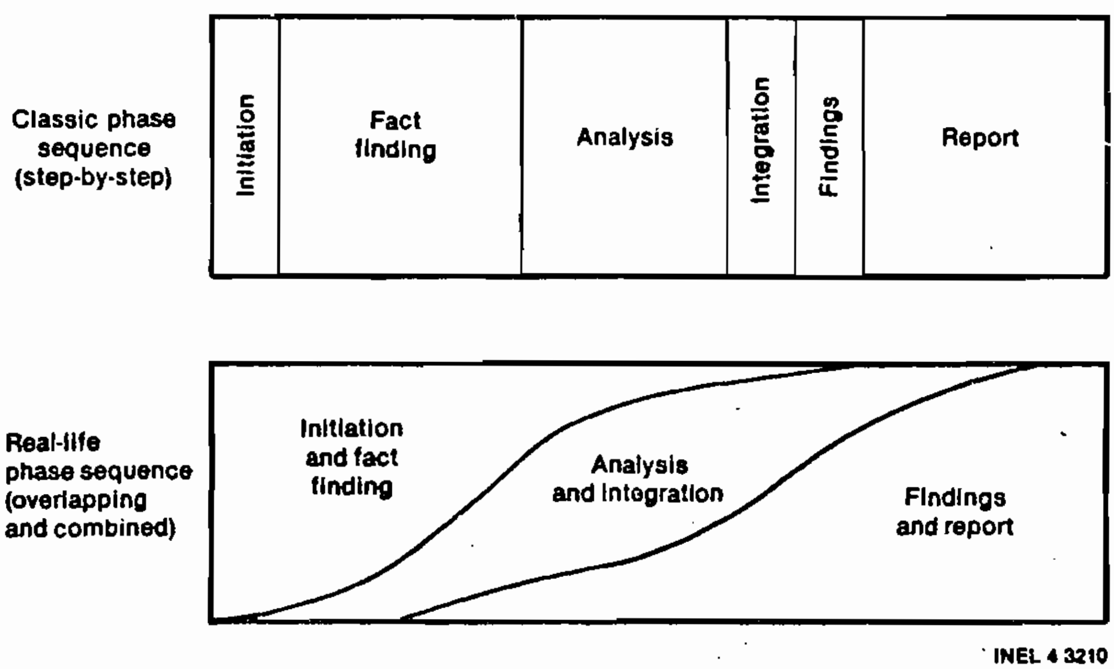

Figure 18. Sequence of Investigation Phases.

2. Assign tasks to board members then or while enroute to the accident scene. (If board members travel by different means or from different locations, do this as soon as possible after arrival.)

3. Get a short briefing from whoever has been controlling the accident scene prior to your arrival and verify what has already been done. Get local organization charts.

4. Establish formal liaison with management.

5. Go to the accident scene with investigation kit.

6. Perform a general survey of the accident scene to get a feel for the accident and make rough sketches of what you see.

7. Prevent unnecessary handling or moving of evidence. Review security provisions to ensure they are adequate.

8. Review preliminary witness statements and find out what each might be able to contribute. Alert witnesses to a possible follow-up interview.

9. Review any photographs already taken and take additional photographs of evidence and the scene.

10. When needed, give the board a briefing on investigation methods.

11. Establish command post (board office) and arrange for other needed resources.

12. Finalize board organization and plan.

13. Assign additional initial tasks or revise previous instructions based on the briefings you have received.

Continuing tasks and activities include:

1. Collecting and preserving evidence

2. Interviewing witnesses

3. Preparing diagrams and sketches

4. Securing as-built drawings; copies of procedures, manuals and instructions. Also getting maintenance records, inspection and monitoring records, alteration or change records, design data, material records, and personal histories

5. Conducting reenactment where necessary or useful

6. Arranging for laboratory tests where necessary or useful.

These, in conjunction with continuation of several of the initial activities, comprise the collecting of relevant factual information (Phase 2).

The collected information is analyzed (Phase 3) simultaneously with fact-finding, both in the minds of board members and in the analytical methods they use. The analytical methods help determine what additional information should be sought through the fact-finding process. This will help determine causes and recommendations.

As the board gathers and analyzes facts, the members arrive at factual findings and analytical results which they integrate (Phase 4) and confirm to arrive at valid and meaningful conclusions (Phase 5). Each conclusion reached should be firmly based on investigation facts.

The establishment of valid and realistic recommendations to prevent recurrence (Phase 6) is only as effective as the evidence, analyses, and conclusions are accurate.

The overlap and integration of investigative phases in answering basic questions about the accident, its results, and the actions to be taken in response are displayed in Figure 19. Notice that the iterative fact-finding analysis cycle leads to answers to the "what should have," "what did," "how," "when," and "where" questions. Analysis and conclusions are concerned with "why," and conclusions (especially judgments of need) and recommendations, with "what now."

Figure 20 shows the primary investigative phases in flow chart format, with the key factual evidence sources, analytical methods, and conclusions identified. Each of these will be discussed later in this chapter.

The final phase (Phase 7) of formal board activities is preparation and submission of the investigation report and recommendations letter. Its primary objective is to clearly communicate the board's findings and recommendations to the appointing authority for action and distribution. Suggestions for writing and structuring the report and recommendation letter, in accordance with DOE requirements, are found in Chapter V and Appendix B (DOE Order 5484.1).

Proper management of the complex investigative activities and interactions is an ongoing function through all phases of the investigation and is critical to investigative efficiency and success. It is discussed in the next section.

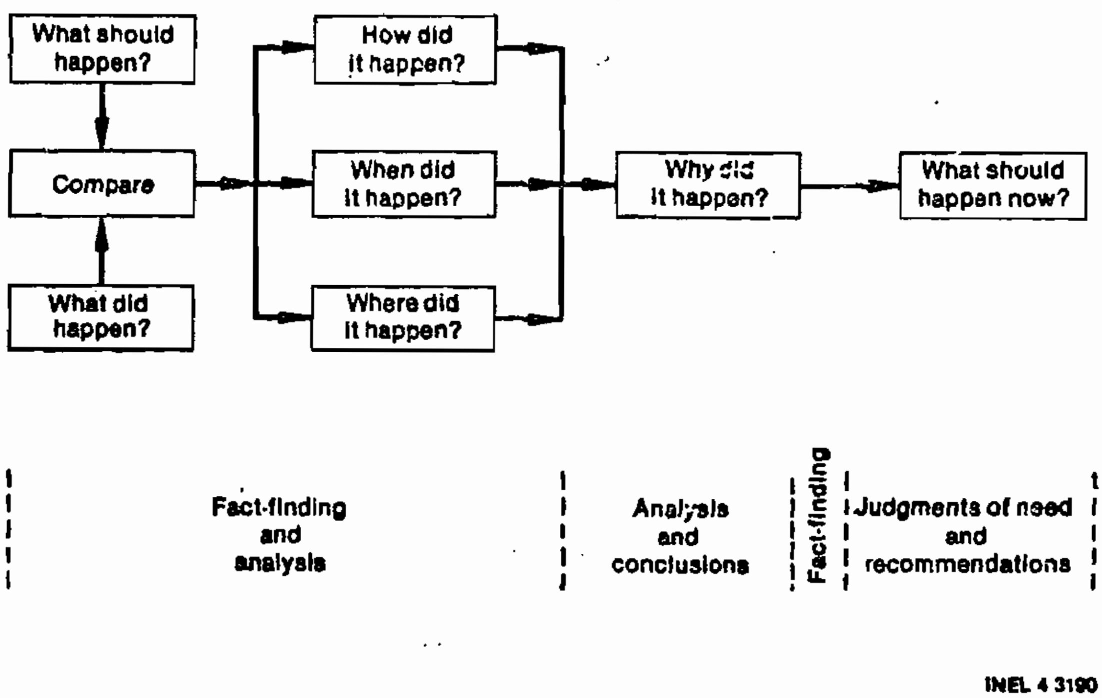

Figure 19. Investigative Questions and Phases Relationships.

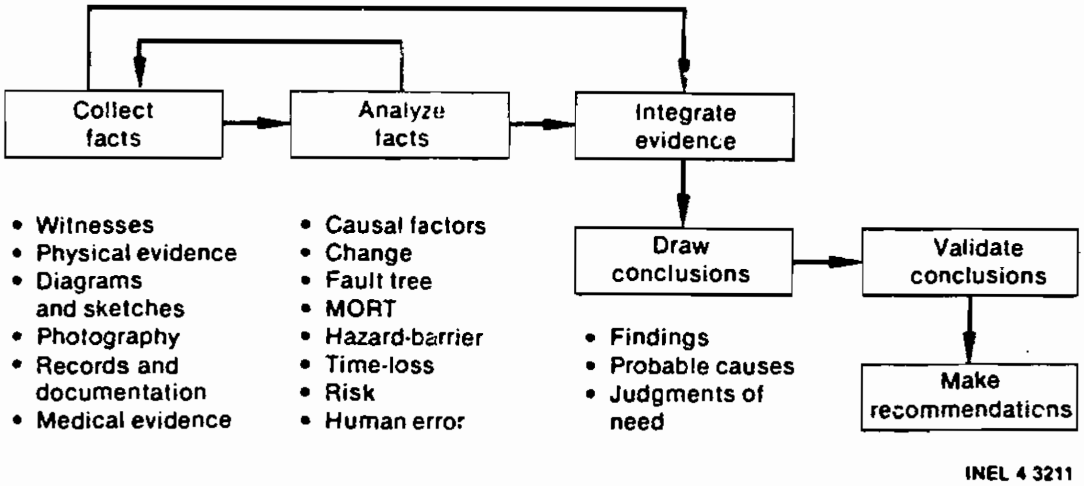

Figure 20. Investigation Activities Flow Chart.

Manage Investigation

The investigation board chairman manages the investigation. He should be specially selected for his ability to do so. It is his responsibility to organize and direct the investigative team and to bring order from the chaos that frequently accompanies a major accident. He is called upon to manage a diversity of interests, coordinate a variety of interactions, and be knowledgable and current in the subject of the investigation. He should have experience and/or training in investigation, but it is of less importance than his managerial and discipline capabilities—particularly, if he has a well qualified Trained Investigator to assist him. He must be both managerially and functionally independent of the principals involved in the accident (and ensure that board members are also), so that undue influence cannot be exerted which may affect the investigation's progress and findings, and the board's objectivity and credibility. He should be strong and decisive, but not domineering; have highly developed administrative and coordinating skills; be tactful and able to appreciate the subtleties and the sensitivity of the accident situation; be an effective liaison between senior management and the investigating board; and be capable of delegating responsibility and monitoring investigative progress in accordance with established schedules, plans, and deadlines.

Management of the investigation by the board chairman, with delegated responsibilities to other members of the board, can be broadly classified into the four areas identified in Figure 21. They are: (a) direct investigative activities; (b) coordinate investigative activities with persons involved; (c) process evidence, including collection, analysis, integration, validation, and release; and (d) develop the investigation output.

Direct Investigative Activities. In directing investigation activities, the board chairman will ensure that the initial investigative actions (discussed in the previous section) are carried out. He will also be familiar with initiating actions that should be taken by the appointing official. This is so that he can take any needed actions that were not done by the appointing authority, or that were partially or incompletely done. He will review those preliminary actions taken by line management and accident response persons and then direct accomplishment of any oversights or omissions. He will organize the work of the investigative team; assign tasks to board members, consultants, advisors, and specialists; administer investigative resources; control the accident scene until he releases it to the operating organization; and handle board/team communications. In all of these activities he should be assisted and advised by the Trained Investigator on the board, who serves as his investigative specialist.

Specific responsibilities of the chairman in directing the investigation include:

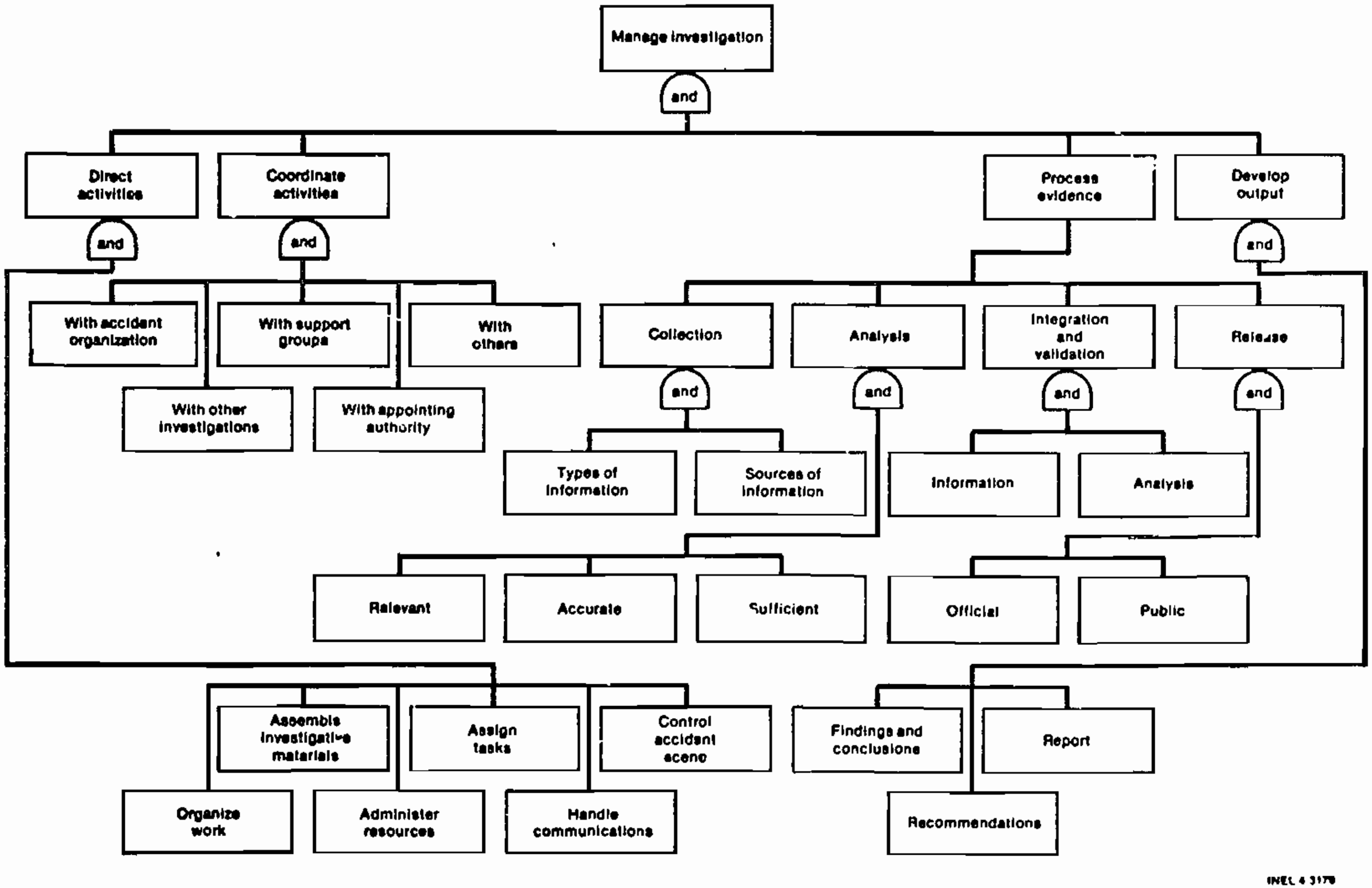

Figure 21. Managing the Investigation.

1. Direct and manage the investigation.

2. Assemble, or have assembled, needed investigative materials, if not already done.

3. Organize work of the investigative team, including establishing schedules, plans, work tasks, daily team coordination meetings, etc.

4. Assign tasks to board and team members in accordance with their knowledge, experience, and capabilities. If the board or team needs to be restructured, or members replaced or added, the chairman should accomplish this in consultation with the appointing official.

5. Use the abilities of the Trained Investigator to outline and expedite the work, train team members, process evidence, reach conclusions and recommendations, and prepare the report.

6. Establish a command post or team office. He should not use his own office or building where the normal office work could interfere with his primary responsibility of accident investigation.

7. Do not permit board or team members to dilute their investigative commitments with any other work assignments. Their sole work activity should be accident investigation, until their investigative roles have been satisfactorily completed.

8. Administer resources provided and get resources needed to properly carry out all necessary investigative tasks.

9. Ensure that the accident scene is safe and that investigative activities do not compound the event or interfere with emergency operations.

10. Ensure that the accident scene is secured and protected until all evidence has been recorded and collected.

11. Release the scene to operational management for repair, rehabilitation, and operation when it becomes reasonable to do so.

12. Handle requests for information, witnesses, technical specialists, laboratory tests, and administrative support with a liaison member of management.

13. Handle all communications with the DOE field organization and public officials. Remember that in Type A or B accident investigations the field office is normally responsible for public news releases.

14. Keep the appointing official informed of all significant findings, developments, and investigative progress. If established deadlines cannot be met, work out an appropriate extension of time with him.

15. Ensure that the investigation functions in such a way that it does not usurp, interfere with, or relieve line management of operational responsibility.

16. Call and preside over all board and team meetings.

17. Remember and ensure that each board and team member knows that work on the investigation team takes priority over all other work and may involve long hours that can interfere with personal life for the duration of their involvement.

Coordinate Investigative Activities. Coordination of investigation-related activities can be a complex and time-consuming task in a major accident investigation. Even on lesser events, the diversity of interests and the complexity of organizational structure and interactions can make it difficult and demanding. Coordination must be done with the accident organization, support groups, field office, and appointing official, and may be necessary with other investigators and such other persons as public officials, news media, employees of non-DOE organizations, and families of injured personnel.

Coordination with the accident organization and the cognizant field office involves such things as arrangements for office space, administrative support, access to files and work areas, impounding of records, obtaining of technical specialists, photography, mapping, medical, availability of witnesses, etc. It is usually accomplished through designated liaison persons, who process board requests and provide the needed services. Frequently, specialists at or from analytical laboratories will get involved in collection, protection, preservation, shipping, analysis, or evaluation of physical evidence and reporting of analytical findings. Their participation needs to be coordinated with other investigative activities.

When investigations result from dramatic or sensational accidents which attract much media attention or public interest or have significant public or political impact, it is not unusual for more than one investigative board to be appointed by the different organizations who have vested interest in the investigation outcome. Sometimes additional boards are appointed to protect involved organizations from biased or slanted investigations, or when it is felt that appointed boards cannot produce credible and accurate findings. Other times, it is done to look at different aspects or different levels of interest than the appointed board is chartered to do. Sometimes, the appointing authority will appoint a second committee to follow up on areas of concern uncovered by an investigative board, but beyond the scope of that board. Also, it is not unusual for a contractor board to begin an accident investigation which is later determined to warrant a Type A or B investigation by a DOE-appointed board. Almost always, a preliminary investigation is done by management or safety personnel before the arrival of the appointed investigation board. Cooperation and coordination between investigators in sharing of evidence and findings is essential to conduct efficient and effective investigations and to give greatest assurance of consistent, objective factual findings, conclusions, and recommendations. It can also reduce or eliminate the time, trauma, and operational impact of repeated reviews of the same material and interviews of the same witnesses, whose testimonies are fragile at best.

Finally, the board chairman or his designee shall coordinate with public affairs offices on all news releases and statements to the press, and have approval authority to ensure they are factual, accurate, and nonspeculative as to cause or fault. Basic releases should indicate that a complete investigation is being conducted by a highly qualified board and that information will be released when the investigation is completed. Premature conclusions to satisfy news reporters tend to be counterproductive and compromise investigative purposes.

Process Evidence. This is the core of the investigation. Everything else the chairman does is peripheral to its accomplishment and is designed to facilitate the collection, analysis, integration, and validation of accident evidence. This enables valid and meaningful conclusions to be reached and reasonable and realistic recommendations to be made. With the assistance of the Trained Investigator, proper judgments of the types and sources of information pertinent to the accident can be determined. The investigative team can then be organized and directed to collect them. Specific assignments need to be made, making best use of the talents on the team. Team members must have appropriate training and expertise for proper recognition, collection, analysis, and interpretation of factual evidence. The work of individuals and groups of board members, technical specialists, and consultants must be properly supervised and coordinated. Daily progress reports (usually verbal) and daily coordination meetings are essential to stay on track. They help avoid needless duplication while alerting team members to pertinent findings. Problems and means to overcome the problems can be discussed and new areas identified to be examined. Daily reports also ensure all potential causal factors are being studied, update ongoing analysis, verify schedules and progress, and evaluate, clarify, modify, and reallocate task assignments. Decisions have to be made on evidence retention, release, additional examination or disposal, and official or public releases of emerging facts and findings. Evidence, analytical results, and investigative conclusions must be pulled together to prepare to write the investigation report.

Develop Output. The proof of the quality of an investigation lies in well founded conclusions and recommendations clearly expressed in a well written report which traces them to their strong factual base. The hard work of the investigators then pales in significance, and the report they produce becomes the standard by which their performance is judged. Development of the board investigation report, therefore, requires careful and conscientious management. It should be put together in timely fashion. The information from various team members needs to be put into proper format and integrated into a consistent style. Team members should not be released until their information has been submitted and accepted. Board members should participate in a comprehensive and critical review to ensure completeness, accuracy, and continuity of the report. It should be acceptable to all board members, or be supplemented by an additional report by those who disagree on findings.

It is often wise to give an oral report on factual findings to contractor management before leaving the site. If additional factual evidence is offered by management in this outbriefing, it should be received, evaluated, and fed into the report facts, analysis, and conclusions sections, if warranted.

Utilizing Specialists and Consultants. Consultants and specialists are those persons who have specialized knowledge or skills that may be useful to the investigation board. They are appointed in the same manner as board members, but usually serve for a limited time, or on a part-time basis, rather than full-time for the duration of the investigation.

The Role of Lawyers in Investigations. The appointment of a legal advisor to an investigation board is not a DOE requirement. However, such appointment should be carefully considered in view of the nature of the board's role.

Whether a lawyer is a member of the board or an advisor to it, his primary mission is to assist in the definition, ascertainment, and analysis of the facts, the interview of witnesses, and the organization and preparation of the board report.

The Role of Physicians in Investigations. The investigation board should obtain a physician's assistance when medical and human factors may have played a causal role in the accident. Investigators should also work with medical officers to develop advance plans for investigation appropriate for local conditions.

Medical and human factors should be evaluated by a medical investigator as part of any accident investigation, for a number of reasons:

1. To ensure the completeness of the investigation

   No accident/incident investigation is complete, despite detailed study of technologic, engineering, and management systems, unless human and medical factors are also evaluated. Human failure continues to rank high in accident causal factors. Many times it is not detected or the significance of its role in accident causation and prevention is not fully appreciated due to a superficial medical/human factor evaluation.

2. To rule out human failure in accident causation

   Human failure may be a primary cause or a contributing cause of an accident or incident. It may be found in many forms and in many systems. Too frequently the medical and human factor evaluation is limited to looking for obvious operator error or operator incapacitation. Attention should also be given to possible contributing human factor failures in safety management systems, procedures, and practices, and in the area of equipment design. Special attention should be given to the design of control, monitoring, and warning systems in terms of minimizing the possibility of operator error in reading and interpreting instruments and signals, and in control input responses. One must be certain that warning and monitoring signals are designed with high attention stimulation, unambiguous, and fail-safe features. One must also be certain that control systems are not complicated, that critical controls are distinctively designed and functionally located, and that monitoring systems do not cause excessive boredom and fatigue.

The human failure spectrum that should be covered in a thorough investigation is outlined in Table 1 of Appendix D.

3. To establish cause and time of death

This information is always important for an accurate reconstruction of the sequence of the accident events. In some accidents, it has altered the direction of the investigation and the determination of the causal factors.

4. To establish mechanisms of injury

This information is necessary for accurate reconstruction of the sequence of accident events and for the determination of causal factors. It is also essential for the evaluation of the adequacy and effectiveness of safety and health protection procedures and equipment.

5. To identify victims

In addition to the humane and legal considerations, the location and identification of victims' remains are essential for the accurate reconstruction of events and the determination of causal factors. In accidents involving severe destruction of remains, the medical investigator plays a major role in identification. He can determine the need and arrange for special biochemical and forensic pathology studies.

6. To help in reconstruction of the accident scene and events and in the determination of causal factors

From the foregoing, it is evident that establishment of the time and cause of death, location and identification of victims, and the mechanisms of injury will be of substantial help to the investigation team in its efforts to determine the causal factors.

In the evaluation of human factors, the medical investigator should play a major role. A true and complete human factors evaluation must look at all aspects of the man/machine interface, and this requires a team approach. The team should include capability in the area of operations and maintenance, engineering and design, and occupational medicine.

7. To help evaluate adequacy and use of safety and health protection procedures and equipment, and emergency escape procedures and equipment

It is important to establish the relationship between the injured tissue, the structures, protective devices, and emergency escape procedures. The physician can accurately assess the nature of the forces that inflicted the injury. He can also determine whether injuries are premortem or postmortem. Upon examination of the structure, the physician may be able to identify obscure or small amounts of tissue or clothing and to correlate these findings with the injuries.

8. To apply special biomedical techniques, as needed

Here the medical investigator will determine what special biomedical studies, if any, are needed. In order to make proper judgments, he should be well informed on the progress and course of the overall investigative effort to date. Participation in periodic investigation board progress briefings is an excellent method of keeping the medical investigator informed. Examples of special studies that might be needed include blood and tissue toxicological studies for specific toxins, alcohol and drug determinations, and the use of a consultant forensic pathologist to perform or assist the local coroner in performing an autopsy where the cause of death is obscure. Detailed instructions regarding toxicological studies and autopsies may be found in Appendix D.

9. To help evaluate adequacy and use of emergency plans, procedures, and equipment

10. To establish physical/mental fitness for subjects' assigned jobs at time of event

11. To help evaluate adequacy of plans, procedures, equipment, training, and response of rescue, first aid, emergency medical care, and follow-up medical care elements

12. To evaluate adequacy of workers' medical/physical standards and the screening, selection, and preplacement process

13. To help determine if the accident was survivable

14. To help determine if application of other plans, procedures, or equipment could have rendered the accident survivable

15. To help evaluate impact on other employees, plant and site environments, the general environment, and the general public at large.

Physicians have major roles in DOE programs for occupational medicine, radiation protection, industrial hygiene, and emergency preparedness. However, the extensive network of DOE contractor physicians has been underutilized in accident investigations, particularly in comparison with the roles of physicians in aviation accidents and National Highway Traffic Safety Administration studies of traffic accidents.

The following guidelines are intended to assist investigators and physicians in planning for participation in accident investigations.

1. Physicians can assist in investigations in at least three roles:

    a. As board members, when medical and human factors appear to be primary causal factors

    b. As consultants, when medical and human factors are important, but technological, engineering, or management systems are primary. (This role would avoid requiring physicians to spend time on nonmedical aspects.)

    c. As advisors, when medical and human factors do not seem important. It is desirable in all cases for the investigator to review findings with the medical advisor to detect medical or human factors questions. (This role should probably be established in the standard practices of the field organizations and contractors.)

The board chairman or special investigator should consult with the medical officer and make case-by-case decisions as to the physician role most suitable to the particular accident investigation.

2. Primary emphasis is on assessment of medical and human factors, including:

    a. Sources of error

    b. Effects of toxic or other substances

    c. Effects of alcohol or drugs (including effects of medicines, prescribed or proprietary)

    d. Effects of disease processes

    e. Effects of physical or mental stresses (including changes in family or social situations)

f. Evaluation of participants in the accident (supervisor, key operators, & witnesses)

i. Physical, mental, and emotional status prior to and at time of accident

ii. Physical, mental, and emotional status of witnesses (validity)

iii. Possible suicidal or homicidal factors

g. Evaluation of injuries in relation to injury-producing mechanisms

i. Trace energies from source to injury, e.g., forensic aspects, foreign object in wounds, or nature of wounds may indicate energy transfer mechanisms

ii. Adequacy of delethalization design features of equipment and facilities

iii. Barriers (all types), including adequacy and use of safety equipment.

h. When it is deemed necessary to obtain tissue or body fluid specimens for special biomedical/toxicological studies, the participating physician should use standard release forms[a] and comply with local laws and regulations The most important element in this endeavor is the early establishment of good rapport with the local coroner or medical examiner. Preplanning visits to the local coroner/medical examiner by the local DOE or DOE contractor physician is of great value.

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a. See sample form in Appendix D.

3. Advance planning is of paramount importance to effective investigation. Plans should include arrangements and decisions with regard to:

a. Medical history

i. Availability (in general, only with release form)

ii. Evaluation of medical findings in terms of behavioral implications, including gross failures such as unconsciousness; i.e., any causal relationship to the accident or subsequent emergency response (may be just a negative report)

b. Personal history (collected primarily by others)

i. From personnel records (nonmedical), e.g., absenteeism, transfers, credit problems, divorce, disciplinary actions

ii. From interviews (family and friends)

c. Personal effects

i. Custody-retention until released by investigator

ii. Examination

d. Handling of fatalities

i. Preplan procedures

ii. DOE/contractor physician examine when possible

iii. Autopsy whenever possible

iv. Evaluation of local practices and procedures of coroner/medical examiner.

4. Evaluation of preventive programs is a major purpose of investigations. The physician can give expert evaluation of emergency medical services. The Federal standard for emergency medical services, published by the National Highway Traffic Safety Administration, is applicable to Federal reservations and sites. Thus the physician also has a role in advance planning for compliance and in development of services, i.e., training paramedical personnel. The standards of the American College of Surgeons for hospital emergency departments are also valuable in both preaccident and postaccident evaluation.

   The physician can also evaluate the effectiveness of measures aimed at early detection of medical conditions, mental changes, or emotional stresses. Early detection can trigger preventive measures by supervisors and others. Again the physician can provide instruction to nurses and supervisors, including effective communications between these key groups.

5. Medical records related to the accident investigation should be treated as privileged information. This includes personal medical records, pictures, autopsy reports, and toxicological reports.

   In general, it is found advisable to exclude complete medical reports, pictures, autopsy reports, etc., from the official accident report and instead to include a brief overall summary report prepared by the participating physician. Where an illustration is essential to understanding the report, a drawing may be better than a medical picture.

   Only those portions of the medical records deemed necessary to the development of a complete and accurate accident investigation should be incorporated into the official accident report. The remainder should be returned to medical files.

   If it is determined that medical records of survivors are needed, they should be obtained by the participating DOE physician using a standard medical information release form (see sample form in Appendix L).

6. As provided in the general instructions, amelioration, such as rescue and emergency medical service, takes any necessary and common-sense precedence over the initiation of investigation.

Other specialists may be needed (depending on the nature of the event). These include:

1. Human factors

2. Reliability and quality assurance

3. Radiation

4. Design, test, etc.

5. Relevant engineering specialists.

Maintain Safety During the Investigation. The board chairman is the manager of the investigation and as such takes on many responsibilities, including the responsibility for the safety of the members of the board.

He should keep in mind that most of the investigators will normally work at office jobs. When they start their work as members of the board, they may suddenly be exposed to adverse weather conditions, physical exertion, extreme altitude, and long hours of work. For a short period of time, the investigators can probably cope with these problems, but if it appears that the investigation will run much longer than about 1 week, the chairman should establish a regular work schedule. Pacing the work of the investigators can increase their efficiency and will probably result in the completion of the investigation in a shorter time.

1. In many cases the scene of an accident is more dangerous than it was prior to the accident. For example:

   a. Electrical equipment may be damaged and the investigator must be assured that it cannot be energized while he is examining it.

   b. Following an accident involving fissile material the investigator will need to take steps to ensure that he does not initiate a criticality accident.

   c. A building may be damaged following a fire or explosion to the extent that there may be questions regarding its structural stability.

   d. Radiation sources or toxic material may be released from their confinement barriers.

   For cases such as these, the board will need to get technical and logistic support from the contractor. The contractor should provide protective equipment and should brief the board on hazards, communications, and emergency equipment. Additionally, it is appropriate that a board member prepare a written procedure for entry and work in the accident area. The procedure should be reviewed by the technical advisor and approved by the board chairman before work commences. The board chairman should know where each board member, consultant, or staff member is.

2. A second problem area relates to actions that the contractor may wish to take after an accident. Clear lines of authority should be quickly established between the board and the contractor. It is necessary for the board to designate the area in which it is to have jurisdiction and to require that any actions the contractor wishes to take in that area, or any actions which might affect that area be approved by the board. If this is not done, there may be the possibility of loss of evidence, further damage to the facility, or injury to the investigator.

   It is human nature for the organization that has been involved in an accident to want to put everything back to the way it was before the accident. The board must be very alert to make sure that such actions are done in the manner that they approve. Extreme care must be taken in approving such actions as:

   a. Restoring electric power and other utilities

   b. Moving radiation sources or fissile materials

   c. Recovering damaged equipment

   d. Moving motor vehicles

   e. Working with high explosives.

3. The board chairman also may have to consider emergency preparedness plans to help ameliorate any second accident that might occur. If the investigation is being conducted at a remote location, he will need to know about the availability of medical service. An investigation in a facility contaminated with radioactive material may require the use of respirators or air breathing equip-

ment. Emergency rescue capability will need to be reviewed. The ability to detect and suppress a fire should be considered for such a location and at other investigation sites where fire might present special problems. These problems should be reviewed with the contractor supplying the emergency service, and a clear assignment of responsibilities must be made between the board and the contractor.

4. If the board has been working in contaminated areas, the board chairman should see that proper health measures are taken before the board is dismissed (blood-urine samples, whole body counts, etc.).

Collect Information

Collection of evidence should begin before the investigation team arrives. Line management and emergency response teams will carry out preplanned accident response, including securing and preservation of the accident scene; collection and preservation of transient evidence; identification of witnesses and gathering of preliminary witness statements; and early time recording of accident elements through photography, diagrams and sketches, and audio and/or video recordings. As soon as the board chairman and Trained Investigator are appointed, they should contact their liaison person at the accident organization to verify that the essential initial actions identified above have been taken, insofar as that organization is capable. Upon arriving at the accident site, the investigation team should move quickly, but cautiously, to gather all evidence that could bear on the accident investigation. They should be liberal in their collection of evidence because surplus information and samples may be disposed of, but any vital evidence not collected and recorded may be lost forever. Figure 22 identifies the general types of evidential information that should be collected; and the sources from which, or by which, it is gathered and recorded.

The types of information with which the investigative team should be concerned fall into four basic classes: (a) accident factors and sequences; (b) systemic factors; (c) changes; and (d) specific hardware, software, organization, and activity involved. In evaluating the accident factors and the sequence of events and conditions through which the accident developed and progressed to the loss stage, the investigators have to look beyond the immediate work environment into the upstream processes that created them or permitted them to exist. It is in those processes that the contributing systematic factors originating in personnel, plant and hardware, and procedures and management control systems or their interfaces are found. Di Grazia and Latimer suggest the following questions to obtain information regarding work process and management system accident contributions.

1. Was a safety evaluation performed during the planning phase? Were hazards identified and risks evaluated? Was the safety organization contacted for assistance?

2. Was the hardware (facilities and equipment) used for the job properly designed? Was the design reviewed? Was it properly obtained and installed? What about the maintenance plan?

3. What controls were selected for the work? Was it the best combination of physical barriers and behavioral controls? What about emergency controls—were they available?

4. How were personnel selected and trained for this work? What provisions were made for new personnel and upgrading of old.

5. Was an operational readiness evaluation performed before the work was allowed to start? Was the correct hardware present? Were required controls and barriers in place and working? Did the supervisor check to see if all those involved knew what to do and were physically able to do it?

6. Were there pertinent codes, standards, and regulations applicable to this work? Was a safety procedure required? Were job instructions prepared? Were they followed? If not, why not?

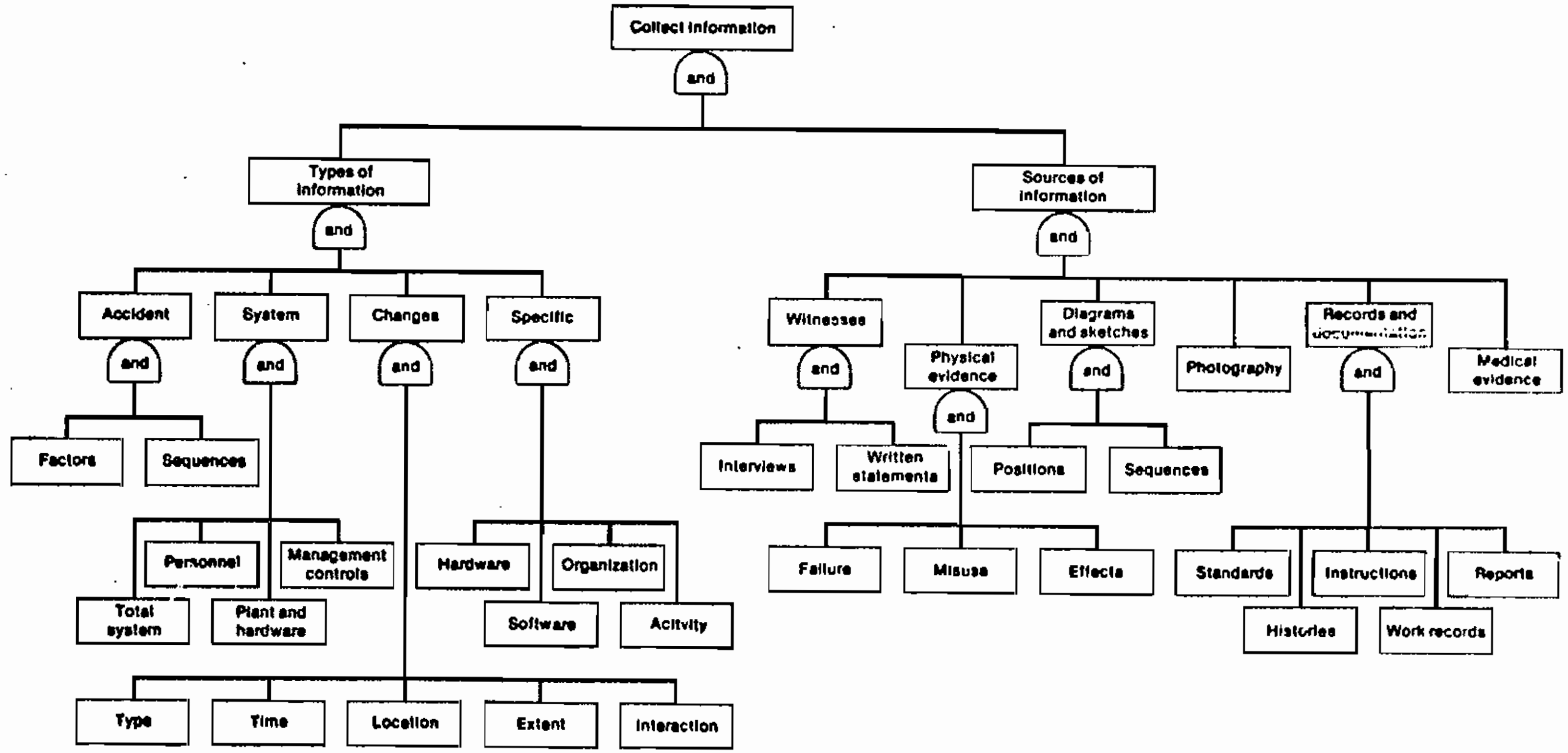

Figure 22. Collection of Information.

7. Did the supervisor observe the work in progress? What changes had occurred? Had the changes been noticed by the supervisor and what had he done about them?

8. What incidents had occurred before this one and what had management done about them?

9. How was the emergency action handled? Was the emergency plan followed? Could some action have been taken at the onset of the incident which would have reduced the impact of the accident?

10. Did emergency response personnel respond to the accident? Did they follow their plan? Did they perform as anticipated?

Change is invariably involved as a contributing cause in serious accidents and is usually present in minor ones. It can originate in personal performance, hardware malfunction, variant environmental conditions, modified procedures, etc. The investigating board should identify the type of changes, the time or times they occurred, their geographical or process location, their magnitude and extent, and their interaction with other changes and existing conditions to produce or contribute to accident causation and loss.

The investigators also need to collect and evaluate information concerning the specifics of equipment, materials, tools, procedures, instructions, work records, personnel, work activities, facilities, and organizational structures and functions related to the accident they are investigating. They should find out what is different about these hardware, software, personnel, activity and organizational elements, and their interfaces and interactions that could have led to the accident.

The accident information sources can also be grouped into three or four general classes: (a) people or witness evidence (b) physical evidence, and (c) paper evidence; or, as Kuhlman identifies them, people, parts, positions and paper—the four P's of evidence. As shown in Figure 22, people evidence consists of witness interviews and written statements. Physical evidence consists of equipment, tools, materials, other hardware, plant facilities, scattered debris, which are collected and evaluated to determine how, when, and why failure occurred, whether misuse or abuse was involved, and whether the failures contributed to the accident or resulted from it. Position evidence, often a subcategory of physical evidence, consists of pre- and postaccident positions of accident-related elements, as well as the time-related sequences through which the accident developed. It is depicted through sketches, diagrams, and photography and sometimes videotape. Physical and position evidence is collected at the accident site by making observations, collecting samples, making measurements and taking pictures or making sketches. Paper evidence is made up of records and documentation, such as standards, policies, procedures, instructions, personnel and hardware histories, and work records and reports including accident reports. It is collected through examination of these management, engineering, and safety documents, correspondence, reports, and records.

Kuhlman points out that the sources of factual evidence and their recognition, collection, and evaluation are the lifeblood of an investigation. They are the foundation blocks upon which valid conclusions and recommendations are built. It is, therefore, essential that factual evidence be collected, handled, evaluated, transported, analyzed, and preserved in a cautious and knowledgable manner. If this is not done, fragile evidence can become unusable or more hazardous through loss, distortion, or breakage. Fragility of evidence varies from people evidence, which is most fragile, to paper evidence, which is least, as indicated in Figure 23. Notice in this figure, that positions evidence and parts evidence are shown as subcategories of physical evidence. Observe, too, that the descending order of fragility applies within the physical evidence class, as well as between classes.

Figure 24 shows typical ways that people, physical, and paper evidence are lost, distorted, or broken. To minimize this destruction of evidence, team members should record their observations and findings as information is collected and evaluated. The means of recording are varied, but are basically written, verbal, or pictorial. In all cases, the recorded information should be properly identified by source, date and time, location, basic content and purpose, recording means, and name of the person making the recording.

Collection of information using the sources depicted in Figure 22 will be discussed by source type in the order they are depicted, except for medical evidence which is addressed in Section IV and Appendix D.

1. People evidence — Most fragile
2. Physical evidence
   - Positions
   - Patterns
   - Parts
   - Properties
3. Paper evidence — Least fragile

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Figure 23. Fragility of Evidence.

People Evidence. People evidence is recorded through all of the senses and powers of observation and is stored in the memories of the witnesses. It is fragile in both its recording and its remembering. People's senses can mislead or misinform them, and their powers of observation can be impaired or clouded by their background, knowledge, physical capabilities, experience, mind set, point of reference, and the trauma of the accident. Their memory can fail through forgetfulness, rationalization, external influence, internal conflict, misunderstanding, embellishment, misinterpretation, transference, and stressful interaction with an interviewer. People evidence is collected through written statements and interviews. It can be provided by those involved in or witnessing the accident, and also those who are involved in or familiar with the organization, management system, safety program, work activity, upstream processes, amelioration, and the personalities involved.

Preliminary statements, both written and oral, should be obtained by line management from everyone involved in or witnessing the accident and its amelioration as soon as practical after the accident and certainly before people depart at the end of the work shift. Getting to witnesses promptly helps get the most accurate information. It is also essential that preliminary statements (particularly oral statements) be obtained from individuals separately, not as a group.

	Form of Fragility		
Evidence Source	Loss	Distortion	Breakage
1. People	Forgotten Overlooked Unrecorded	Remembered wrongly Rationalized Misrepresented Misunderstood	Transferred Influenced Personal conflicts
2. Physical	Taken Misplaced Cleaned up Destroyed	Moved Altered Disfigured Supplemented	Dispersed Taken apart
3. Paper	Overlooked Misplaced Taken	Altered Disfigured Misinterpreted	Taken apart Incomplete Scattered

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Figure 24. Evidence Sources and Forms of Fragility.

The witness phase, both preliminary and with the appointed board, is critical to a good investigation. Typically, witness statements gathered through interviews constitute half of the investigative evidence. Physical reality as portrayed by maps, sketches, diagrams, photographs, documentation, and objects is the other half.

Witness interviewing can be time consuming, contradictory, and expensive. It must be properly managed and conducted for greatest effectiveness. Appendix E discusses important considerations in interviewing witnesses, including basic philosophy, locating witnesses for interviews, expediting the start of interviews, conducting interviews successfully, identifying witness types, recognizing factors affecting witness testimony, analyzing witness observations, and using silence effectively as a communicative aid. A few key interviewing considerations will be discussed here.

1. Locate and identify witnesses. This must be done promptly so that key witnesses will not be lost. In major DOE accident investigations, the appointed investigators do not arrive until a few hours to a few days after the accident, so the essential early location and identification of witnesses needs to be fed into accident response planning and procedures, and carried out by line management or safety officials at the scene. The board chairman should verify that this has been done and see that it is initiated if it has not.

2. Collect preliminary statements as soon after the accident as practical. Again, this should be preplanned, entered into response requirements, performed by line management or safety officials, verified by the board chairman as soon as he is appointed, and initiated by him if action has not been taken. It isn't unusual for this to have been done incompletely, and so it requires board followup on arrival at the accident site. Preliminary statements are important, not only as accurate, early time reports of observations, but also as indicators of probable best witnesses for interview.

3. Prepare for interviewing witnesses by (a) getting the overall picture through a management overview briefing and a board survey or orientation of the accident scene; (b) evaluating preliminary statements and board observations and making a witness list and location chart; (c) getting preliminary information about key witnesses; (d) analyzing collected evidence to determine information needed and questions to ask; (e) gathering photographic, schematic, and other visual aids to assist witnesses and enhance board understanding of testimony.

4. Establish witness interview order. It is usually best to start with supervisory personnel, then people involved in the work upper management and safety officials; and, finally, midmanagement. This results in interviewing first the most directly knowledgeable, i.e., key supervisor, technical or work experts who do the jobs, eye witnesses, and accident and amelioration participants. Second, interview upper level line and safety management who define policy and requirements. Lastly, interview those in midmanagement charged with implementing policy and requirements. Within these groupings, initial interviewees provide core information, and follow-on witnesses fill in details and information gaps and confirm observations. Within groupings, interview friendly witnesses before disinterested, unwilling, or hostile ones. Finally, the witness order list must be kept flexible to adjust to unfolding evidence, and to allow additions, deletions, and rearrangements, as the investigative needs dictate.

5. Select a suitable location to interview. Primary considerations are witness physical, emotional, and psychological comfort; privacy, freedom from distractions and interruptions, quiet, availability of aids to understanding, appropriate size, and convenience to witness' work station. Invariably there are trade-offs, and selection is usually predicated on the best combination of factors. Location also may vary from one witness to another and range from his work location to the board's office.

6. Make appointments with witnesses through the management liaison person. Let those to be interviewed remain at their work stations, performing their normal work activities until they are called. Two benefits result: (a) witnesses are not kept waiting in a situation where they would be prone to compare observations and influence one another's testimony, and (b) interviewers

have a time between interviews to compare notes and impressions, evaluate information gained, and make last minute preparations or adjustments to the intended lines of inquiry for the next witness.

7. When interviewing begins, one witness at a time should be interviewed by the whole board, or in complex investigations with much to do, by specified investigators. It is wise to have two or more investigators participate in each interview, with all questions being channelled through a single interviewer initially, and others asking followup questions when invited to do so. If the witness wants his lawyer, union representative, or other advisor present, he should be so allowed.

8. Conduct an interview, not an interrogation. The witness has information you need and may only share it if he is approached in a friendly, respectful, cooperative manner. He does not need to tell you anything, and if he does not like your approach or manner, he can resist or refuse to give you any information.

9. Set the stage by explaining the purpose of the interview and the investigation. It is the same for both—to discover how the accident happened and how the system failed and let it happen, and to determine what recommendations should be made to management to prevent its happening again. He should get the message that the investigation is not to place blame or find fault; but it is wise not to specifically mention "blame" or "fault," because they are often emotionally charged words which are remembered out of context. Introduce the board members and explain the need for a joint effort to find the facts and help resolve the problems that led to the accident and injury. Properly setting the stage should set the witness' mind at ease, calm his fears about getting someone in trouble, and establish the board as the "good guys" working together with him to achieve a common, desirable goal.

10. Get the essential identifying information on record, i.e., name, job, work location, where he can be reached, etc.

11. Record all information given, but get the interviewee's permission before doing it. Again, explain the need to record his testimony and the use to be made of it. The order of preference for methods of recording testimony is:

    a. Court recorder

    b. Tape (with backup notes)

    c. Stenographer

    d. Investigator notes

    The recording should be as unobtrusive as possible, and the witness should be permitted to review and correct any transcript of his testimony, if he requests it. If the witness refuses to permit his testimony to be recorded, honor his request, and reconstruct his statement as best you can, immediately following the interview. Records of the interviews, whether written or taped, should be identified by witness' name, date, time, and recorder's name.

12. Have the witness tell what he knows without interruption in his own words and from his point of reference. He should relate the events and his observations as they occur to him. Allow the witness periods of silence to draw out his memory and organize his thoughts. Don't rush him. Make brief notes as he talks, so you can follow up on key points.

13. When he has told his story, use short, simple, open-ended questions to clarify points, gather

additional information, and improve understanding. Be objective. Do not ask leading questions. Avoid multiple choice questions and, questions which can be answered "yes" or "no." Assist in his explanations and your understanding with visual aids (sketches, diagrams, photographs, maps, etc.) as appropriate and available. Appropriate followup questions should be (a) responsive to what the witness has already said, (b) drawn from preplanned lines of inquiry, and (c) center on the what, where, when, who, and how of the facts involved. They should address:

a. Action sequences

b. Training and preparation

c. Stress and emotional status

d. Failure histories and human errors

e. Information gaps

f. Inconsistencies in evidence

g. Confirmation and validation of other evidence

h. Similar acts, conditions, or accidents and their frequency of occurrence

i. Management and staff involvement

j. Possible causal areas.

14. If errors in judgment have contributed to the accident, attempt to uncover the "original logic" that led to the error. The error in judgment almost always made sense to the man prior to the accident. He may forget his "logic" following the accident, or he may not want to admit his errors in reasoning. To conduct a thorough investigation and to prevent similar future errors in judgment, attempt to get at this "original logic" (which should not be confused with post-accident alibis and rationalizations). One can then take appropriate countermeasures to prevent future errors. Key investigatory questions: Why did this action make sense prior to the accident? What led you to believe this was the right way to do the job in this particular instance?

15. Several things are advisable in closing the interview:

a. Seek suggestions for preventing recurrence of this or similar accidents

b. Ask if he has anything else the board should know at this time, and invite him to inform the board if anything else he feels is pertinent occurs to him later

c. Advise him that a followup interview may be necessary if additional information is needed

d. Ask who else the witness feels can provide valuable information to the board

e. Express appreciation for his time, information, and cooperation

16. Finally, begin interviews as soon as possible, and keep them short, simple, informal, friendly, courteous, and businesslike. Listen attentively to the witness. Give him feedback to indicate you are with him and understanding what he is saying, but don't argue or expound your theories. Let him do the talking, for then is the time when you gather the facts you are seeking.

Physical Evidence. Physical evidence consists basically of solids, liquids, and gases related to the accident or accident scene. More specifically, it involves equipment, tools, materials, hardware, plant facilities, environmental factors, pre- and postaccident positions of accident-related elements, scattered debris, and patterns, parts, and properties of physical items associated with the accident. Physical evidence overlaps paper and people evidence, in that work-generated records give indications of potential failures, as well as failure experience; and people give similar information as well as observations of pre- and postaccident locations and conditions of accident-related elements. Physical evidence needs to be systematically collected, protected, preserved, evaluated, and recorded to determine how, when, where and why failures occurred. Whether use, abuse, misuse or nonuse was involved; whether the failures contributed to the accident or resulted from it; and whether or not it is relevant to the accident being investigated also need to be determined. Physical evidence is collected primarily at the accident site by making observations, collecting samples, making measurements and sketches, and taking photographs. It may be found elsewhere in its preaccident, undamaged condition, as well as postaccident, but still usable, condition. Though, generally more durable than people or transient positional evidence, it can be particularly fragile in its postaccident condition. Then it is likely to be lost by being carried off, misplaced, cleaned up, or destroyed; distorted by being moved, altered, disfigured, or supplemented; or broken by being mishandled, torn up, taken apart, or dispersed. Often this is done by operating or maintenance personnel (purposely or inadvertently) or by response people; sometimes (particularly when it is not on a government site), by sightseers or souvenir hunters; and all too often, by careless, unknowledgeable, or overzealous investigators. Another reason physical evidence is lost by investigators is that it is often inconspicuous (except to the trained eye of an expert), and investigators pass it by without recognizing its value. That is a primary purpose for selecting specialists and consultants as members or advisors to the investigation board.

Collection of physical evidence, particularly that which is transient and may evaporate or disappear quickly, should be initiated by managers in concert with knowledgeable specialists before board arrival at the accident site. It should be built into advance planning and preparation for both accident response and accident investigation so that it becomes a methodical, preplanned process, executed by designated and qualified specialists.

Positional physical evidence which is depicted by sketches, maps, diagrams, and photography will be discussed in the next two sections. Here, considerations relevant to the part types of physical evidence will be addressed. Field protocol to gather and preserve evidence of failures will be defined, typical failure signs will be touched upon to assist in their detection, and some key aspects and problems in failure analysis will be outlined. The collection and examination process will be discussed in terms of (a) field protocol; (b) survey or initial familiarization with the accident site; (c) consideration of the use of consultants; (d) preservation of physical evidence, including identification, examination, and removal for test and evaluation; (e) test, evaluation, and analysis of collected physical samples, parts, or hardware; and (f) analysis of work-generated software. The flow chart in Figure 25 depicts the entire process of physical evidence preservation, collection, examination, and disposition, as perceived by Kuhlman. Although discrete steps are shown, in reality they overlap and interact throughout the process.

Field protocol. It is essential that the investigator carefully follow a field protocol whenever failure is suspected as a causal factor. In general:

a. Become familiar with the scene of the event.

b. Begin field notes and sketches. Record all possible observations (relative position of debris, marks, fluids, and especially any anomalies).

c. Request expert assistance at the first sign of need.

d. Begin photography.

e. Begin master sketch.

f. Initiate the process of creating hypotheses and looking for positive and negative evidence, being careful to avoid jumping to conclusions or trying to prove a favored hypothesis to the exclusion of others.

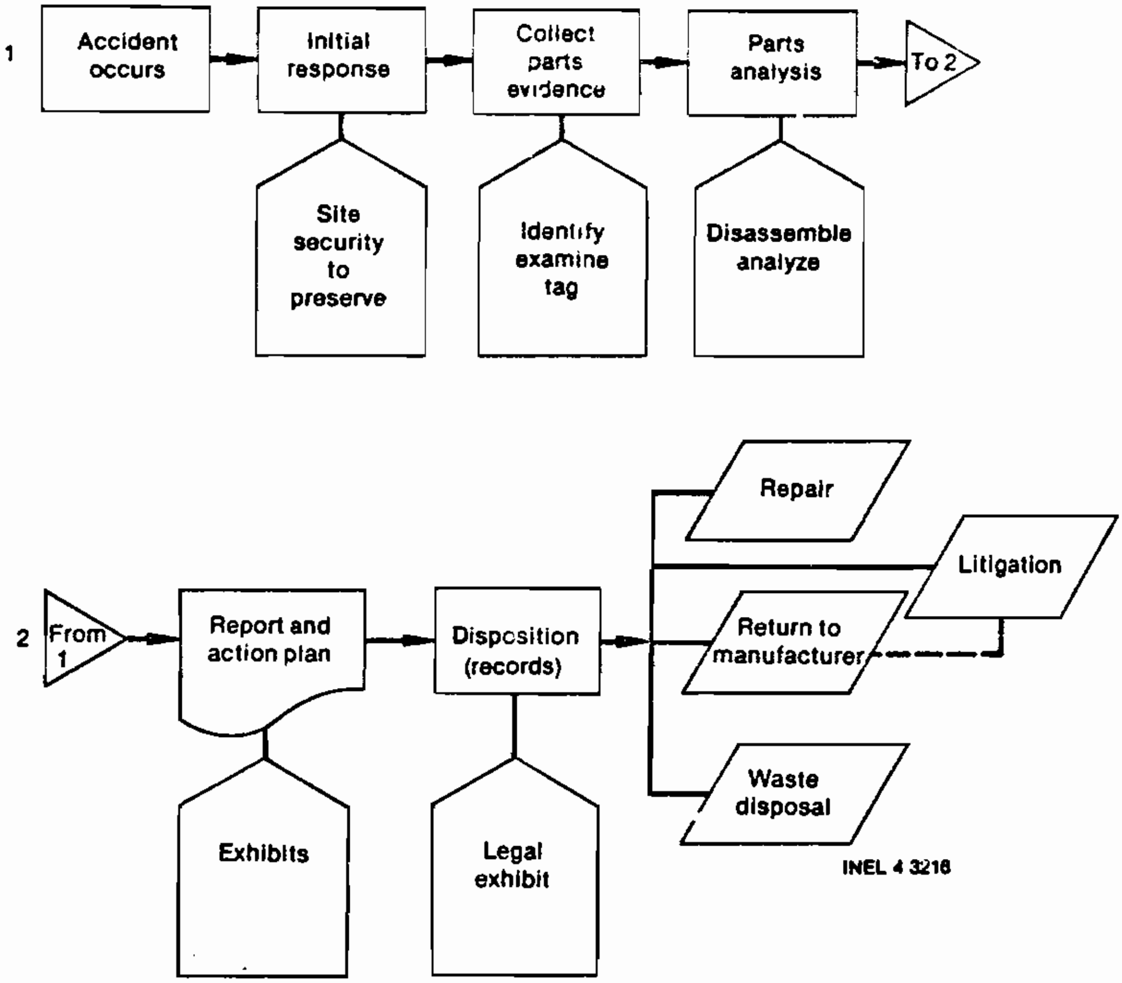

Figure 25. The Physical Evidence Preservation Process.

g. Collect samples of smeared material, ash, paint, fluids, etc., as needed.

h. Initiate closeup photography of details (scratches, gouges, smears, fractures, and relative positions).

i. Tag key parts.

j. Obtain or develop a grid map as needed.

k. Do not move anything until evidence locations are thoroughly recorded.

l. Give responsibility for preparing evidence for transport to laboratory personnel who will do the analysis, if possible; otherwise rely upon experts assigned as board members or consultants.

Initial Familiarization. Investigation board members, with their advisors and consultants, should survey the accident scene to get the general picture and begin preservation of the physical evidence. Kuhlman suggests that a good guiding principle is to conduct a comprehensive examination of all the physical evidence at the site of the accident as a matter of routine. This principle will ensure that all available information is extracted from the equipment, materials, and physical environment before any of these items are moved or destroyed. Frequently, some of these items that appeared insignificant at the outset acquire great importance as the investigation progresses. At other times, conditions of physical items reveal substandard practices which have strong implications in loss control. Feedback information is the only return for the cost of an accident. Even where the causes are almost certain from the outset of the investigation, examination of the effects of the accident can provide valuable feedback for management control.

Additional information regarding arrangements, positions, functions, conditions, etc. of accident site physical items, before and after the accident, come from the testimony of facility personnel. Observations should be documented through field notes, photographs, sketches, marked up drawings, and grid sketches or maps, as appropriate.

Familiarization with facility operation is also fundamental and should include identification and evaluation of its functional activities; types of systems, hardware, and materials involved in the operation; known system and hardware failures; suspected and projected failures; and evidence of change or modification. These can reveal how a particular system or piece of hardware contributed to the accident. Ferry suggests the following guidelines for making that determination.

a. Look for indicators of desired operating conditions (switch or valve positions, etc.)

b. Look for records and logs which show chronic conditions or recent problems and corrective actions.

c. Know generally how the system works and look for malfunctions.

d. Look for missing parts or components.

e. Look for installed wrong parts and foreign objects.

f. Check for compliance with service bulletins and directives.

g. Look for changes in color, smell, shape, location, position, general appearance, and obvious damage. Compare with a similar unit when possible.

h. Check if the condition of this hardware or system is revealed through indications in another.

i. Combine observations on all systems or hardware to search for a pattern, trend, or composite picture that will account for most of the observations.

j. Correlate findings with others examining the same, similar, or connecting systems.

k. Try to resolve apparently unrelated or contradictory observations by feeding time intervals and sequences into the picture, and postulate scenarios that could fit.

l. Discuss hypotheses critically weighing positive and negative aspects. Bench test those that hold up, as appropriate, to substantiate validity.

Consideration of Consultants. Failure analysis requires engineers and scientists who are expert in the materials involved and knowledgeable of stresses and failure modes in the specific equipment and systems involved. Because of the great diversity of equipment used in DOE work, and because experimental equipment often approaches technological boundaries, it is not feasible to train investigators in all relevant fields. The expedient goal is development of a detective skill-sensitivity to failure modes likely to show as evidence and preservation of such evidence.

The Trained Investigator's prior education and experience will largely determine his role in failure analysis of a specific accident. He may be qualified to carry out failure analysis in a specific accident, but, in general, he and other members of board will rely on engineering and scientific specialists.

The logical tasks for which expert consultants may be needed are:

1. Initial survey of evidence before anything is touched

2. Sample collection and preparation for analysis

3. Detailed pre-tear-down photography

4. Tear down of equipment and parts

5. Complete coverage throughout the evidence preservation process.

Needed specialists are usually appointed with the board, acquired locally, selected from within DOE or other federal organizations, or from national or regional consultant indices.

Preservation of Physical Evidence. Proper sample collection, preparation for analysis, and documentation are essential to acceptable preservation of evidence for evaluation and analysis. Collection and removal of physical items from their postaccident positions need to be well controlled, methodical processes. Before equipment and other parts or physical items are moved or removed from the accident scene, their original location should be recorded. Removal should be done or supervised by a technical specialist who knows its characteristics. Particular care should be taken to avoid investigator-caused alteration of the evidence and damage to it. Investigators should collect evidence liberally, because often important evidence is not obvious on initial collection. If it isn't collected, it may be lost forever. If unneeded items or samples are collected, they can be disposed of later when their importance has been logically determined. Samples of all potential evidence should, therefore, be gathered and recorded.

Guidance on the identification of potentially valuable physical evidence is given in a seven question checklist provided by Kuhlman.

1. "Could this part have been involved in either the cause or effect sequence of the accident?

2. Does the part have any potential for cause-effect involvement?

3. Is the part identified as a critical part which has a high failure history or potential high loss as a result of failure?

4. Does the part show indications that inspections were not performed properly and as frequently as required?

5. Does the part show indications of inadequate maintenance and care?

6. Does the part indicate energy transfer?

7. Is the part construction compatible with current state of engineering art as is commensurate with its loss potential?"

As evidence is collected for removal from the scene, it should be prepared for analysis. Proper handling and packaging are essential and must be done under the direction of a knowledgable expert. When physical evidence has been handled in an uncontrolled, unprofessional manner, it has invalidated the evidence and has made it difficult, if not impossible, to find true causes of the accident. Tags, shown in Figure 26, should always be used to identify collected samples. Receipts should be obtained that are equally descriptive when samples are transferred to others for examination and analysis.

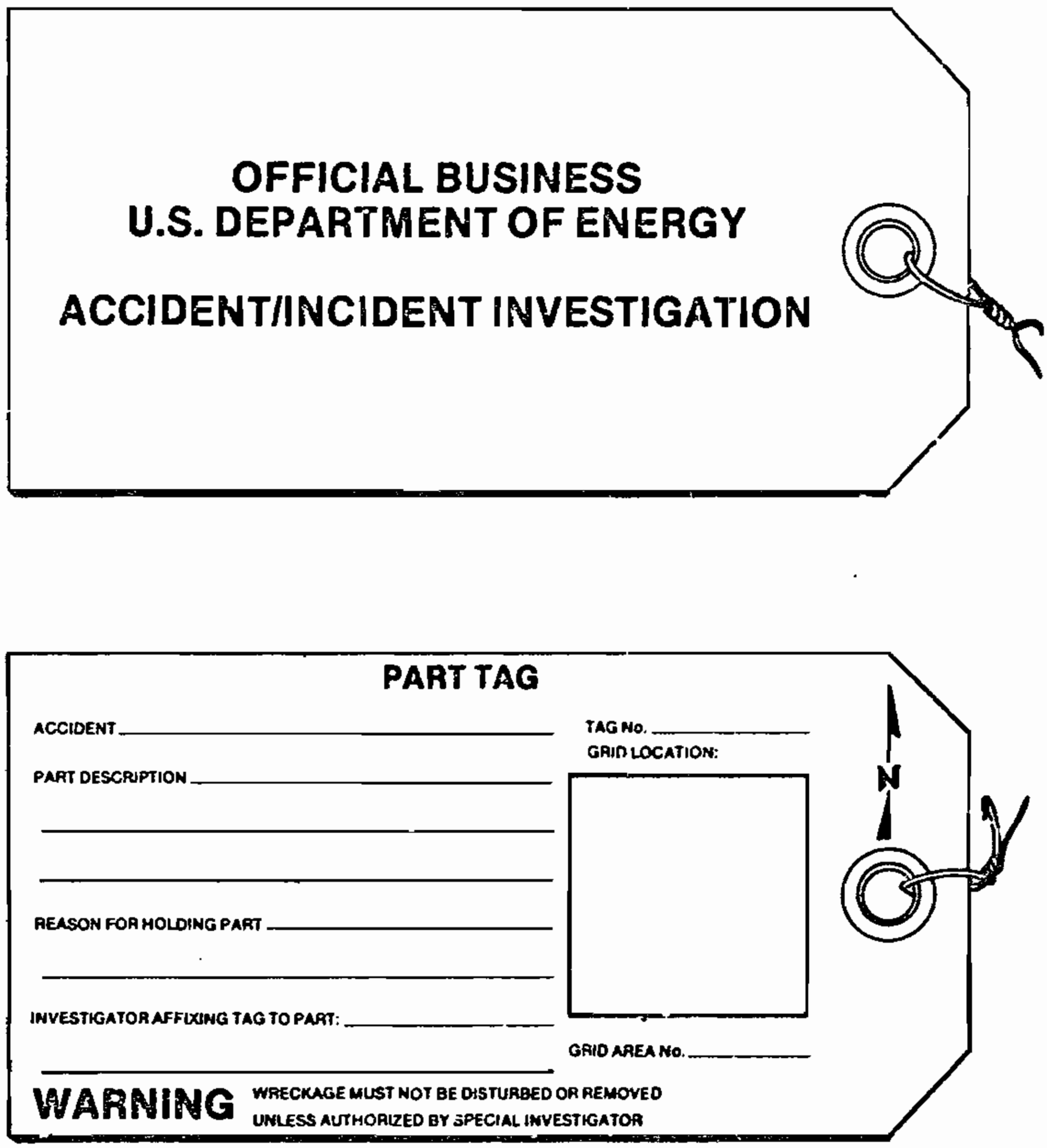

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Figure 26. Physical Evidence Tag.

Proper packaging is essential to protect the samples or parts from damage or loss, prevent spills, and avoid cross-contamination and increased danger. Tags, containers, and handling gear should be included in the investigator kits (Appendix C). Sample sizes vary for different materials, so the kits should be tailored for the particular needs of the organization or facility. Therefore, generic tests of kit contents cannot be totally satisfactory for all investigations. The samples and parts, once they have been packaged and tagged, need to be transported appropriately and safely to the proper analysts or analytical laboratories for examination and evaluation.

The following excerpt from the "Aircraft Fire Investigators Manual," NGPA No. 422M-1972, gives recommended procedures for controlling aircraft parts or chemicals sent to laboratories for analysis. These are generally applicable.

"a. During the course of an accident it may be necessary to have an analysis of a particular aircraft component, hydraulic oil, lubricating oil, or other chemicals. Specific information must accompany the sample for identification purposes and with specific instructions to the laboratory for the type of analysis required. The following minimum information must accompany the samples:

(1) Identify each sample immediately by securely attaching a sample tag to the container.

(2) Identify the contents and, if possible, lot or batch number, when or if appropriate, and manufacturer.

(3) Identify the aircraft type, aircraft serial number, and the manufacturer.

(4) Include serial number for the sample itself. The serial number can be determined by taking the calendar year as the prefix number and assigning consecutive numbers as the samples are submitted. For example, in 1972, the first sample submitted shall be 72-1 and the second 72-2 (followed by aircraft SN).

(5) The date the sample was taken.

(6) Individual who took the sample.

(7) Tests required in detail; i.e.,

(a) water, sediment, etc.;

(b) metallurgical type failure (shear, tension, heat distortion, etc.); and

(c) electrical test.

b. A member of the accident investigation board may be designated to have control of all samples that are shipped out to laboratories. Also, all analytical reports will be forwarded back through the same individual. This type of control is particularly beneficial when many samples and analyses are needed to support an accident investigation."

Analysis of Physical Samples, Parts, and Hardware. DOE maintains widely distributed personnel and facilities for physical evidence analysis. Thus the investigators' task is to recognize signs of failures and to know where and how to get analytic assistance.

The National Transportation Safety Board (NTSB) and the Department of Transportation schools have small metallurgical laboratories and collections of failed parts from various modes. The personnel make many analyses for both agencies, but teaching by demonstration receives major emphasis. NTSB reports also reflect increasing reliance on tests and analyses performed by the National Bureau of Standards.

Regardless of whether examination and analysis of evidence is done locally, there are some important considerations with which both the investigator and the analysts should comply.

1. Examination should be done without altering the postaccident condition of the part or equipment. It should be examined for stains, scratches, gouges, relative positions, relative dimensions, etc.; and these should be recorded by sketches, photographs, or verbal descriptions on a cassette tape. Photography is usually the best means but is often supplemented by the other two.

2. Cleaning with an appropriate means and with great care not to score, scratch, abrade, or otherwise mar or alter the surface should precede further examination.

3. Parts and equipment should be analyzed for defects in form, fit and function, or for faulty design or modification, including missing, misfitting, or wrong parts.

4. Tear down of hardware should be preceded by pre-tear-down photography and should be done by a knowledgeable expert.

   It is usually very important that the evidence not be damaged or destroyed in the tear down process—the part should be carefully torn down to find internal defects or failures and not be destroyed in the process. Photography should be done at each stage of the tear down, and it is a good practice to simultaneously tear down a good part for comparison.

5. Failure modes usually can be identified as affecting either structural integrity or functional integrity. Structural integrity failure modes relate to environmental factors, i.e., chemical, embrittlement, radiation, corrosion, etc. Functional integrity, which also often involves structural failure, suffers from unwanted energy impacts, i.e., stresses, strains, forces, etc.

6. Parts fail in characteristic ways depending upon stresses and materials involved. Aside from environmental stresses, metals usually fail from loads or mechanical stresses. Single overload tension failure is the most common; but compression, bending, shear, torsion, and fatigue failures are also found. They all have characteristic failure signs that are easily recognized by knowledgeable specialists, even when there are combination failures. Similar characteristic failures are seen in other structural materials, such as wood, in which the fibers and grain indicate failure mode; and plastic, which has varying fracture characteristics, depending upon the particular plastic structural type.

7. A conscientious effort should be made in examining and evaluating failed parts to determine the failure sequence. It is important to know whether the particular failure contributed to other failures and accident causes, or was the result of them, i.e., whether it was a cause or an effect.

Software Analysis. Clues to physical evidence also lie in work-generated software and documentation. Operating parameters are found in tapes, logs, charts, etc., from system operations, support and utilities, and individual equipment or system components. Life cycle review shows the impact of various phases on the accident configuration. Correlation of hardware failures with design and operating limits, adequacy, and adherence or nonadherence to them is revealing. Consideration of the hardware history can reveal helpful evidence in quality assurance and reliability records, test records, and operating and maintenance logs. Evidence can be found by examination of the hazard analysis process, information systems, monitoring systems, risk assessment system, and the control and analysis of changes, which directly relate to system, hardware, parts, and materials failures and physical evidence. All of these software sources can add validity and confirmation to findings from the gathered physical evidence, or suggest additional evidence that should be sought among the physical items at the accident site.

Diagrams and Sketches. This section and the following one on photography go hand-in-hand, for they both deal with the recording of position evidence. Rough sketches of the accident scene made during initial orientation or survey establish what should be recorded in greater detail by photography, as well as indicating the positions and directions for taking photographs. Properly conceived and taken photographs, on the other hand, may become detailed grid maps for accurate location of the scatter of accident debris. Photographs are particularly helpful for this purpose when they include the use of a simple perspective grid to establish reference lines for grid map construction. Techniques for high quality, informative maps and sketches are very similar to those for good accident photographs. So suggestions in either section have validity when applied to the other.

Accurate location and depiction of the positions of people and physical evidence at the accident scene are critical to understanding what happened. To be properly done, accident-investigation must have adequate preplanning, and the needed equipment must be included in investigator kits or available onsite. It must be started early before transient evidence disappears and needs to be recorded on position data forms and accident site maps and sketches, such as are shown in Figures 27, 28, and 29. (These come from Baker and Kuhlman, both of which are excellent references on methods, materials, and equipment.) Note in Figure 29 that Kuhlman recommends the use of double letters (AA, CC, etc.) for reference point designations, and single letters for evidence positions. Reference points should be carefully selected from fixed immovable points which can be easily identified and recognized, such as posts, poles, pillars, room or building corners, doorway portals, etc. Through use of fixed reference points, a compass, and a steel measuring tape, evidence positions can be precisely determined and plotted by triangulation and distance-direction or distance-angle techniques. When accident evidence is scattered directionally, rather than concentrically, its position may be fixed by its perpendicular distance from a heading line from the scatter source, in the general direction of scatter. Large pieces of evidence, with significant length or breadth can often be located and oriented more precisely by reference lines to their extremities than by a single central reference line.

When using existing drawings for sketching or mapping positional evidence, it is often wise to simplify the drawing by removing superfluous details.

There are four types of information that can come from positional evidence and should be identified and located. They are: (a) postaccident positions of victims, equipment, parts, material, spills, stains, breakage, motion tracks, scattered debris, etc.; (b) work station layout—including operating positions, controls and safety devices, hazards locations, moving equipment, activity paths, work material, storage areas, etc.; (c) witness locations, which show their span of vision and the point of reference for the observations they report; (d) interference factors—including obstructions, physical restrictions, distractions, and environmental conditions. Postaccident positions of accident scene elements, work site layout, witness locations, and physical obstructions can be measured and mapped using the methods already discussed. Environmental conditions and their effects can be measured with standard environmental sensing instruments (sound level meters, light meters, oxygen sensors, gas samplers, and temperature and pressure instrumentation).

Gradient or contour maps can be constructed from measurements to reveal sources of discomfort, preoccupation, and inattention. Comparisons of pre- and postaccident site conditions can indicate changes, movements, and missing elements which may have had a critical impact on accident causation or loss severity. Mapping of damage clusters and relative positions can give indications of the sequence of damage propagation and help isolate sources of unwanted energy flows.

Sketches, maps, and photographs of physical positions of evidence at the accident site display a major portion of the positional evidence collected and evaluated by investigators. The other portion is displayed in the time-phased position evidence which is charted on causal factors diagrams. They portray the sequence of events and conditions which interacted to produce the accident and its resulting losses. Additional time-phased diagrams can include energy trace and barrier analysis diagrams, which trace energy flows through failed or inadequate barriers to accidental losses. Both causal factors analysis and barrier analysis will be discussed later as analytical methods.

Photography. Photography is a valuable and versatile tool in accident investigation. It is capable of identifying, recording, and preserving physical accident evidence that cannot be effectively collected by any other means. It supplements maps and sketches in documenting positional evidence and often provides the basis of information for final, detailed maps and sketches. It provides accurate evidence from the accident scene that is easily portable and can be examined, evaluated, and analyzed in the board office. Photography can be used in a variety of ways to emphasize areas or items of interest and to display them for better understanding. It must be properly planned,

Completed by: ROBERT SMITH
ENGR. AIDE

Instructions

Date 6/12/83
Time 4:30 PM

Code #	Object	Reference Point	Distance	Direction
1	LOCATION OF INJURED FEET (MARKED IN CHALK)	N.E. CORNER CHAMBER 2560	4'5"	35°
2	DITTO - HEAD	" "	10'7"	60°
3	LARGEST FRAGMENT OF DOOR	" "	8'4"	75°
4	LARGE FRAGMENT	" "	17'6"	155°
5	GOUGE ON WALL	" " FLOOR	14' 56"	95° UP
6	OUTER LIMITS - SMALL DEBRIS	N.E. CORNER	5'6"	30°
7	" "	" "	12'3"	45°
8	" "	" "	15'4"	165°
9				
10				
11				
12				
13				
14				
15				
16				

Attach sketch on grid paper

INEL 4 3215

Figure 27. Position Data Form.

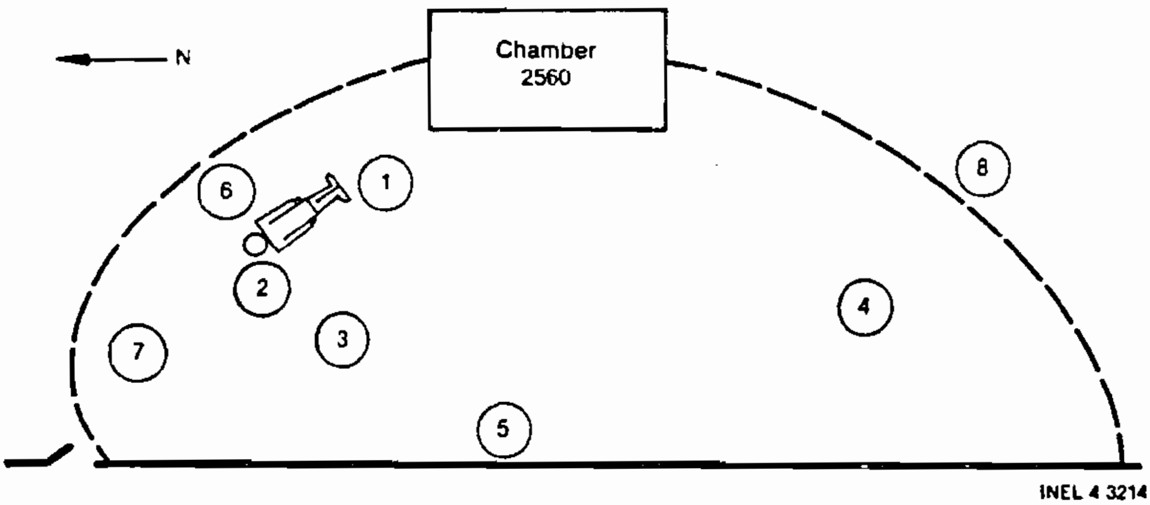

Figure 28. Accident Site Sketch.

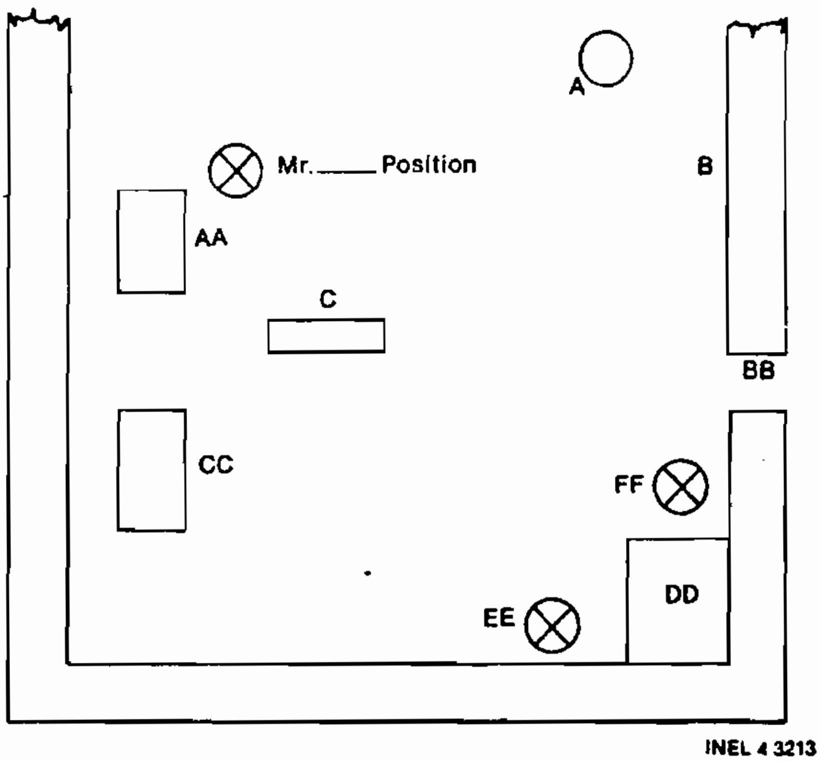

Figure 29. Accident Site Map.

properly done, and properly managed to be most effective. It is best done by a specialist in accident photography but must be supervised and directed by an investigator. Basic considerations in the use of photography in accident investigation are discussed here under four headings: (a) responsibility for photographic coverage, (b) planning photographic coverage, (c) photographic technique, and (d) camera equipment.

Responsibility for Photographic Coverage. Good photographic coverage of the accident is essential even if photographs are not going to be used in the final report. The chairman must decide how to acquire good technical photography which will assist him in the investigation. Five choices are listed in order of preference.

In-plant Photo Lab—The in-plant photographic laboratory should be able to respond quickly to photograph those transient items and portions of the scene that are likely to change. Most labs are equipped well enough to take the initial pictures that may be required.

Other DOE or DOE Contractor Photo Labs—If the facility is small and does not have its own lab, the nearest DOE office or contractor facility may be able to provide photographic support and generally would be a better choice than hiring outside help.

Commercial Photographer—If it becomes necessary to hire a photographer from outside the plant, make certain that the one chosen is qualified to do the kind of job that is required. The better qualified the photographer is, the more useful the photographs will be.

There are commercial, industrial, medical, aerial, legal, portrait, and scientific photographers. Probably the best ones to assist in accident investigation would be industrial, legal, or scientific.

A Member of the Investigation Board—Some member of the investigation board may have to take the photographs. Even an investigator who would be considered a good amateur photographer would probably not produce as good a result as a professional. Planning the photographic coverage is the investigator's responsibility.

Security Personnel—Security units may be able to provide photographers if there is no one else available.

Planning Photographic Coverage. Plan to take many pictures because film is cheap and lost evidence can be costly. Even though most photos will not be used in a report, they are helpful in the investigation. Following are factors affecting photography.

Response Time—It is important to obtain coverage as soon as possible after the accident. The accident scene is a dynamic one that is rapidly changing. The photographic task may be in two stages; one immediately after the event, and some well planned or staged pictures later to clarify details.

Time Frame of the Photographs—While the investigator is concerned with postevent photography, he should not overlook pre-event and possibly photographs taken during the event. Photographic lab files, amateurs, and newspaper photographers are all good sources to be considered.

Types of Photography to Consider—Besides conventional photography, specialized photographic techniques may be desirable to assist in the analysis of the event. Some of the more useful ones are:

1. Aerial photographs. In large accidents a direct aerial photograph can be helpful in determining the direction of major occurrences. The availability of a pre-event photograph would be very helpful here.

2. Photo micrographs. Ultra-closeup pictures of very small portions of debris are sometimes helpful in establishing the cause of failure points.

3. Ultraviolet and infrared. Special lighting and narrow wavelength optical filters can be of use to show certain features not visible to the eye.

4. Motion pictures. These may be helpful for recording reenactments of personnel movements and actions.

5. Video tape. Video systems may be used in higher radiation areas where film is not suitable and where instant results or playbacks are required. Also, they may operate under lower light levels than a camera in some inaccessible areas.

6. Stereo. A major disadvantage of photographs is their lack of depth. Stereo cameras are available which show the proper arrangement of features three dimensionally. A static subject can be photographed in stereo by merely taking two pictures of the subject, with the camera locations 6 to 12 inches apart. The resulting pictures can then be viewed in stereo.

7. X-ray. Parts or portions of rubble can be x-rayed to reveal stress or breaking points.

8. Thermal scanners and thermal video cameras. These operate in wavelength regions beyond what the eye sees and generally can see heat emitted from objects. They may be useful after explosions and fires to pinpoint origins of fires.

Request for Photography—In order to obtain satisfactory photographic results, it is necessary to tell the photographer in detail what is required.

1. Expected results. How many photographs will be required.

2. The type of scenes to be photographed. To determine from what angles the scene should be photographed, written instructions and sketches as shown in Figure 30 may be used.

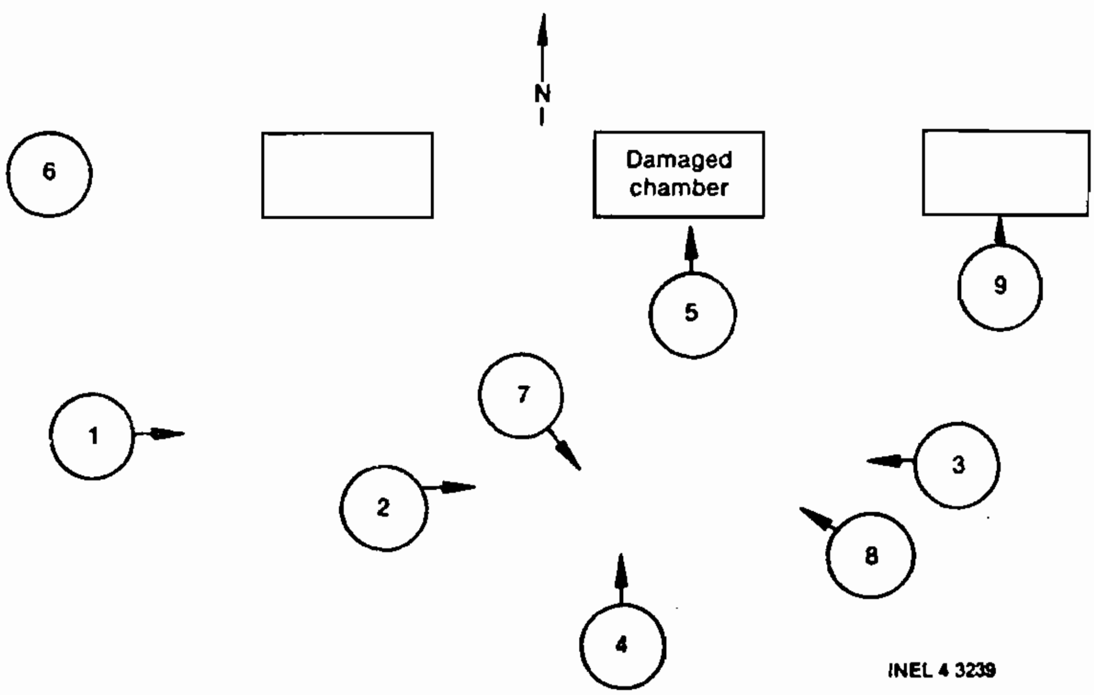

Figure 30. Sketch of Desired Photography Locations and Orientations.

3. How large the accident is. Determine what size is to be covered.

4. Whether pictures will be taken day or night. Determine whether they will be taken out in the open or in buildings.

5. Whether color or black and white should be used. Color has better information content and should normally be used.

6. Whether reference objects such as rulers are required in the pictures.

7. How the photographs will be identified, e.g., numbering system, photographic log sheets.

8. How many prints are required and how soon. What size the prints should be.

Photographic Technique. Certain basic qualities make good pictures that are accurate representations of the accident scene. Photographs can easily misrepresent a scene and lead to false conclusions or findings about an accident. Some misrepresentations occur unknowingly while others may be purposely contrived. By reviewing the attributes of good pictures here, the investigator will be aware of possible misrepresentations.

1. Show enough of the scene to provide good orientation. Several pictures may have to be taken in sequence to provide this orientation. An overall shot, medium, and close-up may be required.

2. Use proper perspective. The use of wide angle and telephoto lenses alters the perspective and causes distortions. Normal focal length lenses should generally be used. Use a perspective grid for later construction of a grid map of evidence.

3. Use proper lighting. The angle and type of lighting greatly affects the appearance of the subject. While no single lighting arrangement is correct for all conditions and subjects, the lighting should be examined for uniformity to see that it does not produce an abnormal appearance.

4. Correct camera settings are essential to good pictures. The three basic settings of shutter speed, aperture, and focus must be correctly applied to obtain a correct representation of the scene. Shutter speed must be fast enough to stop action in the photograph. The aperture, along with allowing enough light to pass through the lens, also controls how much of the near and far portions of the picture will be in focus (depth of field). Action photos will not usually have good depth of field because the aperture must be open to compensate for fast shutter speed. The focus setting used in conjunction with the aperture setting controls the depth of field of the picture.

5. Keep the camera level for easy orientation and reference.

6. Use known objects in the scene as size references wherever possible. In overall scenes, the presence of a person may be sufficient. In close-up photos of rubble or damaged areas, a hand, coin or a ruler or portion of a 6-foot rule may be best.

7. Use color film for maximum information content. While black and white film is easier and cheaper to print, the information in color prints is often essential to understanding and analyzing an accident event. The color record must be properly done, however; otherwise it will be misleading. The use of neutral gray cards in some photos is desirable.

8. Identification and labeling of the photographs is essential. Figure 3[1] shows a type of log sheet. One should be used by a photographer at the time of taking the pictures. After the pictures are printed, captions should be used to point out pertinent details and to eliminate all ambiguity about whether the picture was taken at the time of the accident or staged. Photographs are usually

PHOTOGRAPHER ________________

LOCATION ________________

CAMERA TYPE ________________

LIGHTING TYPE ________________

FILM TYPE ________________

DATE OF ACCIDENT ________________

TIME OF ACCIDENT ________________

FILM ROLL NO. ________________

Picture No.	Scene/Subject	Date of Photo	Time of Photo	Lens f/ℓ	Direction Camera Pointing
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Figure 31. Photographic Log Sheet.

date-stamped on the reverse side, but if that information is pertinent to the analysis, it should be included in the caption.

9. While every accident is unique and will have its own set of important features, here are some general guidelines about what to photograph.

   a. Location of major identifiable pieces

   b. Collision debris—dirt, etc.

   c. Pools of liquids

   d. Gouges, scratches, collision points, and damage

   e. Temporary view obstructions, especially from view of operator or other key person

   f. Mobile equipment

   g. Material storage areas

h. Scaffolds, jigs, racks, and temporary rigs

i. Close-up of failed elements.

10. If there is a fire associated with the event, pictures taken during the event are very useful. Photographs should include:

    a. Flames. They indicate what material is burning and how fire started and progressed through the structure.

    b. Smoke. Also indicates what material is burning by smoke color

    c. Structure

    d. Spectators. Many times if arson is involved, the arsonist will stay around to watch the fire. If a series of fires is started, he may be in all photographs.

11. It should be reemphasized here that even though official photographers may not be on hand to photograph a fire, amateur or press pictures may be available and used.

12. After the fire is out, there are several key areas to photograph that may assist in the analysis.

    a. The most charred or burned area.

    b. Any combustible materials—matchbooks, papers, paint thinner, kerosene, etc.

    c. Fusing methods that may be visible.

    d. Spectators around the accident location.

Camera Equipment. The choice of camera equipment either by a photographer or the investigator, if he is taking his own pictures, will affect the quality and the cost of the photographs. For most investigations, a roll film 35 mm or 120 mm (2-1/4 x 2-1/4 in.) single lens reflex camera is preferred. The major considerations are:

1. Modern color films are very good and capable of rendering minute detail and color balance on small image formats.

2. A large number of pictures can be taken with very little weight to carry around—an important consideration when taking pictures in the remains of an explosion or rubble from a fire.

3. Roll films are lower in cost per picture than large format sheet films.

4. Thirty-five mm and 2-1/4 x 2-1/4 format cameras have short focal length normal lenses that have inherently better depths of field than lenses used on 4 x 5 or 8 x 10 cameras.

5. Lens construction on smaller cameras allows for larger apertures that minimize lighting requirements. Because of their longer focal lengths and smaller apertures, 4 x 5 and 8 x 10 view cameras require much higher lighting levels .

Should the investigator be forced to take his own pictures, an Instamatic camera with Kodacolor II film and automatic flash could be used. Limitations would be in the poorer lens (image) quality and fixed lighting arrangement.

In some instances, such as quick reference pictures taken with a Polaroid, either black and white or color may be used. The Polaroid camera is generally not a good choice because of the effect of heat on the unexposed film.

The colors of the print material are not reproduced faithfully and an incorrect analysis could be made from the interpretation of the color.

Paper Evidence. Paper evidence constitutes the third major source of accident information. It is the least fragile, generally being significantly more durable than people evidence and physical evidence. However, most of it is not located at the accident scene or work area and, consequently, is less visible and can easily be overlooked. Paper evidence should immediately be impounded to prevent intentional or inadvertent misplacement, alteration, or destruction. Those records which are at the work area are often kept for only a day to a week, so they have to be gathered quickly after the accident and preserved for examination. As with other forms and sources of evidence, the value and significance of much of the paper evidence may not be obvious at the early stages of the investigation. Therefore, investigators should gather all papers relating to the accident, and retain them until their relevance has been determined, and needed information extracted from them. Preplanning is essential to identify papers to be collected, preserved, examined, and evaluated for accident evidence.

Paper evidence can generally be grouped into four categories: (a) management control documents, (b) records, (c) reports, and (d) follow-on documentation. Management control documents communicate management expectations of how, when, where, and by whom work activities are to be performed and include definition and preparation of facilities, equipment, materials, instructions, procedures, and people to perform those activities. Records indicate past and present performance and status of the work activities and the people, equipment, and materials involved. Reports identify the content and results of special studies, analyses, audits, appraisals, inspections, inquiries, and investigations related to work activities. Follow-on documentation describes actions taken in response to the other three types of documentation. Collectively, they give important clues to the underlying causes for errors, malfunctions, and failures that led to the accident.

Following is a more specific list of the types of paper evidence that should be sought.

1. Facility description, specifications, and operating and maintenance requirements Environmental studies and impact statements.

2. Mission, budget, and schedule constraints and changes

3. Hazard analysis process documentation, including prior appraisals of:

   a. Information search

   b. Hazard identification

   c. Hazard and loss control

   d. Risk assessment; acceptance decision level

   e. Independent review

   f. Safety analysis reports

   g. System safety analyses.

4. Policies, standard directives, safety and management manuals, procedures, and job safety analysis or task analysis. When available, obtain established criteria for analyses, procedures, and their review.

5. Design, manufacture, purchasing, installation, test, operations, maintenance, repair, and modification records. Construction progress photos, which may show features later covered by construc-

tion, and construction completion reports. Decommissioning and disposal plans, procedures, and records, when pertinent.

6. Machine and equipment manufacturer's manuals

7. Maps, drawings, schematics, and system design descriptions

8. Monitoring and tracking systems

9. Relevant training given manager, supervisor, and employees

10. Supervisor conducted training, job instructions, and safety observations

11. Work and loss records and failure histories

12. Error rates; first aid and medical cases of similar nature

13. Employee selection, training, certification, transfer, and personal history

14. Suggestions and RSO (reported significant observations) studies and their disposition

15. Employee meetings and other means of communicating management policy and expectations

16. Appraisals and followup action (internal and DOE). Include Research and Quality Assurance and engineering appraisals as they are relevant. Review inspections and audits.

17. Publications activities and press releases

18. Personal files and medical files. These should be obtained only for professional evaluation and then returned to safeguarded files.

19. Organizational structure, charts, and position descriptions

20. Accident investigation reports, recommendations and corrective actions, and accident experience records.

Nonrelated Evidence. When a board is conducting an in-depth accident investigation, it is not uncommon for them to find evidence of errors, malfunctions, faulty practices. and worksite or systemic deficiencies that are not directly related to the accident. If they are related to the work area or work group involved in the accident and are within the board's scope of work, they should be evaluated as related factual findings and included in the investigation report and recommendations letter. If they are unrelated to the accident work area or work group, or are beyond the investigative scope, the appointing authority should be consulted. He may extend the scope to cover them, but normally, he will direct the board to stay within its scope. He will either appoint a separate board of inquiry to pursue them or will refer them to cognizant management for review and correction.

It is very important not to reject or summarily dismiss these factors which did not directly contribute to the accident. Under somewhat different circumstances, they could precipitate future accidents of equal or greater magnitude. Few accidents are exact replicas of previous ones, and the seeds for future losses can lie in these work site and systemic deficiencies.

Analyze Facts

Careful and complete analysis of collected information is necessary to arrive at the causes of an accident. The analysis should fully utilize the combined knowledge and expertise of board members and the specialist consultants who advise them. The goal is to arrive at the causes and contributing factors in the accident. The results of properly selected and well done analyses form the bases for reaching conclusions and making recommendations which can be effective in correcting current problems and preventing future accidents and losses.

Analysis is not a single, discrete step in the investigation process. Rather, it is an ongoing process with multiple iterative cycles blending with other investigative steps, as suggested in Figure 18. It ties several investigative stages together (as shown in Figure 32), like a series of bridges between available information and factual data and conclusions and recommendations. Each analytical bridge defines and refines what is known or not known and the implications.

The deductive analytical process begins as soon as initial information is collected, and continues in iterative fashion. As facts are gathered and analyzed, gaps in information are recognized, and more facts are sought and reanalyzed to make better sense out of what has been accumulated. Factual findings of conditions and events are fit together with analytical results to reconstruct the accident occurrence sequence. Deeper analytical probing goes beyond the symptomatic truths to the root causes found in upstream processes, management action or inaction, and system organization and functioning. Analytical methods then assist the investigator in: (a) deciding what facts to seek; (b) sorting out the relevant and important among those found; (c) determining probable cause, contributing factors, and judgments of need; and (d) arranging results in an orderly and lucid manner to report findings and recommendations.

Proper analyses, whether formal or informal and conscious or unconscious, underlie every investigation. In fact, the quality of the investigation will depend upon the quality of the analyses that guide the fact-finding process. If, for example, the investigators arrive at premature, informal conclusions, based upon perceptions rather than facts and upon feelings rather than analysis, their search for facts will be shallow and incomplete, and their report and recommendations will likely be inadequate and erroneous. If on the other hand, well-chosen, effective analytical methods are employed to guide the fact-finding process, true and complete factual findings will result, the investigation will be high quality, and the report and recommendations will address the right things.

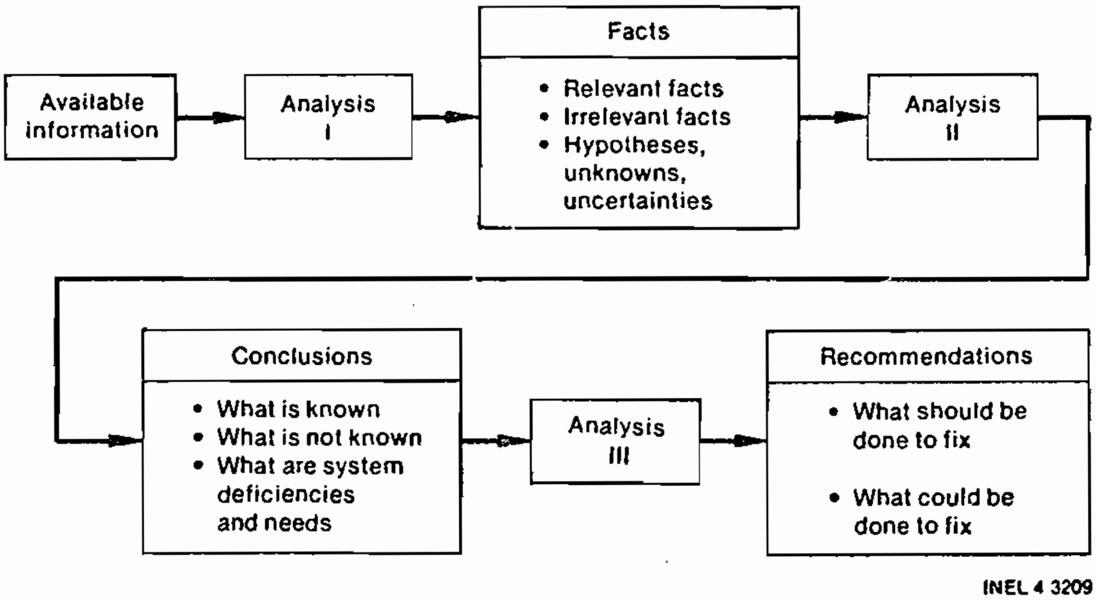

Figure 32. Analytical Stages.

There are cautions, however, in application of analytical methods. They cannot be used mechanically and without thought. No matter how good the method is, it can become ineffective and troublesome, if it is not used rationally and adapted to the investigative needs at hand. Also, no single method will accomplish all the analysis required. Each has its strengths and limitations. Therefore, a blend of methods, which are complementary, coordinated, and cross validated for analytical correlation, is required for effective investigative analysis of facts.

In this section, the analytical methods which have proven valuable and effective in accident investigations, identified in Figure 33, will be discussed. It would be unusual to find all of these approaches fully used in any but the most serious accident. However, properly tailored application of all of them to any accident will increase the depth and quality of investigation; reduce oversights, omissions, and uncertainties; and produce better reports and recommendations.

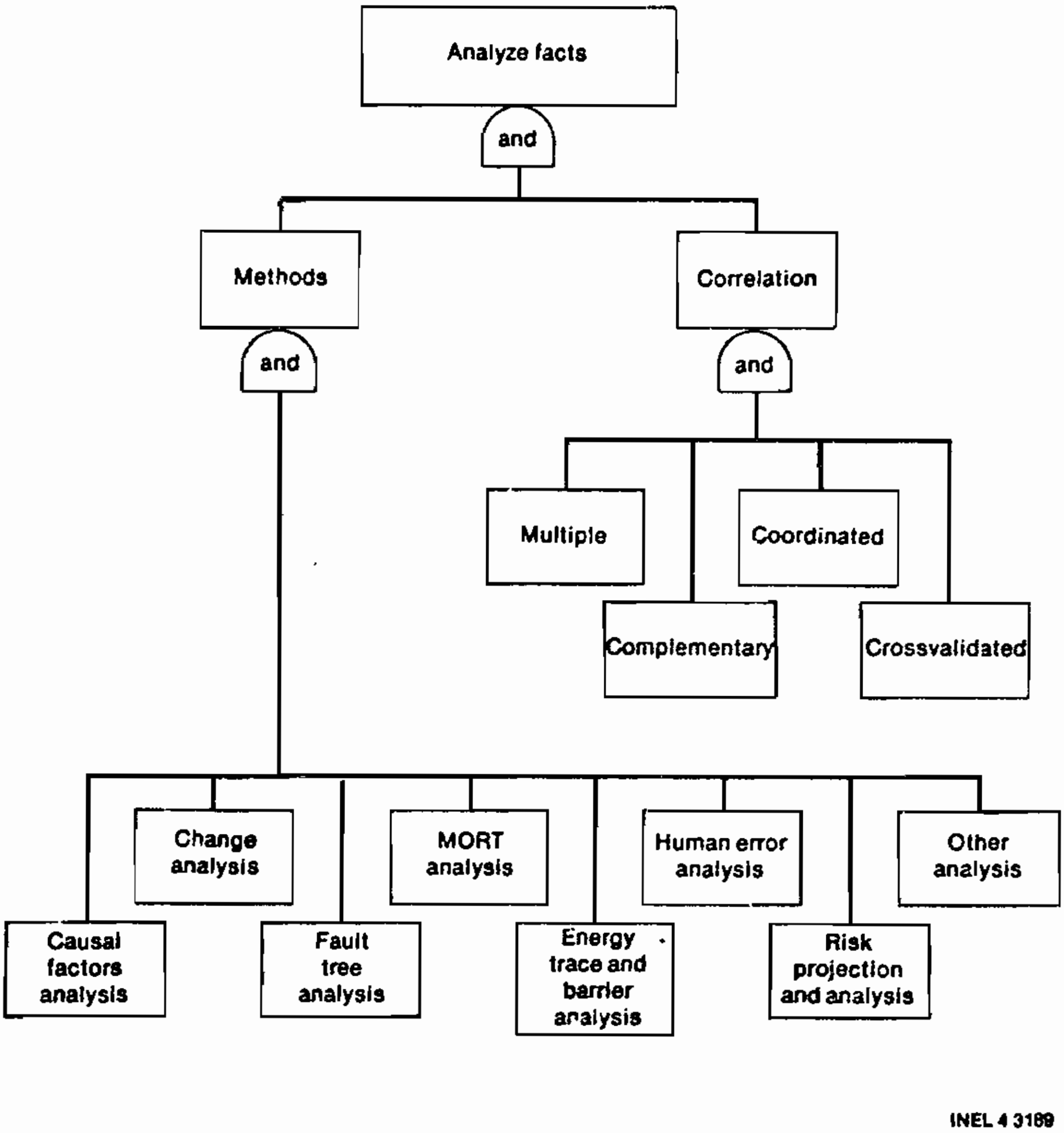

Figure 33. Analytical Methods and Correlation.

Causal Factors Analysis. 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 the events and the conditions that create accident situations, and the managerial control systems that let these events and conditions develop, so that the root causes can be identified. Identification of these root causes necessitates understanding the interaction of events and conditions through a sequence of activities from an initiating event through the final accident. Vital factors in accident causation emerge as sequentially and/or simultaneously occurring events, which interact with existing conditions. These events are traced 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 controls implicated in accident occurrence further reveals a well-defined sequence in accident development.

Ludwig Benner suggests two 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 occurs in the course of well-intentioned work activity but that culminates in unintentional 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 Causal Factors (CF) diagram, which depicts in logical sequence the necessary and sufficient events and conditions 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.

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, direct approach can be used which breaks the entire sequence into a logical flow of events from the development of the accident 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 the 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 causal factors chart should begin as soon as the accident investigator begins to gather pertinent factual evidence. The events and causal factors will usually not be discovered in the sequence in which they occurred, so the initial causal factors chart will be only a skeleton of the final product and will need to be upgraded as additional facts are gathered. Even though the initial causal factors chart will be incomplete and contain many information deficiencies, it should be started 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, causal factors charting is most effective when used with the other MORT tools that provide supportive correlation. Causal factors on the 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 causal factors chart in establishing sequence chains. A meticulous trace of unwanted energy transfers and their interrelationships facilitates:

1. Questioning and testing of accident hypothesis

2. Using barrier analysis to examine possible energy flow interruptions

3. Identifying energy channels which lead directly to injury or damage, or contribute to their occurrence.

An appropriate combination of the major MORT analytic tools, including events and causal factors charting, provides the core for a good investigation.

The following guidelines are suggested for use in constructing events and causal factors charts for accident analyses and inclusion in investigation reports.

1. *Suggested Format:*

   a. Events should be arranged chronologically from left to right.

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

   c. Events should be connected by solid arrows.

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

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

   f. 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 solid connecting arrows.

   g. 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 34).

   h. In reconstructing activities of specific individuals, it is often helpful to break out each person on a separate horizontal line. They would later be integrated appropriately on an executive summary chart.

   i. Events should track in logical progression from the beginning to the end of the initiation-

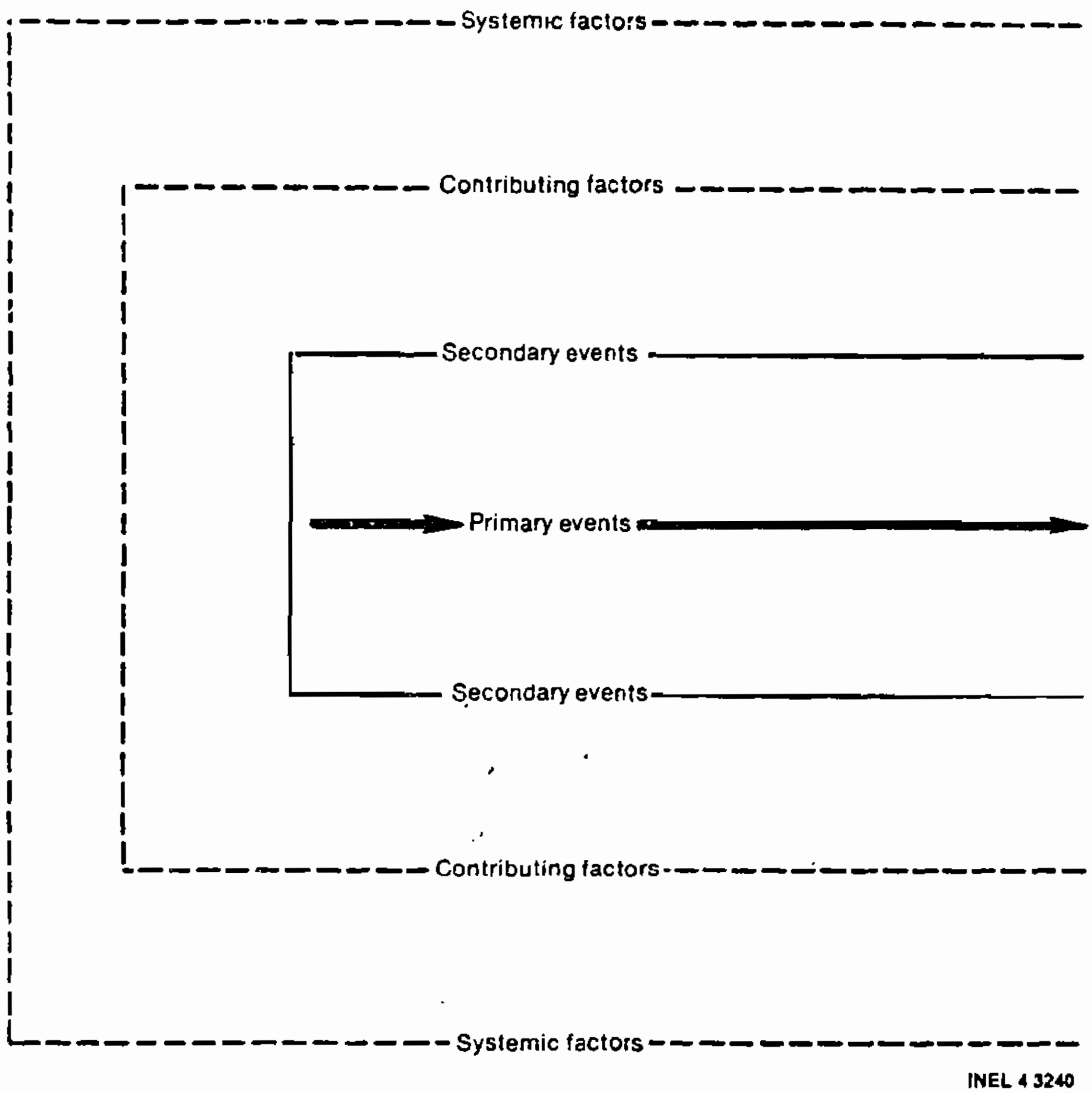

Figure 34. Causal Factors Relationships.

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 causal factors sequences.

2. *Suggested Criteria for Event and Condition Descriptions*:

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

b. 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."

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

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

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

f. Each event block should contain time and date of the event when available.

g. 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.

The criteria for conditions are similar in that they should be precisely described, quantified when possible, posted with time and date when possible, and be derived directly from the condition or conditions immediately preceding them. They differ from events in that they describe states or circumstances rather than happenings or occurrences; are passive rather than active; and describe single, discrete states or circumstances.

Application of the suggested format and event description criteria for constructing a typical causal factors chart of a simple accident are illustrated in the following example.

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.

Figure 35 is the causal factors chart of this accident. 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. Events 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 of 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 is shown in the generalized causal factors charts in Figures 36-38.

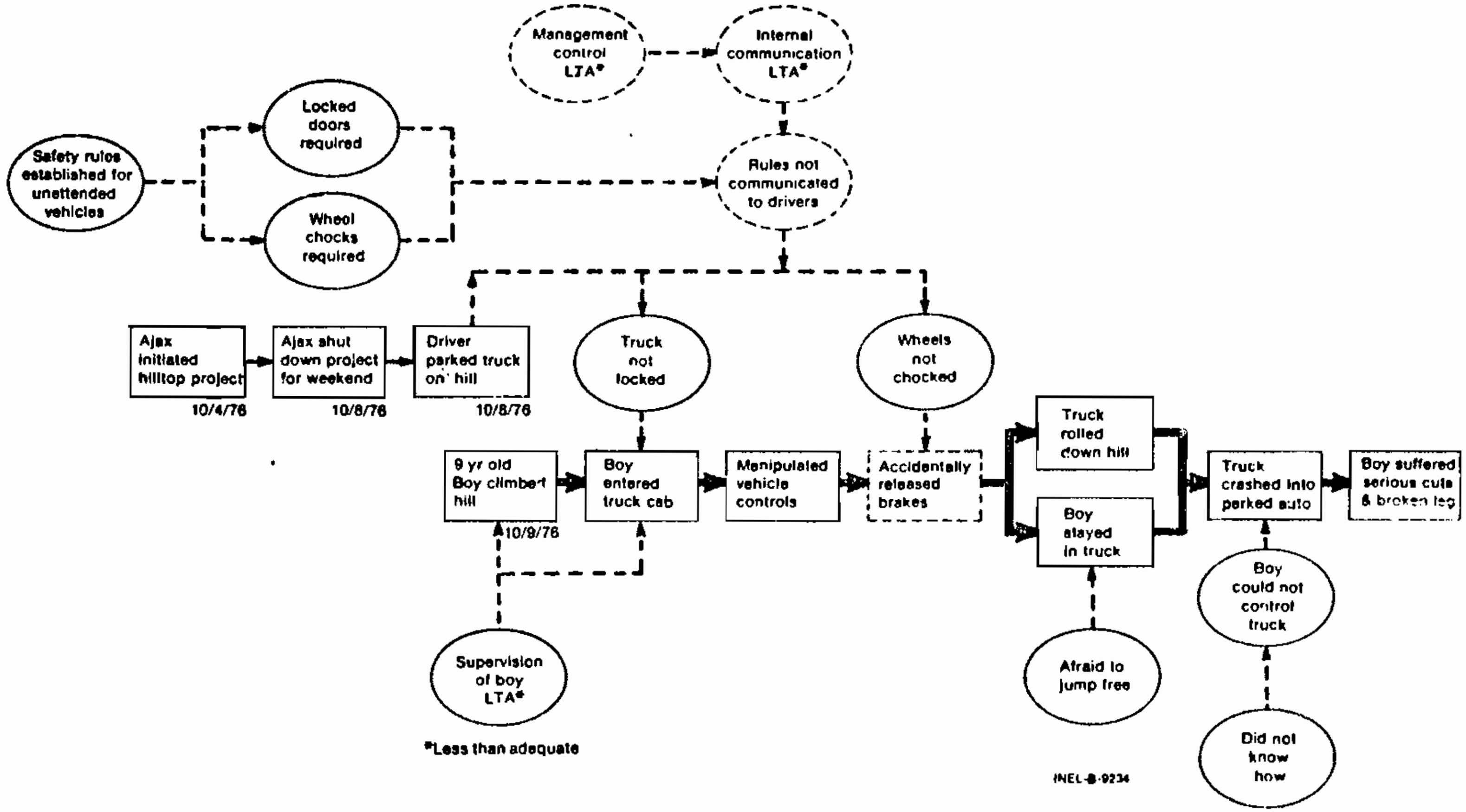

Figure 35. Causal Factors Chart Example.

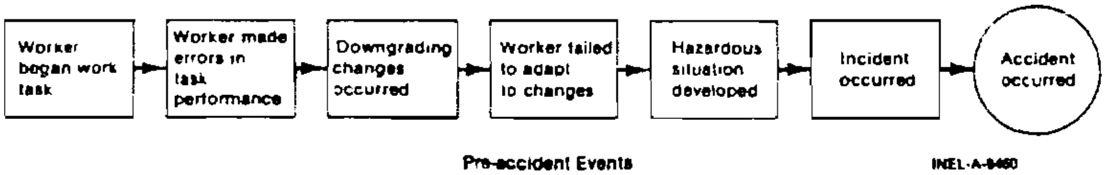

Figure 36. Generalized Causal Factors Chart—Pre-accident Events.

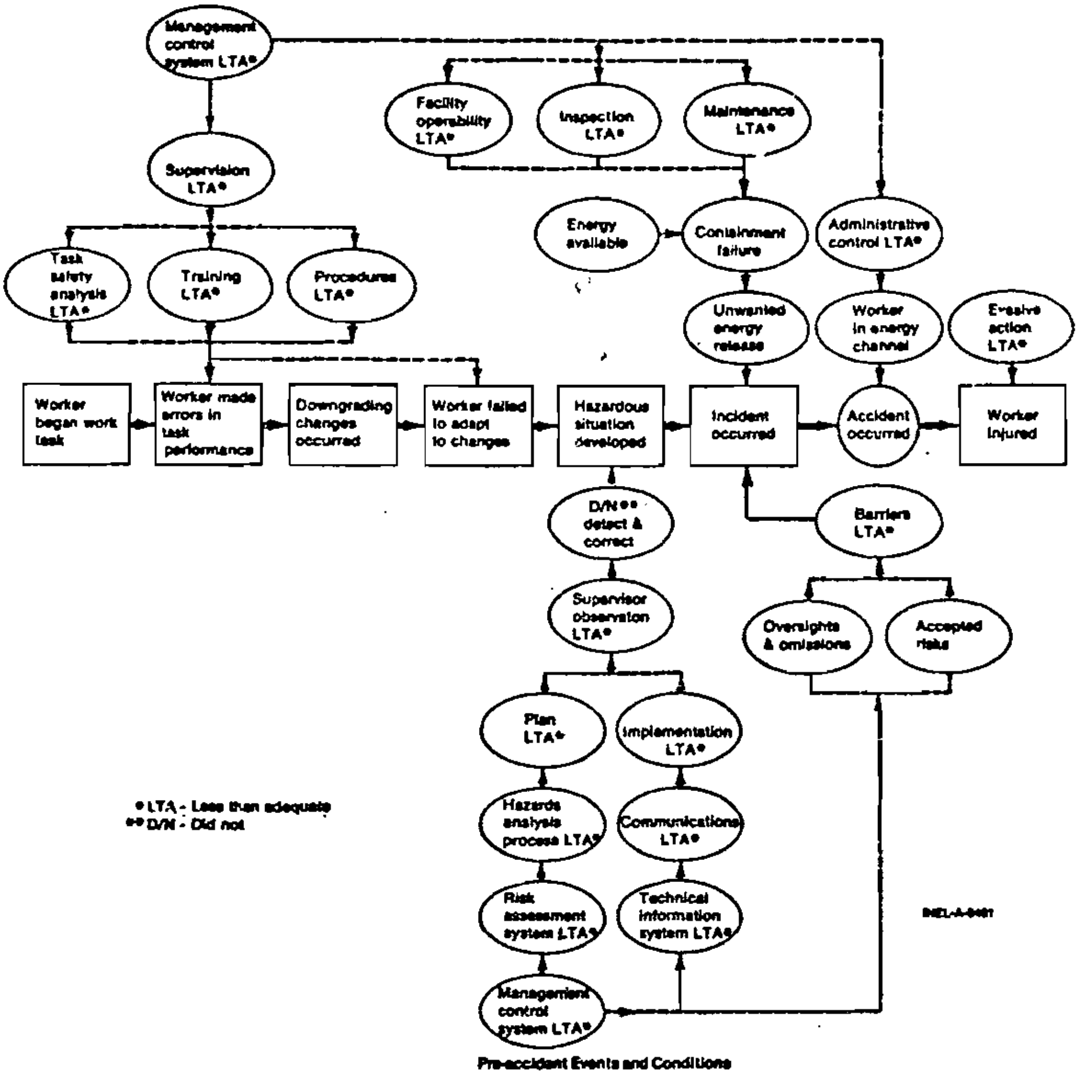

Figure 37. Generalized Causal Factors Chart—Pre-accident Events and Conditions.

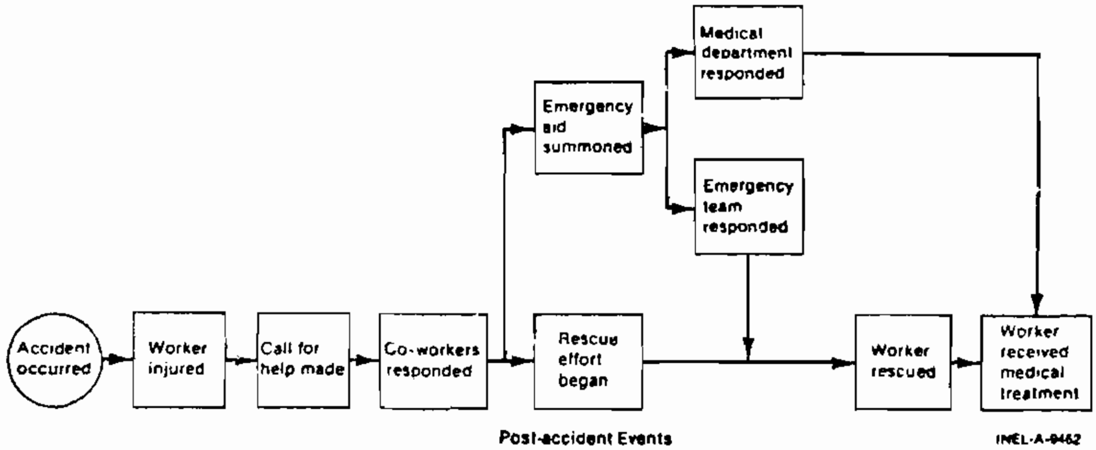

Figure 38. Generalized Causal Factors Chart—Post-accident Events.

Charting the causal factors contributes in the following ways to investigative effectiveness.

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.

Additionally, the causal factors chart assists investigators in formatting and writing the accident report in the following ways:

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 range 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. Aids 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.

How can an investigator best apply causal factors charting? The experience of many people participating in numerous accident investigations has led to the identification of seven key elements in the practical application of causal factors 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 to rough out a fault tree of the occurrences to establish how the accident could have happened. This can prevent false starts, but must be done with caution so that you don't lock yourself into a preconceived scenario of the accident.

2. Use the suggested guidelines. They will assist you in beginning 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. Causal factors usually do not emerge during the investigation in the sequence 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 deeper probing by investigators which will uncover the 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 repetitious and time-consuming. Successive redrafts of the causal factors charts 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 (or similar aids, such as 3M Post-It) 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 causal factors chart can be drawn for inclusion in the investigation report. Several investigators have testified to the value of this approach, commenting that it made their investigations more expeditious and thorough.

5. Correlate use of causal factors charting with that of other MORT investigative tools. The optimum benefit from MORT-based investigations can be derived when such powerful tools as the causal factors 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 causal factors 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 causal factors 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 it 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 causal factors 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 causal factors chart to make an executive summary chart for the report. The causal factors 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 causal factors chart in the investigation report, for its primary purpose is to provide a concise and clear orientation to the accident sequence for the report reader. When a detailed causal factors 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 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 causal factors 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.

Change Analysis. Change is one of the most important factors in producing serious accidents. When a system is perturbed by change, the frequent results are errors, loss of control, and accidents. Change is usually a contributor in major accidents. The rate of change is usually increasing exponentially in today's sophisticated systems. Even when change is well-intentioned, it can and does cause unwanted effects if it is not properly coordinated and controlled. Change can be sudden and dramatic, or gradual and difficult to detect. Changes in accident causation can be singular or multiple (most often the case), and are invariably additive and synergistic in their effects. Sensitivity to change and its effects is needed to keep it under control. So is sensitivity for the need for counter-change to keep changed systems functionally safe, efficient and accident free. The skill and knowledge needed to detect and analyze change are essential investigative attributes.

In the process of evidence collection and analysis, both changes and the results of changes will be found. When changes are found which may have had significant effect on accident occurrence or loss magnitude, they should be evaluated to find their causes and cures. When results of change are detected, the producing changes should be sought and their causes determined. Change analysis is the means of doing this. It must be organized and systematic to prevent oversights, omissions, and unidentified critical changes.

The basic change analysis approach was developed by Kepner and Tregoe as a management tool that they called "problem analysis." It has been adapted and modified to fit accident investigation needs. It primarily consists of identifying what is distinctive about an accident situation, and finding the changes that led to those distinctions. Within those changes and their generation will lie causes of the accident.

Change analysis is a simple, five step process, followed by an integration step to fit the results into the total accident investigation analytical picture (Figure 39). Those steps are:

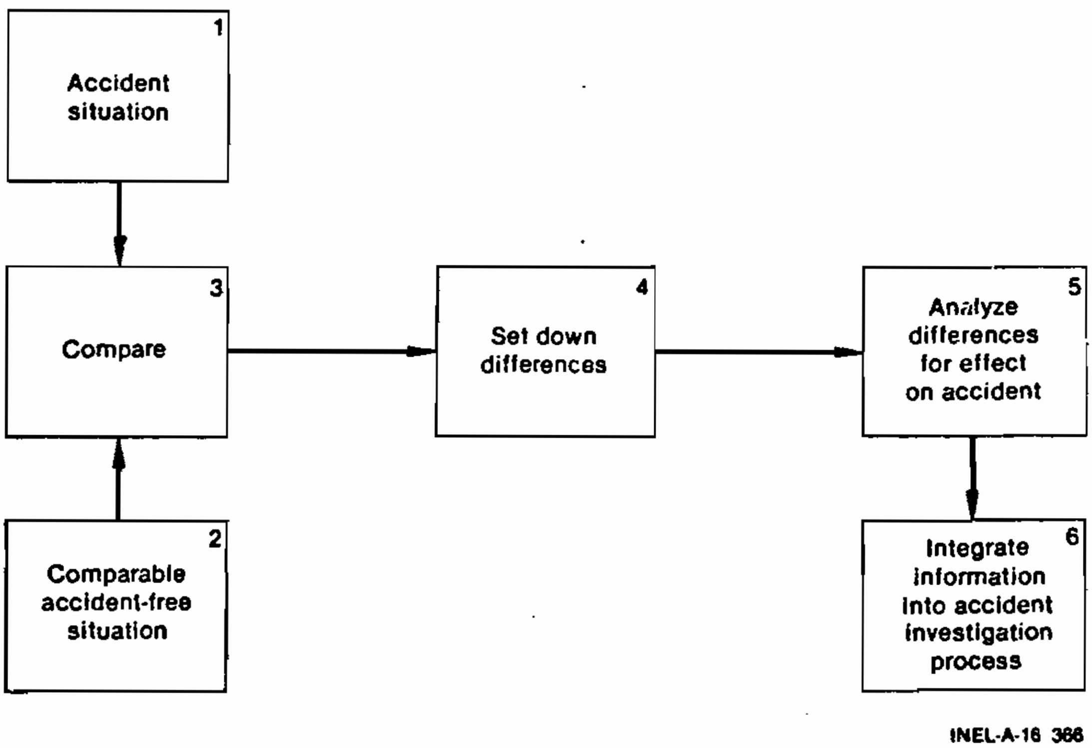

Figure 39. Change Analysis Schematic.

1. Describe the accident situation precisely

2. Describe a comparable accident-free situation

3. Compare the two to detect all differences

4. Write down *all* the detected differences or distinctions that set the accident situation apart from the safe situation, whether they appear to be relevant or not

5. Analyze the differences and distinctions to identify the underlying changes, and to determine their effects on the accident. Give careful attention to obscure and indirect relationships, and to the compounding or synergistic interacting of changes that increase their effects on accident consequences.

6. Integrate change analysis results with those of other analytical methods for confirmation, validation, and clearer understanding of accident occurrence and prevention.

Figures 40 and 41 provide basic formats that have proven effective in exploring changes which have contributed to accidents. The printed forms are usually too small for handy use in investigative change analysis, so paper from a large easel pad, desk pad, or butcher paper roll is often lined out in the same basic format to provide greater visibility and ease of use. The forms are also generic and probably should be modified for specific investigations. The five column headings usually remain the same, but often the general and specific factors, which are used to define accident and comparable situation specifics, are tailored to the accident being analyzed. The main factors of what, where, when, who, and how or "how much" (extent) are of prime importance in specifying the accident and comparable situations. They are supplemented by situation-specific factors, such as those suggested in Figures 42 and 43. "Why" is not a specification factor; it will emerge from the analysis of affective changes in column five.

In using the suggested formats for change analysis, the first three columns are completed first, then the "Differences" column and, lastly, the "Affective Changes" column, to arrive at change-based causal factors—the "why's" of accident situation distinctions. Results are then correlated with other findings and are integrated into the causal factors chart (discussed in the preceding section).

The suggested approach to change analysis on accident investigation is:

1. Use large sheets of paper as work sheets.

2. Line them out in a five column format like Figures 40 and 41.

3. State the analysis subject or accident descriptor, concisely, at the top of the sheet.

4. List the general factors in column one.

5. Develop accident-specific factors under each general factor.

6. Describe the accident situation elements, using selected general and specific factor categories.

7. Select and describe comparable situation elements, using the same factors. Comparable situations can be the same activity at an earlier time, or a similar activity being done properly and without this type of accident.

8. Compare the two situations, factor by factor, to identify all differences and distinctions, and enter them in column four.

Subject ____________________

Factors	Accident Situation	Comparable Situation	Differences/ Distinctions	Affective Changes
What Object(s) Energy Defects Protective Devices				
Where On the Object In the Process Place				
When In Time In the Process				
Who Operator Fellow Worker Supervisor Others				
Task Goal Procedure Quality				
Working Conditions Environmental Overtime Schedule Delays				
Trigger Event				
Managerial Controls Control Chain Hazard Analysis Monitoring Risk Review				

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Figure 40. Change-based Accident Analysis Worksheet.

Subject:

INVOLVEMENT FACTORS	A. Accident/ incident situation	B. Comparable safe situation	C. What is distinctive about "A"	D. What has changed in/about "C"
1. WHO Workers Supervisor Management Others				
2. WHAT Object Energy Environment Barriers				
3. WHERE Location On the object In the process				
4. WHEN In time In the process				
5. EXTENT How bad Trend				
6. MANAGEMENT CONTROL Control chain Monitoring				

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Figure 41. Change Analysis Worksheet.

Subject: Boy Injured In Runaway Truck Crash

Involvement Factors	Accident Situation	Comparable Situation	Differences (All)	Affective Changes (Why)
What Vehicle	2½-ton dump truck	Other vehicles/equipment		
Barriers	None	Present and in place		
Unattended Vehicle Rules	Not communicated	Communicated		
Where Location	Hillside condo construction site	Elsewhere on level ground		
	Near residential area	Remote		
When in time	Saturday, Oct. 9	Normal work activities before		
In process	Shutdown for weekend after first week's work			
Who Worker	Dump truck driver	Other drivers or operators		
Victim	Jimmy	Other boys Adult		

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Figure 42. Change Analysis Examples—First Three Columns.

Subject: Boy Injured in Runaway Truck Crash

Involvement Factors	Accident Situation	Comparable Situation	Differences (All)	Affective Changes (Why)
What Vehicle	2½-ton dump truck	Other vehicles/equipment	Cab unlocked. Entry possible Controls not lockable. No fence around equipment compound. No wheel chocks on truck.	
Barriers	None	Present and in place		
Unattended Vehicle Rules	Not communicated	Communicated	Some drivers didn't know rules.	
Where Location	Hillside condo construction site	Elsewhere on level ground	Trucks and heavy equipment could roll downhill.	
	Near residential area	Remote	Easy access for nearby residents.	
When In time	Saturday, Oct. 9	Normal work activities before	Equipment unattended. No site guard and no fence installed.	
In process	Shutdown for weekend after first week's work			
Who Worker	Dump truck driver	Other drivers or operators	New hire. Hurrying to get ready for hunting trip. Unfamilar with rules.	
Victim	Jimmy	Other boys Adult	Fascinated by trucks. Unsupervised. Adventurous, inquisitive, young, inexperienced.	

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Figure 43. Change Analysis Example--Fourth Column Added.

9. Analyze the differences and distinctions to identify affective changes and nonchanges (those existing deficiencies which interact with changes to cause or contribute to the accident).

10. Pinpoint the causal factors and verify their fit with the accident situation.

11. Correlate causal factors with findings from other analytical methods and integrate them into the causal factors chart and the total investigative process.

A simple application of this approach is illustrated in Figure 42. The accident used is the runaway dump truck example from the Causal Factors Analysis Section. Figure 42 shows the first three columns completed. They are then evaluated to determine accident situation distinctions to enter in fourth column, Differences (Figure 43), and that is then analyzed to complete column five, Affective Changes (Figure 44), and arrive at "why" or accident causal factors.

Fault Tree Analysis. One of the problems that investigators can encounter is getting locked into a preconceived scenario of the accident occurrence and then seeking evidence to support their preconceived notion. The simple approach of roughing out a fault tree of the occurrence to establish the different ways it could have happened has been helpful in keeping open minds, thus minimizing this problem. It also aids in preventing false starts. This section will discuss only this application of fault tree analysis to accident investigation. Additional information on the construction and use of analytical trees can be found in the *Reliability and Fault Tree Analysis Guide* (SSDC-22) and the *Standardization Guide for Construction and Use of MORT-Type Analytical Trees* (SSDC-8).

The use of analytic trees originated as fault tree analysis in the early 1960's in the aerospace industry, as an attempt to prevent oversights, particularly at system interfaces, which had previously resulted in costly retrofits or inordinately short operational lifetimes for promising systems. Fault tree analysis was strongly hardware-oriented, but also showed promise as an analytic tool for evaluation of systems involving a great deal of human performance. Development of the MORT concept a decade later and its acceptance by AEC and its successors for agency-wide use made application of the fault tree analysis techniques to management systems a reality.

An analytic tree is simply a graphic display of information to aid the user in conducting a deductive analysis of any system (human, hardware, or environmental) to determine critical paths to success or failure. It identifies the details and interrelationships that must be considered to identify oversights or omissions that led to failures. It enables the investigator to:

1. Systematically identify the possible paths from base failures to accident losses

2. Show relationships, system deficiencies, and common failure modes involved in accident development

3. Identify management system weaknesses and strengths

4. Display a clear visual record of the analytical process

5. Provide a basis for rational decision making and corrective actions by management.

In an investigative analytic tree, an unwanted or injurious occurrence is stated as the top event. On the next lower tier are listed those events required to achieve the top event. Each of these is subsequently broken down into its constituents to reveal the events, causes, and sources that contribute to the occurrence of the top event. Construction of an analytic tree, therefore, constitutes a deductive analysis of a management system or safety system, proceeding from general to specific, or outcome to source, and answering the question, "How could this happen?"

Once an analytic tree has been developed, it can be used in the investigation of accidental losses to identify not just the symptoms, but also the root causes and sources of these accidents and the management system weaknesses that permitted them to occur.

Subject: Boy Injured in Runaway Truck Crash

Involvement Factors	Accident Situation	Comparable Situation	Differences (All)	Affective Changes (Why)
What Vehicle	2½-ton dump truck	Other vehicles/equipment	Cab unlocked. Entry possible. Controls not lockable. No fence around equipment compound. No wheel chocks on truck. Some drivers didn't know rules.	Rush to start on Oct. 4 after Sept. 26 award of contract to beat winter freeze. New hires not briefed on unattended vehicle rules, including truck driver, who failed to lock and chock truck.
Barriers	None	Present and in place		
Unattended Vehicle Rules	Not communicated	Communicated		
Where Location	Hillside condo construction site	Elsewhere on level ground	Trucks and heavy equipment could roll downhill.	Leveling of equipment compound delayed by use of needed equipment on another job
	Near residential area	Remote	Easy access for nearby residents.	
When In time	Saturday, Oct. 9	Normal work activities before	Equipment unattended. No site guard and no fence installed.	Rapid award of contract. Early start date on Oct 4 resulted in start without equipment protected on weekend. Guard and fencing due to arrive Oct. 12.
In process	Shutdown for weekend after first weeks work			
Who Worker	Dump truck driver	Other drivers or operators	New hire. Hurrying to get ready for hunting trip. Unfamiliar with rules.	Hired Oct. 7 from hall. Received no orientation and no briefing on Ajax Comprehensive Safety Program. Preoccupied with hunting trip at close of shift. No followup by supervisor.
Victim	Jimmy	Other boys Adult	Fascinated by trucks. Unsupervised. Adventurous, inquisitive, young, inexperienced.	Permission from Mother to go to friends home, saw equipment and diverted to construction site. Entered unlocked truck. Could not control truck.

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Figure 44. Change Analysis Example—Fifth Column Added.

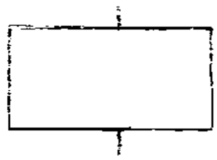
The steps in developing and using an investigative fault tree are:

1. Define the top event as an unwanted, damaging occurrence.
2. Acquire a working knowledge of the accident results, the work situation and activities in which they developed, and the upstream processes that preceded them.
3. Postulate the possible scenarios by which the accident occurred.
4. Construct a fault tree to depict these scenarios.
5. Validate the fault tree for completeness, logic, and accuracy.
6. Use the fault tree to analyze each of the scenarios for best fit with the accident facts as they are collected and evaluated.
7. Add to the fault tree as new evidence is acquired and new possible scenarios are discovered. Check out all possible scenarios. Do not reject any because they are improbable, but only because they do not fit the facts.
8. Through the process of analysis and fact-fitting, pinpoint the scenario or scenarios which give the best match with factual data and integrate that information with the findings from other analytical methods.

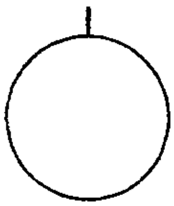
A few simple principles and guidelines will be helpful in constructing useful investigative fault trees.

1. Use common and accepted graphic symbols for events (or system elements), logic gates, and transfers. (See Figures 45, 46, and 47.) For simplicity, investigators will often use only the rectangle to represent all events or elements, rather than distinguishing them by type.
2. Keep the analytic tree as simple as the complexity of the system allows.
3. Keep the analytic tree logical and expect no miraculous occurrences. Use only those contributory events which are "necessary and sufficient" to produce the output event. Don't get caught up in the mechanics of tree construction. It is merely a tool to display and analyze for clear thinking.
4. Select the logic gates and constraints (conditional events) which best describe true system functioning or accident scenario development.
5. Select event titles or descriptions which are simple, clear, and concise. Avoid those which are abstract or are not readily understood by the intended users.
6. When constructing complex trees, limit the number of tiers on a single page to four or five tiers.
7. Use transfers to avoid duplication of identical branches or segments of the tree and to reduce single-page-tree complexity (see Figure 47).
8. Follow the convention of indicating order of performance or time sequencing from left-to-right for related events on a single tier.

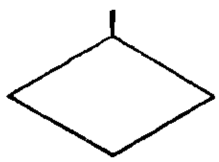
The use of a fault tree in displaying and evaluating alternative hypotheses of accident causation is illustrated in the following example. The example, tree, and explanation were developed by R. J. Nertney.



RECTANGLE
A general event or a gate output event resulting from the logical combination of contributory events acting through a logic gate.

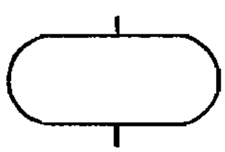


CIRCLE
A base event requiring no further development. It is an independent event used only as a logic gate input.



DIAMOND
An undeveloped terminal event not developed to its cause. Terminated for lack of information, resources or risks, or to avoid redundancy of analysis.

SCROLL
A normally expected event that should occur naturally during normal functioning of the system.



STRETCHED CIRCLE
A satisfactory event that exists noncommittally in the system as a logic gate output and is used to show completion of a logical analysis.

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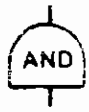
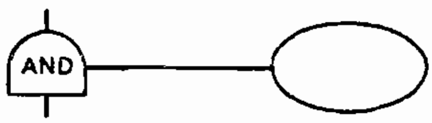
Figure 45. Analytical Tree Event (or Element) Symbols.



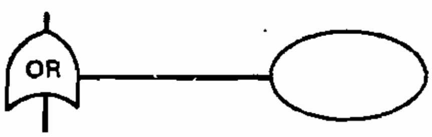
AND Gate
A logic gate that produces an output only when all input events occur. Contains the identifying word "AND".

OR Gate
A logic gate that produces an output when one or more of the input events occur. Contains the identifying word "OR".

CONSTRAINT
A conditional event that applies conditions or constraints to a basic logic gate or output event. Imposed condition is written in the ELLIPSE.



CONDITIONAL AND Gate
Input produces the output provided the conditions written in the ELLIPSE are satisfied. (Example: PRIORITY AND gate specifying order of input event occurrence.)



CONDITIONAL OR Gate
Input produces output provided the constraint conditions are met. (Example: EXCLUSIVE OR gate enabling an output to occur only if a single input is present.)

SUMMATION Gate
A special logic gate which requires that an acceptable combination of input events be present to produce an output. Inputs can be present in varying proportions, as long as the sum of the inputs is adaquate to generate an output.

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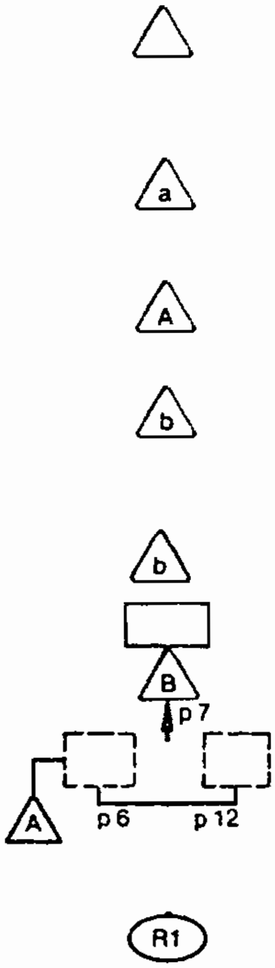
Figure 46. Analytical Tree Logic Gate Symbols.



TRIANGLE
The basic transfer operator represents the exact repetition of a tree section found elsewhere on the tree below an identical triangle.

Intrabranch TRANFER
Transfers substructure within a branch. Has identifying lower case letter.

Interbranch/Interpage TRANSFER
Transfers substructure from another branch or another page. Has an identifying capital letter.

OUT-TRANSFER, Same Page
Horizontal arrow away from symbol shows transfer of substructure to another location on the same page in the direction the arrow points.

IN-TRANSFER, Same Page
Horizontal arrow toward symbol shows transfer from direction of arrow on the same page.

IN-TRANSFER, Other Page
Vertical arrow toward base of symbol indicates transfer from branch on designated page.

OUT-TRANSFER, Other Page
"Recipient events" from other pages in broken lines above oversized triangle indicate transfer of substructure to recipient event locations on designated pages.

SMALL OVAL
Assumed risk transfer is used to transfer an assumed risk from any tree location to the assumed risk event (a SCROLL). The number of the assumed risk is indicated inside the symbol as shown. It normally originates at a DIAMOND (undeveloped terminal event).

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Figure 47. Analytical Tree Transfer Symbols.

An electronics technician is responsible for adjusting and troubleshooting a piece of electrical gear. The equipment is manipulated by an operator under general direction of a supervisor. The equipment includes a cabinet containing exposed high voltage circuitry. The cabinet is protected by interlocks which de-energize the high voltage system when the cabinet door is opened. In the course of a troubleshooting operation, the technician is electrocuted. Access to the high voltage components was via an interlocked cabinet door which was opened in the course of the troubleshooting operation. The operator, supervisor, and technician were all present at the time of the accident. Figure 48 depicts the various scenarios, or alternate hypotheses, of accident development. Nertney's analysis, which is keyed to the numeric designators of events and conditions, follows.

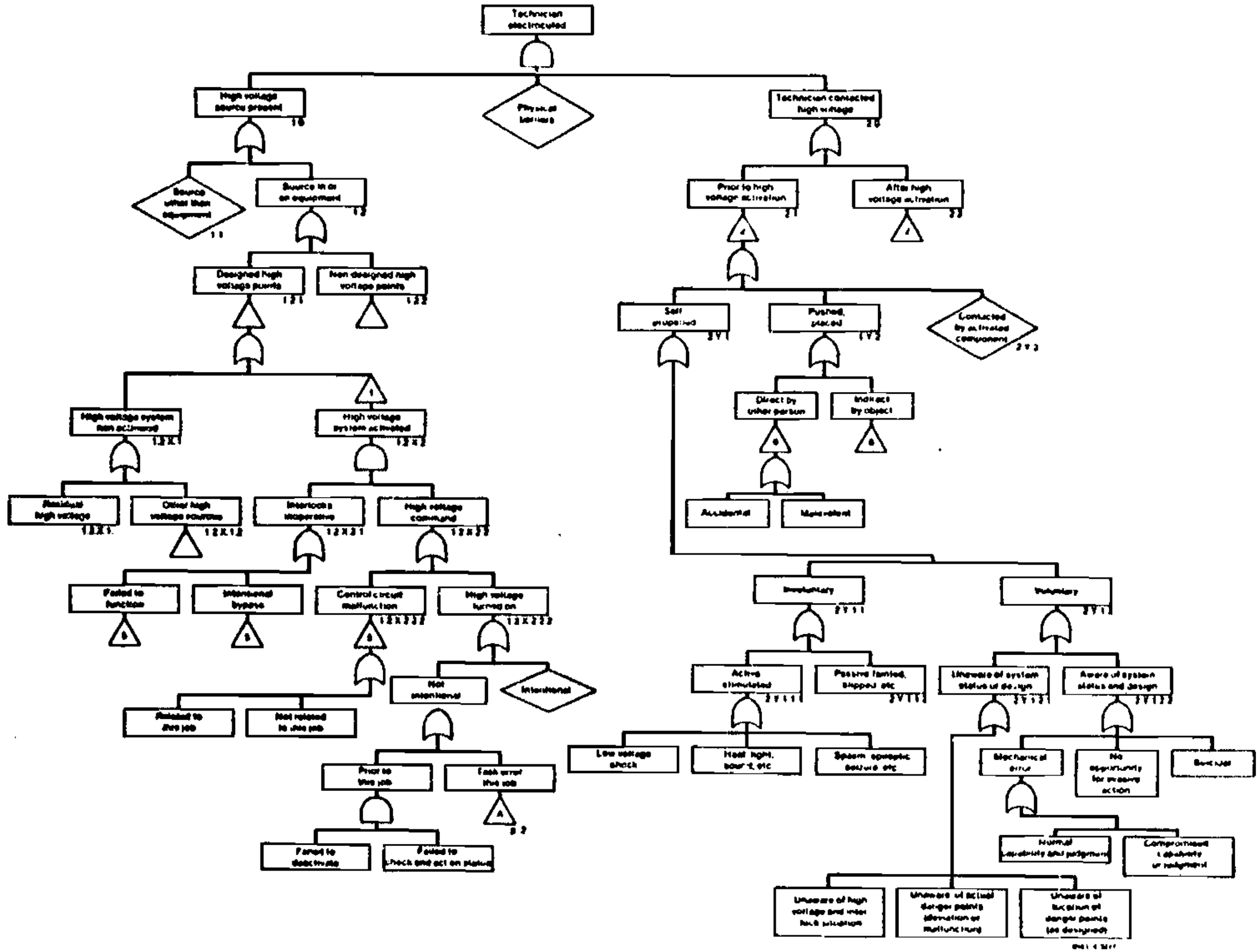
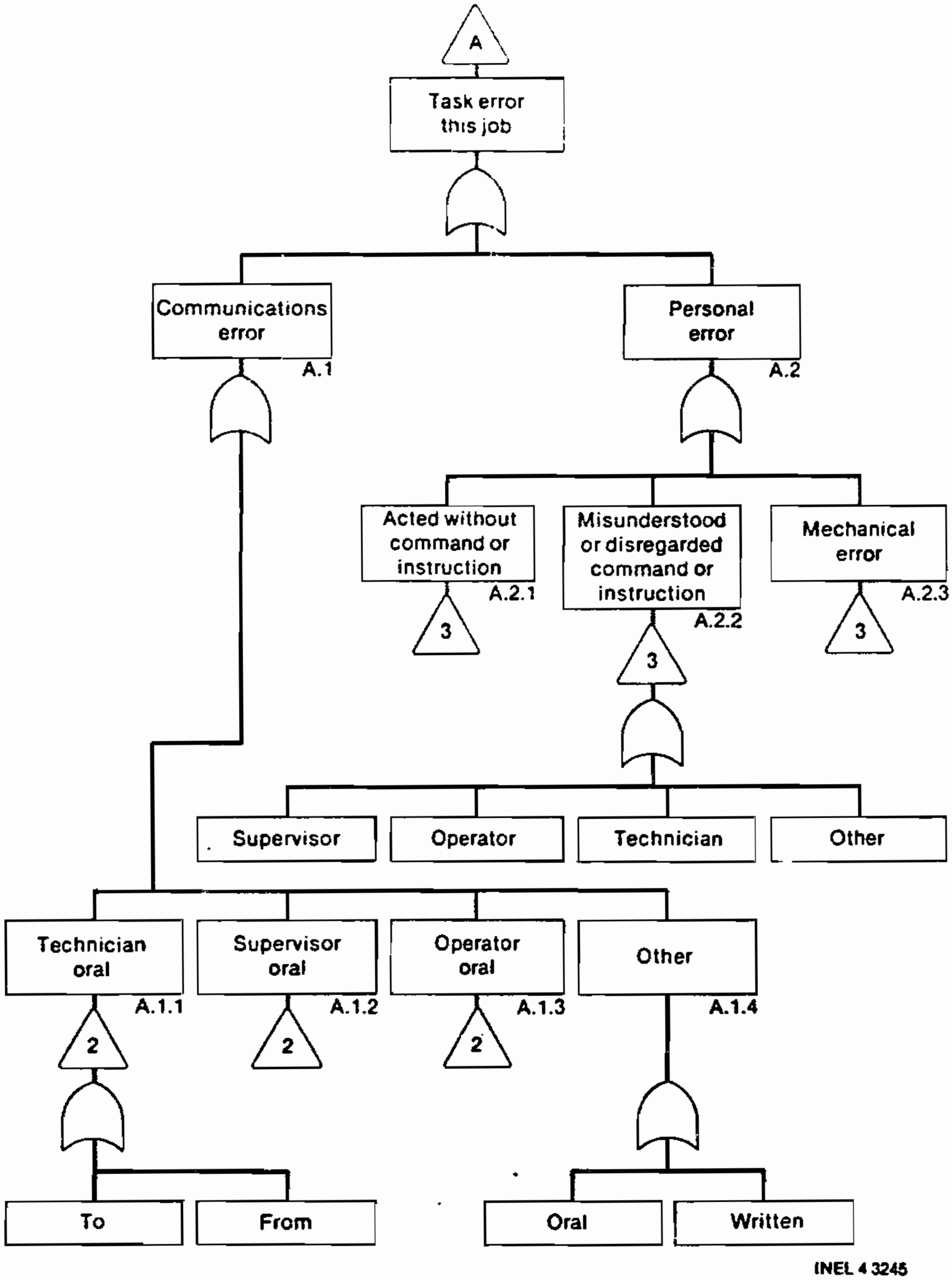


Figure 48. Fault Tree Analysis Example.



Nertney's Analysis.

In order for electrocution to occur, two conditions must exist. An unbarriered source must exist and the technician must have come into contact with the source. It is, of course, necessary to positively validate electrocution as the primary cause of death, by autopsy or other means, prior to entering this particular fault tree. (Often, the other possible causes of death, i.e., heart attack, diabetic seizure, etc., will be included in the fault tree analysis.)

1.0 *High Voltage Source Present*

Two possibilities exist here.

1.1 Electrocution could have resulted from contact with a source other than the piece of equipment which the technician was presumably troubleshooting. Other potential sources should be investigated.

1.2 Electrocution could have resulted from contact with sources in or on the equipment which the technician was troubleshooting.

1.2.1 The high voltage point contacted could have been a designed high voltage point.

1.2.2 The high voltage point could have been a portion of the equipment which was not intended to be a high voltage point (leakage, insulation failure, wiring error, etc.).

In either case (1.1 or 1.2), the system's high voltage system was activated at the time of electrocution or it was not.

1.2.X.1 System's High Voltage System Not Activated

1.2.X.1.1 The electrical energy could have come from stored energy (e.g., a capacitor which was not discharged).

1.2.X.1.2 The electrical energy could have originated in some other high voltage source outside of the equipment under study (system "sneak circuits" or crossties). In this case, "high voltage system activated" must be analyzed for the system (transfer 1).

1.2.X.2 High Voltage System Activated

Two conditions are required here. The protective interlock system must have been inoperative and the high voltage system must have received a "high voltage on" command.

1.2.X.2.1 The interlocks could be inoperative due to failure to function or to intentional bypass. In either case, this could have occurred in a manner related to this job or not related to the job (e.g., a bypass installed or a failure occurring prior to this particular job).

1.2.X.2.2 The high voltage command could originate through a circuit malfunction or through the circuit being turned on.

1.2.X.2.2.2 The control circuit malfunction could be associated with this job or could be unassociated with this job.

1.2.X.2.2.2 The turning on of the high voltage could have been intentional or unintentional. If it were unintentional, it could have occurred prior to this job with failure to detect and deactivate. The second possibility is a task error in the course of this job. See transfer A, page 2 for task error analysis.

2.0 *The Technician Contacted the High Voltage*

Two possibilities exist here. The technician was in contact with a high voltage point prior to activation (2.1) or he contacted a point which was already activated at the time he contacted it (2.2). In either case (transfer 2), there are two possibilities. He propelled himself into contact with the high voltage or he was pushed or placed into contact.

2.Y.1 Self-Propelled into Contact

This could be involuntary or voluntary.

2.Y.1.1 Involuntary

2.Y.1.1.1 This could be an active propulsion stimulated by an external source (low voltage shock, heat, light, sound, etc.) or through internal sources (spasm, epileptic seizure, etc.).

2.Y.1.1.2 Propulsion could be passive through such mechanisms as fainting or slipping.

2.Y.1.2 Voluntary

This could be in one of two situations. The technician could be unaware of system status or design or he could be aware of system status and design.

2.Y.1.2.1 Unaware of System Status or Design

Three possibilities exist here. The technician was unaware of the high voltage and interlock situation, or he was unaware of the high voltage points in the system as designed, or he was unaware of new danger points which might have existed through changes from design (deviations or malfunctions).

2.Y.1.2.2 Aware of System Status or Design

Three possibilities exist here. They are mechanical error, lack of opportunity for evasive action (for example, becoming aware that the system had been turned on only at the moment of shock), or suicidal motives. In the case of mechanical error, one should consider whether the technician was capable of normal judgment and capabilities or whether his faculties might have been compromised through stress, lack of sleep, alcohol or drug problems, etc.

2.Y.2 Pushed, Placed

The individual could have been pushed or placed into contact with the high voltage source. This could have been a direct action by another individual or it could have occurred indirectly through motion of a cabinet door, work dolly, etc. In either case, the act could have been accidental or malevolent in nature.

2.Y.3 Contacted by Activated Component

The final possibility for contact with the high voltage source is that the source itself could have been in motion at the time of contact; e.g., a loose head, patch cord, or some other item of hardware. Care must be exercised in diagnosing this sort of possibility because the high voltage source might not be in the same position as it was at the time of electrocution.

Task Error This Job
(Transfer A, Page 2, Figure 48)

A. This transfer refers to task errors in activating the high voltage. Two possibilities exist here, communications errors *or* personal errors.

A.1 *Communications Errors*

These include:

A.1.1 Oral communications to or from the technician

A.1.2 Oral communications to or from the supervisor

A.1.3 Oral communications to or from the operator

A.1.4 Oral communications from other individuals *or* errors in written communications (work orders, procedures, posted signs and warnings, etc.).

A.2 *Personal Errors*

These include the possibility of three types of errors on the part of the supervisor, the operator, or the technician.

A.2.1 Acted without command or instruction

A.2.2 Misunderstood or disregarded a command or instruction

A.2.3 Mechanical error (pushed wrong button, accidentally tripped a relay, etc.).

MORT Analysis. The Management Oversight and Risk Tree (MORT) is a diagram which arranges safety program and management system elements in an orderly and logical manner. It presents a fault tree of a dynamic, comprehensive, idealized safety system model. MORT structures the largely unstructured safety literature and current best safety practices into three levels of relationships: (a) about 100 generic problems, (b) up to 1500 possible base events or causes, and (c) thousands of criteria to judge system adequacy. It provides relatively simple decision points in the accident analysis that enables the investigative analyst to detect omissions, oversights, accepted risks, and system deficiencies.

MORT has all the advantages of fault trees. It is highly visible, portraying a complex, idealized safety program on a simple sheet, showing the interrelationships of all program elements, thus forming a very useful aid to communication. It is systematic and logical, requiring step-by-step, tier-by-tier, branch-by-branch, element-by-element consideration of the program. This leads the investigator to understand the system under review, seek and find right answers, and evaluate all pertinent system functions and activities completely. It provides for simultaneous analysis of multiple causes and common mode failures. It permits qualitative examination of system strengths and weaknesses, and determination of significant base level failures and critical event paths to the accidental losses being investigated.

MORT has some of the disadvantages of fault trees, as well. It can be complex and time-consuming, particularly the first few times it is used. However, skill in the use of MORT is quickly acquired through conscientious effort and practice. The simplicity of a step-at-a-time approach eases the complexity, even the first time the chart is used. Probably the greatest obstacle to overcome is the tendency to be overwhelmed by its comprehensiveness which makes it seem complex. MORT is a panoramic view of idealized reality, which must be looked at in small pieces to fully appreciate its value as a perceptive and revealing investigative analysis tool. MORT does not have difficulty handling partial failures or the omission of significant system factors, which is a problem with fault trees. MORT is less rigorous and more flexible than most fault trees. Rigor is not as important in the MORT concept as is usefulness as an investigative tool. It is designed to have significant redundancy, based upon the principle that it is better to ask the same question more than once in different contexts than to fail to ask it at all. Additionally, the MORT chart has undergone several reviews, revisions, and on-the-job applications to ensure its completeness and adaptability to all serious accident investigations. It can also be used in an abbreviated form on less serious accidents, incidents, and inquiries.

MORT is a ready-made analytical tree that describes a comprehensive safety program or safety management system. It is people-oriented and consists of several complementary elements which comprise a superlative safe performance system. Those complementary elements are: (a) management goals, policy, and implementation; (b) effective work processes; (c) independent safety review; (d) system performance measurement; (e) human performance enhancement; (f) information management and communication; (g) risk evaluation and assessment; (h) hazard analysis processes; and (i) safety, staff, and higher management services.

MORT is used as a standard of comparison for existing performance systems and safety programs. It can be compared element by element with the system, facility, and activity under investigation. When any MORT elements are missing, or only partially present in an existing system or program, deficiencies probably exist which contributed to the accidental losses, or could contribute to future ones. Deficiencies can exist anywhere in the organization and are as common at the management levels as at the first line operating or worker level. In fact, deficiencies at lower organizational levels almost always mirror similar defective performances at higher levels. So, when accidents, incidents, and losses occur, the investigator should use MORT analysis to look beyond the errors and failures which immediately precipitated them. The investigator must identify system deficiencies at both the worker and management levels to determine the underlying oversights, omissions, performance errors, and accepted risks which are the root causes. MORT uses a systems approach to investigative analysis, and looks for the ways the system failed to permit the accident to happen, as well as looking at the work site and worker contributions to accident causation.

Figures 49-52 show upper levels of the MORT chart. Figure 49 is the top of the MORT Tree and depicts the unacceptable losses and the oversights and omissions, and the assumed or accepted risks which led to them. It also shows the dual nature of accidental loss development: (a) the less than adequate (LTA) specific control factors which identify what happened, and (b) the ever-present management system factors which identify why it happened. Figure 50 shows those system elements which can lead to LTA management system factors. They are policy, management implementation, and the risk assessment system, which involves goals, information system, safety program and its review, system concepts and requirements, and the design and development plan which provides for their implementation. Figure 51 shows specific control factors consisting of accident factors and amelioration or postaccident action factors. Finally, Figure 52 shows the accident ingredients and the operating controls which fail or perform inadequately, and thus contribute to accidents and losses.

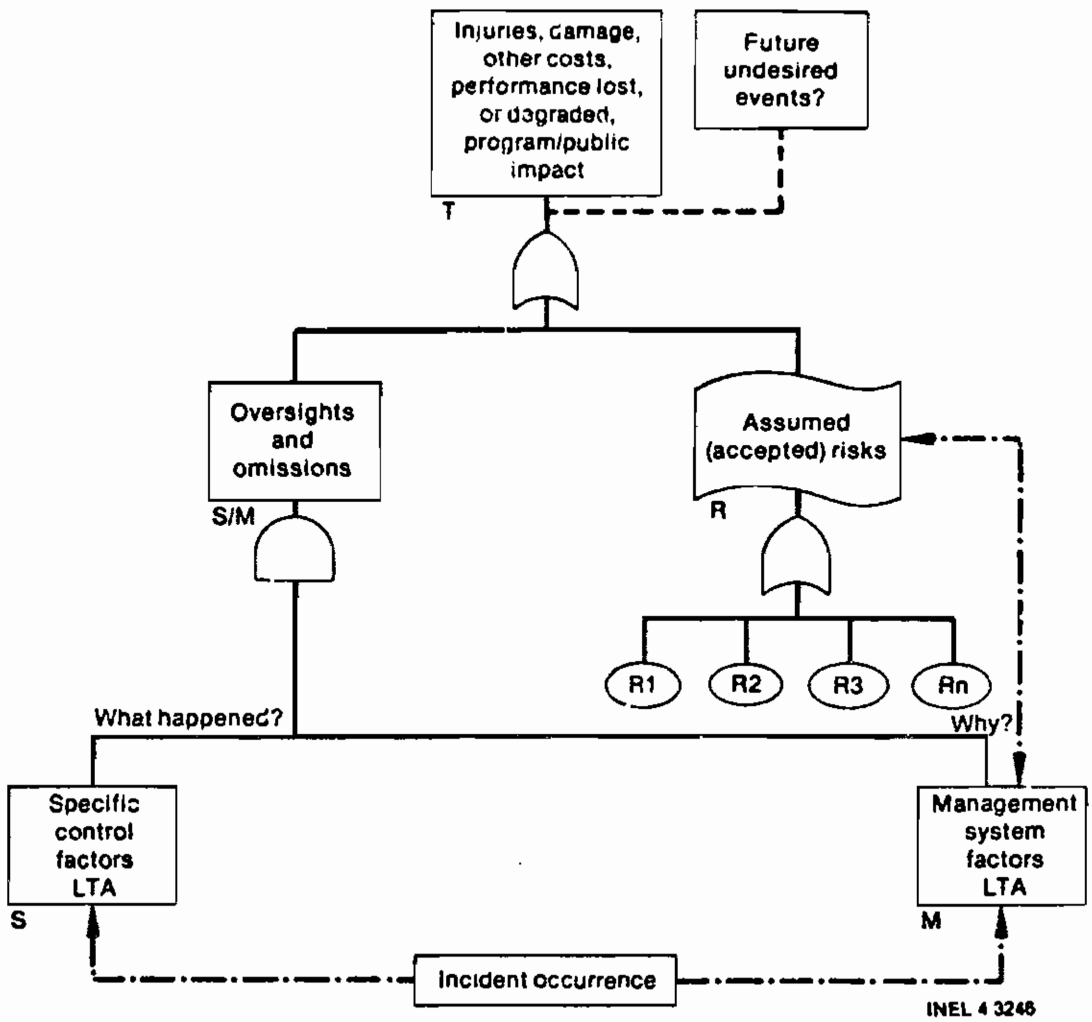


Figure 49. Top of the MORT.

Note on each of the figures that an alphanumeric code identifies each MORT Tree element uniquely. This discrete designation of each system element assists in locating each element on the tree, transferring the elements to other locations, and indexing them to specific pages in the MORT User's Manual (SSDC-4). These pages suggest questions to supplement each tree element during MORT analysis. The indexing code consists of capital letters to designate major tree tiers, lower case letters for minor tiers, and numbers for left to right position on a tier.

Following are practical hints on the use of the MORT Tree.

1. Don't be intimidated by the size and apparent complexity of MORT. Its comprehensiveness is essential for in-depth accident analysis. Use the tree as a guide or checklist. Proceed through it an element at a time, from tier to tier and branch to branch, in a relaxed, nonrigid evaluation of the system.

2. Proceed generally in a top down, left to right direction.

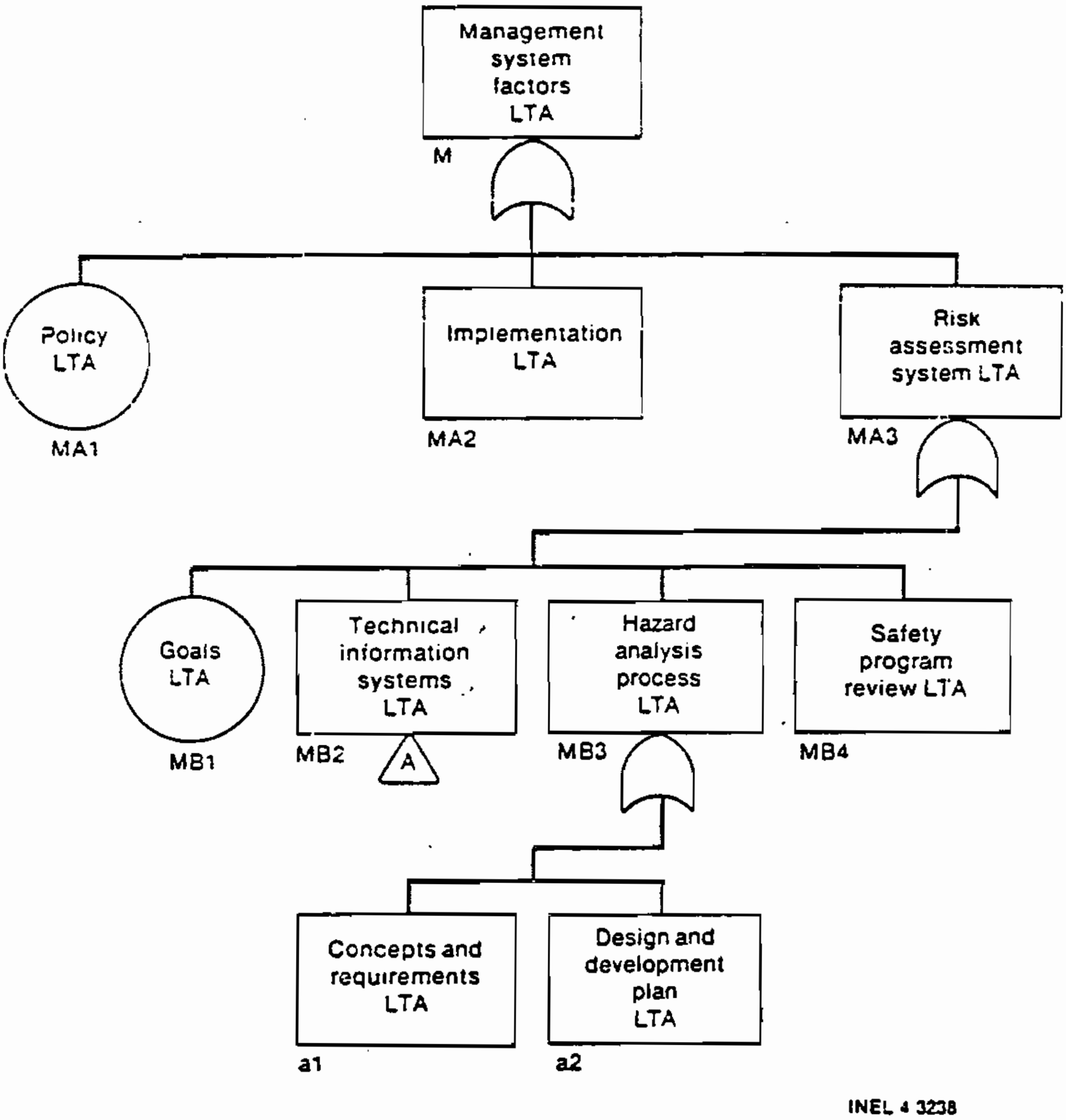


Figure 50. Management System Branch.

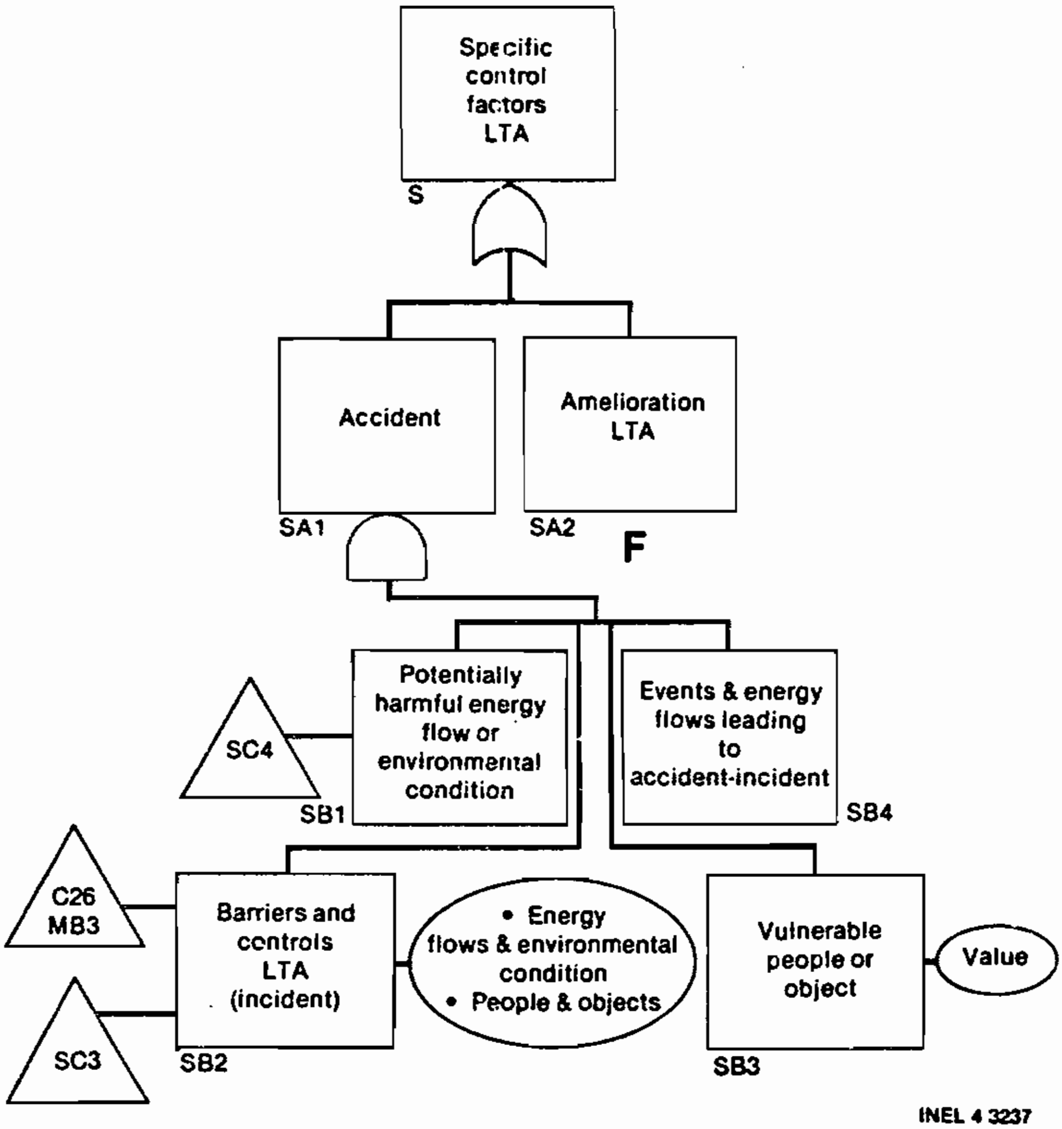


Figure 51. Specific or Worksite Branch.

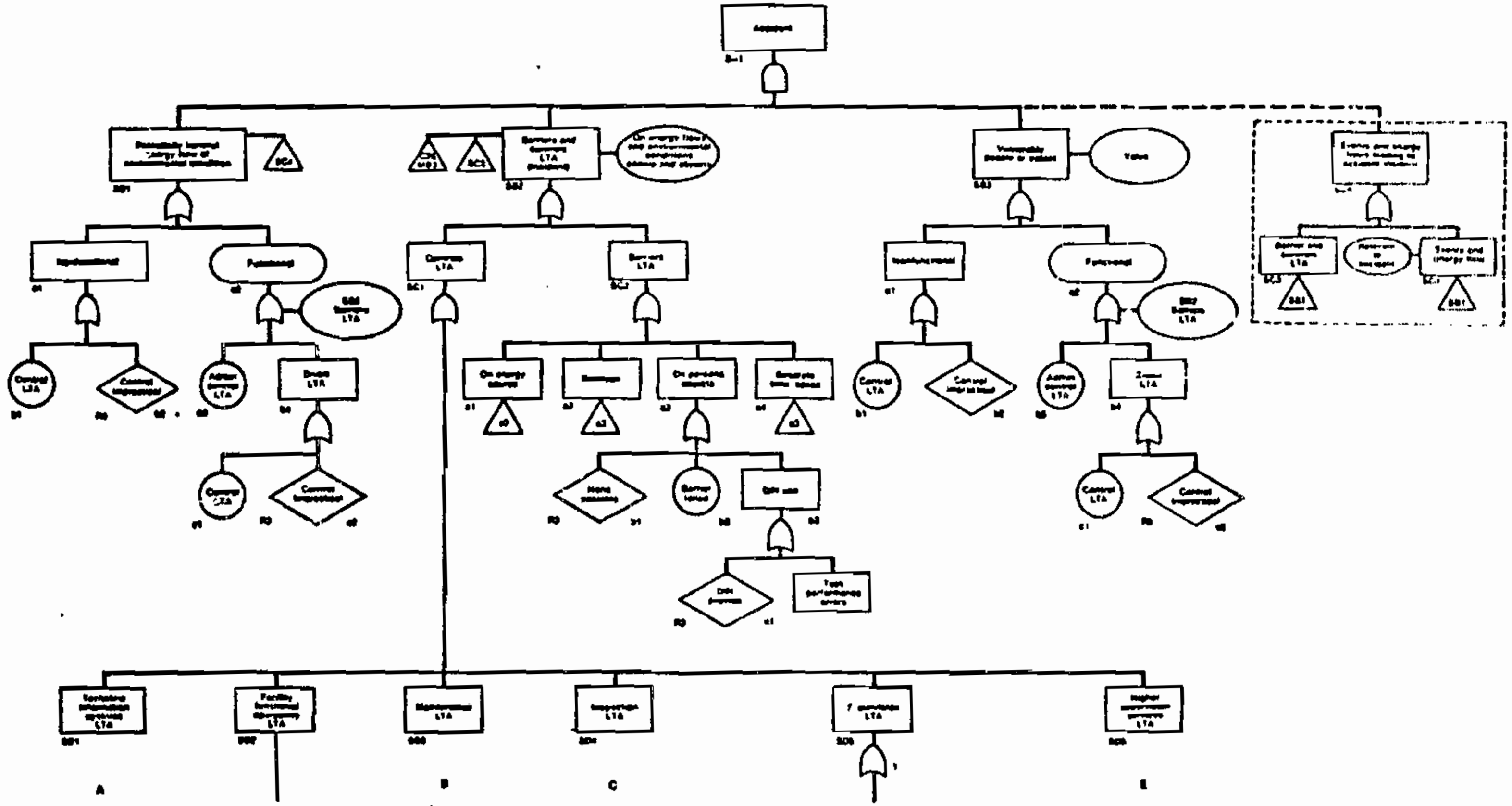


Figure 52. Accident Branch

3. Evaluate and mark each element as you go. Color coding is most often used for marking the status of each element. Green indicates okay; red, less than adequate or not okay; blue, uncertainty or inadequate information to know status and requires investigative follow-up to gather the required information to resolve the uncertainties; and black, usually to cross out the block or branch, indicating that it does not apply to this particular accident investigation. Sometimes, it will be necessary to play back and forth between tiers to determine the status of a particular element. For example, if you are not sure whether the risk assessment system is inadequate, check the next lower tier containing goals, technical information systems, hazard analysis process, and safety program review. If any of them is inadequate (marked red), then that will make risk assessment systems inadequate. In a fault tree, a single red will track through an OR-gate to make the gate output (next higher tier element) red. All inputs to an AND-gate must be red for the output to be red.

4. Maintain focus. There are several parts of the tree that are considered more than once from different perspectives. For example, task performance error is looked at for the supervisor, the injured employee, maintenance personnel, inspectors, rescuers, emergency action teams, etc. Each time you go through the task error branch for a different person, you must stay focussed on that particular person or group. Losing focus or perspective leads to confusion, inaccuracies, and oversights.

5. Record your observations and questions as you proceed. They can be recorded directly on the MORT Tree work sheet, adjacent to the system element, or in a separate log or notebook. Observations are recorded when you determine an element is adequate, deficient, or doesn't apply. Questions are phrased and recorded to seek the answers that will resolve uncertainties and fill information gaps.

6. Keep moving. Don't get bogged down in the mechanics of determining status and marking the blocks. Don't spend too much time on any one element—move on to another and come back to it at another time when you have more information. There is significant redundancy in the tree to make it very forgiving. Also, you don't need to evaluate every tree element on every accident analysis; go only as deep into the tree as the investigation requires.

7. Update the tree as you get more information. You should start the MORT analysis as soon as you collect the first pieces of evidence. Initially, you will have a lot of uncertainty (a lot of blue), but as more information becomes available, the MORT chart status should be updated. Remember the cyclic nature of evidence collection and analysis. Evidence feeds the analysis, and analysis leads to identification of information gaps and uncertainties which require more searches for additional evidence. The MORT chart and other analytical displays should be updated daily.

8. Coordinate MORT analysis findings with the results of other ongoing and complementary analyses, i.e., causal factors analysis, change analysis, alternative hypotheses fault tree analysis, etc.

9. Be realistic in evaluating the existing system. Do not be too critical, especially of facilities, operations, or activities set up years before. Keep in mind that MORT is an ideal and represents a superlative system at the forefront of today's safety technology. When we designate several system elements as less than adequate, it may more properly suggest that the overall system is merely less than superlative.

10. Finally, use the available aids in conducting a MORT analysis—the MORT chart, of course, but also the MORT User's Manual. It consists of basic questions to supplement the MORT chart (or to be used alone for MORT analysis). It is the MORT chart in outline form with some helpful observations added. It was originally prepared by Gerald J. Driessen of the National Safety Coun-

cil, for use with an early edition of the MORT Tree, and has been modified, expanded, and updated to the latest MORT chart.

Energy Trace and Barrier Analysis (SSDC-29). Chapter I indicates that a meticulous trace of hazardous energy flows and environmental conditions is essential to determine the practical opportunities in any system to impose barriers that will prevent harm to people and things. The absence of adequate barriers to prevent harmful contact between hazards and vulnerable persons or valuable objects is found in every accident. These three primary accident ingredients are supplemented by a fourth contributor in nearly all accidents. It consists of the precursor events, energy flows, and failed or inadequate barriers which led to the coexistence of the other three. Almost always a series of such precursors precedes an accident. A barrier analysis will reveal what the precursors are and when and where they should have been interrupted by proper barriers.

Energy trace and barrier analysis is built into the MORT chart. Repetitive cycling through the hazards and barriers branches of the tree, however, can become confusing, difficult, and error-prone. Most experienced investigators, therefore, do a separate energy trace and barrier analysis. It can be easily and productively performed if a few simple steps are followed.

Define Final Loss Event. This is that event which best describes accidental loss or degradation; i.e., injury sustained, equipment damaged.

Define the Harmful Contact. This is usually the unwanted energy flow or hazardous environmental exposure which was the direct cause of the injuries received or the damage that occurred.

Trace the Prior Hazard Releases. Do this until the initiating unwanted energy flow is reached. These unwanted energy flows are best described using action verbs (i.e., line broke instead of line was broken).

Establish Initiating Hazard Release. This is usually an unwanted energy flow and is normally that point where a control barrier failure initiates the hazard release sequence.

Identify Barriers. Work back through the trace noting those barriers that were in place, as well as those barriers that should have been in place. Note that there may be more than one barrier associated with each unwanted energy flow or hazardous environmental exposure.

Evaluate Barrier Status. Work back through the trace and assign status or descriptive condition to each barrier. Examples: adequate, less-than-adequate, barrier not used, barrier not provided, barrier not practical.

Validate Findings. Review the barrier analysis, checking for parallel and series hazard releases. Remember the trace as an analytical technique is inherently iterative, and its value is highly dependent upon clear and concise graphic presentation.

Application of an energy trace and barrier analysis can easily be demonstrated, (see Figure 53), using the previous example of the boy in the runaway truck. It will be shown first in step by step outline and then depicted, as it usually is, in diagram form. Final loss event:

Boy suffered broken leg, cuts, and abrasions.

Harmful contact: (Figure 53).

8. Boy struck windshield, dash, steering column, and steering wheel.

   Energy releases are numbered from 8 to 1, from last to first, in this example. Prior energy releases:

7. Truck collided with parked car

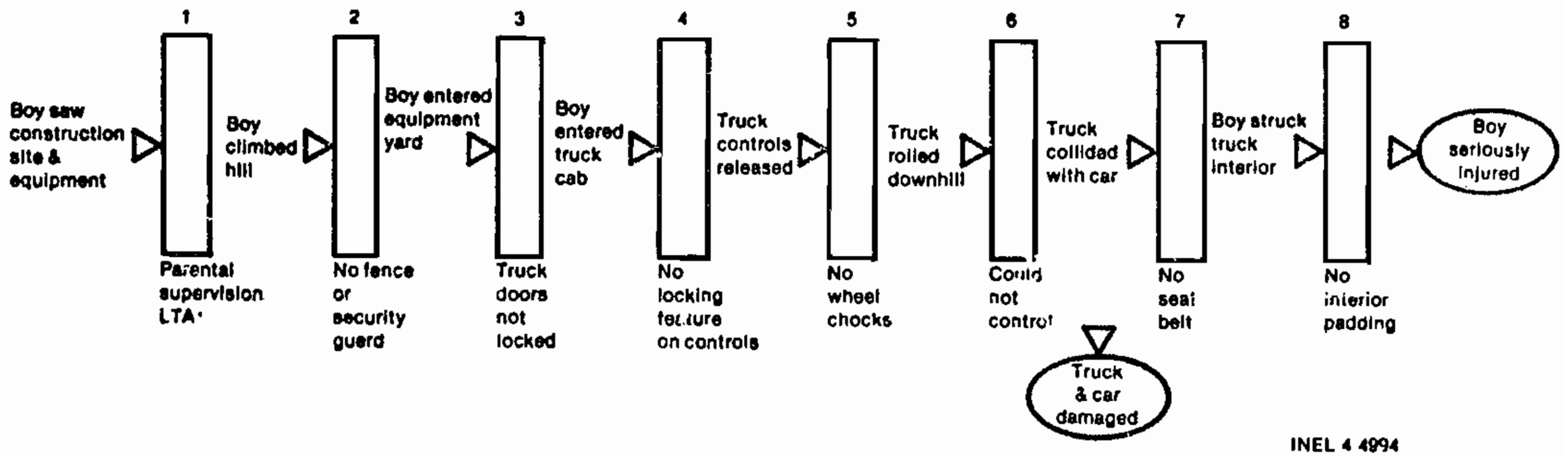


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Figure 53. Example Energy Trace and Barrier Analysis.

6. Truck rolled downhill at increasing speed

5. Boy released truck brake and placed gear shift in neutral

4. Boy entered truck cab

3. Boy entered construction site equipment storage yard

2. Boy climbed hill to construction site.

Initiating energy release:

1. Boy saw construction site and equipment.

Identify barriers:

After 8: No interior padding in truck cab

Between 7 and 8: seat belt

Between 6 and 7: ability to control truck direction and speed

Between 5 and 6: wheel chocks

Between 4 and 5: controls locked when ignition key removed

Between 3 and 4: truck doors locked

Between 2 and 3: fence and security guard

Between 1 and 2: parental supervision.

Evaluate barrier status:

1. seat belt—not used

2. ability to control truck—not provided

3. controls lock—not provided

4. truck door locks—not used

5. fence and security guard—not provided

6. parental supervision—inadequate.

Validate findings:

The analysis is reviewed for completeness and accuracy and confirmed with other accident evidence and analytical results.

Figure 53 is the energy trace and barrier analysis diagram. It portrays clearly and concisely the energy flows and failed or unused barriers that led to the boy's injuries. Note, too, how well it exhibits the many opportunities for installation of barriers to interrupt the energy flows and events that culminated in a serious accident. It should be obvious, even from this simple example, how valuable an aid the energy trace and barrier analysis is in understanding the accident and the sequence that led to it.

Human Factors Analysis. MORT analysis deals extensively with human contributions to accidents. The MORT Tree is a description of an idealized safety management system and is strongly people-oriented. It recognizes and identifies not only the errors of workers at the accident site, but also their supervisors and managers, staff support people (including safety, loss control, and human factors specialists), and the scientists, engineers, and craftsmen who created the work situation in which the accident occurred. MORT also addresses the effects of the physical, psychological, and organizational environment in which workers perform their tasks, and areas in which accidents and other problems are found. It looks at how well the work situation matches the workers at all levels in the organization. It considers motivational factors, as well as skill and design factors and their impact upon human performance. MORT addresses how and how well information is communicated up, down, and across the organization. It evaluates the means by which performance is measured and the standards that determine what should be measured and what is acceptable performance. MORT considers the effects of human and machine performance in one area of a facility or organization upon human performance in other parts of the system. It looks at the impact of selection, training, planning, and organizing upon task execution or task performance. It identifies work, budget, and personal and environmental stresses and pressures upon workers. MORT considers the influence of changes in conditions, equipment, procedures, commitments, and people on human performance and accident development. It evaluates the use and quality of task and job analyses, both common tools of the human factors specialist. It is keyed to the performance errors, oversights, omissions, and risk assumptions at all managerial levels and all functional areas, which are all basic human factors considerations. In short, MORT analysis is basically human factors analysis. It can be enhanced by use of a human factors specialist on the board, or as an advisor, who has the special skills and methods to understand and evaluate human factors that the other investigators may miss. There is nothing else that can match investigative MORT analysis in its comprehensive treatment of human factors as an analytical tool for nonspecialists.

Risk Analysis. Briscoe writes in the introduction to the Risk Management Guide (SSDC 11 revision 1, September 1982):

"Frequently, management allocates significant resources to correct specific hazards without first obtaining sufficient information to determine whether more hazardous conditions are being neglected, or whether the corrective costs are justified by the benefit or the reduction in risk. In addition, management frequently has little or no information of how risk compares to the actual value of a given program, and thus must make many safety-related decisions without sufficient information."

The Management Oversight Risk Tree (MORT) methodology provides a system for identifying management oversights and specific risks. Once risks have been identified, it is then management's responsibility to provide required resources to reduce or eliminate specific risks and to assume the residual risks.

Risk assessment estimates of future losses and the effectiveness of additional controls provides management information to make sound decisions regarding risk. Indeed, knowledge of risk permits the responsible person to decide whether a danger can be accepted, must be reduced, or eliminated by application of additional protective measures, or whether the operation must be cancelled.

As such, risk management and assessment is basic to a system approach to safety management.

Specifically, risk assessment permits or provides:

1. Probability estimates of large or catastrophic accidents

2. Addition of such loss estimates as actuarial predictions of loss to provide a more complete risk estimate

3. Cost-effective safety programs by concentrating on high risk areas

4. Optimization of the combined cost of safety programs and the cost of accidents which are present at a given level of control. This includes selection of the list of the various alternatives regarding specific hazards and control measures.

5. Evaluation of the effects of codes, standards, and regulations and the need for relaxation or additional controls

6. Consideration of various types of risk on a consistent basis minimizing the effects of emotions, fears, and personalities with regard to such related subjects as low probability, high consequence events, environmental and health issues, and immediate versus latent effects.

Various types and degrees of danger are thus treated objectively with biases minimized.

Thus, the role of risk assessment is to provide the necessary information to make decisions regarding the cost-effective commitment of resources to accident prevention and reduction. Risk assessment can also be used to determine if a proposed action is acceptable in those situations where it is impractical to eliminate particular hazards. Obviously, those areas where the greatest gains can be made with the least effort should be given top priority. Such prioritization will effect the greatest safety with any given level of effort.

Part of the accident-related evidence that investigators should gather and analyze is that which will indicate management's effectiveness in assessing and managing the risks in their operations. These indicators are found in several places including Safety Analysis Reports, systems or operations studies, design reviews and readiness reviews, and actual operational performance data. Also included are accident/incident experience and audit, appraisal, and inspection findings.

Past experience, expressed as actuarial data, is usually the best indicator of future occurrences, unless significant changes have been made in system structure or operation. If the underlying causes of past accidents have not been diagnosed and fixed, they will invariably result in recurrence of the same or similar accidents or other operational problems. Investigators, then, look at past experience of the organization to find the seeds of the accident being investigated. They seek to discover whether the accident was typical or atypical of the way the particular system functions. Such knowledge will assist them in their search for accident evidence and suggest areas of emphasis in their investigative approach. If the nature and consequences (losses) of this accident are typical of past system performance, basic systemic deficiencies are suggested, and the accident should have been expected by management. The investigative approach should include searching out and identifying these deficiencies, and recommending reasonable and realistic fixes for the operating system. If the accident occurrence is not characteristic of system functioning, loss of control of changes is suggested, and the investigative approach should be directed toward change identification and analysis. Recommendations should stress improved change analysis and control. In reality, things are rarely as simple as this, and the atypical occurrence is usually complicated with additional systemic problems. Also, when actuarial data on performance are used for risk evaluation and projection, the data consists of performance results and represents only a part of the total performance picture. In spite of these cautions, actuarial risk analyses performed by investigators following accidents have correlated well with true accident losses and timing.

There are a variety of risk analysis and projection methods. All of them are estimates, whether done on the back of an envelope, or specially designed graph paper on a hand-held calculator or on a computer. The focus of the effort dictates the method that should be used. For management decision making, the graphical methods show great merit and are probably the best in most applications.

Typical graphical risk analysis and projection methods are:

1. Gaussian normal—the normal bell-shaped curve that fits many populations of data, but does not fit accident/loss statistics very well without significant modification

2. A log-log plot of frequency-severity

3. A log-normal plot of accident data

4. Extreme value projection.

All of these graphical projections can be done on graph paper produced by the TEAM (Technical and Engineering Aids for Management) Company, in Tamworth, New Hampshire.

Extreme Value Projection. The Extreme Value Projection method will be the only one discussed because of its applicability. This method has proven to be the most helpful in accident investigations because:

1. It uses only the worst loss data, which is easy to find, even in activities which do not do a very good job of recordkeeping.

2. It is quick and easy to do, because minimal data are involved, only the simplest inputs are required, and return periods are read directly from the graph paper.

3. It is self-testing, in that good data on the right paper plot as a straight line.

4. Repeated use in accident investigation has shown good accident correlation. Risk projections of operating systems, done in connection with major accident investigations, have predicted both the magnitude and the return period of the accidents with reasonable accuracy.

The extreme value equation, on which the graph paper is based, is an empirical derivation of the frequency and severity of maximum events represented on the upper tail of the log-normal curve. The major difference between extreme value and log-normal analysis is that it uses only the maximum events, and log-normal uses all events. As previously mentioned, this is a key benefit of its use on accident investigation.

It should be relatively simple for any investigator to perform a risk analysis using extreme value projection, if he follows this nine-step sequence.

1. Select a time period immediately preceding the accident, during which there were no major changes to the operating system. For most DOE contractor organizations, this would probably not exceed five years, and for even the most stable operating systems, would be less than 10 years

2. Break down the selected time periods into appropriate intervals (i.e., years, half-years, quarters, etc.). Ten to twelve intervals gives a good confidence level, but as few as five is acceptable.

3. Identify the maximum loss (i.e., injury, lost time, property damage cost, etc.) in each interval.

4. Rank the losses from least to greatest

5. Calculate the cumulative probability, using the simple formula $N_i/N + 1$, where N is the total number of points, and N_i is the order rank of the loss. For example if there were 5 points, N would be 5, and N_i would be 1, 2, 3, 4, or 5, in order.

6. Select the right extreme value paper, i.e., with either a log or a linear loss scale. You can often tell by the distribution of the data which paper is right, but if you choose the wrong one (it doesn't plot as a straight line), you can redo the plot on the other. If the data does not plot as a straight line on either paper, you probably have used nonhomogeneous data. If they are closely related (i.e. fire losses from sprinklered versus unsprinklered facilities) they may plot as a dog leg. If that is not the case, homogeneity may be achieved by selecting a narrower loss category (i.e., electrical losses, injuries from falls, etc., rather than general property damage or injury losses).

You also have to choose a loss scale which permits you to project loss magnitudes beyond those already experienced. This corresponds to the cumulative probability formula denominator, N + 1, and enables the investigative analyst to determine return periods for greater system losses, if the system deficiencies are not fixed.

7. Plot the data, entering the ordinate and abscissa with loss magnitude and cumulative probability, respectively.

8. Fit the best straight line to the data points. If you cannot fit a straight line to the data, you have probably selected the wrong paper (i.e., log when you need linear, or vice versa).

   Note: If the plot approximates a straight line on linear extreme value paper, the accidental losses and the accidents from which they resulted are likely to be independent events, and the prevention of large accidents is well under control. If there is a straight line data plot on log paper, the plotted accident losses probably resulted from multiple causes that can be traced back to a common source or to cause interactions, both of which suggest system problems which can lead to very large losses. Also, the steeper the slope is, the weaker the loss control and the shorter the return period for a large accident.

9. Evaluate the plot to determine whether or not the present high accidental loss is characteristic of system performance (i.e., fits the straight line systemic data, or is an "outlier"). It should also be evaluated to find the return period for a still greater loss, if corrective system changes are not made in accordance with investigation board recommendations.

A simple example, using this step by step sequence, illustrates the ease of its application by investigators.

An accident resulted in a $49,700 electrical property damage loss. The operations people who experienced the loss declared that they could not understand how it happened, that it was a once-in-a-lifetime accident, and that it could not possibly happen again.

The accident investigators gathered the needed information on electrical losses over the previous five years to do an extreme value projection. These are the maximum losses they found for each of those years.

Year	Loss ($)
1979	593
1980	8,883
1981	707
1982	3,800
1983	49,700

They have now selected a relatively stable period of 5 years (step 1); have broken it down into yearly intervals (step 2); and have identified the maximum loss in each year (step 3).

They then rank ordered the losses from least to greatest (step 4).

Loss ($)	Ni
593	1
707	2
3,800	3
8,883	4
49,700	5

They calculated the cumulative probability, using Ni/N + 1 (step 5).

Loss ($)	Ni	(Ni/N + 1) x 100 (%)
593	1	16.7
707	2	33.3
3,800	3	50.0
8,883	4	66.7
49,700	5	83.3

They selected log extreme value paper as probably the right graph paper after seeing the three orders of magnitude distribution of the data. And they selected a loss scale which extended beyond the $49,700 maximum loss to $100,000 (Step 6).

They plotted the data (Figure 54), establishing each point by its dollar loss and corresponding cumulative probability (Step 7).

They fitted the best straight line through the data points, using the median regression method in Figure 55 (Step 8). The straight line confirmed homogeneous data and proper graph paper selection.

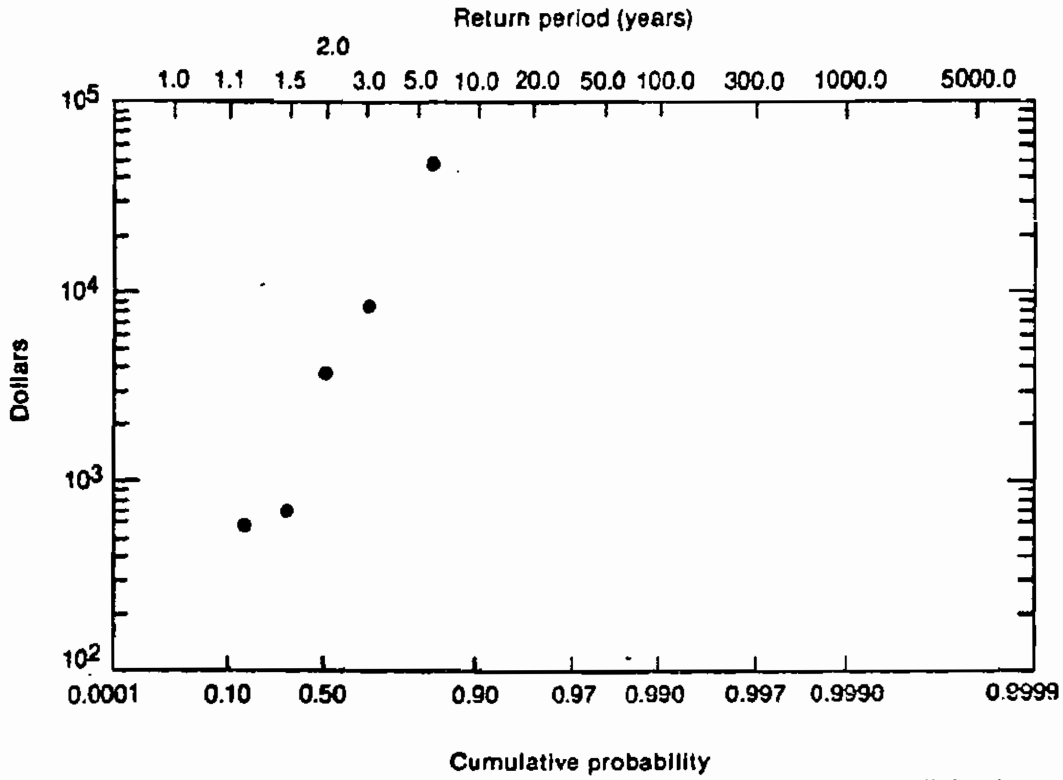

Figure 54. Extreme Value Plotted Data Points.

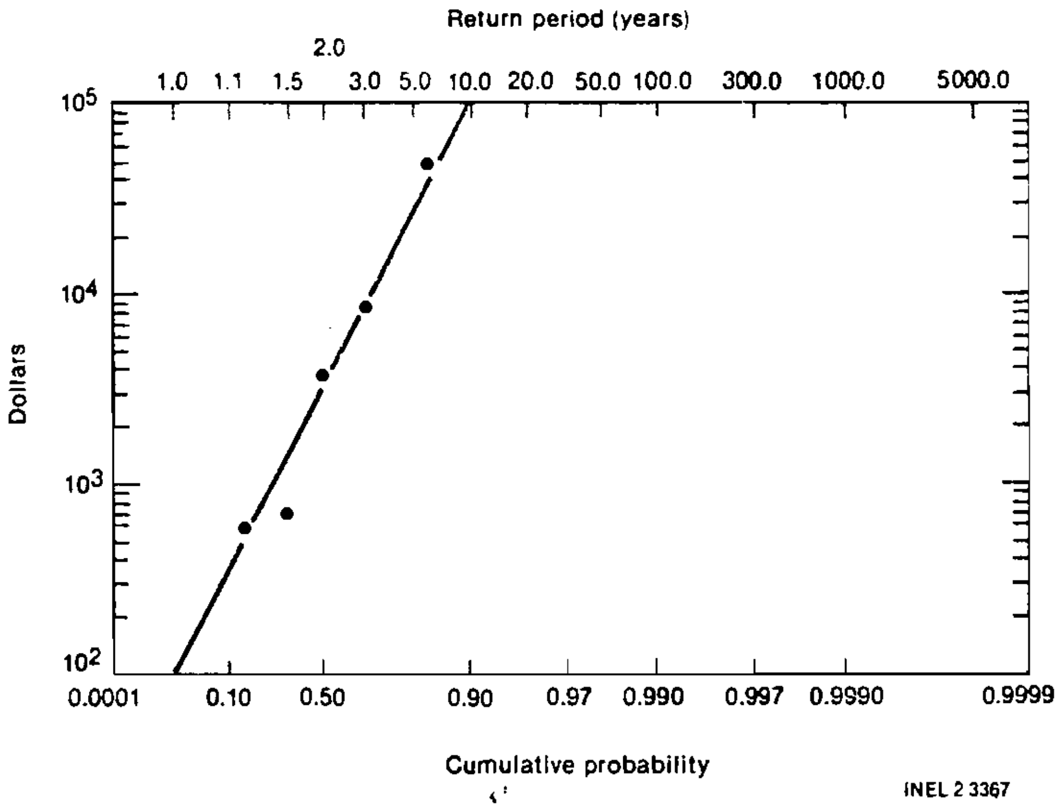

Figure 55. Extreme Value Projection.

Finally, they evaluated the $49,700 loss, found it to fall on the straight line data plot, and concluded that it was characteristic or typical of that organization's electrical loss control system (Step 9). That kind of accident was built into the system and would probably occur again in about 7 years, if the system was not fixed. The return period was determined by entering with the dollar loss value, finding where it intersects the data plot line, and projecting vertically upward to read the return period (Figure 56). They also determined the return period for a $100,000 electrical property damage loss as about 9 to 10 years. The extreme value projection risk analysis gave the investigators important information they would not have otherwise known, and confirmed their need to search out, identify, and evaluate the systemic deficiencies and multiple, interacting causes that led to the accident.

Time-Loss Analysis. When there are problems in the amelioration phase of accident management, the Causal Factors Analysis method can be effectively improved by incorporating Time-Loss Analysis (TLA). It is an analytical approach developed by the National Safety Transportation Board (NSTB) and reported by Driver and Benner. It deals with and evaluates the effect of various types of postaccident intervention on the final loss outcome of an accident.

TLA begins at accident occurrence (t_0) and continues to the determination of final loss (t_{end}), at least as far as it can be known and identified by the accident investigators. During amelioration, losses usually change with time, either increasing or decreasing. For example, once a fire begins and remains unchecked, it will continue to consume flammable materials, with cumulative losses increasing throughout the burn time. As firefighters respond and gain control of the fire, the rate of increase declines, and the direct loss total fire damage reaches its maximum when the fire is extinguished. If people were injured in the fire, and received proper and expeditious treatment for burns and other injuries, their individual injury (or loss) magnitude will decrease through the treatment

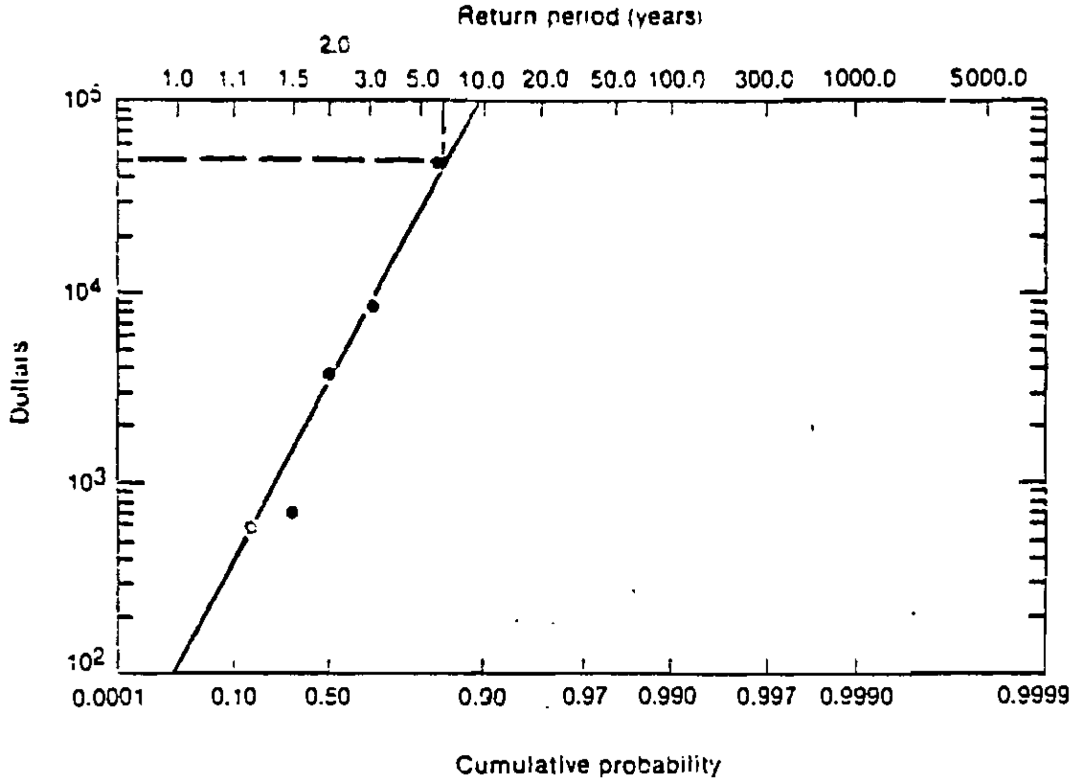

Figure 56. Return Period Determination for a Given Loss.

and rehabilitation period. On the other hand, total accident losses may well continue to climb, due to hospitalization, treatment, and rehabilitation costs. Additionally, other costs such as production decline, work delays, lost work time, accident investigation costs, OSHA penalties, workers compensation, and litigation costs and awards may contribute still further to escalate the total accident cost. It, therefore, becomes very important to identify and evaluate the nature and effect of all accident intervention actions.

Figure 57 depicts the typical loss pattern from accident occurrence at "to" until final loss, without intervention. When intervention action is taken, it can have a destructive, ineffective, or constructive effect on the natural loss pattern, as shown in Figure 58. "I_1" and "t_1" indicate that intervenor number 1 became involved in the amelioration process at time, "t_1".

Intervenors can be either people (personnel intervention) or things (mechanical intervention). Typical personnel intervention might involve such actions as using a fire extinguisher to put out a small fire, pulling a fire alarm, or calling the fire department dispatcher to report a fire. Mechanical intervention could involve a fusible link closing a fire door, a sprinkler actuating, or a flow alarm or smoke detector sending a signal to the fire department. Other classifications of intervenors might include (a) human, engineered and serendipitous, or (b) planned, impromptu and serendipitous. The serendipitous intervenor category would cover the fortunate coincidence when a fire in a facility without sprinklers burns a hole in a plastic waterpipe and releases a deluge of water, which extinguishes the fire.

Although most interventions of significance are triggered by accident occurrence, and, consequently, are in the postaccident phase, some interventions can precede the accident. Such preaccident intervenors are usually part of engineered safety systems that react before "t_0" to prevent loss.

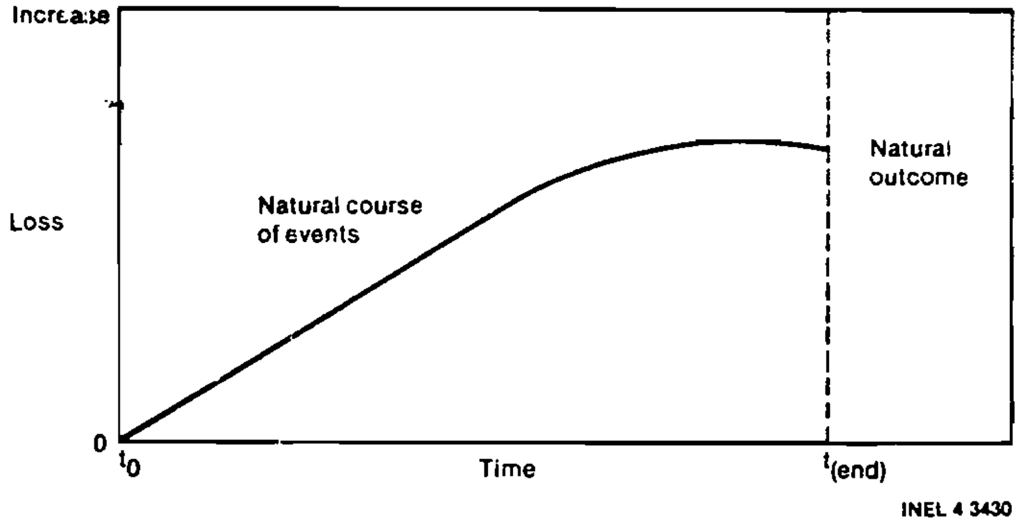

Figure 57. Typical Loss Pattern After an Accident Occurs.

Multiple intervenors are usually involved in accident response, as illustrated in Figure 59, which represents a fire in a bookstore. In addition to the normal racks of books, it contained a rare book collection in a vault that was not watertight. The indicated water damage to the rare books, in this case, exceeded the fire damage to the rest of the store. Important concepts to note here are (a) multiple interventions are usually involved, (b) not all interventions are equally helpful, (c) some interventions are destructive, (d) some interventions are helpful and destructive at the same time, and, most important, (e) effective accident management requires intervenor identification, evaluation, and emergency response planning to use the most beneficial interventions and eliminate the harmful effects of the others.

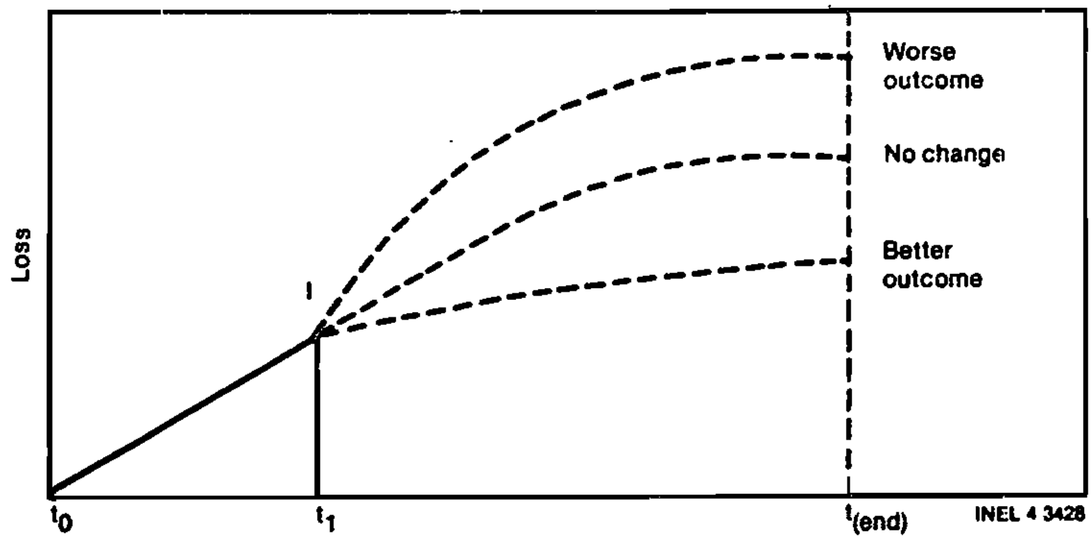

Figure 58. The Effects of Intervention.

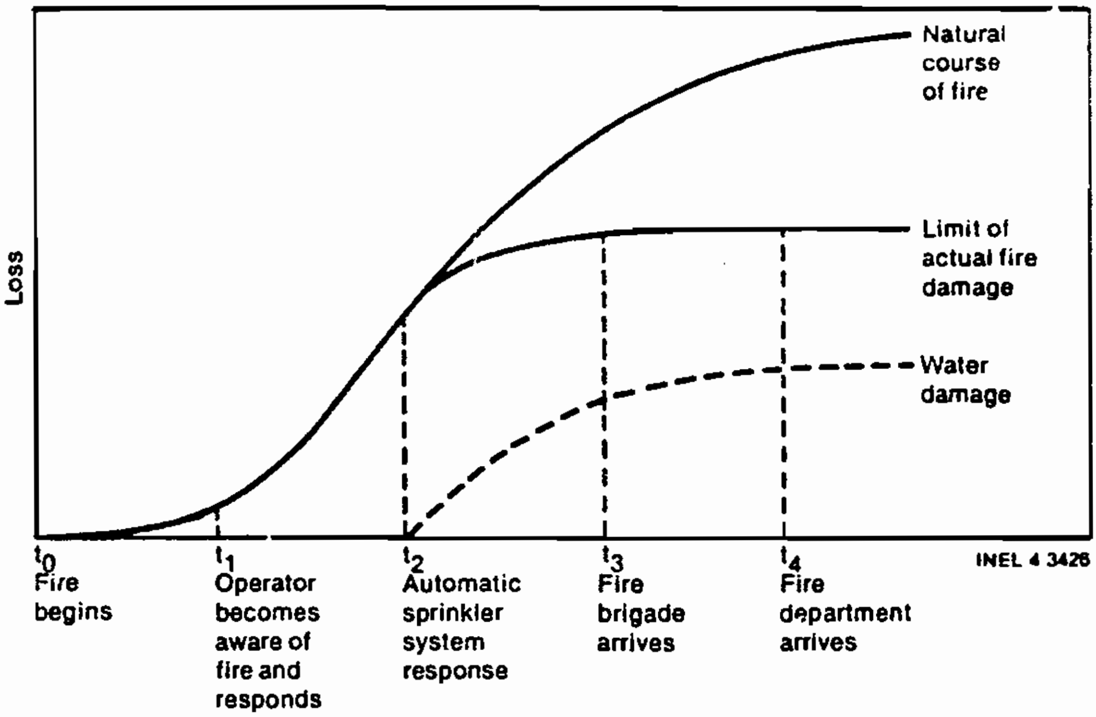

Figure 59. Multiple Intervention and Consequences.

The Time-Loss Analysis method is based on these concepts. It is a systematic method that investigators can use to identify and evaluate the effects of intervenor actions and make recommendations that can improve accident response planning and execution. The method consists of tracking, and then plotting on a time-loss diagram, the following:

1. The actions of all intervenors
2. The times they acted
3. The actual losses
4. The times the losses occurred
5. The relationships between intervenor actions and actual losses
6. The impact of the interventions on the natural (without intervention) loss outcome.

Time-intervenor relationships, time determinations, and related loss estimates become very important considerations in evidence collection. Perhaps the increased awareness of times involved and time-loss and time-intervenor relationships is the first significant benefit of TLA that the investigators will realize.

Driver and Benner employ two examples from NSTB experience to illustrate TLA and its depictions on time-loss diagrams. Figure 60 is a time-loss diagram using data from a 1975 highway accident. The loss values used are best estimates because of the uncertainties surrounding the time of death for the victims and the actual amount of the legal settlements during subsequent litigation.

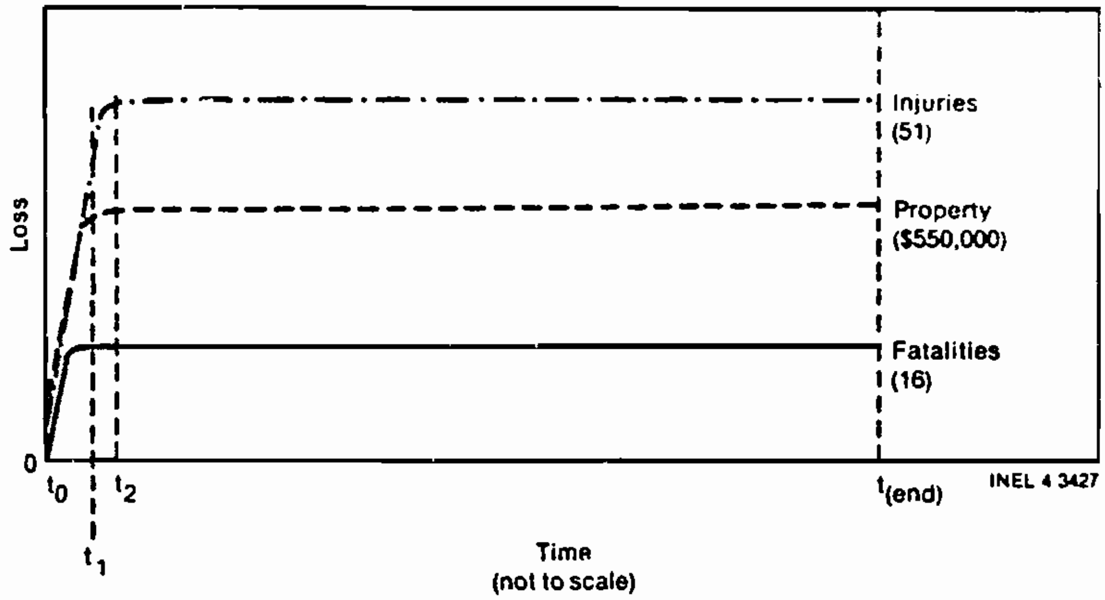

Figure 60. Time-loss Diagram—Example 1.

This accident involved the violent rupture of a bulk liquified flammable gas cargo tank during the accident, followed by the massive release of the gas, formation of a large vapor cloud, and sudden ignition of the vapors. A large tank section was propelled into nearby mobile home residences.

While the time is not precisely to scale, most of the losses in this accident occurred before any emergency response personnel arrived on the scene at time t_1. The 16 fatalities and 51 injuries were almost all burns. Property losses were estimated at $550,000. Losses before the arrival of emergency personnel at the scene illustrate how the time-loss diagram can show the importance of built-in safeguards on the dangerous goods container. The elapsed time between t_0 and t_1 was less than five minutes. Fires were extinguished quickly and the biggest problem was caring for the burn victims.

The second example (Figure 61) is a classic fire safety case, involving a railroad tanker transporting the same type of liquified flammable gas. The containment tank was damaged and weakened in a train derailment accident at a location remote from populated areas (t_0). Times "t_1" through "t_4" were arrival times for response people and onlookers from an adjacent highway. After 40 hours, a BLEVE (boiling liquid/expanding vapor explosion) ruptured the tank violently (t_5). The internal damage, weakened containment, vapor burning, and compartment bulkhead fatigue were not detected by response people who were around and on top of the tanker when it exploded. Fires resulting from the explosion ignited at "t_6." The time-loss diagram shows the initial property damage occurring at derailment and remaining essentially the same until "t_0 + 40 hours," when the explosion and fire killed several people, and burned and injured several others (some of whom subsequently died) and caused almost $2,000,000 property damage.

These examples illustrate or suggest important points about TLA and time-loss diagrams.

1. Loss types (fatalities, injuries, property damage, etc.) are broken out and plotted separately. Other loss types, not shown in these examples, such as law suits, OSHA penalties, business interruption or shutdown, should also be separately depicted.

2. Key interventions and their times of occurrence are depicted. Specific times (i.e., 8:30 a.m.,

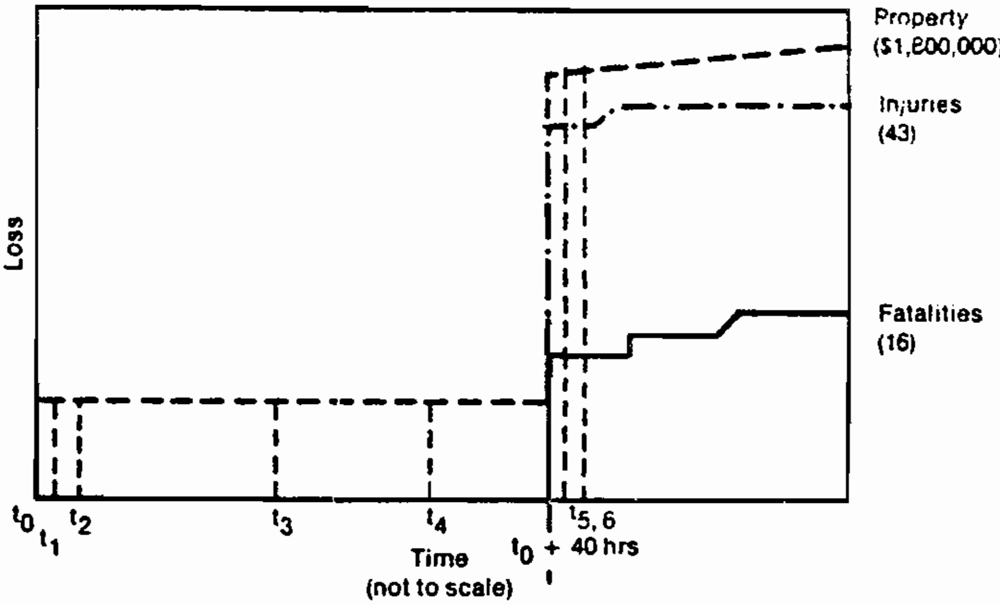

Figure 61. Time-loss Diagram—Example 2.

12:07 p.m., etc.) should be identified with "t," when possible. Specific concise descriptions of the interventions should also be included when possible.

3. The natural loss pattern and outcome should be estimated for comparison with intervenor effects and determination of their nature and timeliness of action.

4. Information obtained from time-loss analyses diagrams should be included in board recommendations and fed back to accident response planners.

Finally, TLA can feed MORT and change analyses. It is directly related to causal factors analysis and represents an amplification of the amelioration phase of the causal factors chart. It is so directly related to that chart that often accident investigators will plot the time-loss diagram and the causal factors amelioration phase together on the same sheet with a common time line.

Integrate Evidence and Develop Conclusions

Integration of investigative evidence and development of conclusions consist of the basic activities shown in Figure 62. Each will be discussed in turn.

Collected and derived evidence must be properly integrated to confirm that pertinent factual findings and analytical results have been considered, that no significant information gaps exist, and that all factual and analytical discrepancies and conflicts have been resolved, in so far as possible. To achieve this, investigators need to (a) cross-check information sources, (b) confirm adequacy of scope and depth of information collection, (c) validate factual consistency, (d) correlate and confirm analytical results, and (e) resolve factual and analytical differences.

Cross-checking of information sources includes comparison and validation within and between two general evidence areas: (a) that which is specific to the actual accident occurrence and (b) that which relates more generally

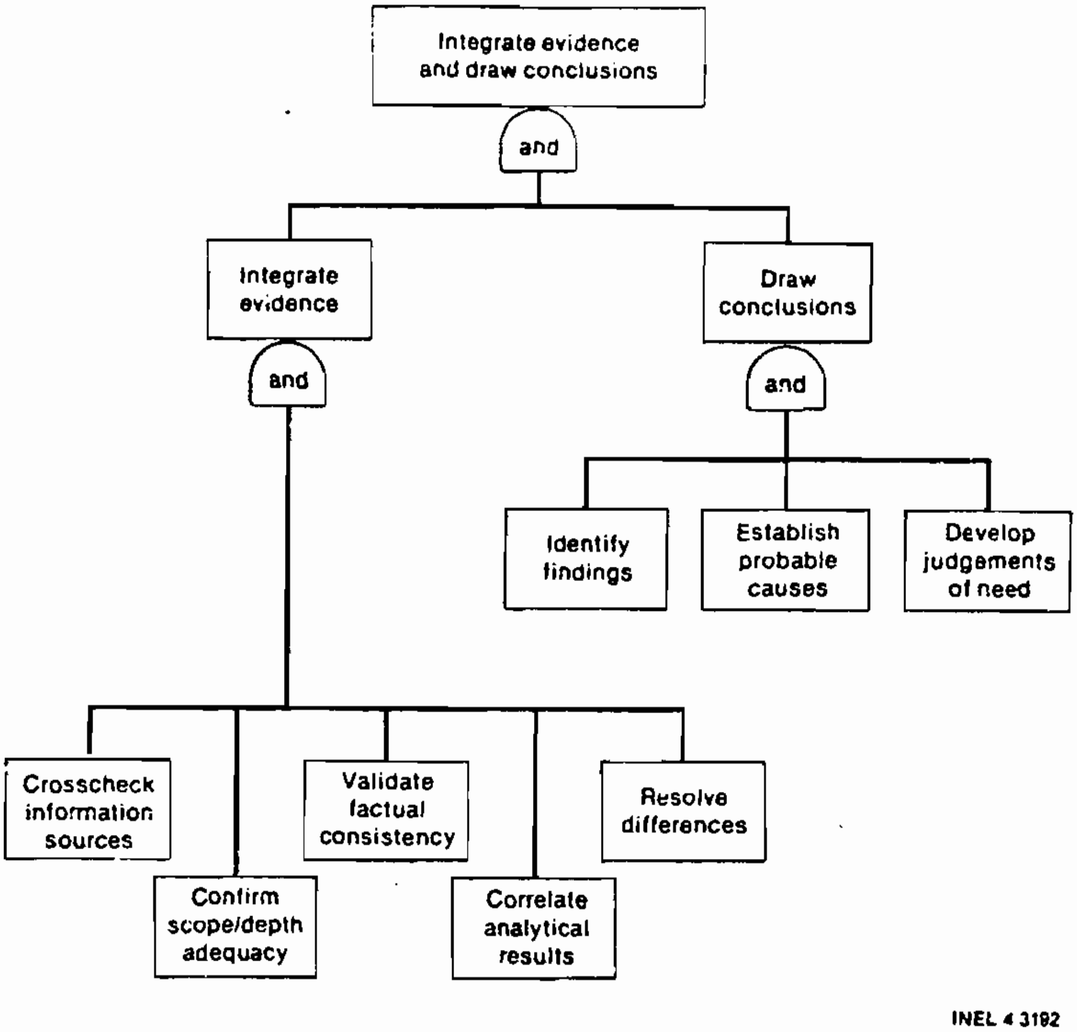

Figure 62. Integrate Evidence and Draw Conclusions.

to the system and disciplines involved. Information specific to the event is that obtained from onsite witnesses, physical evidence, and records and software. General systemic and technical information includes expert testimony; physical-engineering information; and historical-analytical information arising out of system development, upstream processes, operational evaluation, and configuration control. Cross-checking of information from these sources should reveal existing consistencies and discrepancies that confirm that necessary and sufficient evidence either has or has not been collected to arrive at complete and valid conclusions. If there is not sufficient evidence, more in-depth analysis of the information is needed, and more detailed evidence should be sought.

If any combination of informational contradictions between sources exist (such as those between the testimonies of two or more accident scene witnesses, between an onsite witness and an expert, between witness testimonies and physical evidence, or between physical evidence and paper evidence, between engineering analysis and physical, paper or people evidence), any of three responses may be appropriate. First, investigators should use all practical means to resolve the discrepancies or to search for unused means of validation. Second, if this effort proves unfruitful, then investigators should indicate the existence of contradictory evidence. Third, the investigator should cautiously conclude with qualifications suggested by the identified discrepancies and uncertainties.

Sometimes the contradictions or discrepancies are not important enough or relevant enough to really justify concern. For example, if a failure contributing to the accident arose from a common failure mode, the path to failure may be unimportant. When the common failure mode is fixed, the problem is fixed. Figure 63 depicts a pump bearing failure which originated from excessive nitrogen in the bearing coolant. Either of two sequences, (a) loss of heat transfer or (b) loss of lubrication, could have resulted in the bearing failure. However, it does not really matter which sequence was followed since the sequences had an identified common cause: the excessive nitrogen in the coolant. When that common failure mode is fixed and prevented from recurring, the problem is solved without looking in any further detail at the alternate failure paths.

Figure 63 also suggests that there are often occasions when accidents result from independent failure modes, and the failure mode must be determined to identify the cause and make the right fix so it will not happen again. A simple matrix (Figure 64) for comparing alternate hypotheses against both supporting and refuting evidence is very helpful in determining the most likely failure mode. Figure 65 depicts use of the matrix to evaluate human error versus mechanical failure hypotheses in the drop of a valuable gear box being lifted by a bridge crane. This example also illustrates the MORT principle of multiple, interacting accident causes, in that the gear box drop was attributed to a combination of human error, faulty design, and mechanical failure.

Another valuable aid in analyzing and evaluating contradictory information is an expanded, more detailed look at a portion of the causal factors chart. It is particularly helpful when there are different versions of the order in which critically time-sequenced events occurred. When the divergent testimonies are laid out, side by side, on a common time line, as shown in Figure 66, the correct sequence is often obvious.

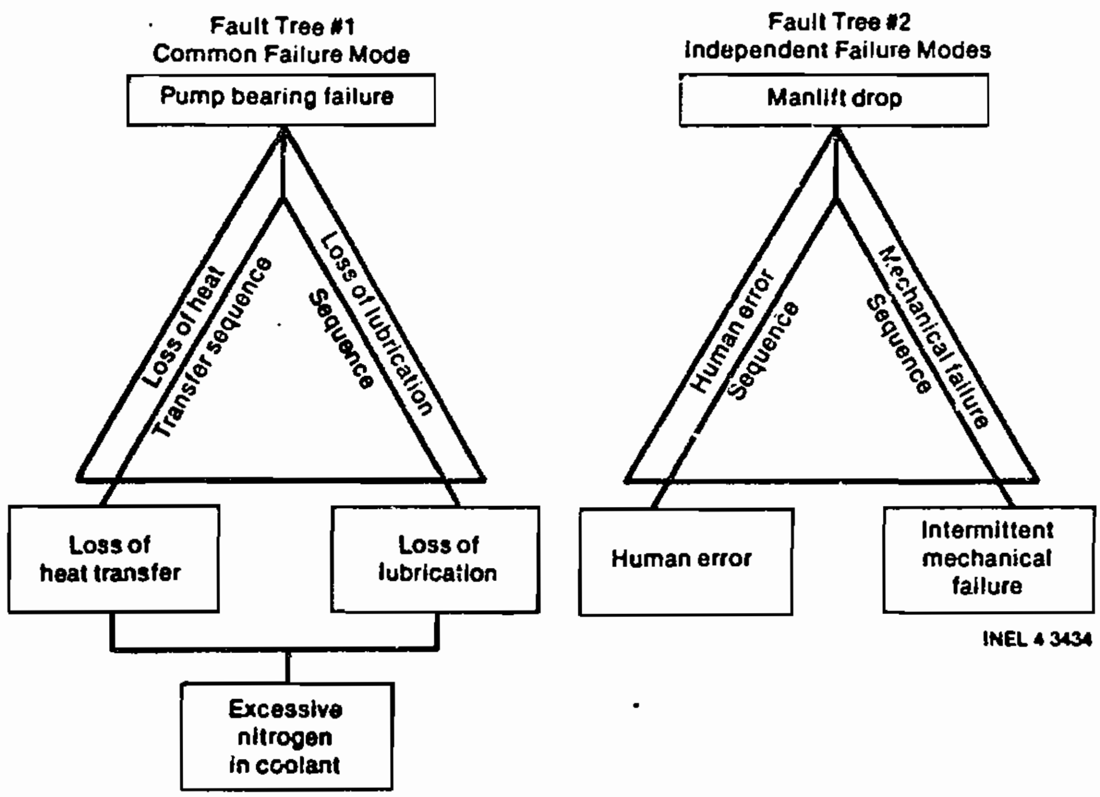

Figure 63. Alternate Failure Modes.

Evidence / Hypotheses	Supporting evidence	Refuting evidence

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Figure 64. Alternate Hypothesis Comparison Matrix.

Evidence / Hypotheses	Supporting evidence	Refuting evidence
#1. Brake failed	Maintenance & inspection LTA. Icing possible. Manufacture's representative said, "Looser than I'd like to use."	OK in 3 uses in 3 weeks. 30 minute warm up, powered up & down 3 times with adequate brake pressure. Load held at 2' stop. OK in test & inspection.
#2. Foot slipped or pressure released	No requalification program for operators. Seldom operated this crane. Brake pedal error-provocative. Brake on at end of fall.	"Most experienced & reliable operator". No evidence of collusion between witnesses.

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Conclusion: Combination of error & error-provocative situation
Recommendation: Fix crane and system and take no disciplinary action

Figure 65. Example of Matrix Use.

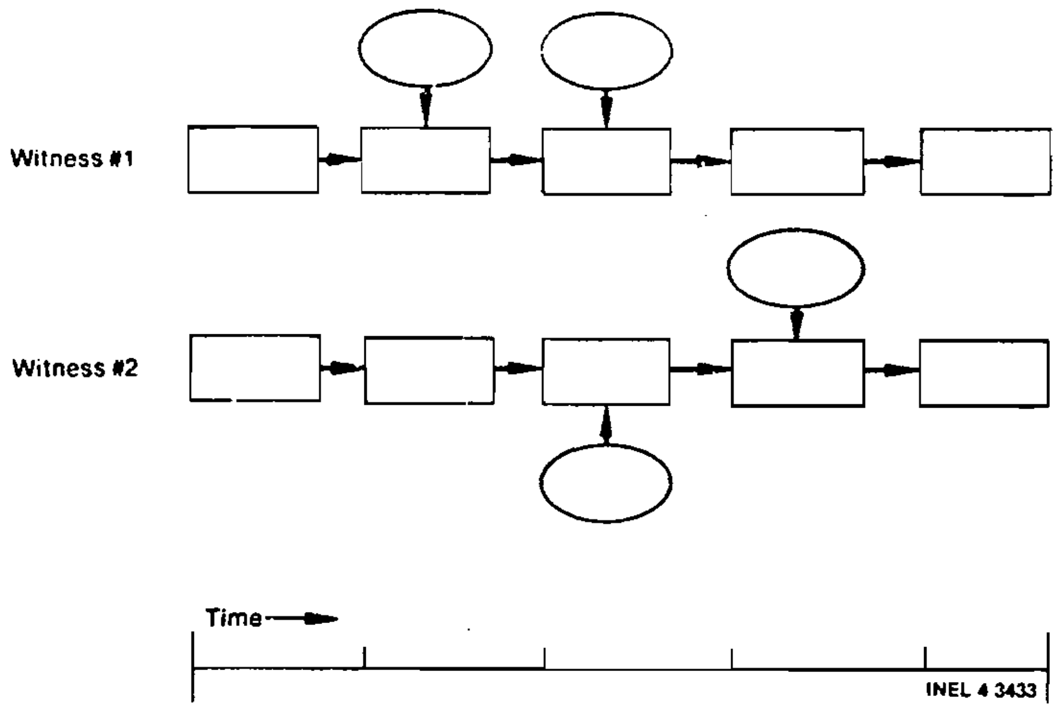

Figure 66. Time Sequenced Events Analysis.

When there is insufficient factual evidence or analytical results for valid conclusions, several actions can be taken. One, investigators should search for additional facts and perform more in-depth analysis of collected evidence. Two, they should identify possible conclusions and specify conclusions which can be definitely rejected or excluded. Three, they should indicate information deficiencies which cannot be resolved practically, and which make positive conclusions impossible. Fourth, they can cautiously conclude, with appropriate qualifications, and indicate what would be required to arrive at positive conclusions.

Selection and use of appropriate analytical methods is fundamental to validating and correlating factual findings; as illustrated in Figure 67, causal factors analysis is the key analytical method. All others are correlated with it and are fed into it or fed by it, just as analytical processes are both fed by and feed the search for factual evidence. The analytical methods not only help investigators make sense out of gathered factual data, but also assist in avoiding the invalidating, but common, practice of "assuming the obvious," in deference to relying on true factual finding and analytical results to arrive at meaningful and accurate conclusions.

Accident investigation board conclusions should identify the "what" (specifics) and "why" (systemic faults) of accident causation. Conclusions should also identify the areas within the operating system and work processes which were deficient in controlling the work situation and protecting people, things, and processes. Conclusions are made up of findings, probable causes, and judgments of need. The findings identify how the accident happened; probable causes identify what contributed to the accident; and judgments of need specify what needs to be done now in response to the accident investigation findings and probable causes.

Findings consist of the significant facts discovered and the analytical results obtained through evaluation of those facts. They should include both the strengths and the weaknesses in the operating system and the work situation in which the accident occurred. They should embrace management control system factors and also specific worksite control factors. They become sound and substantial when based upon well-structured and systematic fact-finding and analytical processes.

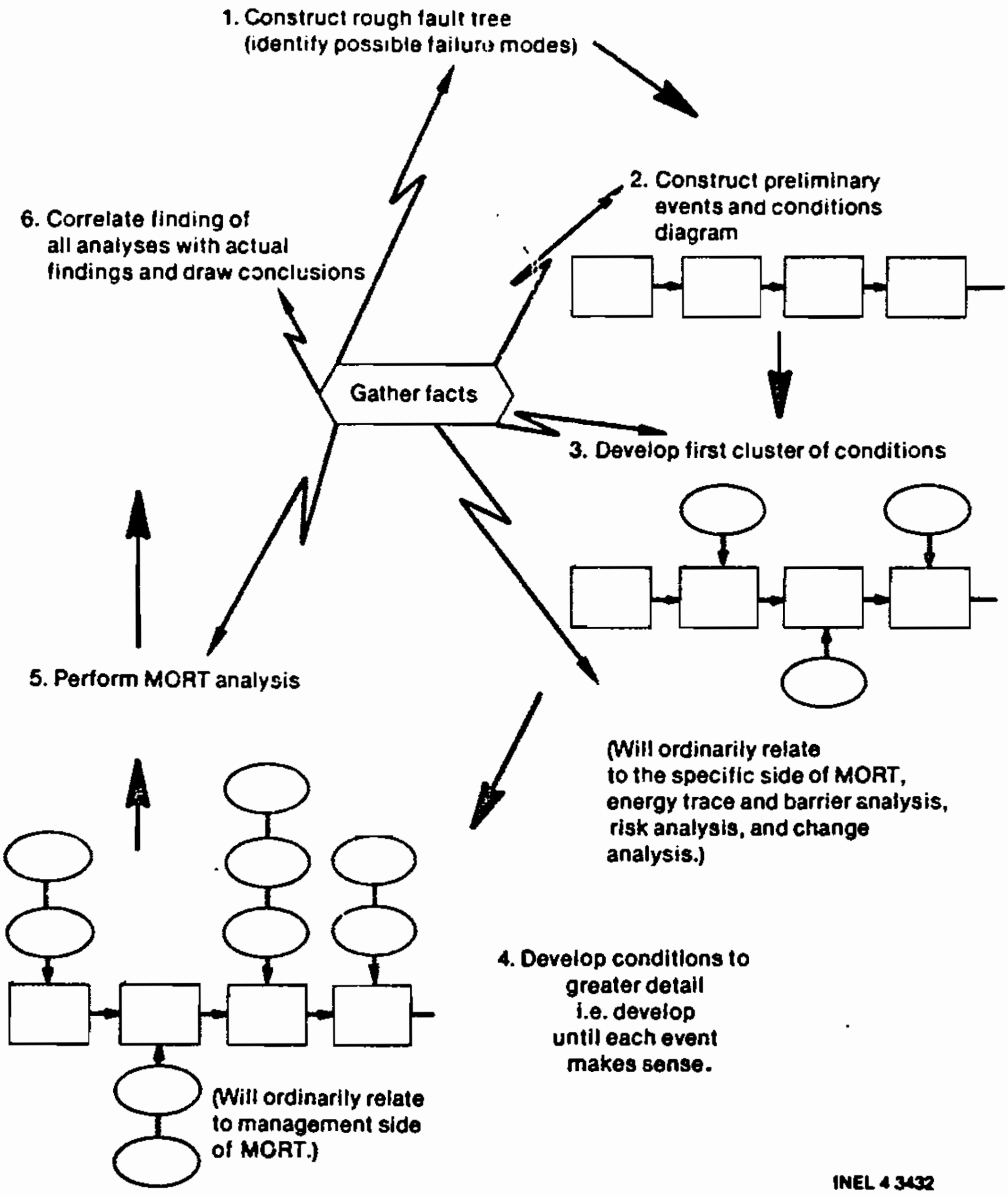

Figure 67. Correlation of Other Analytical Methods with Causal Factors Analysis.

Probable causes are the underlying errors and deficiencies which led either directly or indirectly to accident occurrence. The direct causes relate to what happened and how it happened, and are concerned with specific work site factors. Indirect causes identify why the accident was allowed to happen and are found in management system factors. Direct causes are often also identified as the immediate or proximate basis for the primary, major loss, i.e., injury, damage, etc. Indirect or contributing causes are those which contributed to hazard buildup, hazard release or exposure, ameliorative failures or errors, inadequate plans or preparation, inadequate hazard detection or correction, management system breakdowns, etc. Figure 68 (from Ontario-Hydro literature) shows a concise decision model for diagnosing the development of probable causes.

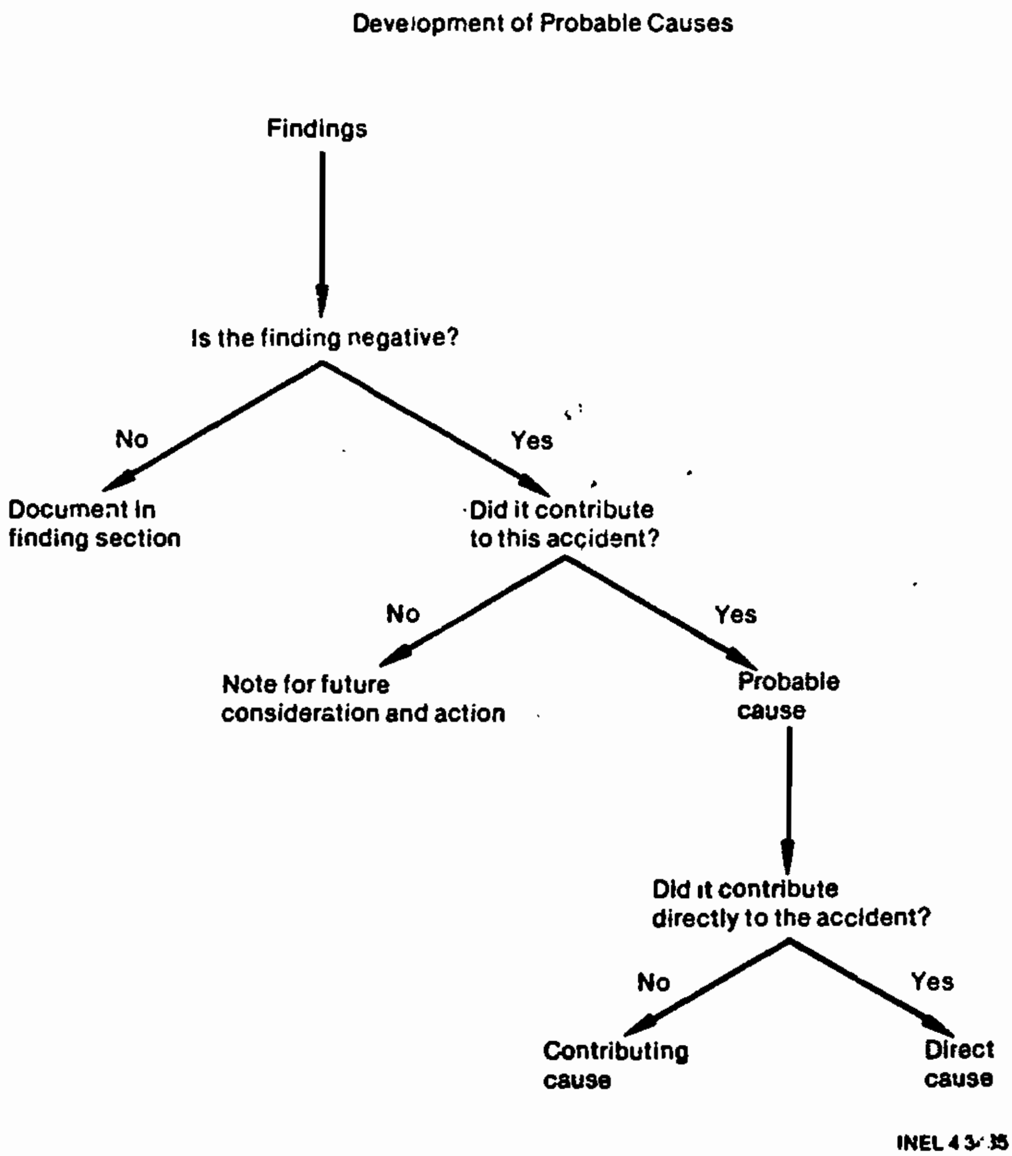

Figure 68. Development of Probable Causes.

Judgments of need represent the investigative board's conclusions regarding areas where managerial controls and safety measures should be applied to prevent or minimize the risks of recurrence of this or similar accidents. They flow from findings and probable causes and form the basis for structuring specific recommendations for corrective management actions.

Figure 69 shows relationships between the three divisions of investigative conclusions and the manner in which their common elements are tied together. Following (Table 1) are sample findings, probable causes, and judgments of need that illustrate their common ties and the development of one from the other, with both probable causes and judgments of need growing out of findings. Also included in Table 1 is a fourth column which displays the recommendations which relate directly to judgments of need. Note that judgments of need identify system and organizational needs as perceived by investigation board members, and recommendations identify what should be done by management to satisfy those needs It is important that the recommendations specify "what to do," not "how to do it," for that is the prerogative of line managers. Note also that there is sometimes a one-to-one relationship between findings, judgments of need, and recommendations; other times, several findings lead to one judgment of need, or a single judgment of need leads to two recommendations, etc.

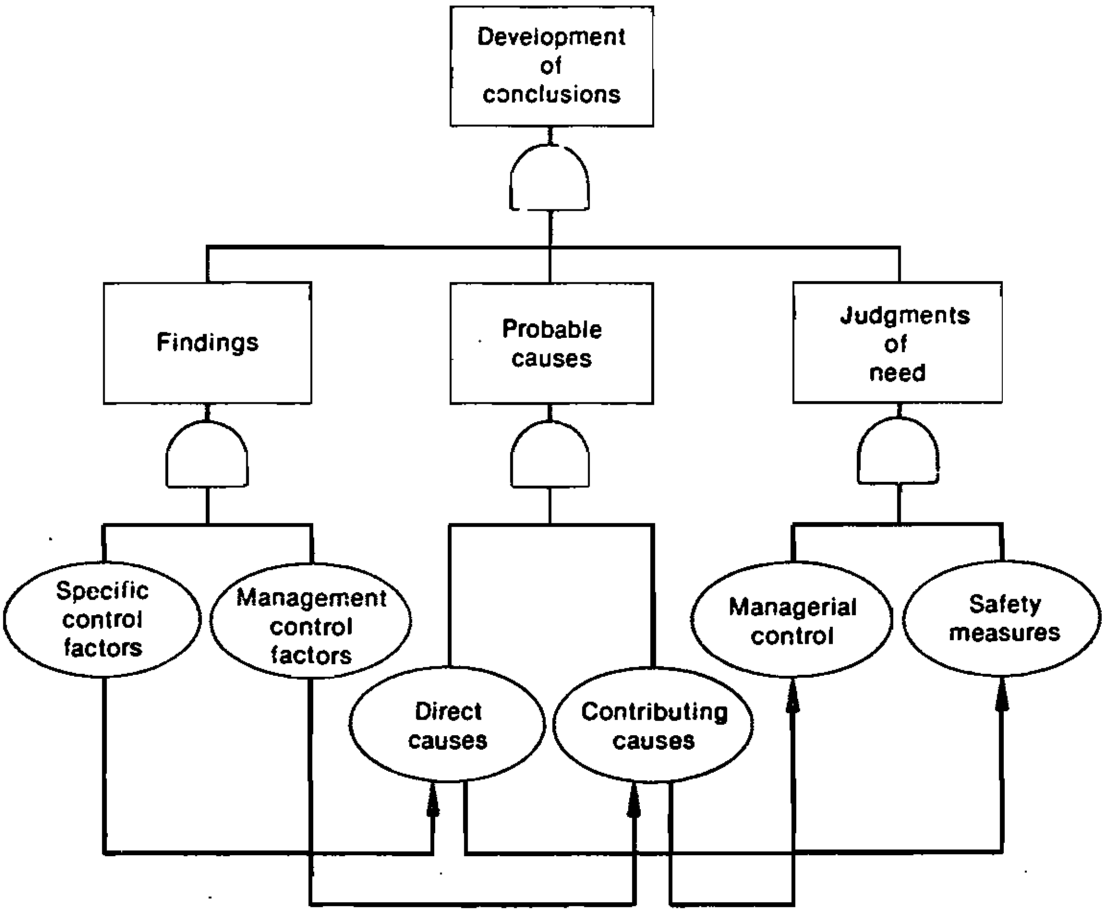

Figure 69. Relationship Between Findings, Probable Causes, and Judgment of Needs.

It is not only essential that continuity exist among findings, probable causes, and judgments of need, but also that all conclusions rest firmly upon a strong factual base. They should track logically, clearly and directly back through analytical bridges to their foundation facts. They should also track forward through additional analysis to practical, realistic, specific corrective action recommendations, as suggested by Figure 70.

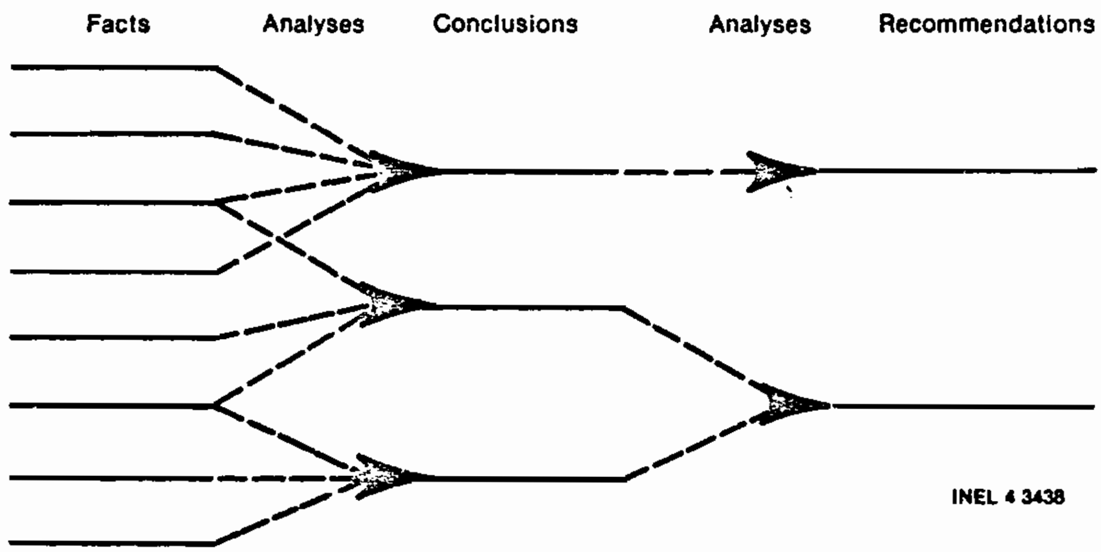

Figure 70. Facts, Analysis, Conclusions, Recommendations.

V. REPORT RESULTS AND TAKE ACTION

The purpose of the investigation report is to convey in clear and concise language the results of the investigation (the facts surrounding the occurrence, the analysis of these facts, and the conclusions). The investigation report constitutes a record of the occurrence by which the investigation is measured as to thoroughness, accuracy, and objectivity, and to which reference may be made at a later date. In addition, any corrective actions directed by the appointing or the reviewing official will be based largely on the contents of the report.

General

The investigation report shall consist of, but is not limited to, four sections: summary, facts, analysis, and conclusions.

The summary is a brief account of the essential facts of the occurrence and the investigators' conclusions. The facts section consists of a recitation of the factual information found in the course of the investigation. It should relate the "who, what, where, and when," of the occurrence. The analysis section of the report is based on the factual information developed and consists of the reasoning of the investigators which supports the conclusions. The conclusions section consists of the findings, the probable causes of and contributing factors to the occurrence, and the judgments of needs.

The investigation report should fully cover and explain the technical elements of the causal sequences of the occurrence and should also describe the management systems which should have, or could have, prevented the occurrence, e.g., the hazard review system and the quality assurance program for safety, including the monitoring of actual operations.

The investigators' recommendations for corrective actions to prevent a similar occurrence should not be contained in the report, but it should be included in the cover memorandum that transmits the investigation report to the appointing official.

Outline of the Report

1. Cover. The cover and title page should state the subject and date of occurrence, the date of the report, and the security classification. The cover and title page should not include distribution lists, internal organization nomenclature, name of organization participating or preparing the report, or other such information.

2. Table of contents. The table of contents should identify the sections and subsections of the report, illustrations, charts and appendixes with their report page number designated.

3. Scope of investigation. This statement should set forth the issues or objectives to be investigated and any special limitations or instructions to the board.

4. Summary. This section should be written in such a manner that the reader, who may be relatively unfamiliar with the subject matter, can obtain the essential facts, the findings and the probable causes and contributing factors with a minimum of effort and time. The summary should not contain information that is not discussed elsewhere in the report.

5. Facts. This section of the report should cover the major areas of investigation in a uniform manner and in a reasonable, logical sequence. Another good board investigating this same accident should be able to reproduce this section. The section should:

   a. Be factual and not include any conclusions

b. Give the reader a good understanding of the accident

c. Stress the areas of the accident investigation bearing on the causal consideration

d. Establish a complete and substantive basis for the analysis and conclusions sections of the report, ensure both accuracy and completeness, and eliminate the tendency to introduce new facts in the analysis and conclusions sections

e. Stress the areas which form the basis for corrective measures

f. Inform the reader, where appropriate, that additional information on a subject is contained elsewhere in the report. Give a concise extract from or description of the reference, and specify the section or appendix where it can be found.

g. Not omit any relevant fact for any reason whatever, i.e., that it might conflict with some preconceived notion of the investigator or interfere with the dissemination of information (bulletins, news releases, etc.). Investigators must, at all times, be critical of their own reasoning to ensure a completely objective and independent account of the occurrence. Examples of information to include are:

   (1) Pertinent background information, when available and appropriate, i.e., brief description of facilities, climate, history, etc.

   (2) Description of injury, exposure, or loss due to the occurrence, as well as the property damage and decontamination costs

   (3) Physical evidence

   (4) Chronological account of events

   (5) Physical hazards and review of safety controls

   (6) Technical data accumulated

   (7) Related events not in the causal sequence, but revealing deficiencies (to be placed at the end of the section).

6. Analysis.

a. This section is intended to present an analysis of the factual evidence collected in the investigation. Its purpose is to show the reader the interpretation of the facts, conditions and circumstances, and inferences which support the findings, probable causes, and judgments of need. This section should include a discussion of the causal sequences, and due consideration should be given to charting the relationship of events and causal factors. Speculated events, facts in controversy, denial of allegations, as well as what could not be determined should also be discussed in the analysis section.

b. Do not introduce additional facts in this section.

c. Make the analysis lead up to the findings, probable causes, and judgments of need. The qualified reader should be able to anticipate the causal factors from the analysis.

d. Make the analysis "accident prevention-worthy" not "blameworthy."

7. Conclusions.

   a. Findings. This subsection consists of significant facts and analytical highlights.

      (1) Organize findings sequentially, preferably in chronological order or in logical sets of sequences, e.g., hardware, procedures, people, organization.

      (2) State analytical conclusions that are clearly supported by the facts and analysis.

      (3) Keep findings to a reasonable number. They are a recap of the significant facts and the analytical highlights, not the entire sequence of events.

      (4) Keep findings as short as possible, and, to the extent possible, put only one highlight in each finding.

   b. Probable causes. The statement of probable causes shall consist of a series of relatively simple statements which summarize the causes and contributing factors, including systematic factors.

   c. Judgments of need. This section consists of the investigators' conclusions as to the kinds of managerial controls and safety measures necessary and sufficient to prevent a recurrence or to minimize its probability or severity. These judgments provide the basis for the subsequent recommendations for corrective action. These statements should be clear, concise, and direct and should be based on the weight of the substantive evidence.

8. Signatures. The chairman and members of the board should sign the report. Any board member has the right to set forth a dissenting opinion about report analyses and conclusions. A dissenting position should be stated in a letter to the board chairman and be transmitted to the appointing official with the investigation report.

9. Minority report. If there is a minority report, it should be limited to those analytical highlights and conclusions which are at variance. The minority report should be signed.

10. Board authority. This is the letter (board appointment) which established the investigation board. It shall include the names, employer, job titles, positions of board members, and the authority for the investigation. It should also detail the scope of the investigation including any limitations. It should be the first appendix or exhibit.

11. Appendixes (exhibits). Material that is pertinent but need not be made a part of the written report in order to understand or use the report should be included as exhibits to the report and should follow the body of the report. These may include written statements, witnesses' statements, letters, laboratory analyses, memoranda, pictures, death certificates, etc. Medical records and legal opinions should not be included in the report.

    Only material that a reader may want to evaluate or material that is in controversy should be included in the appendixes. All such material should be identified with the same label, e.g., "Exhibit A," "Exhibit B," etc. Every exhibit should be introduced in the report in appropriate sequence and, at the time introduced, there shall be a brief recitation of its contents. Long, detailed, complex exhibits shall be avoided.

Recommendations

The natural followup to the judgments of need is the recommendations. Each board should arrive at recommendations intended to prevent similar occurrences. Recommendations should identify to management "what" should be done, not "how" to do it. The utmost care should be exerted in forming the recommendations, so that all are clear-cut, feasible, logical, specific, and applicable to the operations for which they are intended. They should be extended to include the systems that permitted the accident to occur, but only to the extent of relevance. These recommendations should be transmitted to the appointing official in the cover memorandum for the investigation report.

The purpose in separating the recommendations from the body of the report is to reflect the actual implementation process. The head of the field organization, the Office of Operational Safety, the Secretary, and finally the Congress may add to or modify recommendations. In practice, higher authorities have often added or strengthened recommendations. They have seldom, if ever, deleted recommendations. Recommendations concerning major policies or large funding requirements are properly reserved to the Secretary or the Congress.

Figures in the Text

Text figures can be a powerful, easy-to-use aid in reading and understanding. Maps, schematics, and flow diagrams should be simplified and void of unneeded detail. Photographs should have a caption and carry labels, measurements, or other marks to aid in their interpretation.

In general, the figures can be expected to follow an order similar to the following:

1. General map or aerial photograph
2. Area of occurrence (use map or photographs to show locations of personnel, property damage, witnesses, and equipment)
3. Process flow
4. The equipment involved (show if damaged, and show a normal counterpart if available)
5. What the operator and witnesses saw
6. Close-up photographs or drawings (such as cutaways)
7. Debris
8. Amelioration (fire, rescue, etc.).

All of these are included, if significant.

Simple text tables of numbers, if needed to understand findings, can be included in the body of the report; otherwise they should be placed in exhibits or retained in committee files.

Exhibits and Appendixes

1. Exhibits should be relevant, simple, and short. When you have any doubt about including an exhibit, leave it out. The following are examples of exhibits which should be in the report:

    a. Relevant quotes from DOE policy, contract clause, and OSHA general duty clause. (If these are seen as a "standard of judgment" for the conclusions or recommendations, perhaps they belong in those sections.)

b. Details needed to assess the accuracy of findings, where such assessment is likely

   (1) Procedures or excerpts to show gaps or deficiencies

   (2) Written statements

   (3) Additional maps, schematic, or pictures, if needed

   (4) Death certificate—a public document.

c. Details to help the uninformed understand the report; for example, characteristics of chemicals, or explanations of flow or process schematics

d. Pertinent extracts from witness statements. Do not use unless they are really needed for clarity and understanding.

e. Summary Causal Factors charts, if it is not included in the analysis or summary sections of the report (the preferred positions)

f. Brief description of investigative method if not included in the analysis section, so silence is not construed as lack of action; for example, the scene was (was not) secured; the scene was visited and when; a MORT analysis was performed, etc.

g. List of participants by name, title, and organization. This is suggested even if names were used in text. Further, the list should either show supervision and higher supervision of all relevant units, or an organization chart should be included.

h. Personal histories, but only if relevant, nonconfidential, and needed to substantiate a finding or conclusion

i. Samples of news clippings that may help assess public impact

j. A list of material in board files

k. When classified material is used, include it in a separate classified exhibit

l. The working events and causal factors chart should be included.

2. Do not include in the report:

   a. Exhibits not in controversy. One recent report had work orders, radiologs, lists of personal effects, and two weather reports, none of which contained information likely to be assessed. A board finding that "the wind was 5 mph from the SSE" should be adequate.

   b. Personnel records

   c. Medical records, even if released. Medical records are exempt from disclosure under the Freedom of Information Act. Let the physician's medical evaluation of event-related matters (either in text or exhibit) be sufficient.

   d. Legal opinion, consisting of an informed estimate of amounts, probability, and validity of possible claims against the government or information to refute or mitigate the claims of questionable validity. This information should be prepared by the legal office and transmitted to the Office of the General Counsel by separate memorandum.

Investigation Files

The board file should be a complete record of the investigation for permanent retention in the office of the appointing authority. The file should include such material as:

1. Minutes of board meetings. Usually these record no more than brief procedural steps and actions. Do not, for example, include witness testimony or other material included elsewhere in the file.

2. Field notes, sketches, and measurements

3. Originals of all witness or other statements or transcripts of stenographic notes and tapes

4. Any additional photographs not used in report

5. Results of tests or reenactments

6. Location and custody of physical evidence

7. Process diagrams and procedures

8. Routine logs and memoranda not in controversy, e.g., weather reports

9. A record of analysis performed, e.g., MORT and analytic work sheets

10. Details of adverse consequences.

File materials identified in an exhibit may be subpoenaed in the event of litigation. Any privileged or proprietary material which should not be available or subpoenaed (other than classified information) should be excluded from the list.

Medical or personal records should be returned to their proper files.

Personal notes may include notes useful in refreshing memory if called to testify. Any notes reflecting personal opinions as to cause, if retained, should be in such a personal file.

Better Writing

1. The objective is a report that is "intelligible to the technical-minded layman."

   Suggestions for analysis and report format are summarized as follows:

   a. A clear, logical outline is the first step in good writing. If you are not ready to write, continue adding detail to the outline until you feel ready.

   b. Maps, schematics, and photographs in the body of the text should be near the descriptive text.

   c. Essential, but complex or detailed material should be in exhibits rather than text.

   d. Eliminate unnecessary and irrelevant detail in text and exhibits.

   e. Include a description of participants and units by title and function, so that their roles can be understood.

f. Include a glossary of unfamiliar terms, when needed.

g. Use short, active words and sentences and short paragraphs.

2. Be your own harsh critic. Do not embarrass yourselves or your appointing authority by giving him a poor report to transmit for approval. Do not hesitate to rewrite for editorial improvement. Most appointing authorities will require you to do so, if you don't do it on your own.

   a. Do some writing each day of the investigation.

   b. Write, rewrite, correct, edit, shorten, and review.

   c. Ask secretaries to question things they do not understand.

   d. Ask an editor to critique your work.

   e. Ask a technically minded layman to read and comment.

   f. When feasible, ask the appointing official or his representative to review the report to ensure that it fulfills expectations.

3. Follow a reasonable step-by-step structuring process.

   a. Select facts, analyses, and conclusions to be included in the report.

   b. Use a systematic method to ensure continuity from facts to conclusions and recommendations.

   c. Edit the report contents into a clear, consistent, readable style.

   d. Select and design graphics to support and simplify the text.

   e. Select necessary backup material with care for inclusion in the appendixes.

   f. Prepare the report summary.

   g. Submit draft report for review and approval.

Report Review

The report should be reviewed by the appointing authority and those he designates. A brief, initial review should be performed to determine the individuals who are best qualified to conduct a more in-depth report review. Those selected should include technical reviewers, managerial reviewers, investigative reviewers, and professional safety reviewers.

The report should be evaluated against DOE Order 5484.1, other applicable DOE Orders and Implementing Directives, and this Accident Investigation Manual. It should determine whether the scope and conduct of the investigation were appropriate and well documented, and whether the investigation resulted in recommendations that will prevent recurrence. Criticism should be constructive, should benefit the organization involved, and should improve the quality of DOE's accident investigation program in general.

Specific consideration should be given to the following items by each reviewer.

1. Are the facts sufficient, complete, and correct?

2. Is the analysis relevant, accurate, and adequate? Has it resulted in solid, well supported conclusions?

3. Have the conclusions resulted in needed recommendations?

4. Do the recommendations satisfy the judgments of need?

5. Has the full scope of the investigation been addressed?

6. Are there major deficiencies in format, clarity, and editorial quality?

In many instances, a critique of the report will be provided to the investigative board and others involved in DOE's accident investigation program, with the intent of improving the quality of investigative reports. Items normally addressed in these critiques include:

1. Appropriate facts and conclusion in the report

2. Clarity of the text and quality of editorial content

3. Minor deviations in format and organization of the report

4. Clarity and understandability of photographs and figures

5. Reasonable detail in text, figures, and exhibits.

Normally, the review coordinator will consolidate the findings of all designated reviewers and advise the appointing official of their findings. He will then direct appropriate action on the basis of the review.

Recommendations and Corrective Actions

Recommendations and corrective actions following an accident generally fall into four basic categories: (a) immediate actions, (b) board recommended actions, (c) appointing authority corrective actions, and (d) DOE Headquarters corrective actions.

1. Immediate corrective actions are taken by the accident organization to prevent a second occurrence or aggravation of the first.

2. Board recommended corrective actions to prevent accident recurrence and to correct system problems are transmitted through the appointing authority.

3. Following review of board recommendations, the appointing official may recommend additional corrective actions that he feels are appropriate for the operation involved and other organizations with similar accident potential. His recommendations are included in the memorandum transmitting the investigation report to the Office of Operational Safety.

4. After DOE Headquarters review of board recommendations and appointing authority corrective actions, major policy issues that may have emerged will be discussed with the Secretary. Any additional corrective actions suggested by Headquarters will be transmitted by memorandum to the appointing authority and other DOE field organizations whose contractors conduct operations with similar accident potential.

When all recommended corrective actions have been satisfactorily completed, the appointing authority or his designee will close the case. Type A and Type B board investigations must be closed out officially with notifications to the Office of Operational Safety, the Inspector General, and appropriate programmatic division directors.

Followup Roles of Accident Investigators

When the board submits its final report of the accident investigation with its letter of recommendations, its work as a board is generally completed. There are several occasions, however, when specific board members (usually the Chairman and/or Trained Investigator) have some continuing responsibilities related to the investigation. They may be called upon to perform any or all of the following:

1. Interpret board conclusions and recommendations
2. Validate the adequacy of proposed corrective actions in meeting the intent of board recommendations
3. Provide information to others who conduct operations with an accident potential similar to that investigated by the board
4. Track progress on corrective actions recommended by the board and verify satisfactory completion and close-out
5. Maintain investigative files
6. Testify at litigations arising from the investigated accident
7. Perform other followup tasks requested or assigned by the appointing authority or other higher level managers.

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APPENDIX A

SUMMARY OF REQUIREMENTS FOR DOE ACCIDENT NOTIFICATION, INVESTIGATION, AND REPORTING

APPENDIX A

SUMMARY OF REQUIREMENTS FOR DOE ACCIDENT NOTIFICATION, INVESTIGATION, AND REPORTING

The charts of this appendix summarize DOE requirements for notifying authorities and investigating and reporting accidents. They are intended to serve as a quick reference aid. This summary is based on the DOE Order 5484.1, dated 2-24-81 and is subject to changes if the order is changed. This summary was originally published as Environmental Safety and Health Bulletin No. 1, DOE/EP-0031/1.

Table A. Summary of U.S. Department of Energy requirements for accident notification, investigation, and reporting for damage to property

Description	Notification			Investigation			Reports and Forms	Order DOE 5484.1 Reference
	Immediate	Within 72 Hours	Quarterly	Type A All-DOE Board	Type B DOE and/or Contractor	Type C By Involved Organization		
(Value Basis Reporting)								
Property loss or damage $250,000	x			x			Formal report and F5484.5	Chapter I, 1 c
Property loss or damage $250,000 but $100,000	x				x		Formal report and F5484.5	Chapter I, 1 c
Property loss or damage $100,000 but $ 50,000		x			x		Formal report and F5484.5	Chapter I, 1 a
Property loss or damage $50,000 but $ 1,000			x			x	F5484.5	Chapter II, 1 c (3)
Motor vehicle loss or damage $ 50,000 but $250.00			x			x	SF91A	Chapter II, 1.c (2)
Summary of property damage experience			x				F5484.4	Chapter IV, 3 b
(Hazard Basis Reporting)								
Nuclear explosive involved with explosion, fire spread of radiation, injury, death, damage [a]	x			x			Formal report	Chapter I, 1 d
Loss or theft of a material that could pose hazard to individuals	x			x			Formal report	Chapter I, 1 g
Unintended nuclear criticality	x			x			Formal report	Chapter I, 1 j
Radiological assistance occurrence	x			Level to be determined by head of field organization				Chapter I, 1 o
Request to offsite authority for emergency assistance on nuclear operations	x			Level to be determined by head of field organization				Chapter I, 1 p
Unplanned nuclear excursion in a reactor		x			x		Formal report	Chapter I, 2 g
Radioactive shipment that has leaked or contaminated above DOT regulations		x		Level to be determined by head of field organization				Chapter I, 2 h and 2.i

a. Refer to Order DOE 5484.1, "Environmental Protection, Safety and Health Protection Information Reporting Requirements," for specific criteria.

Table B. Summary of U.S. Department of Energy requirements for accident notification, investigation, and reporting for damage to people

Description	Notification			Investigation			Reports and Forms	Order DOE 5484.1 Reference
	Immediate	Within 72 Hours	Quarterly	Type A All-DOE Board	Type D DOE and/or Contractor	Type C By Involved Organization		
(Injuries and illnesses)								
Fatality or imminently fatal	x			x			Formal report and OS forms	Chapter I, 1.a
1 occurrence with 5 or more cases of lost workdays	x			x			Formal report and OS forms	Chapter I, 1.b
Hospitalization for an illness		x			x		Formal report and OS forms	Chapter I, 2.b
Series of illnesses of 5 or more people with at least 1 lost workday		x			x		Formal report and OS forms	Chapter I, 2.c
Illness with more than 5 lost workdays		x			x		Formal report and OS forms	Chapter I, 2.d
All other occupational injuries and illnesses			x			x	Standard OS forms	Chapter II, 1.e (1)

Table B. Summary of U.S. Department of Energy requirements for accident notification, investigation, and reporting for damage to people

Description	Notification: Immediate	Notification: Within 72 Hours	Notification: Quarterly	Investigation: Type A All-DOE Board	Investigation: Type B DOE and/or Contractor	Investigation: Type C By Involved Organization	Reports and Forms	Order DOE 5484 1 Reference
(Radiation Exposure)								
Single or annual accumulated whole-body (WB) radiation exposure 25 rem	x			x			Formal report and HP forms	Chapter II, 1 h
Single radiation exposure 75 rem to skin (WB)	x			x			Formal report and HP forms	Chapter II, 1.h
Single radiation exposure 150 rem to forearms or 375 rem to hands or feet	x			x			Formal report and HP forms	Chapter II, 1 h
Internal uptake of radiation material 5 times annual standard	x			x			Formal report and HP forms	Chapter II, 1 i
Radiation exposure in one calendar quarter exceeding: • 5 rem WB • 15 rem skin WB or thyroid • 30 rem forearms • 75 rem hands or feet		x			x		Formal report and HP forms	Chapter II, 2.e
Internal uptake of radiation material annual standard standard		x			x		Formal report and HP forms	Chapter I, 2.f
Radiation exposure in one calendar quarter exceeding: • 3 rem WB • 5 rem skin WB or thyroid • 10 rem forearms • 25 rem hands or feet			x			x	Standard HP forms	Chapter II, 1 e (4)

a. Refer to Order DOE 5484.1, "Environmental Protection, Safety and Health Protection Information Reporting Requirements," for specific criteria.

b. Standard OS (Occupational Safety) forms include F5484.3, EV-102A, OSHA200, and OSHA 100F, as appropriate.

c. Radiation exposure which also meet the criteria for recordable occupational injury or illness require completion of appropriate OS forms in addition to HP forms.

Table C. Summary of U.S. Department of Energy requirements for accident notification, investigation, and reporting for the environment and special

Description	Notification			Investigation			Reports and Forms	Order DOE 5484.1 Reference
	Immediate	Within 72 Hours	Quarterly	Type A All-DOE Board	Type B DOE and/or Contractor	Type C By Involved Organization		
(Environment)								
Pollutant releases with significant effect	x			x			Formal report and F5821.1	Chapter I, 1 e
Pollutant releases designated "Hazardous" by EPA	x			x			Formal report	Chapter I, 1 f
Radiation releases 5,000 times concentration guides		x			x		Formal report and F5821.1	Chapter I, 1 I
Offsite radiation releases with dose to any member of general population annual standards		x			x		Formal report and F5821.1	Chapter I, 1 I
Any significant contamination from DOE Operations	x			Level to be determined by head of field organization				Chapter I, 1 q
(Special)								
Occurrence likely to have public or press inquiry	x		x	Level to be determined by head of field organization				Chapter I, 1 m
Occurrence with press release or information to other agencies	x		x	Level to be determined by head of field organization				Chapter I, 1 n
Aviation occurrences with fatality, injury, downtime, property damage, or hazardous cargo	x		x	Level to be determined by head of field organization				Chapter I, 1 r

a. Refer to Order DOE 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements," for specific criteria.

b. DOE F5821.1 should be completed for only radiological releases and pollutants.

APPENDIX B

POST-ACCIDENT SEQUENCE OF ACTIVITIES (ACCIDENT REPORTING AND INVESTIGATION)

APPENDIX B

POST-ACCIDENT SEQUENCE OF ACTIVITIES (ACCIDENT REPORTING AND INVESTIGATION)

The sequence of events contained in this Appendix is provided as a checklist of desirable actions prior to and during the conduct of an investigation. Actions by the field safety functions (safety official and investigators) are emphasized with brief statements of collateral actions conducted by other field offices and by Headquarters offices. Specific times are presented for guidance only and should not be interpreted as requirements.

POSTACCIDENT SEQUENCE OF ACTIVITIES
(Accident Reporting & Investigation)

ACTIONS BY SAFETY FUNCTION

TIMELINE: ACCIDENT OCCURS — IMMEDIATE ACTIONS

1. Cognizant Contractor Safety Official:
   a. Ascertains whether rescue, medical, and emergency actions have been initiated. If not, notifies medical, rescue, security, fire department, and others as deemed necessary.
   b. Dispatches safety personnel to scene to assess the situation, record information, obtain photographs, and perform preliminary interviews of witnesses.
   c. Obtains as much information as is immediately available of the accident situation including the following:

      (1) Date and time of accident
      (2) Location of accident
      (3) Type of accident (explosion, fire, collision, etc.)
      (4) Equipment and organization involved.
      (5) Emergency actions taken and their status.
      (6) Number of fatalities/injuries and nature of injuries.
      (7) Whether hazards are under control (fire, possible explosions, radiation, smoke, toxic vapors, etc.).
      (8) All other information to complete DOE immediate notification, as time permits.

TIMELINE: AS SOON AS POSSIBLE

   d. Notifies Cognizant Management and provides assessment of the situation.
   e. Telephones DOE operational Safety Office and provides available information using DOE Order 5484.1 paragraph I.3 as a guide.
   f. Provides personnel office with list of injuries/fatalities.
   g. Supports program officials in the conduct of operations or test failure investigations as appropriate.
   h. Coordinates with the Emergency Director and Cognizant Manager to establish the need for immediate actions to preserve evidence, remove obstructions, identify witnesses, collect preliminary statements. Assures that these actions do not impose further hazards nor restrict the conduct of necessary emergency response actions.

      (1) Evidence protection: establishes guard to ensure that no controls, switches, or other parts of equipment are disturbed until all evidence has been noted and recorded. If necessary, ropes off area and seals all entrances to the area.

COLLATERAL ACTIONS

1. Immediately upon witnessing, discovering, or experiencing an accident, an employee:

   a. Rescues those involved (if within immediate capabilities).
   b. Takes necessary action to aid the injured and to control any existing hazards.
   c. Reports the accident to medical, rescue, fire department, safety office, security office, or other emergency groups in accordance with local emergency action plans.
   d. Reports the accident to the supervisor.

2. Upon notification, the supervisor verifies that the necessary emergency actions have been initiated and provides supplementary information to the Contractor Safety Office.

3. Immediately upon notification, medical, rescue, fire department, security, and other emergency groups initiate appropriate actions to aid the injured and to prevent further injury and damage. These actions may include:

   a. Medical treatment.
   b. Transportation to medical facilities and evacuation of the area.
   c. Posting of guards for directing traffic and controlling access to the scene.
   d. Mortuary services.

4. Emergency Director and Contractor Cognizant Manager initiate action to control hazard and minimize risk of further damage/injury. (Coordinate with the Contractor Safety Office to assure samples and preliminary statements are obtained.)

5. Designated office initiates casualty reporting and notification of next of kin.

6. Cognizant Manager takes action to preserve evidence, remove obstructions, and identify witnesses based on safety official's guidance.

7. Security office provides guards and receives instructions on access and safeguarding evidence.

POSTACCIDENT SEQUENCE OF ACTIVITIES (cont.)
(Accident Reporting & Investigation)

ACTIONS BY SAFETY FUNCTION	TIMELINE	COLLATERAL ACTIONS
(2) Evidence subject to change: checks for and records pertinent information which is subject to change, for example: (a) Tank quantities if tanks are leaking. (b) Hydraulic pressure. (c) Air pressure. (d) Tracks and marks. (c) Position of anything movable.		
(3) Photographs: If possible, arranges for photographs to be taken before any evidence is disturbed.		8. Photography and other installation support provided to the Board
(4) Release: Prevents disturbance of wreckage and entrance to area, except to remove persons, to allow for the conduct of necessary emergency action or to prevent further damage.		
i. Requests the impoundment of pertinent records.		9. Cognizant Manager orders the impoundment of pertinent records per safety official's request.
j. Appropriate safety official meets with contractor and/or Field Office officials to determine class of accident (if not established by number of fatalities/injuries) based on dollar value of damage and needs for a Board of Investigation.		10. Contractor and Field Office officials provide consultation regarding dollar values of damages.
k. Notifies public affairs and legal.		11. Public affairs prepares press releases, regarding the investigation, in coordination with safety and operating officials.
l. Advises contractor field office or Headquarters appointing authority on formation of a board, on appointment of board member, and on acquisition of consultants for the board. A board is required when the accident investigation is classed as Type A or Type B. The contractor cognizant manager may elect to investigate with either a board or a single investigator for less severe mishaps.		12. Legal provides advice to protect DOE's legal interests.
2. Board is formed, and chairman and members are selected, called, and approved.		13. Board letter of appointment issued by appointing authority. Board members notified. Travel and other arrangements made for the Board.
3. Safety Office coordinates with cognizant manager on need for and formation of action center. Provides safety representation as member/advisor/consultant to the Board and action centers.		14. Cognizant Manager considers establishing action center if mishap may cause national interest, Congressional interest, or major program impact.
4. Safety Office and/or Board notifies appropriate local organization of the need for transportation and living arrangements for Board members and consultants.		15. Local organization specified in preaccident plan or otherwise designated makes transportation and living arrangements.
5. Designated official dispatches immediate notification confirmation.		16. Cognizant Manager initiates preventive action as apparent or as cause is developed.

POSTACCIDENT SEQUENCE OF ACTIVITIES (cont.)
(Accident Reporting & Investigation)

ACTIONS BY SAFETY FUNCTION	TIMELINE	COLLATERAL ACTIONS
6. Board chairman determines the need for support and notifies coordinator of support organizations.		17. Those designated as responsible for providing support to the Board will provide supplies and support (special equipment, technical assistance, office supplies, clerical support, message center, communications, etc.)
7. Board Chairman and members arrive.		
8. Board Chairman assumes responsibility for investigative actions.		
a. Receives briefing form safety officials. b. Organizes board members and technical support. c. Establishes working schedule and plan of action. d. Establishes relations with contractor or field office staff for support and assistance. e. Reviews scene and briefs guards. f. Coordinates with legal, public affairs, medical, security, and personnel offices. g. Submits progress reports.		18. Medical official advises Board on report, availability of injured person nel for interview, status or need for autopsy report, requirements for medical assistance, and medical interest in the investigation.
9. Board identifies and collects evidence.		
a. Conduct on-the-scene examinations, identify significant parts and debris for further examination. b. Obtain witness statements. c. Obtain records from program officials. d. Plot wreckage dispersal. e. Identify, tag, and record evidence. f. Request readouts of tapes. g. Request transcripts of voice recordings. h. Request photographs (movies, onboard photos). i. Request other significant data.	ACCIDENT PLUS 1 TO 7 DAYS	19. Contractor Cognizant Manager provides readouts, voice [illegible] photographs, etc.
10. Board determines probable causes and contributing factors, reaches conclusions, and establishes recommendations for preventative action.	(The following time will be influenced by the complexity of the accident.)	
a. Reconstructs wreckage, if appropriate on the scene and/or within an assigned facility. b. Examines parts by disassembly and requests lab analysis as required. c. Reviews and evaluates witness testimony. d. Examines records for precedents and other clues. e. Reconstructs the accident sequence of events. f. Releases scene/wreckage. g. Correlates and verifies other evidence or clues by simulation.	ACCIDENT PLUS 1 TO 3 WEEKS	20. Appropriate priorities established and tests and lab analyses performed and results reported to Board. 21. Guard removed and scene restored to service if practical and wreckage disposed of or restored to service after release by Board Chairman.

POSTACCIDENT SEQUENCE OF ACTIVITIES (cont.)
(Accident Reporting & Investigation)

ACTIONS BY SAFETY FUNCTION	TIMELINE	COLLATERAL ACTIONS
11. Board prepares report: a. Board consolidates findings and recommendations. b. Board concurs on wording of report. c. Board assigns precedence and categorizes causal factors. d. Board prepares draft of a summary of the report deemed appropriate for DOE-wide distribution.	ACCIDENT PLUS 2 TO 6 WEEKS	22. Appointing authority obtains comments of safety and program staff, initiates preventive actions or research.
NOTE: If reasonable confidence in the findings of the investigation is not obtained and if the severity of the accident or public opinion so dictates, further studies or accident simulations may be desirable. If assistance in the conduct of such studies is required, requests should be made to the proposed support organization and to DOE Headquarters, or appropriate Field Office depending on circumstances. Regardless of the existence or nonexistence of conclusive evidence, the report should normally be submitted within 60 days, unless additional time has been granted by the appointing authority. Supplemental reports may be submitted for further studies and accident simulation.	ACCIDENT PLUS 3 TO 8 WEEKS ACCIDENT PLUS 60 DAYS	
12. Board Chairman submits completed investigation report to the appointing authority within the time prescribed by that official. (Or requests extensions in those cases where the final report cannot be completed within the allotted time.)	RECEIPT OF REPORT PLUS 45 DAYS	23. Appointing authority orders corrective action. 24. Contractor officials initiate corrective action.
13. Appointing Authority (normally through the Safety Director) reviews the report and prepares comments to be forwarded within 45 days with 4 copies of the report to the Office of Operational Safety. Additionally, one copy is sent to the appropriate program division director, and one copy each of a Type A investigation report to the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness and the Inspector General. The comments will state concurrence or nonconcurrence with the report, recommendations and corrective action initiated or planned. The Office of Operational Safety will coordinate the Headquarters review of these reports; however, some program related reports may be transferred to other offices for assistance in this coordination, or personnel from these offices may be called upon as specialists to support the Operational Safety during the coordination and closeout phases.		25. Contractor or Field Office officials initiate followup action. a. Obtain progress reports of corrective action. b. Conduct reviews and surveys to determine adequacy of corrective action.

POSTACCIDENT SEQUENCE OF ACTIVITIES (cont.)
(Accident Reporting & Investigation)

ACTIONS BY SAFETY FUNCTION	TIMELINE	COLLATERAL ACTIONS
14. The Office of Operational Safety coordinates the reviews, evaluates the investigation report, recommendations and corrective actions of the appointing official. Review comments and any additional corrective actions suggested by Headquarters will be sent by memorandum to the appointing official.	(120 DAYS) RECEIPT OF REPORT PLUS 30 DAYS	26. Public Affairs prepares proposed news releases by accepting the one submitted with the report or modifying it appropriately. 27. Program/Project provides input and coordinates on proposed news releases.
15. Office of Operational Safety coordinates news releases with General Counsel, Public Affairs, and Program/Project personnel.		28. General Counsel provides consultation regarding news releases 29. Public Affairs makes news releases.
16. Operational Safety checks for completion of followup action on individual basis and/or during safety, reliability, and quality assurance surveys; closes out reports when corrective action is complete; and maintains a permanent file of all actions/closeouts associated with the accident.		

APPENDIX C

INVESTIGATOR KIT CONTENTS

APPENDIX C

INVESTIGATOR KIT CONTENTS

Three suggested lists of contents for investigator kits or "go-bags" comprise this appendix. List number 1 was compiled by Bill Johnson and included in the first edition of this manual. List number 2 was taken from the NASA Safety Manual, Volume 2, *Guidelines for Mishap Investigation*, NHB1700.1(V2), June 10, 1983, and list number 3, from *Professional Accident Investigation*, by Raymond Kuhlman, Institute Press (Division of International Loss Control Institute), 1977. Collectively, they represent the best ideas to date on the composition of investigator kits for effective and efficient investigation of major accidents. They can be used in part, or scaled down for less serious accident investigations. The kits need to be protected and maintained so they will be ready for use when needed.

Assembling the Investigator Kit

1. Each investigator's "go-bag" or accident-ready kit will have to be developed and assembled after careful analysis of:

   a. Location of possible occurrences:

      (1) In or at major plants

      (2) Remote areas, large sites

      (3) Offsite locations.

   b. Types of possible occurrences:

      (1) Occupational (wide ranging—machinery, heavy equipment, tunnel cave-in, cryogenic, oxygen deficiency, explosions, electrical, earthquake, and flood were cited)

      (2) Fire

      (3) Hazardous materials

      (4) Radiation

      (5) Nuclear

      (6) Waste management

      (7) Motor vehicle

      (8) Railroad

      (9) Other.

   c. Assigned responsibilities of others (including operational readiness checks of their preparations), for example:

      (1) Regular emergency authority

(2) Security forces

(3) Fire department

(4) Contractor, in-plant

(5) Contractor, onsite

(6) Specialists (see item b above)

(7) Medical authorities.

Field organization plans will presumably delegate responsibility for the heavier equipment to contractors. All amelioration equipment is presumed handled by regular emergency forces.

Assignment for kit maintenance, e.g., batteries, must be fixed.

If independent investigators are to be assigned from other field organizations or locations, the organization directing the investigation can be presumed to have the heavier equipment required.

2. General equipment.

a. Credentials (and authority, as necessary)

b. Travel orders (one office cited a need for passport, visas, and shots)

c. Purchase orders, credit cards, travel requests, and cash

d. Telephone list (be sure communications center is also prepared), area and city maps, and preliminary witness statement forms

e. Clipboards (plastic cover, hole for template), pencils, template or protractor, and grid paper (10 x 10 in. and 4 x 4 in.)

f. 6-ft rule and 100-ft cloth tape.

g. Compass and range finder

h. Camera (permit, if necessary), flash equipment, film, and cleaning bag

i. Tape recorder, tape, radio (permits, if necessary), flashlight, and heavy duty torch

j. Evidence tags, labels, receipts, bottles, boxes, baggies, freezer tape, chalk, and indelible crayon

k. Standard report forms, checklists, medical release forms, alcoholic influence report forms, standing instructions to line management, investigative task assignment list, preliminary measurement and mapping instructions, preliminary photographic instructions, and briefing materials for board members

l. Analytic materials, MORT, change analysis forms, and 3 by 5 cards for sequence diagrams

m. Perimeter ropes and danger and caution tags

n. Stakes, shovel, and sieve

o. Tool kit

p. One or more carrying bags.

3. Clothing

a. Coveralls

b. Jacket

c. Hard hat

d. Safety glasses

e. Raincoat

f. Umbrella

g. Rubber gloves

h. Rubber boots

i. Work gloves.

(Conditions varying from arctic to desert were cited.)

4. Motor vehicle accidents (perhaps in security patrol car).

a. Flares

b. Portable flashing light

c. Tire depth gauge

d. Tire pressure gauge

e. Standing orders for keeping the accident from getting worse (in hands of security forces where applicable).

5. Equipment to be secured from site or plant services (operational plans and readiness checks required).

a. Tape measuring device (wheel)

b. Emergency floodlights

c. Hydraulic jack, cutting torch, heavy equipment

d. Radiation measuring and protective equipment.

6. The DOE radiological assistance teams' equipment is another resource.

Investigator's Kit

Provisions for an investigator's kit should be obtained and set aside ready for use as part of the preplanning. An organization should be designated as responsible for preparing, maintaining, and providing mobility for the investigator's kit. Suggested contents for such a kit are as follows:

1. *Clothing* appropriate to climate and environment. (If possible, all members should have their own clothing on hand before the mishap. A stock of shoes and coveralls to fit all Board members may not be readily available.)

   a. Coveralls

   b. Hard hats

   c. Safety shoes (reinforced toes) and safety glasses

   d. Gloves, rubberized

   e. Rain coats

   f. Arm bands or other means of identifying Board members while working at the accident scene.

2. *Equipment*

   a. Checklist of equipment

   b. Magnetic compass and tripod

   c. Measuring tape (100 ft)

   d. Drafting board

   e. Graph paper

   f. Notebook

   g. Tags, envelopes, and boxes for marking and storing

   h. Protractor

   i. Draftsmen's scale

   j. Pair of dividers

   k. Calculator

   l. Pencils

   m. Marking pens

   n. Magnifying glass

   o. Flashlights (bulbs, batteries)

p. Maps (grid, country, road)

q. Investigator's checklist

r. Polaroid camera (bulbs, film)

s. Small hand tools (screwdriver, dikes, wrench, crowbar)

t. Aluminum foil or plastic wrap for parts

u. First aid kit

v. Copies of accident report forms

w. Dentist mirror

x. Mirror

y. Knife

z. 100 ft line

aa String

bb Publications; e.g., operations handbooks and trajectory documents

cc Plastic bags

dd Field rations or canned food with camp stove

ee Medical supplies (to be provided by local medical detachment)

ff Tape, cellophane and masking

gg Stakes and rope for boundary markers (500 ft)

hh Clerical kit for remote operation; typewriter, paper, etc

ii Car identification sign

jj No smoking signs

kk Small fire extinguisher

ll This handbook

mm Communication equipment such as walkie-talkie or other two-way radio for remote operations (obtain from local office)

nn Three-by-five cards.

Kuhlman Investigator Kit Recommendations

Several items of equipment are generally needed by an investigator. Measures, note pads, writing materials, graph paper, and report forms are a few that are needed in every case. Collection of these items in a kit prepared in advance makes the mechanics of the investigation easier for the investigator by freeing his mind for analysis and deduction. A list of useful materials for a general investigator's kit are shown in Figure D-1. The basic kit of measuring, marking and recording materials should be packaged to be readily portable, even when the investigator has to walk some distance to the accident site. Each item should be accessible without unpacking and repacking other items. The kits should be readily accessible in the event of an accident, but protected from use as a routine source of tools and administrative supplies. An inventory should be attached for the investigator's information and periodic check of items in the kit. Items which might deteriorate, such as pens, adhesive and scotch tapes, etc. should be cycled with common supplies to ensure the kit items are usable.

To control the size and portability of kits, it is suggested that special equipment used only for certain types or classifications of accidents be kept in separate kits. Valuable cameras and test equipment can also be better protected that way.

Many of the items suggested for the kit are self-explanatory. A few, however, have special or unique uses as will be detailed.

Administrative Items

Investigator's Notebook, with evidence collection check lists, company accident report forms, witness statement forms, graph paper for mapping, photo logs, and sequence diagram charts.

Clipboard and note pads for general investigation notes, sketches, and calculations.

Plastic Bag, heavy, transparent approximately 18 x 24 in. Serves as rain cover for clipboard to permit note and record making in inclement weather. Also serves to collect and protect documents.

Tools

Flashlight, 3 cell explosion proof, or lantern
Spare batteries and bulbs for flashlight
Steel tape measure—100 ft
Scale—12 in. ruler or NU Traffic Template
Protector
Scissors
Pliers
Wrenches, small adjustable or box end
Wire cutting pliers
Screwdrivers—large, medium Phillips
Knife—small sheath or 3 in. blade pocket
Saw—wood and metal cutting blades
Compass
Magnifying glass
Inspection mirrors—large and small dental
Toothbrush—natural bristle
Nails—12d common
Rope—nylon 50 ft
Twine—300 ft package wrapping

Special Equipment

Camera with flashgun
Flashbulbs and film
Cassette tape recorder and cassettes
Sound level meter
Gas vapor analyzer
Electrical receptacle tension tester
Calipers, inside and outside diameter

Medical Equipment

Water
Triangular bandages
Adhesive tape—1 in.
Peroxide
Hand cleaner, waterless
Eye drops and ointment

Administrative Supplies

Investigator's field workbook
Clipboard
Note pads, lined 8-1/2 x 11
Plastic bag to cover clipboard
Graph paper—1/4 in. squares
Accident report form
Witness interview statement
Pocket portfolio
Envelopes, manila 9 x 12
Aluminum foil roll
Paper towel roll
Adhesive labels—2 x 3 in.
Felt tip markers
Ballpoint pens
Soft, No. 3 pencils
Yellow lumber crayon
Black grease pencils
Orange spray paint—small
Eraser—art gum
Scotch tape
Masking tape—2 in.
Cardboard tags, string

Special Devices

Engineer's scale
Metric conversions
Wire rope/hemp rope size calculators
Fluid sample containers
Pin marking flags, 18 in.

Personal Protection

Hard hat
Glasses, protective
Gloves, leather or canvas
Gloves, linemen's
Ear plugs
Vest, orange flagman's

Pocket portfolios provide field files for note categorizing and collection of statement and report drafts.

Envelopes, manila 9 x 12 in., to organize evidence collection for analysis. Provide more security against intermixing and loss of pages than the working portfolios.

Aluminum foil for wrapping parts to protect them from corrosion and contamination. Brown "butcher's paper" can substitute for large item wrapping.

Paper toweling to pad parts when wrapping to protect fracture zones or mechanisms. Also serves for cleaning parts.

Adhesive labels, 2 x 3 in., to affix to wrapped parts for later identification. Also can be temporarily affixed to materials being photographed to label items or points of special interest.

Yellow lumberman's crayon for marking floors, surfaces, equipment, or materials to identify positions or reference points. For marking equipment before disassembly to permit re-mating as originally positioned. Will mark wet surfaces and rough textures better than chalk.

Orange spray paint highly visible marking for dirt, snow, and surfaces not suited to the crayon. Use to outline positions of parts, put identifying symbols on large damaged structures to be photographed, etc.

Cardboard tags with string ties to label small parts and items when such labeling is more suitable than the adhesive labels. Blank tags or a form tag can be used. Information should be put on the tag with grease pencil so it is not erased or smeared by water.

Tools

Flashlight, 3-cell or lantern for reliable light. Should be explosion proof and preferably floating type. At least one set of spare batteries and a bulb should be included; more if used at remote accident sites.

Tape measure, 100 ft, preferably also in metric scale, steel for durability and precision. Surveyors pins, lead weights with closed hook, or common nails to anchor end if to be used by a single investigator.

Scale and protractor, 12 in. ruled for sketches as well as measurement of small items, or as size reference for photographs.

Inspection mirrors, large mechanics and small dental for examination of areas not visible to the eye.

Toothbrush, natural bristle, soft for cleaning metal fracture surfaces and small parts. (Nylon bristles tend to scratch and score softer metals and materials,...)

Nails, 12d common, to mark positions in dirt surfaces, hold tape measure, and anchor points in string used to outline debris areas or hold small parts in position for reconstruction activities.

Rope and string to cordon off parts of the site, outline debris areas for reference and photographs, tie parts of materials together for reconstruction and analysis, and to wrap parts for preservation.

Special Equipment

Camera, equipment and film of suitable type

Cassette tape recorder for witness interviews, oral notes and observations, and oral reports

Sound level meter to measure and analyze noise levels and analyze effects

Gas and vapor analyzer to measure carbon monoxide and other gas vapor concentrations

Electrical receptacle tension tester to test electrical continuity and grounding of receptacles and distribution cords

Wire/hemp rope calculators to measure rope size for analysis of load capability of ropes used for lifting and stabilizing

Calipers for precision measurement of parts. Inside and outside dimension calipers as pertinent

Fluid sample containers of type, material, and size appropriate for collection of fuels, lubricants, coolants, and other fluids.

Personal Protective and Medical Supplies for the Investigator

Water for drinking and cleaning minor cuts

Peroxide for sterilization of cuts from contaminated or rusted parts

Eye drops and eye ointment for dust, foreign objects, and irritations of the eyes

Cotton tipped swabs for cleaning cuts, eyes, ears, nose

Chapstick for lips

Triangular bandages for injuries

Waterless hand cleaner to remove grease, oil, dirt

Hard hat for protection

Protective glasses where required

Flagman's orange vest for conspicuity outdoors

Gloves, leather or canvas for general hand protection; linemen's for electrical

Ear plugs for noisy areas.

The investigator should always wear or provide himself with clothing and equipment suitable to the conditions he is likely to encounter. Protection against hazardous elements should be self-evident, but it is often overlooked. There is no justification for violation of any standards or acceptable safe practices on the pretext of necessity to speed or complete an investigation. Protection against more insidious hazards such as hypothermia, exposure, frostbite, or heat exhaustion is equally essential.

Inadequate clothing also prompts an investigator to hurry his examinations and investigative actions. The investigator should wear clothing suitable to conditions to be encountered for the expected duration of his investigation. An extra, dry pair of athletic socks and possibly an extra pair of gloves frequently prove to be most valuable tools for an investigator.

APPENDIX D

MEDICAL EVALUATION IN ACCIDENT INVESTIGATION—TOXICOLOGY STUDIES

APPENDIX D

MEDICAL EVALUATION IN ACCIDENT INVESTIGATION— TOXICOLOGY STUDIES

The following instructions apply to all toxicological studies:

Tests

By an agreement between the DOE and the FAA, toxicology studies can be done by the FAA's Civil Aeromedical Institute (CAMI) on a cost reimbursable basis.

1. Shipping preparation. The tissue should be placed in ordinary plastic bags or condoms; the air should be expelled from the bag; the bag should be tightly knotted and chilled as soon as possible. The bag should be labeled with the person's name, type of tissue, and estimated time of death and chilling. Once chilled, it should be sealed in a heavy-duty plastic box with ice; three pounds or so of ice per pound or less of tissue per 24 hours estimated shipping time. The common variety of ice is preferable to dry ice, but the package must be well sealed to prevent leakage. The accident committee chairman should include his return address and telephone number. The package will be shipped to:

   Chief, Pharmacology/Biochemistry Laboratory
   Civil Aeromedical Institute
   Will Rogers World Airport
   Post Office Box 25082
   Oklahoma City, Oklahoma 73125

2. Transportation. It is suggested, on the basis of CAMI experience, that samples be sent by REA Air Express. A telegram or telephone call to the addressee (CAMI) is required to give notice of shipment and the estimated time of arrival. The package will then be picked up by special messenger. If problems arise for the accident committee chairman concerning these procedures, he can obtain the necessary help and advice by telephone call to the Chief, Pharmacology/Biochemistry Laboratory, CAMI. The number is 405-686-4866 or 405-721-2441 after office hours.

   If reliable tests can be done locally, they may be done in preference to shipment to CAMI to save time and effort involved in packing and shipping. The investigation chairman should consult with the local DOE or DOE contractor physician as to which laboratory to use for these studies. The Director, Office of Operational Safety, Germantown, is available for consultation on any unusual problems that may be encountered. It is often desirable to split the samples and submit them to two different laboratories as a cross-check.

Specimens

All specimens should be labeled with the name of person and his job assignment at the time of the accident. In addition, a card enclosed in a plastic envelope with the following information should accompany the shipment:

1. Date and place of accident

2. Date and estimated time of death

3. Date and time specimen drawn

4. Date and time of any special preparations (iced, etc.)

5. Specify where in body or debris specimen was obtained and identify insofar as possible.

Remarks

A statement concerning the date and time of the accident and, if known, very brief circumstances of the history of the accident should be submitted with the tissue.

Laboratory Reports

Laboratory analysis reports will be sent to the investigation chairman as quickly as possible. Remember that embalming fluid invalidates most toxicological studies.

Blood Alcohol

Blood alcohol tests are desired on all fatalities. These tests may be done on survivors if they consent.

1. Preservation. Specimens should be placed and tightly sealed as soon as possible in a clean test tube containing sodium fluoride (NaF), 0.1 gm per 10 cc blood as preservative. Make every effort to avoid contamination.

2. Refrigeration. If conditions prohibit immediate preservation with NaF, the specimen will not be altered significantly by temporary refrigeration. No refrigeration is needed after preservative is added.

3. Worthless specimens. Most toxicology specimens are worthless following embalming, but not all.

4. Kits and shipping containers. Special kits and shipping containers for specimen collection and shipment are available to DOE physicians. They may be obtained from CAMI at cost.

Carbon Monoxide

1. Required testing. Carbon monoxide (CO) is a danger in accidents involving fire. CO determinations should be made on all fatalities of accidents involving fire. These determinations can help reveal whether or not:

    a. CO intoxication caused incapacitation.

    b. If fire is associated with the accident, whether or not the victims were breathing at the time of the fire. This is useful in helping to reconstruct the sequence of events leading to the accident.

2. Local testing. Quantitative blood analysis for CO can often be performed locally. If local facilities are not available, this analysis can be done at CAMI.

3. Preservation. Blood is preserved as is blood for alcohol: 10 cc blood in screw-cap test tube with 0.1 cm sodium fluoride. Blood specimens need not be refrigerated after preservation.

4. Tissues. Tissue analysis for CO can be done at CAMI if blood is not available. Deep organs or blood should be submitted. Bloody organs unexposed to fire, such as spleen, liver, and bone marrow, are preferred. Approximately 50 gm is desired.

Cholinesterase Activity

1. Organophosphate chemicals. In accidents involving application with organophosphate chemicals, the cholinesterase activity in the blood will detect recent exposure of the victim to the organophosphate (anticholinesterase) insecticides. These substances can cause incapacitation and death, depending on the amount and rapidity of exposure.

2. Preservation. The blood specimen should be placed in a 10 cc tube with one drop of standard heparin (1000 units/ml) or its equivalent and refrigerated (not frozen), so that the enzyme, cholinesterase, is not liberated from ruptured red blood cells. Some laboratories do serum cholinesterase determinations, others red blood cell determinations, and some, both. Freezing will rupture the red blood cells and invalidate either of these tests. The earlier the test is performed, the more reliable it is. This analysis can be done locally or at CAMI.

3. Paranitrophenol test. A paranitrophenol test can be done on the urine at CAMI or locally. A positive reaction indicates exposure. A false positive may be seen when the person has recently received sulfonamides.

Special Drug Analyses

Special tests can be carried out if deemed necessary by the investigators. If evidence at the scene or by history indicates any possibility of intoxication and/or side effects from medications, specimens should be submitted for analysis. Stomach contents can be a good source of ingested drugs and may be the only specimens submitted in which an easily metabolized drug is found. The larger amount of blood often needed necessitates the use of tissue (e.g., one of the following: lobe of liver, one-fourth brain, one kidney, lobe of lung). The specimen is frozen, labeled (include name of drug suspected), and shipped to CAMI as previously described. Examples of drugs that might be suspected if evidence is present are:

1. Barbiturates.

2. Stimulants (amphetamines, etc.)

3. Tranquilizers.

4. Antihistamines.

5. Narcotics.

Table 1

SPECTRUM OF HUMAN FAILURE

I. Management/supervisory factors. (Does management make safety a vital part of the job?)

   A. Safety policies, plans, procedures, and practices

   B. Quality assurance program

   C. Training and refresher programs

   D. Union relationships

   E. Worker morale/esprit de corps

   F. Emergency plans and procedures. (Are full-scale periodic drills conducted?)

II. Union attitude, role and contribution to safety

III. Design factors

   A. Operating equipment design

      1. Fail safe

      2. Safety interlocks

      3. Redundant system

      4. High visibility, high attention stimulation monitoring and warning systems

      5. Easy to read instrumentation

      6. Avoid information overload

      7. Difficult to misread instrumentation

      8. Uncomplicated control systems

      9. Distinctive, easily identifiable controls which are functionally located

      10. Meet current standards

IV. Maintenance errors

   A. Faulty workmanship

   B. Breach of established procedures

   C. Faulty color coding

   D. Inadequate inspection

V. Failure of personnel involved in accident

A. Incapacitation

1. Complete—partial

2. Permanent—temporary (transient)

3. Sudden—subtle (insidious)

a. Examples of sudden incapacitation:

(1) Acute myocardial infarction.
(2) Severe cerebrovascular accident (stroke).
(3) Drug/alcohol intoxication.
(4) Psychotic/neurotic reaction.
(5) Diabetic coma or shock.

b. Examples of subtle incapacitation:

(1) Epilepsy
(2) Diabetic coma
(3) Psychotic/neurotic reaction
(4) Small stroke syndrome
(5) Drug/alcohol intoxication
(6) Boredom
(7) Fatigue

B. Operator error (note relationship to monitoring and control systems design)

1. Cognitive

a. Alertness

b. Errors in instrument reading

c. Errors in interpretation of instrument readings

d. Failure to note warning signal

(1) Color blindness
(2) Tone deafness

e. Operator overload

2. Reactive (response errors)

a. Wrong reaction and input

b. Too slow

c. Too fast

d. Communications errors

e. Operator overload

EQUIPMENT NEEDED BY PHYSICIAN FOR ACCIDENT INVESTIGATION

Very little specialized equipment is needed The quantities of the following are recommended.

1. Six sterile 10-20 cc screw cap test tubes with 0.1 gm sodium fluoride/10 cc (vacutainer-type tubes can be obtained prepared with preservatives)

2. Three sterile syringes 20 cc (disposable type)

3. Four number 18 long needles; two number 20 spinal needles

4. One surgical knife and blade

5. Two urinary catheters (disposable)

6. Plastic bags ("baggies" or similar products are adequate for small tissue specimens) and supply of rubber bands. Condoms are very useful here.

7. Cold or warm weather gear, sun protection gear, etc., should be taken when necessary. Boots are useful at an accident scene.

8. Knowledge of a readily available source of crushed ice for shipment of tissue specimens

9. In accidents involving pesticides, standard heparin or preheparinized vacutainers should be kept readily available.

10. Camera, film and flash equipment.

Table 2 gives suggestions for use of this equipment.

Table 2

SUGGESTIONS FOR USE OF EQUIPMENT

The following suggestions relate to the kit to be used for transporting specimens. Materials can be kept frozen and shipping time selected to avoid arrival at CAMI on weekends.

1. Specimens requested (in order of preference)

   a. Blood: 20 ml or more, from heart, peripheral vessels or body cavities. Source of blood is useful information. If fresh blood is only specimen collected, remove self-addressed, franked tube mailer from kit and send separately. Refrigerate blood until mailing. Samples will remain cold 24 hours.

   b. Urine: As much as 100 ml if available

   c. Visceral organs: 50-100 gm of liver, kidney, spleen, lung, muscle or brain, as available

   d. Gastric contents: As available, to 100 ml

   e. Pharmaceuticals on person or found at accident scene. Information on medical condition requiring therapy will assist the laboratory in identifying drugs.

2. Packaging. Following are the various recommended packages and packaging procedures:

   a. Individual polyethylene bag for each tissue

   b. Whirl-pak bags for fluids.

   c. Screw-capped bottles for old blood not requiring anticoagulant or preservative.

   d. Vacutainer tubes in plastic mailers for unclotted blood obtained from vascular system at prompt autopsy, or from survivors. Heparin (green stopper) is required for cholinesterase (pesticide accidents). Oxalate-fluoride (gray stopper) is used for blood sugar (suspected diabetes). Either tube can be used for all other analyses. Fill both if enough blood is available. If vacutainer collector not used, inject blood through stoppers.

3. Labeling. Label each container; name on each is essential if multiple casualties. Pen provided in kit will write directly on all surfaces.

4. Preservation. Freeze all specimens, except blood, in vacutainer tubes, immediately. Use no chemical preservatives.

5. Shipping. REA is the quickest method of returning kit to CAMI.

6. Notification. Call 405-686-4866 when shipment has been sent; after office hours, call 721-2441. If informed of shipment, CAMI can watch for arrival and can also send replacement kit or mailers immediately. Unused materials should be returned with kit.

7. Specimens from embalmed bodies *may* be useful for certain analyses. Specimen of embalming fluid should also be sent. Tissues packed in kit frozen will be frozen or cold after 46 to 60 hours. Fill can with conventional ice and include in shipment. Do not use dry ice.

THE AUTOPSY

1. Obtaining autopsy. A strong attempt should be made to obtain an autopsy on all fatalities. Even in extreme cases of incineration, blood and tissue can often be obtained for studies. The heart in such cases is often intact and will be found to contain blood suitable for carbon monoxide, ethyl alcohol, and other studies. In "survivable" accidents, a general X-ray survey of the body is desired. Simple fractures are often missed on autopsy. The human body can survive greater impact forces than believed possible until recently.

2. Preaccident planning. Embalming invalidates most toxicological studies. The key to this problem lies in preaccident planning (i.e., obtaining the cooperation and understanding of the local coroner/medical examiner). Previous understanding with the coroner results in smooth operation in this area of the investigation.

3. Consultant forensic pathologist. If, after an autopsy is authorized, no pathologist is available, or if it is obvious that the local coroner or pathologist is not oriented to forensic pathology, the DOE physician, with the approval of the accident committee chairman, should arrange for the services of a forensic pathologist. In these cases, when delay in autopsy is evident and no refrigeration for the body is available, a compromise may be made concerning embalming. Fresh blood should be drawn prior to embalming.

4. Autopsy expenses. In some states, the coroner/medical examiner requires that his office perform this study and the cost is assumed locally. Charges for autopsy services, rendered in duplicate, should be presented to the investigation committee chairman.

5. Autopsy protocol. The autopsy protocol should be forwarded to the DOE physician for study and analysis. The DOE physician should make the autopsy findings and his interpretation of the findings the subject of a brief summary report to the investigation chairman.

N.B. Statutory authority to order autopsies and tests is provided in Federal law for aviation accidents. SUCH AUTHORITY IS *NOT* AVAILABLE IN ACCIDENTS IN DOE OPERATIONS (except that the National Transportation Safety Board may invoke this statutory authority in the case of a DOE aircraft accident).

An Accident Inquiry

The U.S. Department of Energy and its contractors thoroughly investigate accidents and "near misses" for the primary purpose of preventing a recurrence of the accident or similar accidents.

Design of equipment, procedures, and environmental factors may be major factors in accidents and are thoroughly examined. Human factors are also significant. These may include: effects of medicines and drugs, or chemicals, or illnesses on behavior; the relation between physical capabilities and job requirements; and the injury-producing characteristics of equipment.

The future protection of an employee and his fellow workers is improved if a physician evaluates the medical factors in an accident. Therefore, this authorization for medical evaluation is requested.

* * *

Authorization for Medical Evaluation of Deceased

STATE ______________________________ COUNTY ______________________________

DATE ______________________________ TIME ______________________________

By this Medical Authorization or a reproduction thereof, I hereby authorize and request each physician and person in the medical or related fields and each hospital, clinic, establishment and place rendering __________ any medical or related service to allow a physician designated by his or her employer to have, examine, and/or copy, any and all information, records, reports and X-rays, regarding the deceased's physical condition and treatment therefor, provided that such information is to be used only to prepare a medical evaluation of possible or probable effects and conditions deemed significant in relation to accident prevention.

If the physician deems necessary, I further authorize a medical examination or autopsy of the deceased.

Signature ______________________________

next of kin

An Accident Inquiry

The U.S. Department of Energy and its contractors thoroughly investigate accidents and "near misses" for the primary purpose of preventing a recurrence of the accident or similar accidents.

Design of equipment, procedures, and environmental factors may be major factors in accidents and are thoroughly examined. Human factors are also significant. These may include: effects of medicines and drugs, or chemicals, or illnesses on behavior; the relation between physical capabilities and job requirements; and the injury-producing characteristics of equipment.

The future protection of an employee and his fellow workers is improved if a physician evaluates the medical factors in an accident. Therefore, this authorization for medical evaluation is requested.

* * *

Authorization for Medical Evaluation

STATE ______________________ COUNTY ______________________

DATE ______________________ TIME ______________________

By this Medical Authorization or a reproduction thereof, I hereby authorize and request each physician and person in the medical or related fields and each hospital, clinic, establishment and place rendering me any medical or related service to allow a physician designated by my employer to have, examine, and/or copy, any and all information, records, reports and X-rays, regarding my physical condition and treatment therefor, provided that such information is to be used only to prepare a medical evaluation of possible or probable effects and conditions deemed significant in relation to accident prevention.

It is understood that I shall receive a copy of such medical evaluation for my own use.

Signature ______________________

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APPENDIX E

WITNESSES

APPENDIX E

WITNESSES[a]

Philosophy

The NTSB/FRA philosophy of questioning witnesses to accidents is to interview rather than interrogate. "Interview" connotes a cooperative informal meeting where the interviewer approaches the interviewee as an equal. The cooperation of the interviewee is sought; he is encouraged to tell his story freely without interruption or intimidation. An interview is usually conducted informally with a voluntary or cooperative answering of questions.

"Interrogation" connotes that questioning is done on a formal or authoritative level such as a lawyer/witness situation, a police officer/suspect session, or a parent/child relationship. Here the questioning may be devious, shrewd, or clever with the objective of tricking, trapping, or antagonizing the witness to get the information at any cost.

It is the interview rather than the interrogation philosophy which is desirable in the questioning of witnesses by accident investigators.

Introduction. The category of *eyewitnesses* in this section will be interpreted as persons in the vicinity of the accident site at the time of the accident. Such persons as designers, manufacturers, physicians, maintenance personnel, mechanics, metallurgists, crew members, and other experts in specialized fields shall not, for purposes of this section, be considered as witnesses unless they observed the accident firsthand.

Purpose. The investigator interviews accident witnesses with two basic objectives in mind:

1. Establish a preliminary suspect area
2. Complement other phases of the investigation.

The thoroughness with which these two objectives are carried out is contingent upon the thoroughness of the investigator. The experienced investigator realizes that bits of seemingly insignificant information may assume great importance when combined with investigation findings in other areas.

Locating Eyewitnesses

The locating of accident witnesses often requires an extensive search of the accident site area; the following potential sources are intended as a guide in supplementing the investigator's ingenuity in locating witnesses.

1. Residents in the vicinity of the accident site may have information regarding: time of accident, engine sound, duration of sound, fluctuation of dynamic level, unusual noises, local weather, relative speed, heading, initial condition of wreckage, rescue operations, etc.
2. Local authorities often will have names of witnesses.
3. Terminal personnel, e.g., ticket agents, dispatchers, operators, may have valuable witness information.

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a. Excerpts from Federal Railroad Administration (FRA) literature.

4. A newspaper office is often contacted by the witness who believes he possesses significant information.

5. A plea via local news media may encourage the reticent or transient witness to contact investigation headquarters.

6. Temporary area personnel, such as letter carriers, deliverymen, public utility employees, repairmen, etc., may have been in the area at the time of the accident.

7. Expeditious arrival at the accident site facilitates the questioning of sightseers and the curious regarding as to what attracted them to the accident. Those spectators may also know of other witnesses who have departed the site.

8. Rescue personnel can often provide significant occupant evacuation information prior to rescue operations.

9. One witness may lead to another. Ascertain whether or not the witness was alone at the time of the observation. The reticent or introverted witness may be reluctant to volunteer information and as a consequence may never be found without the aid of his more talkative companion.

Witness Location Significance. The exact spot from which a witness makes an observation may explain why his statement differs from that of other witnesses in the crash vicinity. A witness location chart, to be used in conjunction with the written statement, should be prepared for clarification purposes.

1. A witness downwind of the accident may often hear engine or other sounds not audible to the upwind observer.

2. Sound is deflected and distorted by walls or buildings and may cause the witness to erroneously report direction, sound origin, or dynamic level.

3. Noise level at the point of observation may account for a witness missing significant sounds noted by other observers.

4. The witness looking toward the sun sees only a silhouette, while the witness with the sun at his back may note color and other details.

5. A witness located in a group may be influenced by the power of suggestion. An outspoken member of the group might exclaim, "Those two trains missed a collision by inches!" when, in fact, the lateral separation was 100 ft. The type of individual who hates to be critical of others reports that the trains passed in close proximity when in reality his initial impression was that there was adequate separation.

Sensory Illusions. Most investigators are aware of sensory illusions and their effects on operator actions. These same illusions and their influence on witnesses should be considered by the interviewer. The following examples of sensory illusions will serve to create an awareness of existence and potential influence upon witness observations.

1. The rotating versus the oscillating object. (The experiment with the rotating trapezoidal window is an excellent example of observer susceptibility to illusions.)

2. Consider the relative motion illusion, particularly with reference to velocity, when the observer in motion views a vehicle also in motion. It is incumbent upon the investigator to consider speed and direction in which the witness was moving in relation to the direction of the observed vehicle. The apparent speed of a vehicle will be higher when the vehicle and observer are moving in opposite directions.

3. Visual illusions resulting from false information being fed to the brain may account for erroneous witness observations. The accident investigator must evaluate before accepting credibility, e.g.:

   a. Flicker vertigo: In rare cases people suffer adverse effects such as nausea, vomiting, disorientation, or unconsciousness, resulting from the effect of a flickering light.

   b. Autokinesis: Staring at an isolated light at night can produce a false sensation that the light is moving nondirectionally.

4. Absence of shadows at night makes size and distance estimates difficult.

5. Additional visual problem areas with which the interviewer should be aware are:

   a. Night vision limitations imposed by the physical structure of the eye

   b. Refraction error caused by a wet windshield

   c. Illusion of being closer to signal lights on bright, versus lights on dim

   d. Erroneous estimate of altitude when there is an up or down slope to the track

   e. Reduction in night perception after a bright day on the beach or ski slope

   f. Fatigue, inadequate oxygen, smoking, and distraction of bright lights in the cab also decrease night vision.

6. The possibility of illusions influencing witness observations makes it advisable that witnesses be selected from various points of observation. This tends to provide a more comprehensive coverage of the occurrence. This is not to say, however, that an average of witness observations is to be assigned greater credibility than a competent witness whose observation deviates from the majority.

7. Consideration must also be afforded the local observer who in many cases is more apt to note occurrences significant or unique to local surroundings than is the transient to whom the same occurrence would hold little significance.

Expediting the Interviewing of Witnesses

Prompt arrival at the accident site is probably the accident investigator's finest investigation aid. It affords the opportunity of examining the wreckage before excessive disturbance and permits questioning of witnesses before they reflect on their observations.

The investigator is urged to visit the accident site, survey the situation, and decide upon certain questions which he feels witnesses could answer.

Witnesses forget as time elapses. They are influenced by association with other witnesses and other people. They read newspapers, listen to the radio, and watch television; news media has its effect on the witness. The witness, like the fisherman, may embellish his story when he finds listeners less attentive than when he originally told the story. The best solution for remedying these witness frailties is to interview the witness promptly.

A memory experiment associated with the time lapse was conducted by a group of psychologists and revealed the following facts of significance to the witness interviewer:

1. Interviews taken immediately following an occurrence contained maximum detail and were generally more complete.

2. After a two-day delay, the information was more general with fewer specifics, but the main or more vivid points remained.

3. After a seven-day delay, a few of the more vivid events remained, but there was considerably more conjecture, analysis, and opinion injected by the witness. Certainty as to events observed also declined with time.

Witnesses, when contacted promptly, are usually appreciative of the need for accident investigation and the promotion of safety. Some witnesses may consider the interview an imposition and become indignant and impatient when asked to recount their observations. This situation is unfortunate but preferable to the witness who complains about the complacency of the accident investigators because he was never contacted.

The intelligent witness is aware of voids or blanks in his statement (which the trained interviewer realizes exist in all observations) and endeavors to eliminate them through the application of logic or reasoning. The longer a witness has to reflect on his observations, the more likely he is to modify or supplement the facts in the interest of coherency. Maximum witness reliability can best be achieved via prompt interviewing.

Occasionally subsequent evidence dictates that certain witnesses be requestioned. The requestioning of a witness does not necessarily indicate that the interviewer was remiss in the conduct of the initial interview. Instead, the investigator may employ this technique with the witness who appears to rationalize and analyze during the initial interview. The investigator would attempt to separate fact and analysis by observing whether or not the more vivid areas of observation were presented as they were initially, and whether areas of suspected conjecture and opinion were analyzed differently than when the witness was first interviewed. By this means, the investigator would attempt to separate fact and analysis, and verify witness reliability. Requestioning a witness may also be in order in confirming technical group findings.

A Successful Interview

The information derived from the witness interview is often directly proportional to the skill of the investigator in establishing rapport. The Witness Group spokesman is responsible for the success or failure of the interview.

The interview should not simulate a surprise party. Make prior arrangements to interview the witness at a time and place convenient for him under conditions conducive to maximum cooperation and recall.

Optimum results are obtained by appointing a spokesman for the Witness Group who is responsible for: introducing the witness to members of the Group, the showing of credentials, the allaying of any qualms and questions the witness might have relative to submitting a signed statement, general control of the Witness Group, and establishment of rapport.

Rapport consists primarily of placing the witness at ease and assuring him that he is not going to be grilled or given the third degree. Setting the stage and placing the witness at ease should include explaining the objective of accident investigation—ACCIDENT PREVENTION.

Initially, encourage the witness to tell his story in his own way without questions, comments, suggestions, or interruptions from the interviewer. Periods of silence in this phase, while the witness collects his thoughts, have been found to encourage the witness to expound more fully and to avoid omissions. The investigator's ability to be a good listener and to keep the interviewee doing the talking is essential in this phase.

Questions from Witness Group personnel subsequent to the narration of the witness should be channeled through the designated Group spokesman since he:

1. Has already established rapport.

2. Will screen redundant questions.

3. Can organize questions via subject matter and attempt to question by following the sequence of the occurrence.

Prior planning on the part of the interviewer is necessary to direct the interview in a systematic line of questioning. Predetermined questions concerning suspect areas should be asked of all witnesses.

This does not mean, "use of a prepared list of questions," but rather the exploration of areas of greatest probability based on the technical knowledge of the interviewer. Prior planning has the advantage of:

1. Reducing the number of bare "yes" or "no" responses common to the prepared questionnaire

2. Containing the interview within areas relevant to the occurrence

3. Reducing the tendency of the interviewer to ask leading questions

4. Avoiding the rigid stereotyped interview.

Aids to Interviewing. Successfully interviewing the accident witness is primarily an application of common sense. Show the witness the same consideration that you would appreciate if the situation were reversed. The experienced interviewer adopts his own effective style or technique. The following suggested interviewing tips for the novice interviewer will also serve as a review or checklist for the experienced accident investigation witness interviewer:

1. During the initial narration of the witness it is advisable for the interviewer to take notes. The note taking should be unobtrusive and done only with the consent of the witness. Even with the consent of the witness, discretion should be used, and note taking should cease if it is distracting to the witness. Notes should not be so extensive that the witness becomes absorbed with what the interviewer is doing. Explain to the witness that the notes are used to suggest areas in his narration that may require further explanation.

2. Frequently the witness has difficulty putting into words what he observed. In cases such as this, explanatory sketches or diagrams are valuable supplements to the witness statement. They should not be construed, however, as substitutes for the narrative statement. When there is doubt in the mind of the investigator concerning the exact meaning of a statement, check the answer. The simplest method is to rephrase the answer and get the witness to confirm it.

3. Courtesy and consideration should be afforded the witness at all times. Be patient with the witness if he has difficulty in remembering details. Normal witness observations are expected to have periodic voids. If the witness is indefinite in a given area, allow him to record his statement that way. Do not insist that the witness give a straight "yes" or "no" answer.

4. Attempt to have the witness confine his comments to his observations. Avoid hearsay or areas not within his personal knowledge. If the witness reports that someone else described the accident to him, take the name and contact the person at a later date. Get the full meaning of each statement of the witness. Analyze each answer carefully for suggestions or leads to further questions.

5. After the witness has completed his narrative, the investigator usually will have some specific questions to ask relative to areas that appear in his notes. Keep questions simple; avoid jargon or terminology that could be foreign to the witness.

6. Use the straightforward and frank approach in questioning the witness as opposed to the shrewd or clever technique employed by an attorney. The investigator is interested in obtaining information from the witness and not in tricking him or trapping him into an unguarded statement.

7. Avoid arguing with the witness concerning moral responsibility of the crew, operator, or public. Witnesses have been known to regard the interview as a medium for voicing their opinions on annoying aspects of their jobs. Attempt to keep the witness confined to his observations relative to the accident.

8. Do not assist the witness with terminology when he experiences difficulty in describing some technical phase of his job. The statement should be in the words of the witness and in terms that he understands.

9. Percentages and fractions, when used by a witness in describing an event, should be translated into exact descriptions. There is a tendency to exaggerate in terms of percentages or fractions of the whole, e.g., "That train goes through town too fast about 90% of the time."

10. The wording of the question is very important. The following example illustrates how answers are affected by rewording the question. "Should the United States do all in her power to promote world peace?" Of the people questioned, 97% answered yes. The question was reworded: "Should the United States become involved in plans to promote world peace?" In this instance only 60% answered yes. The connotation of the word "involved" made the difference.

11. Qualifying the witness is important in establishing observation credibility. Witness vocation and experience should be established. When a mechanic specifically describes the sound of an engine as surging or backfiring, this observation should be more reliable than a similar observation of a person totally unfamiliar with the operation of the engine.

12. Use the individual versus the collective witness interview. The collective witness interview allows witness #2 to hear the statement of witness #1. In hearing the statement, witness #2 could possibly take information that is mentioned by witness #1 and use this information to fill blanks in his observation. Many times the collective witness interview will result in one witness contradicting and correcting another. In the collective interview, a witness can be influenced by the statement of another. Conformity of witness observation is not necessarily what the accident investigator desires.

13. Use of a tape recorder is a matter of individual interviewer preference. Consideration should, however, be given to certain associated circumstances and requisites:

    a. A signed written statement is desirable.

    b. Tape must be transcribed and forwarded to witness for signature.

    c. Witness must edit transcription.

    d. Some witnesses concentrate more on the microphone than on their observations.

    e. Environment may not be conducive to recording.

    f. Mechanics of operating the tape recorder may be a disadvantage, e.g., changing tape in the middle of an interview; faulty recording due to inexperienced operator or mechanical malfunction.

    g. Witness should be provided with a copy of his statement.

14. Courtesy during the interview is emphasized. Courtesy is as important in concluding the witness interview as it is in conducting it. Thank the witness for his cooperation and time in providing the information and preparing the signed statement. Bear in mind that the statement was voluntary, and perhaps given on his own time. The investigator should leave a phone number and address where he can be reached, should the witness recall additional information that he failed to include in his statement.

15. It is occasionally necessary that the interviewer assist certain well qualified, observant witnesses with the organization of their statements. A few minutes spent here will aid future readers in grasping the full significance of the information. Valuable witness interviews have been wasted because an investigator has failed to obtain a recorded statement in an coherent form. Application of the following suggestions may help avoid this problem:

   a. Assist the witness with the mechanics of organizing the written statement. Suggest the use of an outline if the witness appears to have difficulty in organizing the report and collecting his thoughts.

   b. Encourage the witness to use drawings, sketches, or photographs if they will help clarify the written statement. These are merely supplements to the report and do not take the place of a written statement.

   c. Assist the witness in organization only. Do not aid the witness with technical terminology; his statement should be written in his own words.

   d. Witnesses tend to minimize or omit observations which, to them, have little significance. The investigator's working background should guide him as to the significance of the information to be included in the statement of the witness. Frequently, relatively insignificant information becomes vital to the cause of the accident once the pieces of information have been put together by the experienced interviewer.

   e. A witness will occasionally omit information from his written statement that he included in his oral description of the accident. It is the responsibility of the interviewer to catch these omissions and ensure that they are inserted in the written report.

   f. A professional approach to witness interviewing requires that the witness be provided with a copy of the statement. This is a common courtesy which should be afforded the witness. The copy may bring to mind additional observations the witness made relative to the accident when he has an opportunity to reread his statement.

Witness Types

There are as many variations in witness types as there are types of people. To better evaluate the observations of the witness, it is advisable that the interviewer have some knowledge of what factors influence some of these types.

Injured Witness. When questioning the injured witness, attempt to keep the witness group small. Obtain the permission of the attending physician prior to interviewing the injured witness. The witness might be under sedation, in a state of shock, or in a condition where no coherent statement could be expected. The investigator should be cautioned, however, to listen to seemingly incoherent statements or ramblings of the injured witness; these ramblings may contain a clue as to the cause of the accident. Limit questions to the essentials; screen and plan them carefully. This could be the only opportunity to question the injured witness. Ensure that the investigator is accompanied by another member of the witness group for verification of witness observations.

Child Witness. Children may be the most objective observers. Unlike the adult witness who analyzes what he sees and may alter his observation in favor of logic, the child will generally report what he sees, regardless of how improbable it may be. Discretion must be used particularly in questioning young children (4-7 years); they sometimes live in a world of fantasy that to them is as real as everyday adult life. The astute questioner should be able to separate fact from fantasy.

Children are particularly susceptible to leading questions. (A leading question is defined as a question which contains the answer.) Most children are quite impressed with the fact that an adult is asking them questions, and they are even more impressed when the adult listens to the answers. In order to retain the adult's attention, the child will attempt to please by giving the answer he thinks the interviewer wants. Here the leading question is particularly dangerous, since the interviewer has already given the child an indication of an acceptable answer.

Illiterate Witness. The interviewing of the illiterate witness may present a delicate situation. Many people who are illiterate prefer to keep it a secret. Should this situation exist, question the witness individually to avoid any possible embarrassment. If facilities are available, it is preferable to have the illiterate witness dictate his statement; however, the interviewer may write the statement for the witness and read it back to him for verification. The interviewer should be a witness, along with another member of the witness group when the illiterate makes his mark.

"Know-Nothing" Witness. The "know-nothing" witness fears involvement, and even though he has witnessed the occurrence, he prefers to remain in the background and not get involved. This type can sometimes be approached by stressing the need for safety or by appealing to his humanitarian nature.

Prejudiced Witness. The prejudiced witness may hate nuclear power, consider it dangerous, and feel that reactors should be declared a public nuisance. This individual may be encouraged to give a statement by sympathizing with him and listening to his complaints.

Intoxicated Witness. The intoxicated witness should be listened to, but his statement should be taken later. Individuals often say things under the influence of alcohol that they would not say if sober. Confront the witness with these remarks the following day when he is sober.

Suspicious Witness. The suspicious witness guards his privacy and resents any intrusion by the public. He is suspicious of government investigators, hates publicity, and in all probability would prefer not to give a written statement. This witness may be encouraged to give a statement by stressing the importance of safety and by convincing him that his help is needed. Present investigator credentials, and try to resolve any fears or suspicions the witness might have relative to giving a statement.

Talkative Witness. The talkative witness is usually the type of individual who is delighted to be the center of attention and will talk for hours concerning his observations. Impress upon this witness the need for a businesslike interview, the importance of safety, and that you have other witnesses to contact. The boasting witness also falls within this category. Impress upon him the need for facts and that any stretching of these facts might mislead investigators as to the actual cause of the accident.

Timid Witness. The timid witness requires moral support and encouragement. This witness is frequently insecure, discounts his own importance, and fails to see why any information that he has would be of interest to anyone else. This category often includes the foreign-born witness who does not speak English. Allow the witness to write his statement in his native language, or permit him to dictate it to a translator, if he prefers. Allow him to write his statement in private, gain his confidence, and be empathetic.

Factors Affecting Witnesses

Various factors tend to influence witness observations. It is advisable that the interviewer have some knowledge of these factors to better understand why witnesses report as they do.

1. Witness reporting reliability is partly dependent upon intelligence. Reliability is not as apparent in observing as it is in the area of ability to recall and in the organization of thoughts. The less intelligent witness tends to have difficulty in recalling specific detail simply because it failed to interest him. He will also have difficulty in organizing his thoughts and presenting his observations in a coherent manner.

2. No witness should be overlooked on the basis of apparent lack of intelligence or as a result of his age.

3. No significant variation has been found in contrasting the accuracy of adult female and male observations.

4. Emotion and excitement tend to produce decided distortion and exaggeration, especially in the verbal description of an occurrence. Emotion will tend to influence the description of an accident where there is personal involvement. Accuracy depends partly on the observer's mental state at the time and partly on the complexity of the situation.

5. Exaggeration tends to creep into the interview after a witness has repeated his observations several times or has been given time to reflect on the events. Witnesses tend to fill in blanks or voids in their observation after they have had time to apply logic and reason. They temper their statements in the hope that their observations will be accepted by the interviewer.

6. A common witness failing is "transposition." The witness reports all the facts, but places them out of sequence with the actual occurrence. The experienced investigator should pick this up and attempt to have these areas clarified when the witness prepares his written statement.

7. Omissions are common in witness statements simply because the witness does not consider certain information important. Omissions concerning details of an observation have been found to be most common in the free narrative type report where the eyewitness is asked to prepare a statement of observation without the benefit of questions.

8. The "completion" or "interrogatory" type statement, as contrasted with the "free narrative," asks the witness to comment on specific areas of observation. The completion type witness questionnaire covers a broader area of observation than does the free narrative, but it also leads the witness to comment in areas where he had no previous impression. Additions are more common in the completion type questionnaire, since the investigator has given the witness a clue to what information he desires. A combination of the free narrative and interrogatory type statement is recommended for accident investigation.

9. When a number of witnesses reflect general agreement in describing an occurrence, the circumstances may, in general, be considered correct. Exercise caution, however, since psychological experiments show that there is a strong tendency for the same errors to appear in testimony of different individuals.

10. Witnesses tend to be particularly astute and perceptive in areas of observation in which they are personally involved.

11. Witnesses who have sustained a frightening or traumatic experience often have difficulty recalling even the most vivid events. This may be a result of the natural tendency of the mind to dispel or push unpleasant thoughts back into the subconscious as a protection against uncomfortable and upsetting memories.

12. In establishing witness credibility, the investigator should be aware of the interviewer tendency to interpret ambiguous answers in accordance with the investigator's particular beliefs, opinions,

or prejudices. For example: the temperance advocate, when interviewing a group of skid row occupants, attributed their misfortunes and current social status primarily to their excessive use of alcohol. A psychologist who was unbiased interviewed the same group; he attributed their situation to alcohol in less than 50% of the cases.

13. The interviewer should be aware of the witness tendency to underestimate long distances or periods of time, but to overestimate short distances or periods of time.

Analysis of Witness Observations

The gathering of the witness evidence comprises about 50% of the witness phase of the accident investigation. The success of the witness phase hinges on the remaining 50%, the ability of the investigator as an analyst to apply his technical knowledge to the seemingly unrelated observations of and to emerge with possible contributing and causal factors.

The purpose behind analyzing witness statements, as opposed to accepting them at face value, is to:

1. Translate layman observations into possible causal factors

2. Evolve order and logic from apparent confusion

3. Corroborate facts by coordinating witness information and other findings

4. Evaluate witness credibility

5. Evaluate the witness as a potential public hearing participant.

Never underestimate the value of any detail in questioning a witness. The investigation is particularly intriguing and challenging when approached through the human element—witnesses. A slipshod job in the witness phase may overlook a suspect area, delay the cause finding, or even mislead investigators to the extent that the cause remains undetermined.

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