ERDA-76-20

Accident/Incident Investigation Manual

Energy Research & Development Administration

For Use In Conjunction With

The Management Oversight & Risk Tree

MASTER

Accident/Incident Investigation Manual

Prepared for
U.S. Energy Research and Development Administration
Division of Operational Safety
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ABBREVIATIONS

AEC	Atomic Energy Commission
AECM	AEC Manual Chapter
AIM	Accident Investigation Manual
ANC	Aerojet Nuclear Company
CAB	Civil Aeronautics Board
CAMI	Civil Aeromedical Institute
CEA	Cambridge Electron Accelerator
CSR	Codes, standards, and regulations
DOD	Department of Defense
DOL	Department of Labor
DOS	Division of Operational Safety, ERDA HQ
DOT	Department of Transportation
ERDA	Energy Research and Development Administration
ERDAM	ERDA Manual Chapter
FAA	Federal Aviation Administration
F-A-C-R	Facts, analyses, conclusions, and recommendations
F-I-J	Facts, inference, judgement
FM	Factory Mutual
FRA	Federal Railroad Administration
HIPO	High potential incident
JSA	Job Safety Analysis
KP	Known Precedent
LTA	Less than adequate
MRG	Master Report Guide
MORT	Management Oversight and Risk Tree
NTSB	National Transportation Safety Board
OSHA	Occupational Safety and Health Administration
PPL	Priority problem list
R&QA	Reliability and quality assurance
RRD	Division of Reactor Research and Development, ERDA
RSO	Recorded significant observation
SAR	Safety analysis report
W	Webster's Seventh New Collegiate Dictionary

FOREWORD

ERDA 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 ERDA 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 ERDA 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 our attempt to apply the state-of-the-art in investigative and analytical methods to the ERDA 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 accidents, improve management and staff functions, and increase safety in ERDA programs and operations.

Administrator
U.S. Energy Research and
Development Administration

ODUCTION

or effort to improve the effectiveness of the gation process for serious accidents * and the quality subsequent investigation reports was initiated in r 1973. This effort included the gathering of the s experiences of investigation board members, and ollection and development of guides on the -the-art in investigation methods and techniques. aterial was consolidated into a manual and used as a ext for training a cadre of investigators who would n future boards. The five thrusts of the manual and rse are:

ilosophy and Concepts of Accidents and Accident vestigations
anagement of the Investigation
ctfinding Technology
nalytic Techniques
e Investigation Report

emphases arise from the nature of our investigation ns. These are:

e wide variety of occurrences in our operations. is requires emphasis on concepts and analytics, ther than checklists which can be used for certain ecific types of accidents.

e small number of serious accidents. A full-time vestigative staff, similar to that used in the nsportation fields, cannot be justified.

strong emphasis on management responsibility. is requires greater depth of analysis than has been ed in this or other fields and presents innovative and erorganizational problems.

4. A board approach in investigations. This has many strengths, but creates more difficult problems in the management of the investigation.

5. Factfinding technology, e.g., witnesses, photography, failure analysis. No guidelines on factfinding technology were available previously to ERDA accident investigators.

6. Report organization and writing. These present more varied problems than in other fields due to the ERDA's decentralized operating organization.

One consequence of these factors is to place greater emphasis on analysis. The manual is aimed at analysis and investigation of the most serious events, even though these are few. A disciplined approach will be useful in less serious cases and will prepare all concerned for major events.

The lack of new developments in the field of accident investigation is evident by the following statement of the National Safety Council:

> "The accident investigation process in industry in general hasn't progressed significantly in the last decade or two. Our search for new innovations or processes turned up a few items that were applicable to traffic and motor vehicle accident investigation, but nothing in the area of occupational safety and health."

Thus, ERDA development in this area is likely to provide guidelines useful to others in government and industry.

* Serious accidents involve loss of life, major property damage, or significant adverse impact on the environment.

I. PHILOSOPHY OF INVESTIGATION.

A. PURPOSES.

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

B. CONCEPTS.

1. General.

a. Qualities of an investigation. An investigation is task oriented, task specific, and bounded; therefore, it is easier to describe, measure skill, and pinpoint training needs than in the broad field of safety in general.

b. Figure 1 shows the basic investigative process. Independence and excellence are sought by a basic triad of competences, by adherence to methods, and by criteria governing the appointments of personnel and the management of the investigation.

c. Analytic schematic (Figure 2). An overview of the investigative process found useful to boards.

d. Separation of facts, inferences, and judgments. This has been a chronic problem in investigations. Figure 3 provides a flow diagram for separating these into the proper section of the report.

e. Scope of the events to be investigated must be defined. The scope will usually embrace the life cycle and management systems to control the work.

f. Importance of investigating "near miss" incidents:

(1) For findings and subsequent corrective measures.

(2) For practice - the International Safety Academy reports that, for each disabling injury, there are 9.8 less serious injuries, 30.2 property damage accidents, and 600 other occurrences.

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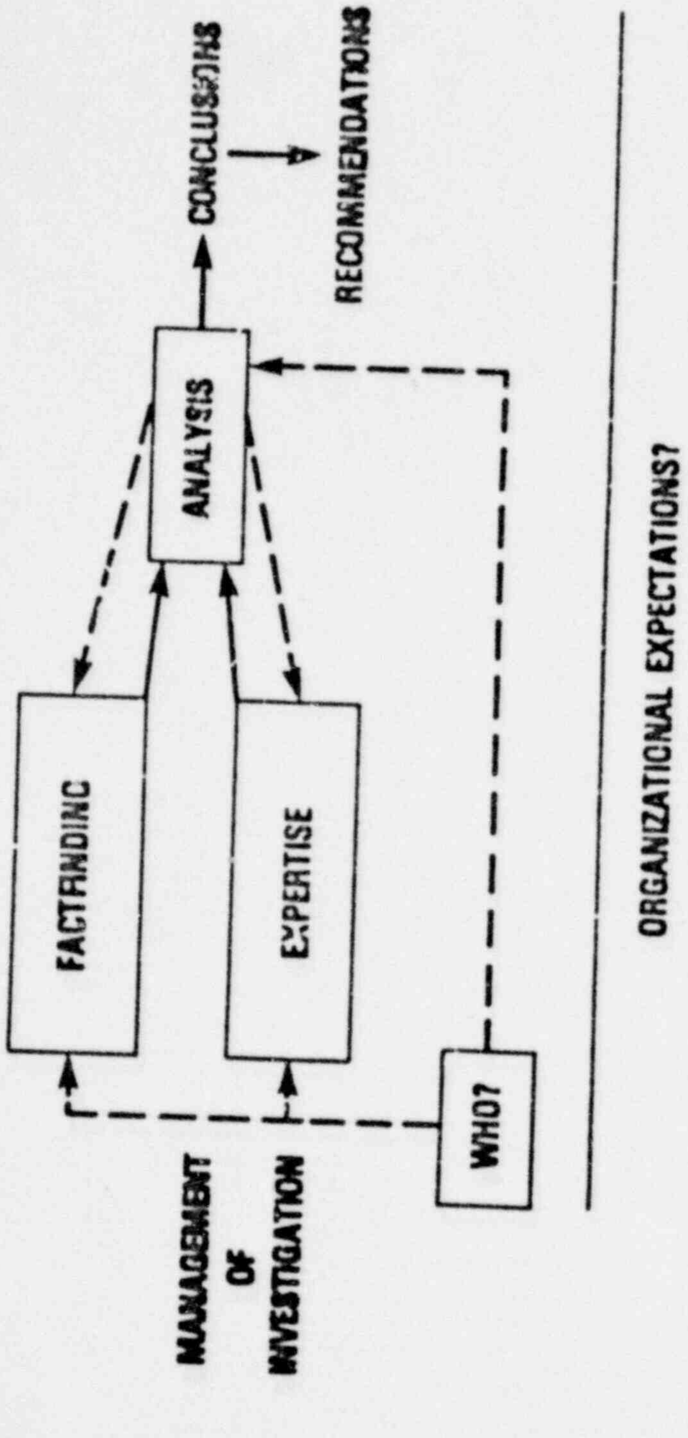

Figure 1. BASIC INVESTIGATIVE PROCESS

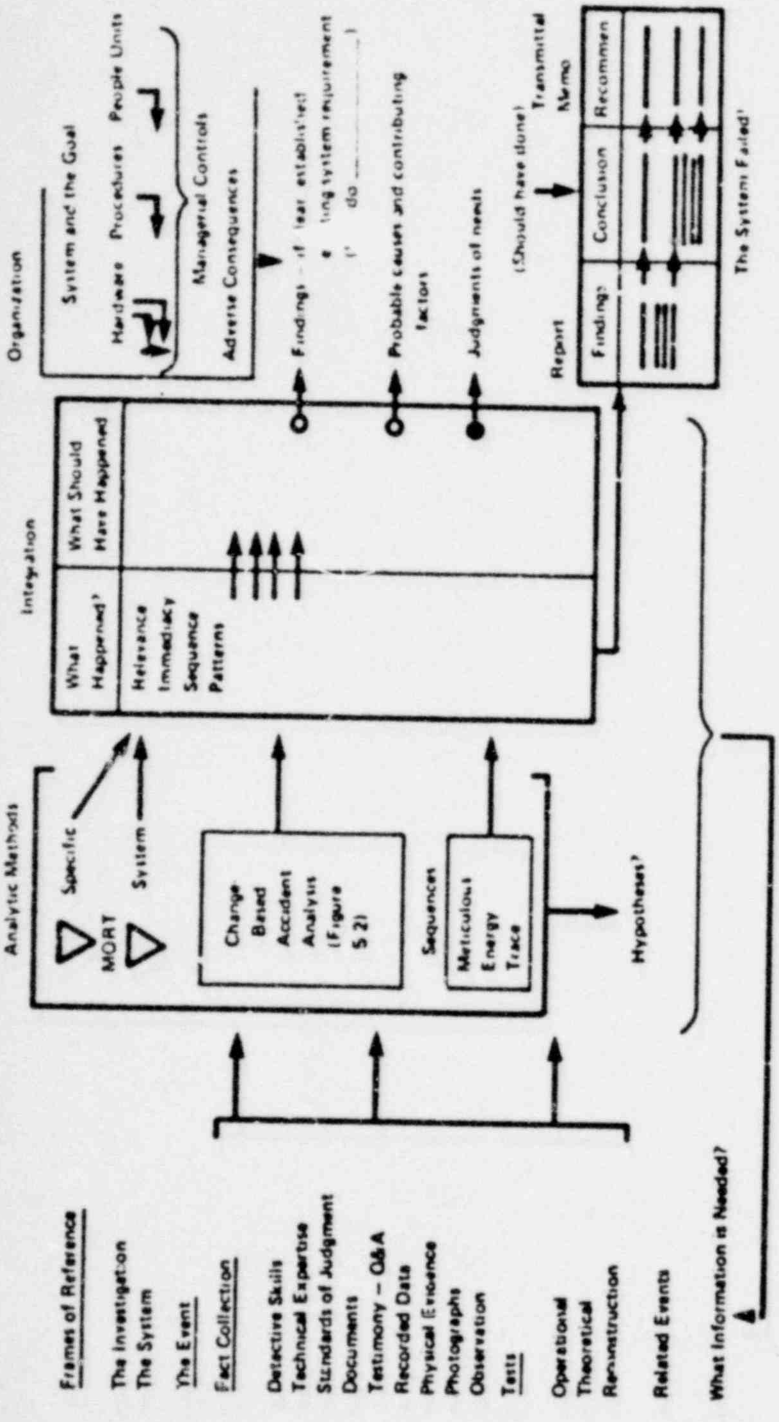

Figure 2. ACCIDENT ANALYSIS SCHEMATIC

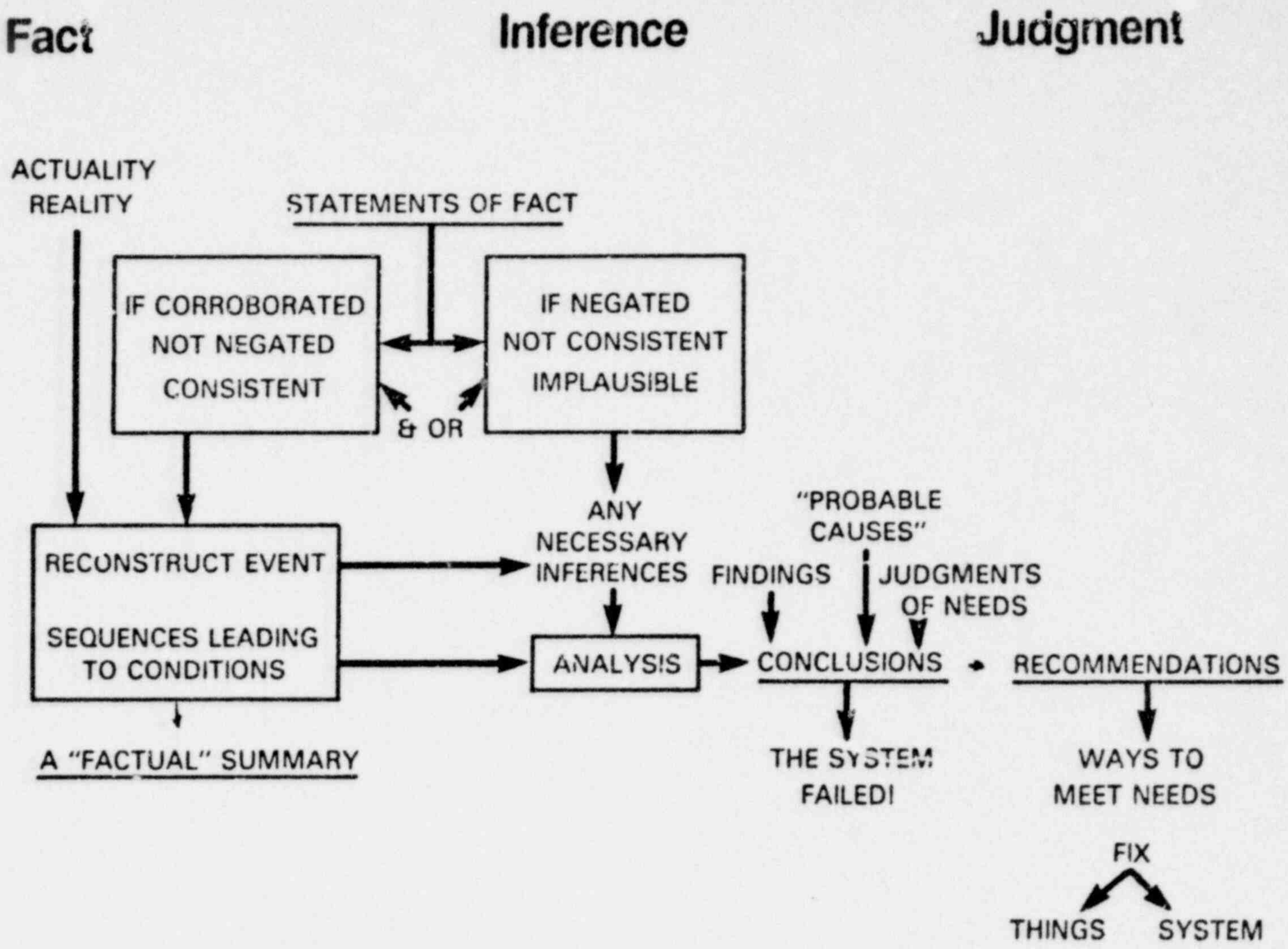

Figure 3. FLOW DIAGRAM FOR USE IN SEPARATING FACTS, ANALYSIS AND CONCLUSIONS

2. **The accident [Management Oversight and Risk Tree (MORT), Part II].**

Concepts affect the kinds of facts sought, observations and perceptions. The following are important concepts involving an accident:

a. Defined. [ERDA Manual Chapter 0502 (ERDAM 0502) and MORT, p. 25]

b. Multifactorial, complex, no single pattern (but there must be pattern in the investigation).

c. Energy and barriers. (MORT, p. 25, chapter 2)

d. Error. (MORT, chapter 4)

e. Change–any perturbation of a stable, homeostatic state (MORT, chapter 5)

f. Sequences. [MORT, chapter 6; Accident Investigation Manual (AIM), section VI.B.]

g. Risk. (probability x severity = probable consequences). (MORT, chapters 7, 21, and 42)

h. Causes.

(1) Remember that accidents are multifactorial. The word "cause" suggests proof "beyond a reasonable doubt" or scientific, experimental verification.

This degree of proof may be possible for a particular factor, e.g., laboratory tests of, or previously established scientific data on, characteristics of materials. This degree of proof is seldom, if ever, available for the entire causal sequence of a single accident. Therefore, the unqualified word "cause" should seldom, if ever, be used. Instead the following words should be used where appropriate:

(a) *Probable Causes*–"likely," deduced, concluded (judgmental)–always plural.

(b) *Causal sequence*–the totality of events and causal factors necessary and sufficient to produce the occurrence (the "musts").

(c) *Causal factors*–

(i) Direct or proximate factors–the primary events in the energy transfer sequence from initiation to conclusion.

(ii) Contributing factors–the events or vulnerable conditions that created the direct factors.

(iii) Systemic factors–the system characteristics which allowed the direct and contributing factors to be created or remain uncorrected.

(d) *Possible causes*–the full list of events or factors that could be involved in the occurrence. Ideally an investigation examines all possible causes to confirm or negate each.

(e) *Changes (perturbations)*–change in a stable homeostatic system is sometimes said to be "the cause." Actually, it is just one element of the sequence of causal factors.

(See MORT, p. 137, for typical numbers of causal factors in thorough investigations.)

3. Prevention.

The following are important concepts found in MORT involving the prevention of accidents.

a. Safety systems (chapter 11).

b. Management (part V).

c. Hazard analysis (part VI).

d. Supervision (chapter 30).

e. Maintenance and inspection (chapter 31).

f. Procedures (chapter 32).

g. Employee selection and training (chapter 33).

h. Performance errors (chapter 34).

i. Motivation (chapter 34).

j. Monitoring systems (chapter 37).

k. Management assessment (chapter 42).

l. Safety programs (part IX).

m. Need for measurement standards (Juran Control Cycle, p. 118).

Remember, when an accident occurs, it is usually the system that failed!

4. Various approaches to accident investigation.*

The following figures show various approaches to accident investigation. Figure 1 shows the basic investigative process. Figure 2 shows the investigating process and source actions and inputs. Figure 3 shows the development of information and the process involved in the report. Figure 4 shows the classic phases versus

* See Appendix B. "Experiences in Accident Investigation."

the real time management of the inquiry life cycle. Figure 5 shows a more detailed inquiry process. Figure 6 shows a general investigative process. Figures 7 and 8 show comparisons between what happened and what should have happened. Figure 9 shows the general forms and scope of occurrence and investigation.

C. DEFINITIONS.

For convenience, brief definitions are assembled below. They are grouped in logical (rather than alphabetical) order because they modify one another.

Sources include: Webster (W), ERDAM 0502 and its Appendix, MORT, AIM, and Department of Transportation (DOT) literature.

1. **Occurrence**–"Any deviation from the planned or expected behavior or course of events in connection with any ERDA or ERDA contractor operations if the deviation has safety, health, or environmental significance." (ERDAM 0502)

2. **Accident**–For a definition functionally related to the task of investigation, see MORT, p. 25.

3. **Incident**–". . . similar to an accident but without injury or damage." [MORT; also see "high potential incident" (abbreviated "HIPO") on p. 233.]

4. **Event.**

   a. "Something that happens; syn: effect, occurrence." (W)

   b. For use in accident analysis, see Benner's definitions (Appendix I).

5. **Investigation**–"A detailed systematic search to uncover facts and determine the truth of the factors (who, what, when, where, why, and how) of accidents." (DOT)

   Syn: Inquiry–". . . . a systematic investigation of a matter of public interest" (W), the term preferred by the National Transportation Safety Board (NTSB), lesser implications of faultfinding, blame, or penalty.

6. **Fact.**

   a. "Actuality, actual existence; event, objective reality." (W)

   b. That which you perceive with your senses.

7. **Evidence**–". . . something that tends to prove; ground for belief; in law, something legally presented before a court which bears on or establishes a point in question." (W)
   Kinds of evidence: direct, circumstantial, real.

8. **Proof.**

   a. Includes "conclusion beyond reasonable doubt; certain." (W)

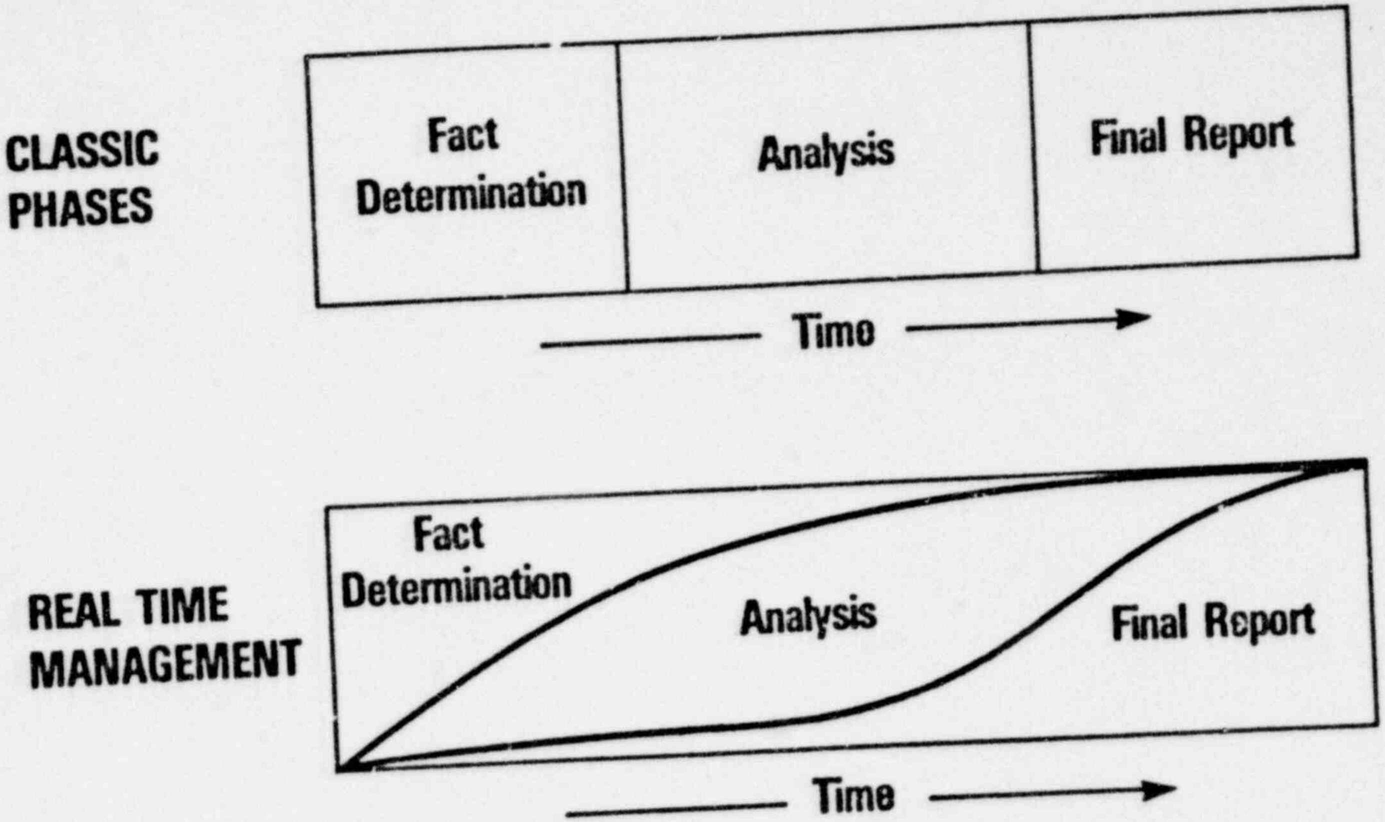

Figure 4. THE INQUIRY LIFE CYCLE

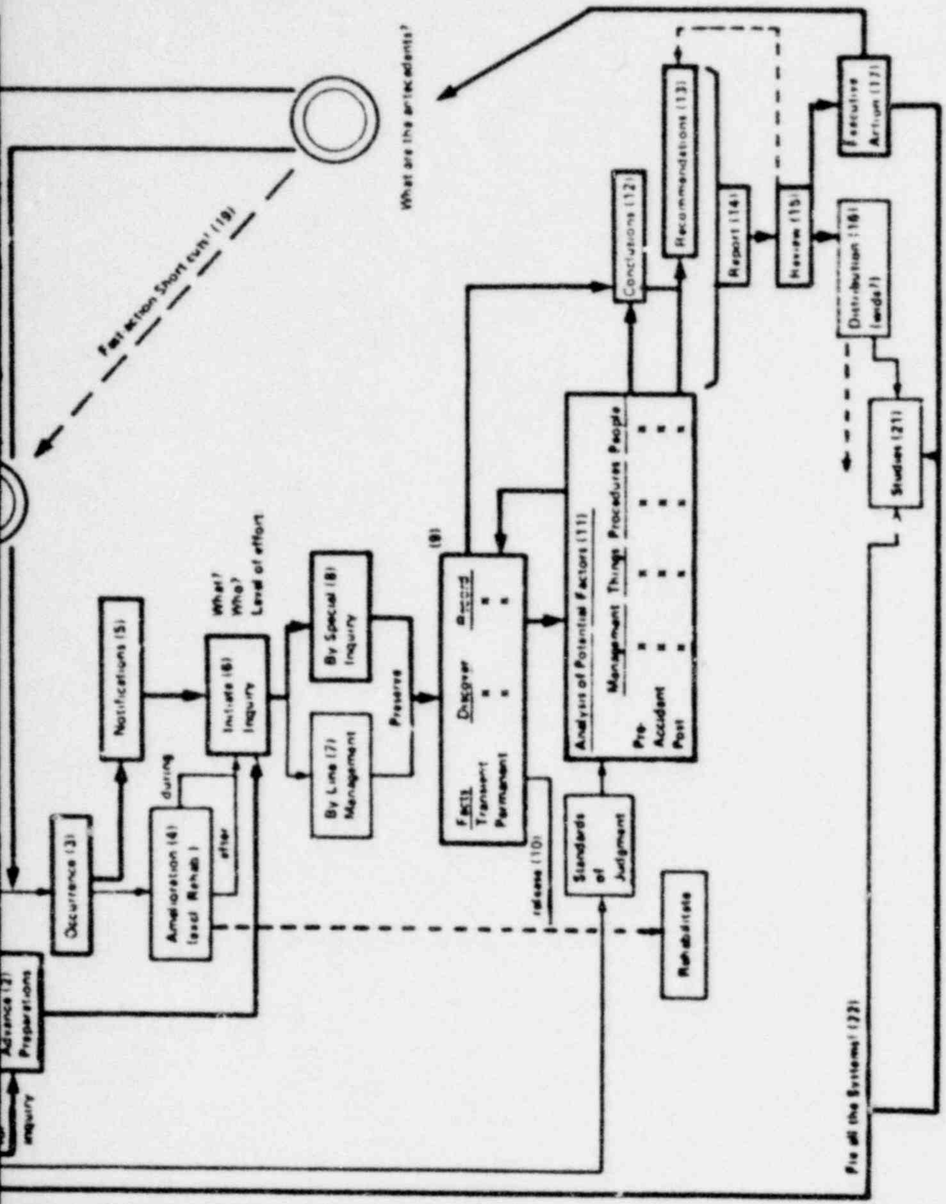

Figure 5. ACCIDENT/INCIDENT INQUIRY PROCESS

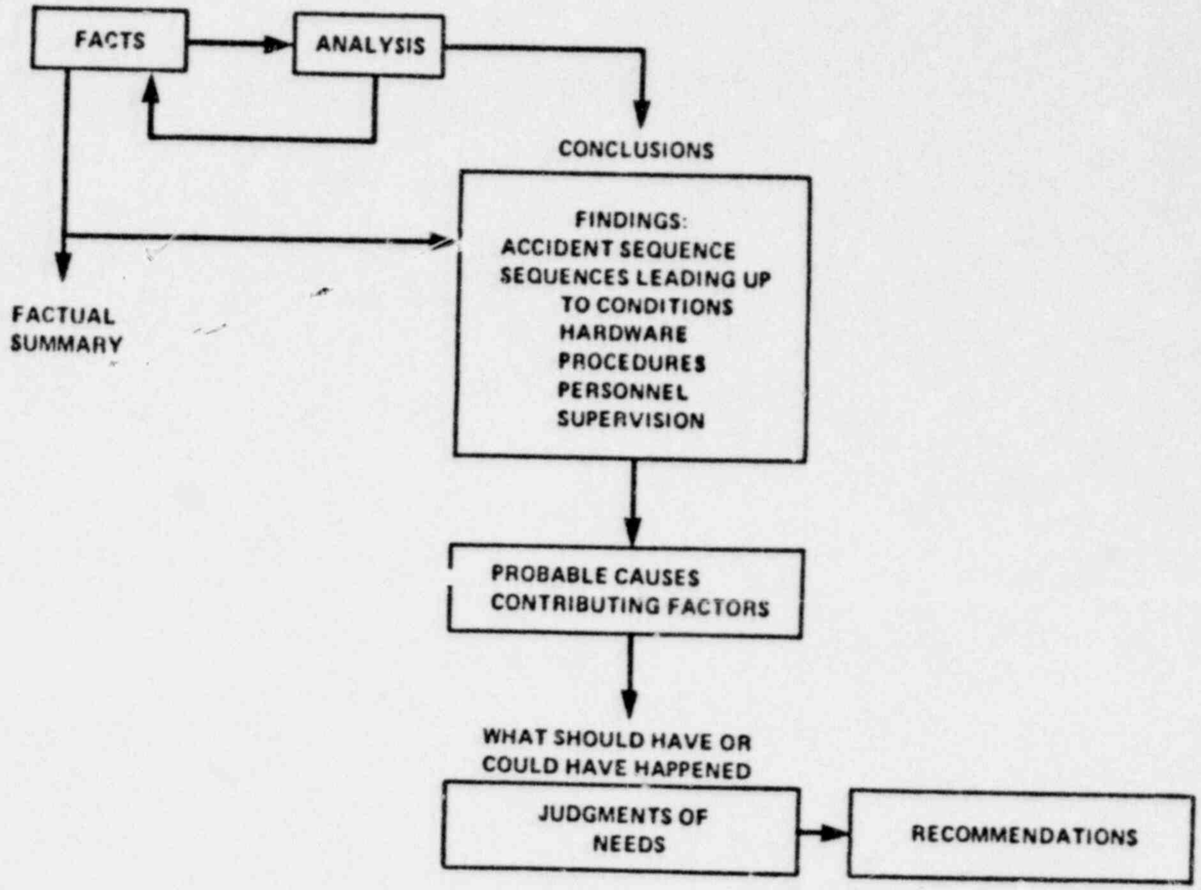

Figure 6. GENERAL INVESTIGATIVE PROCESS

ANALYTICS

WHAT HAPPENED?	WHAT SHOULD HAVE HAPPENED?
METICULOUS ENERGY TRACE	CODES, STANDARDS, REGULATIONS
CHANGE ANALYSIS	SAFETY ANALYSIS REPORT, ETC.
EVENTS & CAUSAL FACTORS CHART	ORGANIZATION PROCEDURES

MORT

Figure 7. ANALYTICS (Restructured)

SEQUENCES

WHAT HAPPENED?		WHAT SHOULD HAVE HAPPENED?	
FINDINGS	CONCLUSIONS	FINDINGS	CONCLUSIONS

Figure 8. SEQUENCES (Restructured)

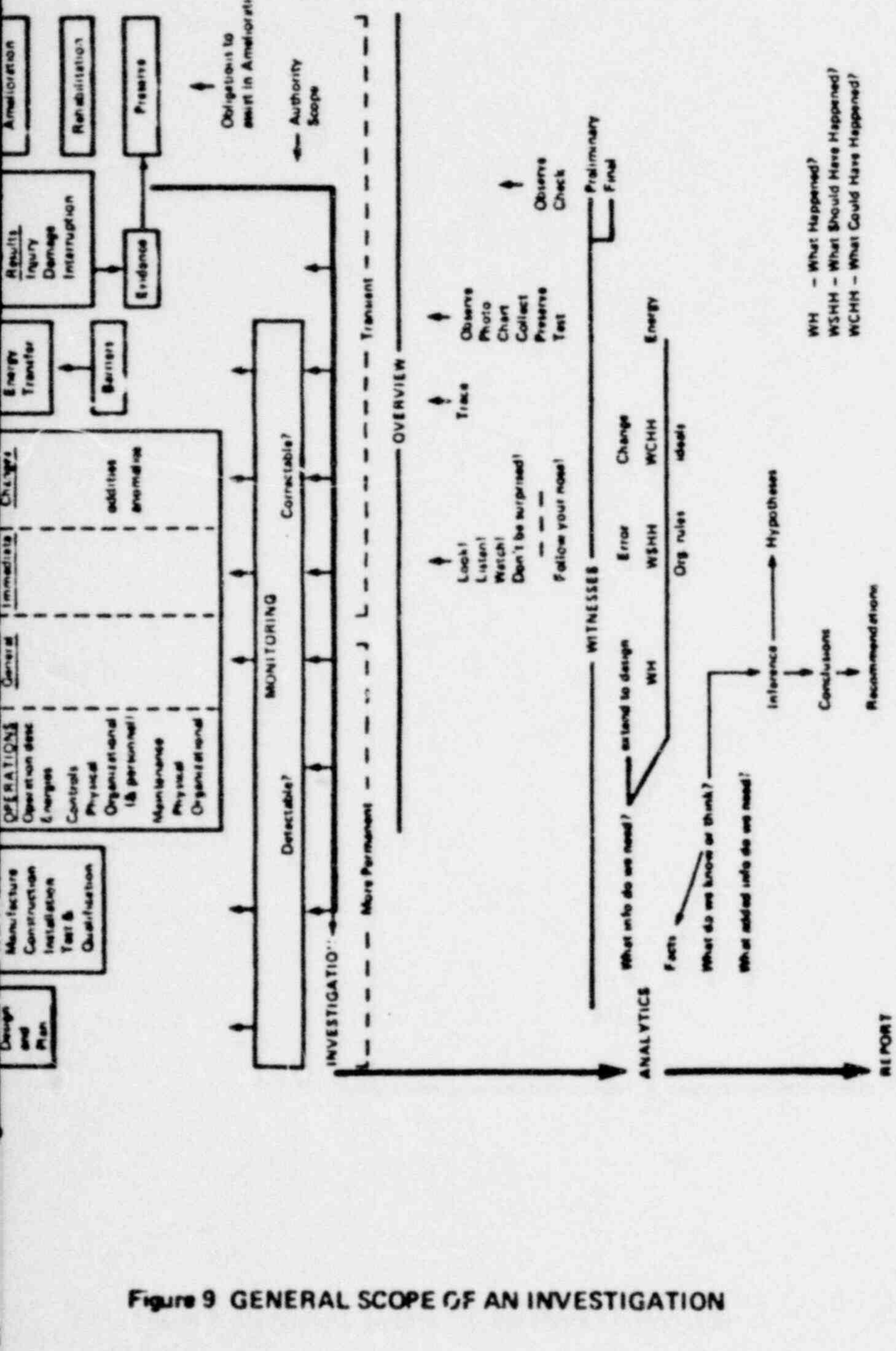

Figure 9 GENERAL SCOPE OF AN INVESTIGATION

b. Scientific or experimental verification.

9. **Analysis.**

a. ". . . an examination of a complex, its elements, and their relations." (W)

b. The use of methods and techniques of arranging facts to:

(1) Assist in deciding what additional facts are needed.

(2) Establish consistency, validity, and logic.

(3) Establish necessary and sufficient events for causes.

(4) Guide and support inferences and judgments.

10. **Hypothesis**–". . . a tentative assumption made in order to draw out and test its logical or empirical consequences; implies insufficiency of presently attainable evidence and, therefore, a tentative explanation." (W)

11. **Interpretation**–". . . explanation of meaning." (W)

12. **Inference**–Passing from fact(s) to a probable fact whose actuality is believed to follow from the former. (W)

13. **Evaluation**–". . . examination and judgment." (W)

14. **Judgment**–"A formal utterance of an authoritative opinion, the process of forming an opinion or evaluation; a proposition stating something believed or asserted." (W)

15. **Probable**–". . . likely . . . to be so; that can reasonably be believed on the basis of available evidence, though not proved or certain." (W)

16. **Finding.**

a. "The results of an investigation." (W)

b. ". . . the salient, factual, and analytical highlights of the accident." (ERDAM 0502)

17. **Conclusions.**

a. ". . . reasoned judgments." (W)

b. ". . . judgments of needs" (ERDAM 0502)

c. ". . . reasonable, based on the weight of the evidence." (ERDAM 0502)

Probable causes–See "Probable" above and "Causes" on page I-5 and in Appendix C.

Judgments of needs–The kinds of managerial controls and safety measures believed necessary and sufficient to prevent or minimize the probability or severity of a recurrence.

18. **Recommendations** Specific methods and corrective actions believed "feasible, logical and practical" and sufficient to fulfill the judgments of needs. In general, each need is expressed in two kinds of recommendations:

a. For fixing the specific problems involved in the occurrence.

b. For fixing systemic problems revealed during the investigation.

19. **Implementation** Syn. corrective actions "... measures taken by the ERDA contractor that are necessary to prevent a second occurrence." (ERDAM 0502)

An hierarchy of statements and guidance ranging from broad and general to highly specific:

20. **Policy** A general statement of prudence, wisdom, and interest intended to guide present and future decisions, issued by the highest authority in an organization.

21. **Codes, Standards, and Regulations (CSR)** Authoritative, specific statements of safety measures. Regulations have governmental sources and the force of law. Standards are usually voluntary. Codes may be either regulations or voluntary.

22. **Guidelines** Less specific than CSR.

23. **Practices** Operating methods and requirements:

a. Standard defined or established by an organization or subdivision, e.g., ERDA Manual chapters.

b. Actual those which in reality or truth are used.

c. Deviations In differences between actual and standard practices, may include more or less safe or unsafe practices, and may include practices necessary and accepted by those doing the work.

24. **Procedure** A written, step-by-step method of performing a task. [Job safety analysis (JSA) is a type of procedure.] (MORT, p. 317)

25. **Management** "... the collective body of those who direct an enterprise." (W)

a. **Top** the chief executive officer and the next tier of managers.

b. **Middle** the group of managers between "top" and "supervision"; syn. higher supervision.

c. **Supervision** the first tier directing employees in task performance.

Some MORT terms frequently used:

26. **Job safety analysis** Safety and management review of step-by-step procedures originating at the work level.

27. **Priority problem list (PPL)** A listing of safety problems, e.g., assumed risks and worst potentials, of principal concern to management.

28. **Amelioration** Steps taken to limit adverse consequences of an accident, including preventing a second accident from the same energy flow or from debris, fire and rescue, medical treatment, and rehabilitation. (MORT, p. 140)

29. **Barriers** Measures to limit, reduce, or prevent an unwanted energy flow from harming persons or objects.

30. **Hazard** The potential in an activity (or condition or circumstances) for an accident, particularly an unwanted transfer of energy, which can occur in random variations of normal operations or from changes in physical or human factors.

31. **Hazard analysis** The functions, steps, and criteria for design and plan of work, which identify hazards, provide measures to reduce the probability and severity potentials, identify re ual risks, and provide alternative methods of further control.

32. **Risk** The probability during a period of activity that a hazard will result in an accident with definable consequences.

    a. *nal* From an unanalyzed, uncontrolled activity.

    b. *Residual* After analysis and some action to control (PPL).

    c. *Calculated* Specific, analyzed, and where possible quantified; probabilities measuring risk in a project or activity.

    d. *Group* Rates and projections for a class of exposure.

33. **Uncertainties**–Nonquantifiable increases in accident probability resulting from the lack of named safety program features (e.g., human factors review, hazard analysis, training); oversights and omissions in a management system.

34. **Error**–"Any significant deviation from a previously established, required or expected standard of human performance, that result unwanted or undesirable time delay, difficulty, problem, trouble, incident, malfunction or failure." (MORT, p. 49)

    Rigby's "tolerance limits" (MORT, p. 52) define errors. Classes include managerial, planning, and operator. Syn: Mistakes (less blameful); oversights, specific.

    Human failure is also discussed on page 2-16.

35. **Monitoring**–Information systems (individually or collectively), which detect deviations from plan and procedures, can trigger corrections, and can determine deviation ra and trends.

36. **Triggers**–Information (planned changes, monitoring outputs, accidents/incidents) which can initiate hazard analysis and correction.

37. **Trigger event**–The event that initiates interaction of latent errors and conditions in a system to produce an accident/incident.

38. **Innovation diffusion**—A research-based technique for gaining acceptance of a desired change in behavior (MORT, Appendix H).

D. OTHER.

1. **Comments on disciplinary actions.** Concern or uncertainty about possible disciplinary actions resulting from investigations frequently cloud or warp investigative efforts. The following observations on discipline, although not a part of the subject matter of investigation, but rather of management action, should be considered:

   a. "Fix the blame and discipline the offender" is a common and historic approach, particularly in the military. It satisfied emotional needs but has not been shown to have preventive value. You get "another apple from the same barrel!"

   b. Most managements have ill-defined philosophies and practices on discipline. The resultant variability has undesirable side effects—uncertainty and unfairness at the least.

   c. Some disciplinary rules may be contained in collective bargaining agreements, but these are usually procedural rather than substantive.

   d. MORT says: "When an accident occurs, it's the *system* that failed!"

   Deficiencies in the hazard review process, human factors review, supervision, inspection and monitoring, and management implementation, including collecting and acting on failure histories, all tend to create error-provocative situations. Discipline measures do not change the situational factors in the error rate and may be grossly unfair. The man, selected in part by chance variation in error occurrence, is hardly to blame. After one accident, a member of the board of directors said, "We set a trap for her."

   > "If an organization has a major trouble, don't fire the office boy!"

   Some specific guidelines may be defensible:

   e. Minor penalties, e.g., suspensions, seem appropriate, and perhaps effective, for willful and flagrant disobedience of enforced rules affecting grave danger.

   f. Major penalties, e.g., termination, hardly seem appropriate or effective as sequels to a single occurrence.

   g. Repeated violations or accidents may indicate a deviant personality, in which case the four viable alternatives are:

      (1) Treat (counsel, get to treatment, provide supportive services).

      (2) Transfer (to low energy situations).

(3) Tolerate.

(4) Terminate.

Three alternatives not deemed effective are:

(5) Train (unless lack of knowledge or skill are specifically indicated).

(6) Talk (propaganda, exhortation).

(7) Threats.

It is advisable that management clarify its beliefs and practices regarding discipline prior to an accident in order to enhance the preventive purpose of investigation and minimize uncertainties.

2. Comments on the investig. . s motives and attitude.

The primary motive or improving accident investigation is to increase the preventive values. To do this we increase the scope and depth of findings, analyses, conclusic .s and recommendations. This means that we will be examining error (nd error-provocative situations) for all relevant roles and functions. We must take special steps to show that our motive is to help decrease error potentials not to just shift some of the guilt implicit in the phrase "human error" from the beleaguered employee to supervisors, designers, management or other groups. This requires:

a. Courteous, considerate treatment, not an inquisition.

b. Concern for peoples' feelings and explanation that people fail, in major part, because of inadequate help and services.

c. Finally, findings, analyses, conclusions, and recommendations must clearly show that failures at any level are system failures, that are correctable by better services and help.

d. The investigation should establish its humane purposes.

Remember:
Failure should be our teacher, not our undertaker.

Safety is positive. It is doing things the right way. It is interest in the welfare of others. It is a contribution to good living, to good government and respect for law and order, to efficient production, and to the welfare of every individual. (From the National Safety Council)

See also "Sermon To ics," (Figure 10) for a cross-reference of investigators' attitudes, and Appendix B.

Thorough (1)

Methodical (5)
- Able to organize

Meticulous (1)
Searching (3)
- Driving
- Hard working
- Tenacious
- Persistent
- Firm
- Industrious
- Patient

But careful in
use of authority

Studious
- Well-prepared
- Developed:
  - specialty
  - method
  - management
- Multi-disciplined

Complete (4)

Objective (1 & 3)

Method-oriented
(3 & 5)

Reasoning (3)
- Analytic (5)
- Intelligent
- Logical (1)

Records contrary
evidence

Sound judgment
- Fairminded
- Judicious
- Realistic
- Common Sense

Truth seeking
- Honest (2)

Unbiased
- No Hobbies

Independent (1)

(See MORT and
Criteria for
Selection)

Method
- Fosters
- Independence

Open-Minded (1 & 2)

Curious (3)

Imaginative (3)

Intuitive (3)

Flexible

Innovative

Observing

Knows what
to know (5)

Knows how to
look

Knows how to
record

Alert

Good Listener

Sensitive to:
- Changes
- Anomalies
- Situations

Perceptive (4)

Other

Humble (2)

Strong-minded
(4)

Cares for people
- Considerate
- Diplomatic
- Tactful
- Sympathetic
- Understanding
- Helpful
- Discreet
- Direct
- Candid (4)

Not fault-
finding (4)

Able to write

Sense of values

Humor
- Eases tension
- Not clowning

Sources:
(1) ERDAM – Appendix 0502
(2) NTSB (and Board guidelines)
(3) DOL guidelines
(4) Ad Hoc AEC committee (see Appendix E)
(5) MORT

The Boy Scout Laws:				
	Trustworthy	Loyal	Helpful	Thrifty
	Courteous	Kind	Obedient	Cheerful
	Friendly	Brave	Clean	Reverent

Figure 10. "SERMON TOPICS"
Some Attitudes of Good Investigators (Investigation) Mentioned by Authorities

3. **Costs of investigations.**

The costs of good accident investigations are substantial. For one major accident, participants estimate $150,000 of direct cost. Discussion with a cross-section of investigators (as well as NTSB's estimates) indicates that 75 to 125 man-days of investigative time are not unusual for serious events.

A "ball-park" approximation of investigative costs for serious events will be useful in gauging the amount of advance preparation likely to be cost-effective. Figures of this type can be guessed/estimated as follows:

Direct costs–investigative time	$ 8,000
Associated costs–personnel involved (contractor)	24,000
Review costs–field organizations and Headquarters	1,000
Overhead	$33,000
Per Case	$66,000

For approximately 20 occurrences per year, the aggregate costs may be on the order of 1-1/3 million dollars. Such an amount is undoubtedly small in comparison with the values to be obtained–the point here is to consider the costs of improved processes as compared with present investments. For example:

Training of special investigators	$1,750 (each)
Advance preparations by special investigators and others	3,000
	$ 4,750
Overhead	4,750
Total in the	$10,000 area

This guess/estimate may then be compared with:

a. Per case costs of $66,000.

b. Benefits (many tangible) of improved process and efficiency.

One of those involved in the case estimated to have cost $150,000 said that costs might have been one-third lower if suitable investigative protocols had been available.

Failing to have good investigation protocols and preparation results in inefficient use of board members' time, as well as reports that are less than excellent. The costs of inadequate procedures and preparations in terms of conclusions *not* perceived and recommendations *not* made are incalculable.

II. MANAGEMENT OF THE INVESTIGATION.

A. INTRODUCTION.

Management of investigation in ERDA is keyed to the following characteristics of operation:

1. Accident/incident investigations within ERDA facilities and ERDA contractor operations employ combinations of mutually supporting responsibilities and competencies placed on both ERDA and contractor line organizations. In turn, each of these involves line management, safety staff, ad hoc boards, and trained investigators. For the latter three, steps are taken to assure independence.

2. The wide variety of operations and technology requires a high degree of flexibility in creating and directing a competent board or other investigative agency.

3. ERDA follows the practice of appointing special ad hoc boards of investigation. In serious events, these are ERDA appointed; in lesser events or incidents, they may be contractor appointed. Many investigations stem from incidents with no injury and/or insignificant property damage. If there is a high potential for injury or damage, important lessons to be learned, or program or public impact, a full-scale investigation is frequently launched by ERDA or by a contractor.

4. Because ERDA and its contractors are responsible for management of direct operations, investigative agencies can and properly do go much further in recommending management preventive actions than would be appropriate in regulatory investigations.

5. Because the typical occurrence is wholly within an ERDA site or facility, the investigation usually begins rapidly, has full control over the site, equipment and personnel, and enjoys the ready availability of technical specialists and the services of a wide variety of laboratories, if needed.

B. GENERAL RELATIONSHIPS OF INVESTIGATIVE ROLES.

ERDAM 0502 and Appendix place primary responsibility for accident/incident notification and investigation on managers and directors of field organizations.

The quality and efficiency of investigations will depend largely on the advance planning done before the occurrence.

1. **Field organization advance plans and coordination of plans are needed due to the:**

a. Diverse responsibilities

(1) of both line and staff elements; and

(2) in both field and contractor organizations.

b. Chaotic circumstances often present after an accident.

c. Priority need for the line organization to carry out ameliorative functions.

d. Possible remoteness of the site.

e. Need to secure the scene.

f. Need to initiate immediate collection of transient evidence.

g. Need to restore operating functions where possible.

h. Need to investigate thoroughly, using trained investigative personnel to assist and advise an independent board some of whose members may not have investigative experience.

2. Given the need for speed in acquiring early information and preserving transient evidence, the interim responsibilities of investigators, both ERDA and contractor, need definition by ERDA field organizations:

a. Contractor safety staff should initiate data collection.

b. ERDA safety or investigative staff should go to the scene and take over data collection pending arrival of a board.

Once these procedures are established, it is possible to set down brief elements of the sequential roles of various responsible groups. An example of this type of a sequential relationship follows (Figure 11).

C. IMPLEMENTATION OF ADVANCE PLANS FOR INVESTIGATION *

1. Issue instructions for the appropriate functions listed in item 5, below to field organization staff and contractor management. Consider the following while developing the instructions:

a. Basis for plans - major events, all possible modes, priority problem lists. (See section IV.B. for lists of places, kinds of occurrences, and responsibilities.)

b. Preplanning with:

(1) communication center and emergency services - fire, security, rescue, etc.;

(2) specialties - trained investigators, and disciplines, e.g., occupational, fire, health physics, nuclear, etc. - all to be in a state of operational readiness;

Figure 11.

GENERAL SEQUENTIAL RELATIONSHIP OF INVESTIGATIVE ROLES

1. Advance Plans			1. Implement advance plans
			Event Occurs
			2. Amelioration (acute)
2. Notification			3. Notification
	1. Go to the scene		4. Secure the scene
	2. Get needed assistance		5. Preliminary witness statements
	3. Review personnel safety		6. Early photos
	4. Observe amelioration		7. Preserve transient evidence
3. Receive	5. Receive		8. Preliminary synopsis
	6. Evaluate magnitude		
4. Decide category	7. Collect transient evidence		
5. Appoint		1. Briefed by authority	9. If incident, appoint
		2. Go to scene	10. Assign top level liaison
		3. Meet with management	
	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	13. Provide information, witnesses and evidence
		7. Collect facts	14. Continue non-duplicative investigation
8. Check on progress		8. Analyze	
		9. Release scene when feasible	15. Continue rehabilitation
		10. Agree on Facts, Conclusions, Recommendations	16. Report actions
9. Review report		11. Write report	

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

**May be contractor appointed or ERDA appointed.

* See ERDAM 0502 and Appendix, and MORT, p. 388.

(3) public officials Federal, state and local, including medical liaison with coroner or medical examiner.

(4) medical.

(5) legal.

2. Prepare plans for boards of investigation.

a. Criteria for selection.

b. Board guidelines (ERDAM 0502-036).

3. Establish responsibility for maintaining competence in investigation, including acquisition and application of methods, within the organization.

4. Establish standing orders for communications, notifications, decision mechanisms and action in the event of an occurrence.

5. Issue instructions to line management. (Keep them simple—in an emergency, it's hard to remember long paragraphs!)

a. Require that line organization, security and maintenance be briefed on philosophy and procedure prior to the accident.

b. Amelioration (preventing an immediate second accident, fire, rescue, emergency medical care) is the first priority.

c. Notification requirements.

d. Standard initial investigative steps:

(1) Secure the area. This is essential and has not always been a standard practice.

(2) Secure from disturbance (do not add, do not take away).

(3) Secure from entry into area of residual hazards.

(4) Make haste, but slowly!

(5) Preserve evidence.

(6) Collect transient evidence—photos, preliminary statements by witnesses, mark locations of injured, etc. What happened? Anomalies?

(7) Have an assistant initiate these phases when possible, even during amelioration.

(8) Make provisions for securing area, and taking photographs and witness statements in remote areas where there is no supervision.

e. Cooperation with independent board or investigator.

(1) Internal agency safety department or board.

(2) ERDA define authority of ERDA investigative agency.

(3) Provide senior staff liaison to investigation to handle requests for documents, witnesses, tests, etc.

(4) Provide support services space, clerical, phone, transportation, personal protective gear, etc.

f. Prepare plans for corrective actions.

D. ACTIVATION OF THE PLAN

1. Decide (from available information):

a. Type of occurrence.

b. Level of effort - when in doubt, scale up!

Be cautious in quick diagnosis of cause. In a previous occurrence, a Headquarters program division call prompted action which caused a second event. Reiterate instructions to secure scene, collect transient evidence, etc.

2. Make the necessary notifications.

3. Appoint a board (promptly).

a. Make selection, per criteria.

b. Give oral message, if speed is warranted.

c. Give letters, with guidelines and scope attached.

(1) Include the names, titles, and organizations.

(2) Include the scope of the occurrence (see item 7 below for discussion of the scope).

(3) Send a copy to contractor management with board guidelines.

(4) State board authority if it needs explicit definition. Also, when it is necessary, the investigator's interim authority should be defined.

4. Brief the board, including scope of investigation (see below).

5. Check on progress as investigation proceeds.

a. Is the board well organized?

b. Are tasks being done?

c. Is support from ERDA and contractor adequate?

d. Is an executive secretary needed?

e. Are any added resources needed? (Good management support has been shown via site visits.)

6. Do not appoint two simultaneous boards (one for occurrence and one for the problem in general).

7. Define scope.

The appointing official of the board is responsible for defining the scope of the investigation, including limitations, if any.

a. The first concern is to broaden the scope to the life cycle of the activity (as relevant), and to the management systems which should have controlled the activity. Desired scope includes the "upstream processes" which produced the work ingredients design, plan, supervision, maintenance, inspection, training, procedures, etc. and the managerial control systems, especially monitoring for prompt correction of deviations.

The bounding of the event may present difficult questions. For example, (1) a tritium release from one plant had a prior sequence of events extending back to a mistake at another laboratory; and (2) a fatality in firefighting had a prior sequence extending to nonobservance of safety recommendations, which initiated the fire.

In such cases, is the board expected to inquire into the causal factors of the prior event?

b. The second concern is to limit the scope to a manageable, ad hoc board activity. This suggests that a board be encouraged to recommend further studies when its findings warrant. This could produce appropriate, subsequent attention to three kinds of problems:

(1) Lengthy early sequences at other locations or places.

(2) Problems requiring research.

(3) General studies of broad programs (e.g., management systems, supervision, labor relations, training, maintenance and inspection, or design resources) or broad problems (e.g., public information, morale or discipline).

One investigation was too lengthy because the scope was too broad.

Some boards have taken control of operations inadvertently by making recommendations or by directing data collection methods which required new organization.

c. The third concern is resources. What scale of effort (time and money) is presumed necessary? The safety analysis report (SAR) for a reactor is essentially unbounded. A nuclear occurrence investigation would be unbounded. A conventional task analysis, e.g., for changing out a pump, is not unbounded. The board should have general guidance on the resources and depth of effort desired. The possibly ambiguous term, "thoroughness," will in fact be determined by resources.

d. An example of a letter of appointment which includes a paragraph on the scope of the investigation follows (Figure 12).

OARDS OF INVESTIGATION.

Why guidelines are needed.

a. Many board members are inexperienced in accident investigation. The complete ERDA manual chapter and appendix, covering much more than the board's responsibilities, are difficult for a board member to use.

b. Management has a responsibility to have on hand, and ready to distribute, guidelines for board chairman and members. The guidelines should be succinct, clear, coherent, functional, and comprehensive for major steps (skip the detail).

2. Plans and criteria for boards and consultants.

a. Manual criteria have been inserted in the guidelines for board members.

b. Values in boards (MORT, p. 386).

(1) Assemble necessary competencies and skills, including managerial, scientific, technical, professional, investigative and specialities.

(2) Foster independence and diversity of view and experience (a difficult objective; see MORT, chapter 28, and numerous Aerojet Nuclear Co. exhibits referenced therein).

(3) Improve judgmental processes and technological solutions, counteract bias, and avoid traps that individuals might miss.

(4) Safety promotion effects on members and their peers.

c. Weaknesses.

(1) Lack of experience in investigation and analysis.

(2) May be cumbersome and slower.

(3) May not be truly independent (see MORT, p. 386, for a case of "incest").

(4) Interpersonal factors may complicate the work.

d. Other criteria largely drawn from prior investigations.

(1) Managerial level of 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 manage the investigation better, and they are not easily awed or fooled during the investigation.

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

Date

Chairman of the Committee
Job Title

INVESTIGATION OF OCCURRENCE AT THE XYZ LABORATORY

You are hereby appointed as Chairman of a committee to investigate an occurrence at the XYZ Laboratory. The following additional personnel are appointed as members of the committee:

Employee A, Job Title, Employer
Employee B, Job Title, Employer
Employee C, Job Title, Employer

In addition, the following personnel are designated as consultants to the committee to be utilized as required and requested by the chairman:

Employee D, Job Title, Employer
Employee E, Job Title, Employer

The investigation and reporting are to be conducted in accordance with ERDAM 0502 insofar as circumstances associated with this subject permit. The report should, of course, fully cover and explain the technical elements of the causal sequence(s) of the occurrence. The report should also describe the management systems which should have, or could have, prevented the occurrence, e.g., the safety or hazard review system, the quality assurance program for safety (including the monitoring of actual operations). Appropriate recommendations for improvement of the management systems will be required.

cc: Appointees

Signature
Appointing Official

Figure 12. LETTER OF APPOINTMENT

(2) Personal qualities desired include open and logical mind, thoroughness, and ability to maintain perspective and independence. Personal qualities to be avoided are "... it all" attitude, "prima donnas," preconceived biases, preoc... ation with normal work, and reluctance to be away from home or regular work.

(3) Members who are remote from site delay progress and review. Evidence and testimony m... alter. Members may short-cut investigation to return h...

(4) Vested interests have bias.

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

(6) The chairman should have a high level of managerial skill as well as having a technical background. Experience indicates that a strong chairman is ne...ded.

(7) Line personne... needed for recovery should not be assigned to investigation. (This comment is based on past cases. It would now be prohibited as not independent.)

(8) Avoid using people just because they are available.

(9) Exclusively "outside" investigators may imply local ERDA staffs are incompetent.

(10) Legal advisors are usually effective in fact collection and analysis, questioning witnesses and report writing.

e. An example. Since limited numbers of people are available a gross scoring system may suggest wise compromises. A possible system could produce such an analysis as follows:

	Relation	Mgr. Exp.	Investigation	Expertise Discipline	Expertise Subject	Expertise Analytic
Chairman	Dist nt	++		++		
Member	Clos	+		+	++	
Member	Safe y		++	+	+	++
Member	Distant	++		++	++	
Member	Distant	+	+	+	++	

In this example, the requirement that the chairman is an ERDA employee is satisfied. 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 an amalgam 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.

f. Disciplines and subject matter—since ERDA imposes no limits on appointed consultants and technical advisors, a lengthy list 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 (R&QA)	Explosives
	Crane operation
Medical	Heavy construction
Human factors	Radiation
Health physicists	Chemical laboratories
Mine engineering	Coal liquefaction
Geophysicists	Extraction technology
	Reclamation technology
	Geothermal and solar development
	Electric power transmission and distribution

Observations from a prior investigation include:

(1) Persons with substantial training in disciplines and specialties involved should be on the board.

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

(3) 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.

(4) 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.

(5) For radiation or other problems, there is a tremendous wealth of expertise within ERDA. Do not hesitate to use it.

3. Guidelines for trained investigators and members of board of investigation. Guidelines should be available for immediate distribution to board members.

a. ERDAM 0502 provisions in brief.

(1) Objectives.

(a) "To investigate and evaluate occurrences to determine their causes and the appropriate measures to prevent recurrences and improve the safety of ERDA and ERDA contractor operations."

(b) "To obtain early, complete, and factual information on occurrences as a basis for (1) reports to the Administrator, Congress, and other Federal agencies; and (2) where appropriate, informing the public."

(c) "To assure the gathering of adequate information on which to base management action."

(d) "To provide a basis for the improvement of codes, guides, and standards used in ERDA and ERDA contractor operations."

(2) Responsibilities.

(a) Directors and managers of field organizations.

(i) Direct investigations.

(ii) "Assure that, except for necessary emergency actions, the scene of any occurrence requiring or possibly requiring a Headquarters or field organization board investigation is not disturbed until the investigation board concurs that recovery or normal operations may be resumed."

(iii) "Appoint field organization investigation boards and establish the scope of their investigations including limitations, if any."

(iv) "Assure that Headquarters and field investigation boards receive the necessary logistic and administrative support."

(v) Review field investigation reports.

(vi) Assure that corrective actions are satisfactorily completed.

(b) Boards of investigation.

(i) "Report directly to the ERDA appointing official during the investigation."

(ii) "Understand the scope of the investigation including the limitations, if any, prior to initiating the investigation. If necessary, the board should discuss the scope of the investigation with the appointing official or his designee."

(iii) "Conduct an investigation and prepare an investigation report which satisfies the requirements in this chapter."

(iv) "Transmit the report with a cover memorandum which includes the board's recommendations to the appointing official within his specified period of time."

(3) Guidelines for investigation.

(a) "Appointing the board . . . ."

(i) "A board of investigation shall consist of three to five members, one of whom is appointed as chairman."

(ii) "All members of Type A investigation boards shall be ERDA employees. Type B investigation boards may consist of ERDA and/or ERDA contractor employees, at the discretion of the field organization head."

(iii) "ERDA employees appointed to a Type A investigation board, and ERDA and ERDA contractor employees appointed to a Type B investigation board shall work for and report to the field organization head during the investigation.

(iv) "At least one of the members of a board shall be a trained accident investigator."

(v) "All competencies should be considered in appointing each board, including managerial, scientific, professional and investigative."

(vi) "The use of necessary consultants or advisors who are experts in certain areas or who are familiar with the operations or management of the program involved in the occurrence is encouraged. These persons may be contractor personnel."

(vii) "A superior and his subordinate shall not serve on the same board."

(viii) "Employees directly related to the operation or activity involved in the occurrence shall not serve on a board."

b. What approach is used? Accident investigation is spoken of as both a science and an art. Certainly it contains elements of both. A controlled method/system is essential, and a clear understanding of the techniques to be used allows investigators to develop a "feel" for what needs to be done and how far to pursue each course of action. The main points to be remembered are that you must:

(1) Decide what organization, procedures, and analytic techniques will be used as soon as possible and follow your plan unless you see a definite need for rearrangement.

(2) Have specific tasks assigned to individuals, and ensure that each task is accomplished.

(3) Explore every possible cause of the accident until it is proved to be an actual cause or ruled out.

(4) Recognize both the extent and limitations of your own knowledge about technical subjects, and call on specialists if necessary.

(5) Maintain courage if the cause is not apparent, and avoid jumping to what appears to be an obvious conclusion.

(6) Record all evidence accurately; corroborate, when possible, and evaluate all statements and testimony.

c. How is an investigation conducted?

(1) Initial actions. Getting started properly is very important; otherwise, evidence can be lost while the board is trying to organize itself. Following these sequential steps should assist in beginning an orderly investigation:

(a) Assemble the board for field organization briefing on synopsis of the occurrence and scope of investigation.

(b) When possible, 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.)

(c) Get a short briefing from the individual who has been controlling the accident scene prior to your arrival. Get local organization charts.

(d) Establish formal liaison with management.

(e) Go to the accident scene.

(f) Perform a general survey of the accident scene to get a "feel" for the accident.

(g) Prevent unnecessary handling or moving of evidence. Review security provisions.

(h) If personnel are readily available, find out what each witness might be able to contribute. Alert him to a possible followup interview.

(i) Photograph evidence and the scene.

(j) When needed, give the board a briefing on investigation methods.

(k) Establish command post and arrange for other needed resources.

(l) Finalize board organization and plan.

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

(2) Continuing tasks.

(a) Collect and preserve evidence.

(b) Interview witnesses.

(c) Prepare diagrams.

(d) Secure as-built drawings; copies of procedures, manuals and instructions; maintenance records; inspection and monitoring records; alteration or change records; design data; material records; and personal histories.

(e) Conduct reenactment, where necessary or useful.

(f) Arrange for laboratory tests, where necessary or useful.

(3) The board should meet at least once daily to exchange information and coordinate results.

(4) An analysis of the accident goes forward simultaneously, both in the minds of board members and in analytics prepared by the trained investigator or consultants. The analytics help determine what additional information to seek and later help determine causes and information to seek and later help determine causes and recommendations.

(5) Prepare an outline, and start writing as soon as feasible.

d. The chairman's responsibilities.

(1) Direct and manage the investigation.

(2) Assign tasks to members; establish deadlines.

(3) Use the abilities of a trained investigator to outline and expedite the work.

(4) Establish a "command post." Do not use your office or even your building. If feasible, separate investigation office from regular work.

(5) Assure that scene is safe and that investigation does not compound the event or interfere with emergency operations.

(6) Assure that the scene is secured until all evidence has been recorded or collected.

(7) Release the scene to management for rehabilitation and operation when possible.

(8) Handle requests for information, witnesses, technical specialists, laboratory tests or administrative support with a liaison member of management.

(9) Handle all communications with the ERDA field organization and public officials. Remember, the field organization is responsible for public news releases.

(10) Keep the appointing official informed.

(11) Assure that the investigation does not function in ways which relieve line management of operational res onsibility.

(12) Call and preside over meetings.

(13) Assure that all potential causal factors are studied.

(14) When the board has determined its findings, conclusions, and recommendations, supervise preparation of the report.

(15) Do not release the board until the report has been completed.

(16) Unless otherwise instructed in the appointment, before leaving the site, brief contractor management on the facts determined (not conclusions and recommendations). Receive additional factual evidence, if offered by management, but revise the factual section of the report only as the evidence warrants.

member–*Board work has priority over all other work. Humility, integrity and n-mindedness are the marks of a good investigator.*

THE TRAINED INVESTIGATOR.

During an investigation, the trained investigator may be the chairman or a member of the board. However, the specific duties of a trained investigator will be defined in the background preparation and situation requirements.

1. Manuals and guidelines (including ERDA Manual chapters).
2. Training.
3. Investigative aids and equipment.*
4. Frequent practice on HIPO's.
5. Role in amelioration (specific to site).
6. Role in interim prior to board appointment.
7. Role with external agencies (police, coroner, Department of Labor, NTSB, and Environmental Protection Agency).
8. Operational readiness checks. Emergency procedures (ERDA and contractor) should be rechecked. At this time, since ERDA does not have enough incidents to develop proficiency, simulations seem to be the answer. These should include cases for associated specialists–nuclear, radiation, hazardous materials, occupational, fire and waste management–because each of these has specialized investigative needs and plans.

The nature of some of these topics, e.g., aids and equipment, will be covered later; but, definition of roles seems to be a major need for each field organization situation. Appendix B provides many useful examples of problems and solutions. For a checklist of investigative tasks see Appendix D.

*An investigator sent from one field office to another is entitled to expect that the local investigator provide services.

G. THE ROLE OF SPECIALISTS.

1. The role of lawyers in investigations.

The appointment of a legal advisor to an investigation board is not a manual chapter requirement. However, such appointment should be carefully considred 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. **

2. 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.

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

(1) To assure 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 failure factors 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. Are warning and monitoring signals designed with high attention stimulation unambiguous and fail-safe features? Are control systems complicated? Are critical controls distinctively designed and functionally located? Do monitoring procedures favor boredom and fatigue?

** See Appendix E for the report prepared by an ad hoc committee of AEC lawyers. The report contains guidelines on investigation reports and the constituency of investigation boards.

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

(3) To establish cause and time of death.

This information is always important to 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 also 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 very 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 and degree of injury and assist in determining the source and 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 judgements, 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 F.

(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 followup medical care elements.

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

(13) To help determine if 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.

b. **Guidelines for physicians.**

Physicians have major roles in ERDA programs for occupational medicine, radiation protection, industrial hygiene, and emergency preparedness. However, the extensive network of ERDA/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.

These 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, or 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) Evaluate 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* 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 ERDA or ERDA contractor physician is of great value.

(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) ERDA/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

* See sample form in Appendix F.

in development of services; for example, in 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, etc. Early detection can trigger preventive measures by supervisors and others. Again the physician can provide instruction of nurses and supervisors, including good communications between these key groups.

(5) Medical records: Medical records related to the accident investigation should be treated on a confidential basis as privileged information. This includes personal medical records, pictures, autopsy reports, and toxicological reports.

In general, it has been 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 to be 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 ERDA physician by the use of a standard medical information release form (see sample form in Appendix F).

(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.

3. Other specialists (depending on the nature of the event).

a. Human factors.

b. Reliability and quality assurance.

c. Radiation.

d. Design, test, etc.

e. Relevant engineering specialists.

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 most likely 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 assure 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 scources 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.

The "Emergency Problem Guidelines" (MORT, pp. 308-310) may be helpful in considering hazards.

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 equipment. 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 who is to supply the emergency service and a clear assignment of responsibilities must be made between the board and the contractor.

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.)

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III. FACTFINDING METHODS.

A. INVESTIGATIVE METHOD.

The effectiveness of methods used will depend largely on four interrelated factors: advance preparations, transient evidence gathering, evidence gathering, and the evidential nature of factfinding. These factors are discussed below.

1. Advance preparations.

a. Instructions to line management as to their roles, especially in securing the scene, preserving transient evidence, and obtaining preliminary witness statements.

b. Maintain trained investigators and essential equipment and resources.

c. Speed and response in appointing investigative body, which is directed to give full time (if needed) until report acceptable to chairman is drafted.

2. Transient evidence gathering.

In the inquiry, the initial concentration should be focused on transient information. Further, recording of temporary and short-lived measurements, e.g., a small pool of water or a scuff mark is URGENT.

3. Gathering other evidence is the next task of inquiry. This may be done by a variety of types of inquiries. The type, nature, and purpose of inquiry methods are as follows:

a. Type of inquiry.

(1) Witnesses.

(2) Maps, diagrams, schematics, and charts.

(3) Photographs.

(4) Physical things.

(a) Persons and objects, records thereof.

(b) Tests and reports.

(5) Other.

In this concept, item (1) witness testimony is statement of fact (reality), items (2) and (3) portray physical reality pictorially, and item (4) physical things are reality as determined by measurements and reproduction in photographs and testimony, and preservation and test of things themselves.

b. Nature.

(1) Transient.

(2) Permanent.

c. Purpose.

(1) Portrayal, e.g., events sequence.

(2) Analytic, e.g., crash kinetics, MORT.

4. Evidential nature of factfinding.

a. Even though the inquiry purpose is preventive action, rather than legal action, principles and procedures of evidence should be considered from two viewpoints:

(1) Usefulness to boards in an inquiry.

(2) Usefulness in an inquiry and in legal proceedings.

b. Boards commonly have procedural problems in defining facts and findings (as contrasted with conclusions and recommendations). To assist boards in resolving problems, note that some simple considerations may be helpful in two ways:

(1) What is good evidence, e.g., what is real evidence, what is circumstantial, what was witnessed?

(2) How should evidence be treated, e.g., by securing the scene, measurement, handling and processing physical evidence, photography, and retention?

A review of the literature on evidence reveals a heavy and inappropriate (for our purpose) emphasis on criminal cases. Thus succinct outlines or checklists do not seem practicable.

The approach used in this manual is more along the lines of offering specific, common-sense suggestions for the honest handling of information from witnesses, maps, photographs, physical tests of materials, file cabinet records, and other sources. However, in the area of handling physical evidence it does seem desirable to come up to at least some minimal legal standards for handling and preservation of such evidence.

c. For both debris maps and photographs, it is essential that three potential flaws be prevented:

(1) Item is in original resting place after the accident - not moved.

(2) No item was removed.

(3) No item was added.

ASSEMBLING THE INVESTIGATOR'S 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) Off-site 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, on-site.

(6) Specialists (see item b above).

(7) Medical authori..ies.

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-foot rule and 100-foot cloth tape.

g. Compass and range finder.

h. Camera (permit, if necessary); flash equipment; film; and camera bag.

i. Tape recorder, tape and radio, (permits, if necessary); flashlight; and heavy duty torch.

j. Evidence tags, labels, receip s; 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, s..ovel, 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 ERDA radiological assistance teams' equipment is another resource.**

C. PHOTOGRAPHY.

1. **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:

a. In-plant photo lab. The in-plant photographic laboratory should be able to respond quickly and 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.

b. Other ERDA or ERDA contractor photo labs. If the facility is small and does not have its own lab the nearest ERDA office or contractor facility may be able to provide photographic support and generally would be a better choice than hiring outside help.

c. 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 pictures that result will reflect the kind of photographer that is hired.

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

d. 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.

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

2. Planning photographic coverage

a. Response time. It is important to obtain coverage as soon as possible after the accident. The 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.

   Take a lot of pictures. Even though most will not be used in a report they are helpful to the investigator in establishing the cause and analyzing details.

b. Time frame of the photographs. While the investigator is concerned with photography post-event 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.

c. 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 minute 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 the lack of depth when only recording two dimensions. Stereo cameras are available which show the proper arrangement of features in all planes. A static subject can be photographed in stereo by merely taking two pictures of the subject 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 image emitted heat from objects. They may be useful after explosions and fires to pinpoint sources or origins of fires.

d. 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, when pictures will be required.

(2) What type scenes to be photographed, from what angles the scene should be photographed. Written instructions and sketches as shown in Figure 13 may be used.

(3) How large the event is, what size is to be covered.

(4) Whether pictures will be taken day or night, whether they will be taken of open areas or buildings.

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

(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.

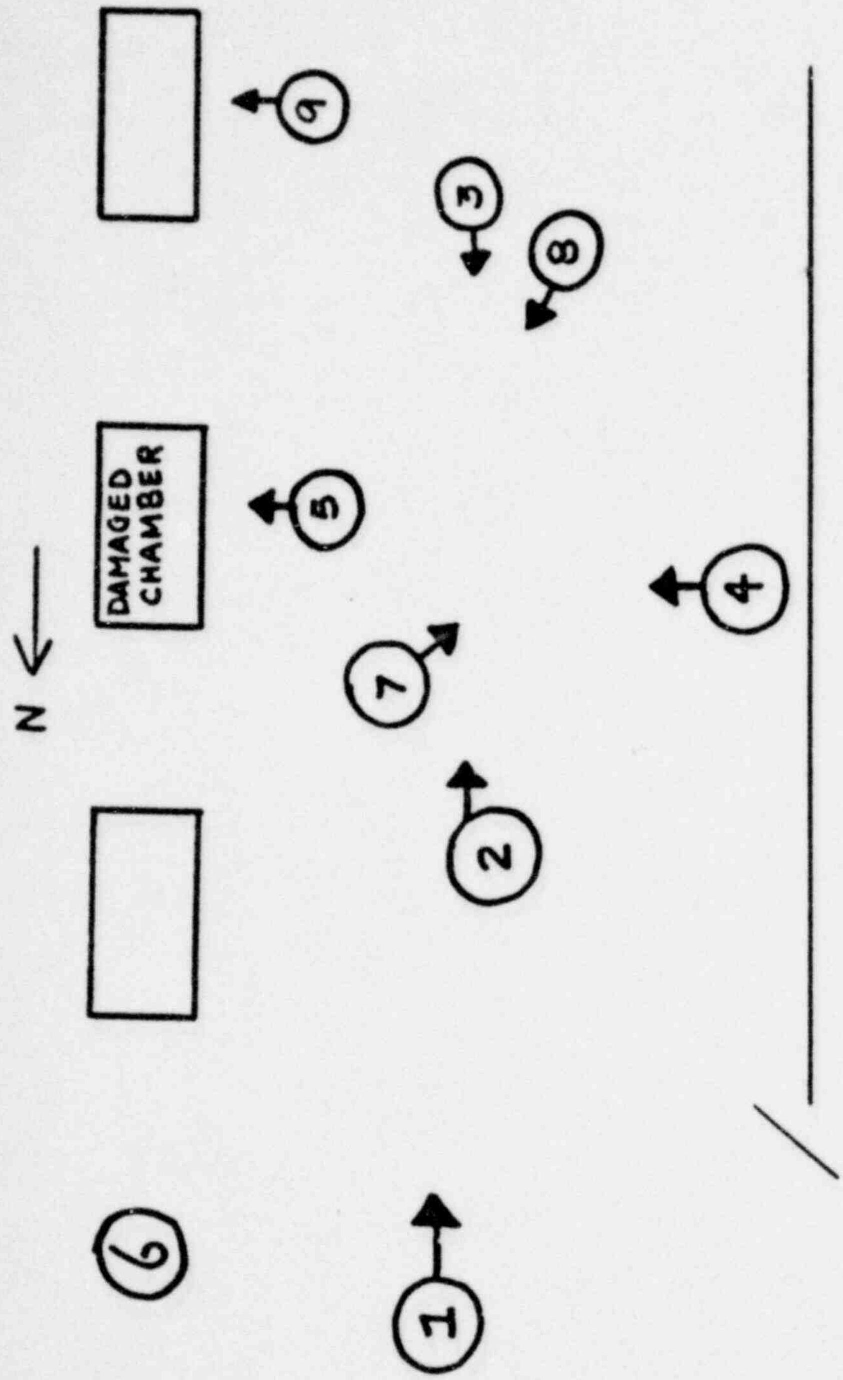


Figure 13.

ROUGH SKETCH OF DESIRED PHOTOGRAPHS FOR PHOTOGRAPHER

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

3. Photographic technique

Certain basic qualities make up good pictures that are factual and 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 made aware of possible misrepresentations in the photographs that are examined.

a. 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.

b. 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.

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

d. Correct camera settings are essential to good pictures. The three basic ones of shutter speed, aperture, and focus setting must be applied correctly in order 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. The focus setting used in conjunction with the aperture setting controls the focus range of the picture.

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

f. 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 or portion of a 6 foot rule may be best.

g. Use color film for maximum information content. While black and white film is cheaper and easier to print, the color information in color prints is often essential to understanding and analyzing an 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.

h. Identification and labeling of the photographs is essential. Figure 14 shows a log sheet that should be used by a photographer at the time of taking the pictures. After the pictures are printed, captions similar to those shown in Figures 15, 16, 17, and 18 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/X	Direction Camera Pointing
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Figure 14. PHOTOGRAPHIC LOG SHEET

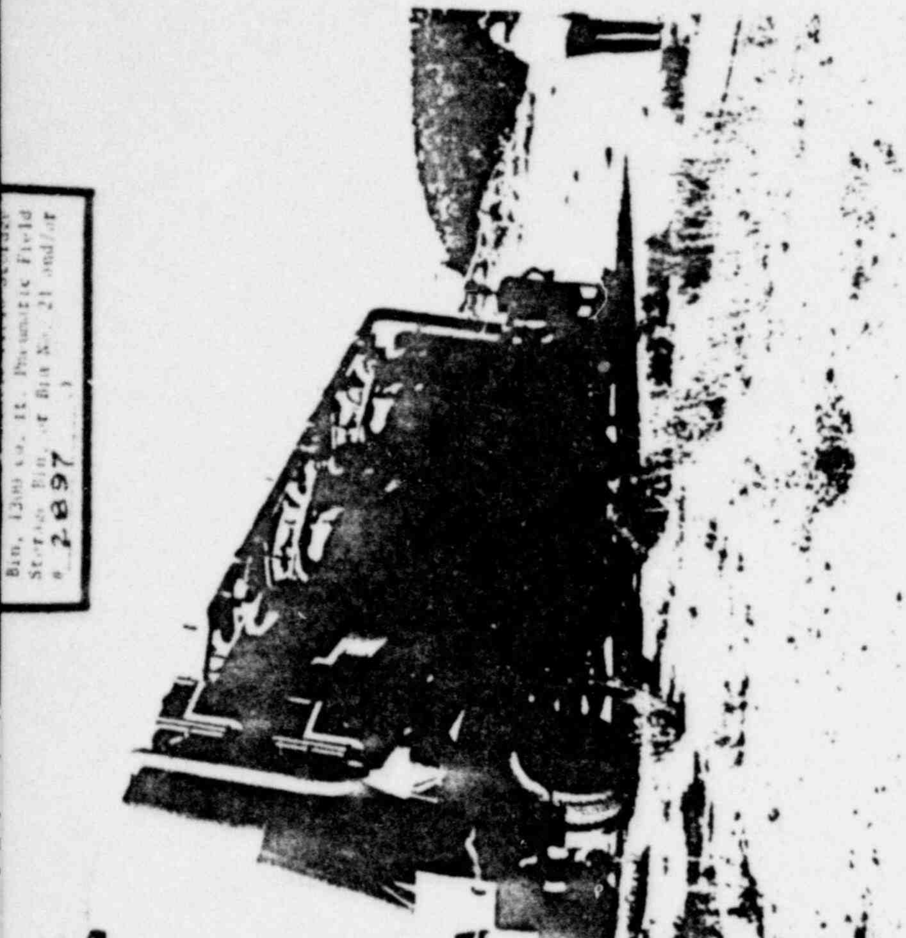


Figure 15. USE OF LABELING AND CAPTIONS IN PHOTOGRAPHS

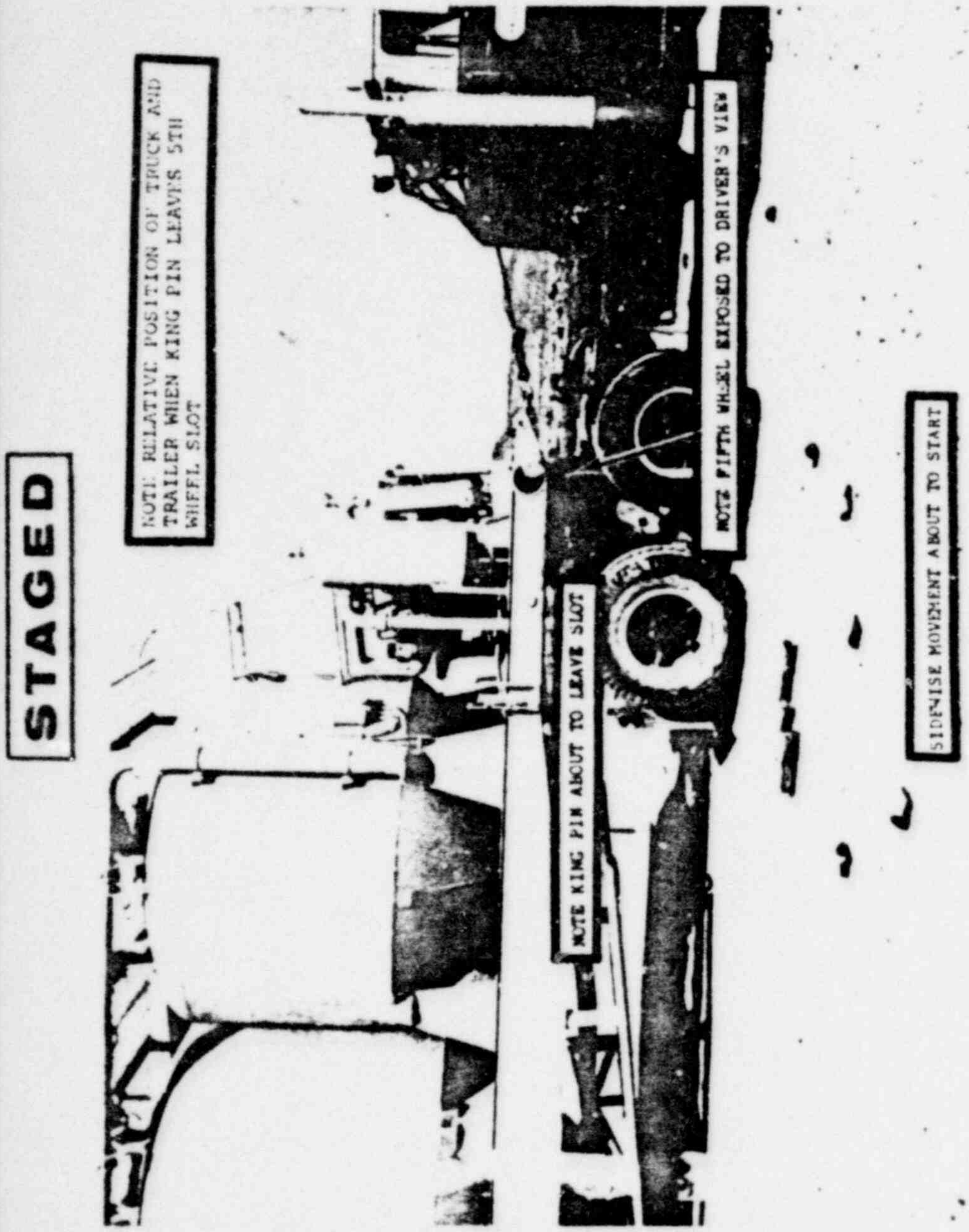


Figure 16. USE OF LABELING AND CAPTIONS IN PHOTOGRAPHS

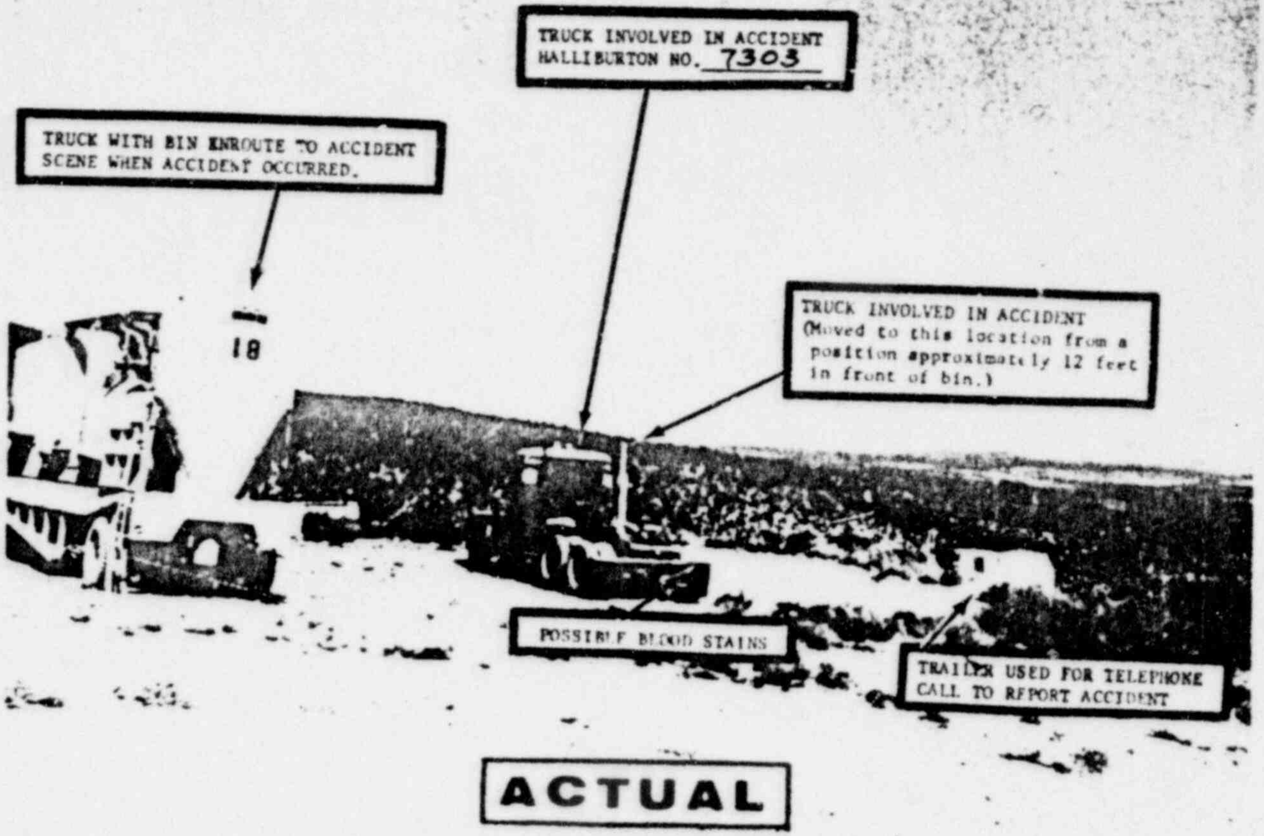
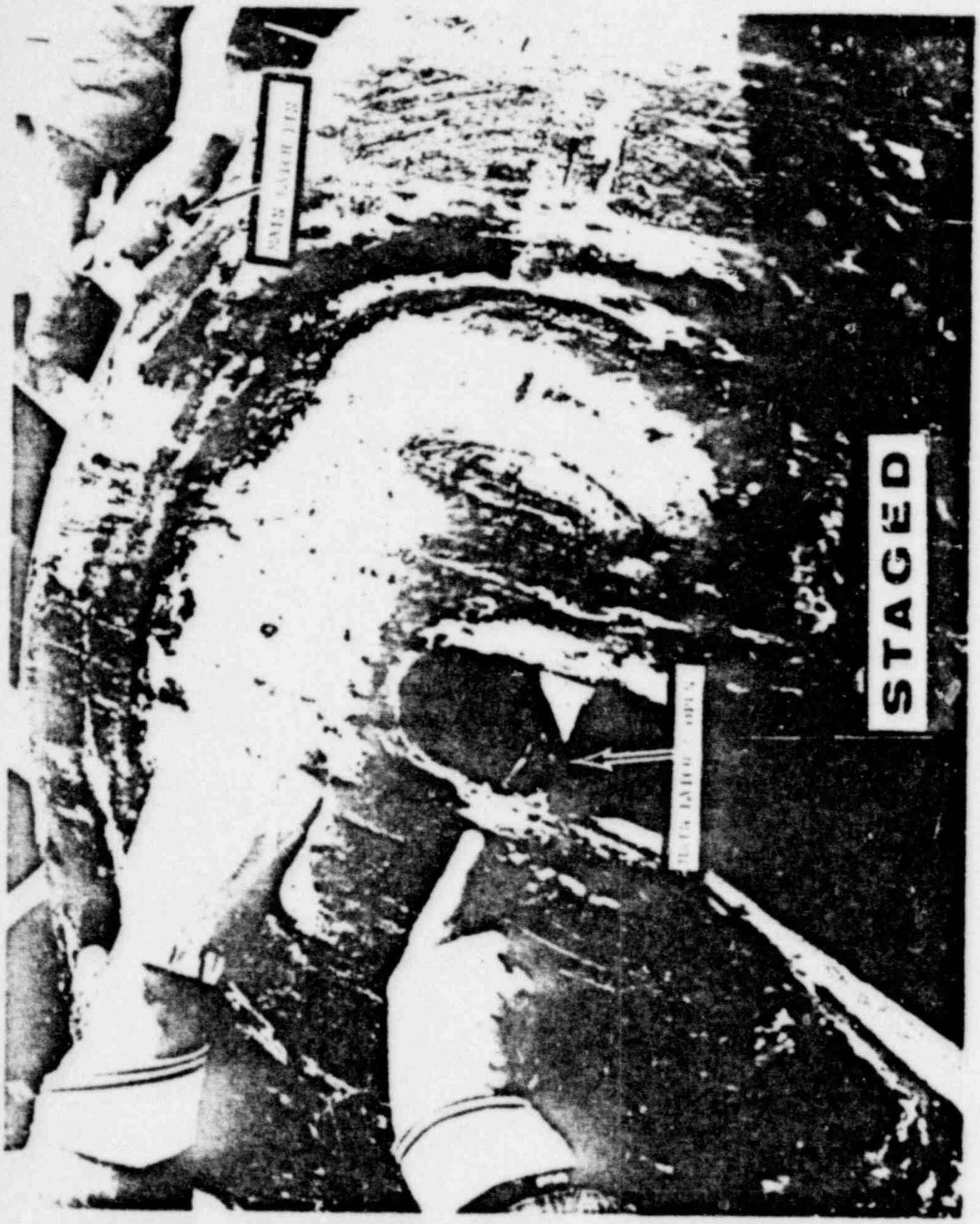


Figure 17. USE OF LABELING AND CAPITONS IN PHOTOGRAPHS



3-17 Figure 18. USE OF SCALE IN PHOTOGRAPHS date-stamped on the reverse side, but if that information is pertinent to the analysis it should be included in the caption.

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

(1) Location of major identifiable pieces.

(2) Collision debris – dirt, etc.

(3) Pools of liquids.

(4) Gouges, scratches, collision points, and damage.

(5) Temporary view obstructions, especially from view of operator or other key person.

(6) Mobile equipment.

(7) Material storage areas.

(8) Scaffolds, jigs, racks, temporary rigs.

(9) Close-up of failed elements.

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

(1) Flames. They indicate what material is burning, how fire started and progressed through the structure.

(2) Smoke. Also indicates what material is burning by smoke color.

(3) Structure.

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

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

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

(1) The most charred or burned area.

(2) Any combustible materials – matchbooks, papers, paint thinners, kerosene.

(3) Fusing methods that may be visible.

(4) Spectators around the accident location.

4. **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 type camera such as a Hasselblad or 35mm single lens reflex camera is preferred. The major considerations are:

a. Modern films, such as Vericolor II, are very good and capable of rendering minute detail and color balance on small image formats.

b. A large amount 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.

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

d. 35mm and 2-1/4 x 2-1/4 format cameras have short focal length normal lenses that have inherently better depth of fields than lenses used on 4 x 5 or 8 x 10 cameras.

e. Lens construction on smaller cameras allow for larger apertures that minimizes lighting requirements. 4 x 5 and 8 x 10 view cameras require much higher lighting levels because of their longer focal lengths and smaller apertures.

Should the investigator be forced to acquire 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, quick reference pictures taken with a Polaroid either black or white or color may be used. This is generally not a good choice because of the effect of heat on the unexposed film. The colors of the prin material are not reproduced faithfully and an incorrect analysis could be made from the interpretation of the color.

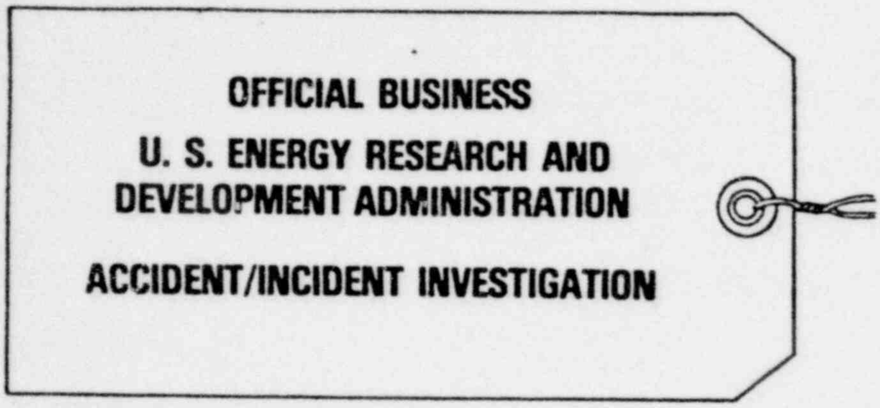
D. PRESERVATION OF PHYSICAL EVIDENCE.

Physical evidence is sometimes handled in an uncontrolled manner. This has invalidated evidence and made it difficult to find cause. If the evidence were needed in a legal case, e.g., an employee's suit against a machine manufacturer, lost or impaired evidence would embarrass ERDA.

Tags and receipts for evidence should always be used. Baker (pp. 223-312) gives many helpful suggestions on locating, protecting, and evaluating evidence. (see Figure 19.)

1. **The following is an excerpt from "Aircraft Fire Investigator's Manual," NFPA No. 422M-1972.**

"421. Recommended Procedures for Controlling Aircraft Parts or Chemicals Sent to Laboratories for Analysis.



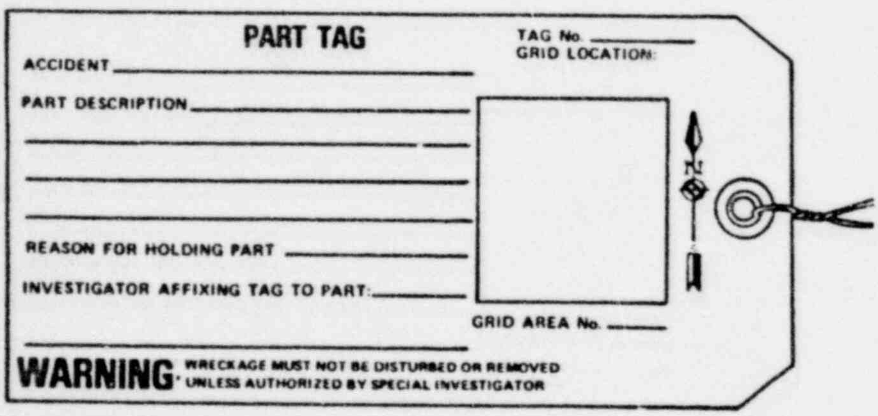


Figure 19. TAG USED FOR PHYSICAL EVIDENCE

"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."

2. Examples of previous experience:

a. "In one case a failed valve was disassembled by maintenance personnel, not under the supervision of an R&QA engineer or other competent professional. Evidence of great potential value was destroyed."

b. "The semi-scale heater was disassembled under the guidance of an R&QA engineer using a fault tree to guide the work and avoid overlooking or destroying failure evidence."

c. "Excellent laboratory test work has enabled the committee to determine cause of explosion, through thermal Gravimetric Analysis, Differential Thermal Analysis, pyrolysis, infrared absorption spectroscopy and gas chromatography."

d. "We used the scientific staff to great advantage to preparing and examining evidence for evaluation by the committee."

e. "Representative to receive residue participated in packaging."

f. "Malfunction duplicated with actual equipment."

g. "Review and physically tested fire protection equipment to determine operational condition after incident. This is done by a fire protection engineer."

h. "There are no approved and/or recommended procedures for an ERDA investigator to authorize funds for chemical or fire analysis necessary for obtaining information in case of fire, etc. Much of the expense would be at his risk, and may or may not be reimbursable".*

i. "Bio results are slow and investigator formed lasting opinions and judgments from preliminary data which later was corrected in type and lower in value."

j. "Assurance that all available data is valid:

(1) "Bioassay data obtained by use of standard approved techniques, calibrated standards used for reference, etc.

(2) "Portable/stationary monitoring instrumentation readings are valid, proper calibration and responses, etc.

(3) "Time and motion studies to reproduce exposure data."

k. "The Health and Safety Laboratory (Idaho) had R&D capability to resolve complex exposure problems which a straight service arrangement for dosimetry lacks."

E. MAPS, DIAGRAMS, DRAWINGS, AND CHARTS.

At the beginning of an inquiry the recording of measurements of transient evidence is essential. Baker (pp. 315-340) is an excellent reference on equipment and methods (see Figures 20 and 21).

In followup stages, engineering as-built drawings can normally be used for reporting.

Before adding transient measurements to as-built drawings, eliminate superfluous detail, e.g., location of irrelevant sewer lines; and highlight relevant detail, e.g., by thickening lines showing sewer location in a waste management accident. Facility drawings should be readily available.

1. Maps.

Overall, small-scale maps of longer distances and directions, as well as large-scale maps of the immediate scene, may be desirable. It is on the latter that witness locations will normally be shown.

* If it is a policy that line management pays the costs of special tests and studies, the solution to this problem may be quite simple. Consult the appointing authority.

Completed by: ROBERT SMITH
ENGR. AIDE

Instructions

Date 6/12/75
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' 58"	95° UP
6	OUTER LIMITS-SMALL DEBRIS	N.E. CORNER	5'6"	30°
7	" "	"	12'5"	45°
8	" "	"	18'4"	165°
9				
10				
11				
12				
13				
14				
15				
16				

Attach sketch on grid paper.

Figure 20. MEASURING AND RECORDING TRANSIENT EVIDENCE

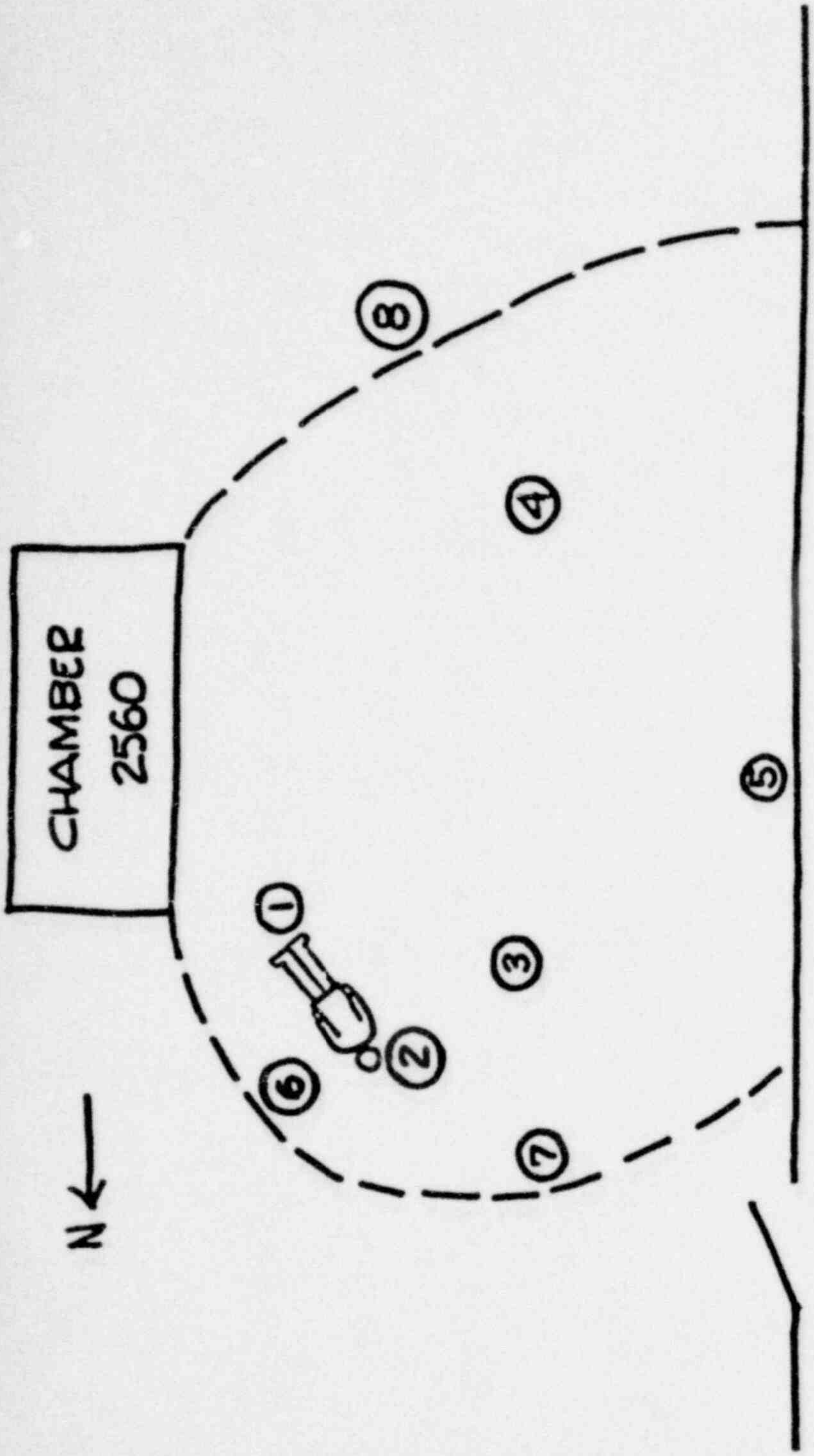


Figure 21.
[DI]AGRAM OF TRANSIENT EVIDENCE FOR MEASURING AND RECORDING

Measurements may be indicated by a reference point (angle and direction), triangulation (two angles), or by using a grid.

Crosby Field's manual, "The Study of Missiles Resulting from Accidental Explosions," stresses mapping completeness for analytic purposes, as well as search for "tell-tale missiles." The manual shows combined use of maps, drawings, and photographs.

An NTSB pipeline report (PAR-73-1) illustrates an intermingling of map, diagram, and photographic techniques and suggests a planning format for maps and photographs. The key figures are:

a. Fig. 1 – Map.

b. Fig. 2 – Broken pipe end pulled by dozer (photograph with captions).

c. Fig. 3 – Remains (photograph).

d. Fig. 4 – Excavation and remains (photograph).

e. Fig. 5 – Diagram of connection.

f. Fig. 6 – Pulled out pipe (photograph).

The rationale behind this selection of figures can illustrate good planning:

	Prior to Accident	After Accident
Overview		1
Near		3,4
Close		2,6
Close-up	5	

Such a planning format is useful in photographic planning as well as in measuring transient data for maps.

The transient evidence to be recorded centers primarily on two elements–locations of wreckage and debris and locations of persons (compiled on the witness map). However, be alert for temporary view obstructions, oddities, and anomalies.

2. Diagrams.

Arbitrary or stylized pictures of reality:

a. Sequence (see MORT, pp. 79-80).

b. Energy flow (see MORT, Appendices A-3 and A-6).

c. Process, flow, motion (see MORT, pp. 82, 105, 116, and 194, especially the latter as relevant to an investigation). This can include flow of materials, plans, personnel, etc.

3. **Drawings.**

These should be simplified pictures of reality, such as manufacturing or construction prints, perspective drawings, cutaway drawings, etc. For examples, see Field, pp. 12, 30, and NTSB-PAR-73-1, p. 8. Drawings can often be highlighted or captioned to call attention to significant detail. The initial effort is to record only transient evidence on a sketch roughly to scale.

Do not measure locations of permanent fixed objects. They can be located on copies of drawings at a later time.

4. **Charts.**

These may include photographic reproductions of records (e.g., temperature and pressure), trend analysis or types and classes (commonly seen as "statistics"), and organization charts.

For statistical charting, the best advice is: consult a good statistician. However, two of the author's phobias must be mentioned.

a. Do not use broken scales on charts. *Possible exception:* If a variation of 1 or 2 % in a factor is significant, (i.e., a causal factor), a broken-scale chart to highlight the detail may be useful. Also, if a single value would compress the scale so as to eliminate useful detail, simply chart it at the top with an arrow pointing up.

b. Do not connect discontinuous data with a trend line–use a bar chart. *Possible exception:* When two or more profiles are being compared.

For organization charts, which should be a required exhibit in most reports, the rule is to complete organization charts in board files; use a report exhibit to show (1) the organizational chain up to the chief executive officer (and to ERDA when necessary), and (2) to show organizational placement of major functions, such as safety, R&QA training, engineering, purchasing, and maintenance. Factors of remoteness may be significant, either because remoteness produced poor communications or remoteness affected the independence of review.

When maps, drawings, diagrams and charts are used to record evidence, note the same types of items which are applicable when making photographs. The study on missiles and the pipeline report contain many excellent examples of the use of maps, diagrams, drawings and charts. In addition, they demonstrate the effective use of photographs. The study on missiles demonstrates the degree of analysis that can be performed when physical evidence is preserved.

Do not use more diagrams, drawings, and charts than absolutely necessary. Unneeded charts can slow understanding.

. **WITNESS INTERVIEWS.**

1. **General remarks.**

The witness phase is critical to a good investigation. Typically, witness statements will constitute one-half the basis for reporting. Physical reality, as portrayed by maps, diagrams, photographs, and objects, is the other half.

Additional material reflecting NTSB philosophy [as applied by the Federal Railroad Administration (FRA)] is supplied in Appendix G.

2. **Two brief topical lists combining ERDA and NTSB experience are supplied.**

a. Consensus points on interviews.

(1) Line management–get preliminary written statements before the end of the shift.

(2) Line management–get preliminary oral statements from key witnesses until investigator arrives (provide oral synopsis to investigator).

(3) From synopsis, begin witness list or location chart.

(4) Make appointments with witnesses through management liaison, preferably on the job.

(5) Get preliminary oral statements from individuals separately (not as a group).

(6) Conduct an interview, not an interrogation. Do not argue! (Some suggest confidentiality; others object strongly. No iron-clad guarantee of confidentiality is possible.)

(7) Explain purpose of investigation; try to establish rapport and put witness at ease (not trying to blame, find fault, or discipline).

(8) If the supervisor was present, begin with him.

(9) Begin by establishing witness location and job function.

(10) Use broad, open-ended questions:

(a) "Would you tell me what you know about this occurrence?" Use silence (see Appendix H). Interrupt only if you don't understand; expect voids. Let witness use his own words.

(b) "Can you tell me anything more?"

(11) Make notes or use recorder, but only if witness agrees and does not appear to be disturbed.

(12) Be objective. Do not ask leading questions. Avoid multiple-choice questions. Avoid questions answerable as "yes" or "no." Use diagrams and photographs to help the witness. Keep questions short and simple.

(13) Followup questions should include:

(a) Apparent or possible reversal of sequence.

(b) Inconsistencies.

(c) Voids (but do not suggest fill-in). Hesitation by the witness may indicate more information is available.

(d) Possible causal areas which are emerging.

(14) In general areas, such as training, inspection, maintenance, etc., seek only facts related to the occurrence. (After fact finding is complete, management group views on needs can be sought.)

(15) Begin the effort to determine how frequently the same or similar acts or conditions occurred.

(16) "Preserve the witness." Thank him for his help. Explain that further discussion or questions may be needed.

b. Possible causal areas to be explored.

From the person(s) directly involved (most frequently the injured, but maybe an equipment operator), obtain the following information:

(1) Action sequence in detail.

(2) Training and preparation.

(3) Stress and emotional status.

(4) Failure histories and human errors.

(5) Changes and their effects.

3. Interview by the board.

a. Decide which statements will be sought by an appointed member and which key statements will be before full board.

b. Channel all questions through a single interviewer initially.

c. Plan each interview as to areas to be covered.

d. Use the above [steps (3)-(16)].

e. If a witness wants his lawyer or a union representative present, do not object. If management wants a representative present, do object, but permit if necessary.

f. All possible causal areas in which witness may have information should be explored as relevant and pertinent.

g. Continue to seek information on frequency of prior acts and conditions related to detectability.

h. If a witness refuses to testify, deal with his management in an endeavor to work out a solution.

i. Recording methods in order of preference:

(1) Court reporter.

(2) Tape.

(3) Stenographer.

(4) Notes.

The more formal the interview, the greater the chance the witness will be hesitant.

j. In any event, a signed statement is desirable, but not a prime objective. Sworn statements are not desired. Signatures cannot be required.

k. Analysis - for causal factors, to evolve order and logic, corroborate facts, evaluate credibility - 50% of the witness phase.

4. Final statement for the board.

The error in judgment almost always, if not invariably, 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 postaccident alibis and rationalizations). One can then take appropriate countermeasures to prevent future errors. Key investigatory question: Why did this action make sense prior to the accident? What was in your mind (prior to the incident) as to why you thought your method was the right way to do the job?

Explore the following areas:

a. **Preliminary statement** - probably well to confine it to what happened in the occurrence.

b. **Final statement** - includes the kinds of questions raised by MORT:

(1) **First query** - degree to which present organization procedures were followed.

(2) **Then**, move to the higher MORT standards. This can be delicate. If the organization did not train supervisors in JSA and require JSA, fairness to the supervisor dictates special care to counter implied criticisms. Similarly with monitoring, if management did not provide safety studies, work sampling, and procedural surveillance, the supervisor might have had little real chance to detect deviations.

Management functions will include not only line management but also design and plan groups, the safety group, the training function, R&QA safety related activities, maintenance, and inspection.

(3) For two sources of causal factor information - supervisor and management (plus its staff) the development of the interview

outline of sequences and subjects should undoubtedly begin with the occurrence and work backward through successive layers of causes. (The number of layers exposed is a criterion of excellence in an inquiry.) In general then, for each person, as appropriate to his role, the interview followup questions would be structured along the following lines:

(a) The occurrence facts he saw; inferences he drew. He is in the nature of an expert witness in this area.

(b) The supervisor.

(i) Operational direction he gave.

(ii) Observations of the actual operation.

(iii) Earlier training and qualification of personnel.

(iv) Prior experience, training and help he had.

(4) Then it seems the inquiry moves into successively difficult areas; in short, the MORT charts upside down. In doing this, it is extremely important to seek relevant facts, but receive opinions. Where indicated, seek the facts that shaped the opinions.

G. FAILURE RECOGNITION.

1. Objectives.

a. To define a field protocol to gather and preserve evidence of failures.

b. To increase ability to detect typical failure signs.

c. To outline some key aspects and problems in failure analysis.

2. Background.

Failure analysis requires engineers-scientists who are expert in the materials involved, and knowledgeable of stresses and failure modes in the specific equipment involved.

Investigator training for a single type of accident, e.g., aircraft, has proved to be practical with 3 to 12 hours of instruction.

Because of the great diversity of equipment used in ERDA work, and because experimental equipment often approaches technological boundaries, it is not feasible to train investigators in all relevant fields.

The expedient goal is 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 the board will rely on reliability and other engineering specialists.

Failure investigation in the board sense is the same as accident investigation. Thus experience in failure investigation will be helpful to accident investigators.

3. **Field protocol.**

It is essential that the investigator carefully follow a field protocol whenever failure can possibly be suspected as a causal factor, in general:

a. Familiarize yourself with the scene of the event.

b. Begin field notes, if not started earlier. Record all possible observations (relative positions 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.

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 a grid map as needed.

k. Do not move anything until evidence is thoroughly recorded.

l. Give responsibility of preparing evidence for transport to laboratory personnel who will do the analysis.

4. **Failure modes.**

a. Structural.

(1) Metals.

(2) Glass and other materials.

(3) Pressure, as a special case.

b. Electrical.

c. Electronics and controls.

5. **Typical failure patterns.**

a. Failure of a major component.

(1) New design.

(2) Changes (note the revision block on blueprints).

(3) Operation outside design limits.

b. Partial failure or malfunction.

(1) Recent repair.

(2) Alterations.

6. Laboratory analysis.

ERDA is blessed with widely distributed personnel and facilities for failure analysis. Thus the investigators' task is to recognize signs of failures and to know where and how to get analytic assistance.

The 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.

7. Data collection.

a. Test histories.

(1) Nondestructive.

(2) Overloads.

(3) Visual inspections.

b. Failure histories.

(1) In design-development process.

(2) In operation, e.g., Division of Reactor Research and Development (RRD) incident reports:

(a) MTBF – mean time between failures.

(b) Bathtub curve – higher rates at start up and at wear out.

c. Maintenance.

(1) Inspection-dependent.

(2) Other.

d. Evidence.

(1) Preaccident failure—causal factor.

(2) Postaccident failure.

(a) Increased severity.

(b) Did not increase severity.

e. Reliability and failure analysis are embodied in MORT, for example:

(1) Design process must be well organized (Chapter 27).

(2) Hazard analysis process must be defined (Chapter 23), including:

(a) Failure mode and effect analysis.

(b) Information search, including failure histories.

(c) Human factors review (Chapter 26).

(d) Risk analysis (various references).

(3) Failure reporting systems, e.g., RRD, are a part of the monitoring system.

f. Specialists in failure analysis (R&QA) normally will be available:

(1) Responding to an incident under their own chapter.

(2) As members/consultants to boards.

(3) On call by the investigator.

g. In the interim from the investigator's arrival at the scene and the arrival of an R&QA member/consultant to a board, the investigator has primary responsibility for detection and preservation of evidence of failure.

8. Some illustrative cases.

a. Bubble chamber, beryllium window—a valuable case of supporting one hypothesis and negating four others.

b. UF_6 escape valve stuck partially open—valve was sent for disassembly, to the maintenance department and potentially informative residue was removed and discarded. Professionals could not determine failure cause.

c. Heavy ion linear accelerator—foil barrier failed.

d. Environmental chamber—safety valve and window failures.

e. Crane boom collapse—stiffners were welded on to repair damage.

f. 3000 psi compressor—not locked out after potential failure was detected.

g. Million-pound hook. h. Centrifuge – modified to increase speed.

i. Semiscale heater.

9. A museum—it would be desirable to assemble a collection of failed parts (or photographs) from ERDA operations for instructional purposes. Perhaps each field organization should establish its own museum.

H. SOURCES OF FILE CABINET DATA.

1. Facility description.

2. Mission, budget, schedule, constraints and changes.

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

   a. Information search. c. Hazard control. e. Independent review.

   b. Hazard identification. d. Risk assessment; acceptance decision level.

4. Procedures and/or JSA. When available, obtain established criteria for procedures and their review.

5. Design, manufacture, installation, test, operations, and maintenance records; construction progress photos, which may show features later covered by construction, and construction completion reports.

6. Machine manufacturer's manuals.

7. Maps and drawings.

8. Monitoring systems (see example in MORT, p. 376).

9. Training given the supervisor.

10. Supervisor's training and safety observations.

11. Failure histories.

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

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

14. Suggestions and their disposition.

15. Employee meetings.

16. Appraisals and followup action (internal and ERDA). Include R& A and engineering appraisals as they are relevant. Review inspections and audits.

17. Press releases and clippings.

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

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IV. ANALYTIC TECHNIQUES

A. GENERAL

Factfinding technologies or methods are designed to produce facts; but what facts? Analytic techniques are intended to assist the investigator in (1) deciding what facts to seek, (2) determining probable causes and contributing factors, and (3) arranging results in an orderly and lucid manner. Relevant information is often readily available once its value is recognized.

Analysis is cheap and fast. Floundering is expensive. Start analysis early.

In this section eight general kinds of analytics are examined. It would be unusual to find all of these approaches fully utilized in a single accident. On the other hand, at least rudimentary use of all will increase the depth of investigation, help reduce oversights, and produce better structured reports.

Analytics–formal or informal, conscious or unconscious–underlie any investigation. This section strongly suggests that the quality of an investigation will depend on the quality of the analytics which guide the factfinding. For example, if one believes that operator error, stupidity and wrong-headedness are major factors in accidents, it will usually not take long to fix "blame." If one knows that undetected or uncorrected changes are common factors, information on relevant changes is often readily available.

A general aspect, "Follow your nose" must be considered, partly because of its established, historic usefulness and partly as a safeguard against the limitations inherent in more mechanical analytics. Consideration of changes, oddities, and anomalies is one aspect.

Another general aspect of analysis is inherent in the specialists and experts on the board or serving as consultants. Their expertise will suggest information needed and will assist in marshaling facts in meaningful ways. They will be performing mental analytics based on engineering and scientific disciplines and their experience.

1. **The use of a structured analytic methods (which some might see as a straightjacket) frees the investigator in three important ways:**

   a. The methods give assurance against oversight, leaving the investigator more time for personal observations to detect oddities, anomalies, changes, puzzles, and reasons.

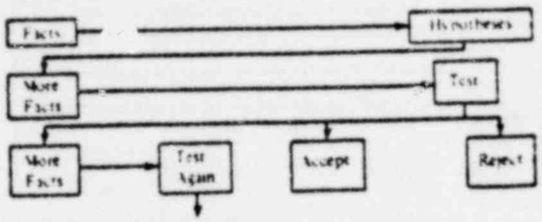
   b. The methods allow the investigator to follow potentially fruitful side paths or divergent sequences, and, when they have been exhausted, he can quickly return to his place in the analysis to continue on in an orderly way.

c. The methods used give a reviewer of a report assurance of the scope and depth of analysis. A report can hardly ever list all the factors found adequate to excellent. Unless the analytic method is stated, e.g., MORT, a reviewer does not know the meaning of silence on a potentially significant point, e.g., preventive maintenance or information search.

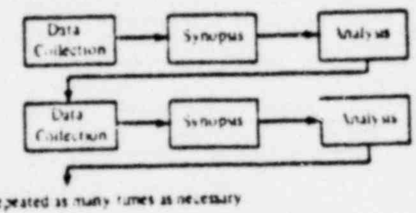
A method is, of course, only a means to an end - a good report for preventive purposes - and the method will be judged finally by its results.

2. Investigative analysis process.

a. The basic flow of investigative analysis is:



b. The process can be shown also as



3. The actual investigative process is affected by a series of intervening considerations:

a. Advance plans which establish a procedural structure.

b. An analytic structure, required by the appointing official or by the investigator to assure excellence.

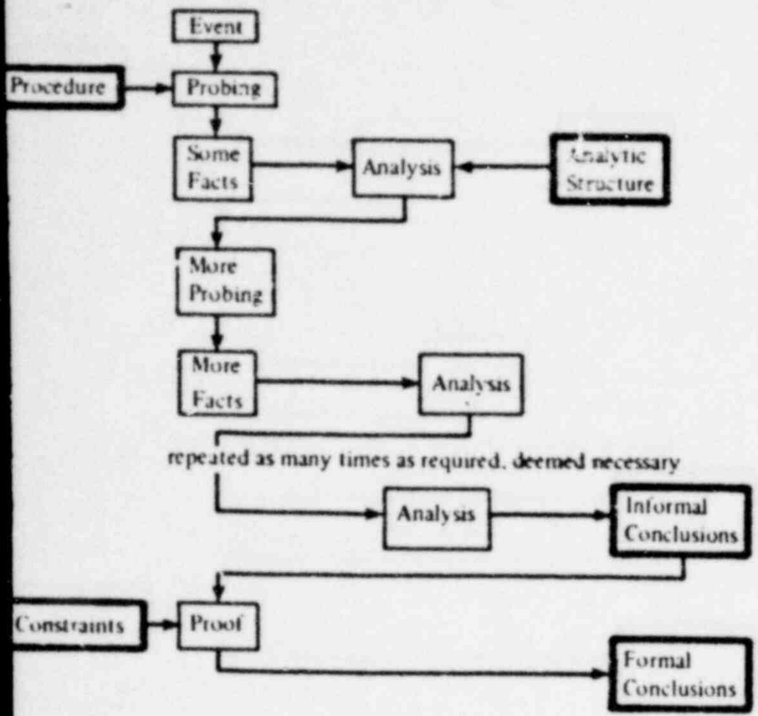
c. Constraints or pressures–time, haste, cost, etc.

d. The tendency for investigators and board members to come to informal conclusions.

e. Data collection to prove informal conclusions.

Experienced investigators report that they can tell when a board has moved to step d. and now wants to move to step e, i.e., "proof." If these occur before fulfilling step b., the result usually will be a shallow, inadequate, or even erroneous report.

The interaction of these factors can also be shown in a flow schematic:



The trained investigator must necessarily follow this same process, e.g., he cannot ignore constraints. He can, however, be aware of the forces and pressures and guide the investigation away from premature conclusions.

SEQUENCES.

Sequences are discussed in MORT (chapter VI) as a fundamental aspect of accidents, and some illustrations of causal sequences are provided.

1. **Uses of diagrams and flow charts.**

Sequence diagrams and flow charts (MORT, p. 385) are useful in three ways:

a. To develop the investigation and assist in confirming or denying the validity of findings, probable causes, and contributing factors.

b. To organize the report.

c. To use as valuable illustrative figures in the final report.

2. **Meticulous Energy Trace.** The meticulous energy trace has demonstrated value, not only in determining what happened but also in a searching analysis for potential barriers. However, this analytic technique can become a part of the analysis below. (See MORT, chapter 3, p. 385, and a variety of examples in Appendix A.)

3. **Events and Causal Factors.** NTSB has pioneered in the use of sequence diagrams as analytic tools and as report illustrations. The culmination of this excellent technique is "events and causal factors" diagrams which depict the "musts" for an occurrence - the elements which must be present to have the occurrence. Thus the tool is not only analytic for the accident as a whole but also helps evaluate evidence. (See Appendix I.) Strict adherence to the rules for developing the diagrams is not necessary. Common sense works as well.

   a. Figure 22 from NTSB report HAR-71-6, dated May 12, 1971, is illustrative. The accident occurred when a tank truck partially filled with liquified oxygen exploded, without warning, after making a delivery. This, and a similar figure in NTSB's "Marjorie McAllister Report" on a tow vessel sinking, is particularly interesting because evidence was scant. In the latter report a fault tree covering all possible causes was also used to focus scant evidence on the probable failure path. Since the problems and dilemmas of obscure or unknown causes in some ERDA occurrences have been mentioned, the techniques used by NTSB may be particularly useful.

   b. Figure 23 shows direct, contributing, and systemic factors in an "events and causal factors" sequence. Comparing this with the previous NTSB figure will show that certain NTSB factors can be classed as systemic factors, such as two lacks of standards and two research problems represented by lack of knowledge.

   c. ERDA, because of its nature, goes much further into managerial systems and controls and implementation, as illustrated in a fatality sequence, Figure 24, involving a farm tractor used for mowing lawns at a laboratory. The supervisory and management factors are significant.

   d. As the result of pilot class lectures provided by NTSB staff, a participant in a board investigation was able to produce a sequence diagram for a tritium incident of Rocky Flats in a very short time (Figure 25).

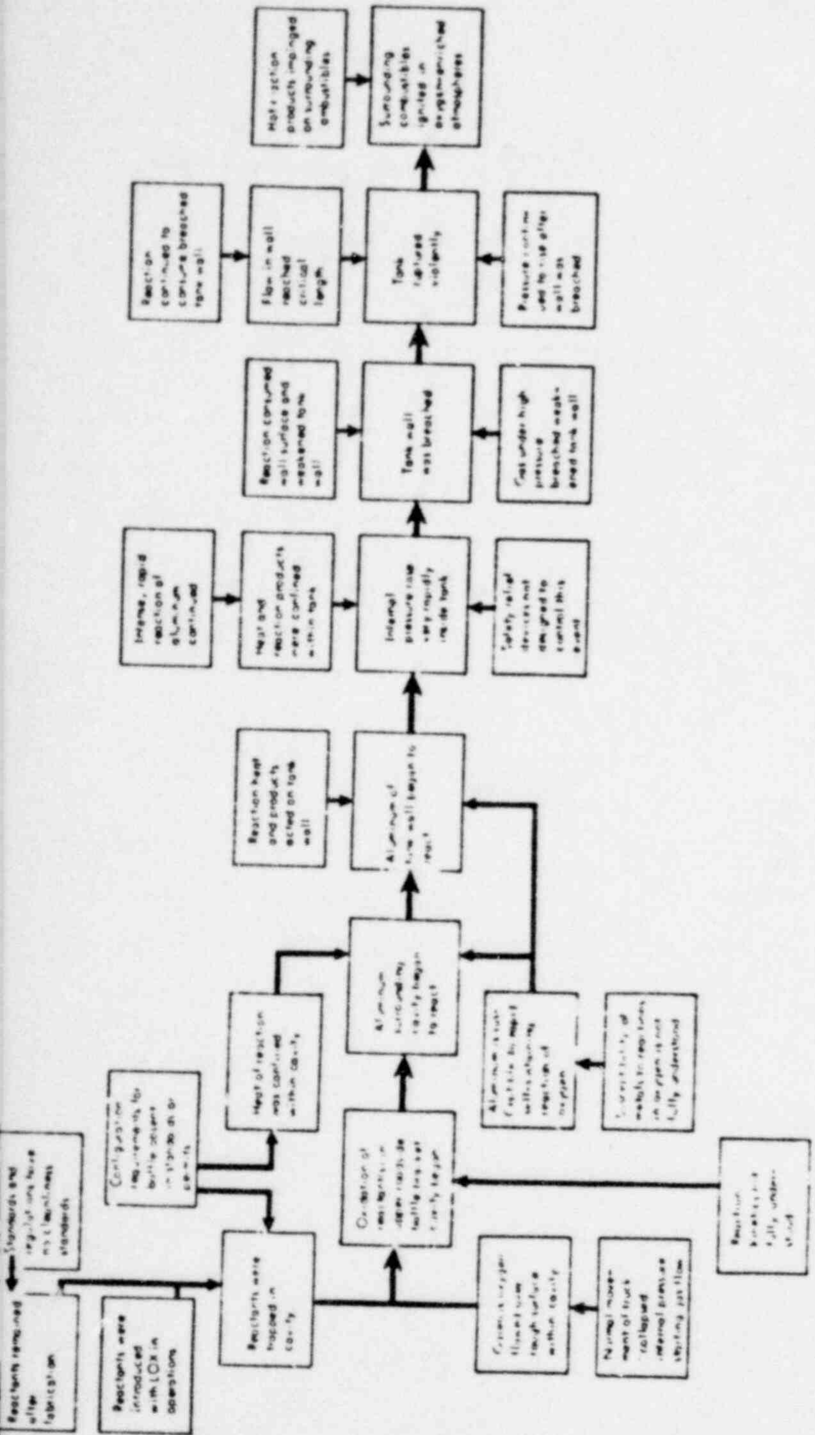
The events and causal factors sequence chart has been the focal point of analysis in several ERDA investigations, with excellent results. The chart itself makes a fine exhibit for the early portion of the conclusions section.

The primary, direct sequence should extend from the stable system, show the beginning of instability, and end with the final outcome of the accident.

Experience has shown that the diagram should be started early in the investigation. Use of 3x5 cards (one per fact or condition) gives flexibility in structuring an evolving sequence chart.

C. CHANGE ANALYSIS.

The Kepner-Tregoe change analysis method is a sharp tool for detecting obscure causes. It is also a guide to information to be sought, and a format for succinct display of causal factors in complex cases.



Source: NTSB report HAR-71-6

Figure 22. RELATIONSHIP OF EVENTS AND CAUSAL FACTORS

POOR ORIGINAL

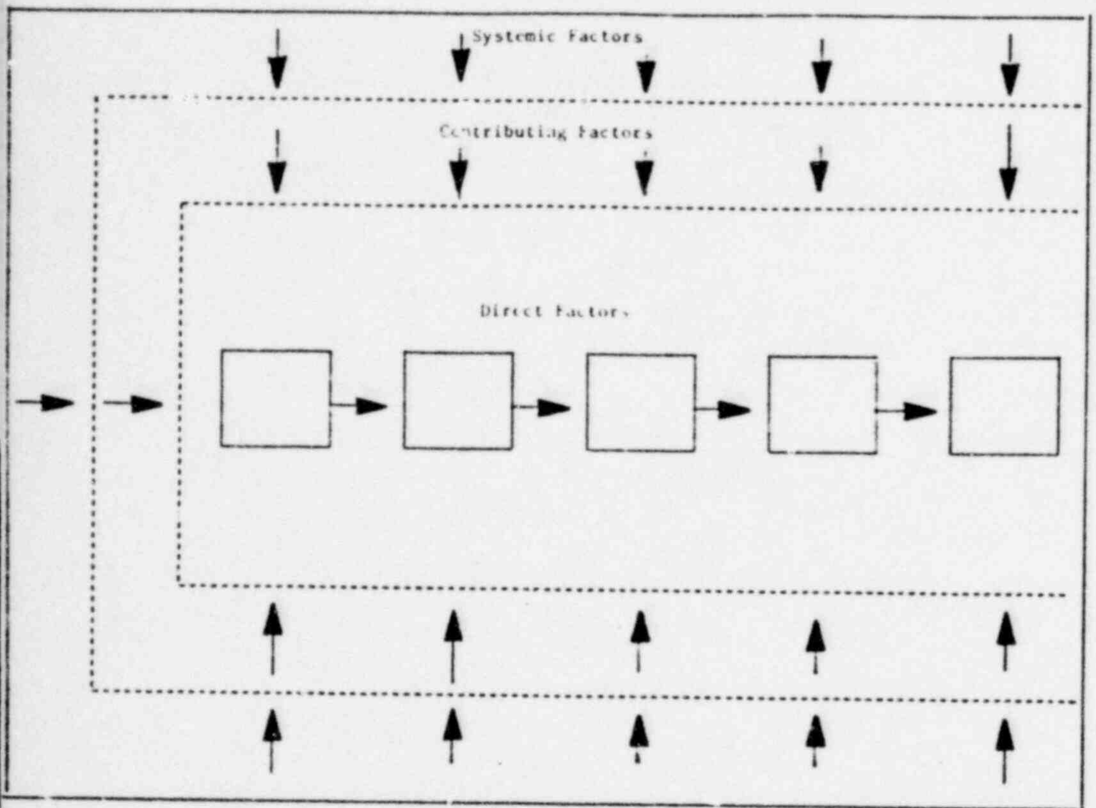


Figure 23. EVENTS AND CAUSAL FACTORS (General Schematic)

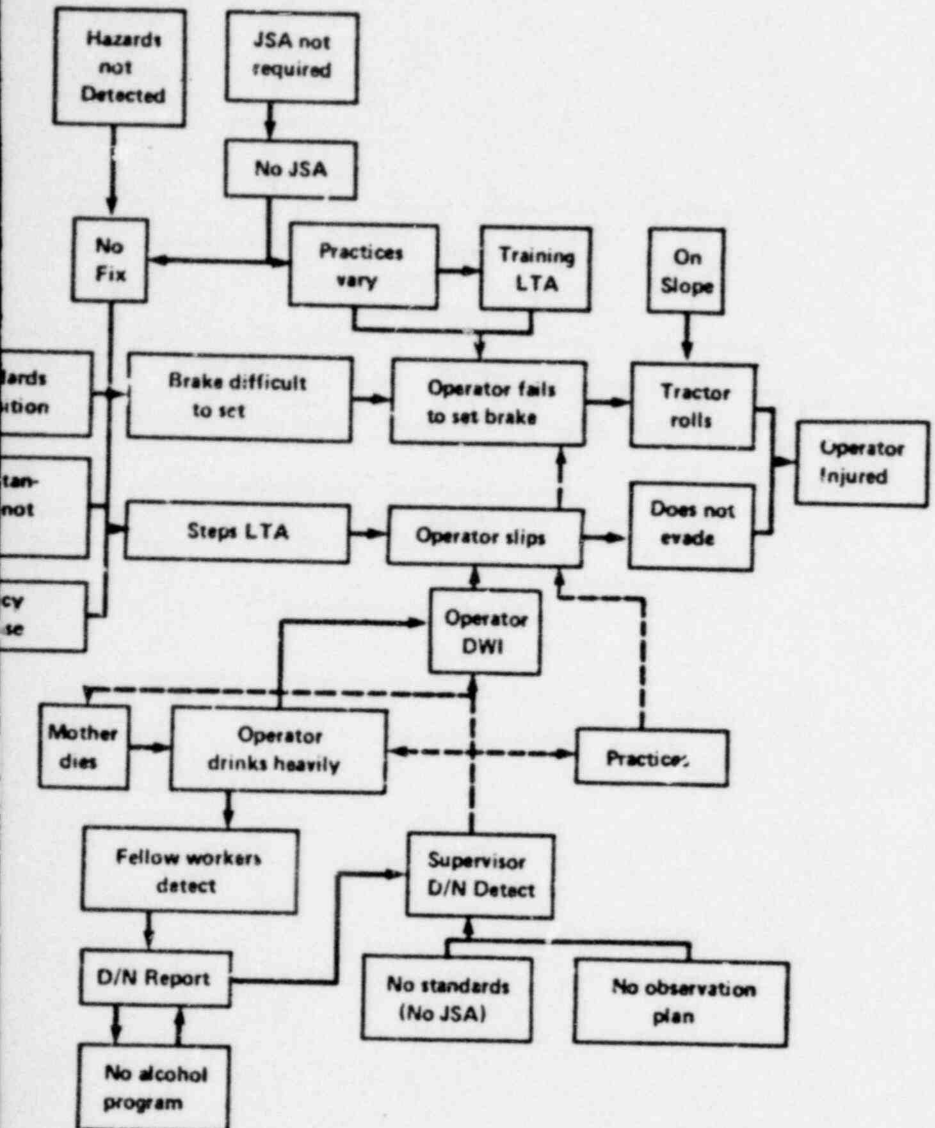


Figure 24. EVENTS AND CAUSAL FACTORS
Farm tractor used for mowing lawns

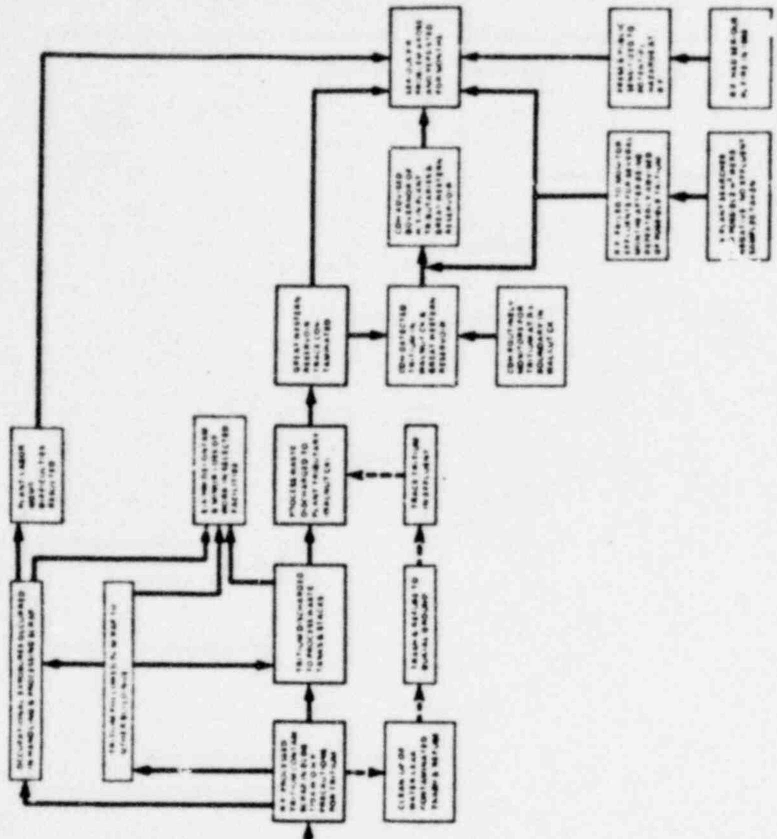


Figure 25. RELATIONSHIP OF EVENTS AND CAUSAL FACTORS
Rocky Flats Tritium Incident

1. **Note the following in MORT:**

   a. The role of change in accidents (chapter 5).

   b. Changes detected by monitoring (chapter 37).

   c. Changes detected by supervision (chapter 30).

   d. Change review procedures (page 270).

2. **Examples, MORT, Appendix A.**

   a. Heavy ion linear accelerator–change makes barrier impractical.

   b. Environmental chamber–changes in valve, gauge, and supervision.

   c. High explosive press–change in man (wife sick).

   d. MAPP gas–plans and construction for new station were not reviewed.

   e. Initiator explosion–changes in room.

3. **Note Accident Investigation Manual (AIM), Appendix J.**

D. CODES, STANDARDS, AND REGULATIONS

Codes, standards, and regulations (CSR's) are considered to be a primary or fundamental aspect of accident prevention, and similarly an essential element in investigation. CSR's represent some degree of consensus of solutions of problems and can be seen as preanalyzed situations. In general, conformance with CSR's takes precedence over more exotic, but more judgmental, potentially valuable analytics. The value in CSR's is precisely the precision written into CSR's. Therefore a callout of applicable CSR's, their status (legally enforceable or advisory), and their observance can be considered a fundamental, essential element in investigation and reporting. CSR's are of such importance that a finding of "none applicable" should be made explicit in the report.

A possible format f[illegible] [illegible]llout of CSR's could be:

1. **ERDA promulgated:**

   a. Externally established: Occupational Safety and Health Administration, Environmental Protection Agency, Federal Radiation Council, etc.

   b. Internally established:

      (1) Prescribed

      (2) Recommended.

2. **Other Federal, State, or local regulations.**

3. **Advisory, e.g., American National Standards Institute, American Society of Mechanical Engineers, American Society for Testing and Materials, and National Safety Council.**

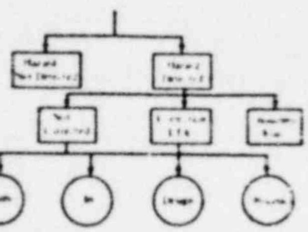
Thus a finding is the callout of relevant CSR's. Another set of findings will cover conformance. A third set of findings will cover reasons, e.g., CSR's developed after construction; CSR's not applied to an already defined hazard analysis process (oversight); violations detected, but correction delayed due to lack of funds (assumed risk), etc.

The recently issued Reynolds Electrical and Engineering Company, Inc., keyword index to ERDA-prescribed CSR's is a valuable aid in information search.

E. SAFETY ANALYSIS REPORTS AND SIMILAR DOCUMENTS.

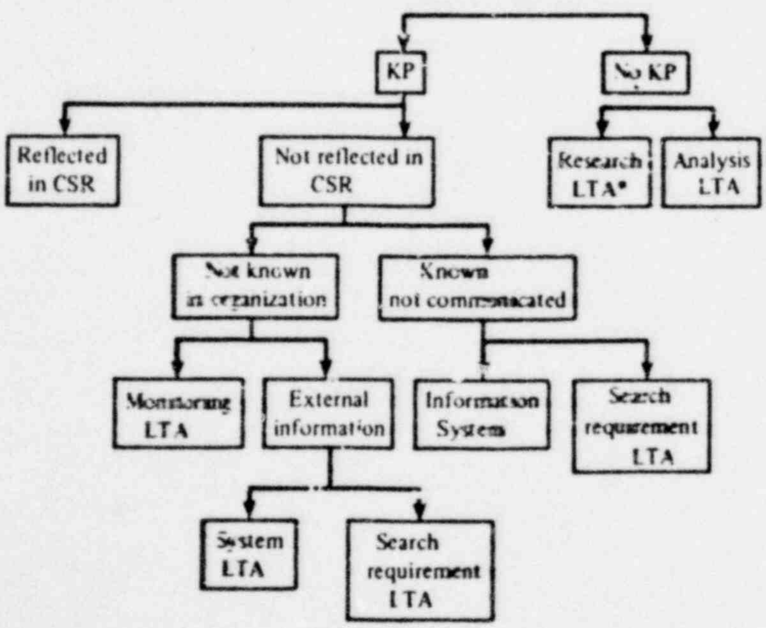
Documentation of the hazard analysis process should be obtained and reviewed. MORT analytics provide criteria.

Specific conclusions will be directed to the logic as follows:



F. KNOWN PRECEDENT.

The logic for examining use of known precedents (KP's) in design and planning process is presented in various elements of MORT but is sufficiently important to assure attention in the analysis process. The logic is:



* LTA = less than adequate

G. PRINCIPLES.

There are certain principles which govern or affect the behavior of things, people, and organizations. Although a specific callout of such principles (as suggested for CSR's) is not feasible, the topic is essential to good investigation.

1. **Physical laws,** e.g., effects of gravity, kinetics, thermal transfer, and radiation, pose little problem. Relevant laws can be stated by appropriate engineering and scientific specialists. For example, argon is heavier than air and will remain in a U-vessel until bottom egress or displacement are provided.

   To understand the occurrence, a brief statement (supported by an appendix) can be helpful to users of a report. For example, an NTSB report (PAR-73-2) had a one-page appendix describing the characteristics of propane. An AEC report did not provide a similar description of tritium. Since substances and reactions used in ERDA operations are not widely understood, special care must be exercised to provide reports "intelligible to the technically minded layman, particularly published reports."

2. **Behavioral principles,** e.g., perception, decision, habit, reaction time, and motivation, pose a considerable problem in that the principles are less precise and more complex than physical laws. Nevertheless, an effort to call out relevant findings seems worthwhile. Behavioral findings are summarized in useful form (Berelson and Steiner, 1964; report in MORT, Appendix I-5).

3. **Organizational laws**—these may be of two types: (1) those promulgated by the organization, and (2) those of a behavioral or scientific nature (and the latter often operate to negate the former, e.g., "small groups can effectively frustrate the attainment of the goals of a larger, formal organization").

   The relevant promulgated procedures of the organization should be specifically called out and quoted, briefly in text where vital, in supporting appendices where text is necessary. For example, if an engineering department operates under ERDA-RRD standards for quality assurance and has other internal mechanisms for detecting and correcting hazards, or if training and operational standards have been promulgated, all such relevant requirements should be specifically enumerated.

It is common in accident investigation to detect situations which violate CSR's or laws and principles but which did not contribute to a causal sequence. All such situations should be reported, because specific and systematic weaknesses detected may be causal factors in subsequent accidents.

H. MORT ANALYSIS.

Much of the foregoing analysis (sections A-G) is in MORT in greater or lesser degree but has been specifically called out because ERDA reports reflect the importance of causal factors in occurrences, or the frequent inattention to these specific aspects of analysis. No analysis has yet become worse from the use of MORT. Even fragments have been helpful. The analytics are difficult to misuse—even if misinterpreted, they will raise questions which are useful.

1. **Five varieties of MORT are available:**

   a. The original "fault-tree charts." The page references to the MORT text are corrected in the fault-tree charts in Appendix K. They are incorrect on the charts in MORT.

   b. The list form (MORT, pp. 159-163).

   c. Dr. Jerry Driessen's question form (Appendix K).

   d. A special sheet appended to the March, 1975 issue of the Journal of Safety Research, National Safety Council.

   e. A special sheet issued by the System Safety Development Center, ANC.

   The variety does not seem to have any great significance. Analysis has been improved by use of any one of the five.

2. **Problems do arise when MORT produces conclusions or recommendations which, in effect, apply new, high standards of program analysis and control to an organization. To alleviate any seeming unfairness, two approaches to conclusions and/or recommendations are useful:**

   a. If a program is well established in the "best practice" organization, alleviate possible implied criticism of individuals with phraseology of the following type in a conclusion: "There was no organizational requirement for . . ." (e.g., job safety analysis, information search, or change review).

   b. If a program is only emerging from aerospace or nuclear system safety or from the MORT study and is not widely used or understood, alleviate possible implied criticism of the organization with phraseology of the following type in a recommendation: "Study, development, and test of an improved system of . . . [e.g., monitoring, independent review, design organization audit, or information search and retrieval] are recommended."

3. **Some ERDA reports give inadequate attention to major elements of basic safety processes, such as:**

   a. Management implementation.

   b. Design and plan process.

   c. Supervision.

   d. Employee participation.

   e. Information.

      (1) Monitoring.

      (2) Data reduction.

      (3) Data retrieval.

      (4) Data feedback.

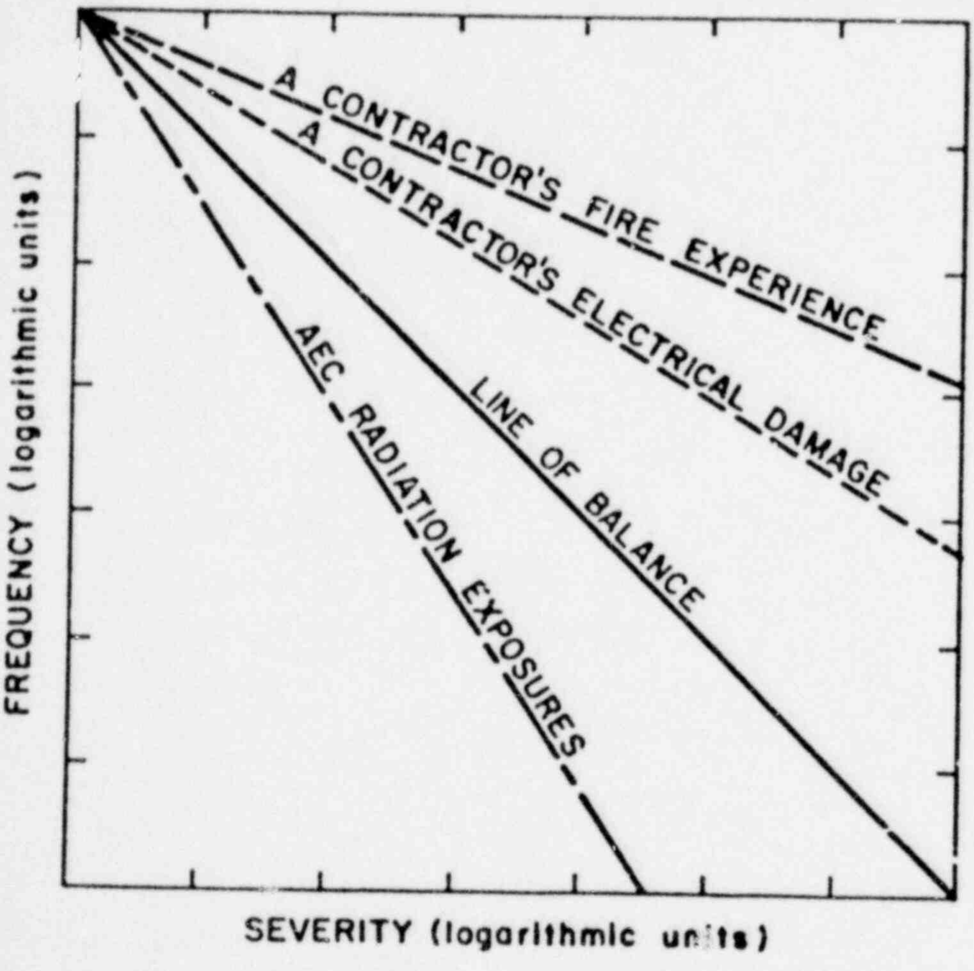

A CONTRACTOR'S FIRE EXPERIENCE
A CONTRACTOR'S ELECTRICAL DAMAGE
LINE OF BALANCE
AEC RADIATION EXPOSURES
FREQUENCY (logarithmic units)
SEVERITY (logarithmic units)

Figure 1.

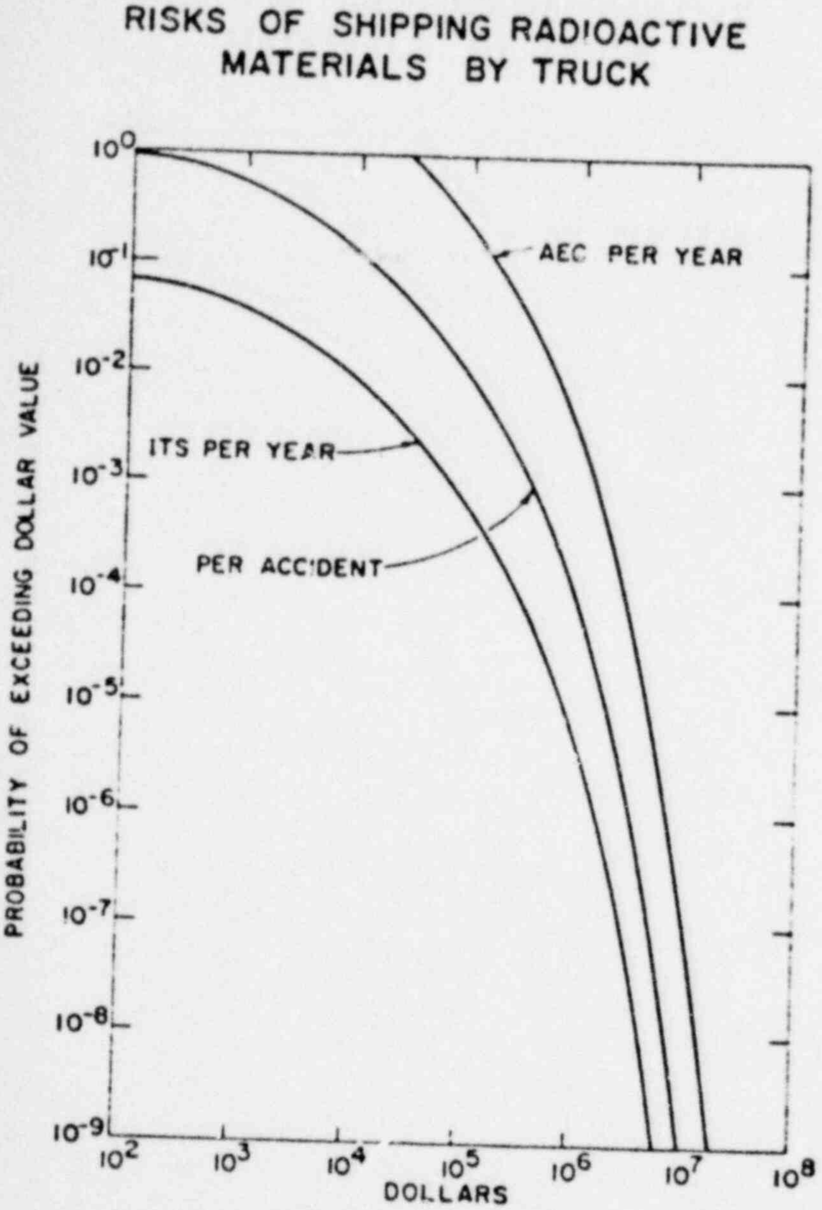


Figure 2. Risks of Shipping Radioactive Materials by Truck

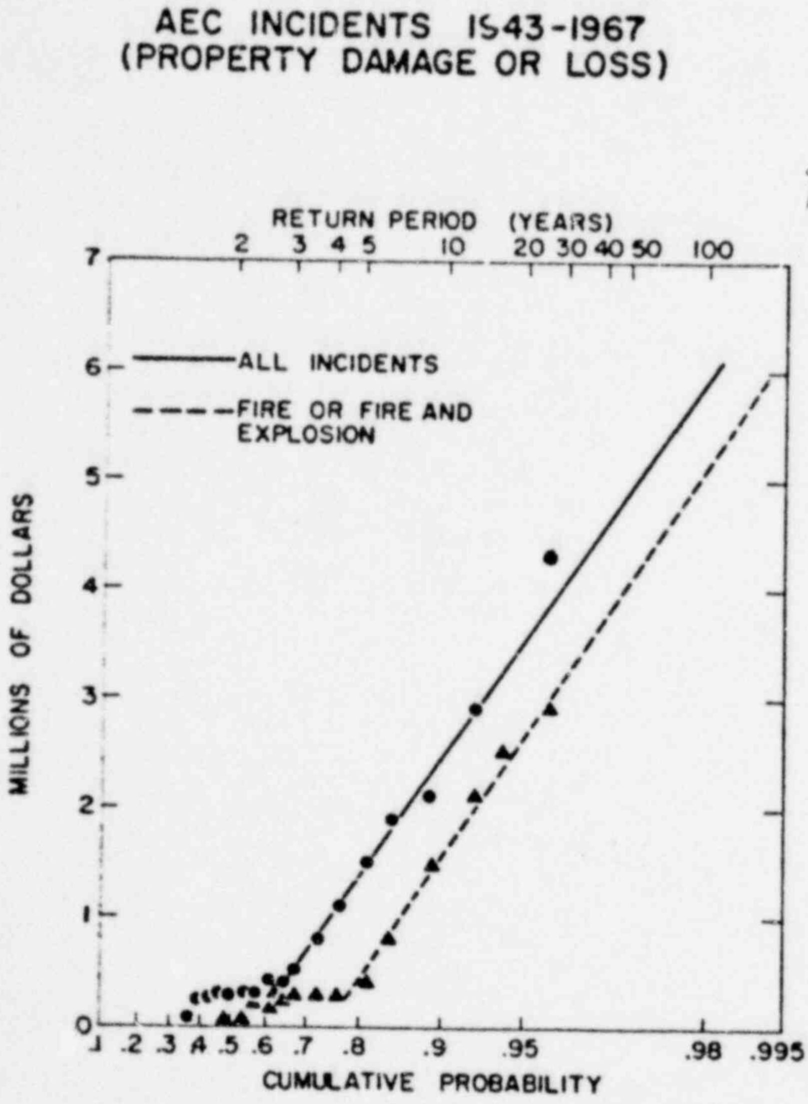


Figure 3. AEC Incidents 1943-1967 (Property [illegible] or Loss)

PROPERTY DAMAGE RATIO vs TIME
1947–1967

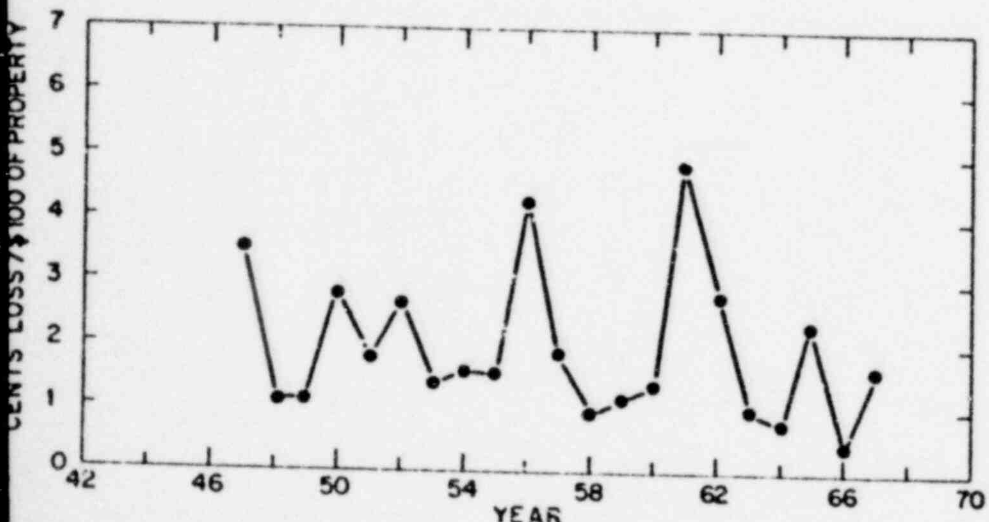


Figure 4. Property Damage Ratio vs. Time 1947-1967

PROPERTY DAMAGE RATIO (CENTS/$100 PROPERTY) 1947-1967

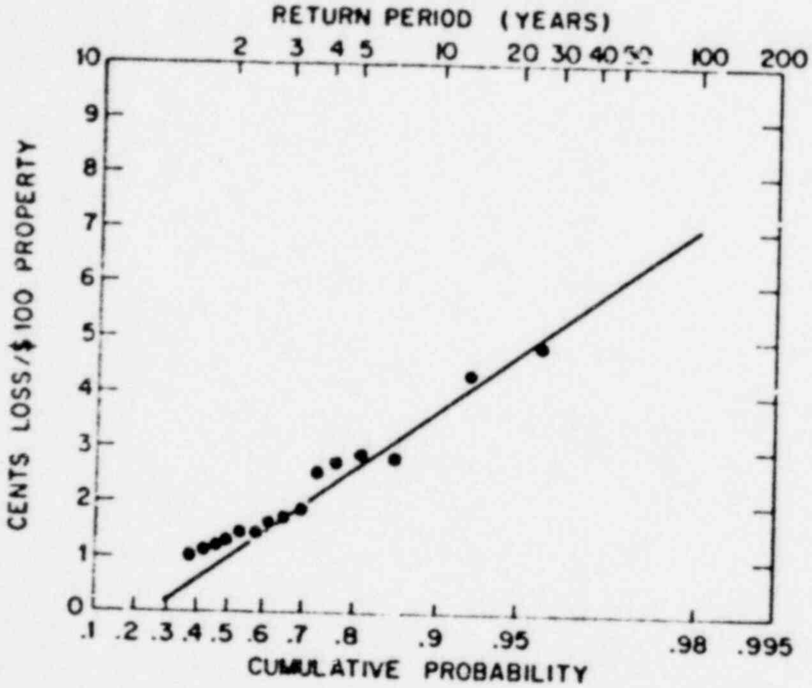


Figure 5. Property Damage Ratio (Cents/$100 Property) 1947-1967

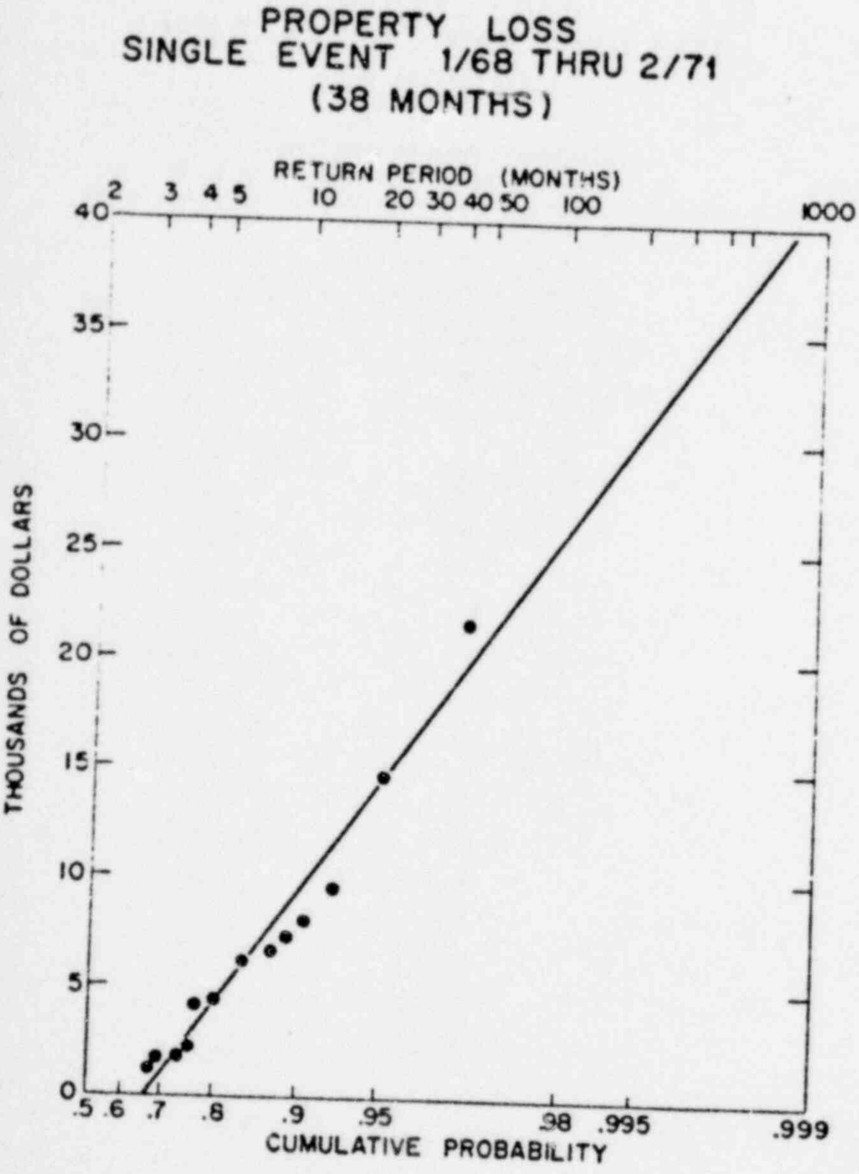


Figure 6. Property Loss Single Event 1/68 thru 2/71 (38 months)

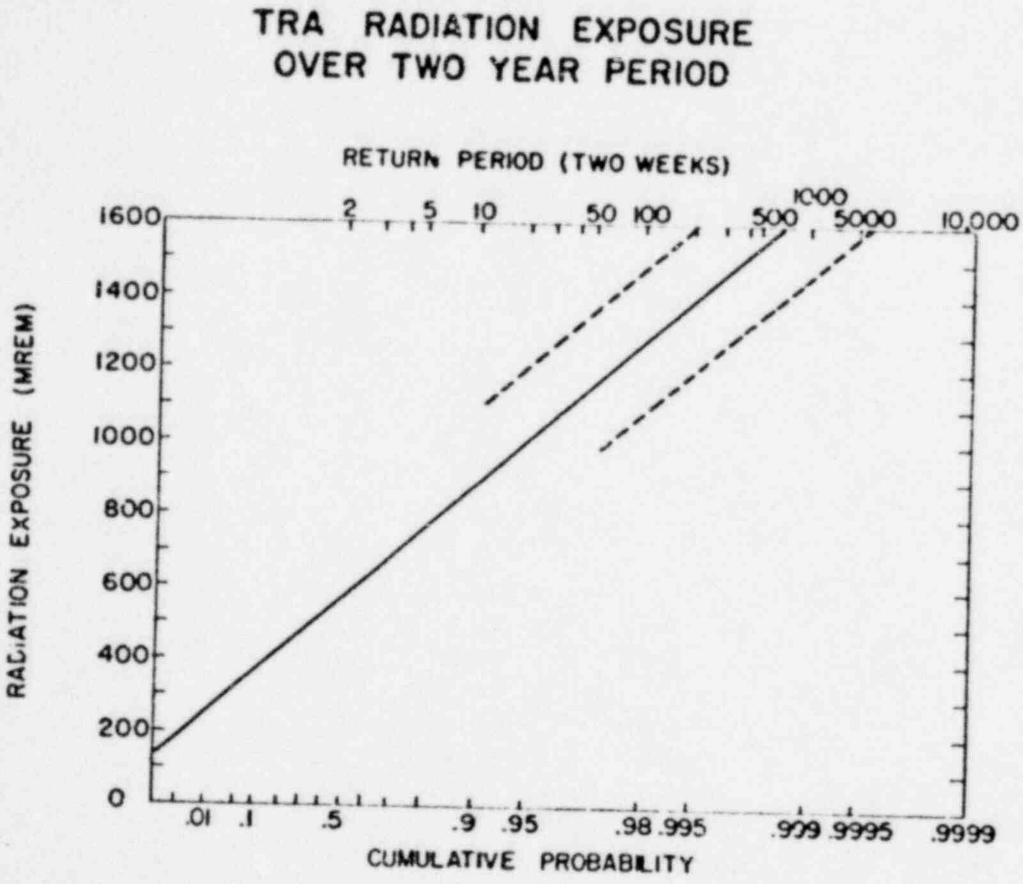


Figure 7. TRA Radiation Exposure Over Two Year Period

SOME POTENTIAL AREAS OF APPLICATION
EXTREME VALUE PROJECTION

1. PROPERTY LOSS
2. FIRE LOSS
3. RADIATION EXPOSURE
4. EFFLUENT RELEASE
   (RADIATION AND NON-RADIATION CONTAINMENTS)
5. ELECTRICAL POWER OUTAGE DURATION
   (FOR PURPOSES OF EVALUATING ADEQUATE SERVICE LIFE FOR EMERGENCY POWER SUPPLIES)

Figure 8.

MANAGEMENT ACTION SHEET

Property Losses Projection

To: (Subordinate Managers)

1. The projected Property Losses indicated on the attached projection sheet are unsatisfactory.

2. The system controlling Property Loss should be:

   ( ) Maintained at the present level of control effectiveness.

   (x) Strengthened with the objective of providing an extreme projected Property Loss of $20,000 over a period of 10 years based on a 3 year projection base.

   Please advise me of action taken or proposed to achieve this objective.

3. Also, please advise me of the circumstances related to any outliers generated during this reporting period and the remedial action taken to prevent similar future loss of control.

Responsible Manager

Figure 9. Management Action Sheet

EXTREME VALUE DATA

TABLE 1

YEAR	MAXIMUM SINGLE EVENT LOSS PLANT A	MAXIMUM SINGLE EVENT LOSS PLANT B
1972	6000*	6000*
1971	3600	1600
1970	2400	600
1969	1200	2100
1968	600	500
1967	1600	1000
1966	4200	1500
1965	<500	1000
1964	2600	1900

*"accident"

TABLE 2

CUMULATIVE PROBABILITY	MAXIMUM SINGLE EVENT LOSS PLANT A	MAXIMUM SINGLE EVENT LOSS PLANT B
0.90	6000	6000
0.80	4200	2100
0.70	3600	1900
0.60	2600	1600
0.50	2400	1500
0.40	1600	1000
0.30	1200	1000
0.20	600	600
0.10	<500	<500

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EXTREME VALUE ANALYSIS EXERCISE

SITUATION:

You are investigating accidents in two plants identified as Plant A and Plant B. These accidents involve 6000 unit losses in both plants (Tables 1 and 2).

You request and obtain historical data indicating the maximum similar losses in Plant A and Plant B for each year over the past nine years.

Investigation indicates the operating modus operandi for the two plants has been essentially constant for "the past ten years" and that effective maintenance programs have kept the plants "in good shape."

EXERCISE:

Plot the data for the two plants on the extreme-value paper provided.

QUESTIONS:

1. Is extreme value projection valid for these two plants. How do you know this?
2. In terms of extreme value analysis, how would you expect the course of the investigation and the nature of the recommendations to differ for Plants A and B?
3. What is the significance of the information in the third paragraph of the situation above? How does the extreme value analysis validate or fail to validate this information?
4. What difficulties might have been experienced if one had utilized frequency-severity data rather than extreme-value analysis in this case?

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