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EVENTS AND CASUAL FACTORS CHARTING

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August 1978

UNITED STATES
DEPARTMENT OF ENERGY
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EVENTS AND CAUSAL FACTORS CHARTING

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1. INTRODUCTION

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

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

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

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

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

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

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

2. NATURE OF ACCIDENT INVESTIGATION

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

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

(1) Organize the accident data.

(2) Guide the investigation.

(3) Validate and confirm the true accident sequence.

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

(5) Simplify organization of the investigation report.

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

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

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

(1) Questioning and testing of accident hypothesis.

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

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

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

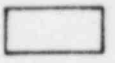
3. DESCRIPTION OF TECHNIQUE[3]

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

First, they will help achieve the goal of increased comparability and consistency in accident reporting within the DOE complex. Additionally, there is such a wide variety of operational activities within DOE and such a wide range of experience and technical expertise among the personnel who conduct accident investigations that the unifying influence of common guidelines for individual analysts is needed for meaningful communications. It is intended that these guidelines be as simple as

possible while preserving the effectiveness of the E&CF chart as a key analytical tool. It is further intended that investigators be provided with helpful guidelines without inhibiting their use of this tool by imposing too many or too complex rules. Consistent with these intentions, then, the following guidelines are suggested for use in constructing E&CF charts for accident analyses and inclusion in investigation reports.

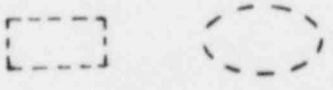
3.1 Suggested Format

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

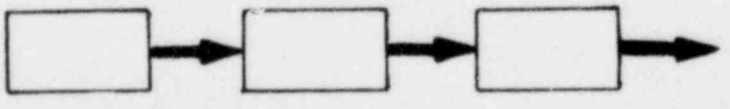
3.1.2 Events should be connected by solid arrows.

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

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

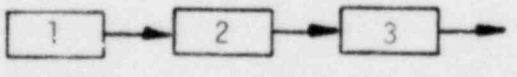


3.1.5 The primary sequence of events should be depicted in a straight horizontal line (or lines in confluent or branching primary chains) with events joined by bold printed connecting arrows.



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

3.1.7 Events should be arranged chronologically from left to right.



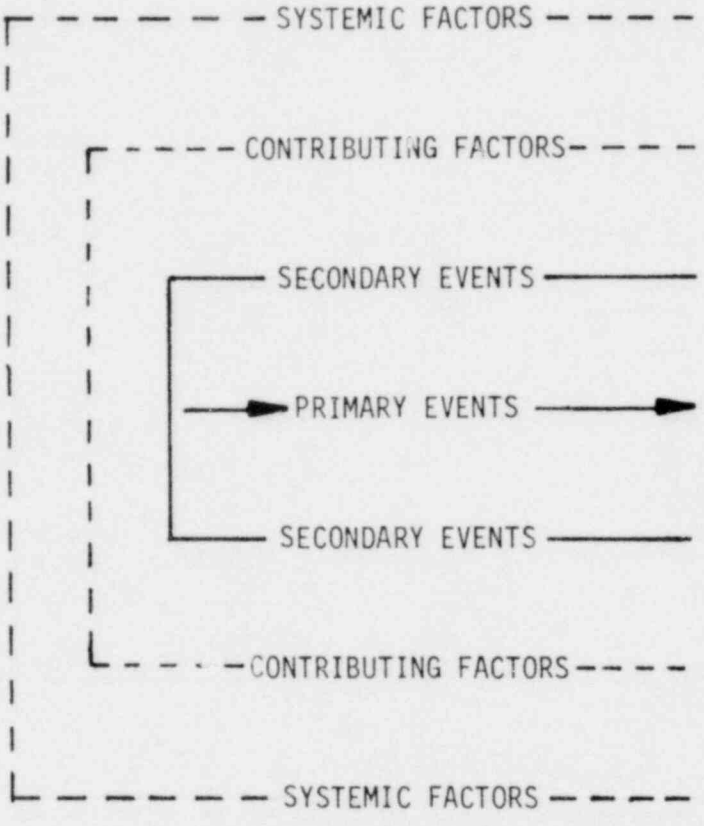


Fig. 1 Events and causal factors relationships.

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

3.2 Suggested Criteria for Event Descriptions

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

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

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

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

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

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

3.3 Typical Application

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

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

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

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

4. BENEFITS OF THE TECHNIQUE

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

4.1 General Purposes of Investigation Served By E&CF Charting

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

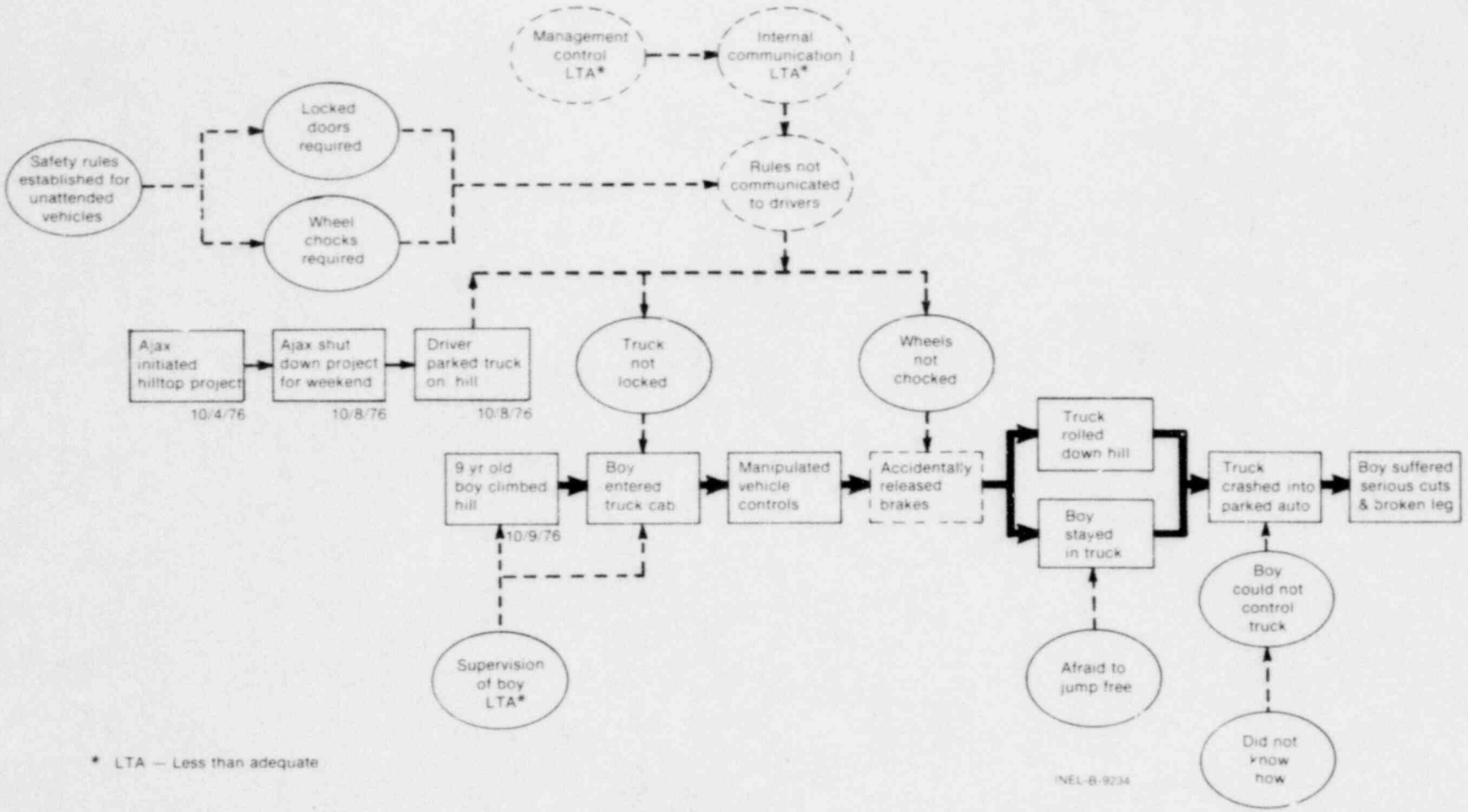


Fig. 2 Events and causal factors chart example

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

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

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

(3) Help delineate areas of responsibility.

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

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

(6) Provide an operational training tool.

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

4.2 Role of E&CF Charting in Conducting the Investigation

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

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

(2) Clarifies reasoning.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. PRACTICAL APPLICATION

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

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

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

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

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

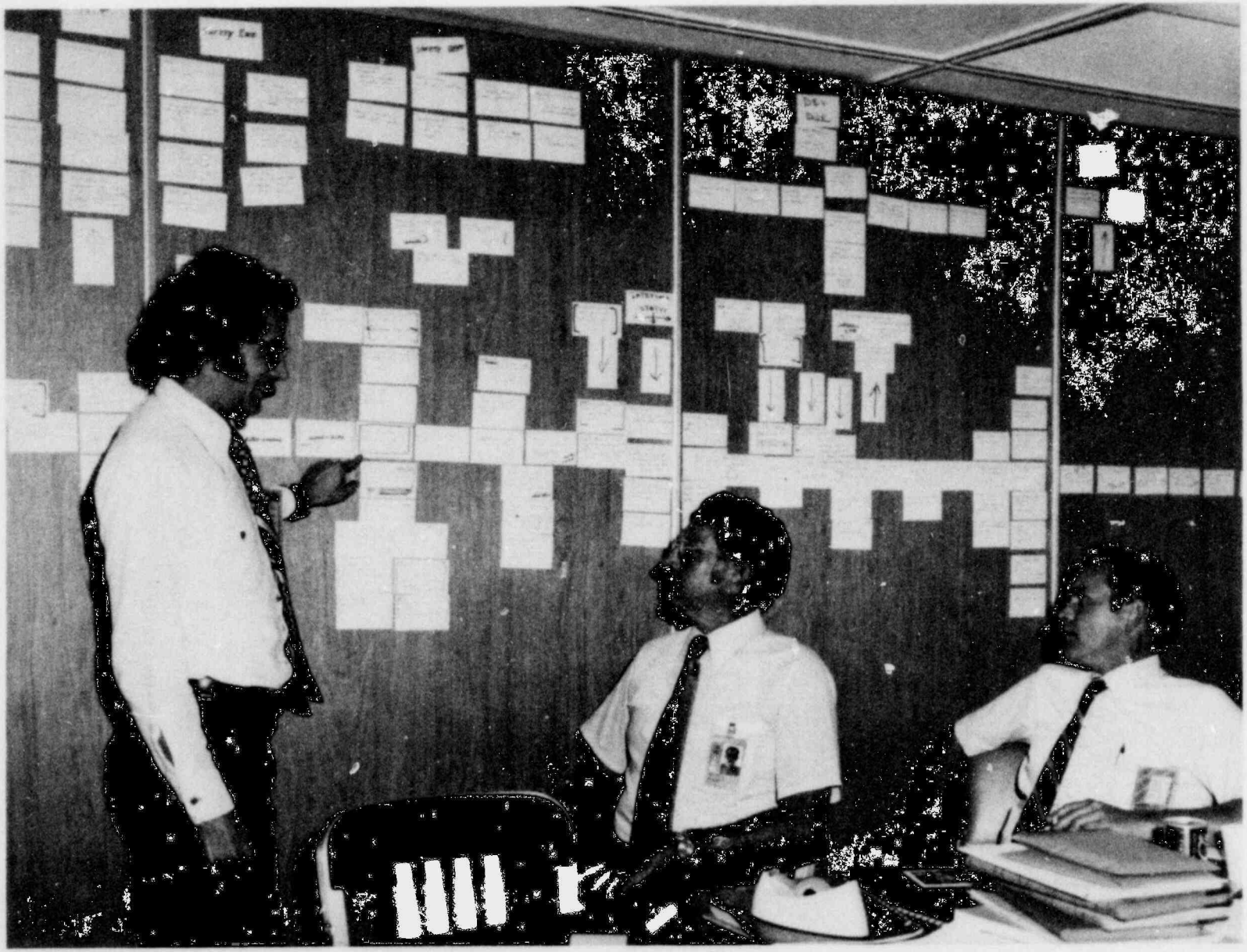


Fig. 3 Events and causal factors wall display.

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

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

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

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

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

(1) Begin early.

(2) Use the guidelines.

(3) Proceed logically using available data.

(4) Use an easily updated format.

(5) Correlate with other MORT investigative tools.

(6) Include appropriate detail and sequence length.

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

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

6. REFERENCES

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

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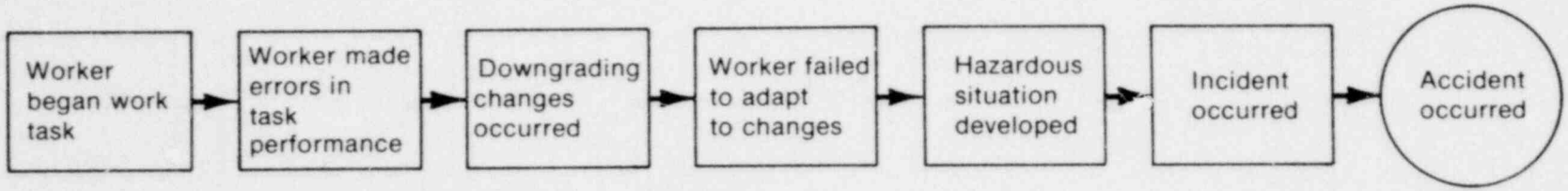
APPENDIX A

GENERALIZED EVENTS AND CAUSAL FACTORS CHART



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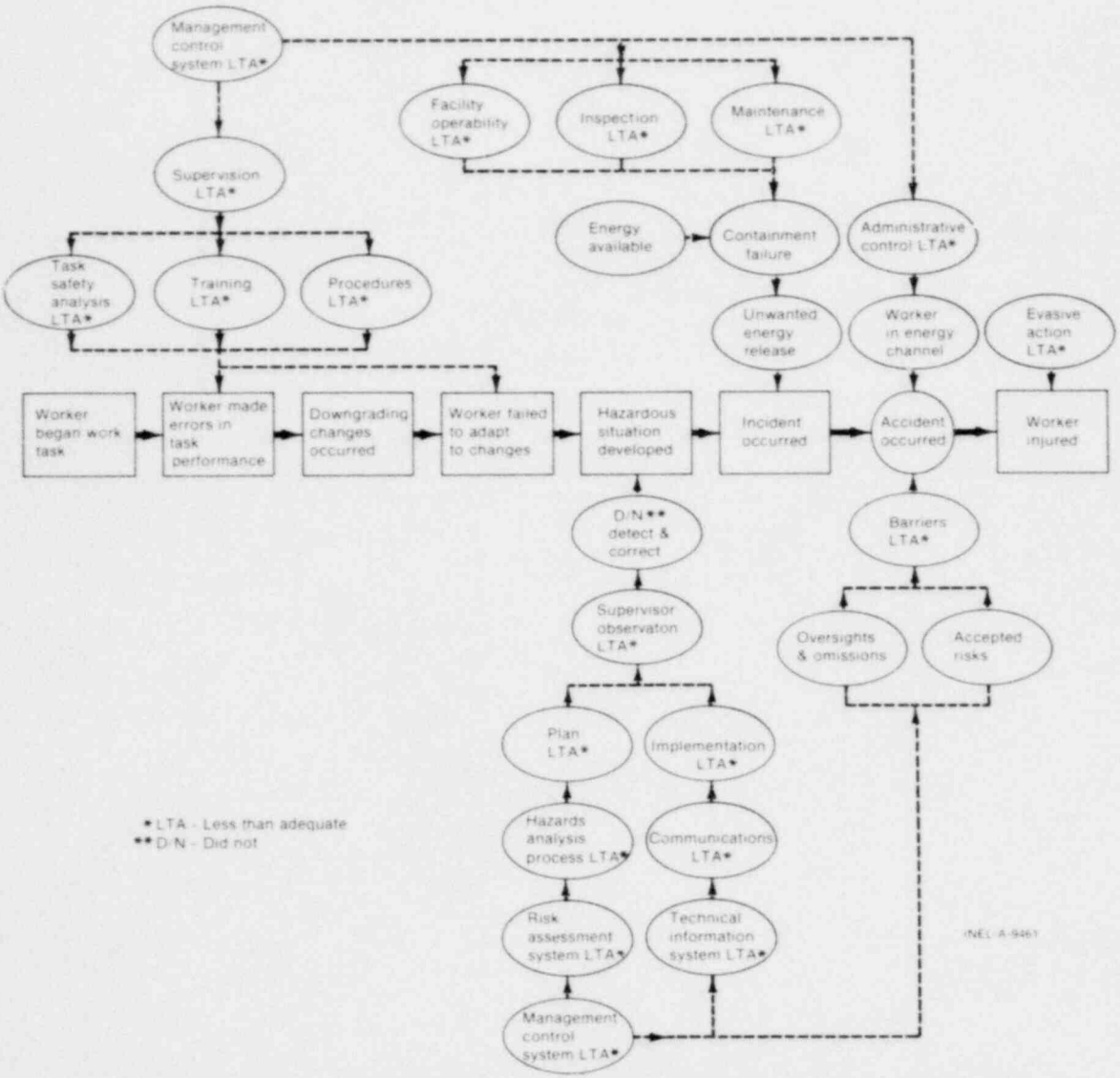
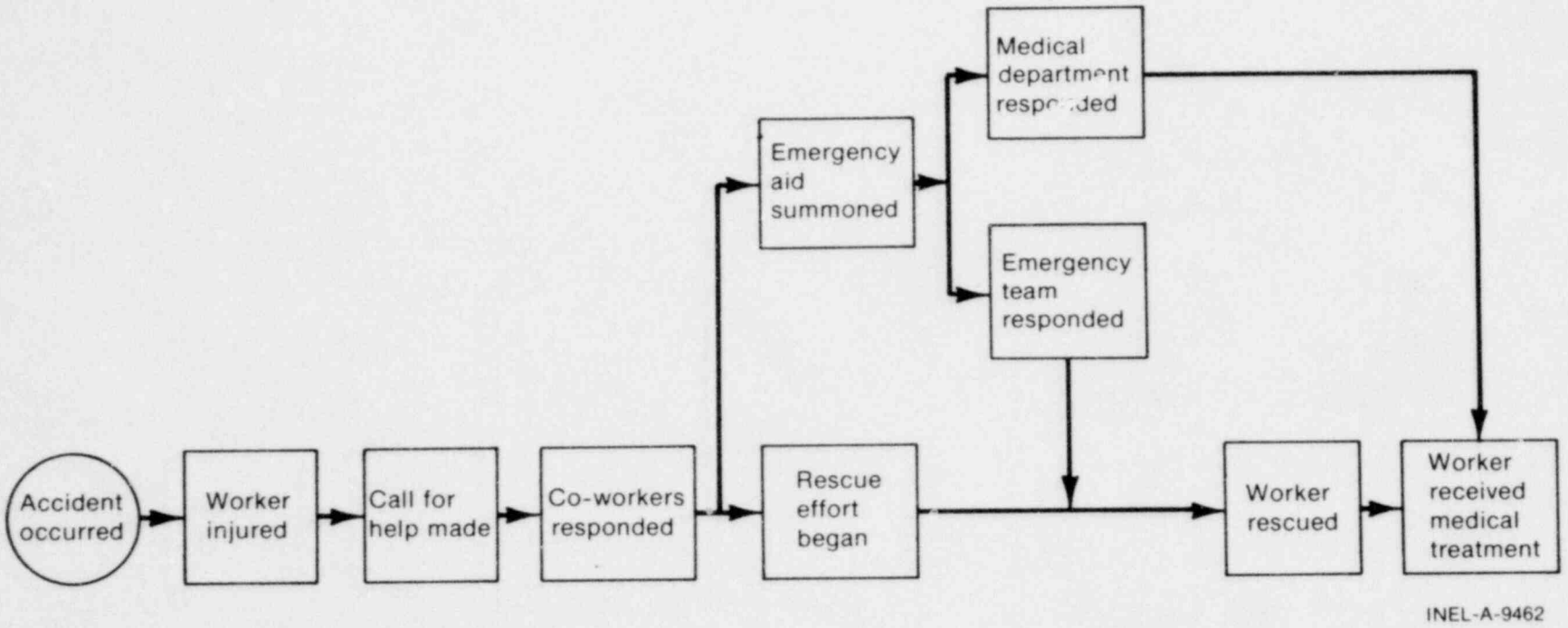
Preaccident Events



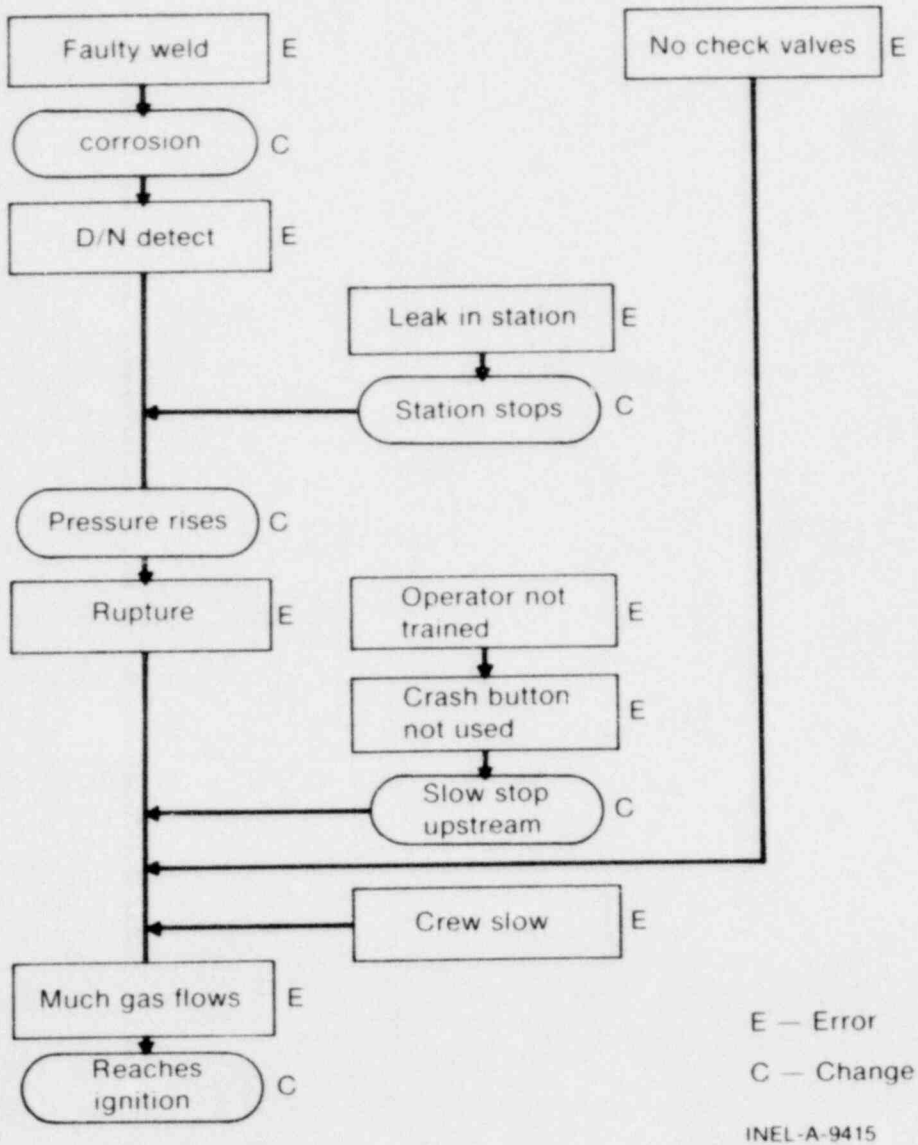
Preaccident Events and Conditions

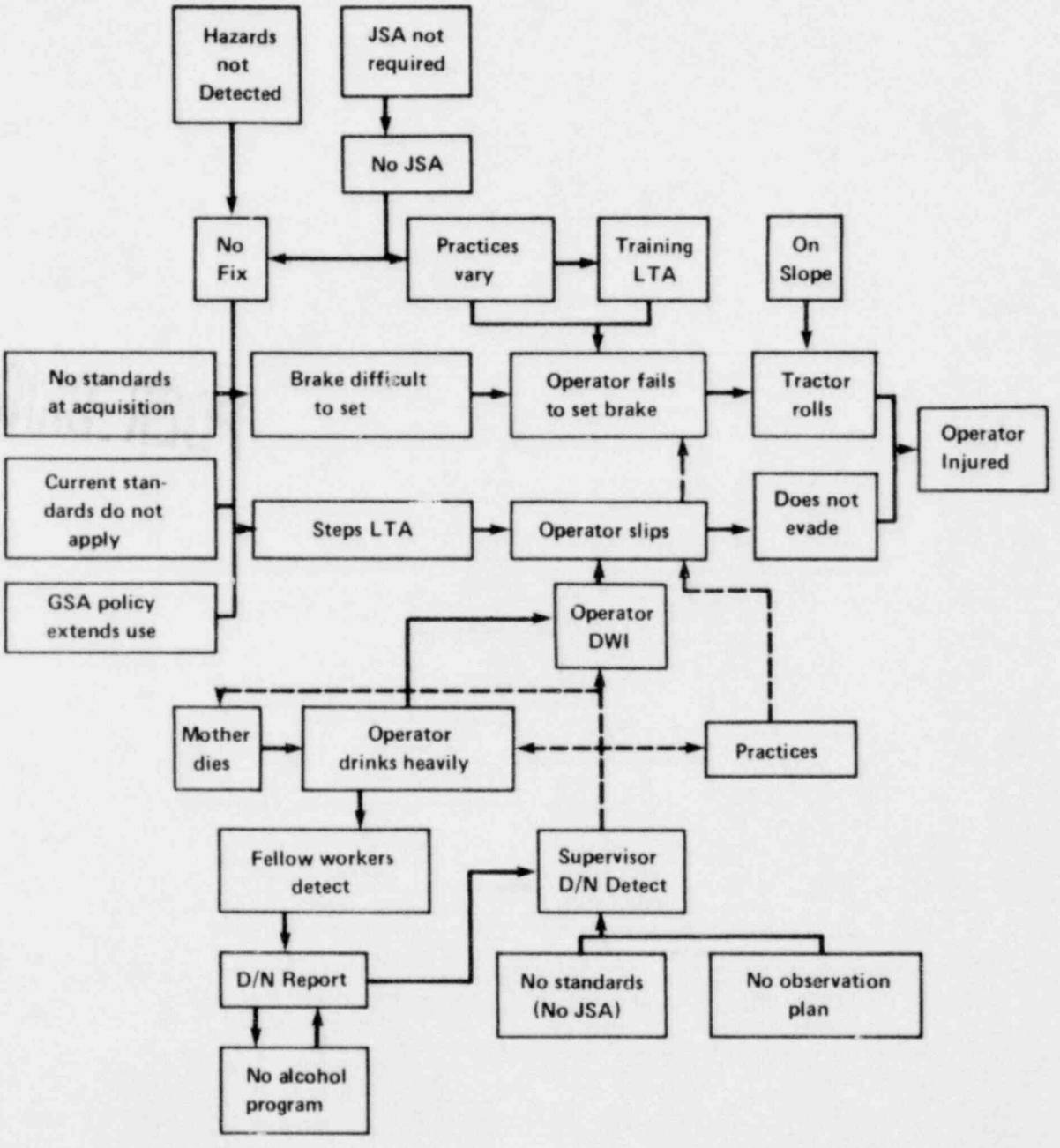


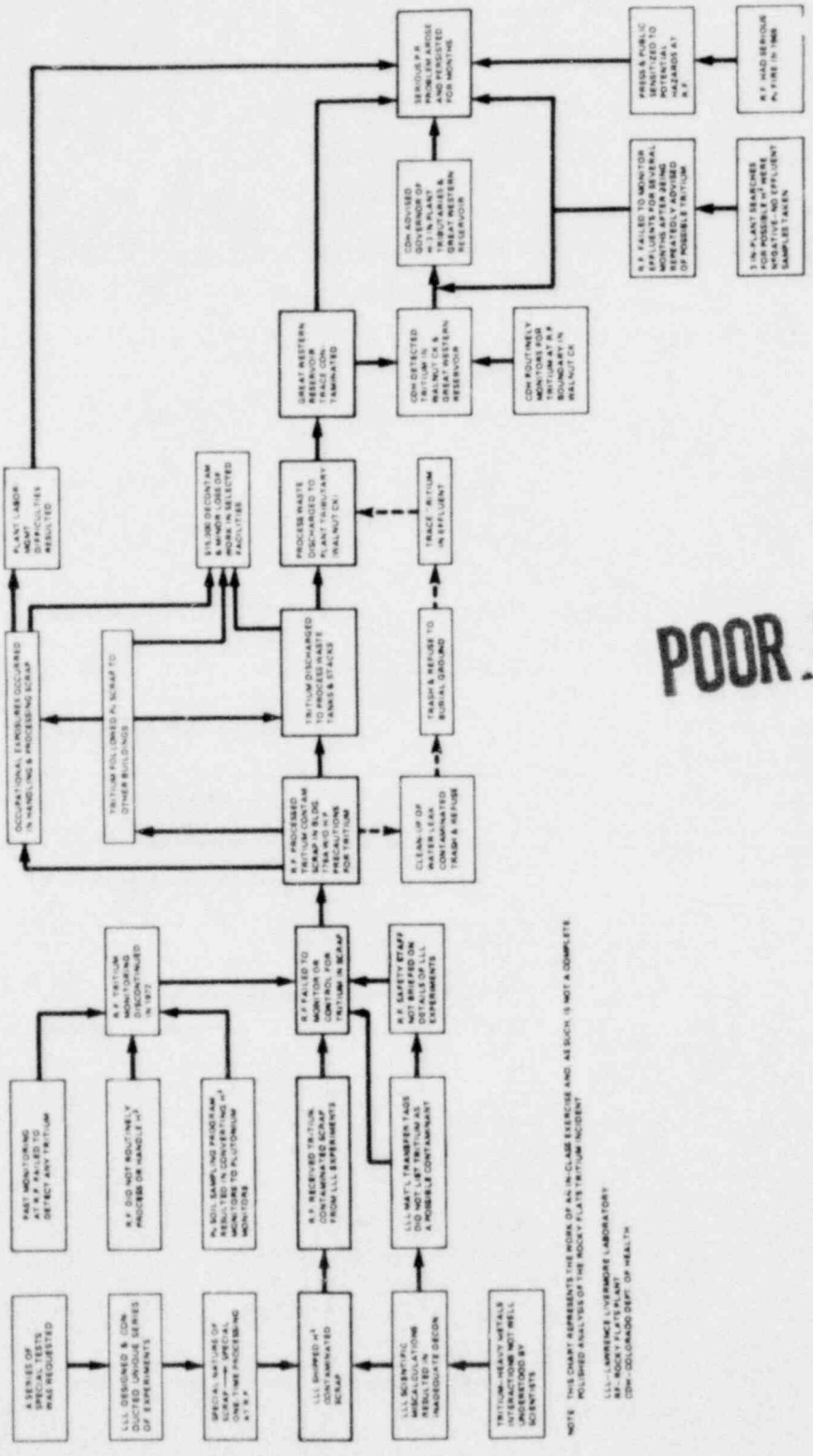
Postaccident Events

APPENDIX B

GAS PIPELINE ACCIDENT[5]




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



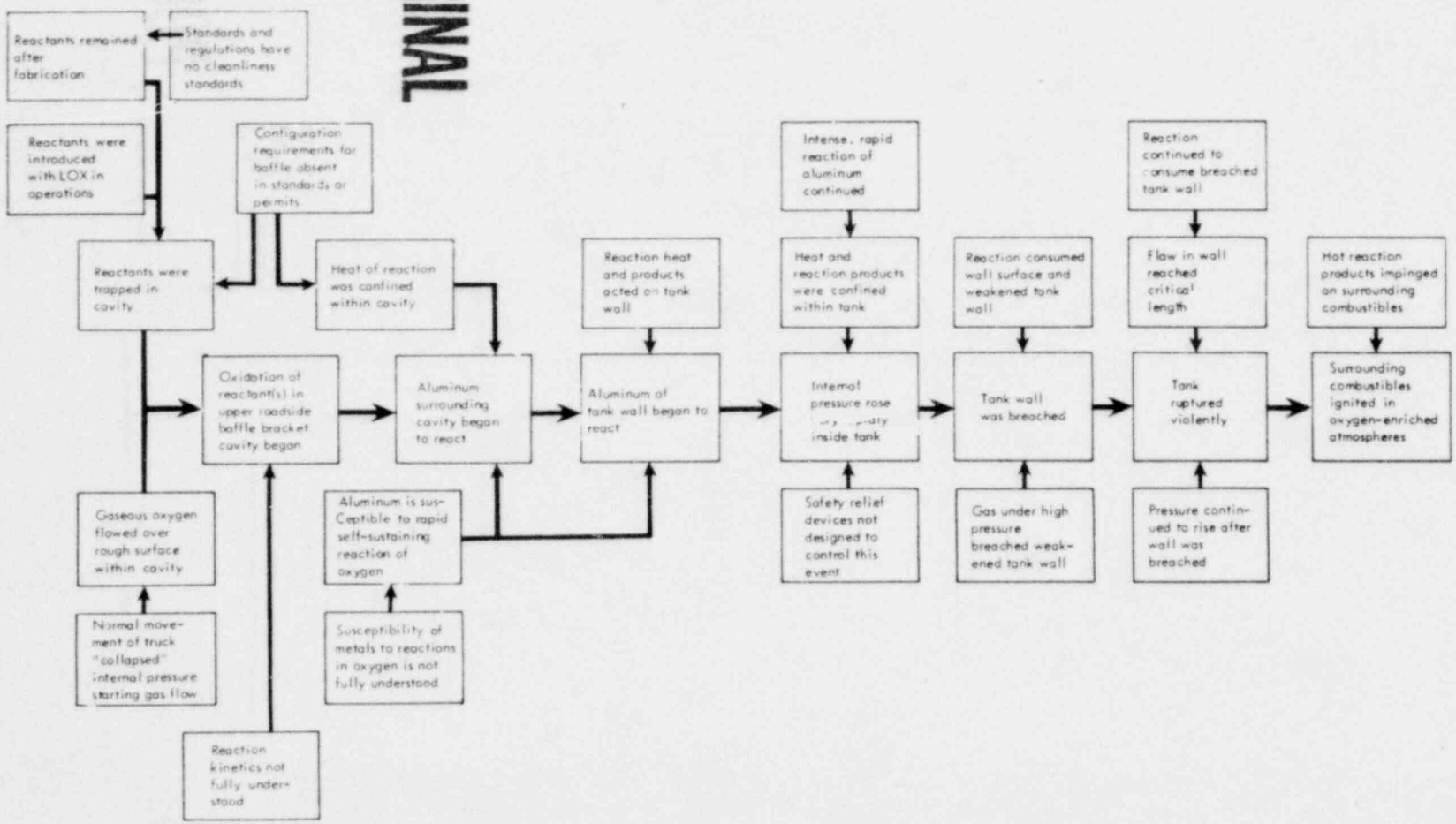
POOR ORIGINAL

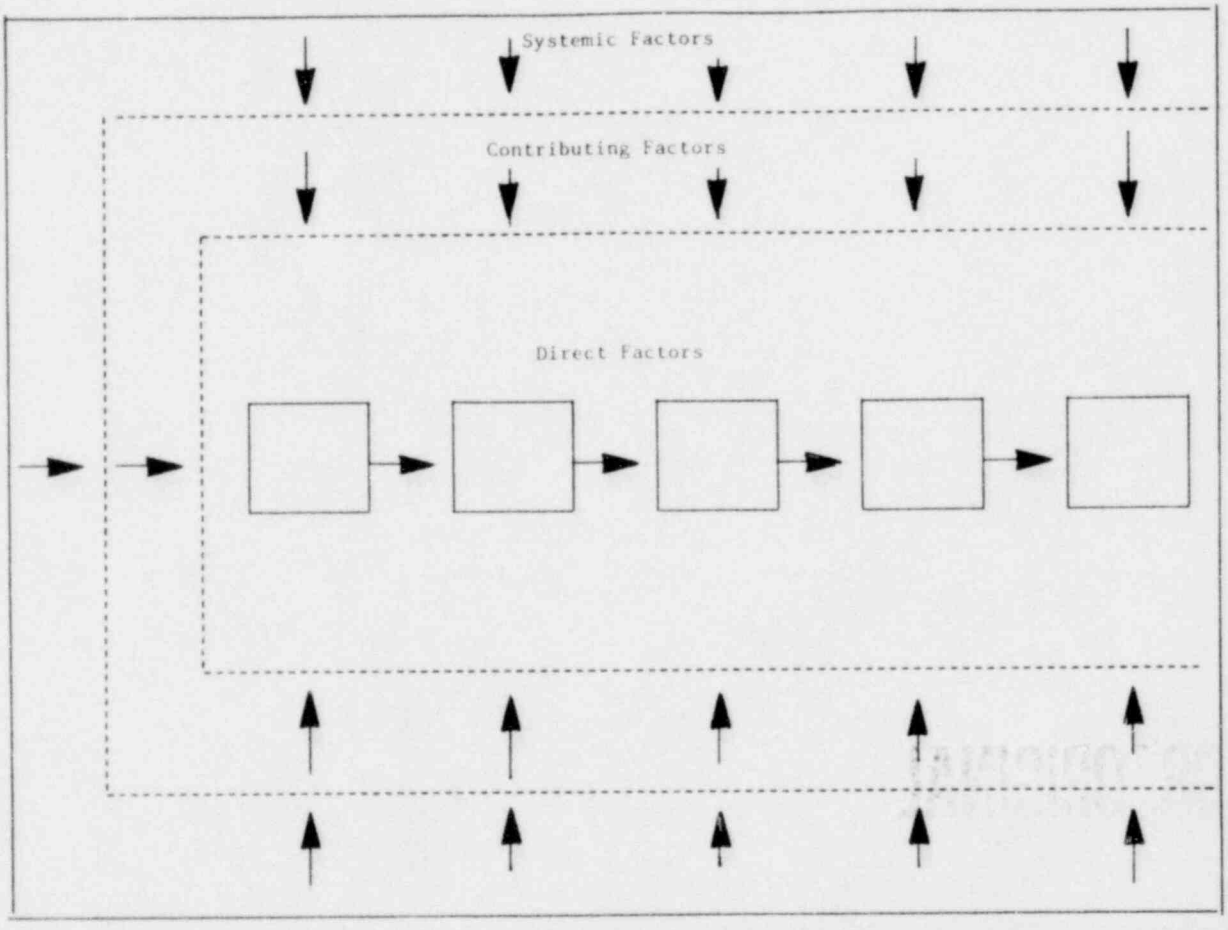
Figure 25. RELATIONSHIP OF EVENTS AND CAUSAL FACTORS
Rocky Flats Tritium Incident

POOR ORIGINAL

APPENDIX D

LOX TANK EXPLOSION[4]



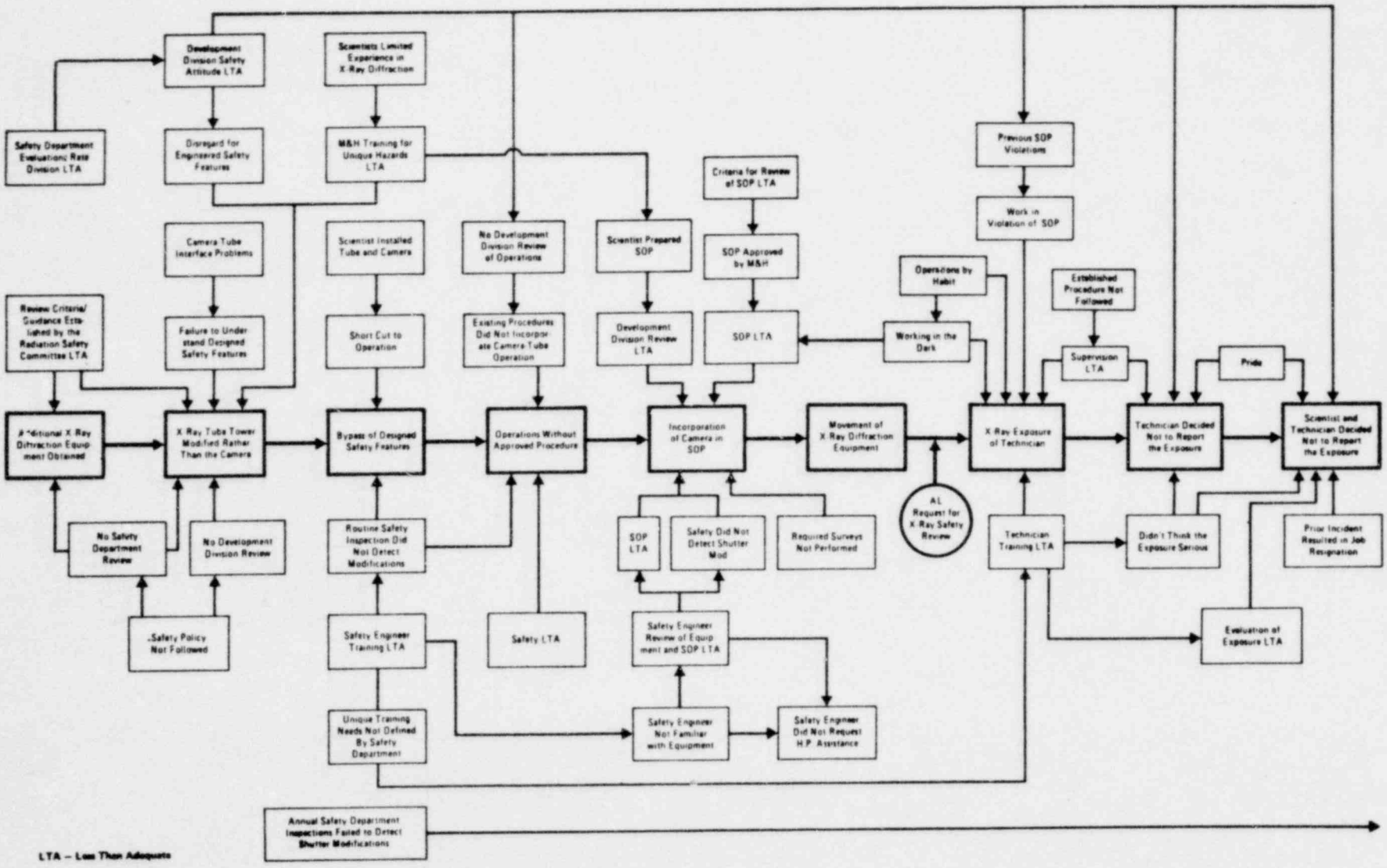


POOR ORIGINAL

Figure 23. EVENTS AND CAUSAL FACTORS (General Schematic)

APPENDIX E

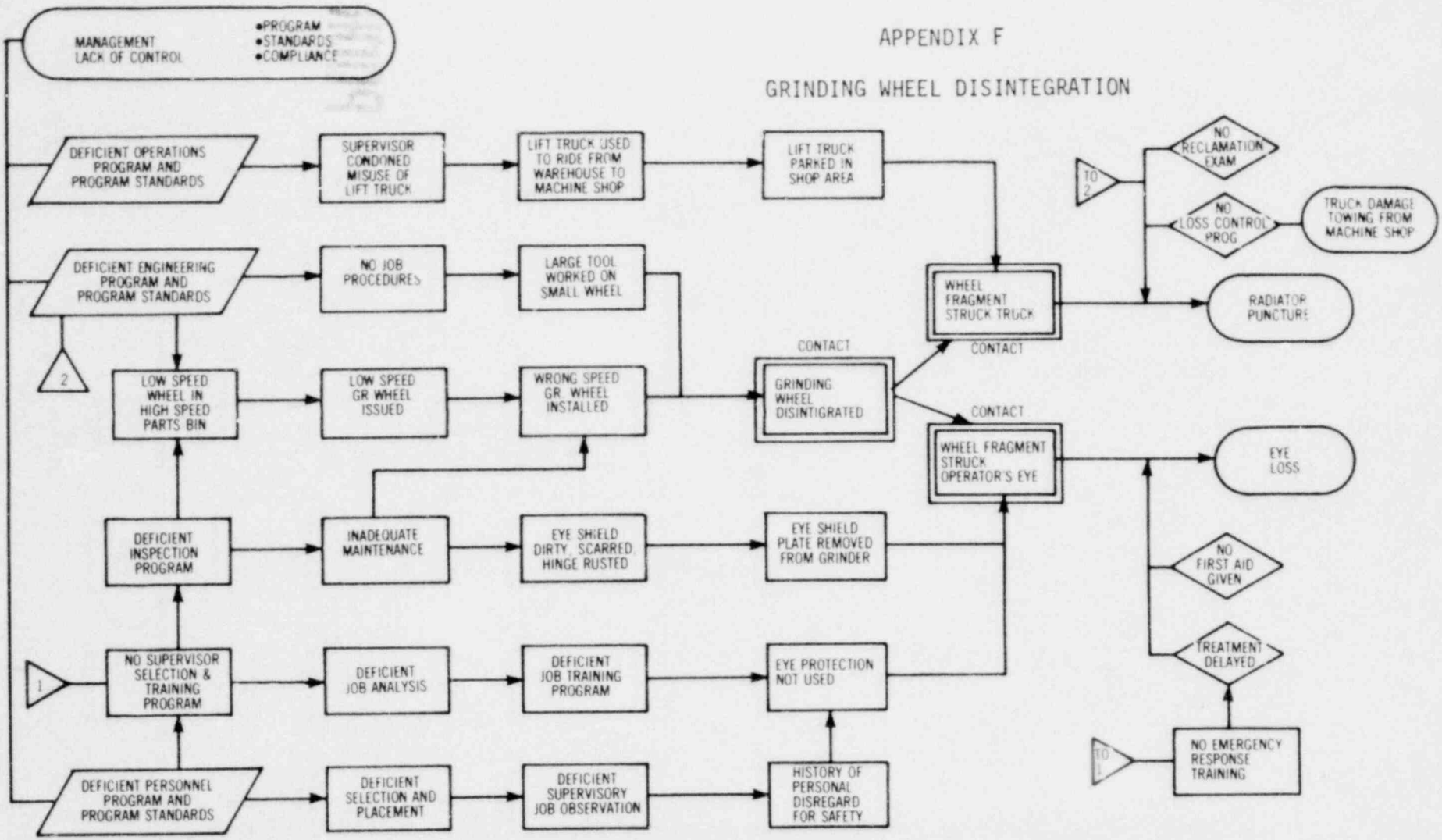
X-RAY EXPOSURE ACCIDENT[6]



POOR ORIGINAL

APPENDIX F

GRINDING WHEEL DISINTEGRATION



Chart

POOR ORIGINAL

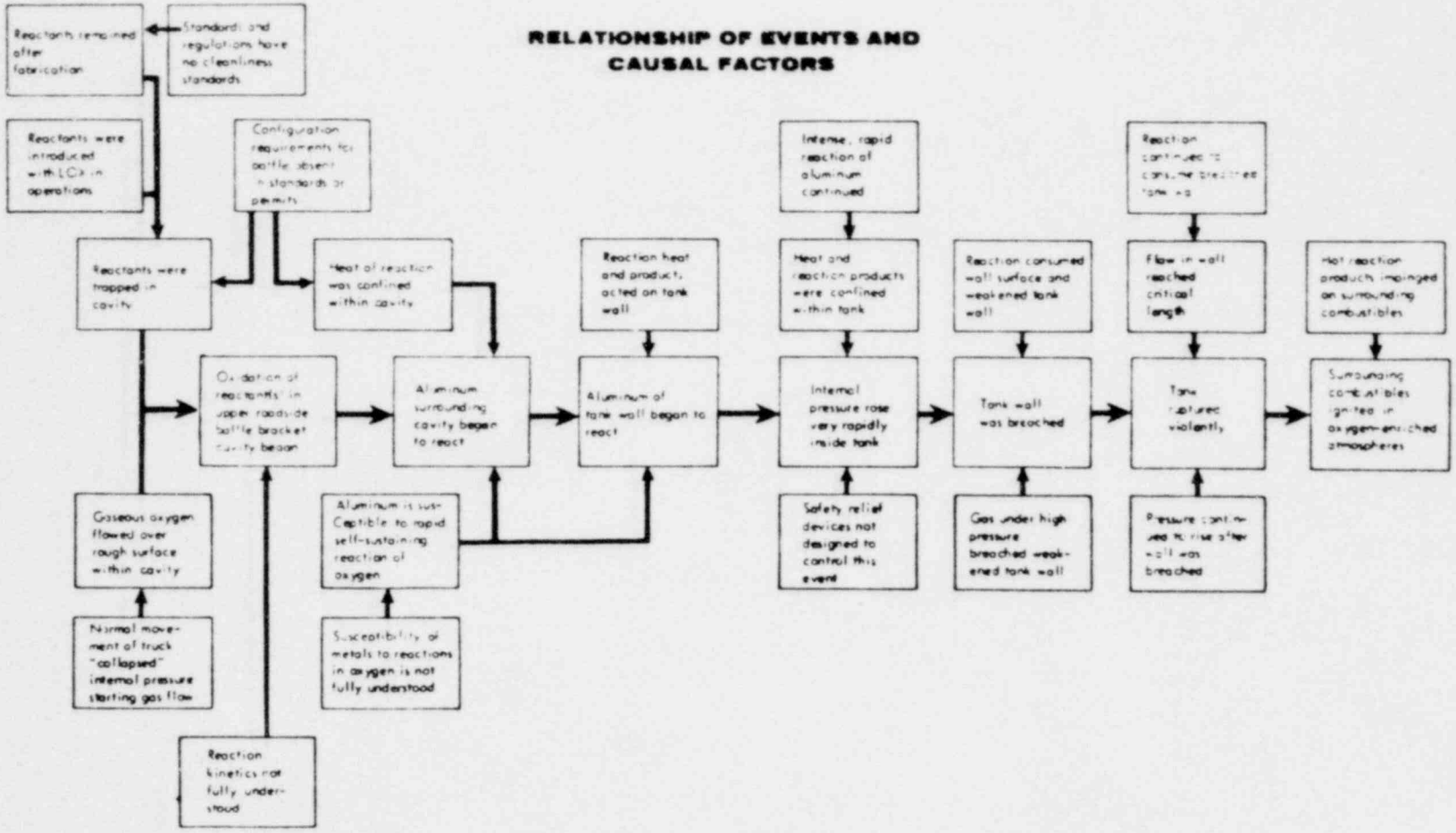


FIGURE 14-3

POOR ORIGINAL

POOR ORIGINAL

Outline

A. Contact between grinding wheel and mower blade resulted in wheel fracture.
- 1. Grinding wheel accelerated to high speed.
  - a. New wheel not run-in after installation.
    - Installed by operator not familiar with run-in procedure.
      - Standards did not prohibit change of wheels by other than maintenance people.
      - Run-in procedure not published.
        - Task analysis not performed.
          - Deficient supervisor training program.
      - Excessively worn wheel not detected by inspection.
        - Not identified as critical part.
        - No inspection schedule established.
          - Supervisor not trained on planned inspection program.
            - Lack of program standards.
      - Grinder spindle speed had been increased to maintain wheel surface speed as wheel wore down.
        - Operator not aware of speed adjustment procedure.
          - Deficient operator training program.
            - Inadequate selection and placement program.
          - Deficient job orientation on transfer.
            - Inadequate selection and placement program.
          - Deficient job analysis.
            - Inadequate supervisor selection and training program.
      - Wheel replacement procedure not published.
        - Not identified as critical job.
          - Inadequate program.
      - Tool room issued wheel to operator.
        - Standards did not differentiate between parts to be issued to maintenance and tools and parts which could be issued to equipment operators.
          - Inadequate program.
  - b. Low speed grinding wheel installed on high speed grinder.
    - Low speed wheels mixed with high speed wheels in parts bins.
      - Stock shifted in reorganization.
      - Returns to stock not repackaged to show identification.
        - Lack of standard for marking return of issued parts.
      - No marking or identification of wheel type.
    - Low speed and high speed wheels have same spindle size.
      - Purchase not coordinated with safety department.
        - Lack of program standards for purchasing.
      - Intentional condition to permit use of excess high speed wheel stock.
        - Lack of compliance with ANSI B7.1
- 2. Mower blade not supported by tool rest.
  - a. Tool rest not reset to 1/8" clearance when new wheel installed.
    - Operator did not understand importance of tool rest and wheel guard position.
      - Inadequate training.
        - No task analysis.
        - No standard job procedure.
      - No supervisory key point typing program.
        - Inadequate supervisory training and qualification.
    - Tool rest clearance not checked by supervisor or technically qualified inspector.
      - Inadequate inspection program.
      - Supervisor not trained on inspection programs.
        - Inadequate program.
    - Tool rest clearance standard not enforced in company.
      - Standards enforcement lax in product development.
      - Standard not considered significant in production area.
        - Inadequate compliance.
  - b. Holders for large work not available within plant.
    - Benefit not evaluated for quality or safety.
    - No safety evaluation of benefit for production line.
      - Inadequate program.

B. Grinding wheel [illegible] not contained by wheel guard or eye shield.
- 1. Wheel guard not in proper position.
  - a. No tongue over upper opening.
  - b. Guard not movable to control upper opening.
    - Inadequate purchasing standards.
    - No safety approval of purchase.
      - Inadequate program.
  - c. Guard turned past 65° position.
    - Operator not aware of guard position standards.
    - Maintenance not aware of guard position standards.
      - Inadequate compliance with ANSI B7.1
        - Inadequate program.
- 2. Eye shield removed from grinder.
  - a. Eye shield dirty and greasy.
  - b. Eye shield heavily scratched.
  - c. Eye shield hinge rusted and frozen.
    - Inadequate maintenance schedule.
    - Inadequate supervisor action.
      - Inadequate program.

C. Grinding wheel fragment struck operator's eye.
- 1. Operator not using personal eye protection.
  - a. Protective goggles hanging near grinder.
  - b. Protective goggles dirty and scratched.
    - Inadequate worker action to maintain goggles.
      - Lack of standard.
    - Inadequate supervisor action on care of equipment.
      - Inadequate supervisor selection and training.
        - Inadequate program.
  - c. Operator had history of disregard for use of personal protective equipment.
    - Workers frequently observed operator without eye protection.
    - Workers did not report violation of standards to supervisor.
      - Deficient compliance program.
      - Inadequate training.
        - Inadequate program.
    - Deficient supervisory job observation.
      - Inadequate supervisor selection and training.
        - Inadequate program.
- 2. No first aid administered after injury.
  - a. Supervisor and work section people not trained in first aid.
    - Inadequate program.
  - b. Injury aggravated by failure to flush foreign material from eye.
- 3. Medical treatment delayed by confusion following the accident.
  - a. No emergency response plan.
  - b. No emergency action training of managers and supervisors.
    - Inadequate program.

D. Grinding wheel fragment punctured mowing tractor radiator.
- 1. Tractor moved into shop area.
  - a. Tractor mis-used as personal transport to shop.
    - Supervisor condoned general mis-use.
      - Lack of compliance with standards.
- 2. Tractor damaged in towing from shop.
  - a. Tow chain wrapped around steering mechanism rods.
  - b. Brake not released before attempting towing.
    - Inadequate planning for control of damaged equipment.
      - Inadequate investigation program.
    - Steering rods bent.
    - Steering rods discarded and replaced.
      - No program for examination and reclamation of accident damages.
        - Inadequate investigation program.
  - c. Transmission damaged by towing tractor backwards after steering rods damaged.
    - Inadequate planning for control of damaged equipment.
      - Inadequate investigation program.

Systems safety analyses are a variety of qualitative and quantitative methods of imaginatively looking at every conceivable way an undesired event could occur. The qualitative methods are highly organized forms of subjective hazard recognition and anticipation. The quantitative methods apply known or experimentally determined probable frequency and severity to evaluate the potential for loss. Each part of the system, the people, equipment, material and environment (PEME) is considered for its entire life from design to disposal. Selection, hiring or purchase, training or installation, use and misuse, maintenance and improvement, transfer and salvage, are all looked at. Proper use, as well as improper use, is evaluated to the extent of the imagination. Effects within the system and its four elements (PEME), as well as effects on outside systems wherever they interface — influence, control or affect each other — are looked at to the extent of activities which are planned or in any way conceivable. Time and imagination are the only constraints. When any analysis technique is considered, the extensiveness of the procedure, and its consequent costs, must be weighed against the benefits as determined by the severity and frequency potentials.

Several types of systems safety analyses will be described in this section, along with their general use in accident investigation analysis. To use the methods, amplified information and instructions will be needed. A more extensive introduction to systems safety can be found in Chapter XVI of *Loss Control Management* and a detailed explanation in the *Handbook of System and Product Safety*. Several other texts are listed in Part IV References.

POOR ORIGINAL

14.7.1. Definitions.

The diagrams, models and mathematics which usually accompany discussions of systems safety are often more discouraging than they are enticing to the safety professional. A mathematical background is not really needed to benefit from the knowledge system safety has produced. An awareness of the different methods and when they might be used can alert the safety professional to situations where he might seek help in analysis from a systems safety engineer.

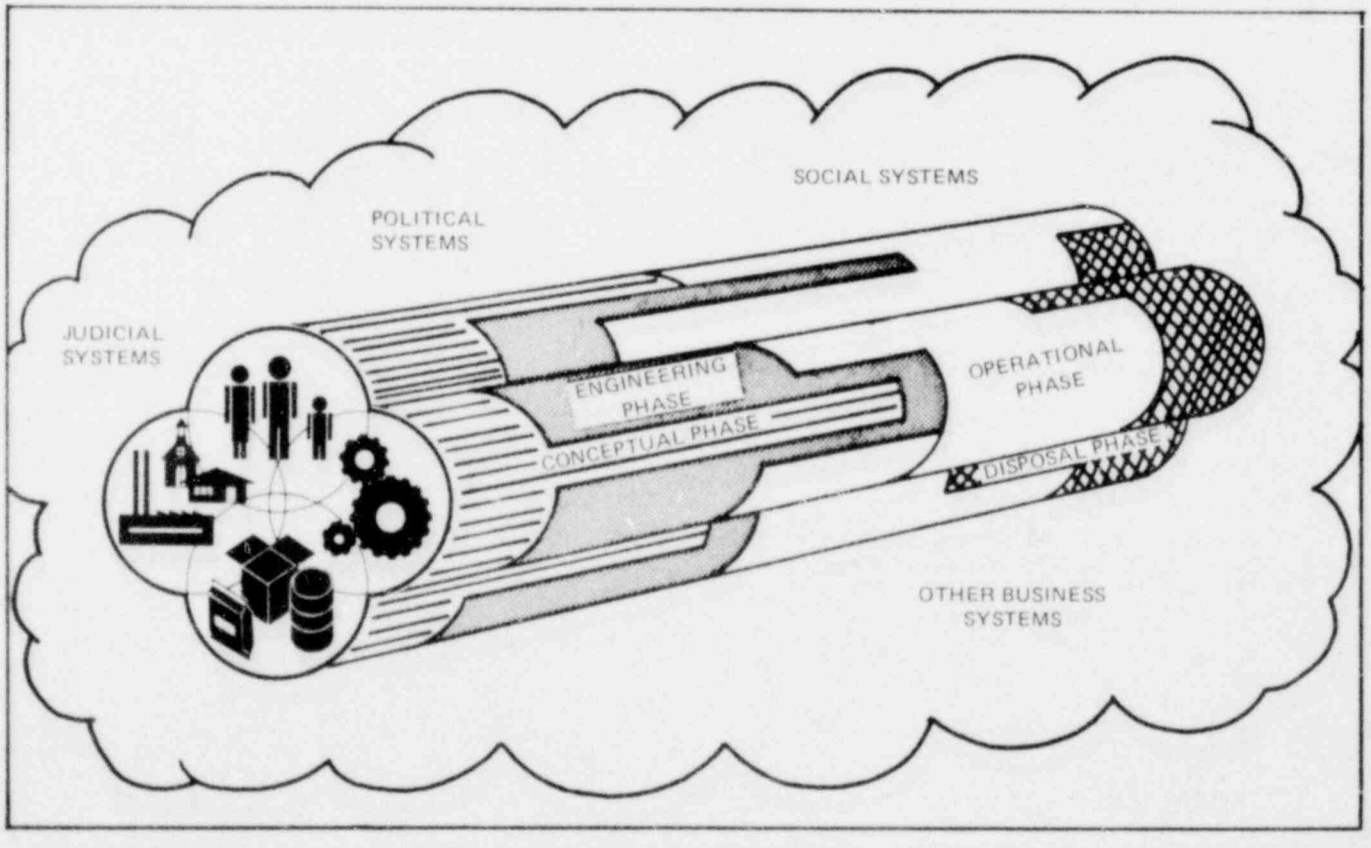
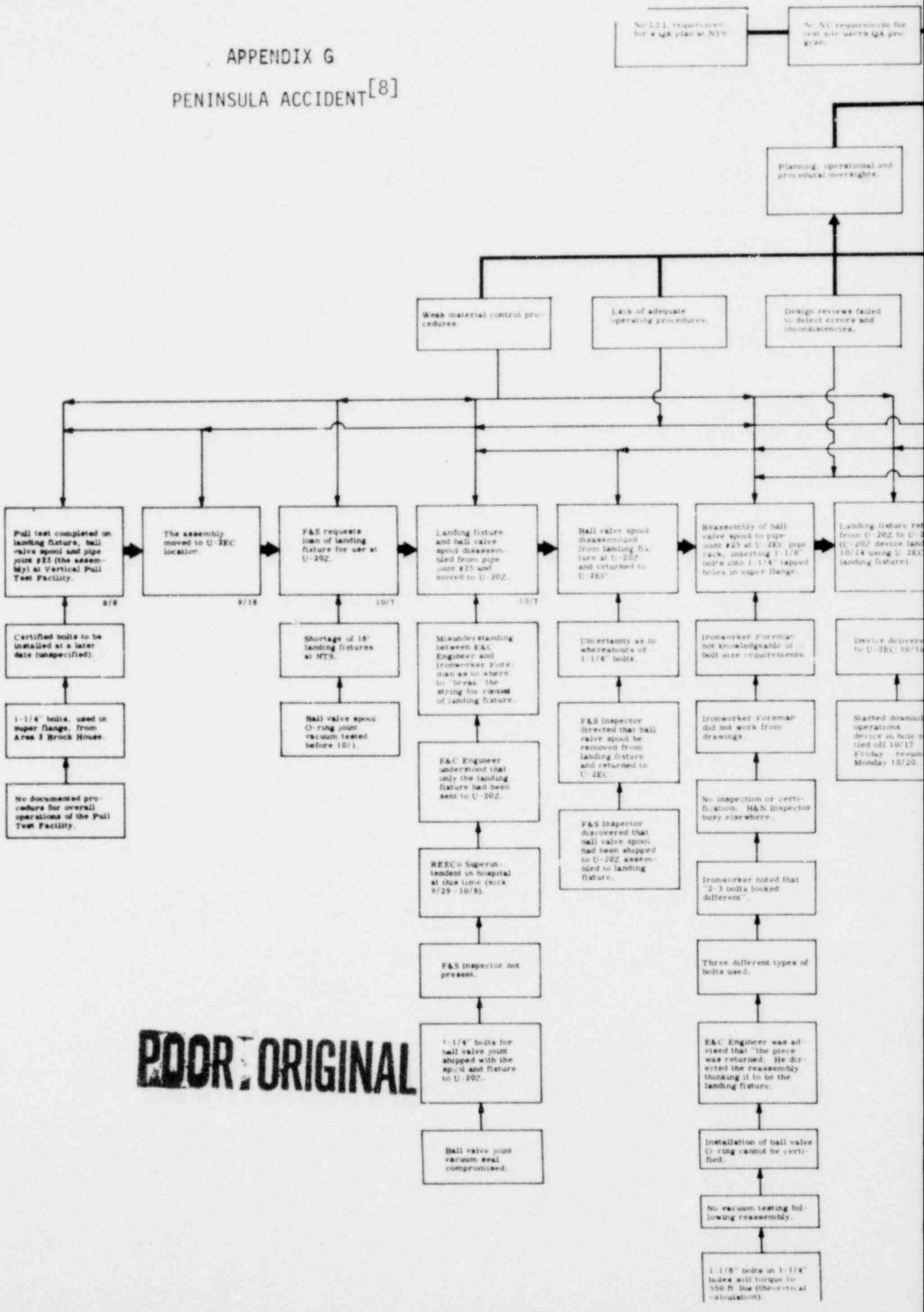


FIGURE 14-7. The business system, its life span and interfaces with the universe that surrounds it

APPENDIX G

PENINSULA ACCIDENT[8]



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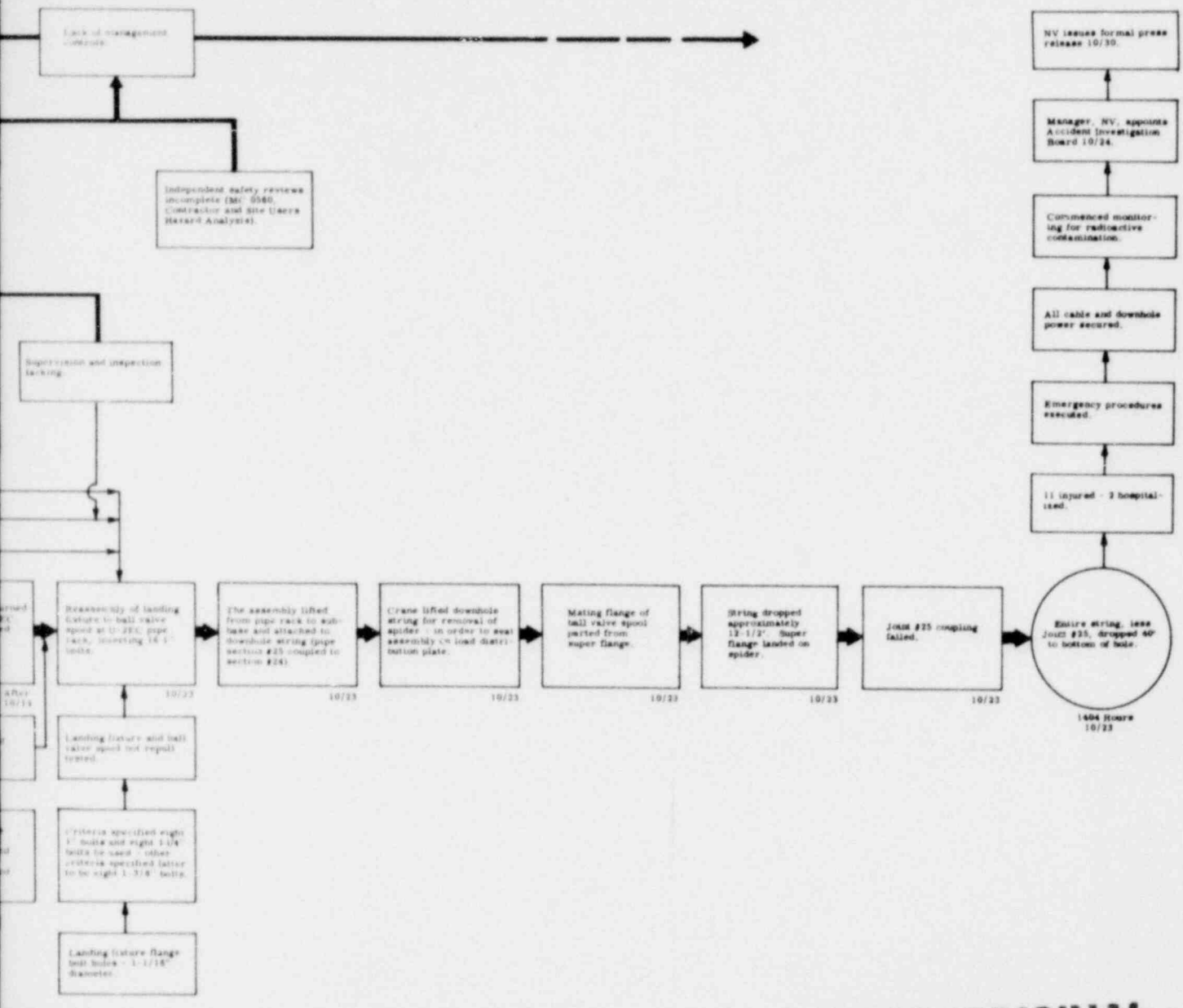


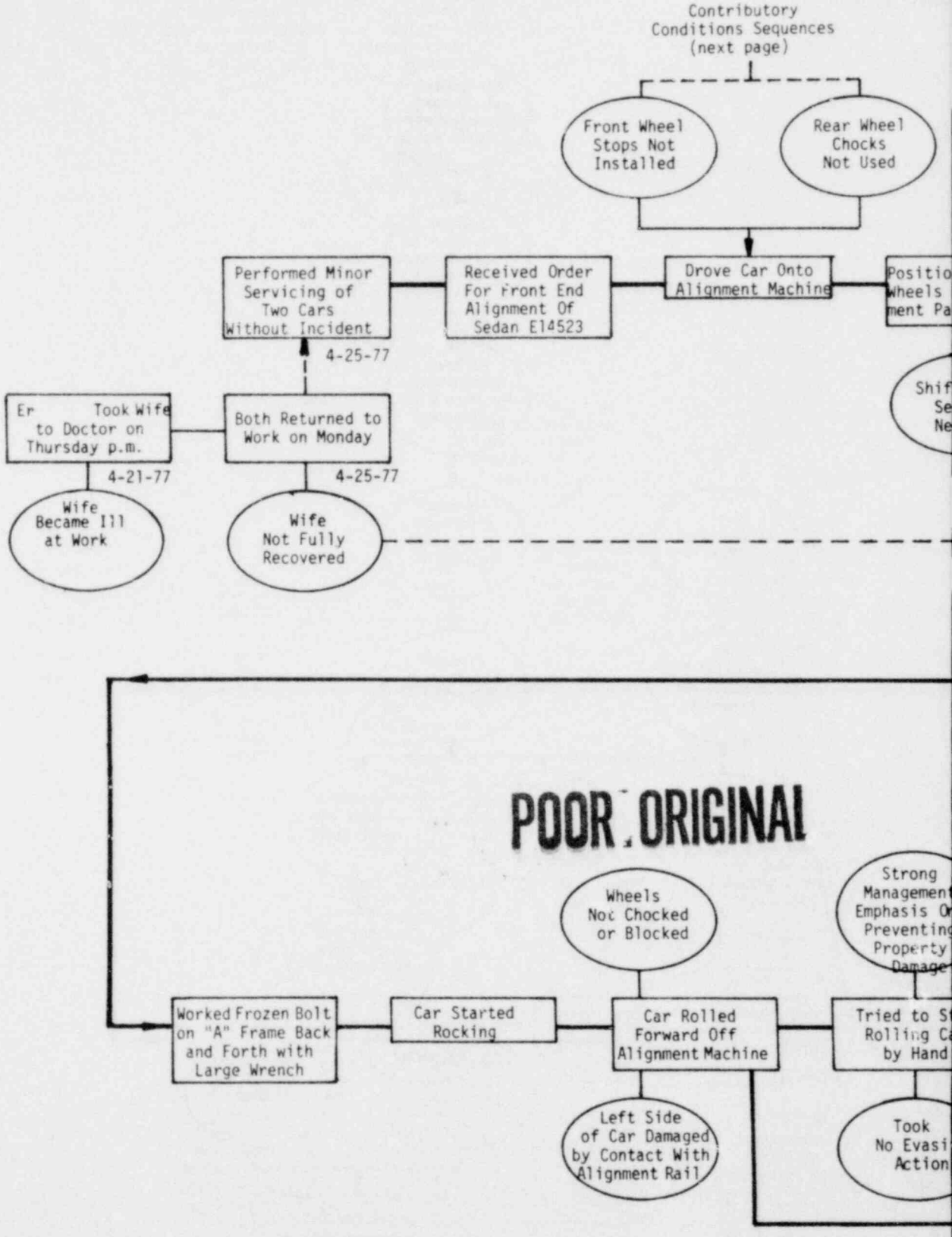
POOR ORIGINAL

LLL - Lawrence Livermore Laboratory

REECo - Reynolds Electrical & Engineering Co., Inc.

F&S - Fenix & Scisson, Inc.

H&N - Holmes & Narver, Inc.



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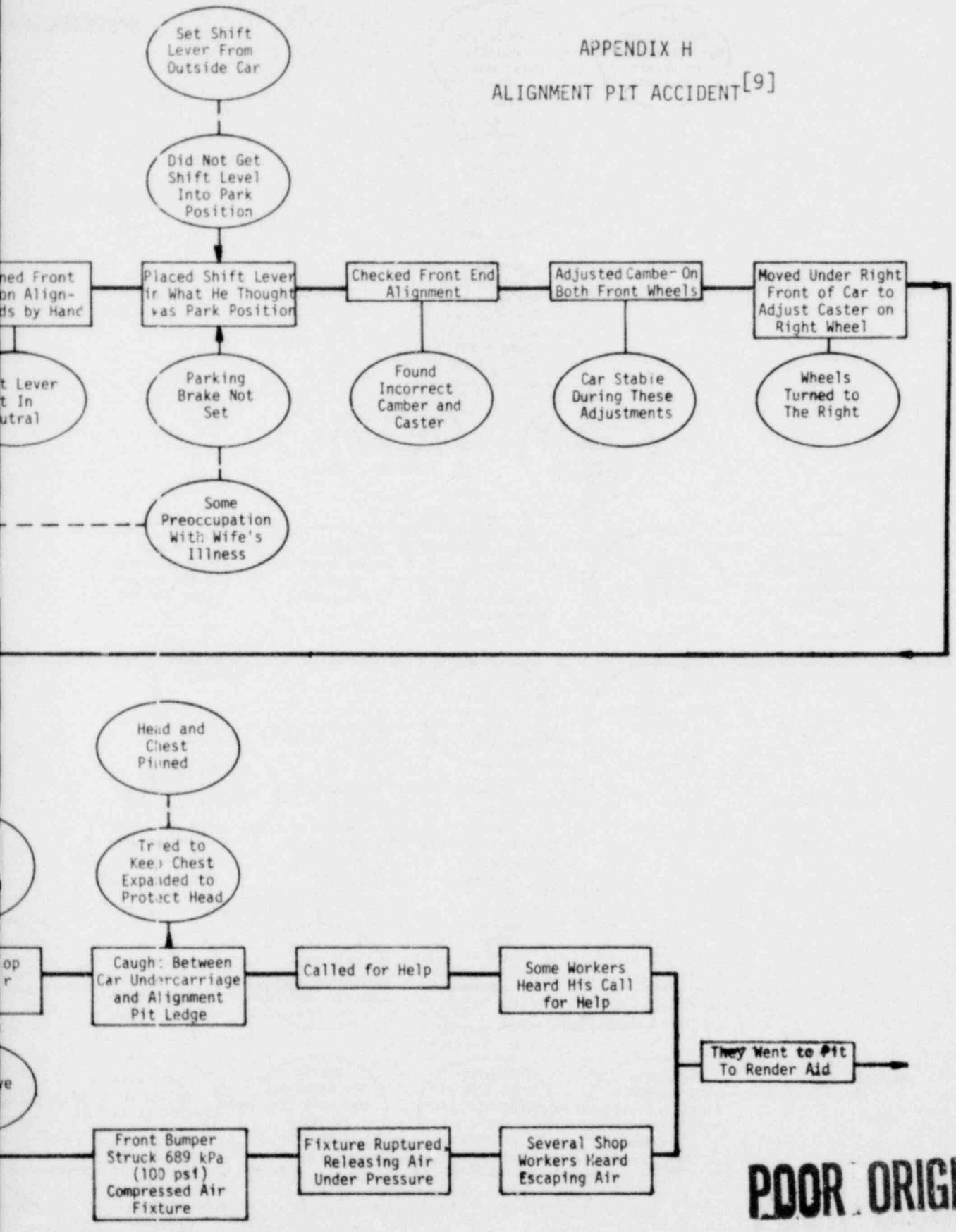
APPENDIX H

ALIGNMENT PIT ACCIDENT[9]



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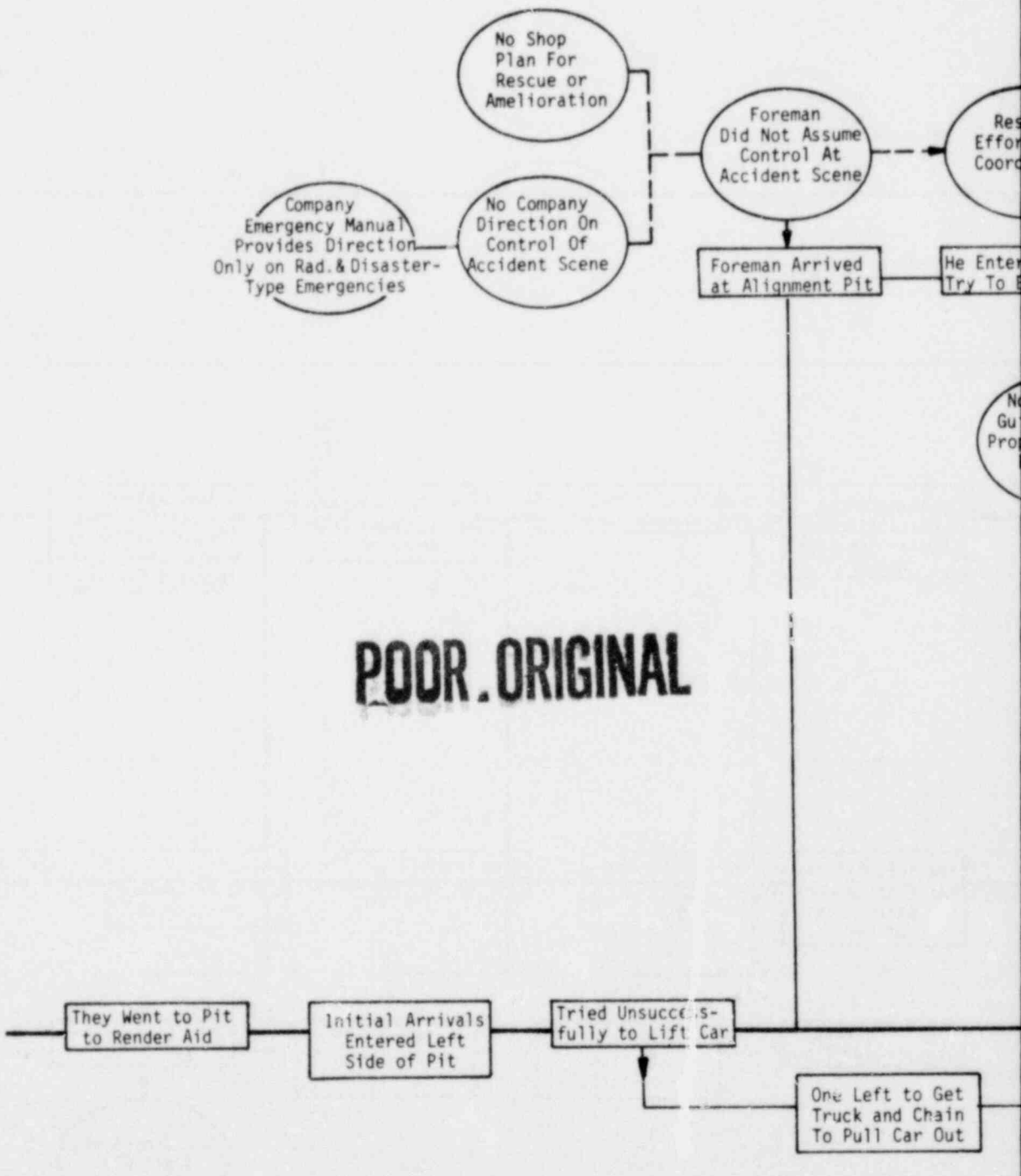
he Accident



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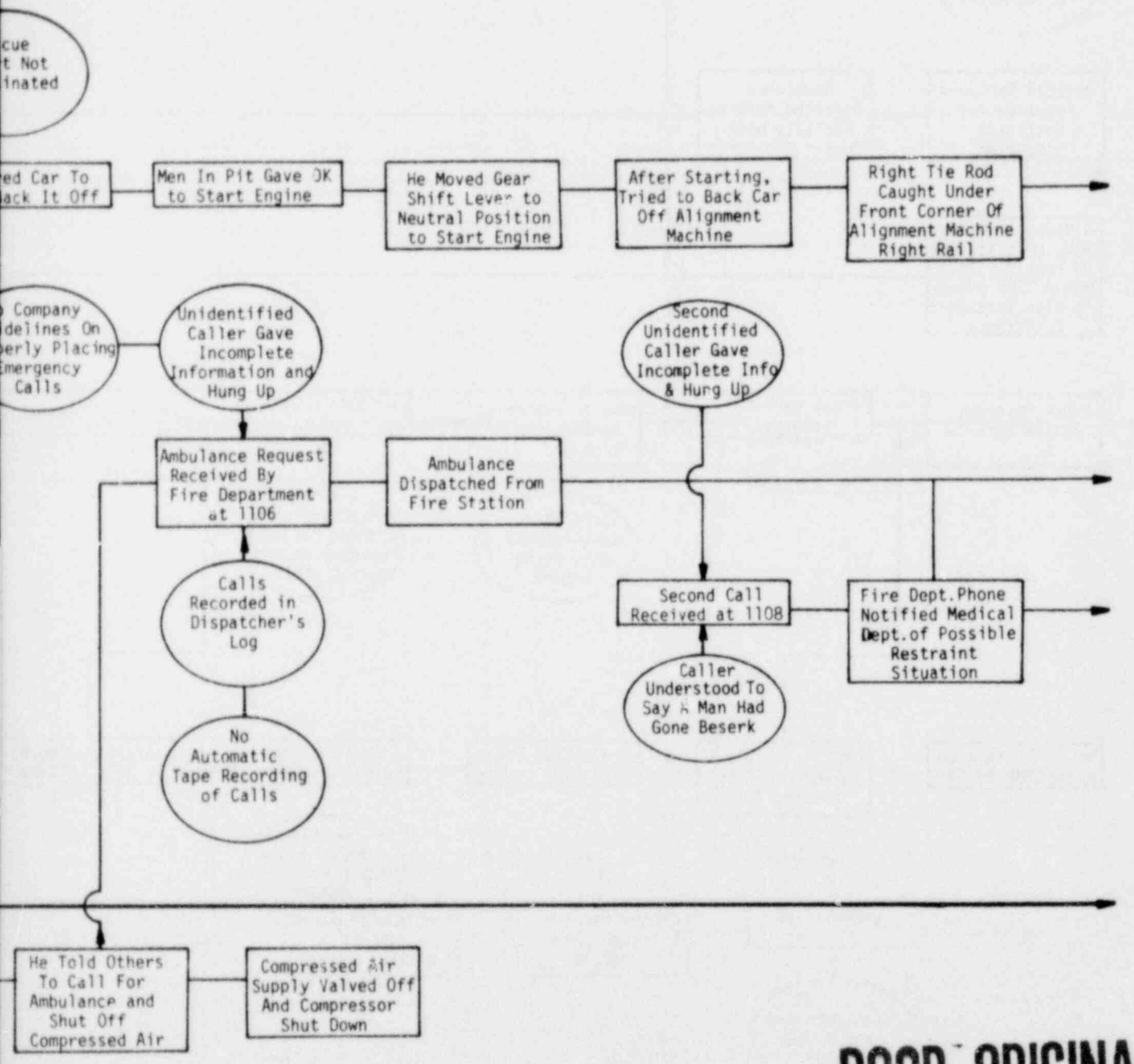

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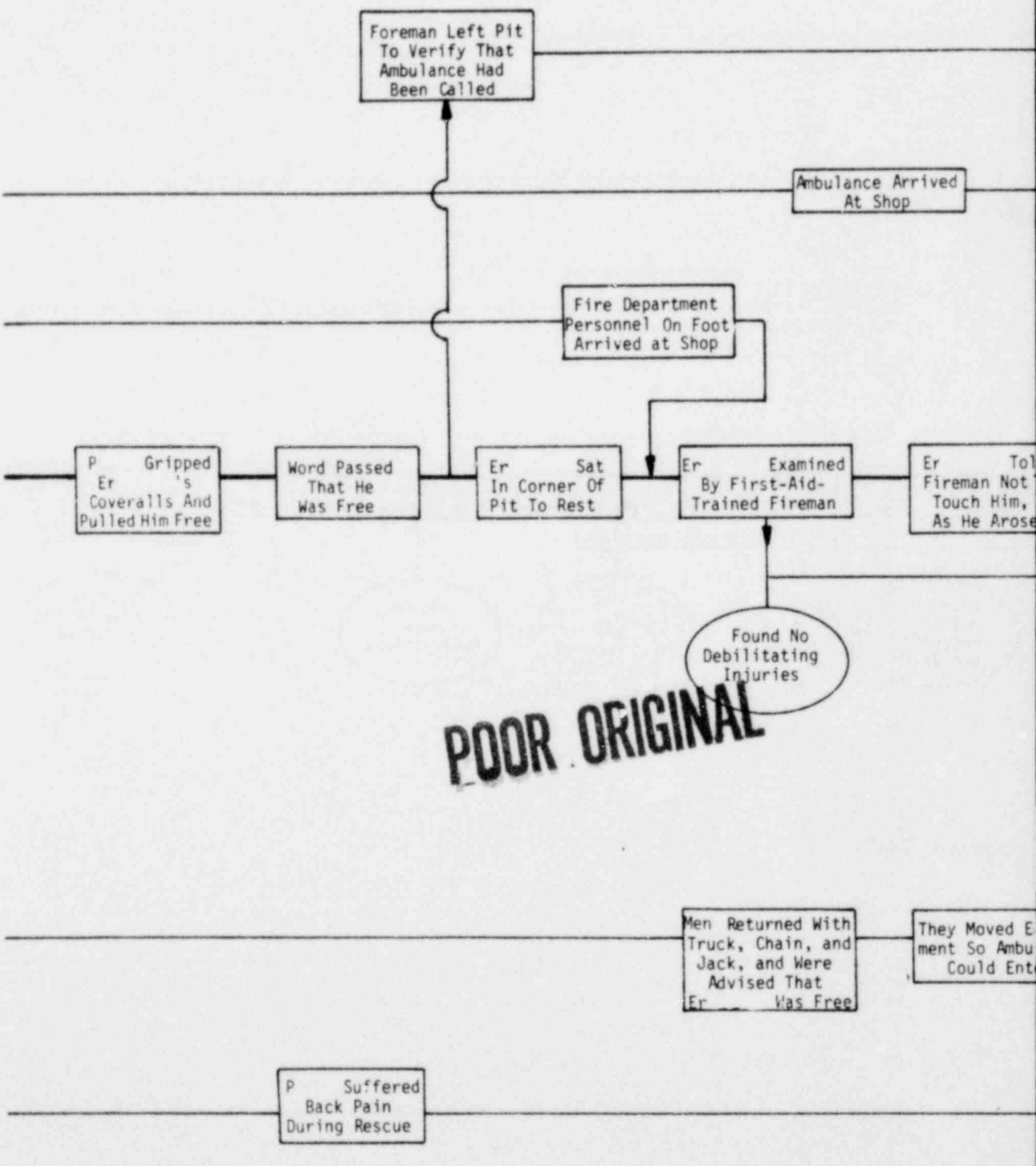

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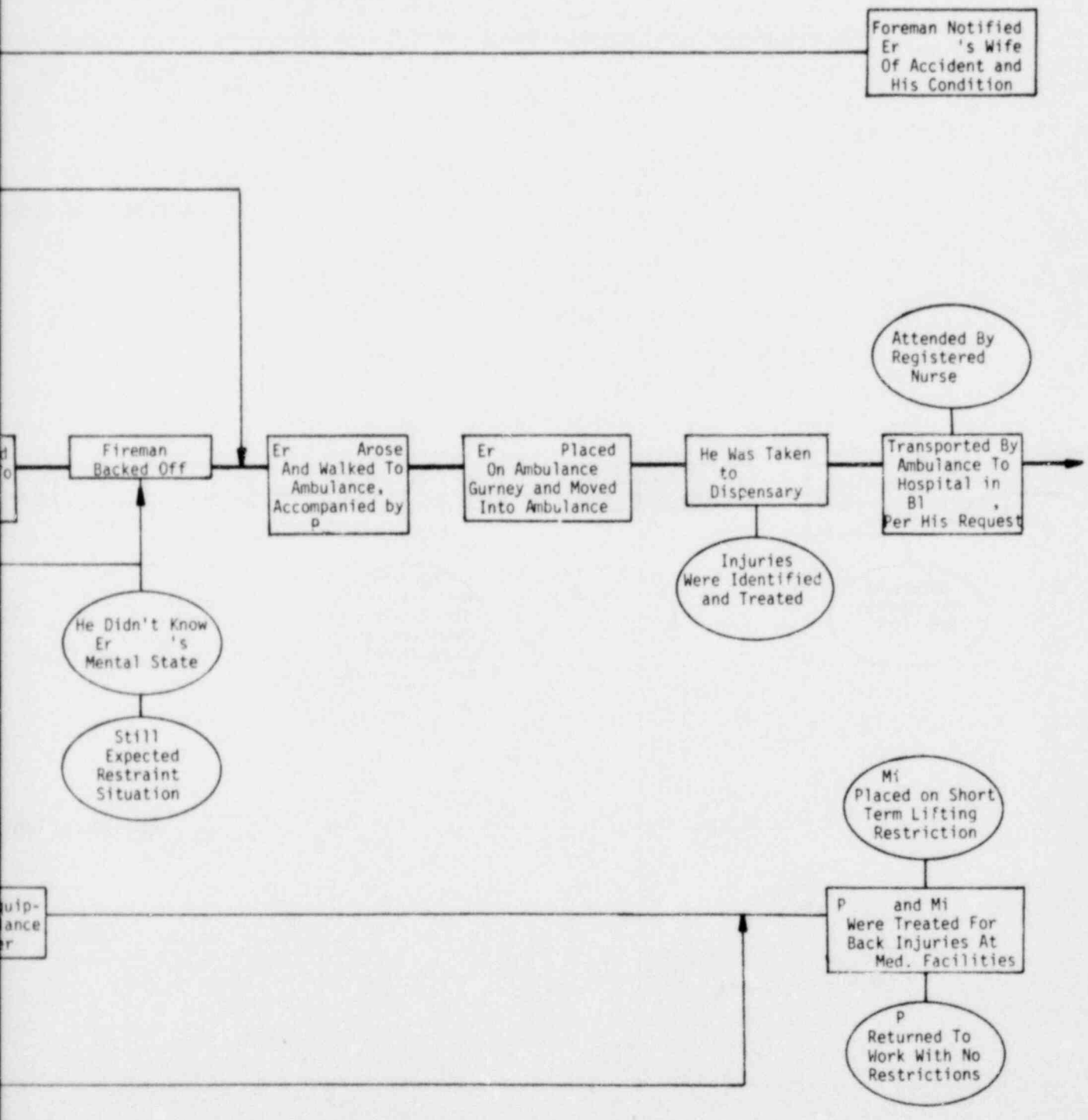

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SSDC-6	Training as Related to Behavioral Change
SSDC-7	ERDA Guide to the Classification of Occupational Injuries and Illnesses
SSDC-8	Standardization Guide for Construction and Use of MORT-Type Analytic Trees
SSDC-9	Safety Information System Guide
SSDC-10	Safety Information System Cataloging
SSDC-11	Risk Management Guide
SSDC-12	Safety Considerations in Evaluation of Maintenance Programs
SSDC-13	Management Factors in Accident and Incident Prevention (Including Management Self-Evaluation Checksheets)

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