MSC-00189

# SPACE STATION

# SAFETY STUDY

## FAULT TREE

## ANALYSES

D2-113070-10

JANUARY 1970





NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

THE BOEING COMPANY
AEROSPACE SYSTEMS DIVISION; SEATTLE, WASHINGTON

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## D2-113070-10

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# PREFACE

This document constitutes one volume of the final report prepared under Contract NAS9-9046, Space Station Safety Study, which was conducted by the Aerospace Systems Division, Aerospace Group, The Boeing Company, under the direction of the Advanced Projects Office, Advanced Missions Program Office, Manned Spacecraft Center, NASA. The objective of the study was to develop a management tool for evaluating conceptual designs of future manned space systems from a safety viewpoint. This objective was achieved through the application of methodical techniques, which are described where necessary in appropriate volumes of this final report, for analyzing space station safety problems. This work resulted in the development of Crew Safety Guidelines which can be used in evaluating future space station concepts.

In Phase I of the study, the work was directed toward a broad class of space stations, using several specific configurations as examples, and considering both crew safety and mission accomplishment as safety goals. In May 1969, the study was redirected by NASA into Phase II to provide more direct support to the NASA Phase B Future Space Station Study, considering only crew safety as the safety goal. To the extent possible, the work done in Phase I was revised and adapted to Phase II and all documents of this final report, except as otherwise noted, include the results from both phases. In both phases the study scope included only on-orbit operations and not launch, boost, de-orbit, and recovery operations, or any operations of the logistics support system, except for close-in rendezvous and docking operations.

The approach taken in the study was to examine the space station from the viewpoint of safety only, with the intent of identifying as complete a list as possible of those measures which should be taken to maximize crew safety. Also, and especially in Phase II, the study dealt primarily with station concepts, rather than specific designs or hardware items. It was not possible, and no attempt was made, to examine the impact of safety measures on other important aspects of space station development, such as cost, design difficulty, or operational suitability. As station development proceeds, trade studies between safety measures and other factors will be required and management decisions must be made as to the extent to which other desirable features will be permitted to override safety measures.

The documents constituting the final study report are:

- D2-113070-4, Condensed Summary Report
- D2-113070-5, Crew Safety Guidelines, Volumes I and II

- D2-113070-6, Supporting Analyses
  - Analysis of Operations
  - Experiment Program
  - Traffic Patterns Analysis
  - Human Requirements
  - Meteoroid Penetration
- D2-113070-9, Logic Diagram
- D2-113070-10, Fault Tree Analysis
- D2-113070-11, Subsystems Analysis

Other documents produced during the study but not part of the final report are:

- D2-113070-1, Detail Study Plan (Phase I only)
- D2-113070-2, Midterm Oral Report
- D2-113070-3, Final Oral Report
- D2-113070-7, Baseline Mission Description (Phase I only)
- D2-113070-8, Baseline System Description (Phase I only)

The references applicable to this document are shown in Section 6.0. However, all the references for those documents which comprise the final study report are compiled in D2-113070-5.

## ABSTRACT

A number of functions in an Earth-orbiting space station concept were investigated for safety implications by the fault tree analysis technique. Certain major undesired events, selected from a logic analysis of the space system concept (see D2-113070-9), were subjected to the fault tree analysis to identify safety guidelines at a level of detail commensurate with study objectives. These analyses provide a rationally developed and orderly foundation for generating the safety guidelines, and display the relationships of potential undesired events to the basic functions that are characteristic of space system operations. This document contains a description of the fault tree technique, a complete file of the trees which were developed during the course of the Safety Study, and an index to the guidelines which were derived from the analysis. The guidelines themselves are compiled in Document D2-113070-5.

## KEY WORDS

decompression

fault tree analysis

radiation hazard

relative motion

space station

space system

temperature extremes

undesired event

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## LIST OF ILLUSTRATIONS

# 1.0 INTRODUCTION

1.1

The systems safety fault tree analysis provides a graphic representation of Boolean relationships between discrete normal and adverse situations which, taken singly or in combination, could result in the development of a specific undesired event. During conceptual evolution of a system, the fault tree technique can be used effectively to identify causes of undesired events, leading to the generation of safety guidelines by which the impact of such undesired events could be reduced or prevented.

1.2

This document contains the three specific fault trees developed during the Space Station Safety Study, explanations of the symbols, terminology and methods which were used, and references to the safety guidelines which were derived from the identification of numerous events. The safety guidelines themselves are presented in Document D2-113070-5. Other potential candidates for fault tree analysis are mentioned in Paragraphs 2.1.3 and 2.1.4, which could be considered for development during subsequent or follow-on studies.

1.3

Although the orbiting space station received primary attention, most safety aspects of the space base also are included since the fault tree analysis was general enough to be equally applicable to either configuration. The top level undesired events analyzed by this technique are extensions of certain proposition statements in the logic analysis document, D2-113070-9, which are repeated at the beginning of the respective fault trees.

# 2.0 FAULT TREE RATIONALE

## 2.1 FAULT TREE ANALYSIS METHOD

### 2.1.1

A fault tree is a model of the various parallel and sequential combinations of component states that can cause, or result in, the occurrence of a specified system state (an "undesired event"). A fault tree analysis is the process by which the fault tree model is generated. It is a deductive technique which can be applied to the investigation of either gross or detailed systems. The depth to which the fault tree can be evolved is restricted only by the level of detail available. The fault tree analysis performed during this study was carried to a level of detail that was felt to be consistent with the space station concepts embodied in Reference No. 92. Thus, confined to this detail, the analytical effort resulted in a gross, top-level fault tree carried down only to major components or functions. A top-level fault tree of this type can make a significant contribution to the primary objective of a preliminary hazard analysis in producing crew safety guidelines related to the selected undesired events. This approach also lends itself to a secondary objective, that of further development with minimum or no modification should the analysis effort be continued later when additional system detail is available.

### 2.1.2

The methods and techniques of conducting a fault tree analysis generally are well known and have been described at length in other documentation; however, in brief, the analysis is conducted in the following manner:

Step 1. State the undesired event.

Step 2. Subdivide the problem by system elements, classes of causes, mission phases, etc.

Step 3. State all the immediate, necessary events which will cause each undesired event of Step 2 to occur.

Step 4. Continue as in Step 3, until the most basic identifiable causal events have been established.

This process results in a progressively downward expanding "tree" of events, whose relationships are shown by certain symbols and interconnecting lines. The symbols and their usage are described in Section 3.0.

### 2.1.3

In addition to continued development of the present work, the scope of this analysis may also be expanded by developing further undesired events identified within the logic analysis. Examples could include such events as:

"Crew members are endangered due to rate of supply of breathable oxygen decreasing below rate necessary to sustain life."---Reference D2-113070-9; proposition 15K.

"Crew members are endangered by exposure to hazardous chemicals."---Reference D2-113070-9; proposition 32B.

"Crew members are endangered due to deprivation of food or water."---Reference D2-113070-9; proposition 41C.

"Crew members are endangered due to collision with parent spacecraft and logistics vehicle."---Reference D2-113070-9; proposition 63B.

It should be noted that the foregoing are not verbatim quotations from the original propositions, but rather have been paraphrased to place them in the fault tree context of undesired events.

2.1.4

Areas of future analysis may also be identified by inductive or intuitive means, and related directly to an undesired event of a specific potential accident, hazardous condition, or subsystem/hardware failure. Examples of these events could include:

"Inadvertent ignition of propulsion module engine."

"Crew endangered by radiation release from nuclear power generator."

"Crew endangered by failure of Environmental Control and Life Support System."

"Cabin atmospheric thermal circuit fails."

## 2.2 FAULT TREE AND LOGIC DIAGRAM PHRASEOLOGY

2.2.1

Fault tree statements are phrased differently from those appearing in the logic diagram. The logic diagram statements used in this study generally reflect a favorable situation or the accomplishment of a successful activity; e.g., "There will be no immediate danger of directly fatal exposure of any crew member to heat." Fault tree statements, on the other hand, assume an unsuccessful mission or hazardous condition: "Crew members will be injured through exposure to potentially fatal heat (or cold)." Thus, a fault tree statement will be in most cases the negative or inverse of a corresponding logic diagram statement. While reasoning processes are the same in either case, the statement of an undesired event as an element in a troublesome situation permits direct identification of a fault or a hazardous condition contributing to that event. Because fault tree statements frequently are given only in topical or key-word form, however, the

reader is cautioned to examine carefully the total context within which these statements are made, to avoid possible confusion, erroneous conclusions or misunderstanding of the analyst's intent.

2.2.2

Failure of an item is termed "primary" when it fails while functioning within its normal operating mode, or "secondary" when failure is due to functioning outside specified tolerance limits or is the result of an extraneous influence. Where the words "command function" or their equivalent appear in the description of an undesired event, they indicate that a failure in the item or function being analyzed occurs as a consequence of an action (or non-action) taking place in some other system or component which dictates ("commands") the manner in which the item functions.

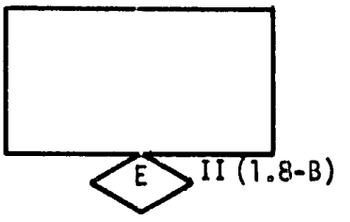
## 2.3 END-POINT CODES

Each event denoted by a circle (3.4) or a diamond (3.5) is the lowest level of development for that branch of the fault tree. Accordingly, the event has been assigned one of the following five codes to indicate its status in the analysis, as of the time the study effort was terminated. Several of the events assigned Code I appear to warrant considerable further investigation, if and when the opportunity should arise during subsequent programs. See Section 4.0 for a detailed discussion on many of the end-points that were identified.

Code

I. An event in which insufficient data or time exists within the scope of this study for effective further development.

II. Continued analysis of this event would be redundant; development of a similar event exists elsewhere. This code carries an additional identifier in parentheses which locates by chart number and event designator where a similar event has been developed in the analysis. In the following example, expansion of an event similar to Event "E" is accomplished on Chart 1.8 under Event "B":



III. The effect of the end-point is deemed insignificant and further development is not warranted.

IV. Basic or inherent fault; no further development possible. (Primary failure.)

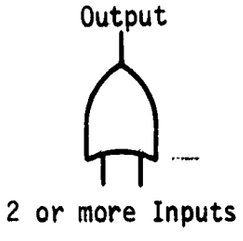
V. A fault event assumed to occur for the development of the fault path. It also may be a naturally hazardous state of the system.

# 3.0 FAULT TREE SYMBOLS

## 3.1 RECTANGLE


A rectangle indicates an event. It is always used in combination with one or another of the following symbols, which is placed immediately below and adjacent to it. The event is identified by a letter in the top portion of the symbol. If the event is repeated on another chart, or elsewhere on the same chart, the chart number and the other identifier are given in the lower portion of the symbol. In some cases the event may be re-stated, when transferred to a new chart, for the sake of clarity and completeness.

## 3.2 "OR" GATE




The "OR" gate indicates a situation wherein the output event will exist if one or more of the input events exist. The analogy of an electric circuit, shown in Figure 3-1, aptly illustrates the "OR" gate concept.

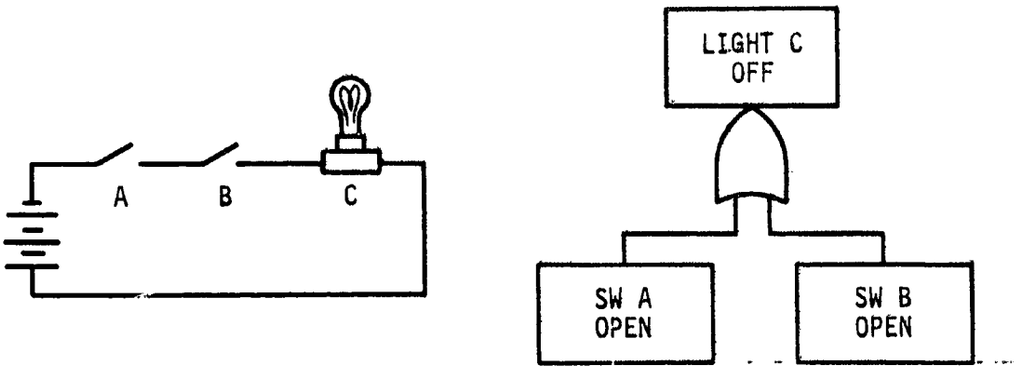
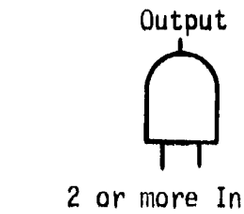



FIGURE 3-1: EXAMPLE OF "OR" GATE

3.3 "AND" GATE




The "AND" gate indicates a logical operation in which the co-existence of all input events is required to produce the output event, as illustrated by the electric circuit in Figure 3-2.

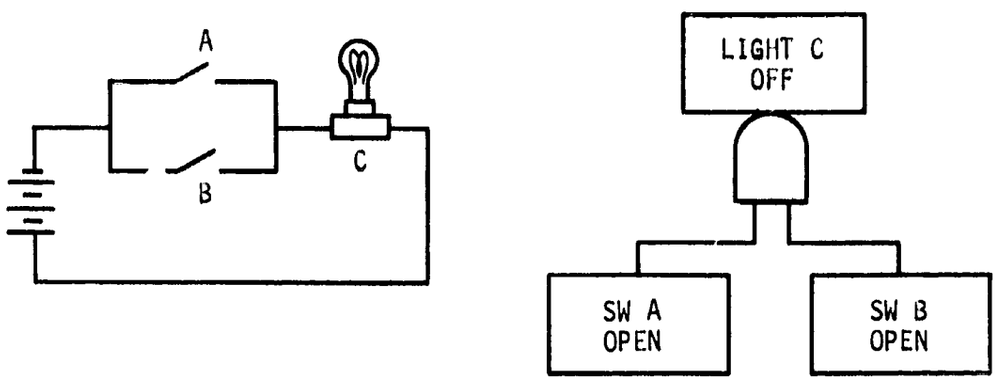
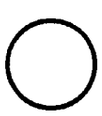


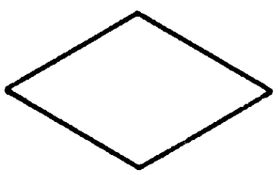

FIGURE 3-2: EXAMPLE OF "AND" GATE

3.4 CIRCLE



The circle indicates an elemental end event which is not amenable to further development.

3.5 DIAMOND



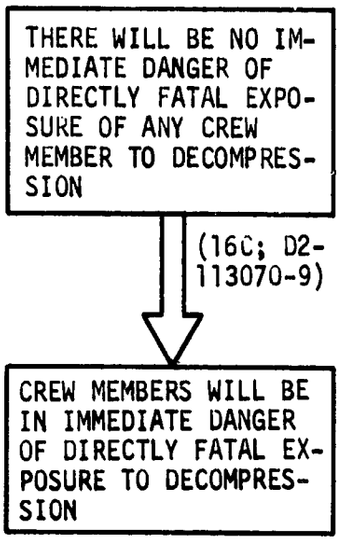
The diamond indicates an event that is the lowest level to which that particular branch of the fault tree has been developed in this study. The possible causes of the event have not been analyzed further either because the event was not considered to warrant further study, the necessary information for further study was unavailable, or study limitations did not permit

continued evaluation. (See Section 4.0.) Each event denoted by a diamond is coded by a roman numeral just below the box to indicate its status in the analysis. The code is explained in Section 2.0.

3.6 TRIANGLE


The triangle indicates that an expansion of the event appears elsewhere. The location of the expansion, that is, the chart number and letter designator of the event, is indicated in the base of the triangle.

3.7 CORRELATION SYMBOL




The top undesired events analyzed in this document are derivations of propositions originating in D2-113070-9, Logic Diagram. For the purposes of this study, an arrow symbol as shown here is used to correlate the initial fault tree statement to an associated statement in the logic analysis. The exact statement in the logic diagram has been repeated in this document in the first box of each fault tree. Reference is made to the source outside the lower right-hand corner. (In the illustration, the reference is to proposition "C" of Chart 16 in Document D2-113070-9.) The undesired event which is to be analyzed by fault tree technique is stated in the box beneath the arrow, and the fault tree is developed below that.

# 4.0 GUIDELINE/EVENT RELATIONSHIPS

## 4.1 GENERAL

The following tabulation provides a cross-index of the guidelines in Document D2-113070-5 which are related to or reference events given in the fault trees. Since the fault trees deal primarily with decompression, heat and radiation, many guidelines in that document are not listed here. A number of guidelines encompass more than one event, and frequently, more than one guideline was derived from or pertained to an event. In the interest of brevity and to avoid redundancy, event descriptions have been omitted from this list; these may be determined from the appropriate fault tree in Section 5.0 of this document.

## 4.2 CROSS-INDEX OF FAULT TREE EVENTS TO GUIDELINES

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 1.1-A | 3.18 | Rapid Decompression Effects |
| 1.1-C | 12.13 | Compartmentation |
| 1.1-D | 8.11 | Oxygen Leak Isolation |
| | 8.12 | Oxygen Quantity and Usage |
| | 8.14 | Oxygen Storage Tanks Redundancy |
| | 8.15 | Oxygen Usage Manual Control |
| 1.1-E | 3.4 | Hatch Automatic Closure |
| | 8.9 | Environmental Control/Life Support Systems (EC/LSS) Redundancy |
| | 8.30 | Warning System--Oxygen Pressure |
| 1.1-F | 8.16 | PLSS Emergency Backup |
| | 8.24 | Suit Loop Checkout |
| | 8.25 | Suit Loop Components Maintenance |
| | 8.26 | Suit Loop Component Redundancy |
| | 8.27 | Suit Loop Manual Control |
| | 8.28 | Suit Loop Outlets |
| | 8.29 | Suit Loop Pressure Monitor |
| 1.1-G | 5.11 | Pressure Suit Repair |
| | 8.24 | Suit Loop Checkout |
| | 12.48 | Monitoring of EVA/IVA |
| 1.1-H | 3.5 | Hatch Closure |
| 1.1-I | 12.18 | Crew Distribution |
| 1.1-J | 3.2 | Crack Propagation in Primary Structure |
| | 3.17 | Primary Structure Inspection and Repair |
| | 3.19 | Spacecraft Structural Strength |
| | 8.17 | Pressure Leak Detectors |
| 1.1-L | 3.10 | Leakage Repair System |
| 1.1-M | | |
| 1.2-B | 8.21 | Pressure Suit/PLSS Oxygen Usage |
| 1.2-C | 5.8 | Injury or Damage from Spacecraft Equipment |
| 1.2-G | 5.7 | Exterior Equipment Design and Location |
| | 5.8 | Injury or Damage from Spacecraft Equipment |

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 1.3-C | 5.2 | Crew Restrictions During Docking |
| 1.3-F | 2.2 | Flight Path Orbit Selection |
| 1.3-G | 6.10 | Propellant Tank Protection |
| 1.3-M | 3.1 | Compartment Integrity |
| 1.3-N | 3.7 | Hatch Pressure Loading |
| 1.3-O | 3.6 | Hatch Positive Closure |
| 1.3-P | 3.8 | Hatch Seal Leakage Rate |
| 1.4-B | 6.11 | Protection of Pressure Vessels |
| 1.4-C | 8.5 | Continuous Control of Cabin Pressure |
| | 8.13 | Oxygen Regulation Component Redundancy |
| | 8.18 | Pressure Relief Valve Repair Procedures |
| 1.4-F | 3.20 | Vented Component Replacement |
| | 3.23 | Venting Provisions |
| 1.4-G | 3.15 | Pressurizable Volume Relief Protection |
| 1.4-M | 6.8 | Pressure System Safing |
| 1.5-B | 3.25 | Warning Systems, Fail-Safe |
| 1.5-C | 3.11 | Medical Equipment for Emergencies |
| | 8.7 | Emergency Life Support Provisions |
| | 8.8 | Emergency Pressurization Oxygen Supply |
| 1.5-E | 3.3 | Equipment Design for Rapid Decompression |
| 1.6-E | 3.5 | Hatch Closure |
| 1.6-F | 12.28 | Emergency Procedures and Training |
| 1.7-G | 12.9 | Cargo Transfer Equipment Redundancy |
| 1.7-K | 5.3 | Docking Closure Rate Control |
| | 5.4 | Docking Light Redundancy |
| | 5.5 | Docking Port Redundancy |
| | 6.10 | Propellant Tank Protection |
| 1.7-L | 5.1 | Bulk Cargo Restraint |

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 1.7-M | 12.35 | Hazardous Resupply Operations Monitoring |
| 1.8-H | 12.13 | Compartmentation |
| 1.9-K | 3.5 | Hatch Closure |
| 1.12-D | 6.7 | Pressure Systems Location |
| 1.12-F | 6.6 | Pressure System Dynamics |
| 1.12-J | 6.5 | Pressure Subsystem Interconnection |
| 2.1-B | 10.6 | Electrical Power System Location |
| 2.1-G | 10.20 | Personnel Protection from Heated Surfaces |
| 2.1-I | 10.25 | Spacecraft Thermal Protection |
| 2.2-C | 10.12 | Heat Monitoring in Operating Equipment |
| 2.2-J | 10.17 | Lubricants |
| 2.3-D | 10.5 | Electrical Power Source Cooling |
| 2.3-J | 10.14 | Ignition Source Control |
| 2.3-L | 12.37 | Incoming Vehicle Emergency |
| 2.3-N | 1.24<br>6.3<br>6.4 | Warning System--Contaminants Detection and Alarm<br>Flammable/Explosive Material Exterior to Spacecraft<br>Hazardous Mixtures |
| 2.4-D | 10.4 | Cryogenics |
| 2.5-B | 10.11 | Heating Element Flame Suppression |
| 2.5-D | 4.14<br>10.19 | Routing of Power Distribution Lines<br>Overcurrent Protection |
| 2.6-D | 10.13<br>10.21 | Hypergolic and Pyrophoric Material<br>Propellant Supply System Location |
| 2.6-F | 10.21 | Propellant Supply System Location |
| 2.6-G | 10.2<br>10.21 | Combustible Waste Materials<br>Propellant Supply System Location |

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 2.6-H | 10.15 | Isolation of Oxygen Source |
| 2.6-I | 10.20 | Personnel Protection from Heated Surfaces |
| 2.7-B | 10.7<br>10.23 | Fire Control<br>Self-propagation of Fires |
| 2.7-F | 12.29 | Emergency Procedures (Fire) |
| 2.7-H | 12.6 | Assistance to Injured Personnel |
| 2.7-I | 12.28 | Emergency Procedures and Training |
| 2.7-M | 6.7 | Pressure Systems Location |
| 2.7-N<br>2.7-P | 12.29 | Emergency Procedures (Fire) |
| 2.7-R | 6.4 | Hazardous Mixtures |
| 2.7-U | 6.12<br>6.13 | Shrouding and Shielding of Pressure Lines<br>Water Electrolysis Unit Cell Reversed Polarity |
| 2.8-G | 10.22 | Protection of Temperature Critical Equipment |
| 2.9-B | 10.7<br>10.27 | Fire Control<br>Thermal Control Temperature Sensors |
| 2.9-C | 12.33 | Fire Alarm |
| 2.9-E | 10.2 | Combustible Waste Materials |
| 2.10-D | 1.1<br>12.33 | Airflow Cutoff to Enclosed Contamination Sources<br>Fire Alarm |
| 2.11-E | 4.4<br>6.2 | Electrical Connections<br>Explosion-proof Electrical Equipment |
| 2.11-F<br>2.11-G | 4.7 | Grounding of Spacecraft and Equipment |
| 2.11-H | 6.1 | Electrical Ignition |
| 2.12-C | 4.3 | Electrical Arcing |
| 2.12-D | 4.5<br>5.9 | Electrical Cable Shorts<br>Mechanical Shielding of Electrical Equipment |

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 2.12-E | 4.1 | Cable Insulation Damage |
| | 5.9 | Mechanical Shielding of Electrical Equipment |
| 2.12-J | 2.1 | Component Design for Meteoroid Impact Protection |
| 2.12-N | 4.6 | Electrical Connector Checks |
| 2.12-O | 5.9 | Mechanical Shielding of Electrical Equipment |
| 2.12-P | 4.2 | Connector Mismating |
| | 4.12 | Protective Covers for Electrical Equipment |
| | 5.9 | Mechanical Shielding of Electrical Equipment |
| 2.12-Q | 4.2 | Connector Mismating |
| 2.15-D | 10.17 | Lubricants |
| 2.15-E | 12.42 | Intercom System |
| 2.15-G | 10.5 | Electrical Power Source Cooling |
| 2.15-H | 12.42 | Intercom System |
| 2.15-J | 1.15 | Hazardous Materials--Quantities |
| 2.15-K | 10.9 | Fire Retardant Electrical Equipment |
| 2.17-C | 1.5 | Control Procedures for Excessive Contamination |
| | 1.15 | Hazardous Materials--Quantities |
| 2.19-E | 10.3 | Containment of Fire |
| | 10.8 | Fire-Resistant Electrical Insulation |
| | 12.6 | Assistance to Injured Personnel |
| 2.19-F | 10.2 | Combustible Waste Materials |
| 2.19-I | 10.16 | Location of Combustibles |
| 3.1-B | 9.14 | Radiation Exposure and Control Program |
| | 9.15 | Radiation Exposure Limit |
| 3.1-C | 9.4 | Microwave and X-Radiation Hazard |
| 3.1-I | 9.2 | Disposal of Radioactive Material |
| 3.1-M | 9.5 | Nuclear Power Radiation Protection |
| | 9.9 | Placement of Equipment and Stores |
| | 9.20 | Spacecraft Radiation Shielding |

| Event | Guideline No. | Guideline Title |
|---|---|---|
| 3.2-H | 9.16 | Radiation Haven |
| 3.3-E | 9.8 | Orbital Path Radiation Environment |
| 3.3-H | 9.1<br>9.3 | Controlled Access and Use of Radiation Sources<br>Handling and Use of Radioactive Material |
| 3.3-J | 9.10 | Protection Against Nuclear Explosion Radiation |
| 3.3-K | 9.5<br>9.6<br>9.7 | Nuclear Power Radiation Protection<br>Nuclear Power Unit Radiation Protection<br>Nuclear Reactor Safety |
| 3.4-D | 9.17 | Radiation Monitoring |
| 3.4-G | 9.15 | Radiation Exposure Record |
| 3.4-O<br>3.4-P | 9.11 | Radiation Detectors Location and Characteristics |
| 3.5-C | 9.18 | Radiation Protection During EVA |
| 3.5-F | 9.13 | Radiation Environment Restrictions on EVA |
| 3.5-H | 9.5 | Nuclear Power Radiation Protection |
| 3.5-K<br>3.5-P | 9.21 | Selection of Materials for Use in Radiation Environment |
| 3.7-D | 9.19 | Radioactive Stores |

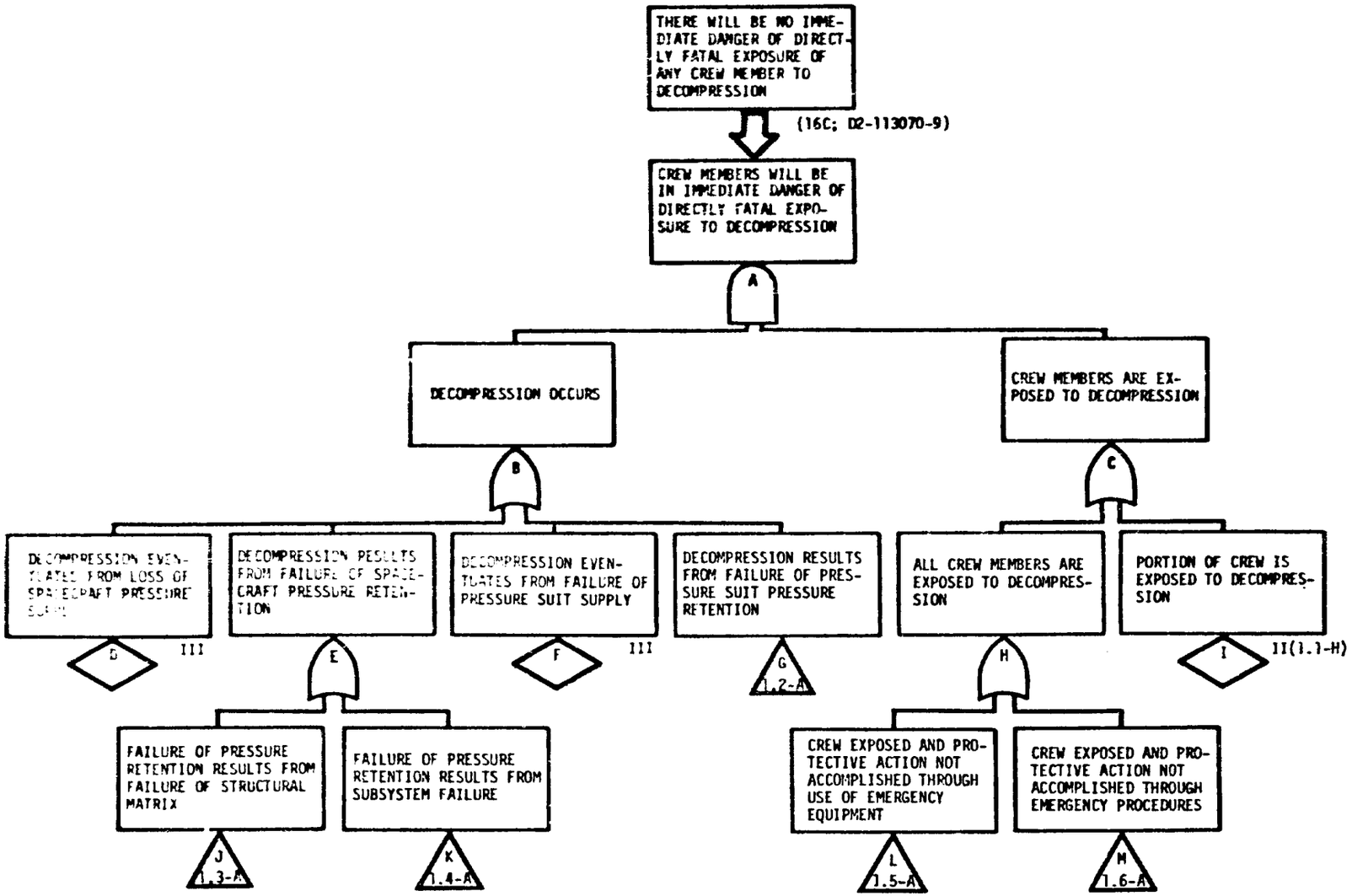
# 5.0 FAULT TREES

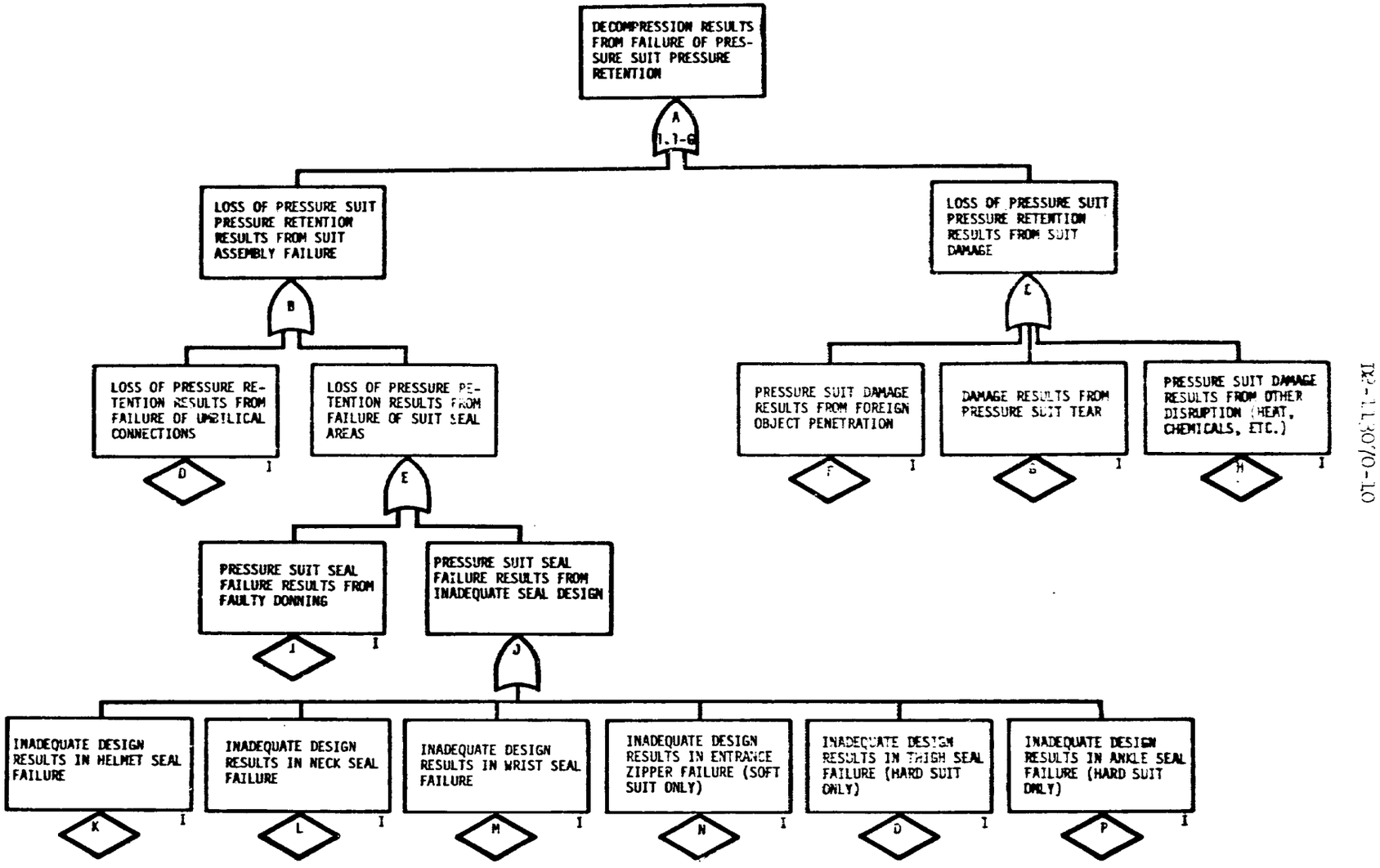
## 5.1 FT-1, EVENTS RELATED TO DECOMPRESSION

Top events of the twelve charts comprising this fault tree are listed below. Numbers in parentheses refer to the predecessor charts in which the events originated.

| Chart No. | Top Event | Page No. |
|---|---|---|
| 1.1 | Crew members will be in immediate danger of directly fatal exposure to decompression. | |
| 1.2 | Decompression results from failure of pressure suit pressure retention (1.1). | |
| 1.3 | Failure of pressure retention results from failure of structural matrix (1.1). | |
| 1.4 | Failure of pressure retention results from subsystem failure (1.1). | |
| 1.5 | Crew exposed to decompression, and protective action not accomplished through use of emergency equipment (1.1). | |
| 1.6 | Crew exposed and protective action not accomplished through emergency procedures (1.1). | |
| 1.7 | Structural matrix failure results from damage during space operations (1.3). | |
| 1.8 | Decompression rate exceeds procedure response time (1.6). | |
| 1.9 | Intracompartment emergency action is delayed (1.8). | |
| 1.10 | Compartment hatch failure hinders escape action (hardware failure) (1.8). | |
| 1.11 | Compartment hatch design hinders escape action (1.8). | |
| 1.12 | Spacecraft liquid system fails explosively (1.4). | |

Chart No. 1.1

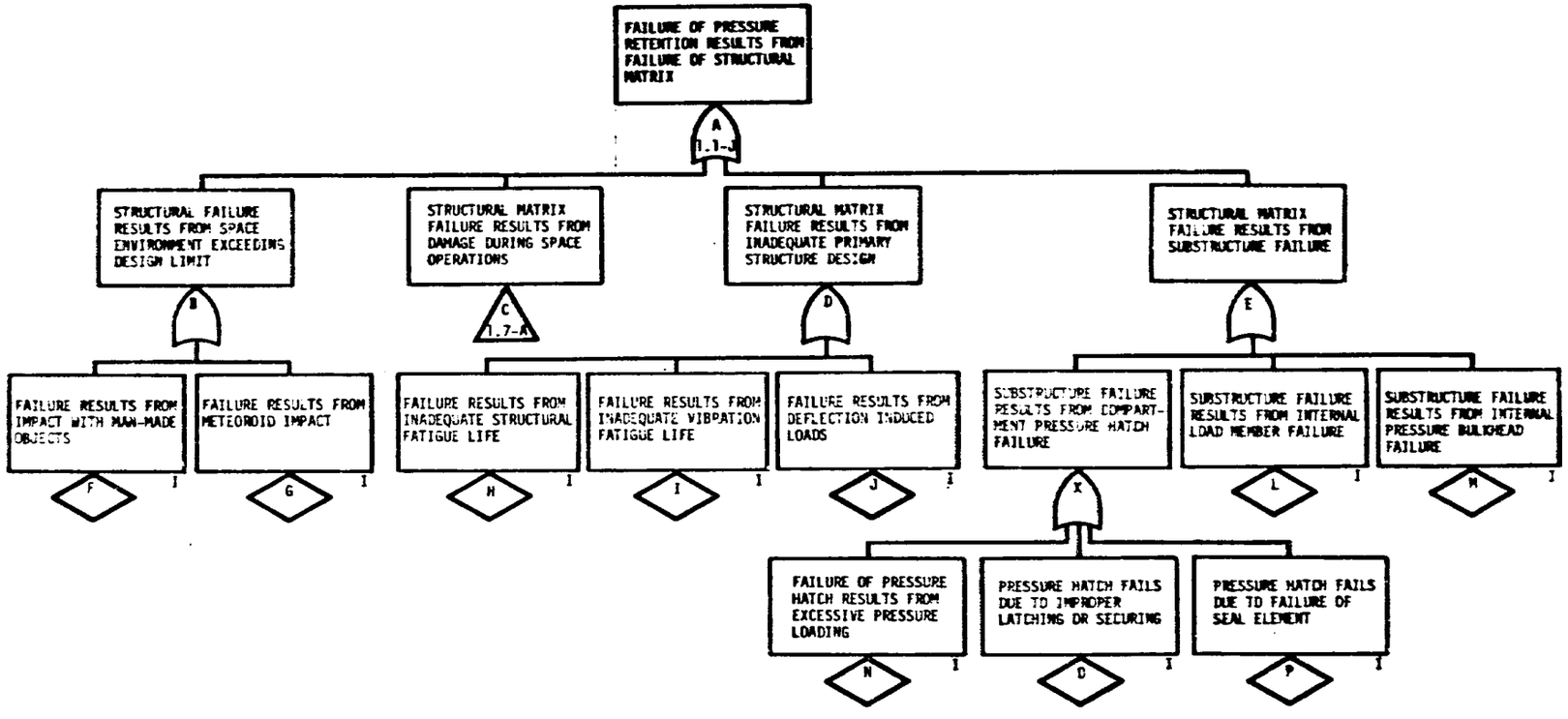

THERE WILL BE NO IMMEDIATE DANGER OF DIRECTLY FATAL EXPOSURE OF ANY CREW MEMBER TO DECOMPRESSION
(16C; D2-113070-9)
CREW MEMBERS WILL BE IN IMMEDIATE DANGER OF DIRECTLY FATAL EXPOSURE TO DECOMPRESSION
A
DECOMPRESSION OCCURS
CREW MEMBERS ARE EXPOSED TO DECOMPRESSION
B
C
DECOMPRESSION EVENTUATES FROM LOSS OF SPACECRAFT PRESSURE SUPPLY
DECOMPRESSION RESULTS FROM FAILURE OF SPACECRAFT PRESSURE RETENTION
DECOMPRESSION EVENTUATES FROM FAILURE OF PRESSURE SUIT SUPPLY
DECOMPRESSION RESULTS FROM FAILURE OF PRESSURE SUIT PRESSURE RETENTION
ALL CREW MEMBERS ARE EXPOSED TO DECOMPRESSION
PORTION OF CREW IS EXPOSED TO DECOMPRESSION
D
III
E
F
III
G
1.2-A
H
I
II(1.1-H)
FAILURE OF PRESSURE RETENTION RESULTS FROM FAILURE OF STRUCTURAL MATRIX
FAILURE OF PRESSURE RETENTION RESULTS FROM SUBSYSTEM FAILURE
CREW EXPOSED AND PROTECTIVE ACTION NOT ACCOMPLISHED THROUGH USE OF EMERGENCY EQUIPMENT
CREW EXPOSED AND PROTECTIVE ACTION NOT ACCOMPLISHED THROUGH EMERGENCY PROCEDURES
J
1.3-A
K
1.4-A
L
1.5-A
M
1.6-A




IM-LL70/70-10

Chart No. 1.2

Chart No. 1.3


FAILURE OF PRESSURE RETENTION RESULTS FROM FAILURE OF STRUCTURAL MATRIX
A
1.1-3
STRUCTURAL FAILURE RESULTS FROM SPACE ENVIRONMENT EXCEEDING DESIGN LIMIT
STRUCTURAL MATRIX FAILURE RESULTS FROM DAMAGE DURING SPACE OPERATIONS
STRUCTURAL MATRIX FAILURE RESULTS FROM INADEQUATE PRIMARY STRUCTURE DESIGN
STRUCTURAL MATRIX FAILURE RESULTS FROM SUBSTRUCTURE FAILURE
B
C
1.7-A
D
E
FAILURE RESULTS FROM IMPACT WITH MAN-MADE OBJECTS
FAILURE RESULTS FROM METEOROID IMPACT
FAILURE RESULTS FROM INADEQUATE STRUCTURAL FATIGUE LIFE
FAILURE RESULTS FROM INADEQUATE VIBRATION FATIGUE LIFE
FAILURE RESULTS FROM DEFLECTION INDUCED LOADS
SUBSTRUCTURE FAILURE RESULTS FROM COMPARTMENT PRESSURE HATCH FAILURE
SUBSTRUCTURE FAILURE RESULTS FROM INTERNAL LOAD MEMBER FAILURE
SUBSTRUCTURE FAILURE RESULTS FROM INTERNAL PRESSURE BULKHEAD FAILURE
F
G
H
I
J
X
L
M
FAILURE OF PRESSURE HATCH RESULTS FROM EXCESSIVE PRESSURE LOADING
PRESSURE HATCH FAILS DUE TO IMPROPER LATCHING OR SECURING
PRESSURE HATCH FAILS DUE TO FAILURE OF SEAL ELEMENT
N
O
P

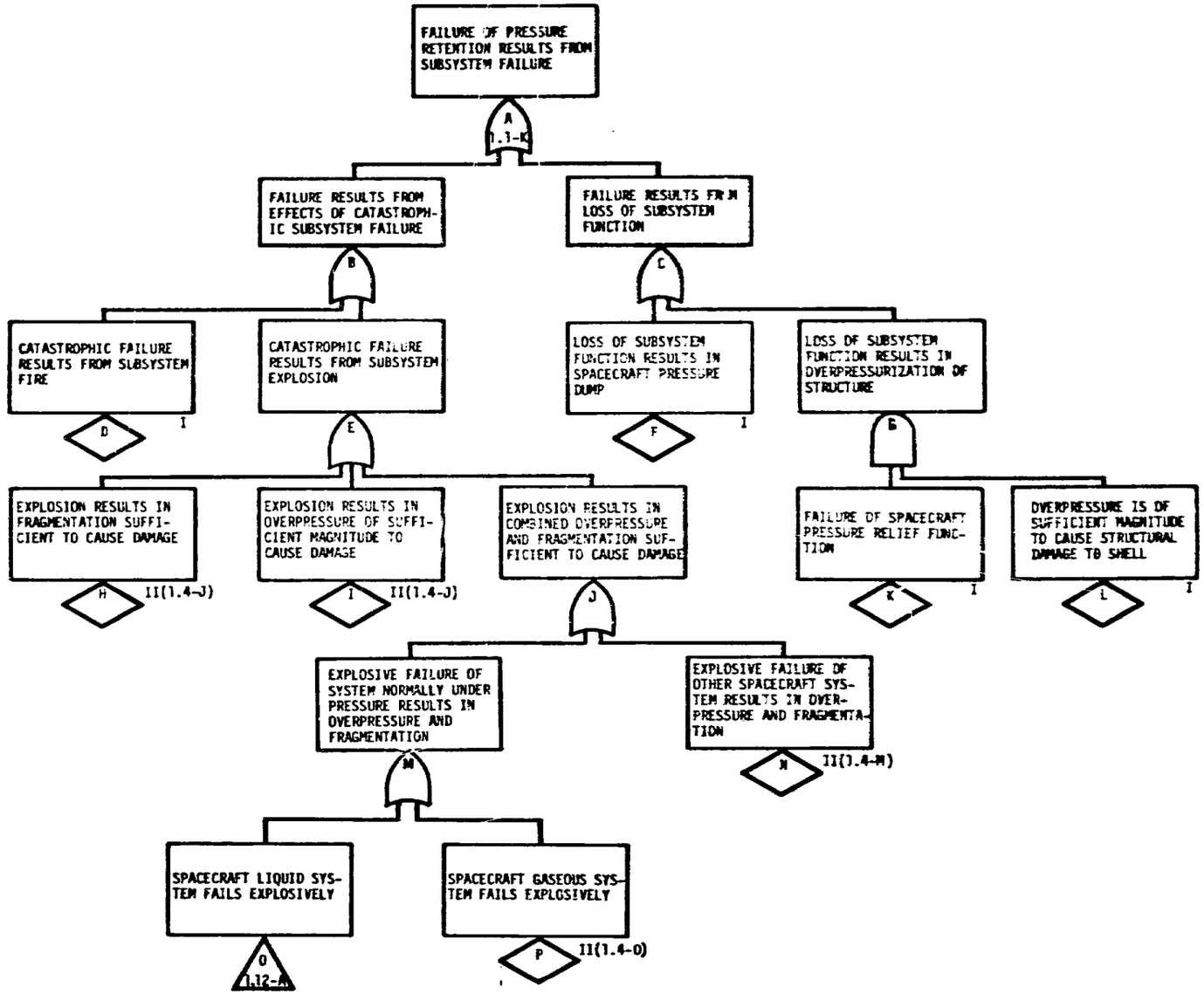
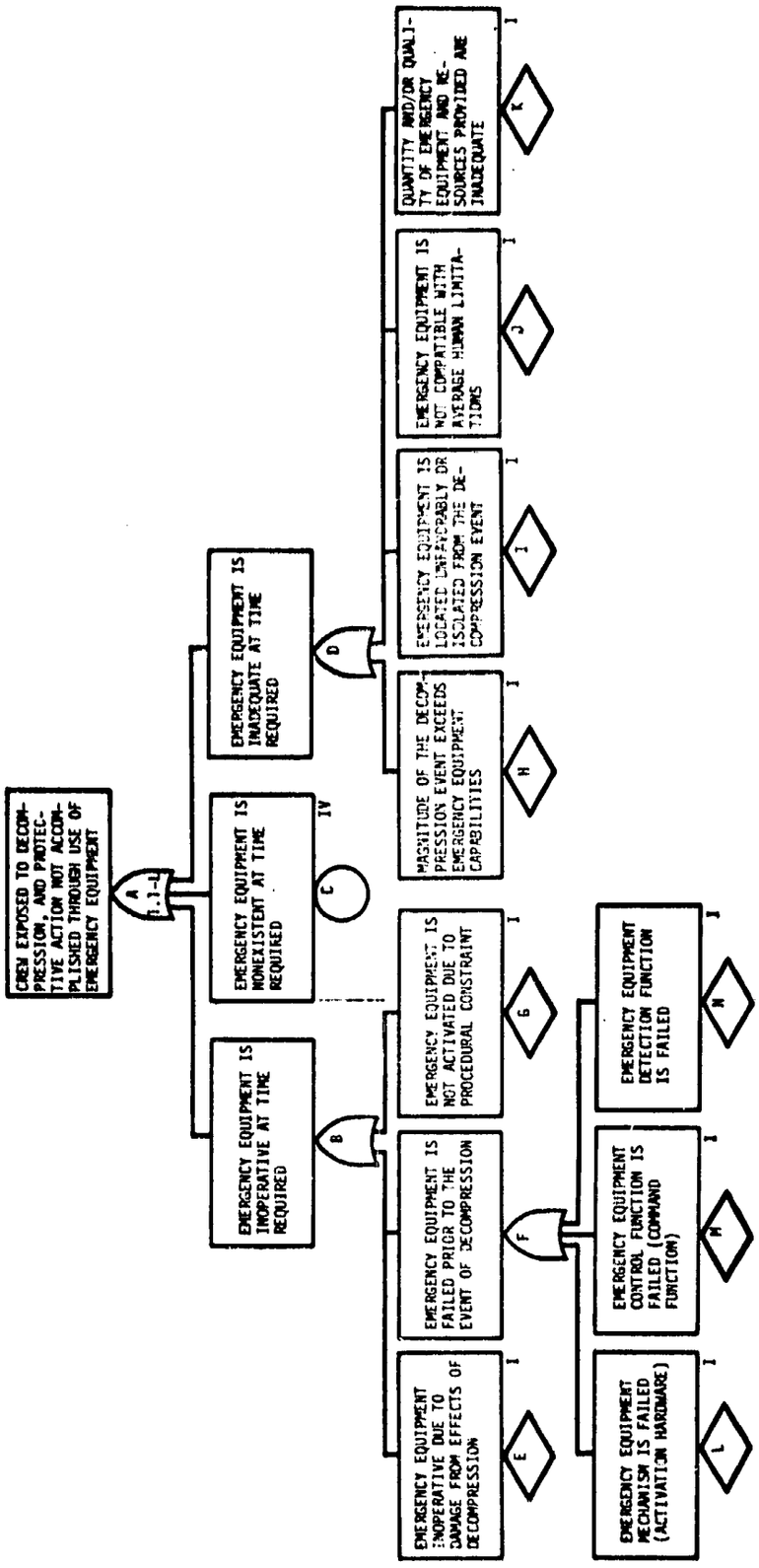

FAILURE OF PRESSURE RETENTION RESULTS FROM SUBSYSTEM FAILURE
A
1.1-K
FAILURE RESULTS FROM EFFECTS OF CATASTROPHIC SUBSYSTEM FAILURE
FAILURE RESULTS FROM LOSS OF SUBSYSTEM FUNCTION
B
C
CATASTROPHIC FAILURE RESULTS FROM SUBSYSTEM FIRE
CATASTROPHIC FAILURE RESULTS FROM SUBSYSTEM EXPLOSION
LOSS OF SUBSYSTEM FUNCTION RESULTS IN SPACECRAFT PRESSURE DUMP
LOSS OF SUBSYSTEM FUNCTION RESULTS IN OVERPRESSURIZATION OF STRUCTURE
D
I
E
F
I
G
EXPLOSION RESULTS IN FRAGMENTATION SUFFICIENT TO CAUSE DAMAGE
EXPLOSION RESULTS IN OVERPPESSURE OF SUFFICIENT MAGNITUDE TO CAUSE DAMAGE
EXPLOSION RESULTS IN COMBINED OVERPRESSURE AND FRAGMENTATION SUFFICIENT TO CAUSE DAMAGE
FAILURE OF SPACECRAFT PRESSURE RELIEF FUNCTION
OVERPRESSURE IS OF SUFFICIENT MAGNITUDE TO CAUSE STRUCTURAL DAMAGE TO SHELL
H
II(1.4-J)
I
II(1.4-J)
J
K
I
L
I
EXPLOSIVE FAILURE OF SYSTEM NORMALLY UNDER PRESSURE RESULTS IN OVERPRESSURE AND FRAGMENTATION
EXPLOSIVE FAILURE OF OTHER SPACECRAFT SYSTEM RESULTS IN OVERPRESSURE AND FRAGMENTATION
M
N
II(1.4-M)
SPACECRAFT LIQUID SYSTEM FAILS EXPLOSIVELY
SPACECRAFT GASEOUS SYSTEM FAILS EXPLOSIVELY
O
1.12-A
P
II(1.4-O)

Chart No. 1.4

Chart No. 1.5


CREW EXPOSED TO DECOMPRESSION, AND PROTECTIVE ACTION NOT ACCOMPLISHED THROUGH USE OF EMERGENCY EQUIPMENT
A
1.1-4
EMERGENCY EQUIPMENT IS INOPERATIVE AT TIME REQUIRED
EMERGENCY EQUIPMENT IS NONEXISTENT AT TIME REQUIRED
C
IV
EMERGENCY EQUIPMENT IS INADEQUATE AT TIME REQUIRED
B
D
EMERGENCY EQUIPMENT IS FAILED PRIOR TO THE EVENT OF DECOMPRESSION
EMERGENCY EQUIPMENT IS NOT ACTIVATED DUE TO PROCEDURAL CONSTRAINT
MAGNITUDE OF THE DECOMPRESSION EVENT EXCEEDS EMERGENCY EQUIPMENT CAPABILITIES
EMERGENCY EQUIPMENT IS LOCATED UNFAVORABLY OR ISOLATED FROM THE DECOMPRESSION EVENT
EMERGENCY EQUIPMENT IS NOT COMPATIBLE WITH AVERAGE HUMAN LIMITATIONS
QUANTITY AND/OR QUALITY OF EMERGENCY EQUIPMENT AND RESOURCES PROVIDED ARE INADEQUATE
F
EMERGENCY EQUIPMENT DETECTION FUNCTION IS FAILED
EMERGENCY EQUIPMENT CONTROL FUNCTION IS FAILED (COMMAND FUNCTION)
EMERGENCY EQUIPMENT INOPERATIVE DUE TO DAMAGE FROM EFFECTS OF DECOMPRESSION
EMERGENCY EQUIPMENT MECHANISM IS FAILED (ACTIVATION HARDWARE)
E
L
M
N
G
H
I
J
K

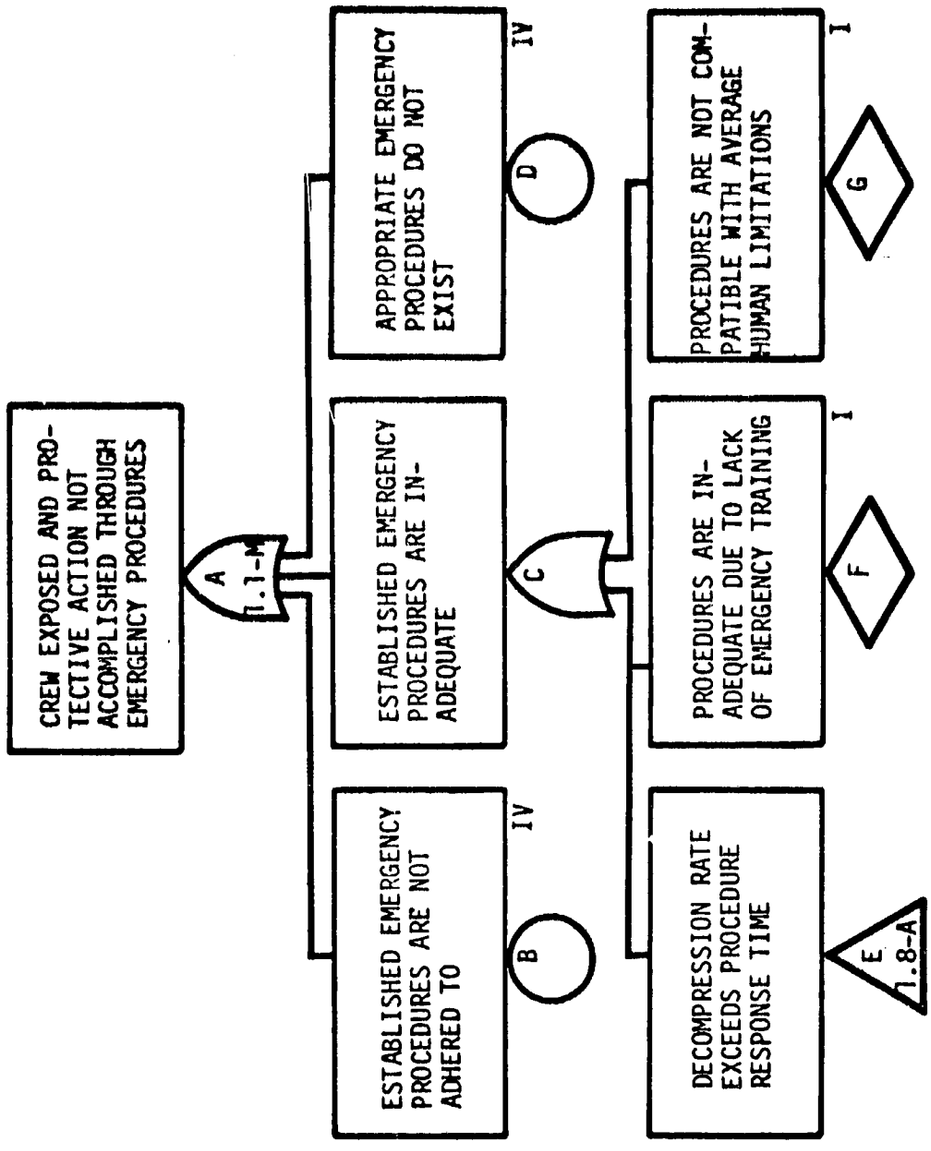
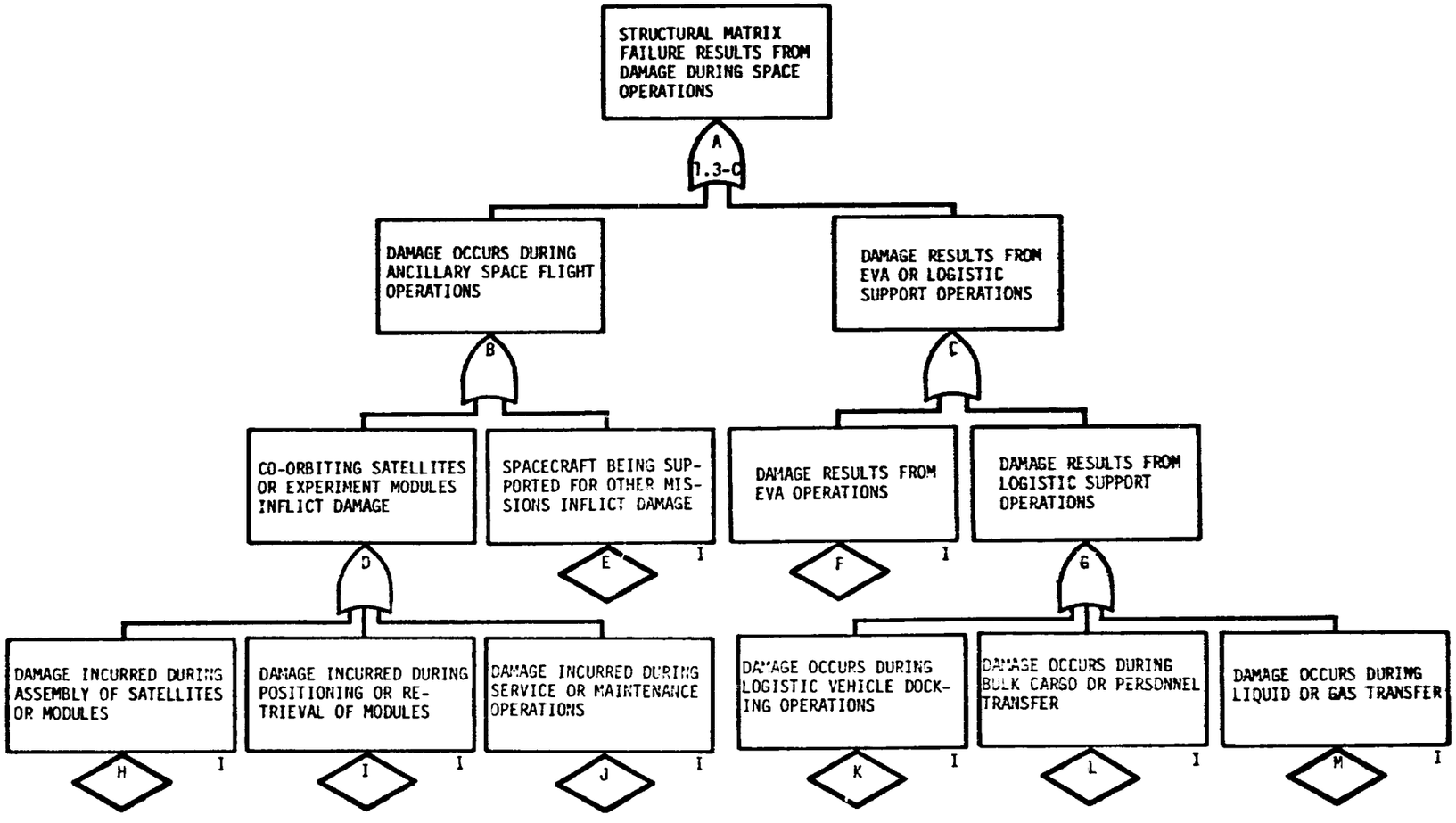

CREW EXPOSED AND PROTECTIVE ACTION NOT ACCOMPLISHED THROUGH EMERGENCY PROCEDURES
A
1.1-M
ESTABLISHED EMERGENCY PROCEDURES ARE NOT ADHERED TO
B
IV
ESTABLISHED EMERGENCY PROCEDURES ARE INADEQUATE
C
APPROPRIATE EMERGENCY PROCEDURES DO NOT EXIST
D
IV
DECOMPRESSION RATE EXCEEDS PROCEDURE RESPONSE TIME
E
1.8-A
PROCEDURES ARE INADEQUATE DUE TO LACK OF EMERGENCY TRAINING
F
I
PROCEDURES ARE NOT COMPATIBLE WITH AVERAGE HUMAN LIMITATIONS
G
I

Chart No. 1.6

Chart No. 1.7


STRUCTURAL MATRIX FAILURE RESULTS FROM DAMAGE DURING SPACE OPERATIONS
A
1.3-C
DAMAGE OCCURS DURING ANCILLARY SPACE FLIGHT OPERATIONS
DAMAGE RESULTS FROM EVA OR LOGISTIC SUPPORT OPERATIONS
B
C
CO-ORBITING SATELLITES OR EXPERIMENT MODULES INFLICT DAMAGE
SPACECRAFT BEING SUPPORTED FOR OTHER MISSIONS INFLICT DAMAGE
DAMAGE RESULTS FROM EVA OPERATIONS
DAMAGE RESULTS FROM LOGISTIC SUPPORT OPERATIONS
D
E
I
F
I
G
DAMAGE INCURRED DURING ASSEMBLY OF SATELLITES OR MODULES
DAMAGE INCURRED DURING POSITIONING OR RETRIEVAL OF MODULES
DAMAGE INCURRED DURING SERVICE OR MAINTENANCE OPERATIONS
DAMAGE OCCURS DURING LOGISTIC VEHICLE DOCKING OPERATIONS
DAMAGE OCCURS DURING BULK CARGO OR PERSONNEL TRANSFER
DAMAGE OCCURS DURING LIQUID OR GAS TRANSFER
H
I
I
J
I
K
I
L
I
M
I

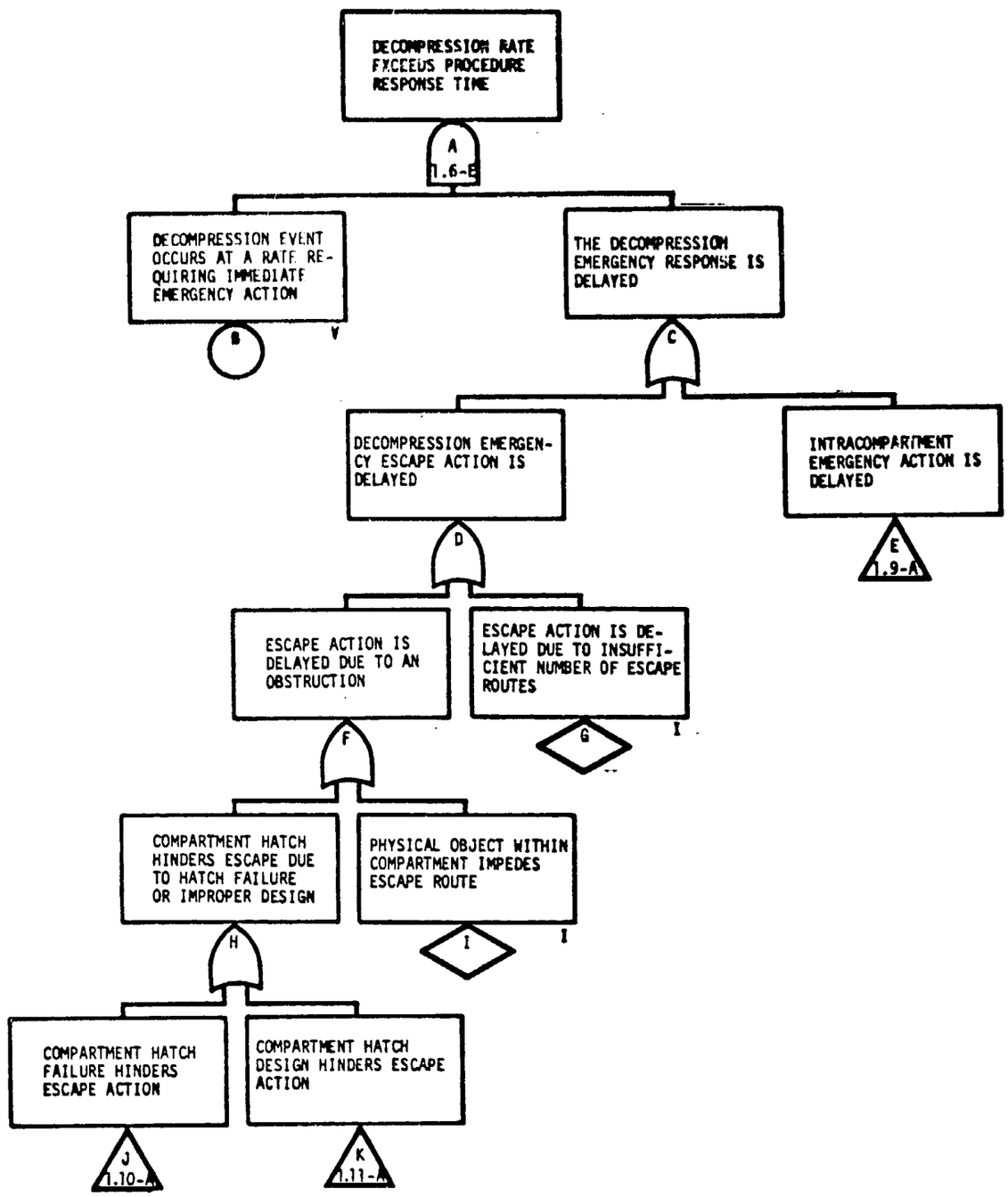
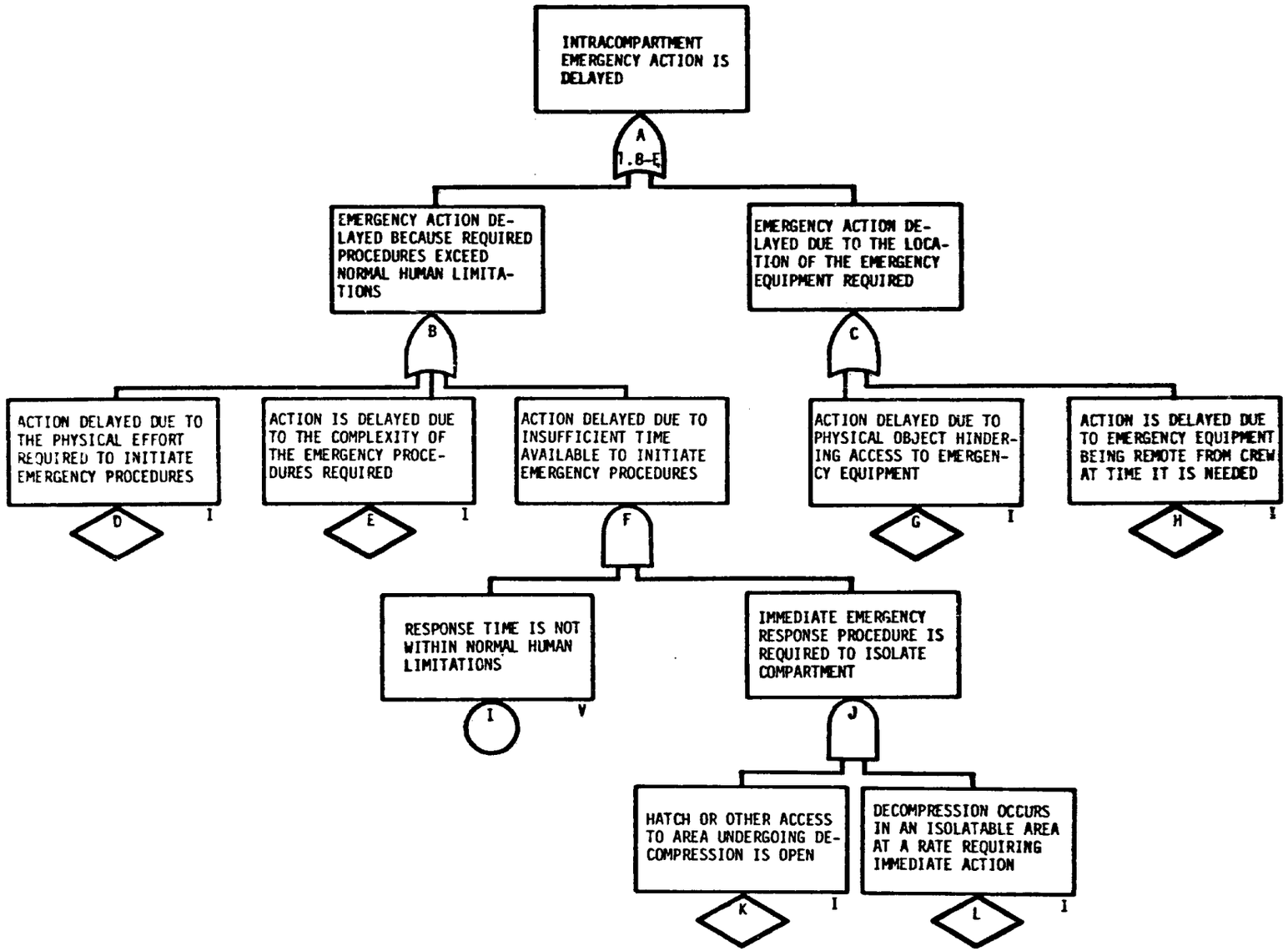

DECOMPRESSION RATE EXCEEDS PROCEDURE RESPONSE TIME
A
1.6-B
DECOMPRESSION EVENT OCCURS AT A RATE REQUIRING IMMEDIATE EMERGENCY ACTION
B
THE DECOMPRESSION EMERGENCY RESPONSE IS DELAYED
C
DECOMPRESSION EMERGENCY ESCAPE ACTION IS DELAYED
INTRACOMPARTMENT EMERGENCY ACTION IS DELAYED
E
1.9-A
D
ESCAPE ACTION IS DELAYED DUE TO AN OBSTRUCTION
ESCAPE ACTION IS DELAYED DUE TO INSUFFICIENT NUMBER OF ESCAPE ROUTES
G
F
COMPARTMENT HATCH HINDERS ESCAPE DUE TO HATCH FAILURE OR IMPROPER DESIGN
PHYSICAL OBJECT WITHIN COMPARTMENT IMPEDES ESCAPE ROUTE
I
H
COMPARTMENT HATCH FAILURE HINDERS ESCAPE ACTION
COMPARTMENT HATCH DESIGN HINDERS ESCAPE ACTION
J
1.10-A
K
1.11-A

Chart No. 1.8

Chart No. 1.9


INTRACOMPARTMENT EMERGENCY ACTION IS DELAYED
A
1.8-E
EMERGENCY ACTION DELAYED BECAUSE REQUIRED PROCEDURES EXCEED NORMAL HUMAN LIMITATIONS
EMERGENCY ACTION DELAYED DUE TO THE LOCATION OF THE EMERGENCY EQUIPMENT REQUIRED
B
C
ACTION DELAYED DUE TO THE PHYSICAL EFFORT REQUIRED TO INITIATE EMERGENCY PROCEDURES
ACTION IS DELAYED DUE TO THE COMPLEXITY OF THE EMERGENCY PROCEDURES REQUIRED
ACTION DELAYED DUE TO INSUFFICIENT TIME AVAILABLE TO INITIATE EMERGENCY PROCEDURES
ACTION DELAYED DUE TO PHYSICAL OBJECT HINDERING ACCESS TO EMERGENCY EQUIPMENT
ACTION IS DELAYED DUE TO EMERGENCY EQUIPMENT BEING REMOTE FROM CREW AT TIME IT IS NEEDED
D
E
F
G
H
I
I
I
I
RESPONSE TIME IS NOT WITHIN NORMAL HUMAN LIMITATIONS
IMMEDIATE EMERGENCY RESPONSE PROCEDURE IS REQUIRED TO ISOLATE COMPARTMENT
I
V
J
HATCH OR OTHER ACCESS TO AREA UNDERGOING DECOMPRESSION IS OPEN
DECOMPRESSION OCCURS IN AN ISOLATABLE AREA AT A RATE REQUIRING IMMEDIATE ACTION
K
L
I
I

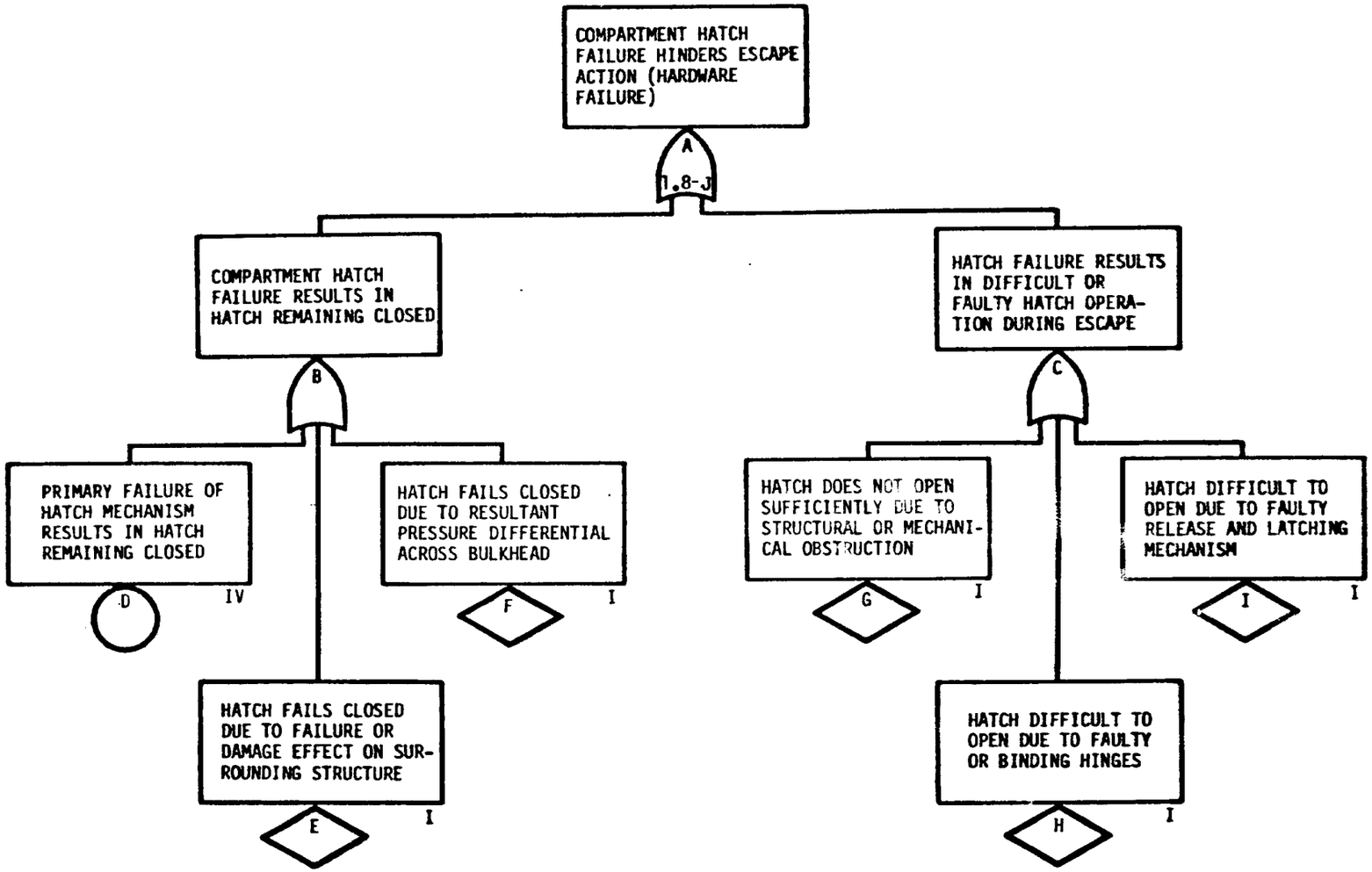
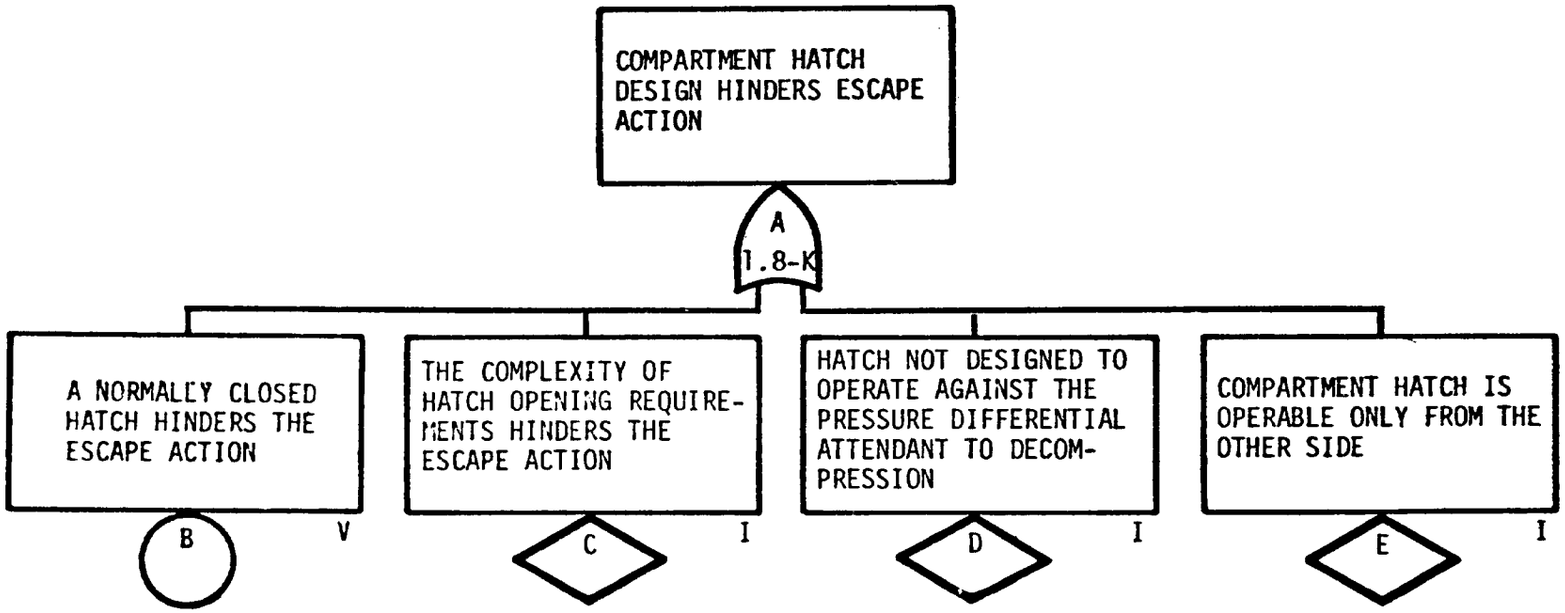

COMPARTMENT HATCH FAILURE HINDERS ESCAPE ACTION (HARDWARE FAILURE)
A
1.8-J
COMPARTMENT HATCH FAILURE RESULTS IN HATCH REMAINING CLOSED
B
HATCH FAILURE RESULTS IN DIFFICULT OR FAULTY HATCH OPERATION DURING ESCAPE
C
PRIMARY FAILURE OF HATCH MECHANISM RESULTS IN HATCH REMAINING CLOSED
D
IV
HATCH FAILS CLOSED DUE TO RESULTANT PRESSURE DIFFERENTIAL ACROSS BULKHEAD
F
I
HATCH FAILS CLOSED DUE TO FAILURE OR DAMAGE EFFECT ON SURROUNDING STRUCTURE
E
I
HATCH DOES NOT OPEN SUFFICIENTLY DUE TO STRUCTURAL OR MECHANICAL OBSTRUCTION
G
I
HATCH DIFFICULT TO OPEN DUE TO FAULTY RELEASE AND LATCHING MECHANISM
I
I
HATCH DIFFICULT TO OPEN DUE TO FAULTY OR BINDING HINGES
H
I

Chart No. 1.10

Chart No. 1.11




D2-11307-1

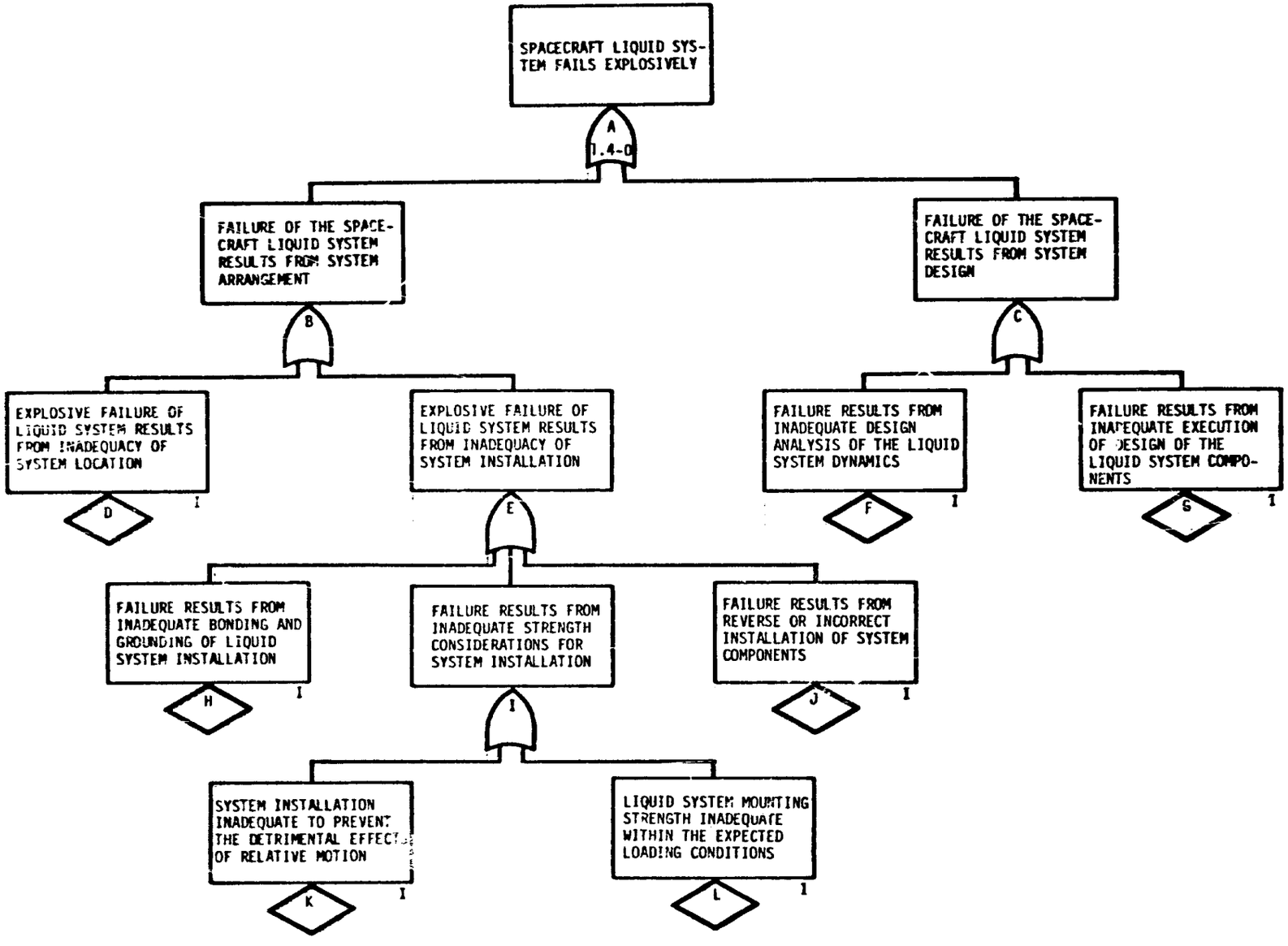

SPACECRAFT LIQUID SYSTEM FAILS EXPLOSIVELY
A
1.4-0
FAILURE OF THE SPACECRAFT LIQUID SYSTEM RESULTS FROM SYSTEM ARRANGEMENT
FAILURE OF THE SPACECRAFT LIQUID SYSTEM RESULTS FROM SYSTEM DESIGN
B
C
EXPLOSIVE FAILURE OF LIQUID SYSTEM RESULTS FROM INADEQUACY OF SYSTEM LOCATION
EXPLOSIVE FAILURE OF LIQUID SYSTEM RESULTS FROM INADEQUACY OF SYSTEM INSTALLATION
FAILURE RESULTS FROM INADEQUATE DESIGN ANALYSIS OF THE LIQUID SYSTEM DYNAMICS
FAILURE RESULTS FROM INADEQUATE EXECUTION OF DESIGN OF THE LIQUID SYSTEM COMPONENTS
D
I
E
F
I
G
I
FAILURE RESULTS FROM INADEQUATE BONDING AND GROUNDING OF LIQUID SYSTEM INSTALLATION
FAILURE RESULTS FROM INADEQUATE STRENGTH CONSIDERATIONS FOR SYSTEM INSTALLATION
FAILURE RESULTS FROM REVERSE OR INCORRECT INSTALLATION OF SYSTEM COMPONENTS
H
I
I
J
I
SYSTEM INSTALLATION INADEQUATE TO PREVENT THE DETRIMENTAL EFFECTS OF RELATIVE MOTION
LIQUID SYSTEM MOUNTING STRENGTH INADEQUATE WITHIN THE EXPECTED LOADING CONDITIONS
K
I
L
I

Chart No. 1.12

## 5.2 FT-2, EVENTS RELATED TO HIGH AND LOW TEMPERATURES

Top events of the nineteen charts comprising this fault tree are listed below. Numbers in parentheses refer to the predecessor charts in which the events originated.

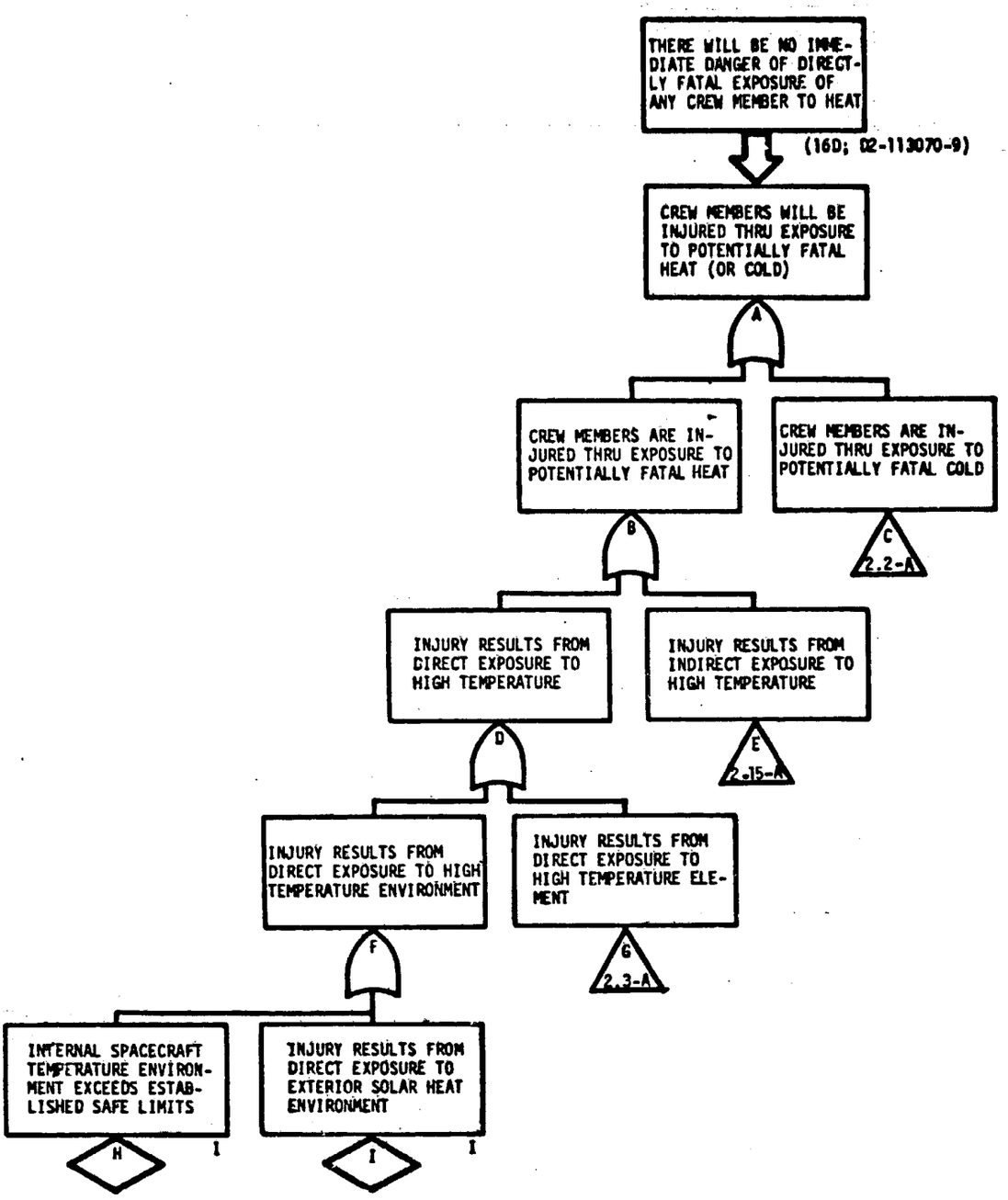
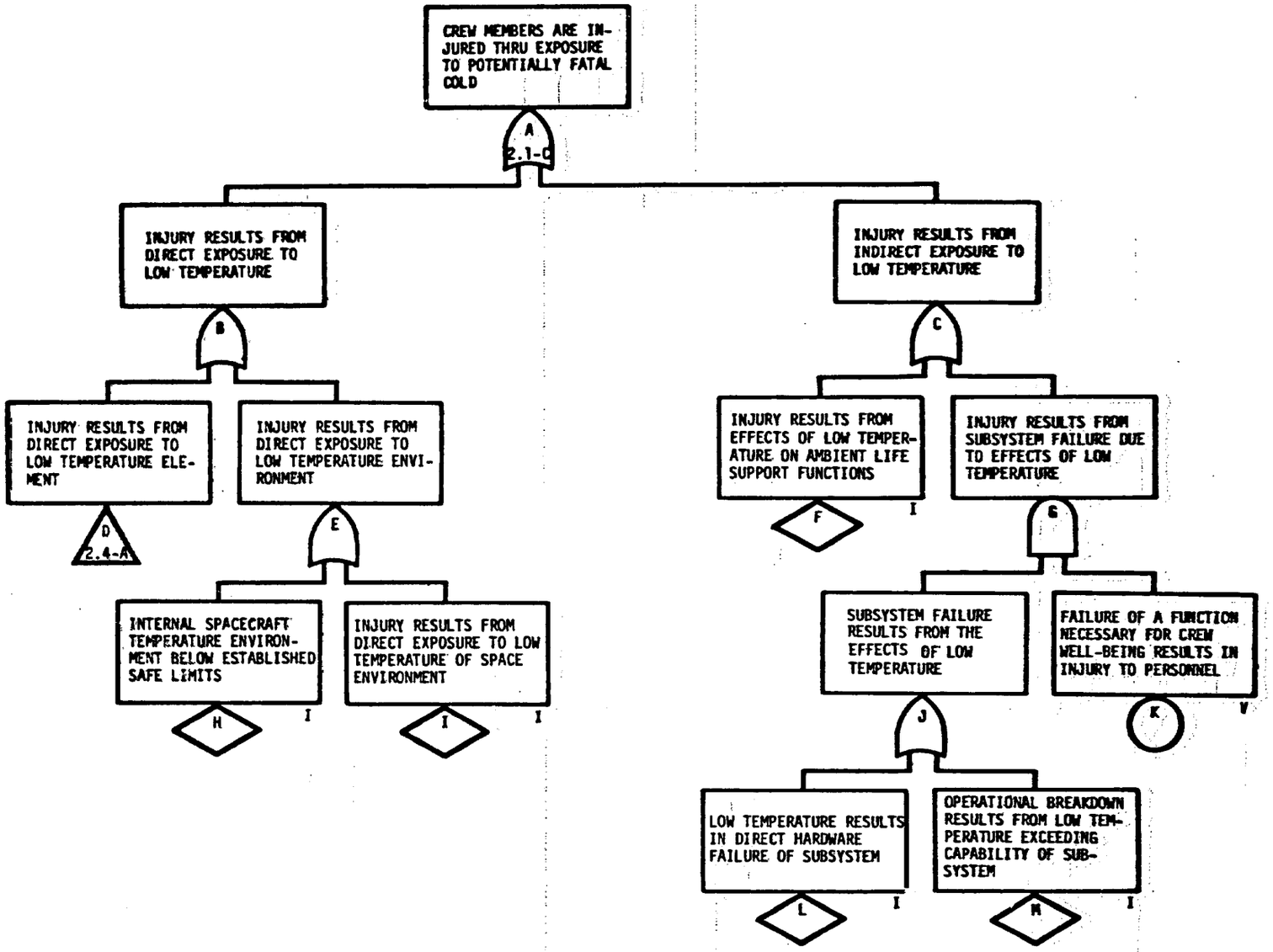

THERE WILL BE NO IMME-DIATE DANGER OF DIRECT-LY FATAL EXPOSURE OF ANY CREW MEMBER TO HEAT
(16D; D2-113070-9)
CREW MEMBERS WILL BE INJURED THRU EXPOSURE TO POTENTIALLY FATAL HEAT (OR COLD)
A
CREW MEMBERS ARE IN-JURED THRU EXPOSURE TO POTENTIALLY FATAL HEAT
CREW MEMBERS ARE IN-JURED THRU EXPOSURE TO POTENTIALLY FATAL COLD
B
C
2.2-A
INJURY RESULTS FROM DIRECT EXPOSURE TO HIGH TEMPERATURE
INJURY RESULTS FROM INDIRECT EXPOSURE TO HIGH TEMPERATURE
D
E
2.15-A
INJURY RESULTS FROM DIRECT EXPOSURE TO HIGH TEMPERATURE ENVIRONMENT
INJURY RESULTS FROM DIRECT EXPOSURE TO HIGH TEMPERATURE ELE-MENT
F
G
2.3-A
INTERNAL SPACECRAFT TEMPERATURE ENVIRON-MENT EXCEEDS ESTAB-LISHED SAFE LIMITS
INJURY RESULTS FROM DIRECT EXPOSURE TO EXTERIOR SOLAR HEAT ENVIRONMENT
H
I
I
I

Chart No. 2.1


CREW MEMBERS ARE INJURED THRU EXPOSURE TO POTENTIALLY FATAL COLD
A
2.1-C
INJURY RESULTS FROM DIRECT EXPOSURE TO LOW TEMPERATURE
INJURY RESULTS FROM INDIRECT EXPOSURE TO LOW TEMPERATURE
B
C
INJURY RESULTS FROM DIRECT EXPOSURE TO LOW TEMPERATURE ELEMENT
INJURY RESULTS FROM DIRECT EXPOSURE TO LOW TEMPERATURE ENVIRONMENT
INJURY RESULTS FROM EFFECTS OF LOW TEMPERATURE ON AMBIENT LIFE SUPPORT FUNCTIONS
INJURY RESULTS FROM SUBSYSTEM FAILURE DUE TO EFFECTS OF LOW TEMPERATURE
D
2.4-A
E
F
I
G
INTERNAL SPACECRAFT TEMPERATURE ENVIRONMENT BELOW ESTABLISHED SAFE LIMITS
INJURY RESULTS FROM DIRECT EXPOSURE TO LOW TEMPERATURE OF SPACE ENVIRONMENT
SUBSYSTEM FAILURE RESULTS FROM THE EFFECTS OF LOW TEMPERATURE
FAILURE OF A FUNCTION NECESSARY FOR CREW WELL-BEING RESULTS IN INJURY TO PERSONNEL
H
I
I
J
K
V
LOW TEMPERATURE RESULTS IN DIRECT HARDWARE FAILURE OF SUBSYSTEM
OPERATIONAL BREAKDOWN RESULTS FROM LOW TEMPERATURE EXCEEDING CAPABILITY OF SUBSYSTEM
L
M
I
I

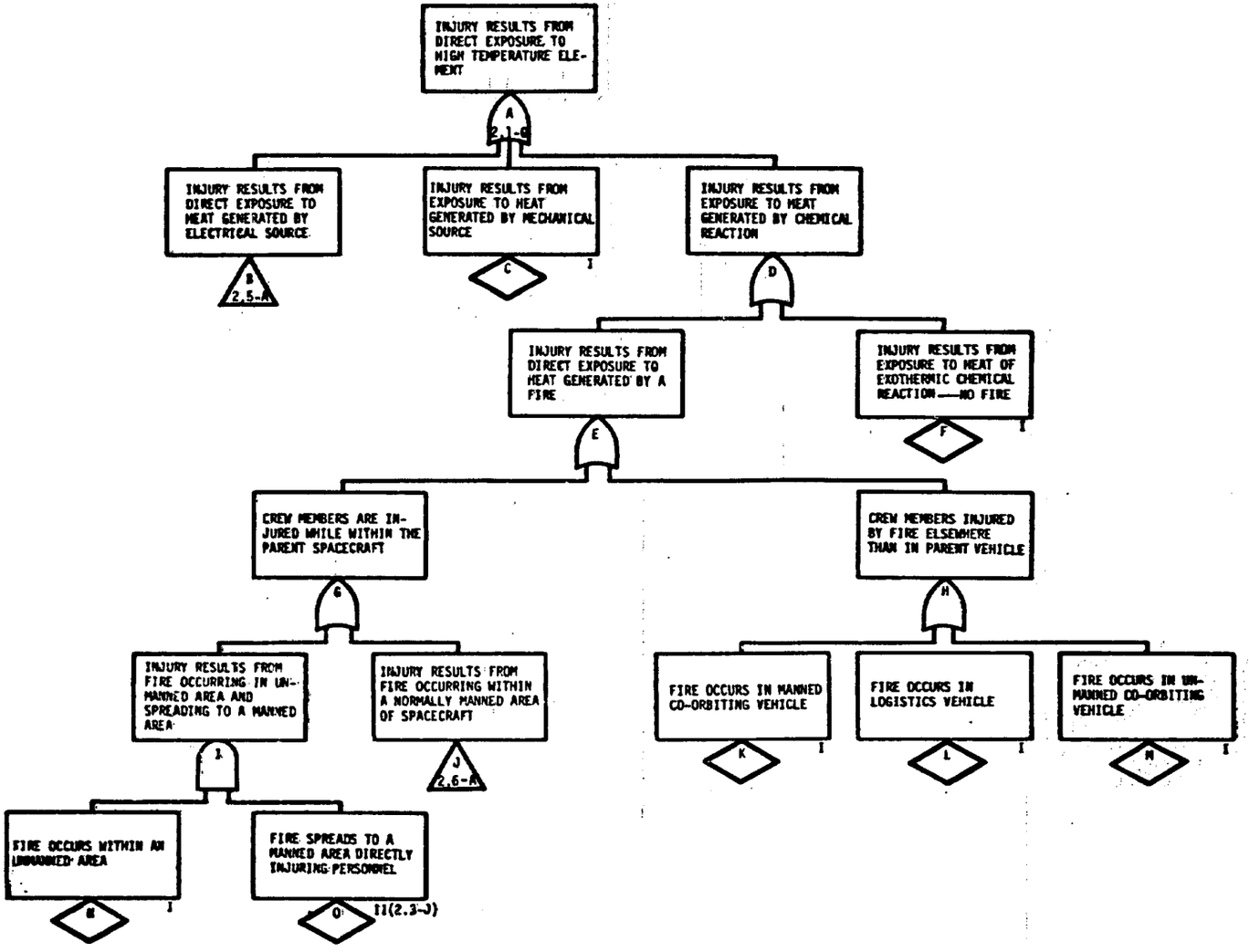
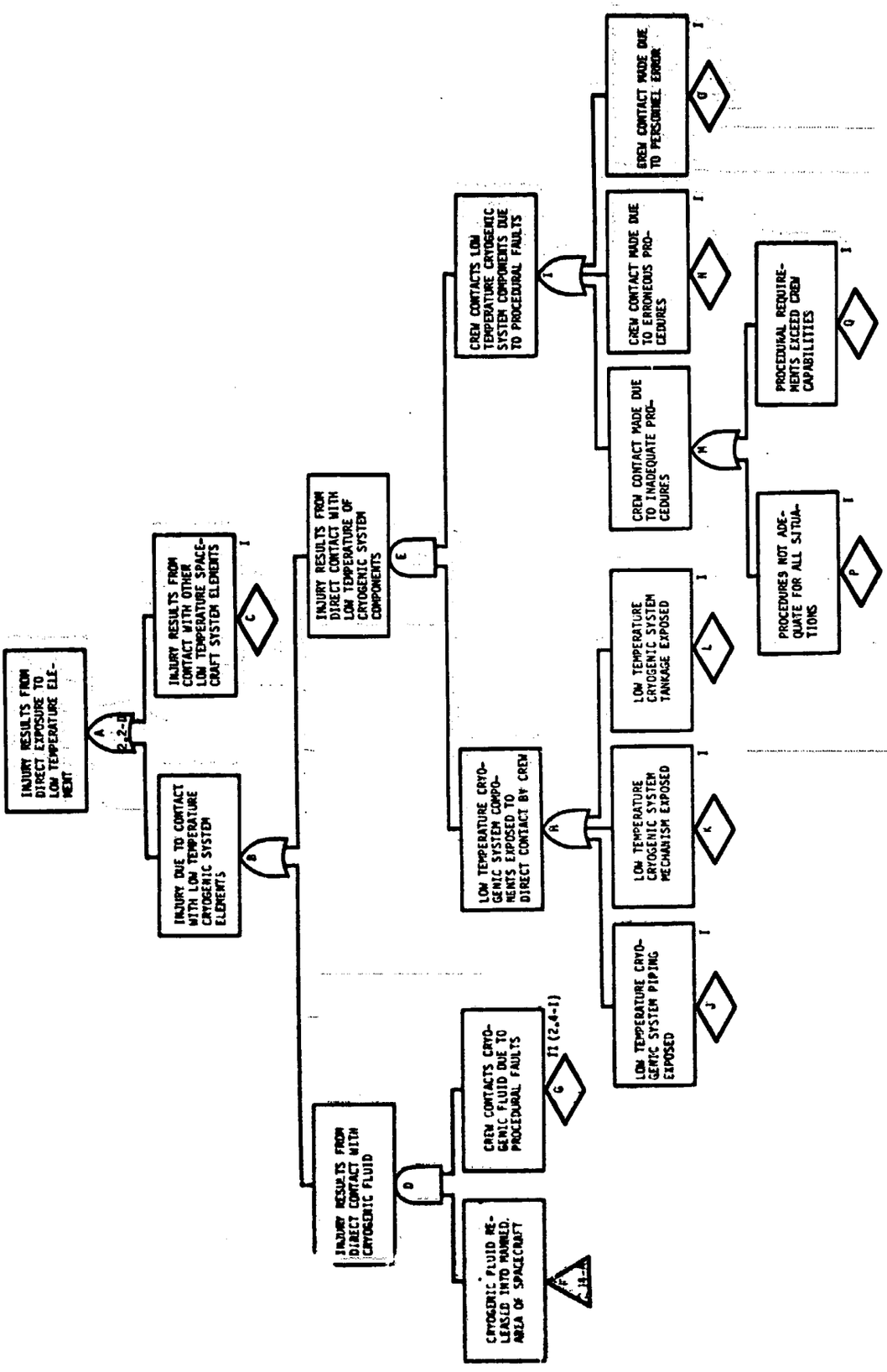

INJURY RESULTS FROM DIRECT EXPOSURE TO HIGH TEMPERATURE ELEMENT
A
2.1-G
INJURY RESULTS FROM DIRECT EXPOSURE TO HEAT GENERATED BY ELECTRICAL SOURCE
B
2.5-A
INJURY RESULTS FROM EXPOSURE TO HEAT GENERATED BY MECHANICAL SOURCE
C
I
INJURY RESULTS FROM EXPOSURE TO HEAT GENERATED BY CHEMICAL REACTION
D
INJURY RESULTS FROM DIRECT EXPOSURE TO HEAT GENERATED BY A FIRE
INJURY RESULTS FROM EXPOSURE TO HEAT OF EXOTHERMIC CHEMICAL REACTION — NO FIRE
F
I
E
CREW MEMBERS ARE INJURED WHILE WITHIN THE PARENT SPACECRAFT
CREW MEMBERS INJURED BY FIRE ELSEWHERE THAN IN PARENT VEHICLE
G
H
INJURY RESULTS FROM FIRE OCCURRING IN UNMANNED AREA AND SPREADING TO A MANNED AREA
INJURY RESULTS FROM FIRE OCCURRING WITHIN A NORMALLY MANNED AREA OF SPACECRAFT
FIRE OCCURS IN MANNED CO-ORBITING VEHICLE
FIRE OCCURS IN LOGISTICS VEHICLE
FIRE OCCURS IN UNMANNED CO-ORBITING VEHICLE
K
I
L
I
N
I
I
J
2.6-A
FIRE OCCURS WITHIN AN UNMANNED AREA
M
I
FIRE SPREADS TO A MANNED AREA DIRECTLY INJURING PERSONNEL
O
II(2.3-J)

Chart No. 2.3

Chart No. 2.4


INJURY RESULTS FROM DIRECT EXPOSURE TO LOW TEMPERATURE ELEMENT
A
2.2-1
INJURY DUE TO CONTACT WITH LOW TEMPERATURE CRYOGENIC SYSTEM ELEMENTS
B
INJURY RESULTS FROM CONTACT WITH OTHER LOW TEMPERATURE SPACECRAFT SYSTEM ELEMENTS
C
1
INJURY RESULTS FROM DIRECT CONTACT WITH CRYOGENIC FLUID
D
CRYOGENIC FLUID RELEASED INTO MANNED AREA OF SPACECRAFT
F
2.4-1
CREW CONTACTS CRYOGENIC FLUID DUE TO PROCEDURAL FAULTS
G
1 (2.4-1)
INJURY RESULTS FROM DIRECT CONTACT WITH LOW TEMPERATURE OF CRYOGENIC SYSTEM COMPONENTS
E
LOW TEMPERATURE CRYOGENIC SYSTEM COMPONENTS EXPOSED TO DIRECT CONTACT BY CREW
H
LOW TEMPERATURE CRYOGENIC SYSTEM PIPING EXPOSED
J
1
LOW TEMPERATURE CRYOGENIC SYSTEM MECHANISM EXPOSED
K
1
LOW TEMPERATURE CRYOGENIC SYSTEM TANKAGE EXPOSED
L
1
CREW CONTACTS LOW TEMPERATURE CRYOGENIC SYSTEM COMPONENTS DUE TO PROCEDURAL FAULTS
I
CREW CONTACT MADE DUE TO INADEQUATE PROCEDURES
M
PROCEDURES NOT ADEQUATE FOR ALL SITUATIONS
P
1
PROCEDURAL REQUIREMENTS EXCEED CREW CAPABILITIES
Q
1
CREW CONTACT MADE DUE TO ERRONEOUS PROCEDURES
N
1
CREW CONTACT MADE DUE TO PERSONNEL ERROR
O
1

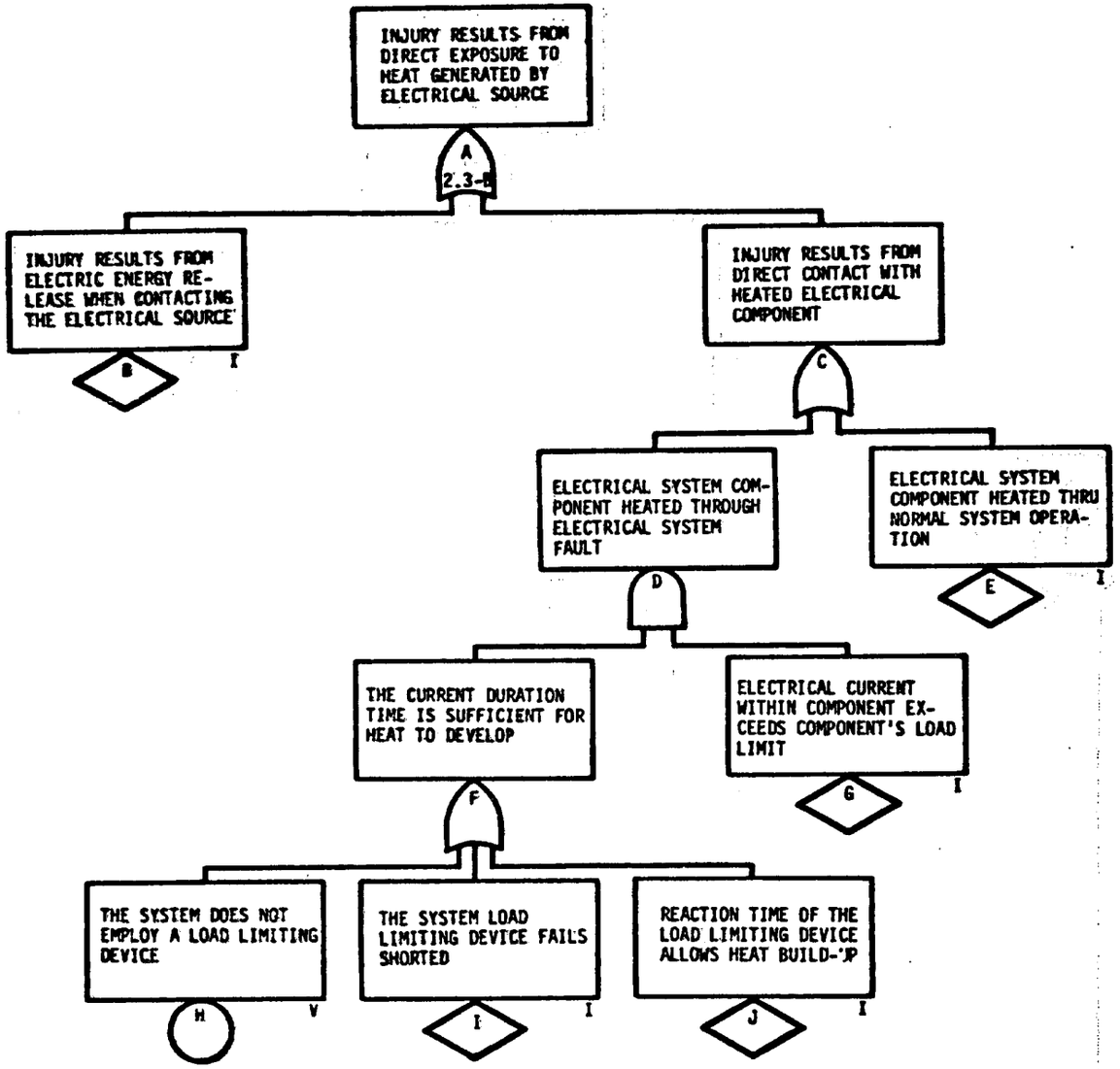
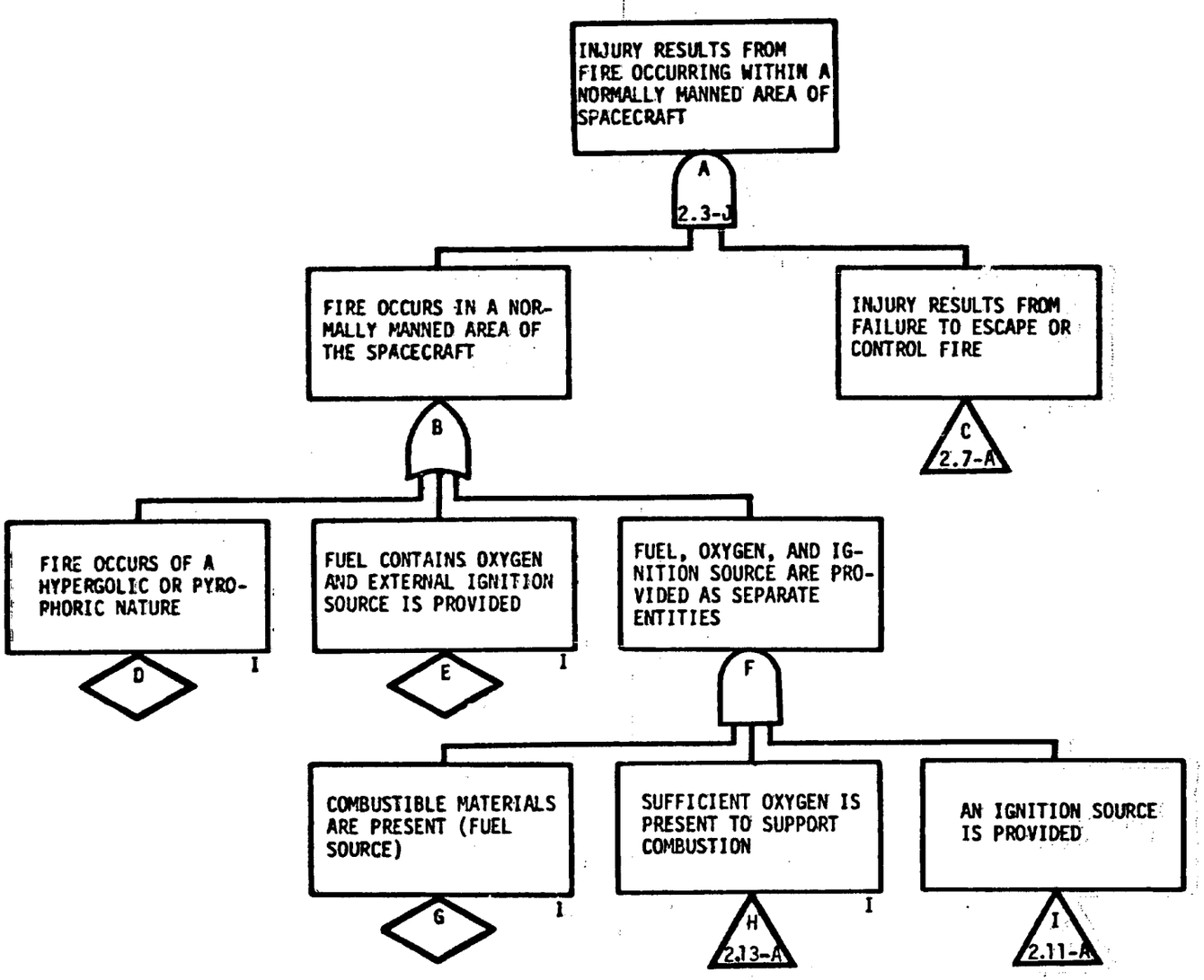

INJURY RESULTS FROM DIRECT EXPOSURE TO HEAT GENERATED BY ELECTRICAL SOURCE
A
2.3-8
INJURY RESULTS FROM ELECTRIC ENERGY RELEASE WHEN CONTACTING THE ELECTRICAL SOURCE
B
I
INJURY RESULTS FROM DIRECT CONTACT WITH HEATED ELECTRICAL COMPONENT
C
ELECTRICAL SYSTEM COMPONENT HEATED THROUGH ELECTRICAL SYSTEM FAULT
D
ELECTRICAL SYSTEM COMPONENT HEATED THRU NORMAL SYSTEM OPERATION
E
I
THE CURRENT DURATION TIME IS SUFFICIENT FOR HEAT TO DEVELOP
F
ELECTRICAL CURRENT WITHIN COMPONENT EXCEEDS COMPONENT'S LOAD LIMIT
G
I
THE SYSTEM DOES NOT EMPLOY A LOAD LIMITING DEVICE
H
V
THE SYSTEM LOAD LIMITING DEVICE FAILS SHORTED
I
I
REACTION TIME OF THE LOAD LIMITING DEVICE ALLOWS HEAT BUILD-UP
J
I

Chart No. 2.5

Chart No. 2.6


INJURY RESULTS FROM FIRE OCCURRING WITHIN A NORMALLY MANNED AREA OF SPACECRAFT
A
2.3-J
FIRE OCCURS IN A NORMALLY MANNED AREA OF THE SPACECRAFT
INJURY RESULTS FROM FAILURE TO ESCAPE OR CONTROL FIRE
C
2.7-A
B
FIRE OCCURS OF A HYPERGOLIC OR PYROPHORIC NATURE
I
D
FUEL CONTAINS OXYGEN AND EXTERNAL IGNITION SOURCE IS PROVIDED
I
E
FUEL, OXYGEN, AND IGNITION SOURCE ARE PROVIDED AS SEPARATE ENTITIES
F
COMBUSTIBLE MATERIALS ARE PRESENT (FUEL SOURCE)
I
G
SUFFICIENT OXYGEN IS PRESENT TO SUPPORT COMBUSTION
I
H
2.13-A
AN IGNITION SOURCE IS PROVIDED
I
2.11-A

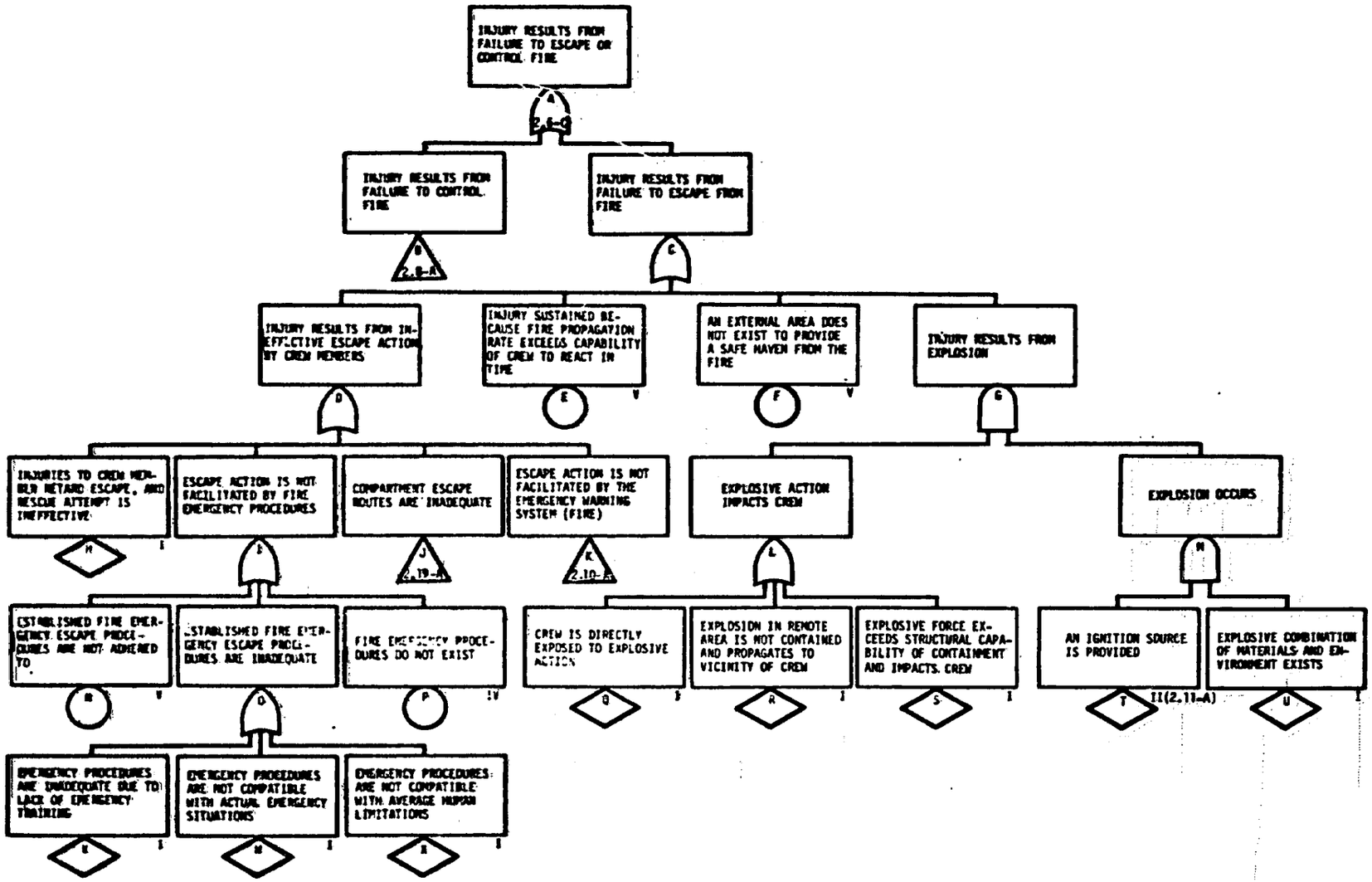
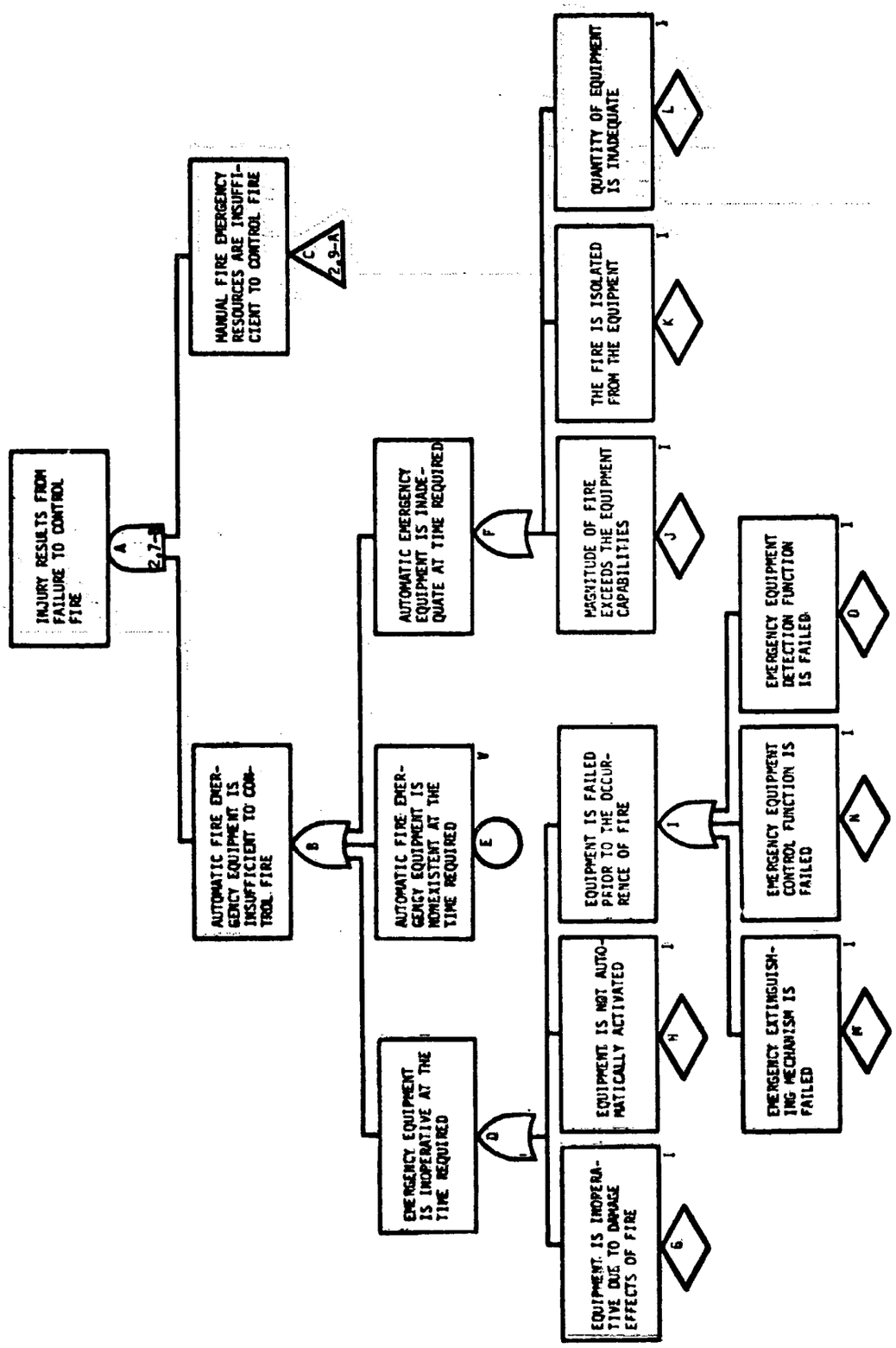

INJURY RESULTS FROM FAILURE TO ESCAPE OR CONTROL FIRE
A
2.8-G
INJURY RESULTS FROM FAILURE TO CONTROL FIRE
INJURY RESULTS FROM FAILURE TO ESCAPE FROM FIRE
B
2.8-A
C
INJURY RESULTS FROM INEFFECTIVE ESCAPE ACTION BY CREW MEMBERS
INJURY SUSTAINED BECAUSE FIRE PROPAGATION RATE EXCEEDS CAPABILITY OF CREW TO REACT IN TIME
AN EXTERNAL AREA DOES NOT EXIST TO PROVIDE A SAFE HAVEN FROM THE FIRE
INJURY RESULTS FROM EXPLOSION
D
E
V
F
V
G
INJURIES TO CREW MEMBER RETARD ESCAPE, AND RESCUE ATTEMPT IS INEFFECTIVE
ESCAPE ACTION IS NOT FACILITATED BY FIRE EMERGENCY PROCEDURES
COMPARTMENT ESCAPE ROUTES ARE INADEQUATE
ESCAPE ACTION IS NOT FACILITATED BY THE EMERGENCY WARNING SYSTEM (FIRE)
EXPLOSIVE ACTION IMPACTS CREW
EXPLOSION OCCURS
H
I
F
J
2.19-A
K
2.10-A
L
M
ESTABLISHED FIRE EMERGENCY ESCAPE PROCEDURES ARE NOT ADHERED TO
ESTABLISHED FIRE EMERGENCY ESCAPE PROCEDURES ARE INADEQUATE
FIRE EMERGENCY PROCEDURES DO NOT EXIST
CREW IS DIRECTLY EXPOSED TO EXPLOSIVE ACTION
EXPLOSION IN REMOTE AREA IS NOT CONTAINED AND PROPAGATES TO VICINITY OF CREW
EXPLOSIVE FORCE EXCEEDS STRUCTURAL CAPABILITY OF CONTAINMENT AND IMPACTS CREW
AN IGNITION SOURCE IS PROVIDED
EXPLOSIVE COMBINATION OF MATERIALS AND ENVIRONMENT EXISTS
N
V
O
IV
P
Q
R
S
T
II(2.11-A)
U
EMERGENCY PROCEDURES ARE INADEQUATE DUE TO LACK OF EMERGENCY TRAINING
EMERGENCY PROCEDURES ARE NOT COMPATIBLE WITH ACTUAL EMERGENCY SITUATIONS
EMERGENCY PROCEDURES ARE NOT COMPATIBLE WITH AVERAGE HUMAN LIMITATIONS
V
W
X

Chart No. 2.7

Chart No. 2.3


INJURY RESULTS FROM FAILURE TO CONTROL FIRE
A
2.7-1
AUTOMATIC FIRE EMERGENCY EQUIPMENT IS INSUFFICIENT TO CONTROL FIRE
B
MANUAL FIRE EMERGENCY RESOURCES ARE INSUFFICIENT TO CONTROL FIRE
C
2.9-1
EMERGENCY EQUIPMENT IS INOPERATIVE AT THE TIME REQUIRED
D
AUTOMATIC FIRE EMERGENCY EQUIPMENT IS NONEXISTENT AT THE TIME REQUIRED
E
AUTOMATIC EMERGENCY EQUIPMENT IS INADEQUATE AT TIME REQUIRED
F
EQUIPMENT IS INOPERATIVE DUE TO DAMAGE EFFECTS OF FIRE
G
EQUIPMENT IS NOT AUTOMATICALLY ACTIVATED
H
EQUIPMENT IS FAILED PRIOR TO THE OCCURRENCE OF FIRE
I
MAGNITUDE OF FIRE EXCEEDS THE EQUIPMENT CAPABILITIES
J
THE FIRE IS ISOLATED FROM THE EQUIPMENT
K
QUANTITY OF EQUIPMENT IS INADEQUATE
L
EMERGENCY EXTINGUISHING MECHANISM IS FAILED
M
EMERGENCY EQUIPMENT CONTROL FUNCTION IS FAILED
N
EMERGENCY EQUIPMENT DETECTION FUNCTION IS FAILED
O

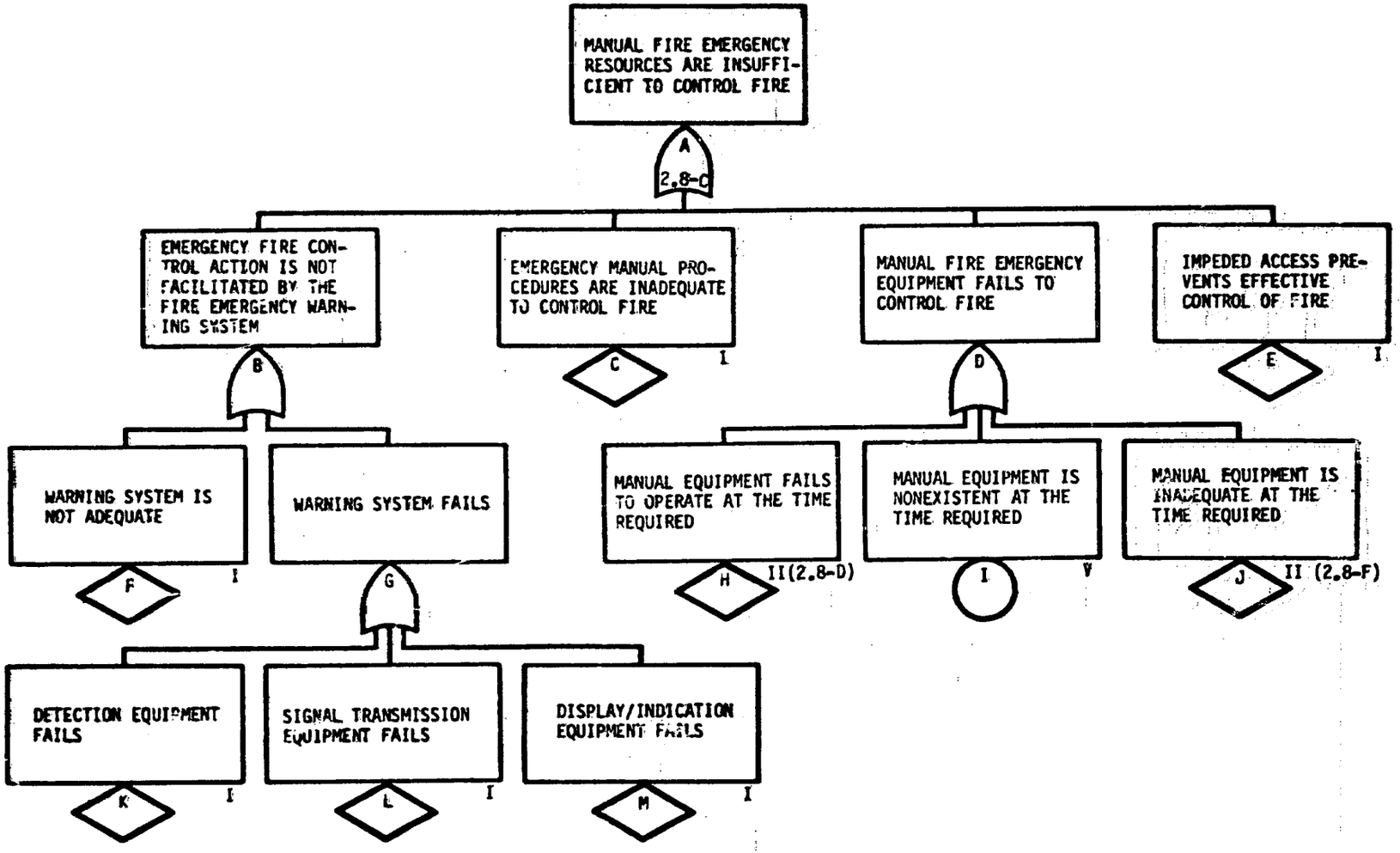
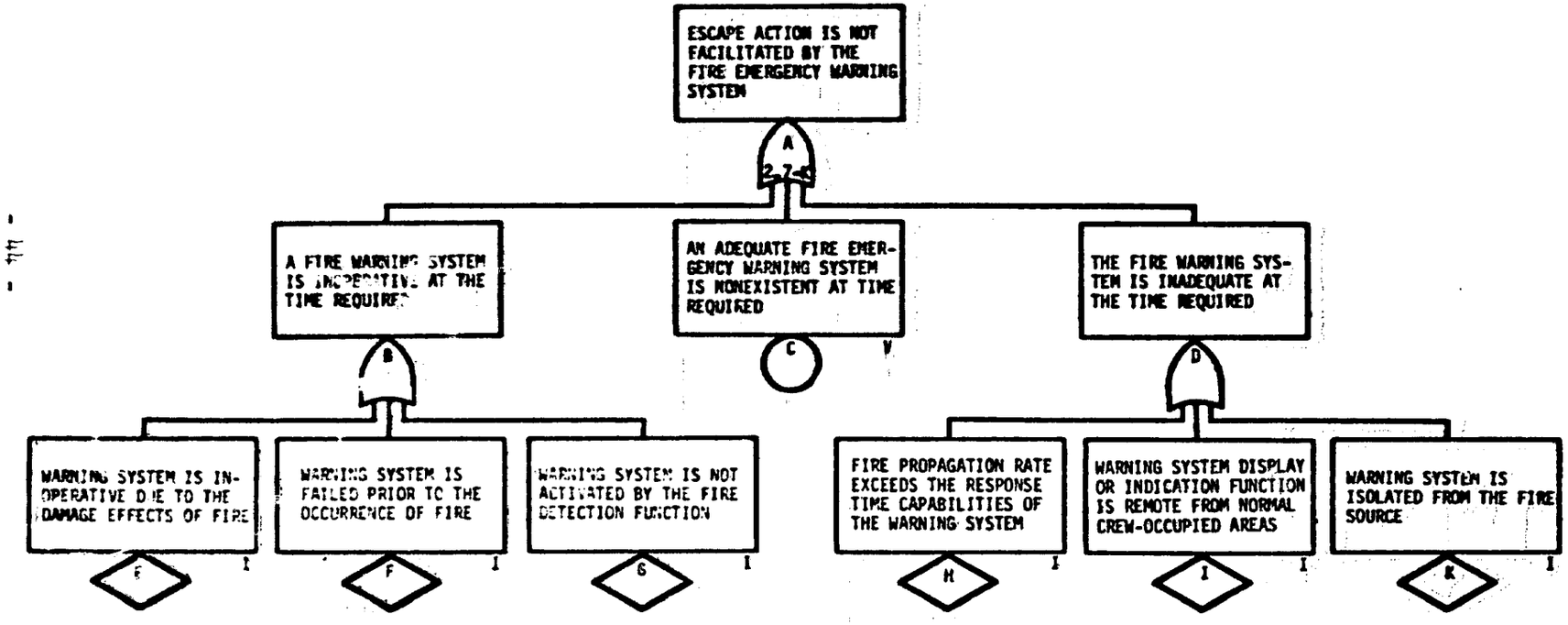
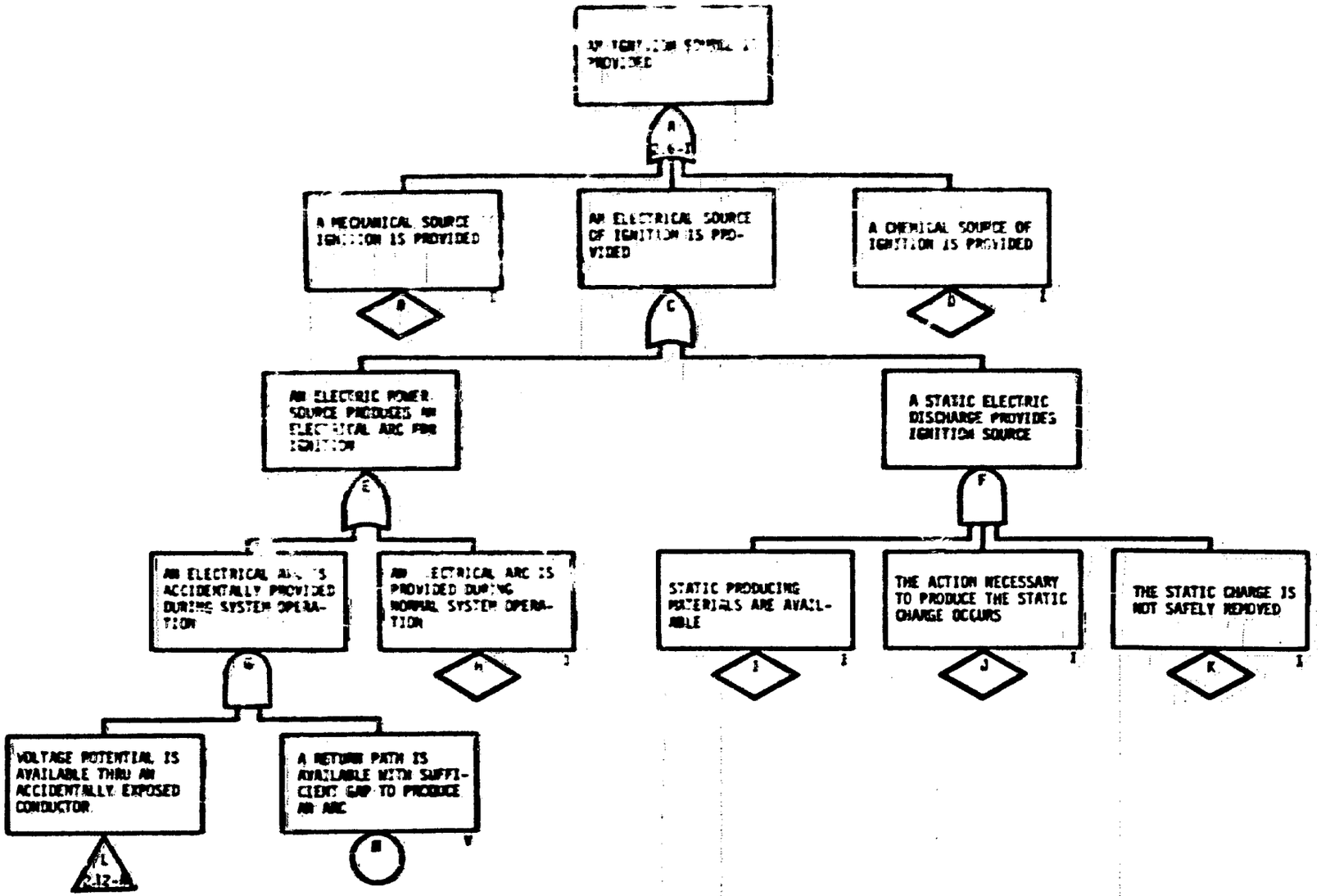
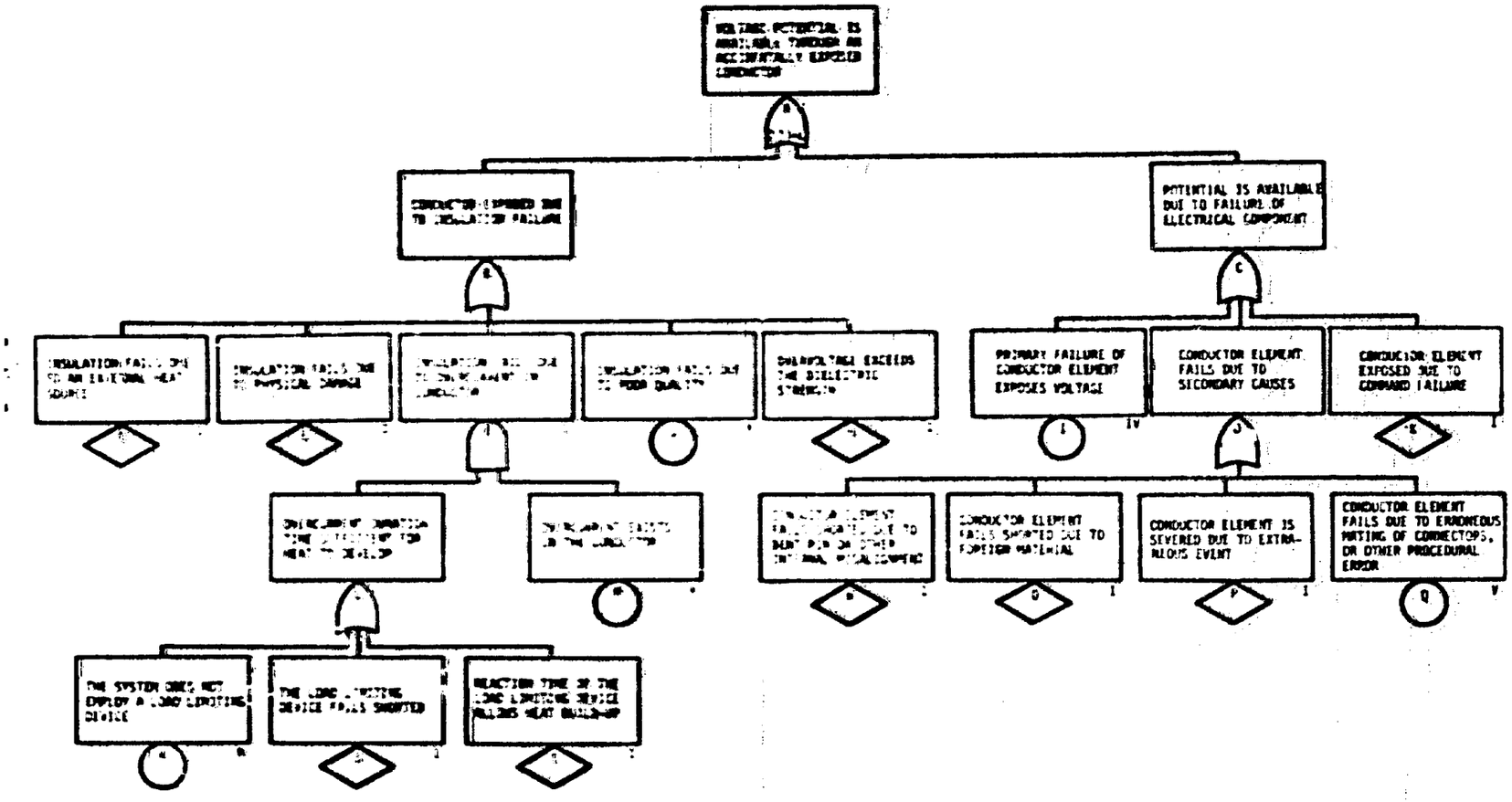

MANUAL FIRE EMERGENCY RESOURCES ARE INSUFFICIENT TO CONTROL FIRE
A
2.8-C
EMERGENCY FIRE CONTROL ACTION IS NOT FACILITATED BY THE FIRE EMERGENCY WARNING SYSTEM
EMERGENCY MANUAL PROCEDURES ARE INADEQUATE TO CONTROL FIRE
MANUAL FIRE EMERGENCY EQUIPMENT FAILS TO CONTROL FIRE
IMPEDED ACCESS PREVENTS EFFECTIVE CONTROL OF FIRE
B
C
I
D
E
I
WARNING SYSTEM IS NOT ADEQUATE
WARNING SYSTEM FAILS
MANUAL EQUIPMENT FAILS TO OPERATE AT THE TIME REQUIRED
MANUAL EQUIPMENT IS NONEXISTENT AT THE TIME REQUIRED
MANUAL EQUIPMENT IS INADEQUATE AT THE TIME REQUIRED
F
I
G
H
II(2.8-D)
I
V
J
II (2.8-F)
DETECTION EQUIPMENT FAILS
SIGNAL TRANSMISSION EQUIPMENT FAILS
DISPLAY/INDICATION EQUIPMENT FAILS
K
I
L
I
M
I

Chart No. 2.9


ESCAPE ACTION IS NOT FACILITATED BY THE FIRE EMERGENCY WARNING SYSTEM
A
2,7,6
A FIRE WARNING SYSTEM IS INOPERATIVE AT THE TIME REQUIRED
AN ADEQUATE FIRE EMERGENCY WARNING SYSTEM IS NONEXISTENT AT TIME REQUIRED
THE FIRE WARNING SYSTEM IS INADEQUATE AT THE TIME REQUIRED
B
C
V
D
WARNING SYSTEM IS INOPERATIVE DUE TO THE DAMAGE EFFECTS OF FIRE
WARNING SYSTEM IS FAILED PRIOR TO THE OCCURRENCE OF FIRE
WARNING SYSTEM IS NOT ACTIVATED BY THE FIRE DETECTION FUNCTION
FIRE PROPAGATION RATE EXCEEDS THE RESPONSE TIME CAPABILITIES OF THE WARNING SYSTEM
WARNING SYSTEM DISPLAY OR INDICATION FUNCTION IS REMOTE FROM NORMAL CREW-OCCUPIED AREAS
WARNING SYSTEM IS ISOLATED FROM THE FIRE SOURCE
E
I
F
I
G
I
H
I
I
I
K
I


AN IGNITION SOURCE IS PROVIDED
A
A MECHANICAL SOURCE IGNITION IS PROVIDED
B
AN ELECTRICAL SOURCE OF IGNITION IS PROVIDED
C
A CHEMICAL SOURCE OF IGNITION IS PROVIDED
D
AN ELECTRIC POWER SOURCE PRODUCES AN ELECTRICAL ARC FOR IGNITION
E
A STATIC ELECTRIC DISCHARGE PROVIDES IGNITION SOURCE
F
AN ELECTRICAL ARC IS ACCIDENTALLY PROVIDED DURING SYSTEM OPERATION
G
AN ELECTRICAL ARC IS PROVIDED DURING NORMAL SYSTEM OPERATION
H
STATIC PRODUCING MATERIALS ARE AVAILABLE
I
THE ACTION NECESSARY TO PRODUCE THE STATIC CHARGE OCCURS
J
THE STATIC CHARGE IS NOT SAFELY REMOVED
K
VOLTAGE POTENTIAL IS AVAILABLE THRU AN ACCIDENTALLY EXPOSED CONDUCTOR
L
A RETURN PATH IS AVAILABLE WITH SUFFICIENT GAP TO PRODUCE AN ARC
M


POTENTIAL IS AVAILABLE DUE TO FAILURE OF ELECTRICAL COMPONENT
PRIMARY FAILURE OF CONDUCTOR ELEMENT EXPOSES VOLTAGE
CONDUCTOR ELEMENT FAILS DUE TO SECONDARY CAUSES
CONDUCTOR ELEMENT EXPOSED DUE TO COMMAND FAILURE
CONDUCTOR ELEMENT FAILS SHORTED DUE TO FOREIGN MATERIAL
CONDUCTOR ELEMENT IS SEVERED DUE TO EXTRANEOUS EVENT
CONDUCTOR ELEMENT FAILS DUE TO ERRONEOUS MATING OF CONNECTORS, OR OTHER PROCEDURAL ERROR

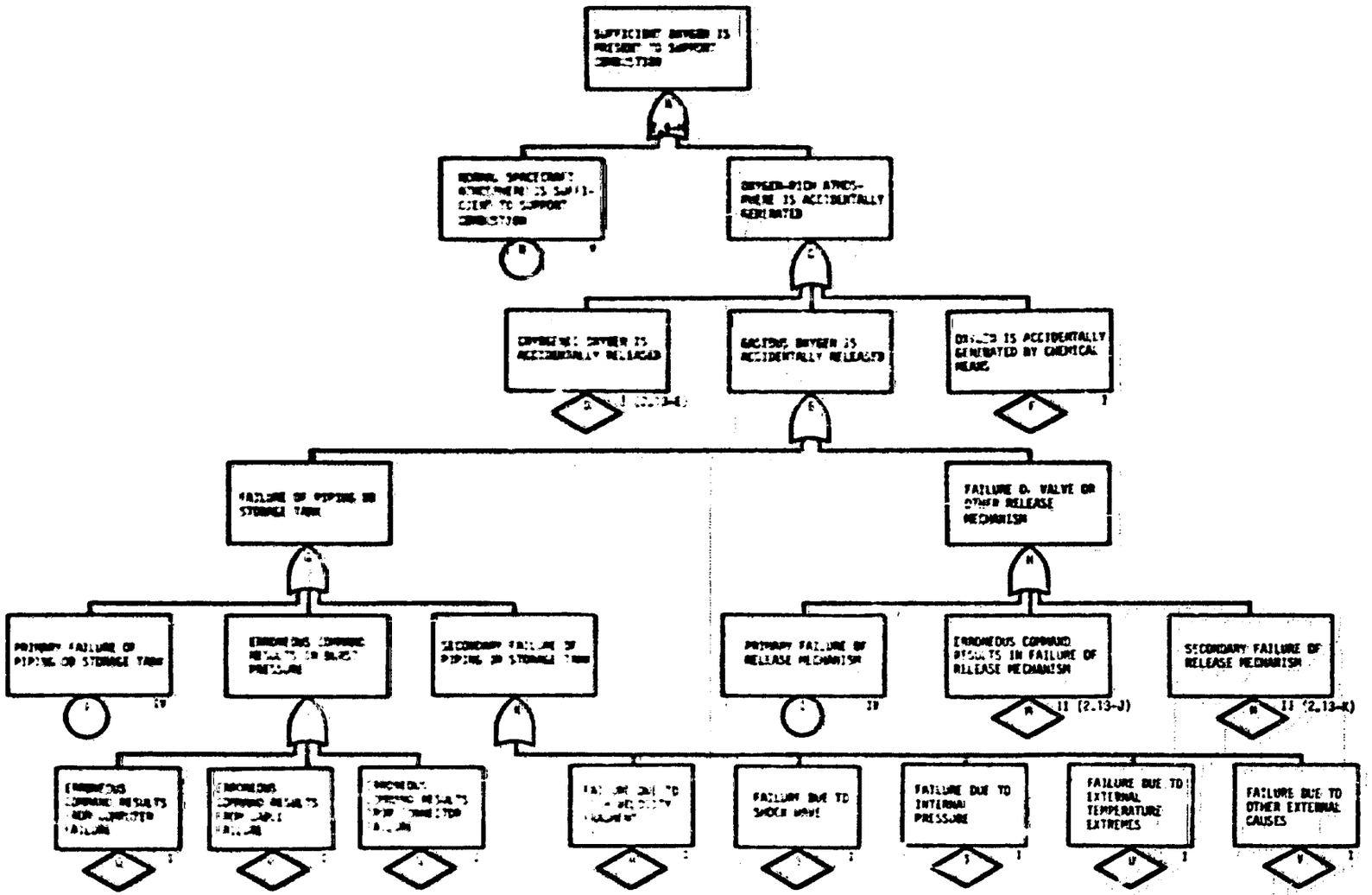
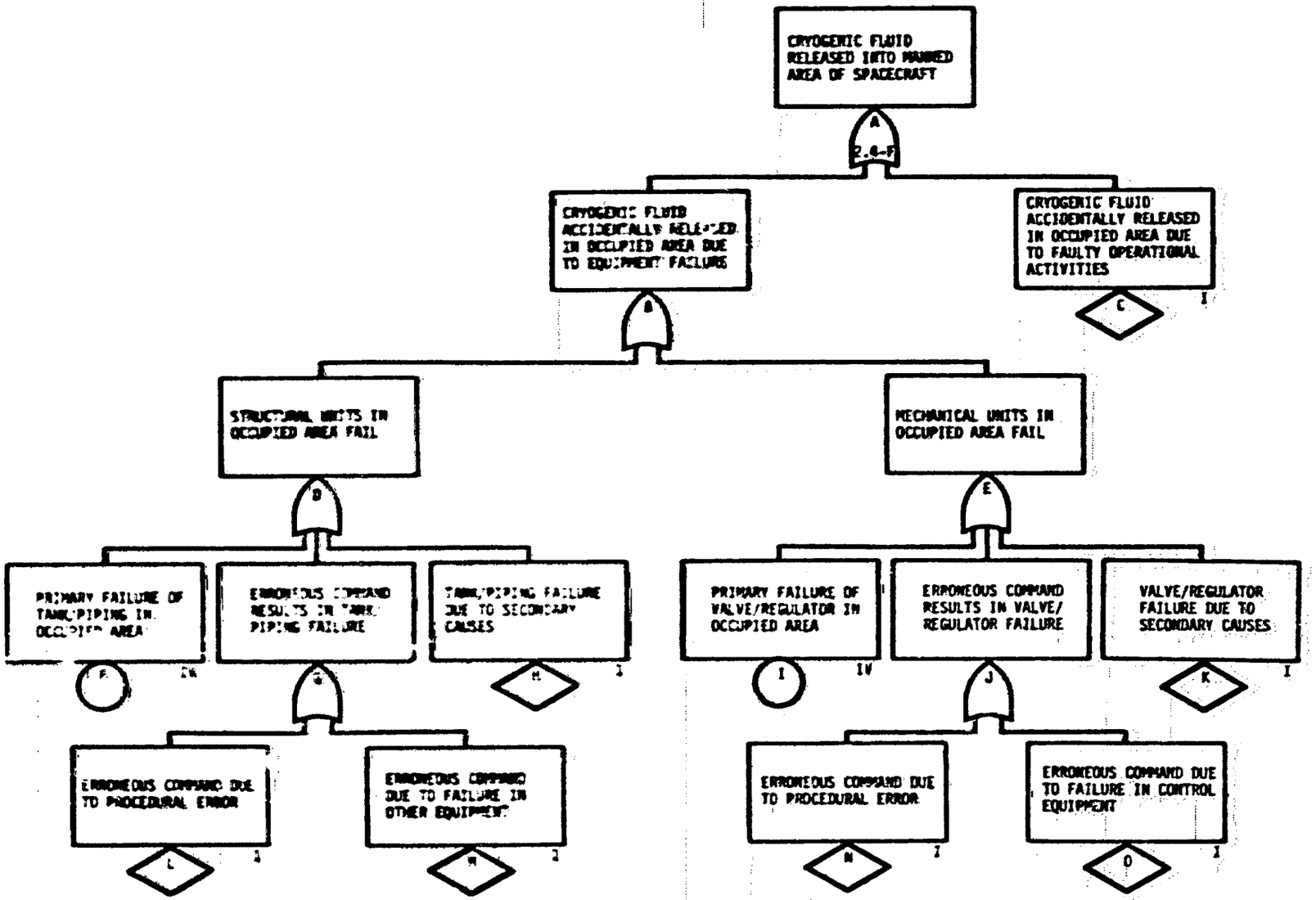
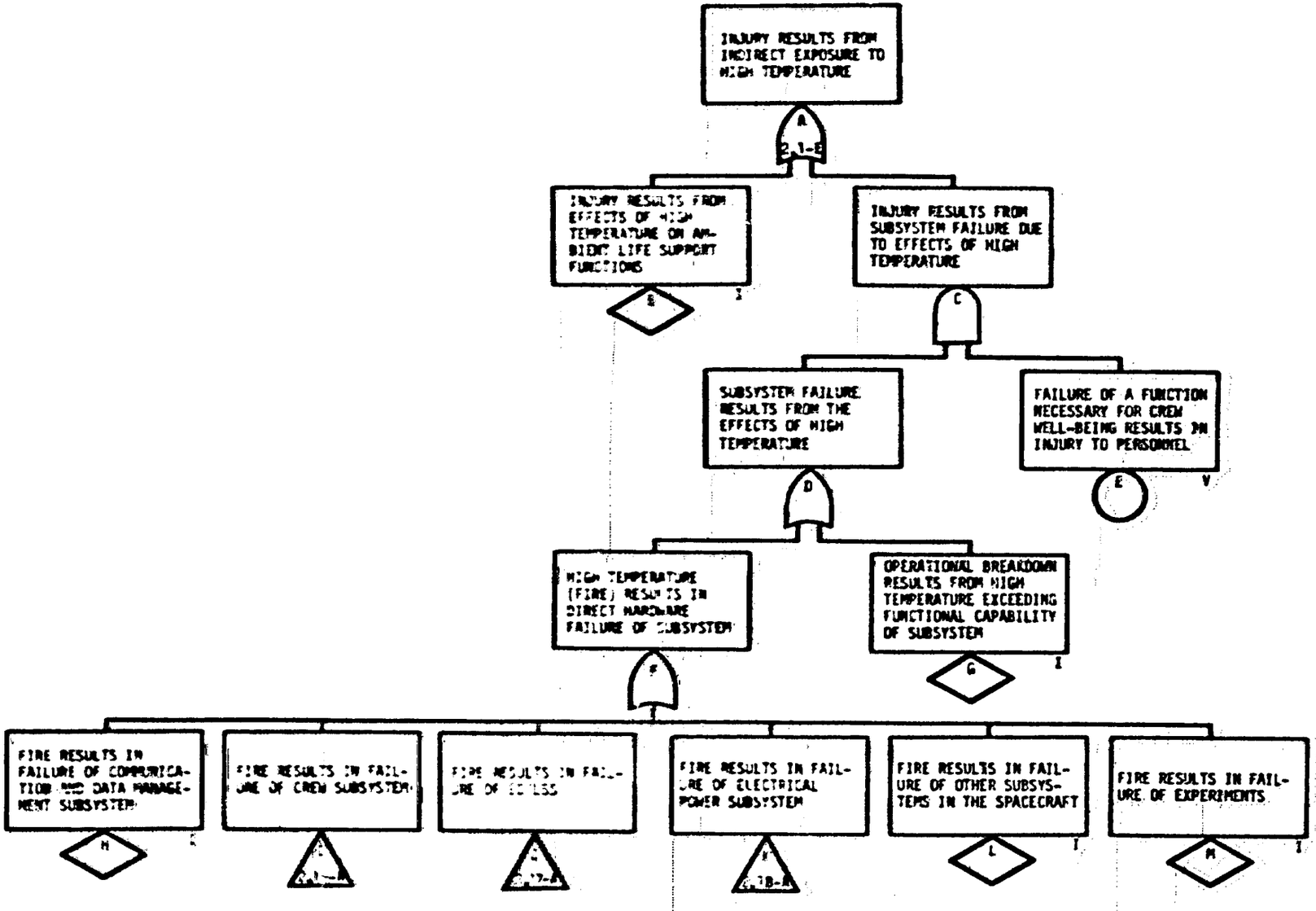

SUFFICIENT OXYGEN IS PRESENT TO SUPPORT COMBUSTION
NORMAL SPACECRAFT ATMOSPHERE IS SUFFICIENT TO SUPPORT COMBUSTION
OXYGEN-RICH ATMOSPHERE IS ACCIDENTALLY GENERATED
GASEOUS OXYGEN IS ACCIDENTALLY RELEASED
OXYGEN IS ACCIDENTALLY GENERATED BY CHEMICAL MEANS
FAILURE OF RELEASE MECHANISM
PRIMARY FAILURE OF RELEASE MECHANISM
ERRONEOUS COMMAND RESULTS IN FAILURE OF RELEASE MECHANISM
SECONDARY FAILURE OF RELEASE MECHANISM
II (2.13-J)
II (2.13-K)
FAILURE DUE TO SHOCK WAVE
FAILURE DUE TO INTERNAL PRESSURE
FAILURE DUE TO EXTERNAL TEMPERATURE EXTREMES
FAILURE DUE TO OTHER EXTERNAL CAUSES

Chart No. 2.13

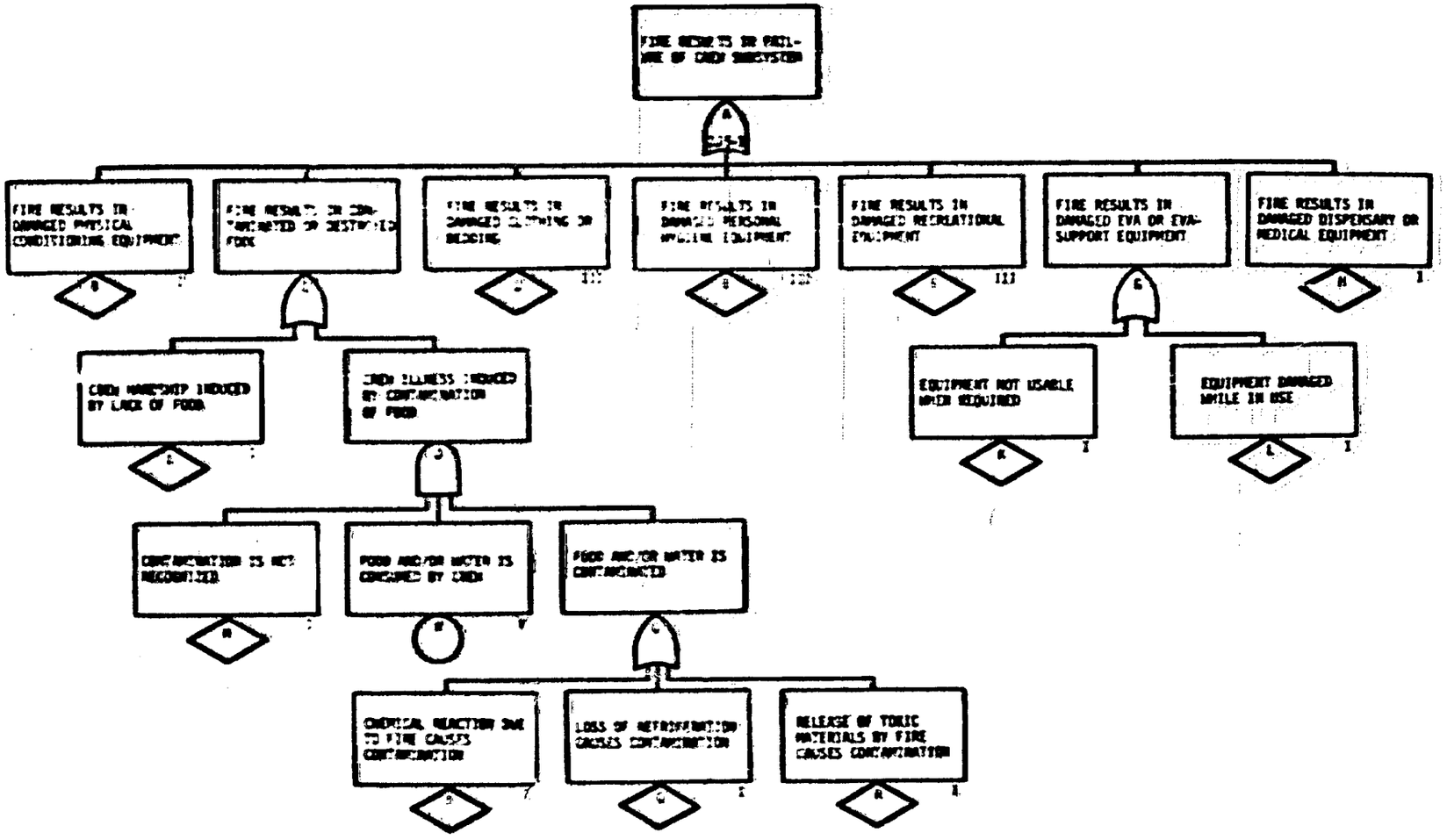
Chart No. 2.14


CRYOGENIC FLUID RELEASED INTO MANNED AREA OF SPACECRAFT
A
2.6-F
CRYOGENIC FLUID ACCIDENTALLY RELEASED IN OCCUPIED AREA DUE TO EQUIPMENT FAILURE
CRYOGENIC FLUID ACCIDENTALLY RELEASED IN OCCUPIED AREA DUE TO FAULTY OPERATIONAL ACTIVITIES
C
I
B
STRUCTURAL UNITS IN OCCUPIED AREA FAIL
MECHANICAL UNITS IN OCCUPIED AREA FAIL
D
E
PRIMARY FAILURE OF TANK/PIPING IN OCCUPIED AREA
F
IV
ERRONEOUS COMMAND RESULTS IN TANK/PIPING FAILURE
G
TANK/PIPING FAILURE DUE TO SECONDARY CAUSES
H
I
PRIMARY FAILURE OF VALVE/REGULATOR IN OCCUPIED AREA
I
IV
ERRONEOUS COMMAND RESULTS IN VALVE/REGULATOR FAILURE
J
VALVE/REGULATOR FAILURE DUE TO SECONDARY CAUSES
K
I
ERRONEOUS COMMAND DUE TO PROCEDURAL ERROR
L
I
ERRONEOUS COMMAND DUE TO FAILURE IN OTHER EQUIPMENT
M
I
ERRONEOUS COMMAND DUE TO PROCEDURAL ERROR
N
I
ERRONEOUS COMMAND DUE TO FAILURE IN CONTROL EQUIPMENT
O
I


INJURY RESULTS FROM INDIRECT EXPOSURE TO HIGH TEMPERATURE
A
2,1-E
INJURY RESULTS FROM EFFECTS OF HIGH TEMPERATURE ON AMBIENT LIFE SUPPORT FUNCTIONS
B
I
INJURY RESULTS FROM SUBSYSTEM FAILURE DUE TO EFFECTS OF HIGH TEMPERATURE
C
SUBSYSTEM FAILURE RESULTS FROM THE EFFECTS OF HIGH TEMPERATURE
D
FAILURE OF A FUNCTION NECESSARY FOR CREW WELL-BEING RESULTS IN INJURY TO PERSONNEL
E
V
HIGH TEMPERATURE (FIRE) RESULTS IN DIRECT HARDWARE FAILURE OF SUBSYSTEM
F
OPERATIONAL BREAKDOWN RESULTS FROM HIGH TEMPERATURE EXCEEDING FUNCTIONAL CAPABILITY OF SUBSYSTEM
G
I
FIRE RESULTS IN FAILURE OF COMMUNICATION AND DATA MANAGEMENT SUBSYSTEM
H
FIRE RESULTS IN FAILURE OF CREW SUBSYSTEM
FIRE RESULTS IN FAILURE OF UTILITIES
FIRE RESULTS IN FAILURE OF ELECTRICAL POWER SUBSYSTEM
FIRE RESULTS IN FAILURE OF OTHER SUBSYSTEMS IN THE SPACECRAFT
L
FIRE RESULTS IN FAILURE OF EXPERIMENTS
M

Part No. ...)

Chart No. 2,1b


FIRE RESULTS IN DAMAGED PHYSICAL CONDITIONING EQUIPMENT
FIRE RESULTS IN CONTAMINATED OR DESTROYED FOOD
FIRE RESULTS IN DAMAGED CLOTHING OR BEDDING
FIRE RESULTS IN DAMAGED PERSONAL HYGIENE EQUIPMENT
FIRE RESULTS IN DAMAGED RECREATIONAL EQUIPMENT
FIRE RESULTS IN DAMAGED EVA OR EVA-SUPPORT EQUIPMENT
FIRE RESULTS IN DAMAGED DISPENSARY OR MEDICAL EQUIPMENT
CREW HARDSHIP INDUCED BY LACK OF FOOD
CREW ILLNESS INDUCED BY CONTAMINATION OF FOOD
EQUIPMENT NOT USABLE WHEN REQUIRED
EQUIPMENT DAMAGED WHILE IN USE
CONTAMINATION IS NOT RECOGNIZED
FOOD AND/OR WATER IS CONSUMED BY CREW
FOOD AND/OR WATER IS CONTAMINATED
CHEMICAL REACTION DUE TO FIRE CAUSES CONTAMINATION
LOSS OF REFRIGERATION CAUSES CONTAMINATION
RELEASE OF TOXIC MATERIALS BY FIRE CAUSES CONTAMINATION

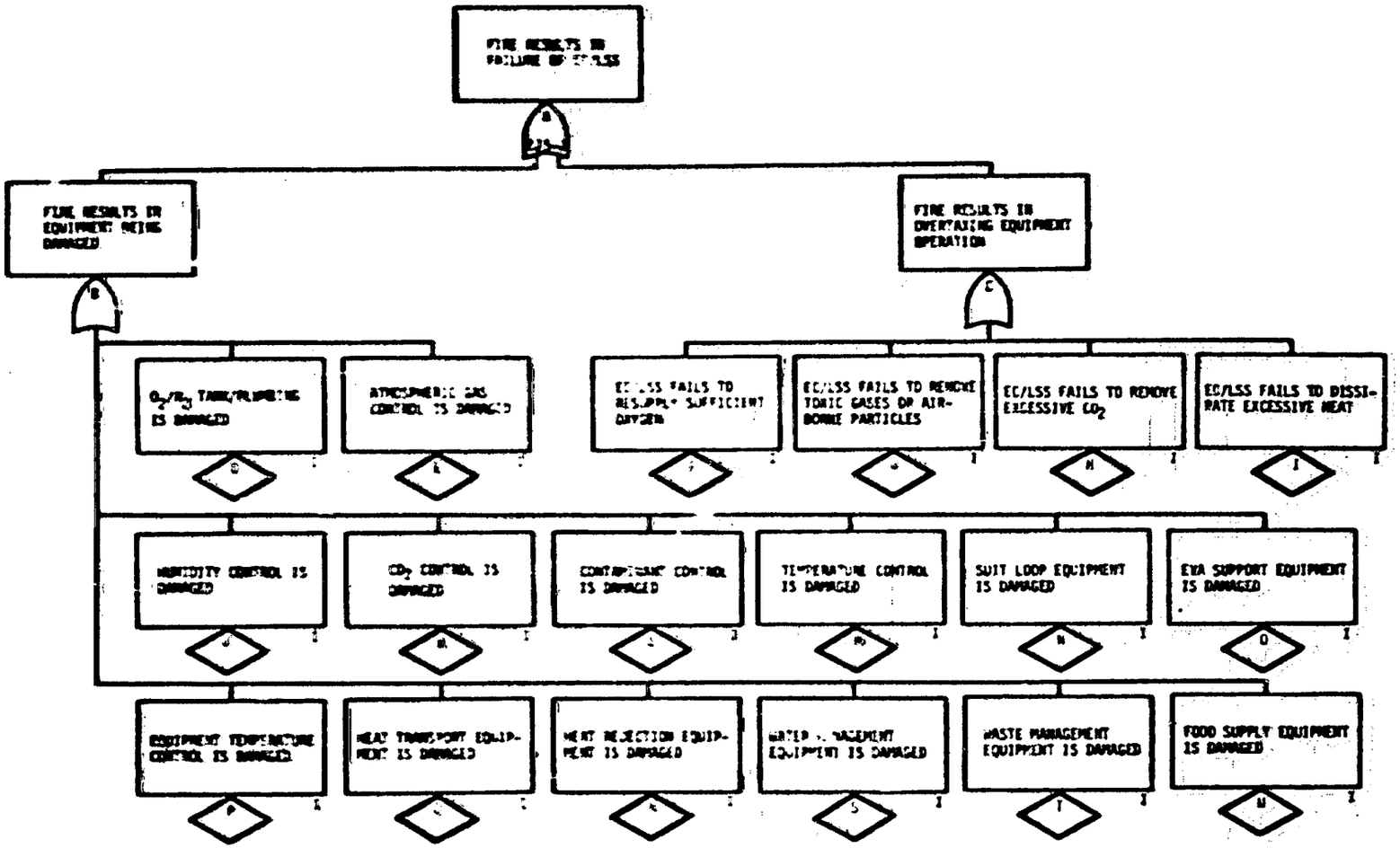
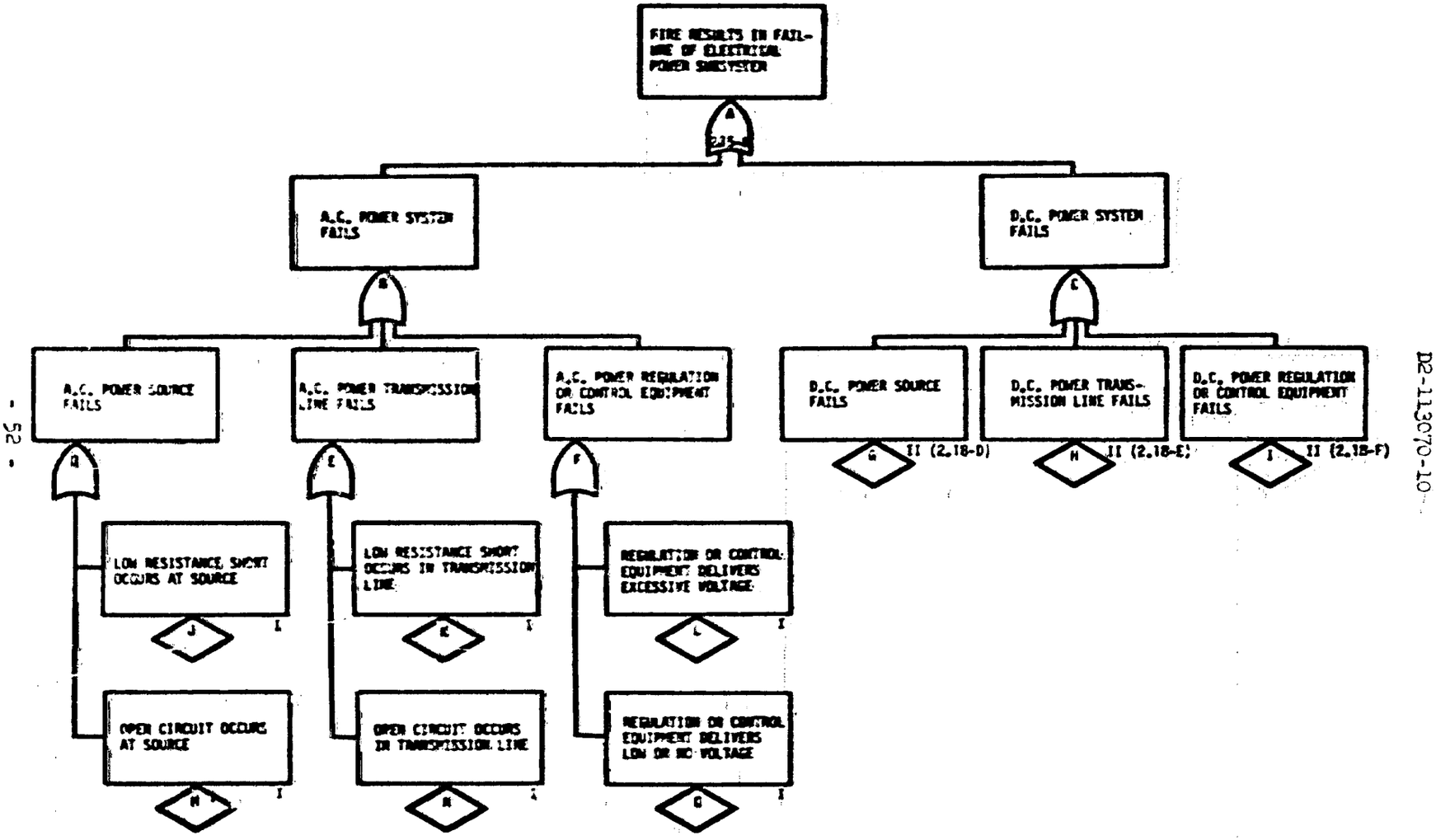

FIRE RESULTS IN FAILURE OF ECLSS
A
FIRE RESULTS IN EQUIPMENT BEING DAMAGED
B
FIRE RESULTS IN OVERTAXING EQUIPMENT OPERATION
C
$O_2/N_2$ TANK/PLUMBING IS DAMAGED
G
ATMOSPHERIC GAS CONTROL IS DAMAGED
L
ECLSS FAILS TO RESUPPLY SUFFICIENT OXYGEN
F
ECLSS FAILS TO REMOVE TOXIC GASES OR AIR-BORNE PARTICLES
H
ECLSS FAILS TO REMOVE EXCESSIVE $CO_2$
M
ECLSS FAILS TO DISSIPATE EXCESSIVE HEAT
I
HUMIDITY CONTROL IS DAMAGED
J
$CO_2$ CONTROL IS DAMAGED
K
CONTAMINANT CONTROL IS DAMAGED
H
TEMPERATURE CONTROL IS DAMAGED
P
SUIT LOOP EQUIPMENT IS DAMAGED
N
EVA SUPPORT EQUIPMENT IS DAMAGED
O
EQUIPMENT TEMPERATURE CONTROL IS DAMAGED
R
HEAT TRANSPORT EQUIPMENT IS DAMAGED
S
HEAT REJECTION EQUIPMENT IS DAMAGED
T
WATER MANAGEMENT EQUIPMENT IS DAMAGED
U
WASTE MANAGEMENT EQUIPMENT IS DAMAGED
V
FOOD SUPPLY EQUIPMENT IS DAMAGED
W

Chart No. 2.17

Chart No. 2.18


FIRE RESULTS IN FAILURE OF ELECTRICAL POWER SUBSYSTEM
A
.25
A.C. POWER SYSTEM FAILS
D.C. POWER SYSTEM FAILS
B
C
A.C. POWER SOURCE FAILS
A.C. POWER TRANSMISSION LINE FAILS
A.C. POWER REGULATION OR CONTROL EQUIPMENT FAILS
D.C. POWER SOURCE FAILS
D.C. POWER TRANSMISSION LINE FAILS
D.C. POWER REGULATION OR CONTROL EQUIPMENT FAILS
D
E
F
G II (2.18-D)
H II (2.18-E)
I II (2.18-F)
LOW RESISTANCE SHORT OCCURS AT SOURCE
LOW RESISTANCE SHORT OCCURS IN TRANSMISSION LINE
REGULATION OR CONTROL EQUIPMENT DELIVERS EXCESSIVE VOLTAGE
J
K
L
OPEN CIRCUIT OCCURS AT SOURCE
OPEN CIRCUIT OCCURS IN TRANSMISSION LINE
REGULATION OR CONTROL EQUIPMENT DELIVERS LOW OR NO VOLTAGE
M
N
O

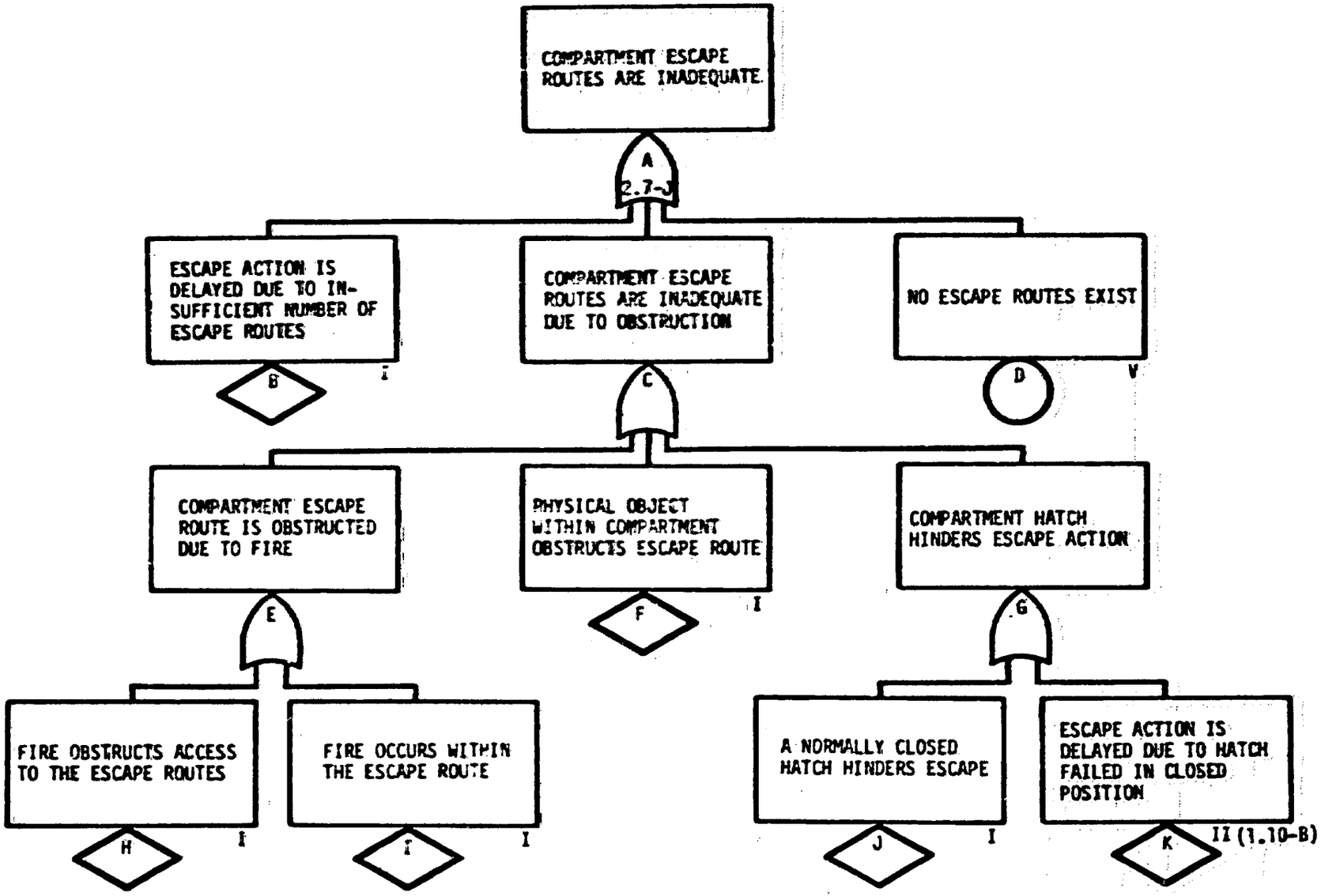
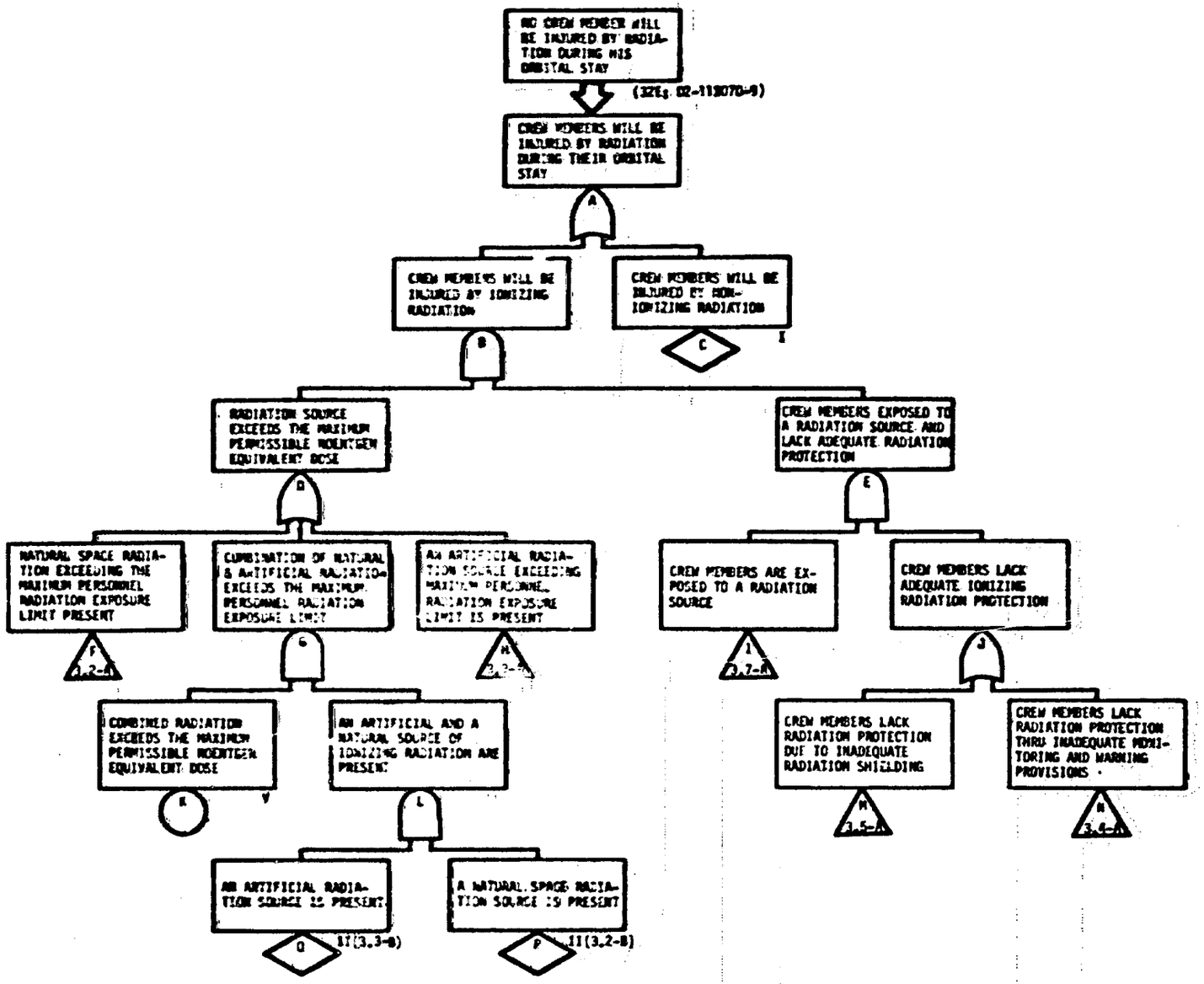

COMPARTMENT ESCAPE ROUTES ARE INADEQUATE
A
2.7-3
ESCAPE ACTION IS DELAYED DUE TO INSUFFICIENT NUMBER OF ESCAPE ROUTES
B
I
COMPARTMENT ESCAPE ROUTES ARE INADEQUATE DUE TO OBSTRUCTION
C
NO ESCAPE ROUTES EXIST
D
V
COMPARTMENT ESCAPE ROUTE IS OBSTRUCTED DUE TO FIRE
E
PHYSICAL OBJECT WITHIN COMPARTMENT OBSTRUCTS ESCAPE ROUTE
F
I
COMPARTMENT HATCH HINDERS ESCAPE ACTION
G
FIRE OBSTRUCTS ACCESS TO THE ESCAPE ROUTES
H
I
FIRE OCCURS WITHIN THE ESCAPE ROUTE
I
I
A NORMALLY CLOSED HATCH HINDERS ESCAPE
J
I
ESCAPE ACTION IS DELAYED DUE TO HATCH FAILED IN CLOSED POSITION
K
II (1.10-B)

Chart No. 2.29

## 5.3 FT-3, EVENTS RELATED TO RADIATION

Top events of the seven charts comprising this fault tree are listed below. Numbers in parentheses refer to the predecessor charts in which the events originated.

Chart No. 3.1


NO CREW MEMBER WILL BE INJURED BY RADIATION DURING HIS ORBITAL STAY
(SEE: D2-113070-9)
CREW MEMBERS WILL BE INJURED BY RADIATION DURING THEIR ORBITAL STAY
A
CREW MEMBERS WILL BE INJURED BY IONIZING RADIATION
CREW MEMBERS WILL BE INJURED BY NON-IONIZING RADIATION
B
C
RADIATION SOURCE EXCEEDS THE MAXIMUM PERMISSIBLE ROENTGEN EQUIVALENT DOSE
CREW MEMBERS EXPOSED TO A RADIATION SOURCE AND LACK ADEQUATE RADIATION PROTECTION
D
E
NATURAL SPACE RADIATION EXCEEDING THE MAXIMUM PERSONNEL RADIATION EXPOSURE LIMIT PRESENT
COMBINATION OF NATURAL & ARTIFICIAL RADIATION EXCEEDS THE MAXIMUM PERSONNEL RADIATION EXPOSURE LIMIT
AN ARTIFICIAL RADIATION SOURCE EXCEEDING MAXIMUM PERSONNEL RADIATION EXPOSURE LIMIT IS PRESENT
CREW MEMBERS ARE EXPOSED TO A RADIATION SOURCE
CREW MEMBERS LACK ADEQUATE IONIZING RADIATION PROTECTION
F
G
H
I
J
COMBINED RADIATION EXCEEDS THE MAXIMUM PERMISSIBLE ROENTGEN EQUIVALENT DOSE
AN ARTIFICIAL AND A NATURAL SOURCE OF IONIZING RADIATION ARE PRESENT
CREW MEMBERS LACK RADIATION PROTECTION DUE TO INADEQUATE RADIATION SHIELDING
CREW MEMBERS LACK RADIATION PROTECTION THRU INADEQUATE MONITORING AND WARNING PROVISIONS
K
L
M
N
AN ARTIFICIAL RADIATION SOURCE IS PRESENT
A NATURAL SPACE RADIATION SOURCE IS PRESENT
O
P
II(3.3-B)
II(3.2-B)

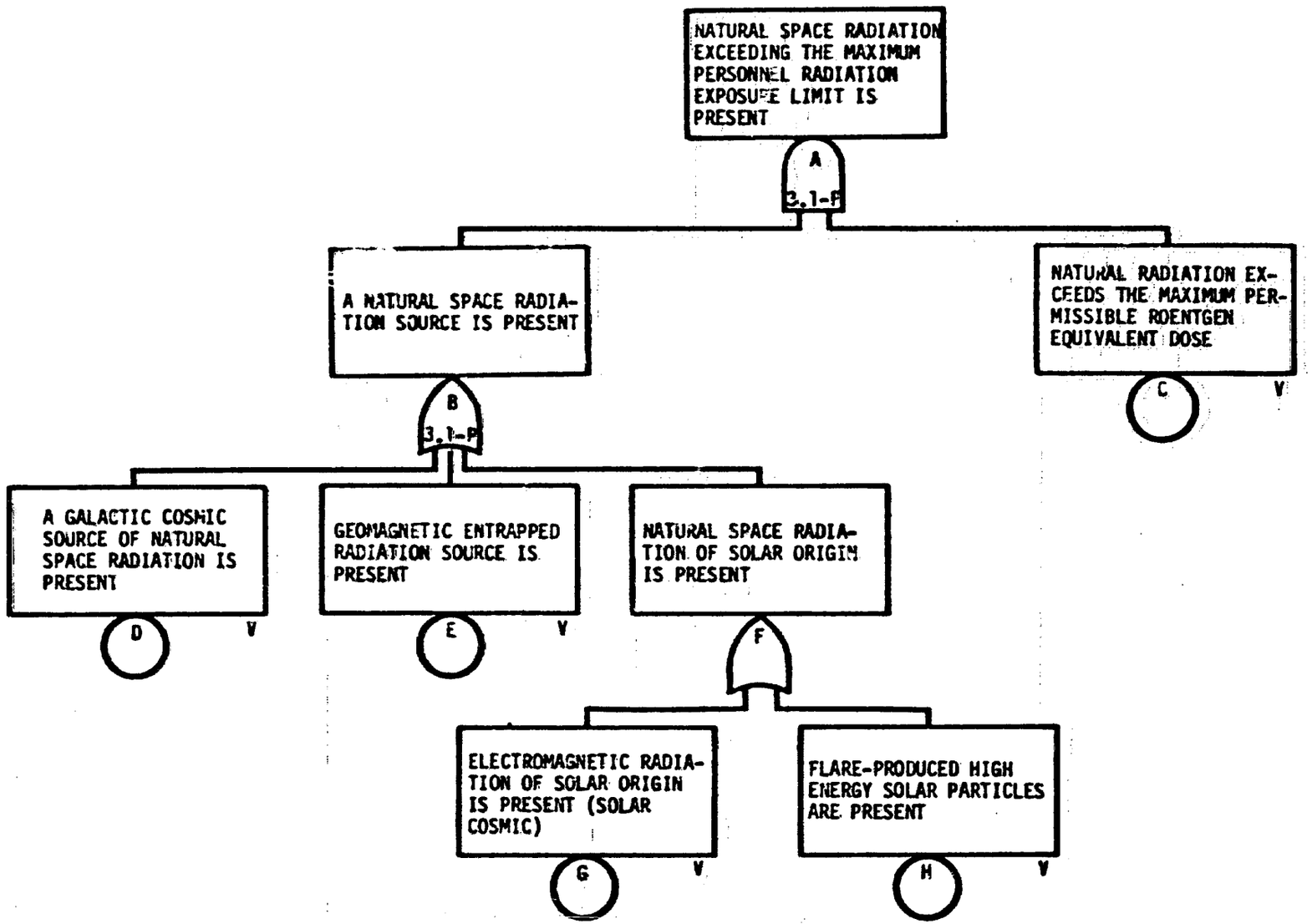
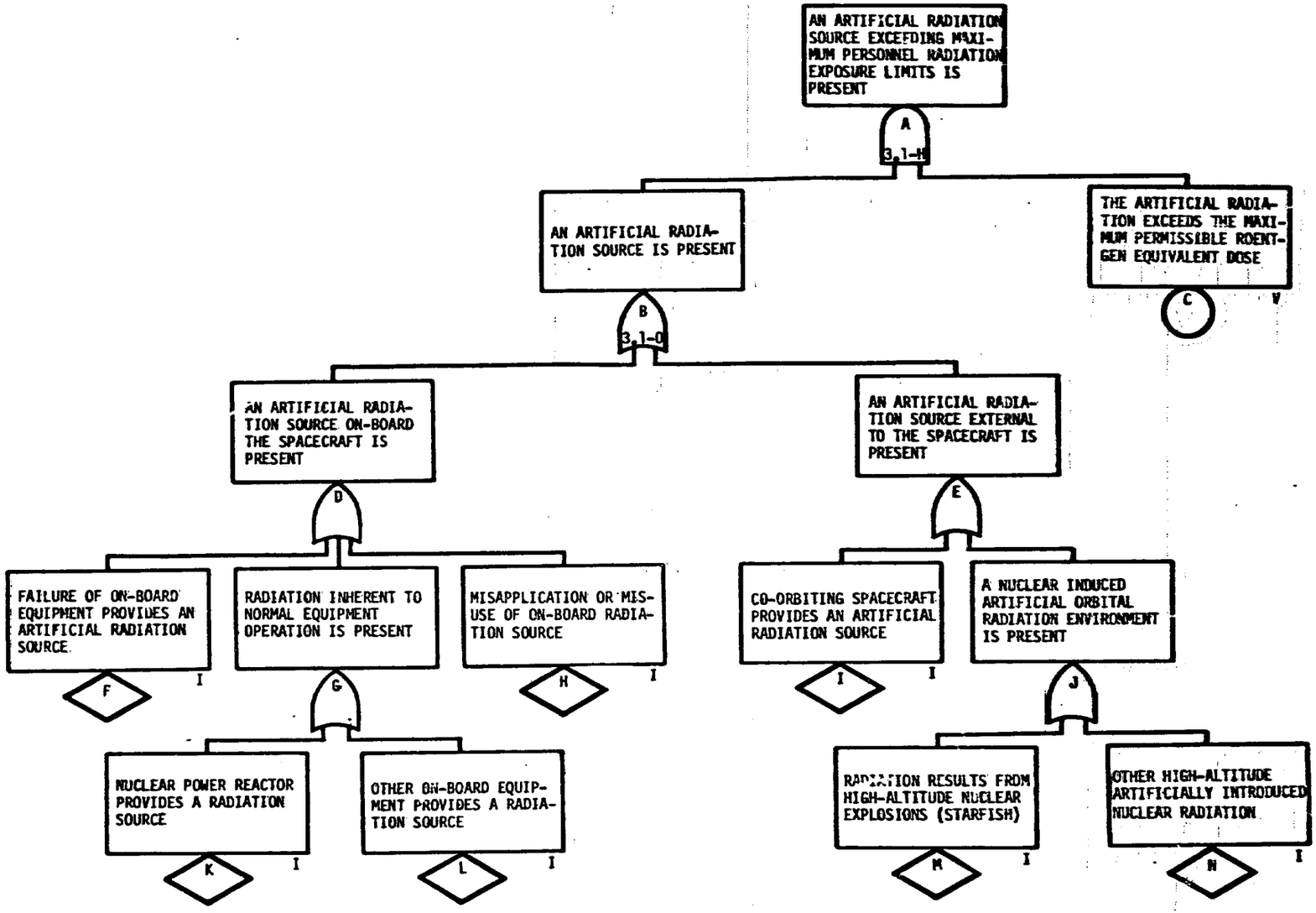

NATURAL SPACE RADIATION EXCEEDING THE MAXIMUM PERSONNEL RADIATION EXPOSURE LIMIT IS PRESENT
A
3.1-F
A NATURAL SPACE RADIATION SOURCE IS PRESENT
NATURAL RADIATION EXCEEDS THE MAXIMUM PERMISSIBLE ROENTGEN EQUIVALENT DOSE
C
V
B
3.1-F
A GALACTIC COSMIC SOURCE OF NATURAL SPACE RADIATION IS PRESENT
GEOMAGNETIC ENTRAPPED RADIATION SOURCE IS PRESENT
NATURAL SPACE RADIATION OF SOLAR ORIGIN IS PRESENT
D
V
E
V
F
ELECTROMAGNETIC RADIATION OF SOLAR ORIGIN IS PRESENT (SOLAR COSMIC)
FLARE-PRODUCED HIGH ENERGY SOLAR PARTICLES ARE PRESENT
G
V
H
V

Chart No. 3.2

Chart No. 3.3


AN ARTIFICIAL RADIATION SOURCE EXCEEDING MAXIMUM PERSONNEL RADIATION EXPOSURE LIMITS IS PRESENT
A
3.1-H
AN ARTIFICIAL RADIATION SOURCE IS PRESENT
THE ARTIFICIAL RADIATION EXCEEDS THE MAXIMUM PERMISSIBLE ROENTGEN EQUIVALENT DOSE
C
V
B
3.1-O
AN ARTIFICIAL RADIATION SOURCE ON-BOARD THE SPACECRAFT IS PRESENT
AN ARTIFICIAL RADIATION SOURCE EXTERNAL TO THE SPACECRAFT IS PRESENT
D
E
FAILURE OF ON-BOARD EQUIPMENT PROVIDES AN ARTIFICIAL RADIATION SOURCE
F
I
RADIATION INHERENT TO NORMAL EQUIPMENT OPERATION IS PRESENT
G
MISAPPLICATION OR MISUSE OF ON-BOARD RADIATION SOURCE
H
I
CO-ORBITING SPACECRAFT PROVIDES AN ARTIFICIAL RADIATION SOURCE
I
I
A NUCLEAR INDUCED ARTIFICIAL ORBITAL RADIATION ENVIRONMENT IS PRESENT
J
NUCLEAR POWER REACTOR PROVIDES A RADIATION SOURCE
K
I
OTHER ON-BOARD EQUIPMENT PROVIDES A RADIATION SOURCE
L
I
RADIATION RESULTS FROM HIGH-ALTITUDE NUCLEAR EXPLOSIONS (STARFISH)
M
I
OTHER HIGH-ALTITUDE ARTIFICIALLY INTRODUCED NUCLEAR RADIATION
N
I

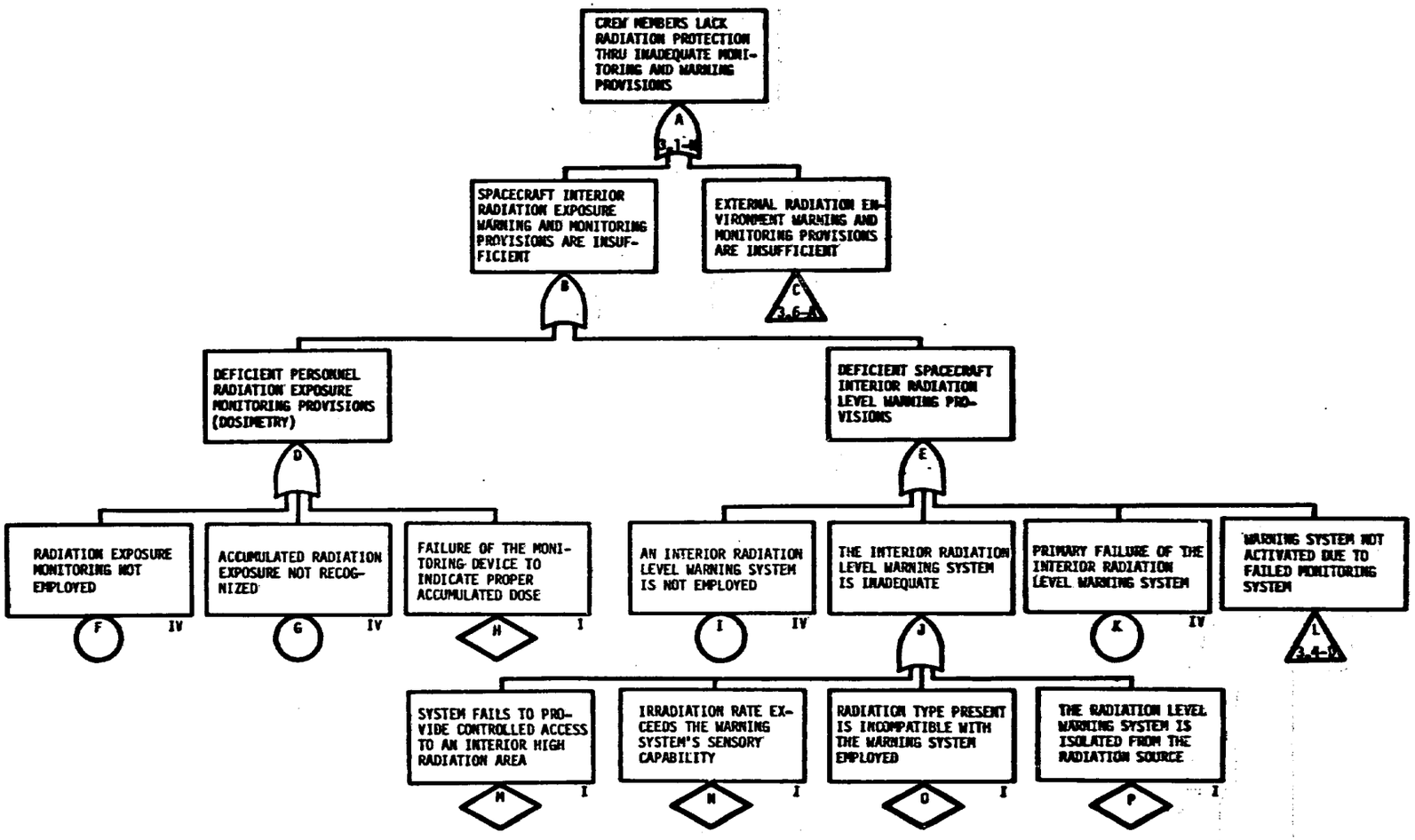
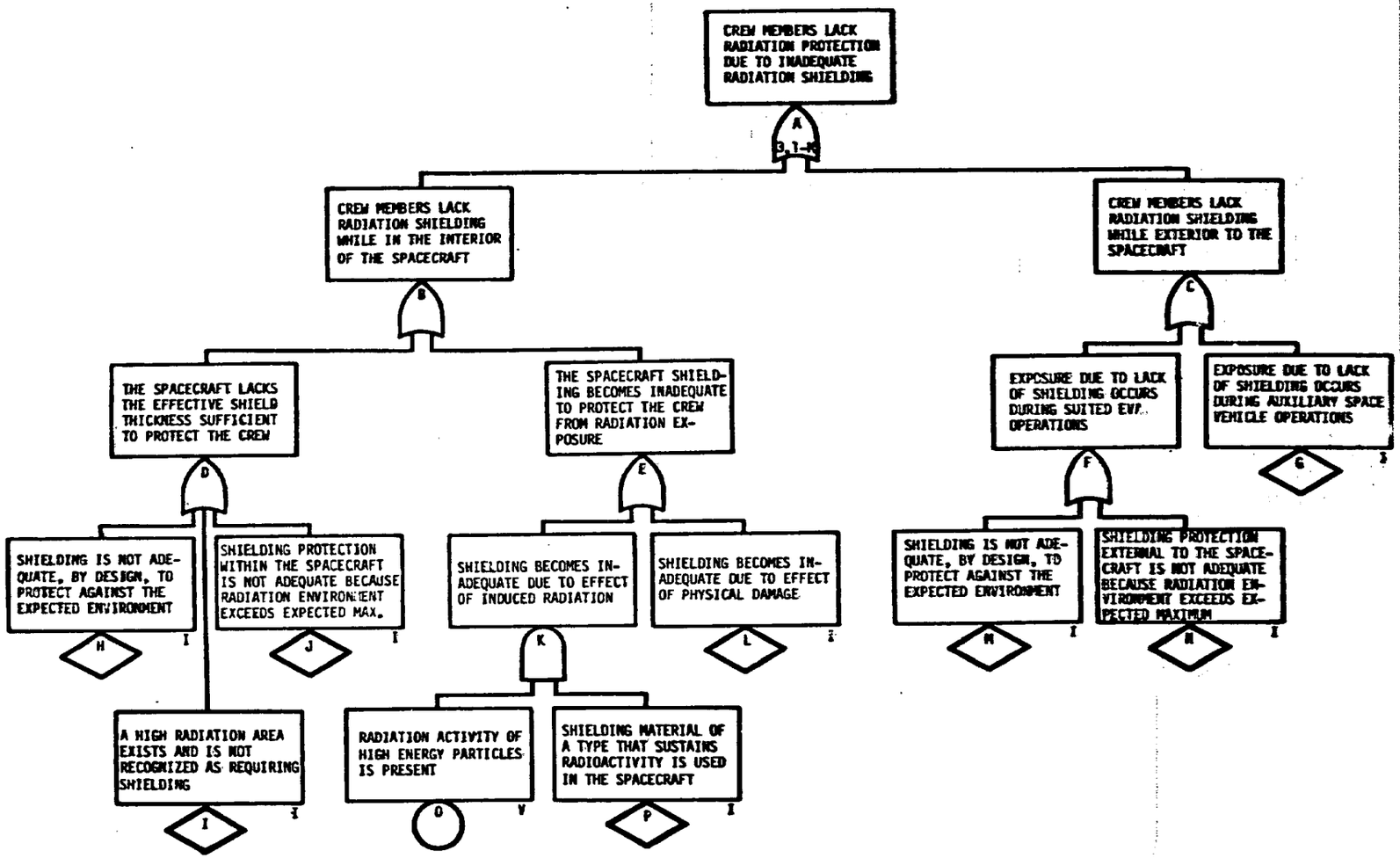

CREW MEMBERS LACK RADIATION PROTECTION THRU INADEQUATE MONITORING AND WARNING PROVISIONS
A
3.1-E
SPACECRAFT INTERIOR RADIATION EXPOSURE WARNING AND MONITORING PROVISIONS ARE INSUFFICIENT
EXTERNAL RADIATION ENVIRONMENT WARNING AND MONITORING PROVISIONS ARE INSUFFICIENT
C
3.6-A
B
DEFICIENT PERSONNEL RADIATION EXPOSURE MONITORING PROVISIONS (DOSIMETRY)
DEFICIENT SPACECRAFT INTERIOR RADIATION LEVEL WARNING PROVISIONS
D
E
RADIATION EXPOSURE MONITORING NOT EMPLOYED
F
IV
ACCUMULATED RADIATION EXPOSURE NOT RECOGNIZED
G
IV
FAILURE OF THE MONITORING DEVICE TO INDICATE PROPER ACCUMULATED DOSE
H
I
AN INTERIOR RADIATION LEVEL WARNING SYSTEM IS NOT EMPLOYED
I
IV
THE INTERIOR RADIATION LEVEL WARNING SYSTEM IS INADEQUATE
J
PRIMARY FAILURE OF THE INTERIOR RADIATION LEVEL WARNING SYSTEM
K
IV
WARNING SYSTEM NOT ACTIVATED DUE TO FAILED MONITORING SYSTEM
L
3.4-V
SYSTEM FAILS TO PROVIDE CONTROLLED ACCESS TO AN INTERIOR HIGH RADIATION AREA
M
I
IRRADIATION RATE EXCEEDS THE WARNING SYSTEM'S SENSORY CAPABILITY
N
I
RADIATION TYPE PRESENT IS INCOMPATIBLE WITH THE WARNING SYSTEM EMPLOYED
O
I
THE RADIATION LEVEL WARNING SYSTEM IS ISOLATED FROM THE RADIATION SOURCE
P
I

Chart No. 3.4


CREW MEMBERS LACK RADIATION PROTECTION DUE TO INADEQUATE RADIATION SHIELDING
A
3.1-K
CREW MEMBERS LACK RADIATION SHIELDING WHILE IN THE INTERIOR OF THE SPACECRAFT
B
CREW MEMBERS LACK RADIATION SHIELDING WHILE EXTERIOR TO THE SPACECRAFT
C
THE SPACECRAFT LACKS THE EFFECTIVE SHIELD THICKNESS SUFFICIENT TO PROTECT THE CREW
D
THE SPACECRAFT SHIELDING BECOMES INADEQUATE TO PROTECT THE CREW FROM RADIATION EXPOSURE
E
EXPOSURE DUE TO LACK OF SHIELDING OCCURS DURING SUITED EVA OPERATIONS
F
EXPOSURE DUE TO LACK OF SHIELDING OCCURS DURING AUXILIARY SPACE VEHICLE OPERATIONS
G
SHIELDING IS NOT ADEQUATE, BY DESIGN, TO PROTECT AGAINST THE EXPECTED ENVIRONMENT
H
I
SHIELDING PROTECTION WITHIN THE SPACECRAFT IS NOT ADEQUATE BECAUSE RADIATION ENVIRONMENT EXCEEDS EXPECTED MAX.
J
I
A HIGH RADIATION AREA EXISTS AND IS NOT RECOGNIZED AS REQUIRING SHIELDING
I
I
SHIELDING BECOMES INADEQUATE DUE TO EFFECT OF INDUCED RADIATION
K
SHIELDING BECOMES INADEQUATE DUE TO EFFECT OF PHYSICAL DAMAGE
L
I
RADIATION ACTIVITY OF HIGH ENERGY PARTICLES IS PRESENT
O
V
SHIELDING MATERIAL OF A TYPE THAT SUSTAINS RADIOACTIVITY IS USED IN THE SPACECRAFT
P
I
SHIELDING IS NOT ADEQUATE, BY DESIGN, TO PROTECT AGAINST THE EXPECTED ENVIRONMENT
M
I
SHIELDING PROTECTION EXTERNAL TO THE SPACECRAFT IS NOT ADEQUATE BECAUSE RADIATION ENVIRONMENT EXCEEDS EXPECTED MAXIMUM
N
I

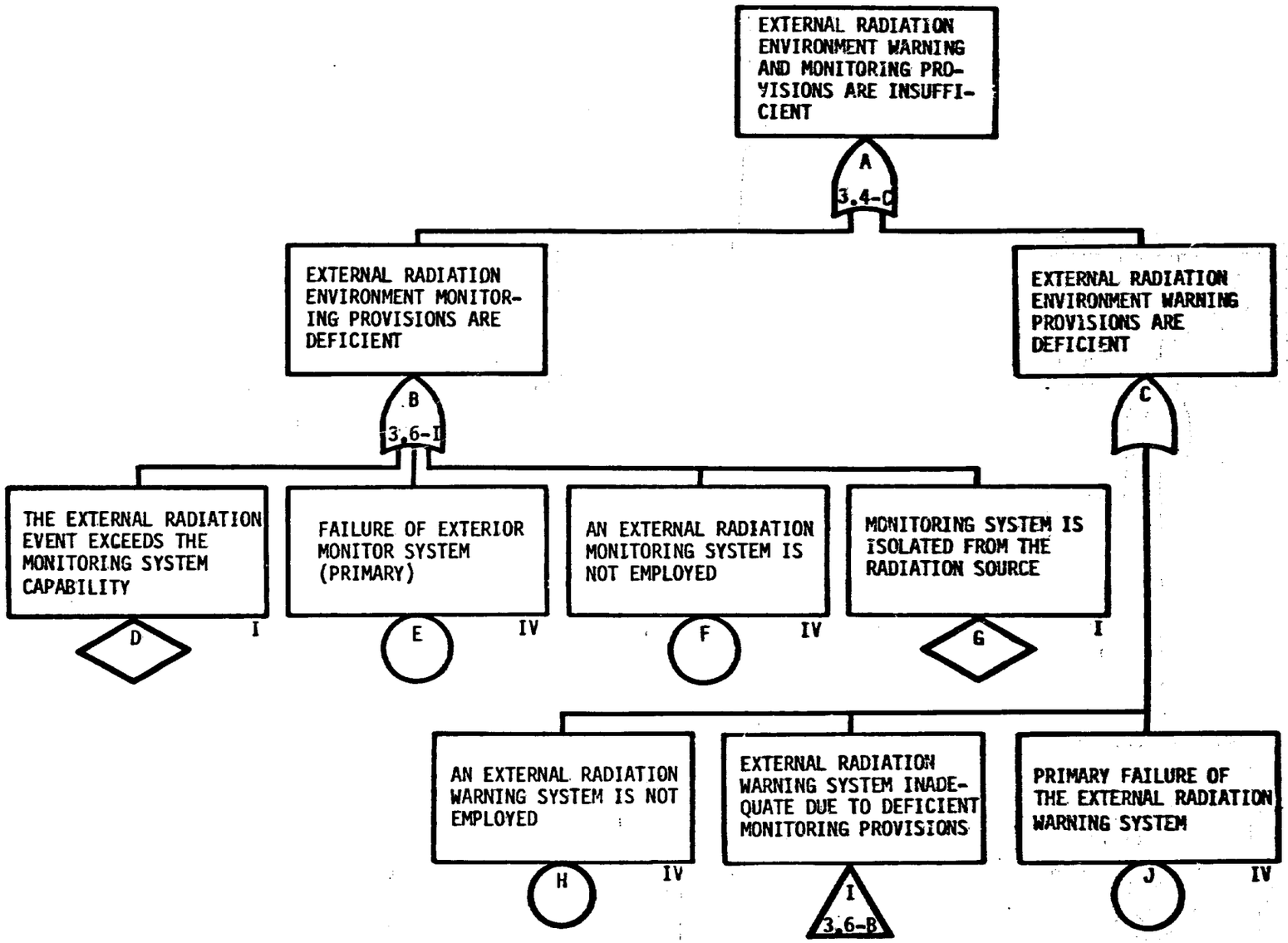
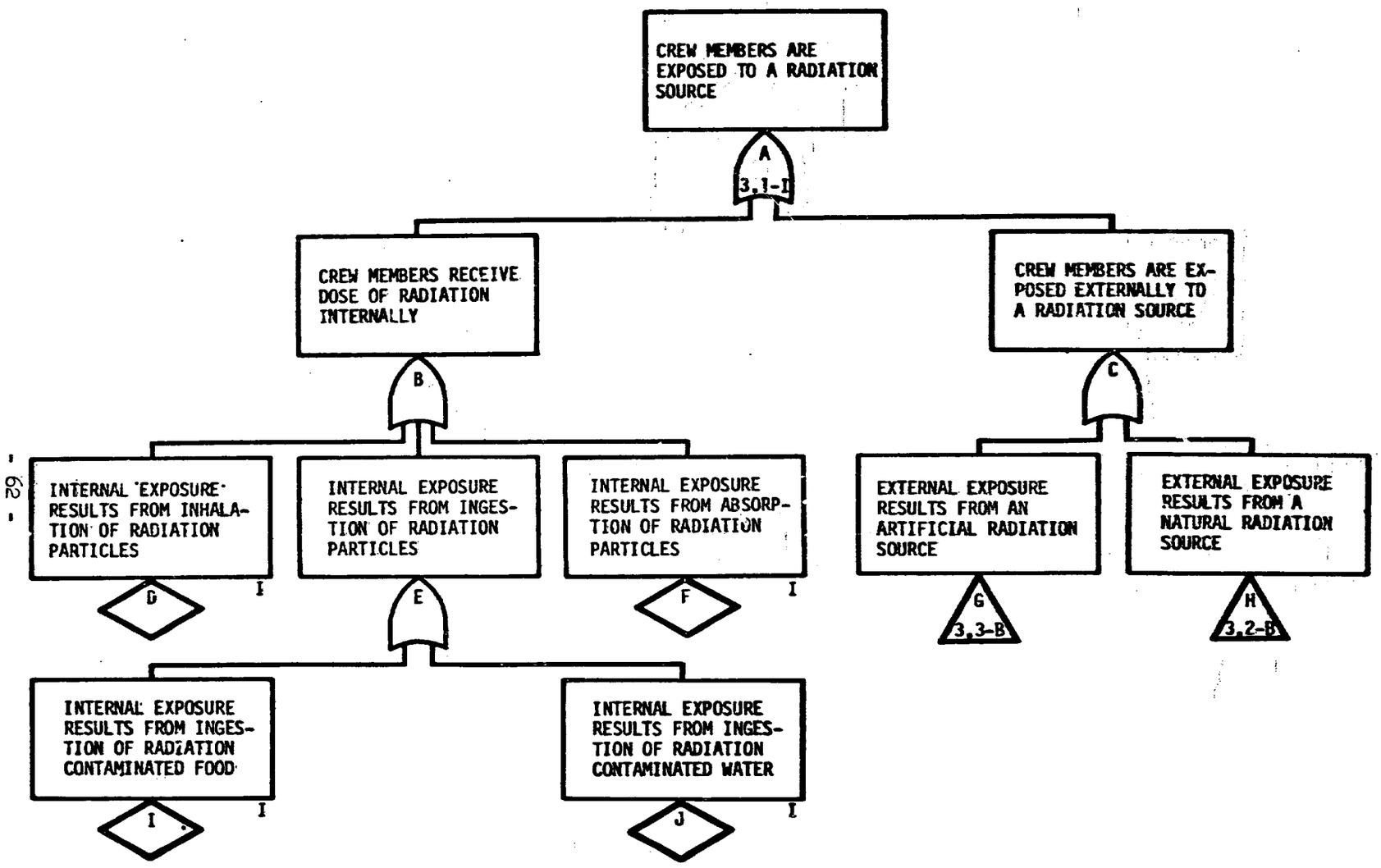

EXTERNAL RADIATION ENVIRONMENT WARNING AND MONITORING PROVISIONS ARE INSUFFICIENT
A
3.4-C
EXTERNAL RADIATION ENVIRONMENT MONITORING PROVISIONS ARE DEFICIENT
B
3.6-I
EXTERNAL RADIATION ENVIRONMENT WARNING PROVISIONS ARE DEFICIENT
C
THE EXTERNAL RADIATION EVENT EXCEEDS THE MONITORING SYSTEM CAPABILITY
D
I
FAILURE OF EXTERIOR MONITOR SYSTEM (PRIMARY)
E
IV
AN EXTERNAL RADIATION MONITORING SYSTEM IS NOT EMPLOYED
F
IV
MONITORING SYSTEM IS ISOLATED FROM THE RADIATION SOURCE
G
I
AN EXTERNAL RADIATION WARNING SYSTEM IS NOT EMPLOYED
H
IV
EXTERNAL RADIATION WARNING SYSTEM INADEQUATE DUE TO DEFICIENT MONITORING PROVISIONS
I
3.6-B
PRIMARY FAILURE OF THE EXTERNAL RADIATION WARNING SYSTEM
J
IV

Chart No. 3.6

Chart No. 3.7


CREW MEMBERS ARE EXPOSED TO A RADIATION SOURCE
A
3,1-I
CREW MEMBERS RECEIVE DOSE OF RADIATION INTERNALLY
CREW MEMBERS ARE EXPOSED EXTERNALLY TO A RADIATION SOURCE
B
C
INTERNAL EXPOSURE RESULTS FROM INHALATION OF RADIATION PARTICLES
INTERNAL EXPOSURE RESULTS FROM INGESTION OF RADIATION PARTICLES
INTERNAL EXPOSURE RESULTS FROM ABSORPTION OF RADIATION PARTICLES
EXTERNAL EXPOSURE RESULTS FROM AN ARTIFICIAL RADIATION SOURCE
EXTERNAL EXPOSURE RESULTS FROM A NATURAL RADIATION SOURCE
D
I
E
F
I
G
3,3-B
H
3,2-B
INTERNAL EXPOSURE RESULTS FROM INGESTION OF RADIATION CONTAMINATED FOOD
INTERNAL EXPOSURE RESULTS FROM INGESTION OF RADIATION CONTAMINATED WATER
I
I
J
I

## 6.0 REFERENCES

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