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COMCAN — A COMPUTER PROGRAM FOR COMMON CAUSE ANALYSIS

PREPARED BY AEROJET NUCLEAR COMPANY FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
IDAHO OPERATIONS OFFICE UNDER CONTRACT E(10-1) -1375

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COMCAN – A COMPUTER PROGRAM FOR COMMON CAUSE ANALYSIS

by

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ABSTRACT

This report is the user's manual for COMCAN, a computer program for locating possible common causes for the failure of fault tree minimal cut sets. The program is written in FORTRAN IV for the IBM 360/75 computer.

SUMMARY

The computer program, COMCAN, searches the fault tree minimal cut sets for shared susceptibility to various secondary events (common causes) and common links between components. In the case of common causes, a location check may also be performed by COMCAN to determine whether barriers to the common cause exist between components. The program can locate common manufacturers of components having events in the same minimal cut set. A relative ranking scheme for secondary event susceptibility is included in the program.

Input required by the computer program consists of:

(1) Basic event descriptors for events appearing in a minimal cut set of the fault tree to be analyzed

(2) The generic common cause susceptibility of each event appearing in a minimal cut set

(3) The minimal cut sets from the fault tree.

Optional inputs to the program include:

(1) The manufacturer of each component with an event appearing in a minimal cut set

(2) A barrier map delineating common locations for various possible common causes

(3) The location of each component with an event in a minimal cut set from the tree to be analyzed

(4) Numbers in the range zero to nine indicating the relative ranking of the susceptibility of the cut set to the common cause.

Input flags are used to control the output of:

(1) A list of all minimal cut sets with a common cause or which contain events from similar components

(2) A list of all minimal cut sets with a common cause and which also contain events from similar components.

Keywords may be used to control the printout of input items for checking the correctness of the input.

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COMCAN – A COMPUTER PROGRAM FOR COMMON CAUSE ANALYSIS

I. INTRODUCTION AND DEFINITIONS

Analysis of common cause events is part of system reliability and safety analysis. A common cause event, sometimes called a common mode failure, is a secondary cause that may contribute to the development of more than one component malfunction. Although common cause events have been of considerable concern in practice, only a small portion of the literature has been devoted to this subject – the reason being that without a well-defined structure, study of common cause events is not generally tractable. Report II of Reference 1 describes the techniques which form the basis for the COMCAN computer program. Portions of that report are reproduced here to make this document more self-contained.

Definitions of several terms are necessary. A significant common cause event is a secondary cause that is common to all the basic events in one or more minimal cut sets[2]. The minimal cut set for which the significant cause event is applicable is called a common cause candidate. In addition, if all the components represented by the basic events in that minimal cut set share a "common location", that minimal cut set is called a prime common cause candidate. Components share a common location if no barriers that are capable of insulating the components from the secondary cause are present. Components may share a common location irrespective of the physical distance separating them.

By limiting the study to the fault tree minimal cut sets, the analysis for common causes becomes tractable because

(1) No additional basic events need to be added to the logic model

(2) No additional minimal cut sets result

(3) Analysis for common causes becomes an option that can be exercised, without preplanning, after other types of analyses are complete

(4) Computer-aided analysis can be used advantageously.

The methods presented in this report are concerned with (1) locating common cause candidates and prime common cause candidates and (2) identifying the associated significant common cause events.

On occasion, a significant common cause event may not be specified for a prime common cause candidate, but rather the identification of the prime common cause candidate is based solely on a "common link condition". A common link is a condition that closely links all the basic events in the minimal cut set. The probability that the condition exists at the time of analysis is assumed to be unity. For example, all components indicated by the basic events in a minimal cut set being produced by the same manufacturer is a common link condition. The prime common cause candidate is then identified without concern for common location. Other common link conditions arise from components being close together in a common location or having some other definable dependencies. Components in the same electrical circuit, chemical flow loop, or even tightly clustered in a cabinet can give rise to prime common cause candidates as a result of common link conditions rather than as the result of secondary cause susceptibility and location of each component.

In Section II of this report are introduced the subjects of generic classification, common links, and tabulation of secondary causes of component malfunctions and conditions that can result in prime common cause candidates. In Section III are details on constructing domains. A tutorial common cause evaluation is presented in Section IV. Section V presents a program description wherein the input format for the computer program is described. Contained in the appendixes are a sample problem fault tree, sample basic event coding tables, the job control language used for COMCAN with the IBM 360/75 computer at the Idaho National Engineering Laboratory, and inputs and outputs for the sample problem fault tree.

II. CONCEPTS OF COMMON CAUSE ANALYSIS

A tremendous number of secondary failure causes are possible. As a result the analysis is subject to omissions or redundancies (representing the same failure mode by different sources, for example, including both "water hammer" and "pipe whip"). Redundancy can largely be eliminated by listing only generic causes (each cause represents a class of conditions or secondary failure causes) and common linking conditions. Omissions can be minimized by organizing the generic causes into natural groupings, or categories, which aids in the selection of entries for the list; the basis for the formation of these categories is the nature of the generic cause. In addition, breaking up the list into these categories not only helps the analyst by reducing his field of consideration, but it greatly simplifies the computer search techniques. The purpose here is not to break the causes down so finely that physical meaning is lost, but rather to eliminate redundancy (for example, by combining "fire" and "high temperature" or "flood" and "moisture").

COMCAN uses the fault tree minimal cut sets as input rather than the addition of secondary events to the fault tree. It is, after all, the occurrence of events in a minimal cut set that causes the TOP event to occur. To attach additional events to the tree is not necessary.

The computer aid, COMCAN, requires the analyst to consider only the most significant generic causes in each of three broad categories (mechanical-thermal, electrical-radiation, chemical-miscellaneous) and common linking conditions for each failure event. A suggested generic list by category, which can be easily updated without methodology modification, is given in Tables I through III. A suggested list of common links is given in Table IV.

Using the Tables of Generic Causes and Common Links (Table I through IV), the analyst chooses those causes applicable to his analysis, adds quantifying details (for example, "temperature over 800°F"), and combines where desired (for example, "conducting medium", "oxidation", and "high temperature" to represent "steam", or "impact" and "vibration" to represent "earthquake"). Where a combination is used, a new unique code letter must be assigned (Section V.4, Generic Cause Susceptibility Input).

The common link category allows the analyst to account for common link conditions existing in a system that increase the probability of a number of components failing. These conditions are conceptually different from the secondary cause susceptibility categories.

No significant common cause event is given for the prime common cause candidate identified on the basis of these common links. For example, if all the components indicated by a minimal cut set lie in the same electrical circuit, the

TABLE I

GENERIC CAUSES OF A MECHANICAL OR THERMAL NATURE

Symbol	Generic Cause	Example Sources
I	Impact	Pipe whip, water hammer, missiles, earthquake, structural failure
V	Vibration	Machinery in motion, earthquake
P	Pressure	Explosion, out-of-tolerance system changes (pump overspeed, flow blockage)
G	Grit	Airborne dust, metal fragments generated by moving parts with inadequate tolerances
S	Stress	Thermal stress at welds of dissimilar metals, thermal stresses and bending moments caused by high conductivity and density of liquid sodium
T	Temperature	Fire, lightning, welding equipment, cooling system faults, electrical short circuits

TABLE II

GENERIC CAUSES OF AN ELECTRICAL OR RADIATION NATURE

Symbol	Generic Cause	Example Sources
E	Electromagnetic interference (EMI)	Welding equipment, rotating electrical machinery, lightning, power supplies, transmission lines
R	Radiation damage	Neutron sources, sources of ionizing radiation
M	Conducting medium	Moisture, conductive gases
V	Out-of-tolerance voltage	Power surge
I	Out-of-tolerance current	Short circuit

TABLE III

GENERIC CAUSES OF A CHEMICAL OR MISCELLANEOUS NATURE

Symbol	Generic Cause	Sample Sources
A	Corrosion (acid)	Boric acid from neutron control systems, acid used in maintenance for removing rust and cleaning
O	Corrosion (oxidation)	In a water medium or around high temperature metals (for example, filaments)
R	Other chemical reactions	Galvanic corrosion; the complex interactions of fuel cladding, water, oxide fuel, and fission products; leaching of carbon from stainless steel by sodium
C	Carbonization	Oil in liquid sodium
B	Biological hazards	Poisonous gases, explosions, missiles

Sodium-water and sodium-air reactions have been left out of the table because the resulting failure modes can be represented by other generic causes: temperature and biological hazards. However, the analyst, for clarity, may expand the table to include sodium reactions.

resulting interdependence creates a prime common cause candidate on the basis of this situation alone with no significant common cause event specified. Subsequently, no checking is carried out of location for any common cause candidate based on this category.

Detailed treatment of these common links is the key to a meaningful common cause analysis. The treatment often requires that attention be given to subtle aspects of the system. For example, two subsystems may appear safe because they are separated, but they may share parallel functions. These parallel functions may cause the subsystems to be subject to the same secondary causes. Specifically, the coolant loops on a reactor may be located physically apart but may share the same test, maintenance, and operation procedures (Table IV). A maintenance man (using the wrong oil, for instance) working on both subsystems may circumvent the design redundancy.

An example of the proper use of the maintenance common link would be to include only those failure events for which the failure probability is significantly increased by faulty maintenance or lack of maintenance. Passive elements (pipes, vessels), for instance, are not greatly affected by maintenance, but some active elements (instrumentation and controls) are affected.

TABLE IV

COMMON LINKS RESULTING IN DEPENDENCE BETWEEN COMPONENTS

Symbol	Common Link	Example situations that can result in system failure when all basic events in a minimal cut set share the common link
E	Energy source	Common drive shaft, same power supply
C	Calibration	Misprinted calibration instructions
F	Manufacturer	Repeated fabrication error, such as neglect to properly coat relay contacts
I	Installation contractor	Same subcontractor or crew
M	Maintenance	Incorrect procedure, inadequately trained person
O	Operator or operation	Operator disabled or overstressed, faulty operating procedures
P	Proximity	Location of all components of a cut set in one cabinet (common location exposes all of the components to many unspecified common causes)
T	Test procedure	Faulty test procedures which may affect all components normally tested together
N	Energy flow paths	Location in same hydraulic loop, location in same electrical circuit
S	Similar parts	Important in the case of minimal cut sets which contain only pumps, only valves, etc.

III. DETAILS ON CONSTRUCTING DOMAINS

A domain is a geographic area, divided and subdivided to indicate barriers against a particular secondary cause. Most buildings contain barriers. Walls, floors, and cabinets are common ones. An oil spill would generally be confined to the room in which the spill occurred. Vibration from a large compressor, on the other hand, may affect every room in the building. Acid vapors may become distributed throughout several rooms by the air conditioning system, or a maintenance error may affect the entire plant. Thus, most secondary causes have a distinct domain because boundaries which are capable of containing one cause often cannot contain another. As an example, Figure 1 represents the basic floor plan of the second floor of Building C. The rooms are labeled with their actual room numbers, the storage cabinets in Room 206 are represented by "A" and "B", and when appropriate (that is, equipment is located there), hallways may be labeled with unique numbers.

The map represented by Figure 1 must present the finest resolution of areas recognized in all the secondary cause domains. However, for a specific secondary cause, not all the boundaries indicated by the map will necessarily be applicable. For example, the wall between Rooms 208 and 210 may be a barrier against an oil

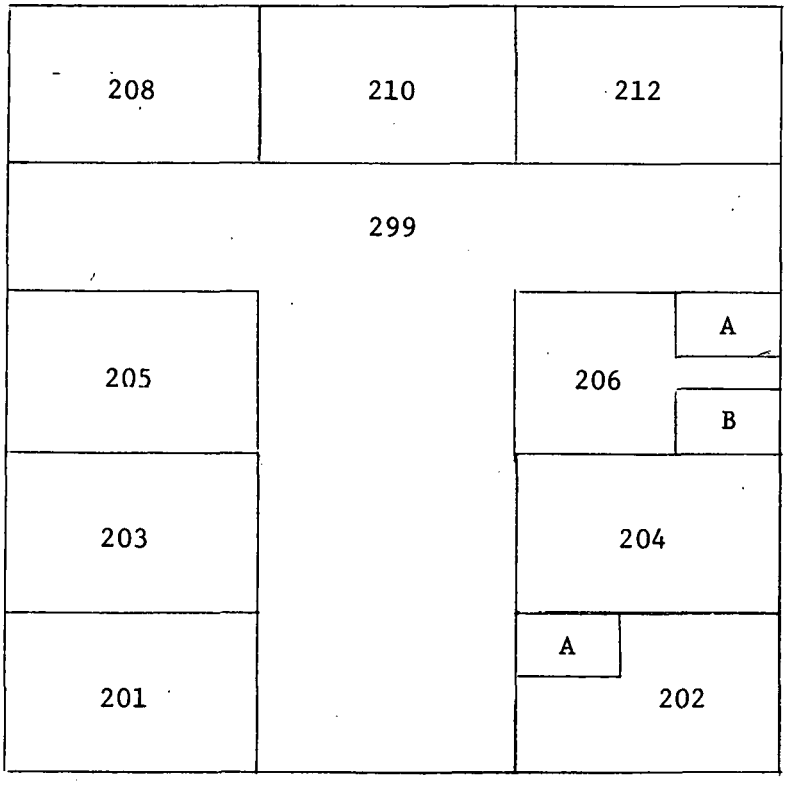

Fig. 1 Basic floor plan of the second floor of Building C.

spill but not against a fire. Therefore, through use of the map, a domain is constructed for each secondary cause. A domain usually does not have as fine a resolution as a map. These domains are part of the input to the computer program. The map (Figure 1) is only an aid to the analyst during formation of the domains.

As an example of a domain from the map in Figure 1, the only barriers against "conducting medium" surround Rooms 201 and 212 and Cabinet 206A. Therefore, the domain for this secondary cause is

Input data	Area 1	201
	Area 2	202, 202A, 203, 204, 205, 206, 206B, 208, 210, 299
	Area 3	206A
	Area 4	212

In practice, for a given secondary cause, every room in a building can easily be represented in a single domain which can be compactly stored in the computer.

IV. TUTORIAL COMMON CAUSE EVALUATION

In this sample problem only one minimal cut set is considered. Table V is a tabulation of all the generic cause susceptibilities for the particular minimal cut set containing basic events B, C, D, F, and H. This table would be formed internally by the computer upon determination that the combination of basic events B, C, D, F, and H is a minimal cut set. Tables I through IV may be used to decode the information given in Table V.

The computer selects the first generic cause susceptibility of Basic Event B: I (impact) in the mechanical-thermal category. The other minimal cut set members are checked to determine whether this susceptibility is shared. If any minimal cut set member does not share the susceptibility, the generic cause (impact) cannot be a significant common cause event. Basic Event D is found not to be susceptible to failure from impact. The process is repeated for all the generic cause susceptibilities of Basic Event B in the first category, comparing only within that category. Generic Cause G (grit) is found to be a significant common cause event; hence the minimal cut set is a common cause candidate. Categories 2 and 3 are searched in a similar manner, but no further significant common cause events are determined based on secondary causes. A check must now be made to determine whether the cut set is a prime common cause candidate by determining whether basic event components are in the same location with respect to grit. For example, if the domain for grit is known to be:

Area 1	A100A, A100B, A100C, A100, A102, A102A, A101, A103, A107
Area 2	A102B

then since all the basic event components are in Area 1, the cut set is a prime common cause candidate with the significant common cause event being grit.

A search of Category 4 shows that "Maintenance Man 2" services all the components in this cut set. Therefore, the cut set is also a prime common cause candidate based on this condition.

A summary of these findings is given below.

Prime Common Cause Candidate	Generic Cause
(B, C, D, F, H)	Grit (significant common cause event)
(B, C, D, F, H)	Maintenance (significant common link condition)

TABLE V

SAMPLE CUT SET EVALUATION

			Generic Cause Susceptibility			
	Location		Category 1	Category 2	Category 3	Category 4
Basic Event B	A102A		ITSG	R	A	M2
Basic Event C	A103		IG			E1M2
Basic Event D	A103		G	VR	A	M2C3
Basic Event F	A100C		IG	M		M2
Basic Event H	A103		STIG	ER		M2E1

Once the output is made available, the analyst applies it to improve the system safety. The analyst, aware of these common cause threats and aided by his knowledge of the system, investigates ways to improve the system. He may protect the system from the grit-susceptible cut set by erecting dustproof partitions between components of the cut set or by installing grit-proof components (for example, by replacing unshielded relays with those having molded casings).

To avoid the maintenance common link, special procedures may be formulated to ensure that no single maintenance person services all components of this cut set.

The main object of this analysis is not to predict probability of failure due to common cause, but rather to indicate weak points in the system and to suggest corrective action.

V. PROGRAM DESCRIPTION

The format to be used for the computer program COMCAN is compatible with the input format used with computer programs for qualitative and quantitative reliability and safety analyses such as PREP[3], KITT[3], and MOCUS[4]. On the sample coding form for COMCAN, given in Figure 2, Columns 9 through 45 are left for use with these codes and are not used in COMCAN. Columns 51 and 55 are not used either. In addition to input cards described by this form, COMCAN uses domain definition cards, cut set description cards, cause ranking cards, generic cause table cards, and various option cards, described in Section V.5 through V.9, respectively. The coding form of Figure 2 is used to input basic event description, location, manufacturer, and generic cause susceptibilities only. These inputs are described in the following four sections. A COMCAN flow chart appears in Figure 3 (page 18).

1. BASIC EVENT DESCRIPTION INPUT

An eight-character computer word in Columns 1 through 8 represents the basic event. This basic event name involves a system code (electrical power, reactor, reactor protection, etc.), component type code (air-operated valve, diesel, pipe, etc.), component identifier (to render each component distinct), and fault mode code (does not close, rupture, short, etc.). For example, the event name, LAMA108Q, would be interpreted as follows:

L	Amplifier	A108	Short to power
Electrical power	AM	Amplifier #08 on Chart #A1	Q

The system code, component type code, and fault mode code are explained in Appendix B. The component identifier code is specified by the analyst. The analyst may employ the basic event identification of his choice, but the code of Appendix B was selected because it is convenient and consistent with the Reactor Safety Study[5].

2. LOCATION INPUT

The physical location of the basic event components is the key to obtaining the prime common cause candidates from common cause candidates. Representing the location of the component in a computer code format can be a tedious task. If the analyst chooses not to use this location option, then all components are assumed to be in the same location. Prime common cause candidates are then minimal cut sets having a significant common cause event. Columns 46 through 50 may contain a five-character alphanumeric location code. If fewer then five characters are used, left adjustment is necessary.

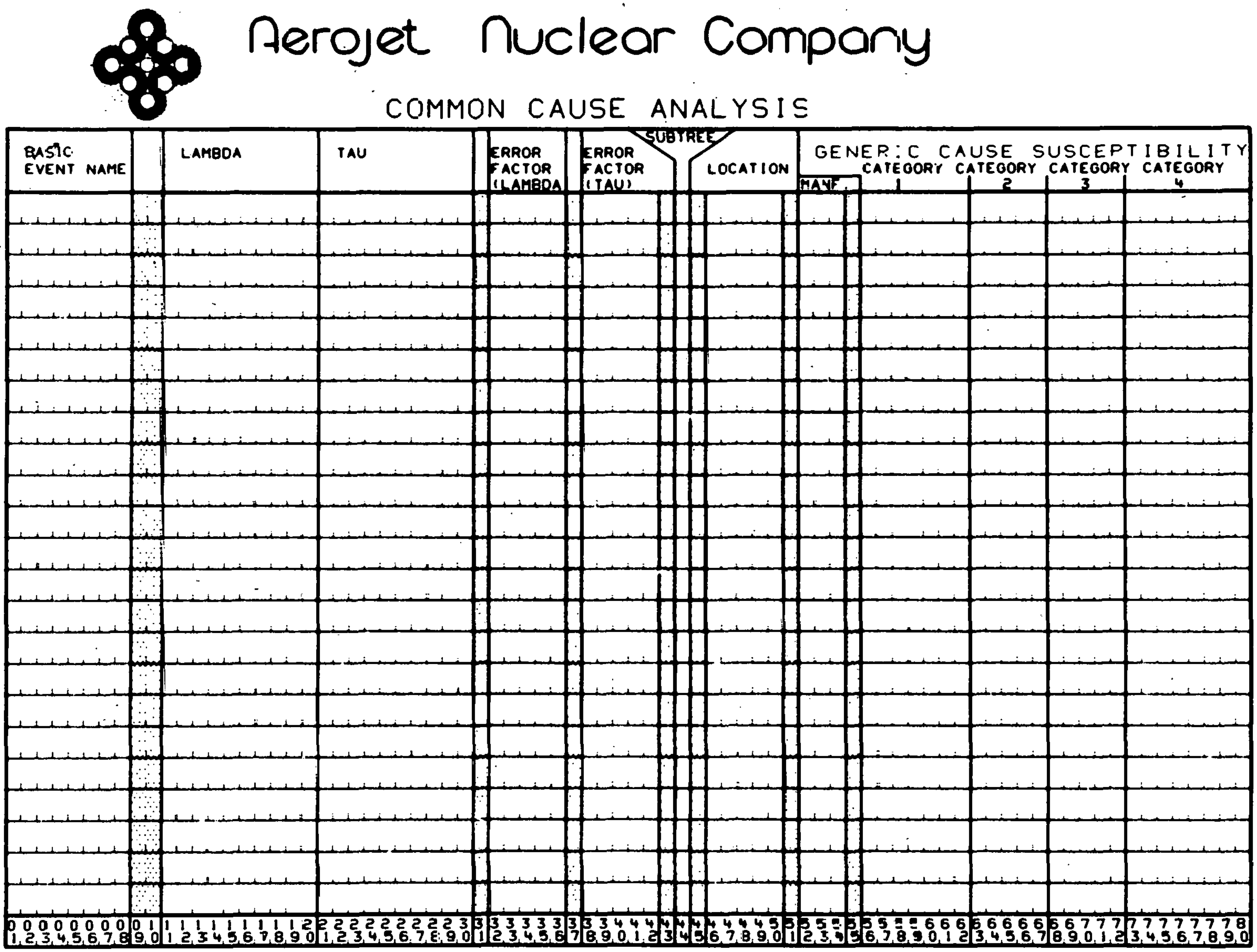

Fig. 2 Sample coding form for input to common cause analysis.

3. MANUFACTURER INPUT

A common manufacturer among all the basic event components in a minimal cut set makes the cut set a prime common cause candidate. This special condition is important enough to receive separate treatment. Columns 52 through 54 may contain a three-character alphanumeric manufacturer code. Left adjustment is necessary.

4. GENERIC CAUSE SUSCEPTIBILITY INPUT

The generic cause susceptibilities require only one alphanumeric character for representation. The common links given in Category 4 require two alphanumeric characters for the description. The first character is used to describe the common link (Table IV), and the second is used to indicate which set of components share the common link. For examples, the first character can denote maintenance, and the second character can indicate the set (for example, Set 2) of components that are maintained by the same individual. If all the basic event components in the minimal cut set share a common link, no common location check is required to identify this cut set as a prime common cause candidate.

The following coding form excerpt shows both the generic cause susceptibilities and the common link representation.

Generic Cause Susceptibilities

Category 1	Category 2	Category 3	Category 4
P	R		N1

The coding form shows that the component in a particular failure mode is susceptible to pressure (Table I) and radiation (Table II), and the component is in energy flow Path 1 (Table IV).

Columns 56 through 62 may contain up to seven one-character codes from Category 1; Columns 63 through 67 may contain up to five one-character codes from Category 2; Columns 68 through 72 may contain up to five one-character codes from Category 3; and Columns 73 through 80 may contain up to four two-character codes, arising from identification of common links in Category 4.

5. DOMAIN DEFINITION

The input on the domain definition cards relates regions within a structure, usually a single building, to causes (from Categories 1, 2, or 3 only) which may represent a hazard to components located within those regions. When a region has been associated with a particular cause, it is called a domain of that cause. A domain is then defined by specifying: (1) a cause, (2) a building or building map, (3) subsections of this map (rooms) and, if required, (4) subdivisions of the subsections (such as cabinets within rooms). Additional details are presented in Section III.

One or more cards may be used to relate a particular map, its subsections, and subdivisions to a particular cause. The first card for each cause should contain a 1, 2, or 3 in Column 3 identifying the cause category. Column 5 should contain the alphabetic code identifying the cause.

Column 10 should contain a one-character alphabetic code identifying the map (building). This code will be attached automatically as a prefix to the section and subdivision codes. If more than one map is used, each must start on a new card. Starting in Column 12, the subsections and subdivisions are entered in free-form format. Each subsection consists of a three digit numeric code; each subdivision consists of a four digit alphanumeric code (for example, 101C). These codes are separated by a comma or one or more blank spaces, or both. All subsections and subdivisions separated by commas with no intervening blanks will make up a common location for that cause indicated in Column 5 of the first card. One or more common locations may occur on a single input card. If more than one card is used for a given common location, all but the last card should terminate with a comma to indicate that the next card is a continuation. The same map code must be placed in Column 10 of the subsequent cards as appeared in Column 10 of the first card. COMCAN will permit up to 100 subsections or subdivisions in all. This limit may be modified by changing the value of MK in the main routine.

6. CUT SET INPUT

The cut set input cards describe the input cut sets. The list of cut sets may be generated by some other program, such as MOCUS or PREP. The data are read from Logical Unit 2. The input should be in card image form in the following format. In Columns 1 through 5 the number of events in the cut set should be entered in integer form (right-adjusted, no decimal point). Eight-character alphanumeric event names may be punched starting in Columns 11, 21, . . ., 71. If more than seven basic events occur in a cut set, subsequent cards may be punched with the basic event names punched in Columns 1, 11, 21, . . ., 71 (eight per card). The number of cut sets allowed as input varies with the core allowed for the problem but currently about 3000 cut sets are allowed.

7. CAUSE RANKING CARDS

The cause ranking cards are interspersed with the basic event description cards; that is, the cards obtained from the coding form of Figure 2. The cause ranking cards permit an importance ranking of the causes. If they are present, the largest rank for each cause, the total rank for each cause, and a graphical representation of the total rank are printed. The ranking cards do not have to be present for every event. If they are present, they must follow immediately behind the corresponding event description card. Columns 1 through 8 must contain the same alphanumeric code contained in the preceding event description card. Columns 9 through 55 are not used. Columns 56 through 80 may contain one-digit numeric ranking codes. These codes must be punched in the same columns as their corresponding cause codes in the preceding basic event description cards. Codes corresponding to common links must be punched in the same column as the alphabetic cause identifier portion of the two-character cause code. Any ranking codes in the wrong columns will not be used, but these will cause a warning message to be printed beside the ranking card on the printout of the event description cards (Appendix C).

8. GENERIC CAUSE TABLE CARDS

The four category tables containing the generic common causes and common links are input on Logical Unit 1. Each category consists of one CATEGORY card, followed by one card for each cause (or common link) in that category. The four categories must be input in numerical order. The CATEGORY cards must contain the word CATEGORY starting in Column 1. Card Columns 9 through 20 are not used. Columns 21 through 80 should contain an alphabetic title identifying the category. The cause cards which follow each CATEGORY card have the following format: The alphabetic identifier is entered in Column 15, and alphabetic text describing the cause is entered in Columns 21 through 60.

The sum of causes in all four categories must not exceed 50. This value may be modified by changing the value of the variable MG in the main routine.

9. OPTION CARDS

Several options are available, most of which control output. Internal to the program, these are logical variables. If their value is true, the corresponding action is taken (on); if their value is false, it is skipped (off). The default value of the logical variable can be reversed by entering a card with the proper keyword. This keyword allows the user to turn on any option which is normally turned off and to turn off any option which is usually on. The default values of the logical variables are set in the BLOCK DATA subprogram, and the coding to modify their state is in the SETPSW routine.

The options are exercised by entering a keyword (one per card). These keywords must be punched starting in Column 1. The first eight columns of all cards are checked plus Column 15 of the RANK option card. The remainder of the cards may contain anything. In cases for which the keywords are fewer than eight characters, blanks must be left from the last character of the keyword through Column 8. The keywords and their meanings are listed in Table VI:

TABLE VI

COMCAN KEYWORDS

Keyword	Default Value of Option	Action
AREAS	off	Controls printing of input domains
CAUSES	off	Controls printout of common cause candidates by cause and location. Requires space to store information for each cut set. For many cut sets, the storage may have to be increased.
EVENTS	off	Controls printout of the basic event description information. This information is the same as printed by the CARD IMAGE option but with a better format.
GENERIC	on	Controls printout of the Generic Cause and Common Link Tables
CARD IMAGES	on	Controls printout of the basic event description information in card images
SINGLES	off	Allows single event cut sets to be included in the analysis
RANK	off	If a ranking number, N, is printed in Column 15 of this card, only those cut sets containing basic events with ranking greater than or equal to N are printed as prime common cause candidates. If Column 15 is blank or contains 0, all prime common cause candidates are printed. (This option card need only be used if ranking information is present and it is desirable to restrict the printed output.)
STORAGE	off	Causes the size of various internal arrays to be printed (not normally used by the analyst)

TABLE VI (contd.)

Keyword	Default Value of Option	Action
SIMILAR	off	Causes the code to compare the second and third characters of the basic event name to determine whether all components involved in a cut set are the same kind. If so, the code will print the cut set as a prime common cause candidate.
MANUFACTURER	off	Causes the code to check all basic events in a cut set for a common manufacturer. If a common manufacturer exists, the cut set will be printed as a prime common cause candidate.
TYPE	off	Produces a printout of only those cut sets sharing a common cause and containing similar type components

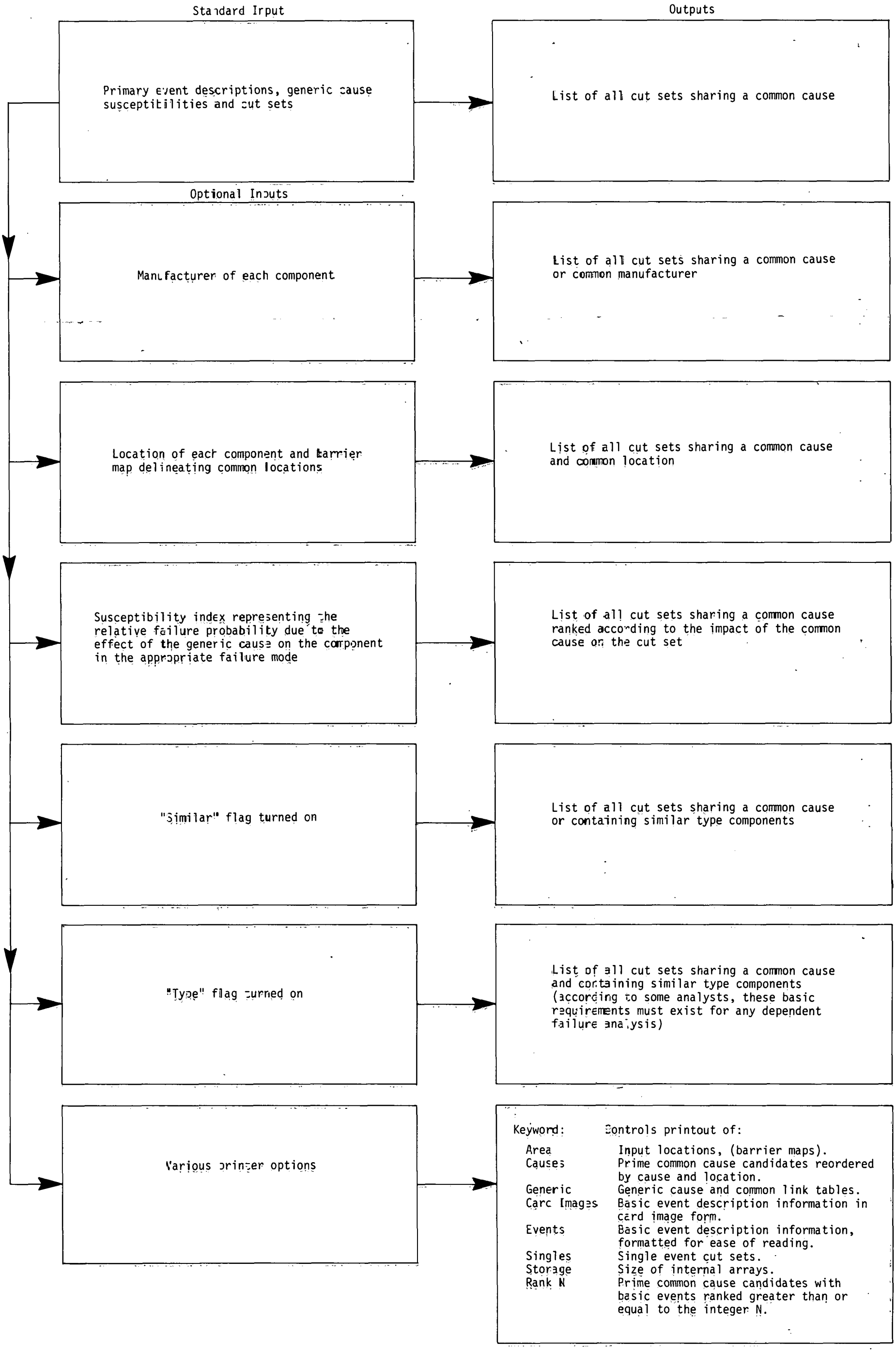

Fig. 3 Common cause analysis flow chart.

10. ORDER OF INPUT DATA

The data for COMCAN must be input in the following order:

(1) The input information for the Generic Causes and Common Link Tables is read from Logical Unit 1.

(2) The cut sets are read in from Logical Unit 2.

(3) The option cards, the basic event description cards (the cards described by the sample coding form of Figure 2), and the domain definition cards are all read from Logical Unit 5. They must be input in the following order:

   (a) All option cards

   (b) A card which reads BASIC EVENT DESCRIPTIONS, starting in Column 1

   (c) All of the basic event description cards

   (d) A card which reads DOMAIN DEFINITIONS, starting in Column 1

   (e) The domain definition cards.

Cards (d) and (e) are optional, except that if card (e) is present, card (d) must also be present. Input Decks (1), (2), and (3) may come in any order if the correct logical unit is used.

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APPENDIX A

SAMPLE PROBLEM FAULT TREES

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APPENDIX A

SAMPLE PROBLEM FAULT TREES

This appendix contains a sample problem in the form of fault trees for an LMFBR interim decay storage (IDS) system. The problem is presented solely for purposes of demonstrating the mechanics of the COMCAN code. The symbol M/T is used for Mobiltherm®.

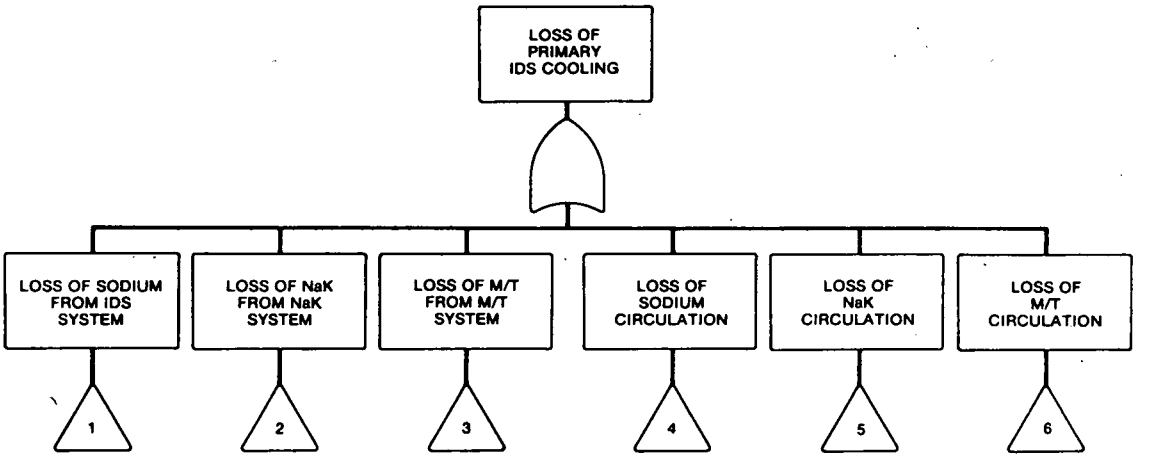

Fig. A-1 Fault tree for loss of primary IDS cooling.

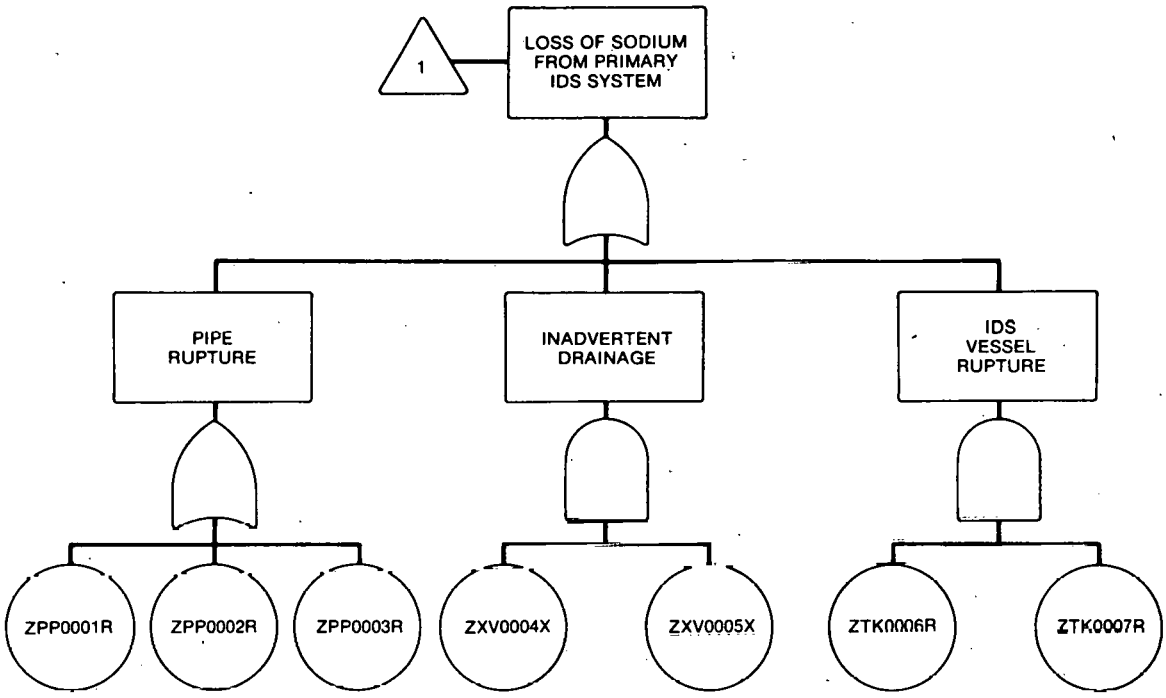

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

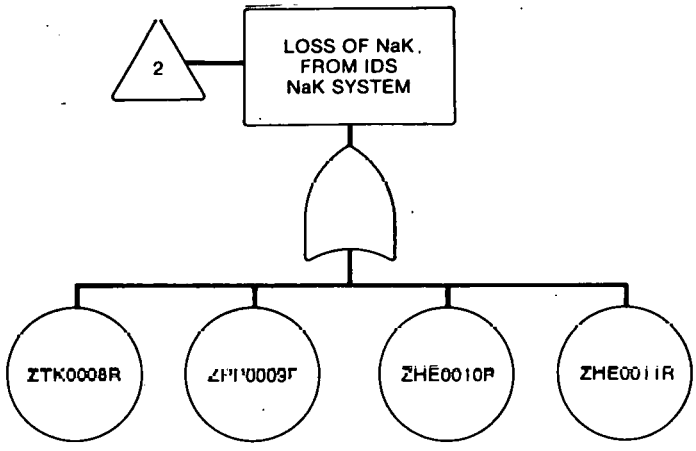

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

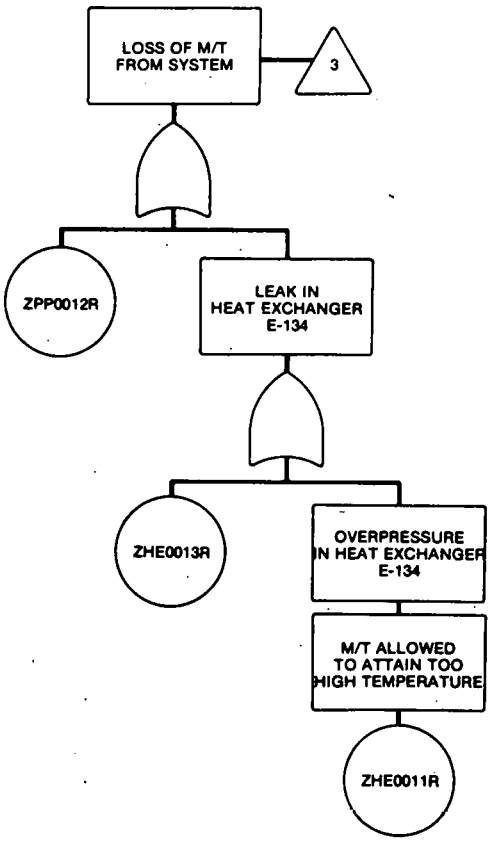

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

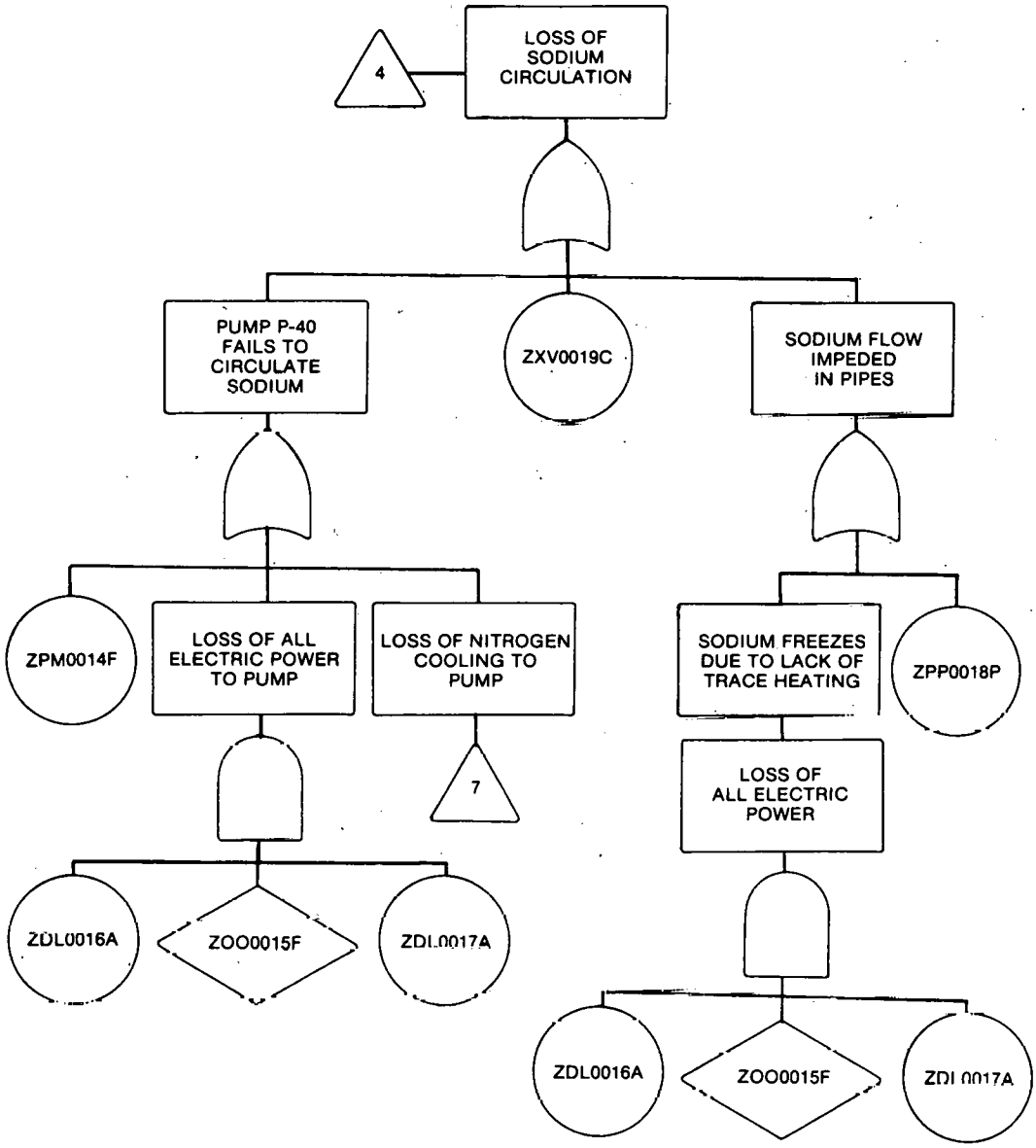

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

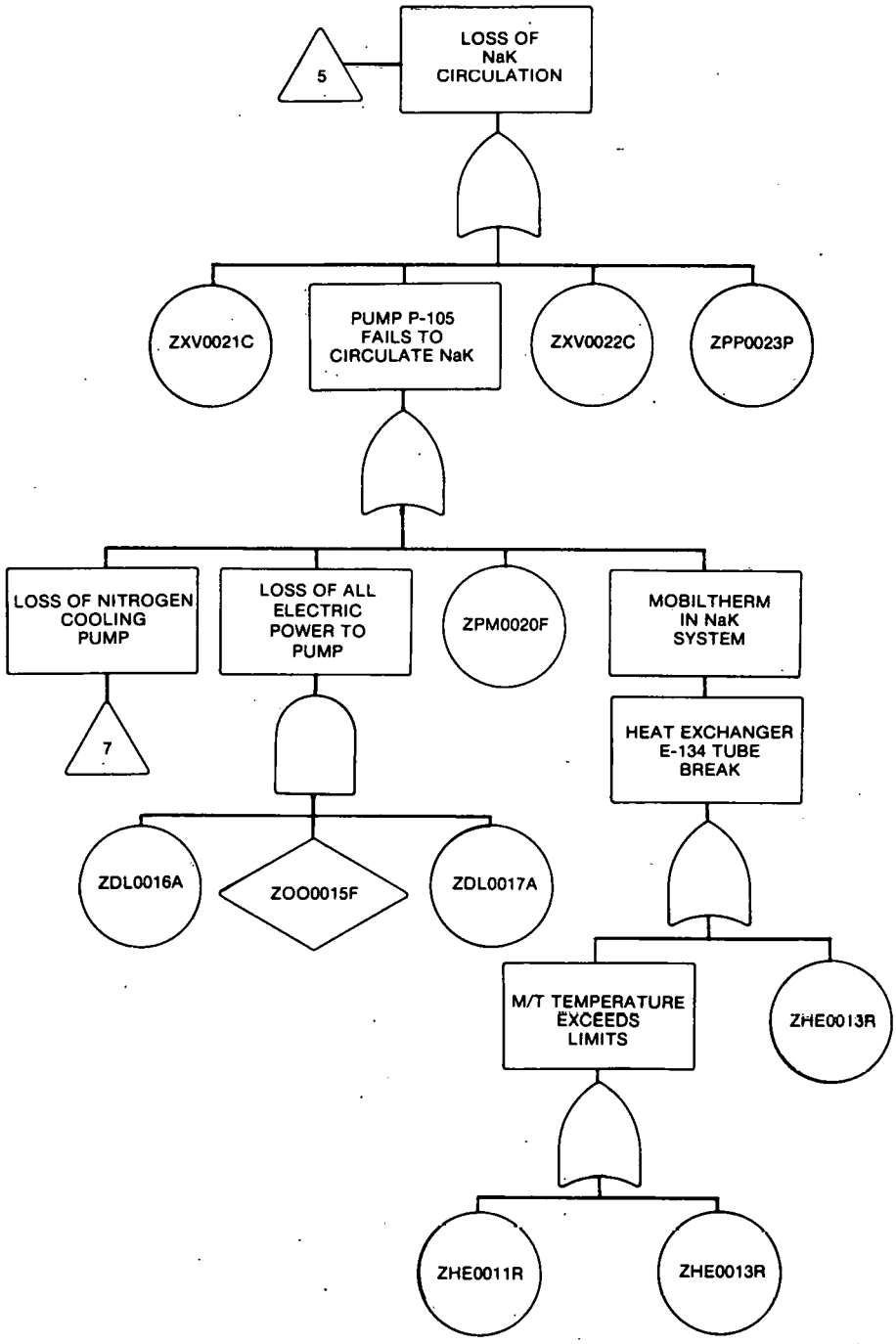

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

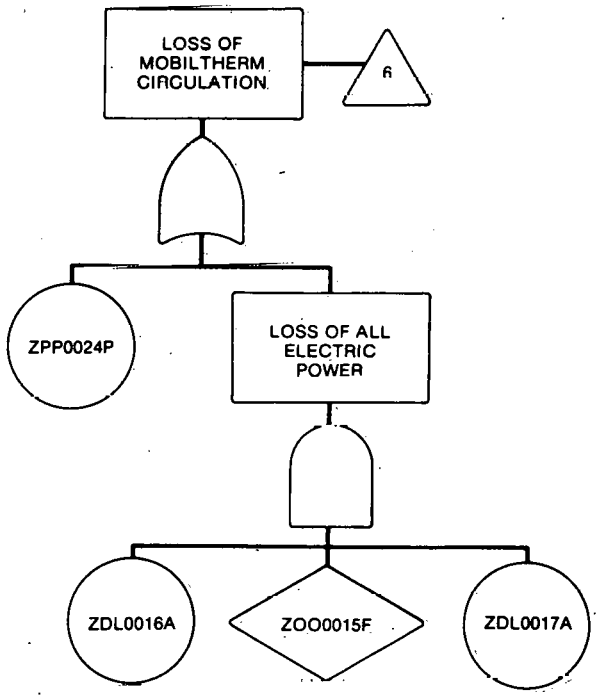

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

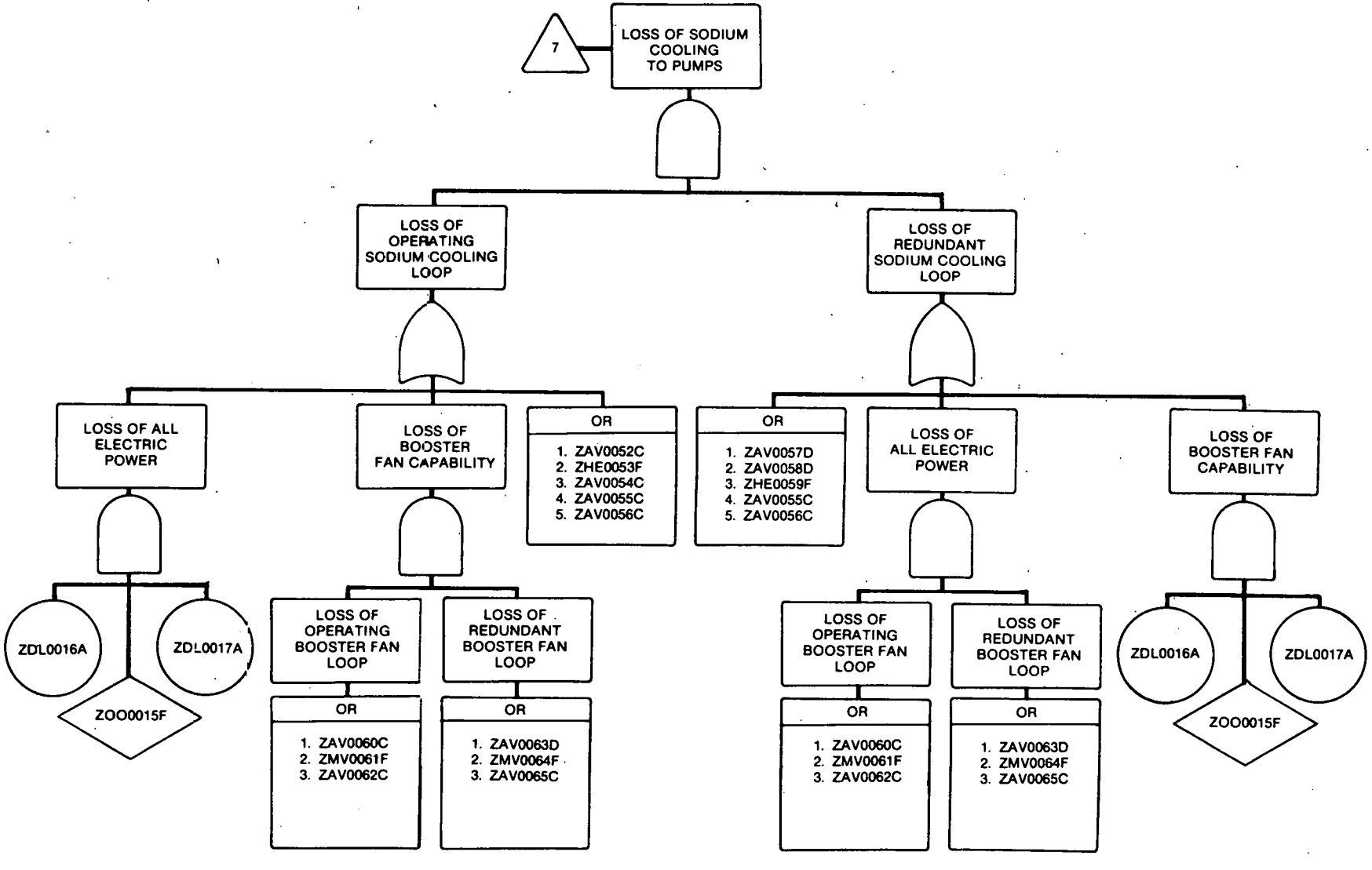

Fig. A-1 Fault tree for loss of primary IDS cooling (contd.).

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APPENDIX B

SAMPLE BASIC EVENT CODING TABLES

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APPENDIX B

SAMPLE BASIC EVENT CODING TABLES

This appendix contains the component type codes and fault mode codes used in the sample problem of Appendix A. The letter "Z" was used as the system code for the IDS system of the sample problem. A description of the basic event input to COMCAN is given in Section V.1.

COMPONENT TYPE CODES

AV	Valve, air operated	HE	Heat exchanger
BL	Blower	MV	Valve, motor operated
BY	Battery	OO	Offsite power
CV	Check valve	PM	Pump
DL	Diesel	PP	Pipe
FD	Fire door	TK	Tank
FL	Fusible link	XV	Valve, manual

FAULT MODE CODES

A	Does not start	O	Open valve
C	Close valve	P	Plugged
D	Does not open	R	Rupture
F	Loss of function	W	Does not actuate

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APPENDIX C

PRINTOUT OF COMCAN INPUT INFORMATION

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APPENDIX C

PRINTOUT OF COMCAN INPUT INFORMATION

This appendix contains the input data deck for the sample problem of Appendix A.

```
SUMMARY OF KEYWORD ACTIONS

    1)  AREA INFORMATION WILL BE PRINTED.

    2)  PRIME COMMON CAUSE CANDIDATES WILL BE PRINTED BY CAUSES AND LOCATIONS.

    3)  BASIC EVENT DESCRIPTIONS WILL BE PRINTED IN FANCY FORMAT.

    4)  TABLE OF GENERIC CAUSE CODES WILL BE PRINTED.

    5)  BASIC EVENT DESCRIPTIONS WILL BE PRINTED IN CARD IMAGES.

    6)  ONLY CAUSES WHOSE RANKING IS GREATER THAN OR IS EQUAL TO 3 WILL BE PRINTED.

    7)  SINGLE EVENT CUT SETS WILL BE PRINTED.

    8)  COMCAN WILL TEST FOR SIMILAR PARTS.

    9)  COMCAN WILL TEST FOR COMMON MANUFACTURER.
```

PRINTOUT OF GENERIC CAUSE TABLES:

TABLE I SECONDARY CAUSES OF A MECHANICAL/THERMAL NATURE

	SYMBOL	GENERIC CAUSE
1	I	IMPACT
2	V	VIBRATION
3	P	PRESSURE
4	G	GRIT
5	S	STRESS
6	T	TEMPERATURE

TABLE II SECONDARY CAUSES OF AN ELECTRICAL/RADIATION NATURE

	SYMBOL	GENERIC CAUSE
1	E	ELECTROMAGNETIC INTERFERENCE (EMI)
2	R	RADIATION DAMAGE
3	M	CONDUCTOR MEDIUM
4	V	OUT-OF-TOLERANCE VOLTAGE
5	I	OUT-OF-TOLERANCE CURRENT

TABLE III SECONDARY CAUSES OF A CHEMICAL/MISCELLANEOUS NATURE

	SYMBOL	GENERIC CAUSE
1	A	CORROSION (ACID)
2	O	CORROSION (OXIDATION)
3	R	OTHER CHEMICAL REACTIONS
4	C	CARBONIZATION
5	B	BIOLOGICAL HAZARDS

TABLE IV COMMON LINKS RESULTING IN DEPENDENCE BETWEEN COMPONENTS

	SYMBOL	GENERIC CAUSE
1	E	ENERGY SOURCE
2	C	CALIBRATION
3	F	MANUFACTURER
4	I	INSTALLATION CONTRACTOR
5	M	MAINTENANCE
6	O	OPERATOR OR OPERATION
7	P	PROXIMITY
8	T	TEST PROCEDURE
9	N	ENERGY FLOW PATHS
10	S	SIMILAR PARTS

PRINTOUT OF BASIC EVENT INFORMATION

	BASIC EVENT NAME	LOCATION CODE	MANUFACTURE IDENT.	POSSIBLE SECONDARY CAUSES OF FAILURE I	II	III	IV
1	ZPP0001R	C576	PIP	IVP S		R	I1
2	ZPP0002R	C576	PIP	IVP S		R	I1
3	ZPP0003R	C576	PIP	IVP S		R	I1
4	ZXV0004X	C576					M1O1P1
5	ZXV0005X	C576					M1O1P1
6	ZTK0006R	C546	BWC	IVP S		R	I1P2
7	ZTK0007R	C546	BWC	IV			I1P2
8	ZTK0008R	C557	LII	IVP S		R	I1
9	ZPP0009R	C576	PIP	IVP S		R	I1
10	ZHE0010R	C555	DAI	IVP S		R	I1
11	ZHE0011R	C555	DAI	IVP S		R	I1
12	ZPP0012R	C576	PIP	IVP S		R	I1
13	ZHE0013R	C555	DAI	IVP S		R	I1
14	ZHE0011R	C555	FW			R	I1
15	ZPM0014F	C570	WE	IV S	M	R	I1M1
16	ZOOOO15F	O	WP	IV T		R	I1
17	ZDL0016A	A	GE	IV G T			I1M1O1
18	ZDL0017A	B	GE	IV G T			I1M1O1
19	ZPM0020F	C570	WE	IV S	M	R	I1M1
20	ZXV0021C	C576	CC	IV S		R	I1M1P1
21	ZXV0022C	C576	CC	IV S		R	I1M1P1
22	ZPP0024P	C576	PIP	G T		R	
23	ZXV0019C	C576	CC	IV S		R	M1
24	ZPP0018P	C576	PIP	G T		R	
25	ZPP0023P	C576	PIP	G T		R	
26	ZHE0053F	C555	ION	IVP S		R	I1
27	ZHE0059F	C555	ION	IVP S		R	I1
28	ZAV0054C	C576	FCC	IV GS	M	R	O1P1I1
29	ZAV0058D	C576	FCC	IV GS	M	R	O1P1I1
30	ZAV0055C	C576	FCC	IV GS	M	R	O1P1I1
31	ZAV0056C	C576	FCC	IV GS	M	R	O1P1I1
32	ZAV0052C	C576	FCC	IV GS	M	R	O1P1I1
33	ZAV0057D	C576	FCC	IV GS	M	R	O1P1I1
34	ZAV0060C	C576	FCC	IV GS	M	R	O1P1I1
35	ZAV0062C	C576	FCC	IV GS	M	R	O1P1I1
36	ZAV0063D	C576	FCC	IV GS	M	R	O1P1I1
37	ZAV0065C	C576	FCC	IV GS	M	R	O1P1I1
38	ZMV0061F	C576	FCC	IV GST	M	R	M1O1P1
39	ZMV0064F	C576	FCC	IV GST	M	R	M1O1P1

AREAS PRINTOUT

CATEGORY	GENERIC CAUSE	AREAS							
I	IMPACT	C576	C546	C557	C555	C570	O	A	B
I	VIBRATION	C576	C546	C557	C555	C570	O	A	B
I	PRESSURE	C576	C546	C557	C555	C570			
		O							
		A							
		B							
I	STRESS	C576	C546	C557	C555	C570			
		O							
		A							
		B							
I	TEMPERATURE	C576	C546	C557	C555	C570			
		O							
		A							
		B							
I	GRIT	C576	C546	C557	C555	C570			
		O							
		A							
		B							
II	CONDUCTOR MEDIUM	C576	C546	C557	C555	C570			
		O							
		A							
		B							
III	OTHER CHEMICAL REACTIONS	C576	C546	C557	C555	C570			
		O							
		A							
		B							

PRINTOUT OF BASIC EVENT INFORMATION (CARD IMAGES)

```
                10        20        30        40        50        60        70        80
       ----+----|----+----|----+----|----+----|----+----|----+----|----+----|----+----|

    1  ZPP0001R                                C576  PIP IVPS        R    I1
    2  ZPP0001R                                            4231        1    2
    3  ZPP0002R                                C576  PIP IVPS        R    I1
    4  ZPP0002R                                            4235        1    2
    5  ZPP0003R                                C576  PIP IVPS        R    I1
    6  ZPP0003R                                            4321        2    8
    7  ZXV0004X                                C576                         M1O1P1
    8  ZXV0004X                                                             1 2 7
    9  ZXV0005X                                C576                         M1O1P1
   10  ZXV0005X                                                             58  2      <====  CHECK THIS CARD

   11  ZTK0006R                                C546  BWC IVPS        R    I1P2
   12  ZTK0006R                                            4723        2    4 5
   13  ZTK0007R                                C546  BWC IV              I1P2
   14  ZTK0007R                                            42               2 5
   15  ZTK0008R                                C557  LII IVPS        R    I1
   16  ZTK0008R                                            1257        1    2
   17  ZPP0009R                                C576  PIP IVPS        R    I1
   18  ZPP0009R                                            5782        1    2
   19  ZHE0010R                                C555  DAI IVPS        R    I1
   20  ZHE0010R                                            8956        2    3

   21  ZHE0011R                                C555  DAI IVPS        R    I1
   22  ZHE0011R                                            2785        2    6
   23  ZPP0012R                                C576  PIP IVPS        R    I1
   24  ZPP0012R                                            2781        2    8
   25  ZHE0013R                                C555  DAI IVPS        R    I1
   26  ZHE0013R                                            2875        3    8
   27  ZHE0011R                                C555  FW                R    I1
   28  ZHE0011R                                                        2    8
   29  ZPM0014F                                C570  WE  IVS     M      R    I1M1
   30  ZPM0014F                                            287     12  5    8 6        <====  CHECK THIS CARD

   31  ZOOOO15F                                O     WP  VTI           R    I1
   32  ZOOOO15F                                            235         2    8
   33  ZDL0016A                                A     GE  VGTI              O1I1M1
   34  ZDL0016A                                            2578                 2 8 6
   35  ZDL0017A                                B     GE  VGTI              O1I1M1
   36  ZDL0017A                                            1278                 3 5 2
   37  ZPM0020F                                C570  WE  IVS     M      R    I1M1
   38  ZPM0020F                                            234     2   8    4 5
   39  ZXV0021C                                C576  CC  IVS           R    I1M1P1
   40  ZXV0021C                                            891         2    7 2 1

   41  ZXV0022C                                C576  CC  IVS           R    I1M1P1
   42  ZXV0022C                                            258         3    8 2 3
   43  ZPP0024P                                C576  PIP GT            R
   44  ZPP0024P                                            23          5
   45  ZXV0019C                                C576  CC  IVS           R    M1
   46  ZXV0019C                                            584         2    8
   47  ZPP0018P                                C576  PIP GT            R
   48  ZPP0018P                                            21          2
   49  ZPP0023P                                C576  PIP GT            R
   50  ZPP0023P                                            25      3   6              <====  CHECK THIS CARD

       ----+----|----+----|----+----|----+----|----+----|----+----|----+----|----+----|
```

PRINTOUT OF BASIC EVENT INFORMATION (CARD IMAGES)

```
         10        20        30        40        50        60        70        80
    ----+----|----+----|----+----|----+----|----+----|----+----|----+----|----+----|

51  ZHE0053F                                C555  ION IVPS        R    I1
52  ZHE0053F                                      1245        2    8
53  ZHE0059F                                C555  ION IVPS        R    I1
54  ZHE0059F                                      1245        2    8
55  ZAV0054C                                C576  FCC IVSG   M    R    I1M101P1
56  ZAV0054C                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD
57  ZAV0058D                                C576  FCC IVSG   M    R    I1M101P1
58  ZAV0058D                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD
59  ZAV0055C                                C576  FCC IVSG   M    R    I1M101P1
60  ZAV0055C                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD

61  ZAV0056C                                C576  FCC IVSG   M    R    I1M101P1
62  ZAV0056C                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD
63  ZAV0052C                                C576  FCC IVSG   M    R    I1M101P1
64  ZAV0052C                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD
65  ZAV0057D                                C576  FCC IVSG   M    R    I1M101P1
66  ZAV0057D                                      2487   2 8  2    2 4 7 1    <==== CHECK THIS CARD
67  ZAV0060C                                C576  FCC IVSG   M    R    I1M101P1
68  ZAV0060C                                      2845   2    3    8 5 2 1
69  ZAV0062C                                C576  FCC IVSG   M    R    I1M101P1
70  ZAV0062C                                      2784   2    8    2 2 4 1

71  ZAV0063D                                C576  FCC IVSG   M    R    I1M101P1
72  ZAV0063D                                      1234   5    8    6 2 3 7
73  ZAV0065C                                C576  FCC IVSG   M    R    I1M101P1
74  ZAV0065C                                      2784   2    8    2 1 5 7
75  ZMV0061F                                C576  FCC IVTSG  M    R    I1M1P101
76  ZMV0064F                                C576  FCC IVTSG  M    R    I1M1P101

    ----+----|----+----|----+----|----+----|----+----|----+----|----+----|----+----|
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APPENDIX D

SAMPLE PROBLEM JOB CONTROL LANGUAGE FOR THE IBM 360/75 COMPUTER AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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APPENDIX D

SAMPLE PROBLEM JOB CONTROL LANGUAGE FOR THE IBM 360/75 COMPUTER AT THE IDAHO NATIONAL ENGINEERING LABORATORY

This appendix presents the control language for COMCAN used with the IBM 360/75 computer at the Idaho National Engineering Laboratory.

```
// COR=140,CPU=002,WT=001
//X  EXEC  PGM=COMCAN,REGION=140K
//STEPLIB  DD  DSN=TEMP.NHMCMCN1,DISP=SHR
//X.FT05F001  DD  DDNAME=SYSIN
//FT06F001  DD  SYSOUT=A,SPACE=(TRK,(30,10)),
//      DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596)
//FT16F001  DD  SYSOUT=A,SPACE=(TRK,(30,10)),
//      DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596)
//FT26F001  DD  SYSOUT=A,SPACE=(TRK,(30,10)),
//      DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596)
//SYSUDUMP   DD  SYSOUT=A
//X.FT01F001  DD  *
```

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APPENDIX E

SAMPLE PROBLEM OUTPUT

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APPENDIX E

SAMPLE PROBLEM OUTPUT

This appendix contains the output for the sample problem of Appendix A.

PRINTOUT OF PRIME COMMON CAUSE CANDIDATES

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZXV0004X (C576) ZXV0005X (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZTK0006R (C546) ZTK0007R (C546)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	4	****/****/	8
P2 -- PROXIMITY	5	*****/*****/	10
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0060C (C576) ZAV0063D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
G -- GRIT	5	*****/****/	9
S -- STRESS	4	****/***/	7
R -- OTHER CHEMICAL REACTIONS	8	***/********/	11
I1 -- INSTALLATION CONTRACTOR	8	********/******/	14
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0052C (C576) ZAV0057D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	4	****/****/	8
G -- GRIT	7	*******/*******/	14
S -- STRESS	8	********/********/	16
M1 -- MAINTENANCE	4	****/****/	8
O1 -- OPERATOR OR OPERATION	7	*******/*******/	14
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0052C (C576) ZAV0058D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	4	****/****/	8
G -- GRIT	7	*******/*******/	14
S -- STRESS	8	********/********/	16
M1 -- MAINTENANCE	4	****/****/	8
O1 -- OPERATOR OR OPERATION	7	*******/*******/	14
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0052C (C576) ZHE0059F (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
S -- STRESS	8	********/*****/	13

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZHE0053F (C555) ZAV0057D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
S -- STRESS	8	*****/********/	13

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZHE0053F (C555) ZAV0058D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
S -- STRESS	8	*****/********/	13

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZHE0053F (C555) ZHE0059F (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
P -- PRESSURE	4	****/****/	8
S -- STRESS	5	*****/*****/	10
I1 -- INSTALLATION CONTRACTOR	8	********/********/	16
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0054C (C576) ZAV0057D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	4	****/****/	8
G -- GRIT	7	*******/*******/	14
S -- STRESS	8	********/********/	16
M1 -- MAINTENANCE	4	****/****/	8

O1 -- OPERATOR OR OPERATION	7	*******/*******/		14
F -- MANUFACTURER				
S -- SIMILAR PARTS				

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0054C (C576) ZAV0058D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	4	****/****/	8
G -- GRIT	7	*******/*******/	14
S -- STRESS	8	********/********/	16
M1 -- MAINTENANCE	4	****/****/	8
O1 -- OPERATOR OR OPERATION	7	*******/*******/	14
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0054C (C576) ZHE0059F (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
S -- STRESS	8	********/*****/	13

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZMV0061F (C576) ZAV0063D (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			

. . . . . .

PRIME COMMON CAUSE ZAV0062C ZAV0C63D
CANDIDATE: (C576) (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
G -- GRIT	4	****/****/	8
S -- STRESS	8	********/***/	11
R -- OTHER CHEMICAL REACTIONS	8	********/********/	16
01 -- OPERATOR OR OPERATION	4	****/***/	7
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE ZAV0060C ZMV0C64F
CANDIDATE: (C576) (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			

. . . . . .

PRIME COMMON CAUSE ZAV0060C ZAV0C65C
CANDIDATE: (C576) (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	8	********/*******/	15
G -- GRIT	5	*****/****/	9
S -- STRESS	8	****/********/	12
R -- OTHER CHEMICAL REACTIONS	8	***/********/	11
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZMV0061F (C576) ZAV0065C (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0062C (C576) ZMV0064F (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: ZAV0062C (C576) ZAV0065C (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	7	*******/*******/	14
G -- GRIT	4	****/****/	8
S -- STRESS	8	********/********/	16
R -- OTHER CHEMICAL REACTIONS	8	********/********/	16
01 -- OPERATOR OR OPERATION	5	****/*****/	9
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

PRIME COMMON CAUSE CANDIDATE: Z0000015F (0) ZDL0016A (A) ZDL0017A (B)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	8	*****/********/********/	21
I1 -- INSTALLATION CONTRACTOR	8	********/********/*****/	21

PRINTOUT OF COMMON CAUSE CANDIDATES

. . . . . .

COMMON CAUSE CANDIDATE: ZPP0001F (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	4	****/	4
P -- PRESSURE	3	***/	3
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE CANDIDATE: ZTK0008R (C557)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
P -- PRESSURE	5	*****/	5
S -- STRESS	7	*******/	7
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE CANDIDATE: ZHE0013R (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	8	********/	8
P -- PRESSURE	7	*******/	7

S -- STRESS	5	*****/	5
R -- OTHER CHEMICAL REACTIONS	3	***/	3
I1 -- INSTALLATION CONTRACTOR	8	********/	8
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZPP0024P
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
T -- TEMPERATURE	3	***/	3
R -- OTHER CHEMICAL REACTIONS	5	*****/	5
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZPP0002R
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	4	****/	4
P -- PRESSURE	3	***/	3
S -- STRESS	5	*****/	5
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZPP0303R
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	4	****/	4
V -- VIBRATION	3	***/	3
I1 -- INSTALLATION CONTRACTOR	8	********/	8
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZPP0009R
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	5	*****/	5
V -- VIBRATION	7	*******/	7
P -- PRESSURE	8	********/	8
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZHE0010R
CANDIDATE: (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	8	********/	8
V -- VIBRATION	9	*********/	9
P -- PRESSURE	5	*****/	5

S -- STRESS	6	******/	6
I1 -- INSTALLATION CONTRACTOR	3	***/	3
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZHE0011R
CANDIDATE: (C555)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	7	*******/	7
P -- PRESSURE	8	********/	8
S -- STRESS	5	*****/	5
I1 -- INSTALLATION CONTRACTOR	6	******/	6
F -- MANUFACTURER			
S -- SIMILAR PARTS			

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COMMON CAUSE ZPP0012R
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	7	*******/	7
P -- PRESSURE	8	********/	8
I1 -- INSTALLATION CONTRACTOR	8	********/	8
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZXV0019C
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	5	*****/	5
V -- VIBRATION	8	********/	8
S -- STRESS	4	****/	4
M1 -- MAINTENANCE	8	********/	8
F -- MANUFACTURER			
S -- SIMILAR PARTS			

COMMON CAUSE ZPM0014F
CANDIDATE: (C570)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	8	********/	8
S -- STRESS	7	*******/	7
R -- OTHER CHEMICAL REACTIONS	5	*****/	5
I1 -- INSTALLATION CONTRACTOR	8	********/	8
M1 -- MAINTENANCE	6	******/	6
F -- MANUFACTURER			
S -- SIMILAR PARTS			

COMMON CAUSE ZXV0021C
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
I -- IMPACT	8	********/	8

V -- VIBRATION	9	*********/	9
I1 -- INSTALLATION CONTRACTOR	7	*******/	7
F -- MANUFACTURER			
S -- SIMILAR PARTS			

COMMON CAUSE ZXV0022C
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	5	*****/	5
S -- STRESS	8	********/	8
R -- OTHER CHEMICAL REACTIONS	3	***/	3
I1 -- INSTALLATION CONTRACTOR	8	********/	8
P1 -- PROXIMITY	3	***/	3
F -- MANUFACTURER			
S -- SIMILAR PARTS			

COMMON CAUSE ZPP0023P
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
T -- TEMPERATURE	5	*****/	5
R -- OTHER CHEMICAL REACTIONS	6	******/	6
F -- MANUFACTURER			
S -- SIMILAR PARTS			

COMMON CAUSE ZPM0020F
CANDIDATE: (C570)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
V -- VIBRATION	3	***/	3
S -- STRESS	4	****/	4
R -- OTHER CHEMICAL REACTIONS	8	********/	8
I1 -- INSTALLATION CONTRACTOR	4	****/	4
M1 -- MAINTENANCE	5	*****/	5
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZPP0018P
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
F -- MANUFACTURER			
S -- SIMILAR PARTS			

. . . . . .

COMMON CAUSE ZAV0055C
CANDIDATE: (C576)

GENERIC CAUSES:	MAXIMUM RANK	10 20 30 40 50	TOTAL RANK
01 -- OPERATOR OR OPERATION	7	*******/	7
V -- VIBRATION	4	****/	4
G -- GRIT	7	*******/	7
S -- STRESS	8	********/	8

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      M1 -- MAINTENANCE                                4   ****/                                    4
      F  -- MANUFACTURER
      S  -- SIMILAR PARTS

            . . . . . .

COMMON CAUSE      ZAV0056C
CANDIDATE:          (C576 )

   GENERIC CAUSES:                                MAXIMUM          10        20        30        40        50     TOTAL
                                                    RANK  ----+----1----+----1----+----1----+----1----+----1     RANK

      01 -- OPERATOR OR OPERATION                      7   *******/                                 7
      V  -- VIBRATION                                  4   ****/                                    4
      G  -- GRIT                                       7   *******/                                 7
      S  -- STRESS                                     8   ********/                                8
      M1 -- MAINTENANCE                                4   ****/                                    4
      F  -- MANUFACTURER
      S  -- SIMILAR PARTS

COMMON CAUSE CANDIDATES LISTED BY CAUSES


CAUSE:  IMPACT

    FOR AREA:  C576  C546  C557  C555  C570  D     A     B

        COMMON CAUSE
         CANDIDATES:     1)  ZPP0001R
                         2)  ZPP0002R
                         3)  ZPP0003R
                         4)  ZPP0009R
                         5)  ZHE0010R
                         6)  ZXV0019C
                         7)  ZXV0021C
                         8)  ZTK0006R  ZTK0007R
                         9)  Z0000015F  ZDL0016A  ZDL0017A
```

CAUSE: PRESSURE

FOR AREA: C576 C546 C557 C555 C570

COMMON CAUSE CANDIDATES:

1)	ZPP0001R	
2)	ZTK0008R	
3)	ZHE0013R	
4)	ZPP0002R	
5)	ZPP0009R	
6)	ZHE0010R	
7)	ZHE0011R	
8)	ZPP0012R	
9)	ZHE0053F	ZHE0059F

FOR AREA: C

FOR AREA: A

FOR AREA: B

CAUSE: STRESS

FOR AREA: C576 C546 C557 C555 C570

COMMON CAUSE CANDIDATES:

1)	ZTK0008R	
2)	ZHE0013R	
3)	ZPP0002R	
4)	ZHE0010R	
5)	ZHE0011R	
6)	ZXV0019C	
7)	ZPM0014F	
8)	ZXV0022C	
9)	ZPM0020F	
10)	ZAV0055C	
11)	ZAV0056C	
12)	ZAV0060C	ZAV0063D
13)	ZAV0052C	ZAV0057D
14)	ZAV0058D	ZAV0052C
15)	ZHE0059F	ZAV0052C
16)	ZHE0053F	ZAV0057D
17)	ZHE0053F	ZAV0058D
18)	ZHE0053F	ZHE0059F
19)	ZAV0054C	ZAV0057D
20)	ZAV0054C	ZAV0058D
21)	ZHE0059F	ZAV0054C
22)	ZAV0062C	ZAV0063D
23)	ZAV0060C	ZAV0065C
24)	ZAV0062C	ZAV0065C

FOR AREA: D

FOR AREA: A

FOR AREA: B

CAUSE: VIBRATION

FOR AREA: C576 C546 C557 C555 C570 D A B

COMMON CAUSE CANDIDATES:

1)	ZHE0013R	
2)	ZPP0003R	
3)	ZPP0009R	
4)	ZHE0010R	
5)	ZHE0011R	
6)	ZPP0012R	
7)	ZXV0019C	
8)	ZPM0014F	
9)	ZXV0021C	
10)	ZXV0022C	
11)	ZPM0020F	
12)	ZAV0055C	
13)	ZAV0056C	
14)	ZAV0052C	ZAV0057D
15)	ZAV0058D	ZAV0052C
16)	ZAV0054C	ZAV0057D
17)	ZAV0054C	ZAV0058D
18)	ZAV0060C	ZAV0065C
19)	ZAV0062C	ZAV0065C

CAUSE: OTHER CHEMICAL REACTIONS

FOR AREA: C576 C546 C557 C555 C570

COMMON CAUSE CANDIDATES:

1)	ZHE0013R		
2)	ZPP0024P		
3)	ZPM0014F		
4)	ZXV0022C		
5)	ZPP0023P		
6)	ZPM0020F		
7)	ZAV0060C	ZAV0063D	
8)	ZAV0062C	ZAV0063D	
9)	ZAV0060C	ZAV0065C	
10)	ZAV0062C	ZAV0065C	

FOR AREA: O

FOR AREA: A

FOR AREA: B

CAUSE: INSTALLATION CONTRACTOR

COMMON LINK: I1

COMMON CAUSE CANDIDATES:

1)	ZHE0013R			
2)	ZPP0003R			
3)	ZHE0010R			
4)	ZHE0011R			
5)	ZPP0012R			
6)	ZPM0014F			
7)	ZXV0021C			
8)	ZXV0022C			
9)	ZPM0020F			
10)	ZAV0060C	ZAV0063D		
11)	ZHE0053F	ZHE0059F		
12)	Z0000015F	ZDL0016A	ZDL0017A	

CAUSE: TEMPERATURE

FOR AREA: C576 C546 C557 C555 C570

COMMON CAUSE CANDIDATES:

1)	ZPP0024P	
2)	ZPP0023P	

FOR AREA: O

FOR AREA: A

FOR AREA: B

CAUSE: MAINTENANCE

COMMON LINK: M1

COMMON CAUSE CANDIDATES:

1)	ZXV0019C		
2)	ZPM0014F		
3)	ZPM0020F		
4)	ZAV0055C		
5)	ZAV0056C		
6)	ZAV0052C	ZAV0057D	
7)	ZAV0058D	ZAV0052C	
8)	ZAV0054C	ZAV0057D	
9)	ZAV0054C	ZAV0058D	

CAUSE: PROXIMITY

COMMON LINK: P1

COMMON CAUSE CANDIDATES:

1)	ZXV0022C	

CAUSE: GRIT

FOR AREA: C576 C546 C557 C555 C570

COMMON CAUSE CANDIDATES:

1)	ZAV0055C	
2)	ZAV0056C	
3)	ZAV0060C	ZAV0063D
4)	ZAV0052C	ZAV0057D
5)	ZAV0058D	ZAV0052C
6)	ZAV0054C	ZAV0057D
7)	ZAV0054C	ZAV0058D
8)	ZAV0062C	ZAV0063D
9)	ZAV0060C	ZAV0065C
10)	ZAV0062C	ZAV0065C

FOR AREA: O

FOR AREA: A

FOR AREA: B

CAUSE: OPERATOR OR OPERATION

COMMON LINK: 01

COMMON CAUSE CANDIDATES:

1)	ZAV0055C	
2)	ZAV0056C	
3)	ZAV0052C	ZAV0057D
4)	ZAV0058D	ZAV0052C
5)	ZAV0054C	ZAV0057D
6)	ZAV0054C	ZAV0058D
7)	ZAV0062C	ZAV0063D
8)	ZAV0062C	ZAV0065C

CAUSE: PROXIMITY

COMMON LINK: P2

COMMON CAUSE CANDIDATES:

1)	ZTK0006R	ZTK0007R

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