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Stage Right Operational Safety Analysis and Evaluation of Pantex Personnel Operations

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Abstract

This report documents a study (Stage Right Operational Safety Analysis) that was performed to evaluate the effects of new Stage Right operations on the safety of Pantex personnel who perform the operations and maintain the equipment. The primary concern of the evaluation was for personnel safety during Stage Right operations, but operations equipment damage and degradation also were taken into account. This analysis evaluates safety of the work process in the staging of dismantled nuclear weapon pits within the modified Richmond magazines only.

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Stage Right Operational Safety Analysis and Evaluation of Pantex Personnel Operations

This document is not a Safety Analysis Report, nor does it address consequences of undesirable incidents in terms of radiation or other hazards to off-site personnel, such as the general public. The purpose of this study was to review and document the effects of new Stage Right operations on the safety of the plant personnel performing those new operations.

Executive Summary

This report documents a study (Stage Right Operational Safety Analysis) that was performed to evaluate the effects of new Stage Right operations on the safety of Pantex personnel who perform the operations and maintain the equipment. The primary concern of the evaluation was for personnel safety during Stage Right operations, but operations equipment damage and degradation also were taken into account. This analysis evaluates safety of the work process in the staging of dismantled nuclear weapon pits within the modified Richmond magazines only.

The report does not address injury due to natural phenomena or other external events. Those phenomena and events were addressed in a Safety Analysis Report (SAR) that was approved in September 1993 [SAR93]. The only event in the SAR that involved work processes was the puncture of a pit container by a lift truck.

This Stage Right Process and Operational Safety Analysis includes the following processes:

- moving the palletized drums from the pallet trailer to the pallet turner,
- staging of pallets and removal of pallets from the magazine,
- recovery from an incident in a magazine,
- setting up, opening, and closing a Zone 4 magazine,
- inventory of palletized drums in the magazines,
- transporting palletized drums from Zone 12 to Zone 4, and
- maintenance on the shielded lift truck that involves removal of the cab shielding.

The analysis includes the following undesirable consequences:

- injury to personnel,
- breach of an AL-R8 container,
- drop of a loaded pallet,
- damage to equipment, and
- equipment unreliability.

The methodology used for this analysis was first to identify, through the development of fault trees, sequences of events (cut sets) that could result in an undesirable consequence. The second step was to estimate the relative probabilities of the cut sets. The probability estimates were very conservative and should not be interpreted as "true" probabilities of the occurrence of the cut sets. The probabilities were used to rank the cut sets and to identify those with the highest relative probabilities of occurrence. The highest probability cut sets are described in the report, and recommendations are made that should reduce the probability of occurrence. Since costs have not been factored into the recommendations, it is possible that costs may be prohibitive compared to the benefits for some of the recommendations. Costs should be considered prior to any implementation.

The evaluation procedure was as follows:

1. Identify processes/undesirable events that could be included in the analysis.
2. Observe the processes, read available written procedures, and discuss the processes with engineers and technicians to obtain information necessary for the analyses.
3. Based primarily on severity of consequences, identify the process/undesirable event combinations to be analyzed.
4. Develop fault trees for the process/undesirable event combinations that were given the highest priority rankings.
5. Assign a conservative probability of failure estimate to each basic event in each of the fault trees. This includes both human error and equipment failure probabilities.
6. Identify the cut sets in each fault tree and rank them from highest to lowest probability of occurrence.
7. Write this report describing the highest probability cut sets in each fault tree and listing recommendations to reduce the probabilities.

The following are generic descriptions of cut sets containing the basic events that are most likely to occur. They are listed under the associated undesirable event. Equipment unreliability was treated in a different manner and, therefore, is not included in the list. The equipment reliability analysis revealed, among other things, that the mean time between failures for the shielded lift truck is about 12.5 times greater than the estimated total operational time over a five year period.

Injury to Personnel

Most injury scenarios consist of two or more basic events and can be grouped into the following two categories:

- those resulting in injury to personnel other than the equipment operator, in which a person is struck by a lift truck, hit by a falling pallet, struck by other equipment, or exposed to radiation above the administrative threshold, and
- those resulting in injury to the operator, in which the lift truck impacts an object, the operator is exposed to radiation above the administrative threshold or is exposed to effluent from a hydraulic fluid fire.

Breach of an AL-R8 Container

Moving lift trucks and the various hydraulic systems provide sufficient force for container

breach. Two main container failures are the following:

- container punctured due to sufficient force by a sharp object, such as the forks or the boom attachment, or by an obstacle in the path of movement, and
- container breached due to sufficient force (from impact, drop, or steady pressure) resulting in pallet structural failure, combined with container rim band failure.

Drop a Loaded Pallet

Event combinations that result in a pallet being dropped can be categorized as follows:

- those in which the pallet catches on an object such as the pallet trailer, the pallet turner, or another pallet,
- those in which the forks are tilted forward or the pallet is carried too high and the apron lift truck suddenly accelerates or is driven over a destabilizing object,
- those involving any sudden acceleration with an off-balance pallet, and
- those in which there is a structural / mechanical equipment failure, or a hydraulic failure combined with check valve failure.

Damage to Equipment

Event combinations can be placed in the following categories:

- those in which the 2000-lb capacity apron lift truck hits the pallet turner, pallet trailer, or staging ramp due to mechanical failure, operator error, or hydraulic system/control failure,
- those that occur during removal, lifting, and replacement of the lift truck cab shield,
- those that occur during the inventory process and involve damage to the PINPAL through impact with an object, environmental or vibration damage, and
- those that occur while loading the inventory pallet on the lift truck or while re-installing the boom attachment.

Recommendations are given that address most of the undesirable event combinations listed above. The recommendations emphasize safe operating procedures, training, maintenance, inspections, and equipment enhancements. Specific recommendations are discussed in the section on *Fault Tree Analyses and Cut Set Rankings* for each process and undesirable event. Recommendations have been consolidated into a separate *Summary of Recommendations* section and grouped by similarity, for convenience in highlighting trends. The groupings of recommendations include the following:

- radiation mitigation --

As the Pantex administrative threshold is lowered for exposure to gamma and neutron radiation, mitigation of the dose received by the pallet turner operator should be considered. Three operational mitigation solutions are discussed, as well as mandatory usage of the two-sided lead apron.

- routine maintenance and unscheduled maintenance --

Routine maintenance is performed twice a year on Pantex lift trucks and requires post-maintenance testing. Procedures and checklists for maintenance of the shielded lift truck should be similar to existing maintenance requirements, but should add maintenance and inspection requirements for the boom, the special safety features, and the shielded cab.

- inspection, daily check, and walk-around --

Mechanical/electrical failures are minimized with a daily pre-operation inspection and a periodic maintenance program. A checklist should be used which covers the daily inspection of the hydraulic systems, the boom attachment, the forks and fork carriage (whenever used), the electrical subsystem, the cab shielding, the safety sensors, and the backup alarm on the shielded lift truck.

- enhancements to existing equipment

The following enhancements to existing equipment are being planned or have been discussed by Pantex personnel: a mobile fixture to hold the boom or fork carriage during the attachment process, absolute positioning for the shielded lift truck control panel, a come-along requiring less leverage, portable lighting for recovery procedures, a pallet guide on the pallet turner, ramp jack levels, audible alarm on the shielded lift truck, and marking or physical stops on the inventory pallet equipment pedestal guide track.

- training

Initial and recurrent lift truck operation/safety training should be continued and should be tailored to the specific Stage Right operations to prevent accidents caused by operator error.

- items for explicit inclusion in general and safe operating procedures

The general procedures have been further grouped by process, as follows: procedures for working with or near lift trucks, operation checks and team operations, recovery procedures, inventory procedures, cab shield maintenance procedures, and procedures for equipment and pallet transportation.

Background

The Final Safety Analysis Report (SAR), approved September 1993 [SAR93], was prepared to describe and evaluate significant environment, safety, and health (ES&H) issues associated with the operation of the Pantex Plant modified-Richmond and steel arch construction (SAC) magazines in Zone 4. The SAR was prepared according to the requirements in U.S. Department of Energy (DOE) Order 5481.1B [DOE87], supplemented by DOE/Albuquerque Operations (AL) Order 5481.1B [DOE88]. In general, the SAR addressed events (natural phenomena, fires, crashes, and other external events) such as aircraft and missile impacts, criticality events, earthquakes and tornados, external explosions and fires, and internal explosions and fires.

Potential human error events occurring inside the facility were not considered in the screening process for the SAR. Many of the external events examined could affect the

safety of plant workers in their work environment. For example, the effects of blast pressures on humans were given as threshold limits for eardrum rupture, lung damage, and lethality. The radii of blast pressure effects for each of these critical target organ threshold limits were given graphically for the blast scenarios analyzed [SAR93, Chapter 4]. Only one event in the SAR addressed the safety of plant workers during the work process. The event of an operational accident with a lift truck, was analyzed through the most limiting operational accident -- the puncture of a pit container by a lift truck [SAR93, Chapter 6 and 7.2.10, for transportation accidents]. Although many of these accident events involve potential for worker injury, they are not re-considered here.

This Stage Right Operational and Process Safety Analysis does not address anything already covered in the SAR. *This current study evaluates the safety of plant workers during the work process and does not re-address injury due to natural phenomena or other external events.* Available operations and equipment maintenance checklists were reviewed. Since the Stage Right process is a new process, any pertinent Operations and Inspections (O&I) Standards, Internal Operating Procedures (IOPs), recovery procedures, and operator checklists either did not exist or were in draft form.

The evaluation of this new process (with the shielded lift truck and the specially designed pallets) is not to be incorporated into the SAR as an unreviewed safety question (USQ) at this time [DOE91]. Any changes affecting the SAR will be incorporated during the normally scheduled periodic review and update of the SAR, as required in DOE Order 5480.23, Section 9.c [DOE92].

Scope of the Study

The magazines in Zone 4 are used for staging or interim storage for pits and other components and materials. There are 60 magazines in Zone 4, 18 modified Richmond magazines and 42 steel arch construction magazines. This analysis evaluates safety of the work process in the staging of dismantled nuclear weapon pits within the modified Richmond magazines only. Staging and interim storage of pits in the SAC magazines may be evaluated at a later time. This analysis is limited to the worker processes, with an emphasis on safety, for the staging of pits within the newly designed four- and six-pack precision pallets.

Analysis Scope

The process operational review starts at the Zone 12 loading dock (12-26) with fully loaded four- and six-pack pallets, ready to be moved into the transport vehicle (pallet trailer). The review includes placement of all material and vehicles to open the Zone 4 magazine, loading of the pallet trailer in Zone 12, movement from Zone 12 to Zone 4, unloading the pallet trailer in Zone 4, and the many operations to move the pallets into the proper locations in the Zone 4 magazine. The review also includes setup of the inventory pallet and performance of the inventory within the Zone 4 magazine. The review will focus primarily on Phase 1A operations (using the shielded lift truck), with a brief examination plus recommendations for Phase 1B (using the AGV - automated guided vehicle). Discussion of the AGV will be included in a follow-on document. Sandia will

examine the process with emphasis on the worker safety aspect and make appropriate recommendations for improvement.

The following were excluded from this analysis:

- environmental and external hazards to the magazine, that were evaluated in the SAR -- This includes earthquakes, tornados, lightning strikes, aircraft crash, missiles, and explosions. There is a management directive to suspend staging operations during inclement weather.
- radiological airborne release modeling and accidents with consequences to the public. (Exposures to workers are based on pre-defined exposure rates and exposure times, or utilize radiation measurements taken by other laboratories participating in the Stage Right study.)
- sabotage or tampering with equipment. Safeguards issues are not addressed.
- drum container evaluation. The container has been certified and tested. It has successfully completed a drop test from 30 feet.
- Limiting Conditions for Operation (LCOs) that were covered in the SAR.

The following areas were included in this analysis:

- operator safety reliability / technician safety during equipment maintenance
- operating, maintenance, and recovery procedures
- equipment reliability, as affects worker safety
- post-accident conditions. Need to evaluate recovery procedures. An example is recovery of the shielded lift truck stuck in the magazine.
- vehicles in transit. The SAR does not consider vehicles in transit. The process safety analysis scope includes the inter-zone pallet trailer, standard electric lift trucks, the shielded lift truck, and the heavy-duty access denial barrier (ADB) mover lift truck.

Primary Incidents to be Examined

After enumerating many of the perceived process steps and the potential incidents, the following incidents were identified for detailed examination and evaluation.

- incidents with the pallet and pit containers, resulting in:
 - breach or puncture of pit container
 - drop of loaded pallet
- incidents during setup, involving:
 - ramp assembly or pallet turner
 - movement of the access denial blocks
- lift truck failure during operation, while:
 - fully loaded and in transit
 - fully loaded with boom extended or raised during pallet staging
 - unloaded, or during inventory
- accident during recovery, involving procedures for:
 - operator egress
 - removal of the lift truck (shielded lift truck or AGV) from magazine interior
- transportation accidents, involving:
 - vehicle movement (lift truck, automated guided vehicle (AGV), shielded lift truck

- (Hyster), new pallet trailer, AGV support trailer)
- support equipment and operations (pallet turner, mechanical tie-down operations, ramp assembly, and guide rails)
- failure of scan system on inventory pallet - **removed from study - safeguards area**
 - battery, cameras, recorders, and other electronic equipment.

Magazine and Equipment Characteristics

Magazines

Each modified-Richmond magazine has a floor to ceiling concrete center wall to divide it into two sides, referred to as sides A and B. Each side then can hold 22 stacks of palletized drums, in a five container high configuration consisting of four-pack pallets on top of six-pack pallets. At the entrance to the magazine door, the normal configuration of four-pack pallets placed on six-pack pallets is altered to four-pack on a four-pack. This configuration results in a capacity of 216 drum containers per side.

There are two drivers for the decision to alter the configuration at the magazine door. The lift truck mast must be in free extension to place a four-pack on a six-pack. The doorway does not provide enough room for this extension. In addition, in one potential emergency recovery scenario, the shielded lift truck may fail in the doorway with no access for personnel to enter the magazine. Changing the first position pallet configuration provides extra room for magazine entry.

The magazines vary in length by 1.5 feet. In the shortest one, the 4-21 magazine used for demonstrations, the last pallet is about one inch from the back wall. There is a 1 to 2 inch space between the pallets, plus a 1 inch error. The space between the pallets and the side wall or the center wall is approximately 11 inches. The safety stop positioned between the guide rails in the rear of the magazine is about 2.5 inches high, and has a flat surface facing toward the front of the magazine.

Magazine Radiation and the Pallet Turner

Most of the radiation exposure (gammas and neutrons) currently occurs during inventory. For magazines in a linear array (*i.e.*, six drums across with two aisles), it takes approximately one hour to conduct an inventory once inside the magazine. The new Stage Right inventory using the physical inventory pallet (PINPAL) takes approximately ten minutes (average time during testing of PINPAL) and does not require placement or operation of the pallet turner. Any radiation exposure during inventory will be to the lift truck driver or to workers during ramp setup. (It may take an hour to get ready for inventory, with magazine opening procedures and ramp setup.)

A pallet turner operator also may be exposed to radiation during staging and removal procedures. The pallet turner is about 6 feet from the magazine door opening. The person standing at the turnwheel, when on the A side of the magazine, is about 5'4" from the front drums, or a little over 4 feet from the door opening. (The nearest container is approximately one foot inside the magazine from the doorway.) According to Los Alamos

radiation exposure measurements [ROB93], the measured total gamma and neutron exposure is 25 to 35 mr/hr for a position at the pallet turner that is 100 cm from the doorway. This is approximately 40 inches. The exposure is 17-23 mr/hr at 200 cm (78.7" or 6.5'). Approximation of the operator's position yields a radiation dose of 29 mr/hr.

The ALARA (As Low As Reasonably Achievable) approach to radiation protection is the process used to limit dose levels as much below the limits given in DOE Orders as practical. The Pantex Plant administrative exposure limit is 1 rem/year. This will be reduced to a maximum of 0.5 rem/year shortly.

Another potential source of radiation may occur during neutron transfer between magazine side A and side B. There are plans to look at neutron transfer. A final point to consider is that neutrons can bounce off surfaces. Because of this characteristic, wrap-around personnel aprons may be more effective than one-sided aprons.

Shielded Lift Truck

On the shielded lift truck, there is a spool valve to lower the boom during recovery. This operation is done from inside the lift truck cab. During emergency recovery operations, the spool valve can bypass fluid from the hydraulic cylinder for lowering. There also is a needle valve to traverse the boom during recovery. This valve is located on the traverse frame. The traverse needle valve is for equalizing pressure across the traverse cylinder to allow a socket wrench to manually operate the traverse. During recovery, a come-along cable may be used to raise the boom loaded with a pallet. The come-along cable attachment is being replaced by an RV winch.

There are two headlights, but they have no separate battery source for operation. The windows on the cab shielding are made of clear leaded plastic. The shielded cab, made of a lead and polymer material, weighs about 7000 pounds and must be removed to access the motor or to change the battery. Removal may be required every two years. The shielded cab is bolted to the lift truck.

The shielded lift truck is carried on a trailer manufactured by Fork Stork Inc. The lift truck is Zone 4 equipment and will not be used elsewhere. There will be a lift truck daily check sheet. There are plans to slow the hydraulics to minimize pallet sway during rotate, install an audible backup alarm, separate traverse and rotate (which are both on an H-lever now), and enhance the operator display panel.

There are three relays for the interlocks. 1) Two photocells detect the truck position, in relation to the rail notches. Movement required by the operator to be in position is indicated by the *Reverse* and *Forward* labeled panel indicators. 2) Optical tapes on the mast are used for the boom height. There are two elevation positions for each staging level. One position is for boom insertion and retract, labeled *Empty*. The other position is for loaded boom pallet putaway and retrieve, labeled *Loaded*. These two elevations are appropriately positioned on the control panel, with the lower elevation appearing on the control panel as the lower light. 3) There is another indicator for whether the boom is in the tucked position, labeled *Boom Tucked*. Yet another indicator is for *Boom tip contact*. Enhancements are underway to provide absolute positioning information on the operator display panel. Other enhancements include a boom camera, an emergency hoist upgrade,

and door latch improvement. The door hinge is being stressed during Pantex operations. The door hinge and the bolt connections for the shielding should be checked for wear or failure during routine maintenance.

Physical Inventory Pallet (PINPAL)

The physical inventory pallet has four CCD cameras with lights with information recorded by four VCRs, four barcode scanners, camera monitor, supervisory computer, hand scanner to interface with the computer, and batteries for power. The cameras and lights are mounted on a pedestal, which is centered using a guide track rail. Camera positions do not have to be precise for a successful scan. During inventory, the scanners read the part number, serial number, and TID (tamper indicating device) from labels on each drum in the magazine. There must be two successful scans for each label. Reconciliation of magazine contents from the current inventory is compared electronically with the anticipated computerized inventory.

Recovery Testing and Equipment

The barrel handler is a hydraulic and battery operated device that is carried by a lift truck. It may be used during recovery scenarios to pick up either loose drums or palletized drums with its grabber tongs.

Recovery tests were performed at Pantex with palletized drums containing sand. Thirty-two pallets were placed in a magazine, with half on each side. Fifteen pounds of sand were placed in each drum for 16 four-pack pallets and 16 six-packs. This resulted in a simulation weight of 897 for the six-packs and 612 for the four-packs. During recovery from a simulated earthquake, it took 1 hour to remove 32 pallets from their fallen positions within the magazine, primarily using the forks on the Hyster. No pallets were dropped. The barrel handler dented a drum, but no real damage was incurred.

In the 50% overload test, 114 pounds of sand were placed in each drum, in 3 bags each containing 38 pounds of sand. This resulted in a simulation weight of 1491 pounds for the six-packs and 1008 pounds for the four-packs. Two tests were performed, one with a four-pack on a six-pack and one with a six-pack placed on a four-pack. The top pallets were pushed off to simulate a pallet drop. In one case, the pallet fell on an edge and the pallet frame bent 2-3", exposing the pallet rim. In the other case, the pallet fell square and bent the end bolts. In both cases, the pallets and drums were still functional and could be picked up by the lift truck [SWY93].

Analysis Assumptions

Readers of this document should avoid comparing summations of cut set probabilities or individual cut set probabilities across the various fault trees. The primary reason is that consequence severity has not been included in the event probabilities. The undesirable top events (drop a pallet, breach a container, injure personnel, and damage equipment) do not have equally severe consequences. As shown in fairly severe pallet drop tests at Pantex, the pallets remain functional with minimal damage. On the other hand, personnel

injury from a lift truck operating on the magazine apron could potentially be severe. If the fault tree for pallet drop on the apron and the fault tree for personnel injury on the apron resulted in equal probabilities of occurrence, the reader should not falsely assume that these two undesirable incidents are equal. The frequency that an operation is performed per year and the consequence severity for undesirable events must be considered. On the other hand, comparison of cut set probabilities within a *single* fault tree is expected to depict a true ranking of the potential incident scenarios. For example, the cut set with the highest probability within a fault tree is expected to be the most likely to occur.

Some of the fault trees have been modeled to different levels of detail, depending on the importance of the undesirable event and the hazards involved, as well as the availability of process detail. Even with the varying levels of detail, comparable events have comparable probabilities of occurrence.

Please note that the probability values used for equipment failures and human errors are conservatively high and may be an order of magnitude or more too high. The reasons for this are two-fold. First, the analysis team wished to provide an upper bound on the estimates of incident occurrence and did not wish to eliminate incident sequences through underestimation. Second, the upper bounding of equipment failures and the standardization of human errors provided uniformity throughout the fault trees and allowed the team to more quickly rank the incident sequences and provide recommendations on the areas requiring the most attention. The probabilities used for the human errors are screening estimates for tasks where at least one human error can occur. These estimates tend to be very conservative, *i.e.*, the human failure probability estimates are high in most or all cases. (Appendix A describes the method used to estimate human failure probabilities.) Similarly, the equipment failure probabilities are conservatively high. Equipment failure probabilities assigned to mechanical failures are based on the failure probability of well-used, or aged, equipment. The assumption is that the equipment has been operated for 1250 hours without a failure, at 250 hours per year over five years. This is equivalent to moving 6240 drums (approximately 1270 pallets) per year for each of five years. The failure probability is based on the assumption of no intervening inspections or maintenance. This aged-equipment bias provides a *very conservative* basis for the calculation of event combinations involving mechanical failures. Since no credit has been taken for repair or periodic maintenance, this evaluation may be viewed as an upper bound, or worst-case frame of reference.

The safety process analysis was performed to highlight operations that may require mitigation to preclude the occurrence of an undesirable event. The *very conservative* probability estimates serve to identify such operations. The probability of an undesirable event for a single operation is computed using a 10 minute operation or mission time and assuming an underlying exponential distribution for equipment failure probabilities. (The component failure probability = $1 - e^{-\lambda t}$, where λ is the component failure rate per unit time and t is the 10 minute mission time. The exponential distribution assumes a constant failure rate over time. More detail may be obtained from reliability and statistics references [CLU74, HIL74].) The assumptions of a 10 minute mission time and 250 hours of equipment operation per year, models the staging of approximately 1500 pallets within one year. Examples of a single operation are: moving one pallet from the pallet trailer to the paller turner, removing one pallet from the magazine and placing it on the

pallet turner, inventorying one side of a magazine, etc. The expected number of occurrences of a particular event combination (cut set) per operation-year is obtained by multiplying the expected number of operations per year (for example, the movement of 1500 pallets in a year, or removal of the shielded cab once in a year) by the probability of an undesirable event resulting from that particular event combination. Two criteria have been used to identify event combinations requiring discussion of mitigation recommendations. These criteria are (1) when the expected number of occurrences per operation-year is greater than or equal to one for a particular event combination (cut set), or (2) when an event combination has been estimated to occur more than once in 100,000 sequences (equivalent to a cut set probability $P > 10^{-5}$). Singleton events and event combinations for infrequently occurring processes (recovery, lift truck maintenance) with even smaller cut set probabilities also may be discussed.

The cut set probabilities and the expected number of event occurrences have been used to highlight potential safety problems and to rank them in order of likelihood within a specific process. The reader should attach no additional significance to these numbers. Note: The discussions in later sections refer to the expectation of an undesirable event occurring within one year of operations. If staging operations take place for more than one year or if a larger number of operations take place each year, the expectation of an undesirable event may increase.

Process Definition and Boundaries

Potential Impacts of Incidents to be Examined

The primary concern in the evaluation was for worker safety during the work process. The impact of potential radioactive material release to the general public was addressed in the SAR. Any radioactive release and exposure of on-site personnel will be addressed using pre-defined exposure rates and length of exposure for the various accident scenarios, combined with radiation measurements taken by a Stage Right team member from Los Alamos [ROB93]. Identification and mitigation of the impact of on-the-job injury to personnel is of utmost importance. Another potential impact is the public's perception and response to incidents (even incidents involving no material release or worker injury). Lastly, potential impacts include equipment and facility damage as well as identification of poor system reliability.

The first step in the analysis was to partition the project scope into the individual processes. With the scope beginning in Zone 12 and ending with staged pallets in Zone 4, the processes identified are as follows: 1) transportation of pallets from the Zone 12 loading dock to the appropriate Zone 4 magazine apron, 2) transportation of pallets from the inter-zone pallet trailer to the pallet turner with a safely completed turnover on the pallet turner, 3) staging / removal of pallets within the Zone 4 magazine, 4) (optional - not addressed in this analysis) center aisle staging / removal within the Zone 4 magazine, 5) inventory of palletized drums within the magazine, 6) recovery operations, 7) operations setup on the Zone 4 magazine apron and the corresponding closing of the magazine. A new process has been added for maintenance on the shielded lift truck involving removal

of the shielding structure. The process definitions and process boundaries are discussed below.

Processes in the Stage Right Process Safety Analysis

The processes that were examined during the process safety analysis included the following:

- **Inter-zone transportation from the Zone 12 loading dock to the Zone 4 apron:**
Process definition: This process covers the inter-zone transportation of the palletized drums from the loading dock outside the Zone 12 pit vault to the Zone 4 magazine apron.
Equipment: The new inter-zone transport vehicle is the recently designed pallet trailer, which is low enough to the ground (12 inches) to require only a standard lift truck for loading and unloading. A standard electric lift truck is required at the Zone 12 loading dock.
Process boundaries: This process includes all the inter-zone transportation between Zone 12 and the Zone 4 magazine apron. The initial process boundary is at the Zone 12 loading dock at 12-26 with fully loaded four and six pack pallets, ready to be moved into the new transport trailer. The process concludes with the pallets located on the new transport trailer, which has stopped at the apron outside the appropriate Zone 4 magazine. Pallet movement from the Zone 12 vault to the loading dock is not included in this study.
- **Transportation of pallets from the pallet trailer to the pallet turner with a safely completed turnover on the pallet turner:**
Process definition: This process includes transportation of pallets from the inter-zone pallet trailer to the pallet turner and ends with a safely completed pallet turnover on the pallet turner. The turnover of the palletized drums is required to move the drums from the vertical position for transportation to the horizontal position for staging.
Equipment: pallet trailer, electric lift truck, ramps, pallet turner
Process boundaries: The process begins with pallet unloading events that occur outside the Zone 4 magazine. This process ends with completion of the rotation of the pallet on the pallet turner. The present system uses a lift truck on the apron and a lift truck on the support trailer (float trailer) for unloading pallets. The proposed system will use a low-level double-decker pallet trailer (lowboy) with an electric lift truck on the apron. Only the lowboy has been examined in this analysis.
- **Staging and removal of pallets within the magazine**
Process definition: This process includes all maneuvering of the pallets with the shielded lift truck in Zone 4.
Equipment: shielded lift truck, pallet turner
Process boundaries: The initial boundary is the pickup of the pallet by the shielded lift truck from the pallet turner. NOTE: The pallet already is in the proper horizontal position for pickup by the shielded lift truck. The process ends with the staging of the pallet in the magazine and the return of the shielded lift truck to the proximity of the pallet turner at the staging ramp outside the magazine.
- **[Staging and removal of pallets within the center aisle of the modified**

Richmond magazine -- not in the project scope]

- **Inventory performance:**

Process definition: This process includes installation of the lift truck attachments as well as the actual inventory of the magazine contents.

Equipment: inventory pallet with trailer, shielded lift truck

Process boundaries: The process begins outside the magazine with the installation of the fork attachment on the shielded lift truck and pickup of the inventory pallet. The process ends with completion of the inventory, removal of the shielded lift truck from the magazine, and installation of the boom attachment on the lift truck.

- **Recovery procedures**

Process definition: This process includes all steps required to recover from the off-normal condition.

Equipment: This depends on the accident or undesirable event. Equipment could include the ADB mover, shielded lift truck, come-a-long cable, protective aprons

Process boundaries: The process begins with the recovery procedures for an accident or undesirable event, and includes any additional accidents that may occur during recovery procedures. The process ends with mitigation of the undesirable event.

- **Setup, opening, and closing of the magazine in Zone 4:**

Process definition: This process includes the apron setup and magazine opening and closing activities specific to staging drums within the Stage Right magazines.

Equipment: access denial block (ADB) mover, ramps, pallet turner

Process boundaries: Events that occur on the magazine apron in Zone 4, before the magazine doors have been opened or after the magazine doors have been closed. All the following setup equipment have been delivered to the apron: ADB mover (heavy duty articulated front loader with forks attached -- has a capacity of 30,000 pounds), shielded lift truck on the fork stork, mobile staging and alignment ramps, pallet turner.

- **Shielded lift truck maintenance**

Process definition: Shielded lift truck maintenance requiring removal of the shielding cab unit is covered in this process.

Equipment: shielded lift truck, shielding cab unit, lifting mechanism

Process boundaries: The process begins with maintenance on the shielded lift truck that requires removal of the shielding unit (ex: for battery removal).

Undesirable Events

As mentioned before, the top-level failures, or undesirable events, include the following:

- Breach of an AL-R8 container
- Drop a loaded pallet
- Injury to personnel
- Damage to equipment (excluding container breach and pallet drop)
- Unreliability (equipment failure)

These undesirable events are defined as follows:

- breach of the drum container --- Breach may occur through the actual puncture of the drum with sufficient force from a sharp object or through a combination of events that include sufficient force to cause pallet failure, in addition to drum container failure from an improperly closed drum rim band or failure of the rim band at the seam or the bolt closure. It is assumed that an improperly closed drum that is palletized will not be a breach until the pallet fails. A breach has the potential for radiation release.
- drop loaded pallet --- Dropping of a pallet may occur when there is sudden acceleration applied to an off-balance pallet or lift truck. Other scenarios include a pallet catching on an obstacle or another pallet and causing a drop, equipment failure (structural failures, hydraulic failure, safety feature failure), or pushing over a staged pallet. A pallet drop may result in equipment damage (addressed under damage equipment), but most likely would result in negative public perception of operations and safety at Pantex.
- injury to personnel --- Lift truck accidents have a significant probability of injuring personnel. Injury also may occur from falling equipment or from lift truck tipping accidents. Poor physical health, which may result in heart attack or stroke, is not discussed. Areas addressed include steps in the process that may lead to injury, omitting effects from poor health.
- damage equipment --- Equipment may be damaged by dropping or by ramming it into an obstacle. The inventory pallet with its sensitive electronics may sustain damage through inclement weather (rainstorms, duststorms, etc.), radiation exposure from the environment inside the magazine, or vibration damage during transportation of the shielded lift truck or the inventory pallet.
- unreliability of equipment --- Equipment unreliability may cause or may exacerbate an accident condition. The shielded lift truck with its safety features is the primary piece of equipment to be evaluated. The ADB mover and electric lift trucks are used in open spaces and have backup equipment, so are not addressed.

Combinations of Processes and Undesirable Events

After enumerating many of the process steps and the potential incidents, eight overall processes were identified. Once the undesirable events also had been identified, the combinations of process and undesirable event were priority ranked for order of evaluation.

The attached chart shows the order for each process to be analyzed. In addition, we have assigned priorities to each combination of process and undesirable event. The priorities range from *high* to *low* with some combinations that are *not applicable* or *not currently in the project scope*. This preliminary priority ranking has been imposed on the combinations of processes and undesirable events in order to guide the order of study and analysis. Highest priorities are assigned to processes with injury to personnel and/or to undesirable events that occur in the confined space of the magazine (ie, staging / removal, recovery, and inventory). Transport of the pallet from the pallet trailer to safe turnover on

Project Stage Right : Operational Safety Analysis									
Analysis Order			Undesirable Event: --->			Injury to Personnel	Drop Loaded Pallet	Unreliability (Equipment)	
			Process:	Damage Equipment	Breach Container				
6	Zone 12 to Zone 4		Inter-zone Transportation	L	L	M	L	L	
4	Zone 4		Setup / Close	L	N/A	H	N/A	L	
			Transport: Vehicle to Safe Turnover on Pallet Turner	L		H			
1	Zone 4		Staging / Removal	M	H	H	M	L	
2	Zone 4		Center Aisle Staging/Removal	NIS	NIS	NIS	NIS	NIS	
[8]	Zone 4		Inventory	M	N/A	M	N/A	M	
5	Zone 4		Recovery	L	H	H	M	H	
3	Zone 4		Shielded Forklift Maintenance	M	N/A	M	N/A	N/A	
7	Zone 4								
KEY:									
	H = high								
	M = medium								
	L = low								
(Priority Ranking)	NIS = not in project scope			fault tree available					
	N/A = not applicable			no fault tree					

the pallet turner was chosen as the first process for analysis because the usage of the electric lift truck on the apron is much less controlled than usage of the shielded lift truck with its safety features, speed limits, and guide rails. Staging and removal with the shielded lift truck was the second process for analysis because of the use of the new shielded lift truck in a small and enclosed space.

Appendix B contains an eight-character coding scheme (identifying the process, undesirable event, operation performed, equipment used, and failure modes with operator errors and/or equipment failures) developed to identify the lowest level fault tree events for use in the later quantitative ranking analysis.

Pantex Process Frequencies

The Pantex processes already have been discussed. The Pantex process frequencies have been estimated conservatively using two different sets of assumptions.

Operation Frequencies - From Zone 12 Line

The following assumptions have been made for the first scenario, where palletized drums are transported from the Zone 12 line to the Zone 4 magazines:

- The Zone 12 line will package and palletize 24 drums per day (6240 drums per year).
- The pallet trailer will carry one complete load each day to Zone 4. The pallet trailer capacity is 24 drums palletized in four six-pack pallets, or six four-pack pallets, or a combination of four- and six-pack pallets.
- Operations personnel will fill side A or side B of a modified Richmond magazine every nine days, then will perform inventory. If staging operations are performed five days per week for 52 weeks, with no stoppage due to inclement weather, both sides of 14 magazines, plus one more side, will be filled during a year's operations. This is a total of 29 magazine sides (A or B), each filled with 20 six-pack and 24 four-pack pallets.

<u>Process:</u>	<u>freq./day</u>	<u>freq./year</u>
Setup/Close	1	260
Inter-zone Transportation of Pallets	1	260
Transport from Trailer to Turner	4-6	1276
Staging of Pallet	4-6	1276
Inventory	-	29
Maintenance on Shielded Forklift	-	1

Operation Frequencies - Intra Zone 4

The second set of assumptions are that the drums from the line will be moved into Zone 4 magazines and will be stored in the dense pack formation. The scenario assumes that the

drums already are stored in Zone 4 and that the following assumptions hold:

- Operations personnel take drums already stored in the vertical-drum, dense-pack configuration in Zone 4, palletize the drums within Zone 4, then store the palletized drums in modified Richmond magazines configured for Stage Right.
- Personnel are assumed to completely fill magazine side A or side B and perform inventory in one day.
- Will fill 18 modified Richmond magazines in 36 working days (7776 drums) in a little over 7 calendar weeks. This results in a total of 36 magazines sides, each filled with 20 six-pack and 24 four-pack pallets.

<u>Process:</u>	<u>freq./day</u>	<u># to fill mod. Rich.</u>
Setup/Close	3	108
Intra-zone Transportation of Pallets (20 6-pks and 24 4-pks)	9	324
Transport from Trailer to Turner	44	1584
Staging of Pallet	44	1584
Inventory	1	36
Maintenance on Shielded Forklift	-	1

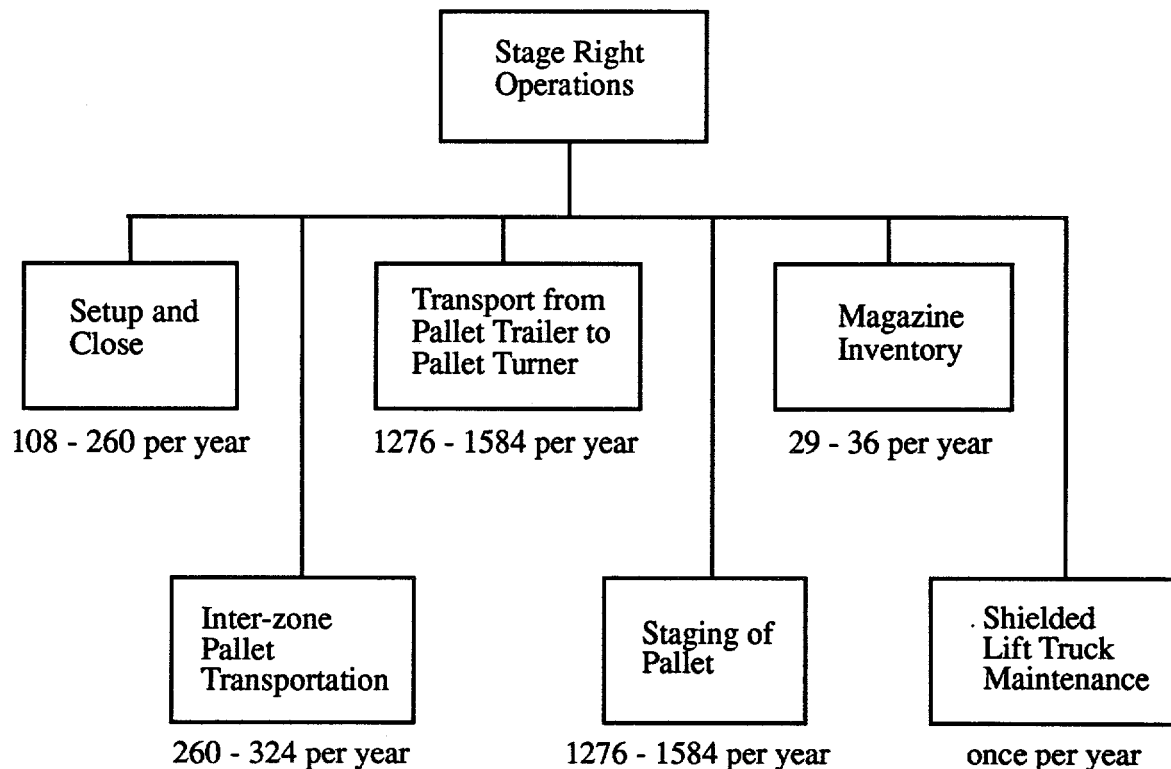
The first set of assumptions does not account for drums currently stored in the dense pack formation (single-level high, vertical drums). Within the second set of assumptions, it is assumed that all drums currently are stored in Zone 4 in the dense pack formation and that any drums brought in from the Zone 12 line initially are stored in the dense pack formation in Zone 4. Both scenarios have been conservatively estimated with high numbers of operations. Neither scenario accounts for suspension of operations during inclement weather. The actual operation frequencies will be a combination of the two scenarios given. The following figure gives conservative frequency ranges for each of the Pantex processes. The actual yearly process frequency multiplied by the event combination (cut set) probabilities of failure per operation gives the expected number of incidents per year for that operation.

Fault Tree Analyses and Cut Set Rankings

Even before including basic event failure rates, many qualitative results can be gained from fault tree analysis. Cut sets show the sets of events required to experience an undesirable event. Minimal cut sets identify *critical events*, single events or minimal combinations of events that can lead to the top level undesirable event.

Quantitative failure rate information (probabilities) are assigned to the lowest level events in each fault tree, using equipment failure rate and human reliability data. Probabilities, in combination with the fault trees and minimal cut sets, identify the probable frequency of occurrence (and the contributing events) for each top-level undesirable event. Cut sets are ranked according to estimated probability of occurrence. Potential steps to reduce critical equipment failure or operator error are identified. These may include changes in

Conservative Pantex Process Frequency Ranges



operating or recovery procedures, inspection frequencies, equipment replacement, purchase of backup equipment, or redesign of the operations process.

Fault trees have been developed for each plausible combination of process and undesirable event. While not explicit in all fault trees, the operations modeled apply to the reverse operations. For example, the forking and transport operations for unloading a pallet from the pallet trailer and loading the pallet onto the pallet turner also apply to the reverse operation of unloading the pallet from the pallet turner and loading the pallet onto the pallet trailer. The fault trees are discussed in detail below.

Transportation of Pallets from Pallet Trailer to Pallet Turner with a Safely Completed Turnover on the Pallet Turner

This process includes all pallet movement on the magazine apron using the electric lift truck. It has the following sub-processes:

- unloading of the new pallet trailer (lowboy) used to transport palletized drum containers from Zone 12 to Zone 4 (or within Zone 4)
- transportation of palletized drums from the pallet trailer to the pallet turner
- pallet loading onto the pallet turner

- completion of the pallet turnover process

The primary safety hazard is the lift truck. Many journal articles discuss lift truck hazards. One analysis [STO87] discussed lift truck injuries from 1983 that were included in two occupational injury databases -- the National Electronic Injury Surveillance System (NEISS) and the Bureau of Labor Statistics Supplementary Data System (SDS). The analysis had the following as the top two accident types: victim struck by an object and victim caught in, under, or between objects. Characteristics of injury victims and the injuries they received were presented, along with scenarios for injuries due to lift trucks. The analysis was consistent with other studies where the most frequent accidents were cases in which pedestrians were struck or run over by forklift trucks. The author recommended that accident prevention efforts be directed at both lift truck operators and pedestrian workers.

Breach Container during Transportation of Pallets from Pallet Trailer to Pallet Turner:

The breach of a drum container can occur in one of two ways. First, there may be enough force applied with a sharp object, such as the lift truck forks, that the drum may be punctured. In addition to the excessive force, there may be an obstacle in the path of movement, sudden acceleration or failure of equipment, or the forks held at an inappropriately high level. Second, both the pallet and drum may fail and result in a breach.

A breach without drum puncture requires that enough force be applied to the pallet itself to cause the pallet to fail. In addition, the drum container also must fail through either an equipment failure of the drum's rim band or the improper closure of the rim band during storage of the pit in the drum. Equipment failure of the rim band is most likely near the band closure where the band bends and the bolt is inserted. It is assumed that failure of the drum closure (rim band) without failure of the pallet does not result in a container breach. A functional pallet is assumed to hold the drum's lid in place and prevent a breach. Any additional release of radiation may be detected by radiation monitoring.

Fault Tree Discussion:

Two types of pallet and container failure due to impact were evaluated: impact causing pallet and container failure by dropping and impact causing pallet and container failure by ramming. During the unloading of the pallet trailer, a container breach may occur from dropping or ramming the pallet or from puncturing the drum container with the forks during pallet removal from the pallet trailer. A pallet drop at the pallet trailer may occur from a height greater than five feet, and cause more damage than a short fall from a height lower than five feet. Once the pallet is on the forks and is being transported to the pallet turner, a container puncture with the forks is not possible. There is the remote possibility that the container may be punctured by ramming the pallet into an obstacle within the transport path, such as the magazine itself, the magazine wing walls, or the access denial barriers. Pallet impact without puncture would require ramming or dropping the pallet combined with pallet failure and failure of the container's rim band in order to result in a container breach. At the pallet turner, the container may be breached through a combination of operator errors or equipment failures involving excessive lift truck

acceleration and failure to brake combined with an operator error of miscalculation and ramming into the pallet turner. Again, failure of the container's rim band combined with pallet failure and force from a pallet drop or ram may result in a breached container. It was noted that during one drop test in the Test Plan, the pallet frame did pull away from the container and expose the rim band. As long as the rim band remains functional, no breach will occur. Container breach during the turnover process may only occur with a combination of structural mechanical failure of the pallet turner, failure of a pallet weld or bolt, and failure of the container's rim band due to a short fall from a height less than five feet.

Puncture of the drum container may lead to pit breach. If enough force continues and the container is pushed against an immovable object, there is the potential for the pit to be punctured or crushed. The apron lift truck could generate sufficient force to puncture the container with an operator error or an equipment failure. Immovable objects on the apron include the ADB (access denial block), magazine with concrete side wings, and ramp. Once the forks are inserted into the pallet, the potential for a drum puncture leading to a pit puncture is negligible since the forks are the primary puncture mechanism with enough force to continue through to a pit puncture.

The only scenario which may be envisioned to lead to a potential pit breach is the following. The first pallet to be removed from either the upper or lower level of the pallet trailer could be pushed against the other pallets in the trailer, which would be unable to move. Since the pallets fit snugly in the pallet trailer and are fastened in place, and since the brakes are assumed to be applied on the truck pulling the pallet trailer, it is unlikely that any object will give way and move once a container has been punctured. In addition, mechanical failures or operator errors must occur to cause excessive lift truck acceleration and speed without enough braking to prevent a collision. Finally, the forks must be grossly misaligned to the pallet forking tubes and must puncture the drum with extreme precision then continue through the drum insulation to impact the pit squarely so that the forks are not deflected off to the side of the pit's surface. The precision has been modeled as a two square centimeter target within the drum's side profile of 600 square inches (30" tall drum with a diameter of 20"), equivalent to 3871 square centimeters. After the first pallet at each level is removed, subsequent pallets pushed with the lift truck will merely slide back on the rollers back into the trailer. With an average load assumed to be three four-pack pallets and two six-pack pallets, there is a probability of 0.4 that the pallet being unloaded will be positioned on the end of the trailer near the cargo door.

Quantitative Analysis for Cut Set Ranking:

Breach of a container during transport on the apron from the pallet trailer to the pallet turner has no singleton cut sets. This means that there is no single event identified that can cause breach of a container during transportation from the trailer to the pallet turner. The highest ranked cut sets, which could lead to a container puncture and that have cut set probabilities greater than 10^{-5} , all consist of two events. Operator errors and unsafe practices tend to dominate the potential hazardous cut set scenarios resulting in a puncture. The cut sets are listed as follows:

- two operator errors: raising the forks too high during insert to remove the pallet from the pallet trailer combined with sudden acceleration of the lift truck

- two operator errors: raising the forks too high during insert to remove the pallet from the pallet trailer combined with lift truck speed above a safe threshold
- two operator errors: ramming the palletized containers into the pallet turner combined with lift truck speed above a safe threshold
- two operator errors: ramming the palletized containers into the pallet turner combined with sudden acceleration of the lift truck
- an operator error of raising the forks too high during insert to remove the pallet from the pallet trailer combined with an equipment failure of the brakes
- the operator error of ramming the palletized containers into the pallet turner combined with an equipment failure of the brakes

All the cut sets listed above consist of two events and result in a container puncture. Each failure sequence has at least one operator error; more than half consist of two operator errors. Either one of two operator errors permeates the highest ranked cut sets: raising the forks too high during insert to remove the pallet from the pallet trailer or ramming the palletized containers into the pallet turner. Each of these must be combined with excessive speed or acceleration or brake failure in order to result in a container puncture. The more likely event is that the container will be dented or visually damaged, with no puncture. Since the apron is a fairly small working area, lift truck speeds will be relatively slow.

Container failure through dropping is far more unlikely, since those cut sets require container failure of the rim band, along with pallet failure from a drop, as well as entire sequences of events leading to a drop (which are listed in the fault tree on *drop pallet during transfer between trailer and pallet turner*). A breach through ramming without puncture also is less likely, since those cut sets require container failure of the rim band, along with pallet failure due to ramming with excessive force (from excessive speed or acceleration, or brake failure), as well as an operator error (forks raised too high or an obstacle in lift truck path).

The highest ranked cut set with the potential to result in a pit breach, consists of three operator errors in addition to the requirement that the pallet be the first one to be removed from either the upper or the lower level of the pallet trailer. The three operator errors are excessive lift truck acceleration/speed, not braking in time to prevent a collision, and having the forks grossly misaligned with the pallet forking tubes yet almost perfectly centered on one of the containerized pits. Since operations occur in daylight on the apron, with other personnel present, it is very unlikely that all three operator errors would occur. The Final Safety Analysis Report discussed a potential worst-case scenario in which the boom on a lift truck crushed a pit enclosed in a horizontally positioned container. The final conclusion was that "workers in the immediate vicinity of the accident site could receive a Marginal radiation dose." [SAR93, pp. 7-34 to 7-41] There are several differences in the two theoretical accident scenarios. The SAR scenario assumed a horizontal container punctured by the boom, which is square in cross-section. The scenario in this document assumed a vertically positioned container with a larger cross-section than the container lid, that is punctured by a fork tip, which is not square and has a smaller cross-section than the boom tip. In the current analysis, the incident is more likely

to be puncturing of the pit than crushing of the pit. Both scenarios are worst-case and conservative.

Recommendations:

Operators should decrease the lift truck speed when approaching the pallet trailer or the pallet turner and inserting forks into pallets prior to removal. Since speedometers are not on the lift trucks, it would be difficult to determine and follow a maximum safe speed limit for apron lift truck operations. A second person could assist the lift truck operator during forking operations.

The lift truck approach to the pallet turner is fairly tight between the pallet turner and the magazine's wing walls. A skilled operator exercising due care can perform the apron operations without incident. Operator training should simulate limited space operations requiring tight turns immediately prior to accurate fork placement.

Drop a Loaded Pallet during Transportation of Pallets from Pallet Trailer to Pallet Turner:

A pallet drop may occur during any of the four sub-processes. During pallet trailer unloading, the operator may fail to notice that the pallet has not cleared the trailer roller stop, or a sudden lift truck backward acceleration combined with an incorrect downward tilt to the forks may result in a pallet drop. During transport from the trailer to the pallet turner, an inadvertent forward tilt to the forks combined with sudden backward lift truck acceleration, sudden deceleration of lift truck forward motion, or the lift truck being driven over a destabilizing obstacle present on the apron may cause the pallet to slide off the forks. In addition, the lift truck may overturn if the pallet is carried too high and the lift truck is driven over a destabilizing obstacle present on the apron. A pallet drop at the pallet turner may result from a mechanical failure of the pallet turner or from removal of the forks from a pallet that is less than halfway loaded onto the pallet turner.

Fault Tree Discussion:

This operation considers four sub-processes where a pallet may be dropped (see Appendix D):

- while unloading the trailer (G4),
- during transport from the trailer to the pallet turner (G2),
- while loading the pallet on the pallet turner (G3), and
- while turning the pallet over on the pallet turner (G6).

While not explicit in the fault tree, the process of transferring a pallet from the pallet turner to the trailer is no different. The events associated with loading the pallet turner are the same as they would be loading the trailer; and those for unloading the trailer are nearly the same as unloading the pallet turner. The boundaries for this process is the pallet on the trailer and the pallet on the pallet turner in the position where the shielded lift truck could pick it up or would have put it in the turner. The fault tree considers plausible events that would contribute to the undesirable primary event of a dropped pallet. The summary analysis below discusses the probability of these events.

The fact that pallets have built-in sleeves for the forks to be inserted into make dropping a pallet difficult, if not creative. Reference G4. In order for the pallet to drop while being

unloaded from the trailer (or the pallet turner), it must catch on part of the structure of the trailer or pallet turner (G5), or there must be a sudden and extreme movement of the lift truck (G10). Catching on the structure means the lift truck operator has not cleared the pallet from the structure *and* is inattentive to the fact that when the lift truck is moving backward, the pallet is not moving with the lift truck. Not sensing the pallet's condition can be a result of the operator's attention being divided between the pallet and the direction the lift truck is being driven. Sudden movement of the lift truck (G11) alone is considered insufficient to cause the pallet to drop (actually slide off the forks); the forks would also have to be tilted forward as far as possible (G14). This sequence is possible by a combination of operator errors alone, mechanical failures alone, or mechanical failures and operator errors.

In considering dropping a pallet while transporting it between the trailer and the pallet turner (G2), the trailer is assumed to be located on the road in front of the magazine, not on the apron. This provides the maximum distance for transport and allows additional "worst-case" scenarios to be considered. As with the unloading process, the pallet must slide off the forks of the lift truck to fall or drop (G7), or the lift truck must overturn (G8). For the pallet to slide off the forks, the forks must be tilted forward (G14) and some upsetting event must occur to severely jar the pallet into sliding such as an acceleration while backing up (G11), deceleration while traveling forward (G24), or driving the lift truck over some object on the apron or road (G30). The only expected object on the apron capable of inducing this condition is the alignment ramp. Other possibilities are large tools or equipment that have not been removed from some other operation.

In order for a pallet to drop while loading it on the pallet turner (G3), the operator must make several errors. These errors are not placing the pallet on the pallet turner completely, then only partially lowering the forks so that the pallet is not free of the forks. Finally, the operator would have to be unmindful that the pallet is supported partially by the pallet turner and partially by the forks. When the operator tries to back away, the pallet may drop. (The same scenario would apply while loading the trailer.)

For the pallet to drop from the pallet turner (G6), only the possibility of a mechanical failure of the pallet turner while being loaded coupled with a retraction of the boom or the forks was considered. The singleton of the pallet turner simply collapsing while the pallet is resting in the turner or being turned over was not considered a creditable event even though it is physically possible.

Quantitative Analysis for Cut Set Ranking:

All cut sets, except for one, have probabilities less than 10^{-4} (where cut set probabilities $P < 10E-4$). Assuming that 1248 pallets are moved per year (one full trailer per day, five days per week), one event combination, consisting of two low-level events, may lead to the expectation of a pallet being dropped once during a year of operations. Even when all event combinations are summed together, this single two-event combination accounts for the entire potential of one pallet being dropped within a single year of operations. The conclusion is that moving pallets between the trailer and the pallet turner does pose a potential problem of dropping a container. All probabilities (P) given in the following discussion are on a per event basis. If 1000 pallets are moved in a year, then the expected number of incidents per operation-year is equal to 1000 times the

probability P.

The single two-event combination posing a potential problem has been mentioned. Additionally, eight other two-event combinations are discussed primarily because they are composed of only two low-level events, even though they are extremely unlikely. The single two-event combination poses a potential problem given that at least 1000 pallets are moved in a year. The probability is $1.0\text{E-}3$ on a per event basis. This combination starts with the operator not lifting the pallet high enough from the trailer to completely clear the roller stop. This error is compounded by the operator backing away from the trailer without noticing that the pallet is not moving with the lift truck, but is dragging on the roller stop and then dropping to the ground because it is no longer supported sufficiently by the trailer or the lift truck (events TOULFFOS and TOULTOPO). It should be pointed out that this model only addresses an incorrect height and does not attempt to put a probability on an exact height that causes the pallet to drag on the roller stop. Combined with the *very conservative* values for the probabilities, the probability of $1.0\text{E-}3$ represents an extreme case.

Three of the eight two-event combinations involve inadvertently steering the lift truck over the alignment ramp. These combinations are steering the lift truck over the alignment ramp and carrying the pallet too high (events TOXLFOPS and TOXLFPHS) causing the pallet to slide off the forks ($P=3.0\text{E-}5$), steering the lift truck over the alignment ramp and encountering an equipment failure in the tilt control mechanism (events TOXLFOPS and TOXLFFTE) causing the pallet to fall ($P=2.7\text{E-}5$), and steering the lift truck over the alignment ramp combined with the operator accidentally engaging the tilt control forward (events TOXLFOPS and TOXLFFTS) again causing the pallet to fall ($P=1.0\text{E-}5$).

Four two-event combinations involve the tilt control problems and sudden acceleration while backing up. Both are caused by either an operator error or a mechanical/electrical failure. These combinations are a mechanical/electrical failure of the tilt control combined with an operator error causing a sudden backward acceleration (events TOXLFFTE and TOULFFAS with $P=2.7\text{E-}5$), the operator causing both the tilt control problem and the sudden backward acceleration (events TOXLFFTS and TOULFFAS with $P=1.0\text{E-}5$), mechanical/electrical failures causing both low-level events (events TOXLFFTE and TOULFFAE with $P=8.1\text{E-}6$), and the operator causing the tilt control problem with a mechanical/electrical failure causing the acceleration (events TOXLFFTE and TOULFFAS with $P=3.0\text{E-}6$).

The last two-event combination ($P=1.5\text{E-}6$) consists of the pallet turner failing or being damaged during pallet loading by either the 2000-pound lift truck or the shielded lift truck coupled with the operator attempting to retract the forks or boom allowing the pallet to fall from the failed pallet turner (events TOLPTTSE and TOLPTTSO).

Recommendations:

All but one of the event combinations discussed above involve operator awareness and skill. Initial operator training and recurrent training have been shown to dramatically reduce accidents caused by operator error [FRI87, FEA89]. Since Pantex already has a training program, the recommendation here is for Pantex to ensure an active and

interesting recurrent training and safety awareness program. Mechanical/electrical failures are minimized with a daily inspection and a periodic maintenance program.

Injury to Personnel during Transportation of Pallets from Pallet Trailer to Pallet Turner:

Many potential injuries to personnel will be due to impacts with the lift truck or with a loaded pallet. For an accident to occur, the lift truck must be moving and a person must be in the path of the lift truck movement. There are many potential contributors to an accident. There may be inadvertent acceleration, or the brakes may fail due to component failure or inadequate maintenance. Both the lift truck operator and any pedestrian in the area should check the path of movement before moving and should be aware of their surroundings. The lift truck alarm must be maintained and should sound the alarm during backward movement.

In general, lift truck service brakes tend to be only in the driving axle. All lift truck operators and pedestrians working in the area should be aware that the braking ability of lift trucks has been limited. One reason is that lift trucks usually are operated at low speeds on near-level surfaces. Another reason is that a loaded truck braked too abruptly may result in the load sliding off the forks or the truck upending [EVA74]. As a result, ANSI test criteria have been developed for safety testing of lift trucks. Also, the lift truck stopping distance is fairly long, even with a quick response time on the part of the operator and slow lift truck speeds [MIL88, LOV77]. With appropriate mast tilt, dropping the load is not a substantial problem. On the other hand, there is a real danger to any pedestrians in the operating area of being struck by the lift trucks. It is anticipated that there will be quite a few personnel on the magazine apron during initial startup of Stage Right operations. Pedestrians need to take responsibility for their own safety.

There is a potential for radiation exposure to personnel on the magazine apron. Pantex radiation safety personnel do measure the radiation levels and determine the safe distance from the open magazine doors for operations personnel. The primary concern in the following discussion is for the pallet turner operator, whose distance from the magazine door is largely determined by the location of the pallet turner.

Fault Tree Discussion:

This fault tree is similar to the one for setup and close, except that only the light lift truck is considered a threat to safety. (The assumption was made that personnel will not be within the guide rails for the shielded lift truck as it moves in and out of the magazine.) The fault tree shows that serious injuries to personnel when the lift truck is moving loaded pallets from the trailer to the pallet turner will be due to impacts from lift trucks. With one exception, all injuries will occur when a person is in the path of a moving lift truck and is hit by the lift truck. The single, very low probability exception, is the failure of the forks while someone is in position to be hit by the falling load.

Again, the alarm is taken into account only if the person is several feet behind the lift truck (i.e., the person has time to hear and respond to the alarm). If the person is just a few feet behind the lift truck, the functioning of the alarm is not taken into account because there would not be sufficient time for the person to move out of the lift truck's path. If the person is several feet behind the lift truck, then the assumption is made that the person will

be hit only if the alarm is not working.

Quantitative Analysis for Cut Set Ranking:

A total of 22 cut sets were identified. The ones that are conservatively estimated to occur more than one in one hundred thousand event sequences are shown and discussed below. This is equivalent to a cut set probability greater than 10^{-5} , on a per event basis. The cut sets are in equally probable groups and the groups are arranged from most to least probable.

- person in path of forward moving light (2000-lb capacity) fork lift truck (LF) and operator fails to apply brakes
- person within a few feet of LF (behind) and operator fails to see person

The two cut sets that are most likely to occur each consist of two basic events: a person is in the path of the moving lift truck and the lift truck operator fails to see the person. Failure of the LF operator to apply the brakes will likely be due to the operator not seeing the person. It is extremely unlikely that, given time to apply the brakes, the operator would fail to apply the brakes.

- person in path of forward moving LF and LF moving too fast to avoid impact
- person in front of operating LF and operator suddenly accelerates forward
- person within a few feet of LF (behind) and operator suddenly accelerates

In the above cut sets, a person is in the path of a moving (or operating but not moving) lift truck and the operator either suddenly accelerates the lift truck or is moving too fast to avoid impact.

Two cases involve a person in front of the LF. A person who steps in front of an operating LF could be hit if the operator inadvertently presses the accelerator. A person in front of a fast-moving LF would have to be too close to the lift truck at the time the person is seen by the operator or the LF is seen by the person in the lift truck's path for either to take action to avoid impact.

In the third case, the person is immediately behind the LF and the operator inadvertently accelerates.

- person within a few feet of LF (behind) and brakes fail (equipment)
- person in path of forward moving LF and brakes fail (equipment)

In both cases the lift truck fails to stop because the brakes fail. The brakes fail because an equipment component fails; the failure is not due to inadequate maintenance. The person can be in front of the LF or immediately behind it.

- person in front of operating LF and LF suddenly accelerates (equipment)
- person within a few feet of LF (behind) and brakes fail (maintenance)
- person within a few feet of LF (behind) and suddenly accelerates (equipment)
- person in path of forward moving LF and brakes fail (maintenance)

In two of the above cut sets, a person is in front of the LF and either the brakes fail

because of inadequate maintenance or the LF accelerates because an equipment component fails. A brake failure due to inadequate maintenance should be evident soon after the maintenance is performed. The problem should be discovered when the brakes are tested. In the other two cut sets, a person must be immediately behind the lift truck and either the brakes fail because of inadequate maintenance or the lift truck accelerates because of an equipment component failure.

Recommendations:

The recommendations are the same as those for lift truck injury described in the later section on *setup and close*.

As the Pantex administrative threshold is lowered for exposure to gamma and neutron radiation, mitigation of the dose received by the pallet turner operator should be considered. Approximation of total gamma and neutron exposure at the pallet turner operator's position between the pallet turner and the open magazine on side A yields a radiation dose of 29mr/hr (without taking into account attenuation from protective clothing) [ROB93]. Exposure is less on the B side, since pallet turning operations on the B side take place at a greater distance from the open magazine doors. It takes around 20 to 30 seconds to turn a pallet with the pallet turner and to lock it. The operator should be wearing a wrap-around lead apron, which reaches to the knees and has a v-neck. Note that both the new and the old two-sided lead aprons leave the neck area exposed to radiation and that there is a high susceptibility to cell damage in lymph cells [KNI81, p. 73]. Additional neck protection (perhaps a leaded collar or neck gaiter) may be warranted. If the operator wears only the one-sided lead apron, his back faces the magazine on the A side and is unprotected. Of even more importance, the lead will not shield against the neutron component.

Three operational mitigation solutions have been discussed with Pantex personnel. One is to automate the turning process on the pallet turner. Another is for the pallet turner operator to stand back from the pallet turner and to use a power hand tool (such as a cordless drill) to turn the wheel. The third mitigation solution is to establish a procedure for pallet turner operations, where the operator only stands between the pallet turner and the open magazine during the short time it takes to turn the pallet. At all other times, the operator will move away from the magazine door. Another stipulation being included in the procedure addresses pallet movement during staging. Once the shielded lift truck has removed a pallet from the turner and moved into the magazine to stage the pallet, another pallet will not be placed on the pallet turner until the shielded lift truck has completed the pallet staging and backed out of the magazine past the pallet turner. This requirement will increase the staging operation slightly, but will decrease operator radiation exposure significantly. In addition, the possibility that the operator will be standing between a loaded pallet turner and the open magazine will be eliminated. The procedural exposure mitigation solution should be implemented, whether or not the turning mechanism is modified.

Damage Equipment during Transportation of Pallets from Pallet Trailer to Pallet Turner:

Any of the staging ramp, the pallet trailer, the 2000-pound capacity electric (light) lift

truck, or the pallet turner may be damaged by a combination of excessive speed, a braking control failure, and impact with another object. The pallet turner may be rammed with the lift truck or with a pallet during loading, or the pallet may be set down too hard. The pallet trailer may be hit by the lift truck body or by the forks. The lift truck may be steered into the retaining or wing wall or into the access denial barrier near the apron. Any of the moving vehicles may be backed into the staging and alignment ramps

Fault Tree Discussion:

Four pieces of equipment were considered in the fault tree, the 2000-pound capacity lift truck, the trailer that transports pallets between Zone 12 and Zone 4, the pallet turner, and the staging ramp (including the alignment ramp). Events leading to damage are described in a sub-tree for each piece of equipment (see Appendix D):

- damage to the pallet transport trailer (G2),
- damage to the pallet turner while being loaded or unloaded with the 2000lb lift truck (G3),
- damage to the 2000lb lift truck itself (G4), and
- damage to the staging/alignment ramp (G5).

While not explicit in the fault tree, the events associated with lift truck approach to the trailer apply to the pallet turner and visa versa. The fault tree considers plausible event combinations that would contribute to the undesirable primary event of damaging a piece of equipment. The summary analysis below discusses the probability of these events. For most scenarios, speed and failure to brake are important contributors since little damage normally results when something is nudged or gently bumped.

Damage to the pallet trailer, if it occurs, is expected to be confined to the rear of the trailer. The trailer can be struck with the forks of the lift truck (or a pallet) and damaged (G6 under G2), or damaged by the mast or body of the lift truck as the forks are inserted in the pallet because of a combination of excessive speed and failure to brake (G7 under G2). In G6, damaging the trailer requires a misalignment in height or lateral position (event DALLFYIO). Damage to the pallet turner can occur under similar circumstances.

Damage to the pallet turner can occur if the pallet turner is rammed by a pallet that the lift truck is carrying (G10) or the pallet is set down very hard on the pallet turner (G14). The latter scenario requires the pallet to be lifted too high as the lift truck approaches the pallet turner (event DAXLFPHO under G14). This event also could include the possibility that since the pallet is too high, it may also not be centered over the pallet turner and when it is lowered too fast, a side frame is damaged. Since the pallet turner is relatively light compared to the lift truck and anchored to the staging ramp, it was not considered necessary that the lift truck have much excess speed to cause damage.

Damage to the 2000-pound lift truck requires steering it into a wall, an adjacent ADB, etc. while traveling too fast (G4). Damage could be to the forks, frame, or wheels of the lift truck.

The staging ramp could be damaged if the lift truck hits it too hard (G5). It is assumed that the lift truck is backing up from the trailer and steered into the ramp by mistake.

Quantitative Analysis for Cut Set Ranking:

All cut sets have probabilities less than 10^{-4} (where probability $P < 10E-4$). Assuming that 1248 pallets are moved per year (one full trailer per day, five days per week), no individual event combination is expected to lead to damaging a piece of equipment within one year of operations. However, taking all the event combinations, summing their probabilities, and applying the movement of 1248 pallets produces an expectation of an incident involving damage to a piece of equipment within one year of operations. If more pallets are moved within a year or if the year's timeframe is extended, the expected number of incidents that may occur in the timeframe will increase linearly. The conclusion is that moving pallets between the trailer and the pallet turner may pose potential damage to equipment.

All of the top-ranked event combinations (or cut sets) are two-event combinations. For this reason alone, they are discussed below. They also involve only the trailer and the pallet turner. This appears logical since the trailer and pallet turner are pieces of equipment that the lift truck is expected to be operating near on a routine basis.

The two most probable two-event combinations each have failure probabilities of $P=3.0E-4$. The two combinations consist of the following events: (a) the operator inadvertently turning the lift truck into the pallet turner and not stopping in time to avoid ramming it with the lift truck, causing damage to the pallet turner (events DALLFFCS and DAULFTSS), and (b) the operator moving too fast toward the trailer and not stopping in time to avoid damaging it with the lift truck (events DALLFFSO and DALLFFCS).

The next two combinations ($P=9.0E-5$ for each) result in damage to the pallet turner due to operator errors. In one combination the operator approaches the pallet turner with a pallet that is misaligned and does not stop in time to avoid ramming the pallet turner structure (events DALLFFCS and DAULFTSO). In the other, the operator lifts the pallet too high over the pallet turner and then lets the load drop at maximum speed onto the pallet turner, causing damage to the pallet turner (events DAWLFFOO and DAXLFPHO).

Mechanical/electrical failures begin to appear in the two following combinations that result in damage to the trailer. The first ($P=9.0E-5$) combines an excessive speed condition due to mechanical/electrical failure with the operator failing to apply brakes or otherwise not able to bring the lift truck to a stop before impacting the trailer (events DALLFFSE and DALLFFCS). The second ($P=5.0E-5$) consists of the same problem, excessive speed and failure to stop, but in this case the operator causes the excessive speed condition. A mechanical failure is the reason for the failure to stop before hitting the trailer (events DALLFFSO and DALLFFBE).

Five other two-event combinations all have similar low-level events driving the undesirable event of damaging equipment. All but one involve a mechanical/electrical failure coupled with an operator error. That one is a combination of excessive speed and brake failure, both caused by mechanical/electrical failures (events DALLFFSE and DALLFFBE). The rest combine an excessive speed condition, or a failure to brake with an alignment problem of the forks or pallet load, or steering the lift truck into the pallet turner. Their probabilities range from $5.0E-5$ to $9.0E-6$.

The least likely two-event combination ($P=8.1E-6$) consists of the operator lifting the

pallet too high over the pallet turner prior to placing the pallet on it, coupled with a hydraulic failure at that time allowing the pallet to drop at maximum speed and causing damage to the pallet turner (events DAWLFFOE and DAXLFPHO).

Recommendations:

The highest potential for damaging equipment while transferring a pallet between the trailer and the pallet turner involve human errors. The fact that training greatly reduces the accident rate involving lift truck operations demands initial and recurrent training for lift truck operators. While the probabilities of mechanical/electrical failures were biased toward "aged" equipment for the purposes of this analysis, lift trucks are a reliable piece of equipment. The emphasis therefore should be on training and safety awareness followed by daily inspection procedures and periodic maintenance. Daily inspection procedures should include inspection the hydraulic hoses and connections (checking for cracked or frayed hoses, loose connections or leaks), forks (checking for deformation of the forks, obvious cracks especially at the heel, unusual looseness), visible electrical cables and connections, and tires (checking for bent wheels or missing chunks of tread).

Equipment Unreliability during Transportation of Pallets from Pallet Trailer to Pallet Turner:

Reliability of the electric lift truck used on the apron is of minimal concern, since replacement lift trucks are available on site. The magazine lift truck, with or without its shielding, should not be used with the fork attachment, as a replacement lift truck. The magazine lift truck is not a good replacement truck for the following two reasons: 1) the turret lift has no mast tilt, and 2) the length of the magazine / turret lift truck probably is too long to fit between the pallet turner and the wall. If there is any failure of the alignment or staging ramps or of the pallet turner, operations can be suspended until repairs are performed on site. Equipment unreliability concerns are extremely low with operations on the magazine apron performed within this process.

Staging and Removal within the Magazine

This process includes all pallet movement within and immediately outside the magazine using the shielded lift truck. It has the following sub-processes:

- unloading (or loading) the pallet from the pallet turner
- rotating the pallet to the right or left side for staging within the magazine
- transport to (or from) the staging location
- raising or lowering the boom for pallet staging
- putaway (or retrieval) of the pallet by traversing into (out of) the staging location

The primary safety hazard is the shielded lift truck, with its hydraulic hoist, traverse, and rotate capabilities. Refer to the transport process on the apron for general discussion of lift truck hazards.

Breach Container during Staging and Removal within the Magazine:

The breach of a drum container can occur with the shielded lift truck during pick up

operations using the boom. During pallet retrieval, misalignment of the boom combined with failure of the boom tip switch and the elevation indicators could lead to a container puncture with the boom or lead to a breach from failure of the pallet structure and the container rim band. If the retrieved pallet catches on a previously staged pallet or if the hoist hydraulics or boom fail, the fall may cause a pallet structural failure or a drum puncture from a narrow-edged object such as the rails.

During putaway operations, the pallet being staged may be pushed into a previously staged pallet, or the pallet may fall from a hydraulic or boom attachment failure, or an incorrect retraction of the boom after pallet putaway may drag the pallet or an adjacent pallet from its staged location. The boom elevation sensors would have to fail or be ignored and any inappropriate pallet movement would have to be undetected and unobserved.

A container breach during transport within the magazine would involve pallet and container failure as well as impact with another object. The impact could be from failure of the overrun chocks due to excessive lift truck acceleration resulting in impact with the rear wall of the magazine, from lift truck movement while not in the tucked position (requiring operator override or sensor failure), or from improper pallet rotation without sufficient clearance.

The pit may be breached or crushed, if the container and the pit are pinned between the boom tip and the magazine wall and the container already has been punctured.

Fault Tree Discussion:

In order to breach a container, the container must be either punctured, deformed to the point that the lid falls off, or the rim band breaks or otherwise comes off. Breach is used here to describe all events where the integrity of the container is compromised. The special case of breaching by puncturing a container is included throughout the discussion. Except for a puncture incident, the pallet also must fail for the breach event to occur. Events that could contribute to the primary undesirable event of breaching a container are described within three sub-processes (see fault trees in Appendix E):

- breaching a container during a pick-up (pallet retrieval) inside the magazine (G2),
- breaching a container during transport in or out of the magazine (G3), and
- breaching a container during placement in the magazine (G4).

The undesirable events of G2 and G4 are described as occurring inside the magazine. However, they represent worst-case events at the pallet turner as well. The fault tree considers plausible events that would contribute to the undesirable primary event of breaching a container. The summary analysis below discusses the probability of these events. An additional contribution of puncturing a container and crushing a pit with the boom was also considered in this fault tree.

Breaching a container requires a sequence of several mechanical failures and operator errors. As stated above, breaching a container in a manner other than puncturing involves the failure of the container and the structural integrity of the pallet. Failures were developed for the steady pressure of the hydraulic force applied through the lift truck traverse (currently rated at 3,586 lb. - a value obtained from Hyster), an impact force from

falling, and an impact force developed through the inertia of the 19,000+ lb. shielded lift truck.

Breaching a container during pallet retrieval (G2 - pick-up operations) is divided into breaching the container with the boom (G5) and breaching a container as the result of a fall (G6). Both sub-trees consider the possibility of the container being punctured directly or breached through structural failure of the pallet and the container. Considering the boom alone, a container can be punctured (G7) or otherwise breached (G8) under the same set of circumstances. The outcome is dependent on where the boom would physically make contact. The puncturing of a container (under G19 - landing on a narrow edged object in basic event SERNSCCE and the falling sequences in G20) or breaching it through deformation of the pallet and drum (under G18 - impact forces in basic event SEXSPPSK and G35, and, the falling sequences in G50) were modeled as occurring if either the boom attachment fails, or the pallet being retrieved or an adjacent pallet is dislodged (G20), or, if the mast hydraulic system and safety check valve fail (basic event SERSFMHK under G50 only). This entire set of sequences applies only to a pallet being retrieved from the top row (e.g., a 4-pack on top of a 6-pack pallet). The sequence for a pallet to fall includes mechanical failures and operator errors (under G21 and G22 - G24, G42, and G46). G24 addresses possible situations associated with an incorrect height of the boom during pallet retrieval with the pallet hanging from the boom. If the boom is not in full contact with the pallet carrying-diamond or the pallet is not completely free of the pallet below it, the potential exists that the pallet being retrieved will not be completely captured in the boom, and thus fall. G42 and G46 address a set of possibilities whereby the retrieved pallet and an adjacent pallet may catch on one another and one of the two is dislodged from the top row.

Breaching a container during transport (G3) was determined to be possible either by impacting the carried pallet on some object during routine operation (G10) or impacting the back wall of the magazine due to a series of primarily mechanical failures (G9). The two postulated circumstances associated with routine operation involve rotation of the pallet on the boom (G14 under G13) or hitting some object while moving normally in or out of the magazine (G16 under G13).

For a pallet placement operation (G4), two sub-trees were developed: pushing a pallet into a location that is already occupied or too crowded (G26) causing a container (and pallet) to deform to the point of being breached, or, puncturing or breaching a container after it or an adjacent pallet falls (under G25 - G27 and G28). In pushing one pallet into another (G36 under G26), position sensors need to fail and the operator has to be inattentive and unable to see well inside the magazine (G17 & G15). The operator must not notice a pallet already in the intended position (G38), or that an adjacent pallet is crowding the intended position due to an earlier error in the adjacent pallet's placement. The other branches of this sub-tree involve failure of the structural integrity of the pallet (SEISPPSK) and (G12) failure of the container from the steady pressure of the lift truck traverse. The puncturing of a container (under G28 - landing on a narrow edged object in basic event SERNSCCE and the falling sequences in G29) or breaching it through deformation of the pallet and drum (under G27 - impact forces in basic event SEXSPPSK and G35, and, the falling sequences in G51) were modeled as occurring if the boom attachment fails or the boom is being retracted and the pallet just placed or an adjacent

pallet is dislodged (G29), or, if the mast hydraulic system and safety check valve fail (basic event SERSFMHK under G51 only). This entire set of sequences applies only to a pallet being placed on the top row (e.g., a 4-pack pallet being placed on top of a 6-pack pallet). The sequence for a pallet to fall includes mechanical failures and operator errors (G24 and G31). G24 addresses possible situations associated with an incorrect height of the boom during retraction from the pallet diamond. When the boom is not free of contact with the pallet carrying diamond, the potential exists to drag the pallet from its intended position as the boom is retracted. G31 addresses a set of possibilities whereby the placed pallet and an adjacent pallet may catch on one another (via G40) and one of the two is dislodged from the top row.

The special case of fracturing or crushing a pit during staging or removal of a pallet requires that the container be punctured (G7) and the pit becomes pinned between the end of the boom and the container wall (as the container is then stopped by the wall of the magazine) and squeezed like a ball would be squeezed in a vise (event SEIDCCPK).

Quantitative Analysis for Cut Set Ranking:

All cut sets have probabilities less than 10^{-4} (where probability $P < 10E-4$). Assuming that 1248 pallets are moved per year (one full trailer per day, five days per week), no event combinations are expected, individually or summed together, that would cause the breaching of a container while moving a pallet into or out of a magazine during one year of operations. The conclusion is that moving pallets between the pallet turner and any location inside a magazine does not pose a potential problem of breaching a container within one year of operations.

While no event combination poses a potential problem, the eight event combinations with the highest probability (order of magnitude = 10^{-6} and $> 1.0E-7$) are discussed as examples of possible combinations. Six of the events are similar in that they involve an improper rotation of the pallet either at or near the pallet turner, or inside the magazine. The pallet fails due to impacting a jack top, the pallet turner, the edge of the door opening, another stage pallet, etc. One or more containers fail due to deformation of the container, failure of the rim band, or improper installation of the rim band. For the container to be breached (except for a puncture), both the pallet and a container have to fail. The seventh event involves a double failure of the hydraulic system that allows a pallet to drop (from the height of the second row).

The first event combination ($P=2.0E-6$) leads to a puncture type breach and contains only two low-level events (SERSFBSK and SERNSCCE). This combination consists of the boom failing and the pallet falling across the guide rail. The event of interest here is a boom failure. A boom failure is assumed to be able to happen if four attachment bolts fail or a weld fails.

The next set of event combinations are the same ($P=1.5E-6$) except that the pallet is improperly rotated inside the magazine instead of outside the magazine, and, the pallet fails and a container fails due to deformation of the container, allowing the rim band to fall off and the lid to separate from the rest of the container (event SEXSFBOS or SEXSFBOO, and events SEXSPPSK and SEXDCCCE). Of course, if the shielded lift truck is not at a location where the position interlock sensors allow movement of the

traverse, the override option would have to be engaged.

The next event combination ($P=3.65E-7$) consists of the hydraulic system failing in such a manner that the "check valve" also fails (a double hydraulic failure) along with pallet failing from impact and a container failing due to deformation of the container, the rim band then falling off, and the lid separating from the rest of the container (events SERSFMHK, SEXSPPSK, and SEXDCCCE).

The other two sets of event combinations ($P=3.0E-7$ for one set and $P=1.8E-7$ for the other) are the same as the first set discussed except the container fails in a different manner in each set. One set allows the container to fail because the rim band fails from an impact force and the lid separates in conjunction with the pallet failing; all due to improper rotation of the pallet either inside or outside of the magazine (events SEXDCCCK and SEXSPPSK, and, event SEXSFBOS. or SEXSFBOO). In the last set, the container fails because the rim band was improperly installed. If the pallet fails due to improper rotation either inside or outside the magazine, the rim band is assumed to be able to fall off allowing the container lid to separate from the rest of the container (events SEIDCCCN and SEXSPPSK, and, event SEXSFBOS or SEXSFBOO).

All other event combinations are at least an order of magnitude less than 10^{-8} . The event combination leading to crushing or fracturing a pit is almost impossible. The analysis program SETS trimmed this combination because it fell below the cutoff value of $1.0E-12$. Even though it is physically possible to puncture a container, the chance of the pit becoming pinned between the boom tip and the inside wall of the container is small. The part of the event combination that is almost impossible is the fact that the traverse has a limited motion (46 inches) which is not enough to push the pit against the wall of the container and then push the pit and container against a magazine wall where the pit could then be crushed. Some additional object would have to become lodged in the space between the container/pallet and the magazine wall. Taken together, this is not a credible event.

Recommendations:

Since there are no expected occurrences of breaching a container while moving a pallet between the pallet turner and a position inside a magazine, there is little to recommend as a prevention measure except periodic operational checks of the sensors, and prior to each day's use, inspection of the hydraulic system, particularly hoses and connections, and inspection of the boom attachment. The boom attachment should also be inspected periodically using an established non-destructive inspection method such as dye penetrate.

Drop a Loaded Pallet during Staging and Removal within the Magazine:

Fault Tree Discussion:

Since the boom is inserted into the diamond-hole on the staging pallet, it will be difficult to drop a pallet once it has been picked up by the boom on the shielded lift truck. Sudden boom traverse or uncontrolled rotation combined with an off-balance pallet or lift truck and lack of recovery by the operator may lead to a dropped pallet. The pallet may be off-balance with incomplete insertion of the boom into the pallet or with the pallet catching on the pallet turner due to unlevel jacks or catching on a staged pallet within the magazine. The lift truck may be off-balance if the staging ramp connection to the guide rails fails or

if two or more of the ramp jacks on the staging ramp fail. (Since the ramp is extremely close to the ground level and the ramp jacks are closely spaced, more than one ramp jack would need to fail to result in a severe ramp imbalance.) A pallet drop during pallet retrieval may result from a combination of incomplete insertion of the boom into the pallet, along with the retrieved pallet catching on a staged pallet and sudden acceleration of the boom traverse or the mast lowering to staging height. During hoisting or lowering of the loaded boom, a pallet drop may occur with hydraulic hoist failure combined with check valve failure, or the boom detaching from the lift truck, or when sudden hoist acceleration is combined with the pallet catching on another pallet. A pallet may be displaced, if the operator attempts to putaway a pallet in an occupied staging location due to poor visibility.

Sudden movements are mechanically limited with load lowering controls, and limits on hoist, rotate, traverse, and lift truck travel speeds. Other events which may lead to a dropped pallet include: boom and mast hydraulic failure (for traverse, rotate, or hoist), boom detaching from the rotator on the pivot boom due to structural failure of the boom or the fasteners (twelve bolts), and inadvertently pushing or pulling a pallet with another pallet or with the boom.

In the event of hydraulic failure, conventional lift truck hydraulic hoist circuits use lower control valves (check valves) to limit the maximum lowering speed [HYS92, p.98]. Hydraulic velocity fuses limit maximum lowering speed (mast) in the event of a hose failure [HYS92, p. 23]. The rotator also has check valves and does not rotate unless both lines are intact [HYS 92, p. 101].

Quantitative Analysis for Cut Set Ranking:

Cut sets that have per event probabilities greater than 10^{-5} are discussed. The four highest probability incident scenarios for dropping a pallet during staging and removal are modeled as singleton events. Two are human errors: putting a pallet in an occupied staging location and incomplete insertion of the boom into the pallet prior to rotation. When the boom is loaded with a pallet for putaway into a staging location, the boom tip switch is inside the diamond tube and unable to detect obstructions. During replacement of a single pallet in an otherwise fully loaded magazine, visibility will be limited. In addition, the operator does not have absolute positioning information available within the lift truck. If the operator attempts to putaway a pallet into an occupied staging location, the previously staged pallet will be displaced. There is not enough space between the pallet and the side wall for that pallet to fall to the ground, so the result is a pallet that has been pushed out of position rather than an actual drop of the pallet to the ground level. Since the boom can be rotated into various positions, it is expected that the displaced pallet will be correctly positioned as soon as the pallet on the boom has been putaway.

The other human error involves incomplete insertion of the boom into the pallet prior to rotating to the right or left for staging. The incomplete boom insertion event also occurs in several two- and three-event scenarios. Use of the standard human error probability is high for this event. Rotation occurs outside the magazine where there is ample daylight. In addition to a grossly incomplete boom insertion, the operator is assumed to not recover from the error and to rotate the pallet with enough force to drop the pallet. This scenario is very unlikely, since other personnel on the apron are near enough to notice such a grossly

incomplete boom insertion.

The other two singleton events are hydraulic failures. During hoisting or lowering of the loaded boom, a pallet drop may occur with hydraulic hoist failure accompanied by a check valve failure. Although this has been depicted in the fault tree as a single event, the estimated probability of failure per operation accounts for both the hoist/lowering hydraulic hose failure and the independent failure of the check valve, which limits the lowering hydraulic flow from a hose failure. In the worst case, the maximum pallet elevation occurs when a four-pack pallet is placed on a six-pack pallet. This scenario was simulated to determine damage. In the execution of the Pantex drop test documented in the draft Test Plan, a four-pack pallet was pushed off a six-pack pallet. The four-pack pallet flipped over and fell on the edge of the pallet frame. The pallet remained functional. Since the boom was not inserted into the tested pallet, which would force the pallet to drop straight down to the ground, the drop test was more severe than the postulated hydraulic failure event.

The second hydraulic failure is very similar. It involves hydraulic failure of the hoist line for the lift truck boom and the independent failure of the check valve, during pallet rotation outside the magazine prior to staging. Since rotation does not occur at a large height and the boom is expected to remain in the diamond tube of the pallet, the highest fall possible would not result in damage due to the short distance of fall. (If the rotator hydraulic line were to break, the pallet still would be approximately centered to the lift truck and would not be a problem.) The biggest consequence of either pallet drop due to hydraulic failure would be possible negative public perception of Pantex operations.

The highest probability double-event scenario for dropping a pallet involves the combination of the operator suddenly traversing the boom combined with the pallet catching on the pallet turner because the jacks are not level. Since the pallet fits closely into the pallet turner, unlevel jacks at the pallet turner easily may cause the pallet to scrape against the sides of the pallet turner. The combination of pallet catching and sudden traverse may lead to a dropped pallet. The pallet is expected to fall back on the pallet turner, with minimal or no physical damage to the pallet or pallet turner. The biggest consequence would be possible negative public perception of Pantex operations.

The next two highest probability scenarios are modeled as singleton events. These cut sets address hydraulic rotating, hoisting, or lowering that involve an equipment failure where the loaded boom detaches from the lift truck due to a boom weld failure or failure of the twelve bolts connecting the boom attachment to the rotator arm of the lift truck. Bolt failure severe enough to cause the boom to detach must involve a large number of the twelve attachment bolts, which decreases its likelihood. On the other hand, it is more likely that the boom may detach due to weld failure or metal fatigue. Such a failure may be nearly as likely as a hydraulic failure.

The next group of cut sets includes the following five cut set scenarios which may result in a dropped pallet:

- an equipment failure causing sudden boom traverse AND an operator error where the pallet catches on the pallet turner because the jacks are not level on the pallet turner

- a hydraulic hoist failure causing the boom to accelerate downward combined with an operator error where the pallet on the boom catches on another pallet causing a pallet to drop during vertical movement between the insert/retract elevation and the putaway/retrieve elevation
- two operator errors where the pallet on the boom catches on another pallet and the operator suddenly raises or lowers the boom, causing a pallet to drop during vertical movement between elevations

The equipment failure events involve hydraulic failures of boom hoist and traverse, as in two of the already discussed singleton events. Similarly, unlevel jacks on the pallet turner have been discussed previously. Two cut sets involve an operator error where the pallet on the boom catches on another pallet during vertical movement (hoist or lower) between the insert/retract elevation and the putaway/retrieve elevation for a given staging level. These cut sets do not involve boom traverse. Due to the limited space within the magazine, vertical movement between pallets caught on each other might result in displacement of the already staged pallet. The most severe possibility is that the pallet on the boom catches the staged pallet next to it and continues pulling up until the pallet rolls off to the side. The severe scenario is extremely unlikely, since the space where the pallet falls must be unoccupied and the operator must be unaware of the fall and not prevent it. The less severe case results in displacement of the pallet on the boom or of the already staged pallet, with no damage or falling to the ground.

Recommendations:

There are two issues concerning the lift truck boom attachment. First, the boom attachment is removed (and subsequently reattached) whenever inventory is performed. It is important that procedures check for reattachment of all twelve bolts and reconnection of the circuit for the boom tip switch. Once there are two shielded lift trucks at Pantex, it would be preferable to have one lift truck with the boom attachment and one with the fork attachment. Second, the Hyster document lists the six-pack full pallet design weight as 1100 pounds [HYS92] and the capacity of the boom attachment as 1100 pounds at 20" load center. Since the design weight is at the capacity, stress and failures are more probable. The boom should be inspected periodically, following written checklists and procedures, for metal fatigue or weld failure. It is anticipated that the operator will detect an unbalanced load that is severe enough to result in a pallet drop.

If the pallet turner is not level, the pallet may scrape against the pallet turner sides. Bubble levels may be used on each of the ramp jacks, or on the two jacks supporting the pallet turner. A pallet guide (with a triangular cross section) is planned to assist positioning on the pallet turner and to alleviate potential scraping.

Procedures should stipulate that pallet rotation occur outside the magazine. Check valves on the hydraulics currently offer some protection against pallet drop due to hydraulic failure. The daily lift truck walk-around prior to operation should include inspection of the hydraulic lines. Two inspection considerations are examination of the ground under the lift truck for hydraulic leaks and running a clean rag over the hydraulic lines and connections for signs of leaks. (The second consideration may not be practical.) Lift truck checklist procedures are covered in more detail in the section on shielded lift truck

equipment reliability. The bolts for the boom and fork attachments should be examined during periodic maintenance.

Absolute positioning is planned for inclusion in the enhancement of the lift truck control panel. Absolute positioning may not be critical during initial staging of pallets in empty magazines, as long as the magazine is filled from back to front to take advantage of the natural light coming in the doorway. Staging in the morning will provide additional light, if necessary, since all magazines face east. During an extended maintenance mode when single pallets may be removed from the magazine and then returned, absolute positioning will be very beneficial. Within a full magazine, visibility will be limited due to the shielded lift truck and stacked pallets blocking most daylight. With the current lift truck control panel, the operator is responsible for determining his position from the doorway and the distinction between ground and upper pallet staging levels.

Injury to Personnel during Staging and Removal within the Magazine:

Injuries are possible to either the lift truck operator or to other personnel in the area. Potential injury to the operator may occur under conditions of excessive lift truck acceleration and impact with another object such as the rear magazine wall or an object within the lift truck path. Additional conditions for injury to occur are that the operator is not wearing a seat belt and is thrown into the cab. There may be radiation exposure if the protective cab fails during the impact.

Fault Tree Discussion:

During staging of a pallet in a magazine or removal of a pallet from a magazine, events were divided into (see Appendix E):

- injuries to the operator of the shielded lift truck and (G2)
- injuries to other personnel in the immediate area (G3).

The fault tree includes plausible events that would contribute to the undesirable primary event of injuring someone while moving a pallet into or out of a magazine. The summary analysis below discusses the probability of these events.

For the operator of the shielded lift truck, three types of injuries were considered; burns or smoke inhalation resulting from a fire (G4), exposure to radiation (G6), and injury as a result of a crash (G7). Both radiation exposure and injury resulting from a crash depend on the shielded lift truck accelerating out of control due to mechanical failure or operator error and impacting the back wall of the magazine (G11 under G6 and G7). A crash injury is also possible after accelerating out of control in reverse and impacting a vehicle or other object after exiting off the staging ramp (G22 under G17). In the case of radiation exposure, the integrity of the protective cab is assumed to fail (either by coming loose from the lift truck or developing cracks in the shell as a result of the crash. In the case of injury to the operator, the seat belt is assumed to fail or not be secured.

There is a small potential for a hydraulic fire. Injury from burns or smoke inhalation (G4) is assumed to be the most plausible while inside the magazine since the operator always has two exit paths outside of the magazine and smoke will disburse more readily once outside. Several ignition sources were identified (events under G18) that may start a hydraulic fire given a hydraulic failure. With a hydraulic failure, there will be hydraulic

fluid on the magazine floor. The SAR noted that the hydraulic fluid has a combustion point of 400 degrees F, while lift truck brakes have a temperature up to 450 degrees F under normal operating conditions [SAR93]. When the brakes are not in use, they will cool at a rate of 0.5 degrees F per minute. Operations within the magazine are performed at slow speeds so very little braking is required. In addition, the hoist and traverse operations require that the lift truck be fully stopped, so the brakes will cool down during those operations. Other potential ignition sources include an electrical short from a lift truck component or safety sensor, or a spark from metal contact most likely caused by falling pallets. Sparks from the lift truck are unlikely, since the lift truck has a UL-EE rating. Since there are no flammable materials stored in these magazines, the injury would be smoke inhalation or a burn during operator exit, if a trail of burning hydraulic fluid is in the operator's exit path. Hydraulic fluid fires will be difficult to ignite and sustain (especially a burning oil trail). (In addition, one source has seen welding slag fall into oil with no effect [MOR93].) The brakes may smoke and cool, but a full blown fire is remote. A real concern is atomizing spray from a pinhole leak. An aerosol can pose an inhalation hazard as well as a fire danger.

Other operations personnel in the area may be injured. Injury to other personnel consists of being hit by the shielded fork as it exits the magazine (G19), being hit by a pallet falling from the pallet turner (G20), remaining in the area immediately in front an open magazine that is more than three quarters full (G21), and tripping on or falling from the staging ramp causing serious injury and lost work days (event SINSROPS). Once the magazine doors have been opened, radiation levels are measured to determine the safe distance for personnel to stand from the door. The person rotating the pallets to the horizontal position, is assumed to stand between the pallet turner and the open magazine door. If the area is vulnerable to radiation exposure and appropriate protective clothing is not worn, the exposure may be above the administrative threshold during extended operations. Approximation of total gamma and neutron exposure at the pallet turner operator's position between the pallet turner and the open magazine on side A yields a radiation dose of 29mr/hr (without taking into account attenuation from protective clothing) [ROB93]. Gate G21 and event SINSROPS represent human errors or accidents not involving mechanical failures.

G19 and G20 represent the more serious injury possibilities to other personnel while moving a pallet into or out of a magazine. Of these two, being hit by the shielded lift truck (G19) requires that a person outside of the magazine receives no warning that the shielded lift truck is backing up (G25), and the operator either does not see someone on the staging ramp or the shielded lift truck is suddenly out of control (G24).

Quantitative Analysis for Cut Set Ranking:

All cut sets have probabilities less than 10^{-4} (where probability $P < 10E-4$). Assuming that 1248 pallets are moved per year (one full trailer per day, five days per week), no event combinations are expected, individually or summed together, that would cause the injury to personnel while moving a pallet into or out of a magazine within a single year of operations. The conclusion is that moving pallets between the pallet turner and any location inside a magazine does not pose a potential problem to personnel safety within a single year of operations, under the given assumptions.

One singleton is in this fault tree. This is the possibility ($P=1.0E-4$) of someone tripping or falling in/around the staging ramp or pallet turner causing serious injury (event SINSROPS). This was modeled as an undeveloped event consisting of tripping or falling ($P=.01$) and that mishap resulting in one or more lost days of work ($P=.01$). This is a unique hazard of the staging and removal process because the staging ramp is unique to this operation. The type of accident is not unique. The tripping event was included because the staging ramp does present a potential hazard to personnel safety due to its slight elevation off the ground, the many cross members of its structure, and the fact that people routinely will be working on and around it.

Event combinations leading to a potential of injury to the lift truck operator due to burns or smoke inhalation were in the order of magnitude of 10^{-5} . These were all three-event combinations. Given the very conservative nature of the failure probabilities, there does not appear to be a clear probability for a fire inside the magazine. This sub-tree did not include the operator being unable to exit in case there was a fire. The conservative assumption was that if there was a fire, there would be an injury. Since the operator would, in reality, have a chance to escape, the potential for burns or injury due to smoke inhalation should be even smaller.

Other three-event combinations in the 10^{-5} order of magnitude involve someone being struck by the shielded lift truck as it backs up. These include failure to alert people that the lift truck is backing up because of a back-up alarm failure or the operator not sounding the horn (event SIXSFFVE or SIXSFHUS) or the lift truck getting out of control due to brake failure or uncontrolled speed or acceleration (under G25 - G12 or G24). Perhaps the most serious threat to personnel safety from the lift truck is the potential of people to become complacent and inattentive because the shielded lift truck normally moves very slowly and does not appear to pose a threat.

Recommendations:

Identifying the staging ramp in ongoing safety awareness programs for personnel working in Zone 4 is warranted. An enhancement to include an audible backup alarm on the shielded lift truck is underway. Ensuring that the back-up alarm or horn is working on the shielded lift truck should be part of the daily inspection. Identification of the hazards of working around lift truck operations, especially electric lift trucks in Pantex's ongoing safety awareness programs is necessary. Special attention should be given during training to ensure that a warning is sounded prior to backing up. Personnel need to be reminded that electric lift trucks are relatively quiet and may not be noticed if the person's attention is focused elsewhere.

Radiation exposure at the pallet turner is described in more detail in the section on *injury to personnel during transportation of pallets from pallet trailer to pallet turner*.

Damage Equipment during Staging and Removal within the Magazine:

Equipment that may be damaged includes the pallet turner, the actual four- and six- pack pallet frames, the guide rails, and the shielded lift truck. Because of the guide rails, it is improbable that the shielded lift truck can ram the pallet turner. It is possible that the boom can impact the pallet turner with a pallet during rotation or loading.

The pallet frames potentially may be damaged by ramming into another object or by

dropping. During Pantex drop tests with a 50% overload, the end bolts on the pallet bent, but the pallet was still functional. In another Pantex overload test, the pallet frame bent a little when it hit the edge of the frame during a drop. Again, the pallet was still functional.

The guide rails may be damaged where the staging ramp connects. Damage also may occur if a loaded pallet falls on the rails.

The protective features to protect the palletized drums also protect the shielded lift truck. The overrun chocks installed in the magazine prevent impact with the rear wall. Speed limit controls on the hoist, traverse, rotate, load lowering, and forward/reverse motion protect the lift truck as well as the pallet. The boom tip switch has two sensors, both of which must fail in order for the safety interlock to fail. If the safety features fail, the lift truck equipment may be damaged. Reliability of the lift truck components is discussed in a separate section.

With the exception of impacting the back wall with the lift truck, damage to equipment should be minor. Substantial damage could occur, however, if the lift truck drove over the safety stops and hit the back wall. We assume, that with sufficient speed, the lift truck could drive over the safety stops. Given that the lift truck has cleared the safety stops, an impact with the wall that will damage the boom is very likely.

Fault Tree Discussion:

The fault tree shows that damage to equipment will occur if the shielded forklift drives over the safety stops and impacts the back wall of the magazine. Other equipment damage that could occur, *e.g.*, damaging the pallet turner with a pallet, is not shown because such damage should be minor. If the forklift hits the back wall, however, significant damage could be sustained.

It is assumed that the forklift could drive over the safety stops. It is further assumed that if the forklift clears the safety stops, it will hit the wall and the impact will cause significant damage. In order for impact with the wall to occur, the speed of the forklift has to enable it to drive over the safety stops. This may occur because of sudden acceleration or because the brakes do not slow the forklift sufficiently.

Quantitative Analysis for Cut Set Ranking:

Five cut sets were identified and all warrant further discussion. The first three address lift truck speed:

- shielded lift truck speed sufficient to propel it over safety stops and brakes fail (equipment)
- shielded lift truck speed sufficient to propel it over safety stops and brakes fail (maintenance)
- shielded lift truck speed sufficient to propel it over safety stops and operator fails to apply the brakes

In the above scenarios, the forklift is driving in the magazine and it simply drives over the safety stops. It drives over the safety stops because either the brakes fail or the operator does not apply the brakes. The conservative assumption was made that the operator will not have time to stop the forklift after the front tires have rolled over the safety stops.

- shielded lift truck is within a few feet of the safety stops and it suddenly accelerates (operator error) with enough speed to propel the lift truck over the safety stops
- shielded lift truck is within a few feet of the safety stops and it suddenly accelerates (equipment failure) with enough speed to propel the lift truck over the safety stops

The above cut sets state that the lift truck must suddenly accelerate when it is very close to the safety stops and the speed reached by the forklift must enable it to drive over the safety stops. The lift truck must be close enough to the safety stops when acceleration occurs to attain the necessary speed, but not so far away that the operator has time to apply the breaks.

Recommendations:

The safety stops should be capable of stopping the lift truck when it is moving at the maximum speed that it will be driven in the magazine.

Equipment Unreliability during Staging and Removal within the Magazine:

Reliability of the shielded lift truck is of primary concern in equipment reliability. A separate analysis has been performed and is included in the section on *Equipment Reliability: Reliability of the Hyster Lift Truck*.

Recovery

At the June meeting at Pantex, the apparent response process for a severe emergency was to close the magazine. Then the emergency response team could determine and practice recovery procedures, until they were ready to perform the actual recovery. Two issues may need to be addressed in the response plan. First, if there are pallets remaining on the pallet trailer, are they returned to Zone 12? Second, if the shielded lift truck fails when the loaded boom has only partially staged the pallet, is the pallet staging completed or is the pallet removed with the lift truck from the magazine?

The recovery process may be initiated by a hydraulic failure on the shielded lift truck. Failure of any hydraulic line implies that hydraulic fluid leaks on the floor of the magazine. Hydraulic line failures can be independent. For example, failure of the hoist line still can permit traverse movement of the pallet using the manual controls on-board the lift truck [HYS92, pp. 96 & 99]. Failure of the traverse line still can permit manual lowering of the boom attachment using on-board controls. The rotate line also is independent, but rotation should not occur within the magazine. In addition, recovery of a primary hydraulic failure may be performed using on-board manual controls.

NOTE: It is important to clarify the terminology used in the discussion on recovery. The term *physical movement* requires that an external force be applied. The external force may be an operator physically ratcheting the boom up and down with the come-along cable or physically opening the needle valve on the traverse frame and guiding the pallet into position while the pallet's weight is supported by the boom or come-along cable. *Manual control* refers to operation of the controls on-board the shielded lift truck. A third term, *remote control* refers to control from the remote console in the Support Vehicle for the

Automated Guided Vehicle; remote control is not applicable with the manned and shielded lift truck.

The recovery process may require any of several operations for raising, traversing, lowering, and pulling the shielded lift truck from the magazine. Recovery scenarios include the following:

- raising the loaded boom from the bottom of its limit of travel (boom attachment fully supported by the pallet). With the pallet in the tucked (centered) position, the come-along cable can be attached and the boom raised.
- raising the boom without a pallet from the bottom of its limit of travel. Again, the come-along cable can be used to lift the boom, if necessary. During the recovery operations specified in the Pantex draft Test Plan, it was shown that the boom could not be lower than 29 inches off the ground.
- raising the loaded boom, which is fully supported by a fully staged pallet. In this case, the boom also must traverse and lower to a safe height (in the tucked and normal carry position) in order for the lift truck to be pulled out of the magazine by the ADB mover. It is assumed that the boom is retracted from the staged pallet rather than lifting and removing the staged pallet. The boom does not weigh enough to deform the pallet, since the diamond-shaped lifting mechanism routinely supports the fully loaded six-pack pallet.
- raising the loaded boom, which is supported by a partially staged pallet. (The boom is fully inserted in the pallet.) If this pallet is on the lower level, the pallet will be resting on the guide rail. If the pallet is on the upper level and more than half of the weight is supported by the lower level, the loaded boom will need to be raised, then traversed and lowered. It is anticipated that the pallet will be staged before the lift truck is removed from the magazine. If the pallet is on the upper level and less than half of the weight (of pallet, boom attachment, and weight of the inner mast weldment) is supported by the lower level pallet, the pallet will slide until it is wedged between the pivot boom, the traverse frame, and the lower level pallet. There is the potential for a lift truck attachment to break.
- raising the unloaded boom, which is partially inserted into a staged pallet. Assume that the pallet will remain staged. A concern is whether the weight of the boom and inner mast weldment can dislodge the staged pallet.
- picking up palletized drums with the barrel handler. The barrel handler is hydraulic and has a battery.
- pulling the loaded lift truck from the magazine with the heavy-duty ADB mover.
- There is a small potential for a hydraulic fire. If a hydraulic failure occurs with a partially staged pallet, the magazine may need to be closed while the recovery team prepares for recovery. There will no longer be personnel around with fire extinguishers, in the remote event of a fire. (If deemed necessary, the hydraulic fluid may be covered with a fire preventing agent prior to closure of the magazine.) Other than the spilled hydraulic fluid, there will be no flammable materials within the magazine.

Breach Container during Recovery:

Fault Tree Discussion:

If the hoist hydraulic line has broken, then with conventional lift truck hydraulic hoist circuits, the lower control valves will limit the maximum lowering speed and the boom will go to the bottom of its limit of travel (or until the mast hangs up). If the boom is in the tucked position, the boom will lower toward the floor of the magazine. (NOTE: The boom cannot be nearer to the floor than 29 inches.) With the controlled lowering speed, there will not be enough force to breach any drum containers. Even if the controlling check valve also fails, the boom will remain in the pallet and the fall will not be as severe as that simulated in the Pantex drop test described in the draft Test Plan. A dropped pallet where the pallet is pulled away from the drum rim band may result in a container breach, if the rim band also fails. Similarly, if the fully loaded boom is supported by a fully staged pallet, there is no opportunity for breach unless the boom weighs enough to deform the pallet (which must also contain a drum that was not properly closed). No breach can occur otherwise.

Only three recovery scenarios have the potential for a container breach. First, a fully loaded boom supported by a partially staged pallet will slip if less than half of the weight (of pallet, boom attachment, and weight of inner mast weldment) is supported by the lower level pallet, resulting from a fall leading to recovery. If the slip damages both the pallet and a drum, lifting the pallet with the come-along cable during recovery may complete the structural failure of the pallet. Or, with a higher probability, if the operator fails to control the pallet raising with the come-along cable, additional damage may cause the pallet to fail. If the pallet fails, the container rim band also must fail to result in a container breach. Container puncture appears to be impossible.

Second, a fully loaded boom which is not tucked during removal of the shielded lift truck from the magazine by the ADB mover, may catch on an obstacle (such as a staged pallet or a guide rail) resulting in a container breach. A breach would require steady pressure from the ADB mover pulling on the lift truck to result in pallet structural failure from the pressure. These events would have to be combined with container rim band failure from the steady pressure, from the pallet fall leading to recovery, or from improper closure of the rim band during the pit packing and storage assembly process. Again, a container puncture is not considered possible.

Third, the barrel handler is both hydraulic and has a battery. The hydraulic grabber tongs on the barrel handler possibly may puncture a drum or damage the pallet structure during recovery. It is anticipated that once the operator has positioned the grabber tongs on the drum, he will simply close the grabber tongs. If the barrel handler is misaligned to the drum, the hydraulic pressure during closure of the grabber tongs may result in a container puncture. A second incident scenario with the barrel handler is postulated as operator misalignment of the grabber tongs to the pallet surrounding the drum container, sufficient hydraulic force to result in pallet failure, combined with container rim band failure from the pallet drop leading to recovery, from improper closure during the pit packing process, or from the steady pressure exerted by the hydraulic barrel handler.

Quantitative Analysis for Cut Set Ranking:

Only one cut set meets the criteria to be included in the following discussion. That cut set is the postulated scenario where the hydraulic grabber on the barrel handler punctures a container. The two events contributing to the incident include operator misalignment of the grabber tongs to the drum followed by the operator simply closing the grabber once it is thought to be in place. Both events are operator errors. If the force is not enough to puncture the container, the grabber will merely deform the container.

The next highest ranked cut sets have significantly smaller probabilities of occurrence and fall below the cutoff point for discussion. They address misalignment of the barrel handler to the pallet resulting in pallet failure.

Recommendations:

During recovery, it must be decided if the barrel handler or the fork attachment on the shielded lift truck is more appropriate for the operation. If the operator is more practiced and adept with one piece of equipment, that equipment may be preferable for the recovery operation.

If the barrel handler is used, caution must be exercised during alignment and prior to closure of the grabber tongs. During pickup operations with the barrel handler outlined in the Pantex draft Test Plan, the barrel handler resulted in some denting and visual damage to the container. If visibility is limited within a fully loaded magazine, the chance of damage will increase. A second person check could be performed prior to closing the tongs.

A drum puncture is theoretically possible with either the hydraulic barrel handler or the fork attachment. Partial crushing or container deformation is more likely than container puncture. Hydraulic pressure may be adjusted to preclude container damage.

Additional lighting should be provided within the magazine during recovery operations to determine the extent of possible damage and to increase visibility for off-normal pallet pickup operations. Refer to the next section for more detail.

Drop a Loaded Pallet during Recovery:

Fault Tree Discussion:

Four recovery scenarios have the potential to result in a pallet drop. First, the pallet or drums may be dropped while the traverse frame with the loaded boom is supported by the come-along cable. If the supporting come-along cable fails or becomes detached from the traverse frame, the hydraulics probably will be unable to lower the pallet slowly a second time. The boom may fail structurally, through failure of the attaching bolts (there are twelve) or a weld failure. The pallet or its drum containers may be dropped during recovery, if the pallet has been damaged during the fall leading to recovery and the operator fails to control subsequent lifting of the pallet with the come-along cable during recovery procedures. Lack of control may cause enough additional damage to the pallet to cause it to fail.

Second, an additional pallet drop may occur during procedures with the barrel handler. The pallet may be dropped if the operator misaligns the barrel handler and the barrel

handler equipment fails (hydraulics or battery failure). The pallet may fail and cause pallet and drum containers to fall, if the pallet has been damaged during the fall leading to recovery and the operator fails to control the barrel handler during pallet pickup. The barrel handler is not normally used in the staging process, so the operators are not expected to be as adept with that equipment. It is assumed that once the operator believes the barrel handler to be in place, he will close the grabber tongs hydraulically.

Third, an untucked pallet may drag down another staged pallet while the crippled lift truck is being pulled from the magazine. If the shielded lift truck must be pulled from the magazine with the ADB mover, the boom tucked indicator may not be operational. Note that all lift truck auxiliary equipment (including lights) is on one circuit and may be inoperable, if the lift truck has no power. Alternately, use of the come-along cable may yield false elevation readings or false readings with the boom tucked indicator. Visibility may be poor in the rear portion of the magazine and result in the operator not putting the loaded boom in a fully tucked position. The untucked pallet potentially can protrude enough to drag a staged pallet.

Fourth, if the loaded boom is too low in elevation during a manual retract executed from on-board the shielded lift truck, the retrieved pallet may drag a staged pallet or the boom may catch on the pallet rather than retract from the diamond tube. In this fourth scenario, the hoist hydraulic line has broken with a four-pack pallet only partially staged on a six-pack pallet. The boom has lowered until it is supported by the four-pack pallet. The come-along cable has been used during the recovery procedures to raise the traverse frame with the boom and the four-pack pallet enough to complete staging, or to retrieve the pallet on the boom and remove it from the magazine with the lift truck. In the accident model for the latter case, the pallet on the boom is too low in elevation and drags a previously staged pallet. In the accident model for the other case, the on-board lift truck controls are used to traverse the pallet into its staged position and to retract the boom after the pallet has been staged. During retraction of the boom, the boom catches on the pallet's diamond tube and drags the pallet.

Contributing events to a dropped pallet include: failure of the come-along cable or its attachment to the traverse frame, boom structural failure, pallet failure (initiated by the accident or undesirable event which led to the recovery procedures), or dragging a pallet down with another pallet or with the boom not retracted from the diamond tube. In addition, picking up a damaged pallet with the barrel handler during recovery may complete the structural failure of the pallet. Or, the pallet being picked up may be dropped, due to a hydraulic failure of the barrel handler. Again, the boom must be in the tucked (centered) position before physical removal of the shielded lift truck from the magazine.

Quantitative Analysis for Cut Set Ranking:

All per event cut set probabilities are greater than 10^{-5} . It should be noted that cut sets and single events for recovery scenarios may misleadingly appear to have occurrence probabilities identical to cut sets and single events for other processes. The probability of even being in the recovery process must be considered. It is anticipated that Pantex Plant will rarely, if ever, be in the recovery process. On the other hand, the pallet staging process may occur multiple times daily.

Within recovery, the singleton cut set with the highest ranking for occurrence is the event where the come-along cable is not securely attached to the traverse frame with the loaded boom and fails when the pallet is lifted, resulting in a pallet drop. This is an operator error and may occur in a recovery scenerio when visibility is poor due to insufficient lighting. The second ranked cut set may occur when the loaded boom is supported by the come-along cable. The cut set is a singleton event consisting of boom structural failure due to failure of the twelve attaching bolts or a boom weldment failure. The third ranked cut set is a singleton event where the come-along cable itself fails.

Two cut sets address use of the barrel handler:

- pallet drop due to the operator misaligning the barrel handler grabber tongs to the pallet combined with equipment failure (hydraulic or battery failure) of the barrel handler
- pallet fails due to pallet damage from the fall which led to the recovery procedures, combined with pallet structural failure due to operator failing to control pallet pickup with the barrel handler

The next cut sets in the ranking have the potential to occur during a very specific incident scenario, the fourth recovery scenario described in the fault tree discussion above. In this scenario, the lift truck hoist hydraulics fail (through either a hydraulic hoist line break or failure of the hoist pump motor controller, pump shaft or seal leading to loss of Primary Hydraulic power [HYS92]). This failure occurs during staging of a four-pack pallet on the top level, with less than half of the four-pack pallet positioned over the lower level pallet. The come-along cable is used to support the traverse frame with the loaded boom. The relative infrequency of events leading to this scenario has not been factored into the event probabilities. The specific cut sets are as follows:

- pallet drop due to two additional operator errors: boom too low in elevation during traverse of loaded boom back to tucked position, combined with the pallet on the boom dragging an adjacent pallet
- pallet drop due to two additional operator errors: boom too low in elevation during traverse of unloaded boom back to tucked position, combined with the boom catching on the pallet diamond tube during boom retraction

The next ranked cut set addresses pulling the shielded lift truck from the magazine with the heavy lift truck used to move the access denial barriers.

- staged pallet dragged out of position by the pallet on the boom which is not in the tucked position

If the staged pallet is surrounded by other staged pallets, it is unlikely that it will fall. The pallet may be moved slightly to occupy the small space normally present between the staged pallets (about 1 to 2 inches). If no pallets are between the pallet being dragged and the magazine door, the pallet may fall on its side. Most likely the operator will see the pallet moving and recover.

The last ranked cut set may occur when the loaded boom is supported by the come-along cable.

- a pallet is damaged during a fall requiring recovery procedures combined with operator failure to control the pallet raised with the come-along cable

Scenarios where recovery from an operator error may not occur because the operator cannot see what is happening due to insufficient lighting, include the fourth recovery scenario in the fault tree discussion. In that scenario, the pallet is supported by the come-along cable, the boom is too low in elevation, and either the pallet on the boom drags a staged pallet or the boom catches on the partially staged pallet and drags it during manual retraction of the boom executed from on-board the lift truck.

Recommendations:

Dropping a pallet during recovery may make recovery more difficult but should not cause significant additional damage. Execution of the Pantex drop test described in the Test Plan resulted in very little damage to the drum containers, with the pallet remaining functional. A dropped pallet where the pallet frame is pulled away from the drum rim band may result in a container breach, if the container rim band also fails. This sequence is discussed under *container breach*. The biggest consequence of a dropped pallet, without container breach, is negative public perception. In addition, any damage to the pallet will need to be fixed. (Note: A container breach is not addressed under dropping a loaded pallet.)

The boom should be inspected periodically for weld failure or metal fatigue.

Provisions for additional lighting during recovery operations in the darkened magazine interior would give more visibility and help to assure proper attachment of the come-along cable, if needed. Currently, all lift truck auxiliary equipment is on one circuit. A separate power source for lift truck lights could be considered to provide lighting during recovery procedures. A separate battery for lighting would not cause additional discharge of the current primary battery during recovery. Another consideration is a portable power source with lights to use during recovery procedures.

Operator training should address acceptable traverse frame locations for attachment of the come-along cable during recovery. Two locations have been pointed out during operations demonstrations: a round opening for the hook attachment and a horizontal plate on the traverse frame. Procedures for a check of the come-along connection by a second person or a second check by the operator who made the original attachment may be required.

During verification procedures discussed in the Test Plan, the operator could not get enough leverage with the come-along cable system to raise a four-pack pallet (approximately 750 pounds). Additionally, it may be necessary during some postulated recovery scenarios to lift the six-pack pallet (weighing approximately 1100 pounds) over the guide rail (6" from the floor plus necessary clearance). A come-along requiring less leverage is required and is currently under investigation.

The barrel handler was envisioned for dense pack magazine operations and not Stage Right applications. Since it is not used in normal palletized container staging operations, the operators may not be as adept with its use. During implementation of Pantex Test Plan scenarios, the barrel handler caused minor denting and superficial deformation of the drum container surface. As an alternative, pickup operations could be performed with the fork attachment on the lift truck, even when the pallets were placed in the simulated

earthquake-aftermath formation. The barrel handler may not be required unless a pallet has failed and its containers are no longer contained by the pallet.

Injury to Personnel during Recovery:

Injury to personnel during operations for recovery of the staging vehicle requires that the come-along be used to support the loaded boom and that the boom fails while supporting the pallet. A person must be near the come-along cable and the loaded boom being supported by the cable when the cable or supporting equipment fails. If there is no need to use the come-along cable, no one should be near the boom or pallet during failure. For the injury to occur, the boom must have a structural failure allowing the supported pallet to fall.

The protective clothing is another concern. Workers that are exposed to the radiation environment (either packing the pits into drum containers or handling drums in the present single-level, vertical dense pack) wear two-sided aprons for radiation protection. Given the worker's height and proximity to the single-level radiation sources, the apron protects the trunk from exposure.

With the Stage Right magazine configuration, the horizontally stacked and palletized drums now extend from the floor to well over the worker's head. The worker's neck and lymph glands will be nearer to the radiation sources. Although the two-sided lead apron may increase the difficulty of recovery, they should be worn inside the magazines. The double-sided lead aprons do provide some protection against the gamma radiation, and gammas are the main concern. The aprons provide no protection against the neutrons. It may be appropriate to add a lead collar to the current protective clothing during any extended exposure involved in recovery operations, but the collar may add little protection while making the protective clothing more cumbersome.

Fault Tree Discussion

The fault tree shows that for an injury to occur during recovery of the shielded lift truck a person has to be in position to be hit by a loaded pallet when it falls or in the path of the whipping cable if it should break. If the boom fails, the pallet will drop; if the cable equipment fails the boom with the pallet will lower to the floor; if the cable breaks or the cable/traverse connection fails, the pallet will accelerate to the floor while the cable whips.

An injury can occur because an individual is either hit by the pallet when it falls or is hit by the whipping cable when it breaks. Since the cable is small and the length of cable that will suddenly accelerate is just a few feet, depending on where it breaks, any resulting injury is likely to be minor. The pallet could cause a severe injury but, unless the individual's body is touching the pallet when it falls, the injury is likely to be minor.

Quantitative Analysis for Cut Set Ranking:

Six cuts sets were identified and all had relatively low probabilities of occurrence. In all cases, in order for a serious injury to occur, a person has to be in a location where either the pallet or cable strikes the person. The person has to be in position to be hit by either a boom with loaded pallet that falls when the boom or come-a-long cable fails, or a person has to be in position to be hit by a whipping come-a-long cable when it breaks.

The assumption was made that the boom would be checked following installation to

ensure that it is properly secured, especially, that all of the bolts have been installed. If the boom is going to fail because of inadequate installation, it is likely to happen on the first lift, probably outside the magazine and not during the recovery of the shielded lift truck from the magazine. A lift test following installation would virtually ensure that the boom will not fall due to inadequate installation.

If the boom fails, it will probably fail at or near a point of attachment. In that area, the hardware could be weak or the boom could be inadequately secured. The boom itself could be cracked or the welding in the area could be breaking down. In either case, the deficiency would have to go unnoticed when inspected. In order for the boom to be inadequately secured, bolts would have to be omitted or inadequately installed.

Inadequate attachment of the boom should be discovered and corrected before the lift truck is delivered to the magazine.

If the cable or other cable equipment breaks while supporting the weight of the pallet and boom apparatus, the load will not accelerate down as fast as it would in free fall.

Therefore, even a person leaning against the pallet might not be seriously injured.

Recommendations

Recommendations for preventing fork failure were given in an *Industrial Engineering* article [CRO79]. The author advised a daily inspection of forks. The person performing the inspection, who could be the operator, would check for cracks, deformations, and damage. The inspections should be a "...daily reportable assignment...not left to chance. Printed forms for inspection schedules assist accurate record keeping." Since the abrasion that results from rubbing against objects can "thin" and weaken blades, the author recommended "frequent" checking of the blades' dimensions and recording them. Another recommendation is for a semi-annual inspection that is more thorough than the daily inspections. Methods for performing these inspections (dye penetrant testing and magnetic particle testing) are described in the report.

The referenced article indicates that frequent inspections and tests of forks are desirable. The boom for the shielded lift truck should be inspected and tested at least as thoroughly as forks.

Test the boom after installation (i.e., after the exchange from forks to the boom) to ensure that it performs all functions while supporting a load that is as heavy as a 6-pack.

On days when the boom will be used, inspect it prior to use. This should be part of a safety check of the lift truck; a checklist should be used.

Minimize the number of installations (and, therefore, the number of opportunities for human error) by using one of the two lift trucks for operations requiring a boom and the other for operations requiring forks.

Although not in the fault tree, if the lift truck failed in the magazine door a person may have to climb over two four-pack pallets and the lift truck itself to get inside the magazine. If the person wore a lead apron while climbing, the climbing would be difficult and dangerous. The climb to the top of the lift truck should be done quickly and without a lead apron. The lead apron can then be handed to the person on the lift truck.

Damage Equipment during Recovery:

Recovery operations are performed because equipment has either been damaged or is inoperable. Pallets or containers could be damaged during the recovery operations, but those items are covered under "drop a pallet" and "breach a container." Equipment that may be damaged includes the shielded lift truck, the boom and the tip switch (if there is mechanical failure of the boom), the come-a-long cable, and the ratchet for the cable. The existing item of equipment that is most likely to be damaged during recovery is the come-a-long cable. The cable could break or some other part of the equipment could fail. A stronger come-a-long cable and ratchet are required that have more leverage.

During a simulated recovery scenario, there was not enough leverage to lift a four-pack pallet. During that test, it became apparent that a modification (e.g., a longer handle) was needed to get enough leverage and to make the come-a-long easier to use. An enhancement or substitute lifting mechanism currently is being considered. Procedures should specify the equipment that will be used in the event that the come-a-long fails.

Equipment Unreliability during Recovery:

Reliability of the shielded lift truck is of primary concern in equipment reliability. A separate analysis has been performed and is included in the section on *Equipment Reliability: Reliability of the Hyster Lift Truck*.

Setup and Close

Breach Container during Setup and Close:

not applicable

Drop a Loaded Pallet during Setup and Close:

not applicable

Injury to Personnel during Setup and Close:

Fault Tree Discussion:

The fault tree shows that serious injuries to personnel during setup and close will be due to impacts from lift trucks. With one exception, the injuries will occur when a person is in the path of a moving lift truck and is hit by the lift truck. The single, very low probability exception, is the tipping of the shielded lift truck (SF) while unloading it from the trailer (forkstork) that delivers it to the magazine.

The basic events shown in the fault tree are the same for the heavy lift truck (HF) that removes and replaces the concrete barriers and the light lift truck (LF) that delivers the ramp and other items. A person could be in the path of either lift truck when it is moving backward or forward. The alarm is taken into account only if the person is several feet behind the lift truck (i.e., the person has time to hear and respond to the alarm). If the person is just a few feet behind the lift truck, the functioning of the alarm is not taken into account because there would not be sufficient time for the person to move out of the lift truck's path. If the person is several feet behind the lift truck, then the assumption is made that the person will be hit only if the alarm is not working. In the case of the shielded lift truck, a person could be hit when the SF backs off the forkstork.

A lift truck can fail to stop before impacting a person who is in its path because:

- the lift truck operator fails to see the person,
- the lift truck suddenly accelerates, or
- the lift truck's brakes fail.

Sudden acceleration and brake failure can be due to operator error or equipment failure.

Quantitative Analysis for Cut Set Ranking:

A total of 49 cut sets were identified. The ones that are conservatively estimated to occur more than one in one hundred thousand event sequences (where probability $P > 10^{-5}$) are shown and discussed below. The cut sets are discussed in groups that are equally probable. The groups of italicized cut sets, which are followed by discussion of each cut set in the group, are arranged from most to least probable in this section of the report.

- person behind SF, unaware it is moving and operator fails to see the person
- person in path of forward moving LF and operator fails to apply brakes
- person within a few feet of LF (behind) and operator fails to see person

The three cut sets that are most likely to occur all require a person to be in the path of a moving lift truck (light or shielded) and the lift truck operator to fail to see the person. Incidents involving the light lift truck are more likely than the same incidents involving the heavy lift truck because (1) the light lift truck is small and quiet, therefore, it is less threatening, and (2) more people are likely to be in the vicinity when the light lift truck is operating.

In the SF case, the lift truck is backing off the forkstork and the person is near the trailer and unaware of any danger posed by the lift truck, but the person can be in the path of the SF when it backs off the trailer and turns to face the magazine.

Failure of the LF operator to apply the brakes will likely be due to the operator not seeing the person. The operator will simply fail to see the person who is in the lift truck's path in time to avoid the person by stopping or turning. It is extremely unlikely that, given time to apply the brakes, the operator would make an error of commission that involves such a highly practiced, skilled task.

In the third case, a person is immediately behind the light lift truck and the operator fails to see the person before backing. The assumption is made that, even if the operator were to see the person before impact, the operator would not have time to avoid hitting the person.

- person in path of SF backing off trailer and operator suddenly accelerates
- person in front of operating LF and operator suddenly accelerates forward
- person in path of forward moving LF and LF moving too fast to avoid impact
- person within a few feet of LF (behind) and operator suddenly accelerates

This group of cut sets also involves the SF and LF. In these scenarios, a person in is the path of a moving lift truck and the operator either suddenly accelerates the lift truck or is

moving too fast to avoid impact.

Again, in the SF case, the lift truck is backing off the forkstork and the person is near the trailer. This sequence of events could occur if the person is behind the SF after it has turned to face the magazine. The lift truck then suddenly accelerates backward.

Two cases involve a person in front of the LF. A person who steps in front of an operating LF could be hit if the operator inadvertently presses the accelerator. A person in front of a fast-moving LF would have to be too close to the lift truck for the operator to avoid.

In the last case, the person is immediately behind the LF and the operator inadvertently accelerates.

- person in path of forward moving LF and brakes fail (equipment)
- person within a few feet of LF (behind) and brakes fail (equipment)
- person in path of SF backing off trailer and brakes fail (equipment)

In all three cases the lift truck fails to stop because the brakes fail. The brakes fail because an equipment component has a defect; the failure is not due to inadequate maintenance. The person can be in front of the LF or immediately behind it, or in the path of the SF as it backs off the trailer and turns.

- person in path of forward moving HF and operator fails to apply brakes
- person within a few feet of HF (behind) and operator fails to see person
- person in path of forward moving LF and brakes fail (maintenance)
- person in path of SF backing off trailer and SF suddenly accelerates (equipment)
- person within a few feet of LF (behind) and LF suddenly accelerates (equipment)
- person within a few feet of LF (behind) and brakes fail (maintenance)
- person in front of operating LF and LF suddenly accelerates (equipment)
- person in path of SF backing off trailer and brakes fail (maintenance)

The first two cut sets involve the heavy lift truck. These incidents are less likely than the same ones involving the light lift truck because (1) it is less likely that anyone will stand behind a lift truck that is huge and loud, and (2) few people will be in the vicinity (maybe only one security guard) when it is operating.

Four of the cut sets involve the light lift truck. In two cases, a person is in front of the LF and either the brakes fail because of inadequate maintenance or the LF accelerates because an equipment component fails. A brake failure due to inadequate maintenance should be evident soon after the maintenance is performed. The problem should be discovered if the brakes are tested. In the other two cases involving the LF, a person is immediately behind the lift truck and either the brakes fail because of inadequate maintenance or the lift truck accelerates because of an equipment component failure.

In two of the cut sets, someone is in the SF's path when it backs off the forkstork (trailer) and the lift truck either accelerates because of an equipment failure or the brakes fail because of inadequate maintenance.

Recommendations

A report on injuries involving lift trucks [STO87] summarized the findings of several studies performed in the 1970's and 80's. The author found that "...the most frequent accident types reported are ones in which workers are struck by or run over by forklift trucks." The most frequent injuries occurred when workers' feet were run over by lift trucks.

Some areas in the vicinity of the magazine should be designated "safe areas," *i.e.*, areas where lift trucks will not operate. For example, if lift truck operation is restricted to the concrete apron, then personnel who are off the concrete would be in safe areas.

Safe operating procedures should keep personnel clear of lift truck paths.

Personnel in the area need to know where the safe areas are located and stay in those areas when possible. Lift truck operators must be aware of safe areas and not operate in them.

All of the light, heavy duty, and shielded lift trucks should have backup alarms.

Each lift truck's brakes and alarms should be tested following regularly scheduled maintenance and repairs.

Damage Equipment during Setup and Close:

The forkstork should be used to transport the shielded lift truck to and from the magazine to prevent damage. Road unevenness and the bumpy transition between the road and the apron could cause damage to the shielded lift truck. The lift truck has solid rubber or polyurethane tires and a very small ground clearance for the guide roller assembly [HYS92]. In addition, a severe jarring to the lift truck could cause damage to the hinges for the shielded door, which is quite heavy. (The entire shielded cab weighs 7000 pounds.) This area has not been examined in detail in this analysis, but equipment damage at the door hinges is resulting in design enhancements.

Equipment Unreliability during Setup and Close:

Failures of the heavy-duty lift truck or the electric lift truck used on the apron are of minimal concern, since there are similar or identical lift trucks on site, which can be used as backups.

Inventory

The inventory process requires several operations to complete. These include the following:

- installing the forks and fork carriage on the shielded lift truck, then re-installing the boom attachment after inventory
- loading the inventory pallet on the inventory pallet trailer and on the lift truck
- transporting the inventory pallet to/from the magazine on the inventory pallet trailer
- performing the inventory
- re-installing the boom attachment on the shielded lift truck, then re-connecting the

boom tip switch sensor

Observations:

The boom tip switch is disconnected whenever the forks are attached. It is possible to omit re-connection of the boom tip switch sensor when the boom is re-installed after inventory. There is no indication that this step has been completed or omitted -- and the boom is operational without its safety feature.

Everything in the PINPAL (physical inventory pallet) is solid state, except for the single floppy. Although the PINPAL has been ruggedized, its electronics, computer and VCR internals, as well as its single computer floppy disk may be sensitive to weather conditions, extreme vibration during transport, or the radiation conditions inside the magazine. Simulations showed the silicon radiation dose absorption to be at extremely low levels [MOR93]. Exposure to the magazine radiation conditions will not get close to the 1000 rad to experience CMOS and SCR failures [DRU93]. On the other hand, the presence of high energy neutrons can cause single-event-upset (SEU) errors in digital electronics [CUR93].

It is up to operations personnel to protect the PINPAL. An inoperational PINPAL will impact operator safety indirectly, if the automated inventory system breaks down and the operator must perform the inventory by hand. The inventory should not be performed until an alternate physical inventory pallet has been brought on site.

Breach Container during Inventory:

not applicable

Drop a Loaded Pallet during Inventory:

not applicable

Injury to Personnel during Inventory:

Fault Tree Discussion:

The Hyster document states that either of the boom attachment or the forks and fork carriage "may be installed using wrenches and a hoist by two people in a couple of hours" [HYS92]. Another possible installation method discussed during Pantex site visits considered an electric lift truck to hold the lift truck attachment at the necessary height during attachment. Injury to personnel is more likely with the second method, which has been modeled in the fault tree. Some type of equipment is required to hold the attachment at the required height while the twelve bolts are fastened.

Personnel may be injured if the boom or fork attachments fall during installation or during inventory (if they were not attached correctly during installation). Personnel also may be injured during setup if the lift truck accelerates toward the person guiding the insert of the forks into the inventory pallet or if the lift truck accelerates toward another nearby person within two feet of the lift truck. There does not appear to be any opportunity for injury of personnel during the actual inventory process itself.

Quantitative Analysis for Cut Set Ranking:

The highest ranked cut set within this injury fault tree has been modeled as a single event,

where the fork attachment falls because it has not been connected securely. Since the positioning of the forks in the inventory pallet is performed as a team operation, a person is very near the pallet should the forks fall. Since that person is positioned to the side of the inventory pallet, the possibility of serious injury is very remote. The fork attachment would be expected to fall during initial pickup of the 1500 pound inventory pallet. A very conservative estimate, consisting of two human errors, has been used. The two tasks are incorrect fork attachment and the presence of a person to get hurt. In actuality, there are twelve bolts connecting the fork or the boom attachment to the shielded lift truck. Either attachment connects to the lift truck rotator, which in turn is connected to the pivot boom. The attachment to the rotator is done with six bolts in a circular arrangement on the rotator top and six bolts on the bottom.

Positioning of the forks in the inventory pallet was performed as a team operation during the operations observed, to assure accurate positioning of the forks in the pallet forking tubes. The second and third ranked cut sets also have been modeled as single events. Both involve sudden acceleration of the lift truck. In one cut set scenario, the operator inadvertently accelerates the lift truck toward the person guiding the insert of the forks into the inventory pallet. The other cut set requires the presence of a person within two feet of the lift truck, guiding the fork insertion, but does not involve lift truck operator error. The cut set probabilities are high because each consists of one human error and all human error estimates use the very conservative pre-accident screening values.

The final cut set involving injury to personnel consists of two events during the exchange and installation of the lift truck attachment. First, if the weight of the attachment is supported with the forks on another lift truck (as modeled in this fault tree), the equipment may slide off the forks during alignment of the bolt holes in the attachment process. Second, the person aligning the bolt holes on the attachment with those on the rotator must exert force on the attachment to result in the attachment falling. Alignment is expected to be difficult if the attachment weight is supported by another lift truck.

Recommendations:

Since the cut set involving installation of the forks or boom requires that two events occur, the probability for the sequence is reduced in this model. But incorrect attachment may result in the singleton cut set scenario which has the highest ranking. A change in procedure to use a hoist to lift the lift truck attachment instead of using the lift truck forks would eliminate the possibility of the attachment not being balanced on the forks and falling during the attachment process. On the other hand, if the weight of the attachment is supported by a hoist, it still may be difficult to align the bolt holes on the attachment and the rotator.

To simplify the attachment process and to increase personnel safety, a specialized piece of equipment may be designed to hold the attachment at the correct height to the rotator. The equipment will need to have height and rotational flexibility. This will assist in better alignment of the bolt holes and virtually eliminate the chance of an attachment falling during installation. Some type of rolling cart is envisioned, with something like a transmission jack mounted on top. If two pieces of equipment are designed, one for the boom attachment and one for the fork attachment, all lifting during the attachment exchange process is eliminated. In addition, the attachments may be stored as placed on

the specialized installation equipment, as long as wheel locks to prevent rolling are used. The boom tip switch should be tested whenever the boom attachment is installed.

Damage Equipment during Inventory:

Fault Tree Discussion:

The PINPAL weighs approximately 1500 pounds and is carried on the fork attachment which has a rated capacity of 3000 pounds vertical measured at 24 inches from the face of the forks. No damage to the fork attachment or to the shielded lift truck is anticipated during the inventory process. The fork attachment is sturdy and should not be damaged by dropping. On the other hand, the boom tip switch on the diamond-shaped boom may be damaged by dropping. The boom tip switch stops movement of the boom upon contact with an obstacle and is an important safety feature, which should be protected.

The majority of the potential equipment damage would be to the electronic equipment on the inventory pallet itself. The physical inventory pallet is a complex piece of equipment. It carries four scanners to read the container barcodes and four CCD VCR cameras with lights. These are carried on a pedestal which slides on a guide rail track. The cameras are connected to four VCRs to record the inventory. Additional equipment includes a camera monitor and a supervisory computer with a hand-held scanner for input. Potential damage to the electronic equipment includes damage from incorrect connection of the fork attachment resulting in dropped equipment, damage from vibration during transport to the magazine, weather damage from exposure, radiation damage from the magazine environment, and inadvertent collision with any obstacle.

Another concern is the attachment of the boom or fork attachments on the shielded lift truck. Damage to equipment is more likely with the attachment method using a lift truck to hold the forks and fork carriage, which has been modeled in the fault tree.

Quantitative Analysis for Cut Set Ranking:

The quantification is heavily driven by the potential for damage to the inventory pallet in the magazine and in transportation to the magazine. The fault tree has been modeled at a very high, global level. Because of this, most of the cut sets are singleton events.

The two highest ranked cut sets are tied. One is a scenario where the camera and scanner pedestal on the inventory pallet has been slid over too far on its horizontal guide track so that the equipment sticks out and hits an obstacle during lift truck movement. The inventory pallet is carried using the fork attachment in the side-pickup position. With this particular pallet, the side pickup means that the scanners and cameras on the inventory pallet pedestal are not centered within the magazine aisle. The pedestal may be slid on the horizontal guide track on the inventory pallet to center the cameras within the magazine aisle. Pedestal movement generally is done before the shielded lift truck moves past the pallet turner and into the magazine. It is thus theoretically possible for the equipment to extend far enough to hit the pallet turner as it passes, or the palletized containers in the magazine after entry into the magazine.

The tied top ranking cut set is another operator error. Since the inventory pallet is longer than the staging pallets, it is quite possible that the inventory pallet could hit the back wall of the magazine before the shielded lift truck could be stopped by the overrun chocks.

There is no physical way to overcome this deficiency with the overrun chocks, since they are positioned to permit pallet staging in the position nearest the back magazine wall. Since the inventory is performed slowly, this hazard should be minimal. In addition, the magazines vary in length from front to back by approximately 1.5 feet. The magazine used in the operations demonstrations has the shortest length, with about one inch of space between the last pallet and the back wall.

The next group of five cut sets also are tied. These are all operator error, single events and include the following:

- damage to the PINPAL from weather exposure during transportation to the magazine
- forks raised too high during inventory pallet pickup, resulting in damage to the VCRs and/or batteries
- fork attachment not attached securely, resulting in a fall during pickup of the inventory pallet and equipment damage
- vibration damage to the electronic equipment of the PINPAL caused by driving too quickly over uneven roads during transport to/from the magazine
- pallet too low during loading of the inventory pallet onto the PINPAL trailer, resulting in damage to the electronic equipment

Since Pantex operations are not conducted in inclement weather, any damage would be the result of sudden weather changes. Environment chamber testing was conducted over the temperature range from -20°F to 120°F [MOR93].

If the forks are raised too high during insertion into the pallet forking tubes prior to pickup, they may damage the electronic equipment. Although this forking scenario has been modeled as a single operator error, the operations observed at Pantex included a person available to guide the insertion of the forks into the pallet. A similar operation concerns the loading of the PINPAL onto its transport trailer. If these always are team operations, any equipment damage scenarios would be a combination of at least two operator errors, rather than just one error.

If the fork attachment has not been connected correctly to the lift truck, it may fall when the inventory is initially picked up. Such a fall has the potential to severely damage the electronic equipment on the pallet. Boom installation is similar to fork installation and is discussed in connection with a later cut set.

Vibration damage is possible from driving over uneven roads during transport.

Three cut sets addressing events leading to equipment damage remain to be discussed. First, if the operator inadvertently traverses the inventory pallet during inventory operations within the magazine, the electronic equipment may be damaged. Next, the cut set involving damage to the boom tip switch consists of two events during the exchange and installation of the boom attachment. First, if the weight of the boom attachment is supported with the forks on another lift truck (as modeled in this fault tree), the equipment may slide off the forks during alignment of the bolt holes in the attachment process. Second, the person aligning the bolt holes on the boom attachment with those on the

rotator may exert force on the attachment resulting in the attachment falling. Alignment is expected to be difficult if the attachment weight is supported by another lift truck or by a hoist, as suggested by Hyster.

The third of the final three cut sets describing damage to equipment covers radiation damage to the electronic equipment on the PINPAL. The equipment is off-the-shelf and includes the personal computer with its diskette of input information and the video recorders with video tapes. Although the inventory takes only ten to fifteen minutes, there may be cumulative equipment damage due to repeated exposure to the radiation environment within the magazine. Since diskettes and video tapes are relatively cheap, the major result of damage to those components would be loss of data. The presence of high energy neutrons can cause single-event-upset (SEU) errors in digital electronics [CUR93].

Recommendations:

The inventory pallet plays a dominant role in the reduction of radiation exposure to individuals during the inventory of drums stored in the magazines. If the inventory pallet is damaged, any inventory should be delayed until necessary repairs are completed, to avoid performing inventory with hand scanners.

Since it is possible to position the equipment pedestal on the inventory pallet too far to the side so that it risks hitting the pallet turner or the staged pallets, there is a plan to put in stops on the guide rail track to allow two positions only. The two allowable positions would be the camera-centered position for magazine inventory and the position for storage of the inventory pallet. An alternative preventive measure is to mark the two allowable positions on the pallet's guide rail.

The PINPAL has been bumped into the magazine back wall. The inventory pallet itself extends past the electronic equipment on the leading side of the inventory pallet, as a protective measure. The current overrun chocks are positioned for staging the palletized drums and are not in the correct position to stop the lift truck with the longer inventory pallet. Two additional preventive measures to avoid damage from inventory pallet collision with the magazine rear wall are suggested. The first includes the use of a sensor to detect proximity to the rear wall, or installation of a cushioning bumper on the rear wall. Second, if absolute positioning is included in an enhancement of the lift truck control panel, the operator could easily tell when he has inventoried the pallets in the last position. The addition of a warning indicator could reinforce the information from the absolute positioning.

Fork insertion into the pallet forking tubes and loading of the PINPAL onto its transport trailer should be team operations. Team operations have their own hazards, as discussed in the section on injury to personnel.

Since the physical inventory pallet is a complex piece of equipment, care must be given to protect it from weather and radiation damage or from excessive vibration during transport. Although the analysis considers driving too quickly over bad roads to be a human error, the realization of excessive speed and resultant slowing reduces the error by a recovery factor. There is a protective cover for the PINPAL, which should be readily accessible whenever the inventory pallet is being used.

The diskette containing the input information for the inventory should never be the only source of that data. If the diskette fails while the current inventory information is being written and the new data is lost, the inventory can be redone.

To avoid dropping the boom attachment, a specialized piece of equipment may be designed to hold the attachment at the correct height to the rotator. The equipment will need to have height and rotational flexibility. This will assist in better alignment of the bolt holes and virtually eliminate the chance of the boom attachment falling during installation and damaging the boom tip switch. In addition, the boom tip switch should be tested whenever the boom attachment is installed.

Equipment Unreliability during Inventory:

Reliability of the shielded lift truck is addressed in the section on operations in the magazine. Reliability of the inventory pallet does not affect the safety of the operators.

Inter-Zone Transportation:

This process includes the loading of the pallet trailer from the loading dock in Zone 12 and the subsequent transfer to Zone 4. None of the steps in this process have been observed, so the following discussion is fairly generic.

Previously, it was noted that lift trucks are a common source of occupational injuries. Another source reported that "industry and government experts estimated that 10-25% of all industrial accidents happen at the dock." [MMH88] The source discussed the roles of vehicle restraints to secure the trailer to the dock, dock levelers to bridge between the building and the truck, safety stops to prevent a falling leveler ramp with premature truck departure, guardrails around pedestrian walkways, as well as dock area housekeeping.

Although the scope of this analysis begins at the Zone 12 loading dock, activities prior to the loading dock also may be hazardous. These activities include pallet movement near the pit vault and pedestrian and lift truck movement in the vicinity of GSAP (gamma spectrum authenticator for pallets).

The new pallet trailer will have two levels and will hold up to four six-pack pallets or six four-pack pallets. Pallets will be loaded with the drum containers in the upright position and the pallet diamond tubes facing the trailer door opening. Pallets will be pushed on rollers into position in the pallet trailer and mechanically locked into position to eliminate the need for hand-placement of tie-downs. The trailer will be a single axle 6000 pound load capacity trailer. It will not be backed up to the loading dock. The trailer bottom will be 12 inches off the ground. Pallets are expected to be loaded from the ground level so that there will be no need for a ramp between the Zone 12 loading dock and the pallet trailer.

Currently, there are two potential scenarios for loading. First, a lift truck may drive down a concrete ramp to get to the ground level with the palletized drums. Second, there may be a lift truck at the ground level to lower palletized drums to the ground. From the current literature on safety of lift truck operations, loading docks and ramps are very hazardous for lift truck operations. Use of a lift truck on the ground level appears to offer maximum safety.

Injury to Personnel during Inter-Zone Transportation:

Injuries to personnel primarily may occur during operations with the electric lift truck, moving pallets from the loading dock in Zone 12 onto the pallet trailer. A person in the path of a moving lift truck may be severely injured. Audible backup alarms should be used and should be operational. In addition, the operator should ensure that the lift truck path is clear of personnel during any lift truck movement. Separate areas should be established for personnel movement and for lift truck movement. If feasible, movement of the pallets from the loading dock to the pallet trailer should be done by a lift truck at ground level. It should be determined whether the loading dock is too high to permit this. Potential operator errors and equipment failures include sudden or uncontrolled acceleration and speed as well as insufficient braking to prevent collision.

A person may be hit by a falling pallet during the actual loading of the pallet trailer, if that person is near the rear doors of the pallet trailer and the pallet catches on the forks during fork removal from the pallet. Injury due to a lift truck tipping accident may occur with excessive lift truck acceleration combined with carrying the lift truck load at the height of the upper level of the trailer during a turn prior to loading the pallet on the trailer. Safe lift truck practices should be discussed and practiced during training.

Transportation with the pallet trailer between Zone 12 and Zone 4 may result in an accident. Since the Pantex Plant is relatively flat, little injury to personnel should occur even if the vehicle pulling the pallet trailer goes off the road. In addition, there always is the possibility that the driver may be in poor health and may suffer a heart attack or stroke during pallet transportation.

Information here is sketchy, until more is known about the height of the loading dock to the pallet trailer, any usage of a straddle ramp (and what the straddle ramp connects), and the procedure for loading the pallet trailer. For now, assume that the loading of the pallet trailer is similar to the unloading of the pallet trailer on the apron in Zone 4. The Pantex transportation study and execution of transportation tests are expected to provide better detail on the potential hazards during inter-zone transportation.

Removal / Replacement of the Lift Truck Cab Shielding:

The Bisco Company made a video of a test lift showing removal and replacement of the lift truck cab shielding unit. The shielding unit weighs from 6000 to 7000 pounds and requires a heavy-duty hoist as well as sufficient vertical clearance for removal and replacement. There are numerous brackets and bolts which must be removed before the shielding can be removed as a unit from the lift truck. The most difficult tasks are the actual lifting of the shielding unit and its subsequent alignment with the lift truck during replacement. The removal and replacement operations must be very precise, since the clearance between lift truck components and shielding is tight. Bisco personnel added a mechanical guide to simplify cab shielding replacement operations. The primary sub-processes are removal of the shielding by lifting, replacement of the shielding by lowering, and supporting the shielding with the crane during maintenance operations. There is a maintenance stand to hold the shielding during lift truck maintenance.

Injury to Personnel during Removal / Replacement of Lift Truck Cab Shielding:

Injury to personnel potentially may occur when there is a failure of the cable or crane and a person is in position to be hit. If the crane and cable support the weight of the shielding during lift truck maintenance, personnel may be injured if the crane equipment or cable fails or if the crane cable is inadequately secured to the cab shield. Equipment inspection or maintenance are required as needed. There is a potential for upper extremities to be smashed during shielded cab replacement operations, if personnel are required to align or guide the shielding.

Fault Tree Discussion:

The fault tree reveals that, in all cases, a person has to be in position to be struck by an object for an injury to occur. The person can be struck by (1) the cab shield as it falls, (2) the cable if it should break and accelerate, and (3) the cable equipment if some part of it should break loose and fall.

The cab shield will have to be removed (infrequently) so that maintenance can be performed on the batteries. A film of the removal and replacement of the cab shield showed that personnel were required to handle the cab shield as it was lifted off the lift truck (and lowered back on) so that it would move freely. Even after it was clear of the lift truck, at least one person remained close to it. So, should it fall, it is likely that someone will be close enough to be injured. If the cable were to break, the length of cable below the break would whip downward. Anyone hit by the cable could be severely injured. Finally, if crane equipment were to break loose and fall, both the cab shield and the crane equipment could cause injuries.

Quantitative Analysis for Cut Set Ranking:

A total of six cut sets were identified. Presented and discussed below are two that are conservatively estimated to occur more than one in one hundred thousand event sequences. This is equivalent to a cut set probability greater than 10^{-5} , on a per event basis.

- person in position to be hit by cab shield and cable inadequately secured to cab shield (will not support it)
- person in position to be hit by cab shield and crane equipment failure due to inadequate maintenance

In each of the two cut sets, the cab shield has been lifted enough so that, if it were to fall, a serious injury could occur. The cable attachments, which will be made at each corner of the top of the cab shield, could be tested for adequacy prior to the full lift. Our estimate of the probability of crane failure due to inadequate maintenance may be even more conservative than our other estimates. Routine maintenance of the crane equipment should not involve procedures that could cause the crane to fail if performed incorrectly.

Recommendations:

Minimize the amount of direct handling of the cab shield that is needed as it is being lifted, lowered, or moved by the crane.

Since removal/replacement of the cab shield will occur infrequently and several tasks are

required, a checklist should be used.

A second person should check cable attachments to the cab shield prior to the lift. Also, a second person check should be made prior to the lift to ensure that outside and inside bolts/brackets have been removed, that the cab will not be impeded as it is raised, and that the door is secured.

Test cable equipment following non-routine maintenance, e.g., repairs.

Damage Equipment during Removal / Replacement of Lift Truck Cab Shielding:

Equipment may be damaged during lifting of the shielded cab if the bolts that secure the shielding to the lift truck are not removed and the lift continues, or if the cable or crane hoist breaks. If the crane and cable support the weight of the shielding during lift truck maintenance, damage may occur if the crane equipment or cable fails or if the crane cable is inadequately secured to the cab shield. Equipment inspection or maintenance are required as needed.

From the Bisco video, it looks like a misaligned shielded cab could damage the steering column (and the hand brake) during replacement operations. Bisco's addition of a mechanical guide for replacement operations will help.

Fault Tree Discussion

This fault tree is identical to the previous fault tree except that there is no requirement for a person to be in position to be injured. The equipment items that can be damaged include the cab shield, the cable, and other cable equipment.

Quantitative Analysis for Cut Set Ranking:

A total of six cut sets were identified. Three of the cut sets are single events, but only two of those have a relatively high probability of occurrence.

- cable inadequately secured to cab shield (will not support it)
- crane equipment failure due to inadequate maintenance

In each of the two cut sets, the cab shield has been lifted enough so that, if it were to fall, damage would occur. Again, our estimate of the probability of crane failure due to inadequate maintenance may be even more conservative than our other estimates.

Routine maintenance of the crane equipment should not involve procedures that will result in failure if performed incorrectly.

Recommendations

The same recommendations as those for injury during removal of cab shield.

Equipment Reliability: Reliability of the Hyster Lift Truck

Modeling Scheme

Very little failure data for the Hyster model EL40-XL lift truck or similar trucks was found from the expected sources such as the manufacturer or material handling operations

records. To assess the reliability of the lift truck for the Stage Right analysis, a simple ranking scheme was devised for the following subsystems of the truck:

- Brakes
- Electrical
- Mast/Boom Hydraulics
- Mast/Boom Mechanics
- Speed Control

Rank one corresponds to the subsystem most likely to fail while rank five corresponds to the subsystem least likely to fail.

Data from Pantex maintenance supervisors and mechanics for electric trucks, Hyster's maintenance supervisor for the Albuquerque, NM region, and the Savannah River SEPR database of forklift incident reports were used to rank the failure rates of the five subsystems. The results are shown in the table below. Every source agreed that the Mast/Boom Hydraulics subsystem was most likely to fail followed by the Electrical subsystem. All sources also agreed that the Speed Control subsystem was unlikely to fail.

Table 1. Subsystem Ranks

Rank	Lift Truck Subsystem	Number of Sources for Subsystem
1	Mast/Boom Hydraulics	3 of 3
2	Electrical	2 of 3
3	Brakes	2 of 3
4	Mast/Boom Mechanics	1 of 3
5	Speed Control	3 of 3

Actual failure rates supplied to the Reliability Analysis Modeling Program (RAMP) software are given in the next section. Individual components were used as surrogates for entire subsystems for Mast/Boom Hydraulics, Mast/Boom Mechanics, and Speed Control. Based on expert engineering knowledge, for example, heavily stressed hydraulic hoses were used to model the Mast/Boom Hydraulics subsystem. In every case, conservative values for failure rates were selected.

Failure Rates for Subsystems and Components

Published failure rates for the number of failures per hour taken from published data with potential application to the Hot Experimental Facility [SRL80] form the basis of the reliability model. Each subsystem or component's failure rate in the reliability model for the Hyster EL40-XL electric lift truck was assigned a Gamma probability distribution. The family of Gamma distributions was chosen because of its flexibility to accommodate different kinds of failures. In the present case, failures due to wear out as well as failures due to chance could occur for the forklift.

Table 2 summarizes the failure rates and the values of the parameters used to model the

forklift's reliability.

Table 2. Component Failure Rates and Distribution Parameters

Component	Kind of Failure	Failures/Hour	Shape Parameter	Scale Parameter
Battery	wear out	4.4×10^{-7}	1.1	2.5×10^6
Brakes	chance	4.3×10^{-6}	1.0	2.3×10^5
Mast/Boom Hydraulics	wear out	3.9×10^{-5}	2.0	5.1×10^4
Mast/Boom Mechanics	wear out	1.7×10^{-6}	1.5	8.8×10^5
Speed Control	chance	2.0×10^{-7}	1.0	5.0×10^6
Wiring - cables	wear out	3.0×10^{-5}	1.1	3.7×10^4
Wiring - short to ground	chance	3.0×10^{-6}	1.0	3.3×10^5
Wiring - open circuit	chance	3.0×10^{-6}	1.0	3.3×10^5
Wiring - short to power	chance	1.0×10^{-8}	1.0	1.0×10^8
Wiring - terminals	wear out	5.0×10^{-7}	1.1	2.2×10^6

For subsystems or components subject to wear out failure, the shape parameter of the Gamma distribution was specified so that the corresponding hazard rate increased over time. Larger values of the shape parameter give a more pronounced increase in the hazard rate and accentuate the cumulative effects of aging.

For subsystems or components subject to chance kinds of failure, the shape parameter was specified to give a constant hazard. Since chance failures may occur at any time and time in service plays no role in the mechanisms of these failures, the hazard remains fixed or constant. Specifying a constant hazard rate is equivalent to choosing an Exponential probability distribution for the failure rate.

Given a failure rate and a shape parameter value for a particular component, a straightforward computation can be done to find the value of the corresponding scale parameter.

Reliability Modeling Results

Results from modeling the lift truck's reliability clearly show that the truck is durable and reliable. Even having weighted the model against such a conclusion by using conservatively high estimates for failure rates, the truck's mean time between failures (MTBF) on the average is about 12.5 times larger than the estimated total operational time for five years. Figure 1 contains the relative frequency histogram for the lift truck's MTBF. The wide range for MTBF on the horizontal axis reflects the uncertainty associated with failure rates used in the model.

Figure 2 presents the contribution of each subsystem to the failure of the lift truck. Since the largest contributor appears first, the order of the subsystems along the vertical scale constitutes the model's ranking results. This ranking agrees with the initial ranking scheme devised for the model based on expert knowledge from Pantex and Hyster and the Savannah River SEPR database. Concurrence between four disparate sources such as those used here means that while failure rates or the system MTBF are not known precisely, the model accurately depicts the reliability behavior of the lift truck. That is, the average MTBF given by the model may differ from the actual MTBF by some factor, but the subsystem most prone to failure is the Mast/Boom Hydraulics subsystem.

The dominance of the Mast/Boom Hydraulics subsystem and of the Electrical subsystem make these the key players in the possible failure of the Hyster lift truck. Taken together, these two subsystems account for approximately 90 percent of the truck's failures in this model. Only 6 percent of the truck's failures are attributed to the Brakes subsystem. While Mast/Boom Hydraulics is the largest contributor to system failure, the Electrical subsystem contributes very nearly as much in this model. The magnitude of the Electrical subsystem's contribution in this model apparently disagrees with the Savannah River SEPR data. However, most of the Electrical subsystem's contribution is due to the failure rate used for the Wiring-electrical cables component which was at least an order of magnitude larger than the rates of other components in this subsystem. Uncertainty for any of the particular failure rates covers at least one order of magnitude, so the contribution of the Electrical subsystem may be considerably smaller. At the same time, the SEPR data includes all forklifts and may underestimate the Electrical subsystem failures for electric lift trucks.

Recommendations

Potential failure of the lift truck is most likely due to failure of the Mast/Boom Hydraulics or failure of the Electrical subsystem. Both subsystem's reliability can be improved by simple visual inspection for weaknesses such as leaks, loose connections, or crimped wires. A thorough pre-operation inspection of these systems coupled with an aggressive preventative maintenance schedule should suffice to correct problems with these subsystems and prevent complete failure of the lift truck during staging or removal operations.

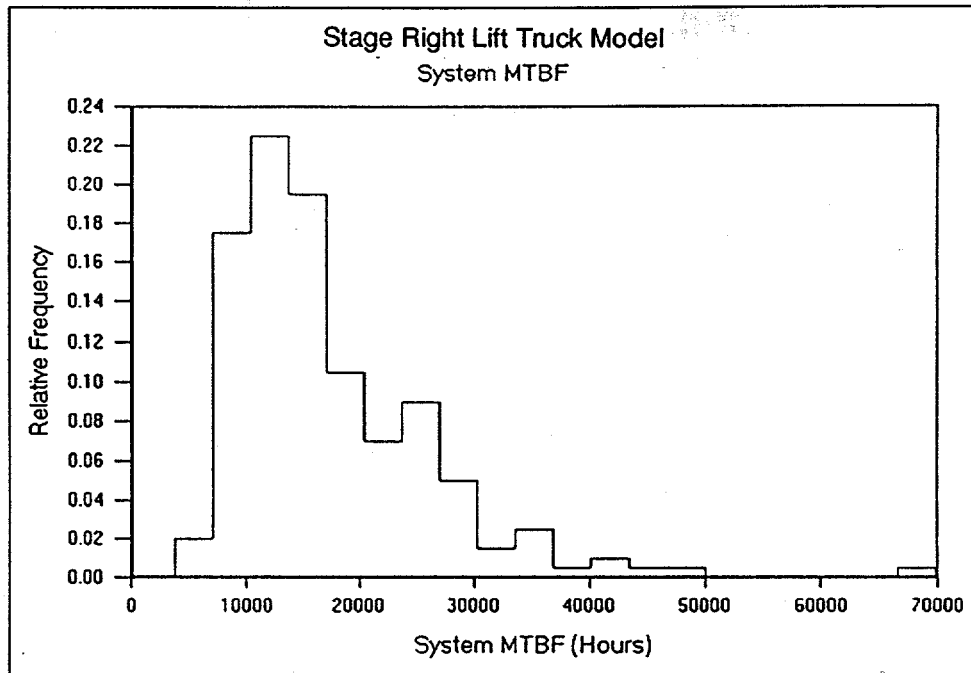


Figure 1. System Mean Time Between Failures (MTBF)

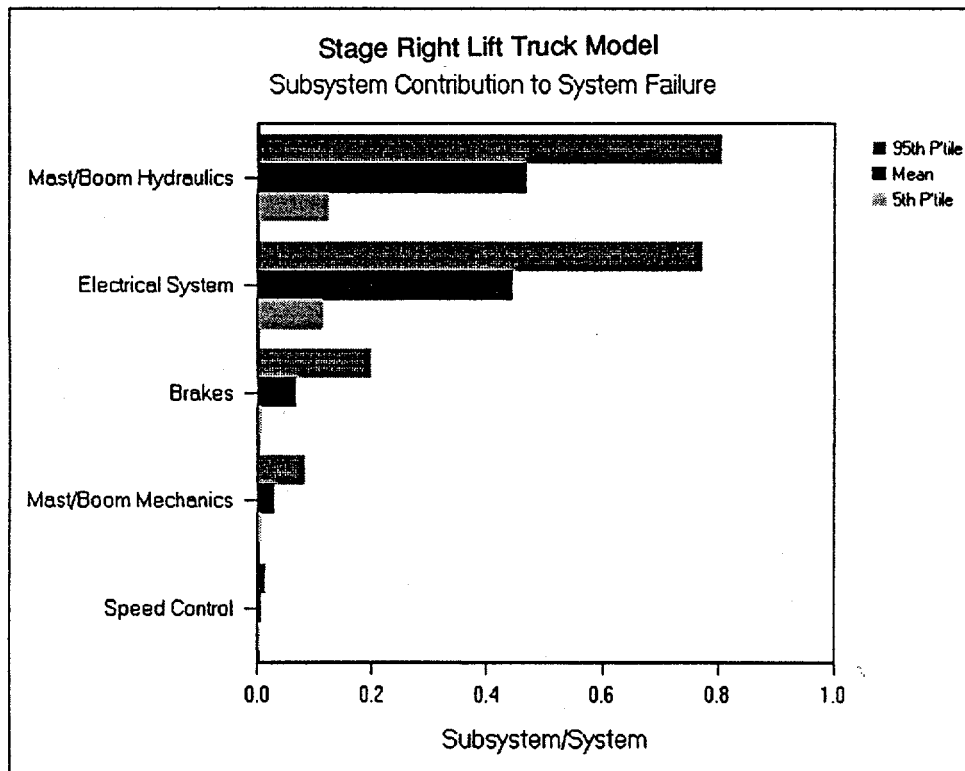


Figure 2. Subsystem Contribution to Failure

Summary of Recommendations

The following recommendations were given in the section on *Fault Tree Analyses and Cut Set Rankings*. They have been consolidated and grouped by similarity for convenience in highlighting trends. The groupings include:

- radiation mitigation
- routine maintenance and unscheduled maintenance
- inspection, daily check, and walk-around
- new equipment (barriers, interlocks) -- not needed here
- enhancements to existing equipment
- training
- items for explicit inclusion in general procedures.

Radiation Mitigation

As the Pantex administrative threshold is lowered for exposure to gamma and neutron radiation, mitigation of the dose received by the pallet turner operator should be considered. Three operational mitigation solutions have been discussed with Pantex personnel.

- Automate the turning process on the pallet turner.
- Require the pallet turner operator to stand back from the pallet turner and use a power hand tool (such as a cordless drill) to turn the wheel of the pallet turner.
- Establish a procedure for pallet turner operations, where the operator only stands between the pallet turner and the open magazine during the short time it takes to turn the pallet. At all other times, the operator will move away from the magazine door. In addition, once the shielded lift truck has removed a pallet from the turner and moved into the magazine to stage the pallet, another pallet should not be placed on the pallet turner until the shielded lift truck has completed the pallet staging and backed out of the magazine past the pallet turner. This procedural exposure mitigation solution should be implemented, whether or not the pallet turning mechanism is modified.

Protective clothing should be used for mitigation. The pallet turner operator always should wear protective clothing.

- Both the new and the old lead aprons leave the neck area exposed to radiation. Since there is a high susceptibility to cell damage in lymph cells [KNI81], additional neck protection (perhaps a leaded collar or neck gaiter) may be warranted.

Routine Maintenance and Unscheduled Maintenance with Post-Maintenance Testing

Much of the equipment used is hydraulic. The hydraulic pressure on the lift trucks and on the barrel handler should be adjusted to preclude equipment damage. During maintenance, it should be verified that the hydraulic pressure is adjusted at the lowest level required to perform the material handling and staging tasks.

Lift truck maintenance is performed twice a year. An aggressive preventive maintenance schedule also should be applied to the shielded lift truck. Maintenance currently is performed in the following areas:

- electrical systems
- wheels and brakes
- steering
- hydraulics
- non-destructive testing for cracks on the forks (dye penetrant testing)

Post-maintenance (PM) testing currently is required as part of the PM procedures. Unscheduled maintenance is performed as needed and follows a maintenance repair order (MRO).

The boom for the new shielded lift truck should be inspected and tested at least as thoroughly as lift truck forks. Currently, there are procedures and checklists for maintenance of Pantex lift trucks. In addition, maintenance on the shielded lift truck should include the following:

- The boom should be inspected periodically, following written checklists and procedures, for metal fatigue or weld failure. The boom attachment should be inspected periodically using an established non-destructive inspection method such as dye penetrant.
- Test the boom after installation (*i.e.*, after the exchange from forks to the boom) to ensure that it performs all functions while supporting a load that is as heavy as a six-pack pallet.
- The special safety features should be inspected and maintained.
- The boom tip switch should be tested whenever the boom attachment is installed, as well as during periodic maintenance.
- The bolts for the boom and fork attachments should be examined during periodic maintenance.
- The door hinge and the bolt connections for the shielded cab on the shielded lift truck should be checked for wear or failure during routine maintenance.
- Each lift truck's brakes and alarms should be tested following regularly scheduled maintenance and repairs.
- The semi-annual inspection should be thorough and should employ specific testing

methods, such as dye penetrant testing and magnetic particle testing. Checking and recording the fork blades' dimensions was suggested by one author.

- Use printed forms for inspection schedules to assist accurate record keeping.

Inspection: Daily Check and Walk-Around

Mechanical/electrical failures are minimized with a daily pre-operation inspection in addition to the periodic maintenance program.

- A checklist should be used for the daily inspection of the shielded lift truck.
- The daily lift truck walk-around prior to operation should include inspection of the hydraulic systems (checking for cracked or frayed hoses, loose connections or leaks). Two inspection considerations are examination of the ground under the lift truck for hydraulic leaks and running a clean rag over the hydraulic lines and connections for signs of leaks.
- Inspect the boom attachment daily. Check for weld failure, unusual looseness, or damage. Assure that the boom tip switch safety feature is working correctly.
- Inspect the forks and fork carriage daily (whenever in use), checking for deformation of the forks, damage, unusual looseness, or obvious cracks -- especially at the heel.
- Daily inspection of the shielded lift truck electrical subsystem should include inspection of visible electrical cables and connections (checking for loose connections or crimped wires), and tires (checking for bent wheels or missing chunks of tread).
- Inspect the cab shielding, especially the door hinges, for stress.
- Perform periodic operational checks of the sensors, especially all safety sensors.
- Ensure that the back-up alarm or horn is working on all lift trucks.

Enhancements to Existing Equipment

The following enhancements to existing equipment are being planned or have been discussed by Pantex personnel:

- A specialized fixture may be designed to hold the boom or fork attachment at the correct height to the rotator during the attachment process. The equipment will need to have height and rotational flexibility to assist in better alignment of the bolt holes. A mobile fixture with a transmission jack mounted on top is envisioned. If two fixtures are designed, one for the boom attachment and one for the fork and fork carriage, the attachments may be stored on the fixture.
- Absolute positioning is planned for inclusion in the enhancement of the shielded lift truck control panel. Absolute positioning may not be critical during initial staging of pallets in empty magazines, as long as the magazine is filled from back to front to take advantage of the natural light coming in the doorway. During an extended maintenance mode when single pallets may be removed from the

magazine and then returned, visibility will be limited due to the shielded lift truck and stacked pallets blocking most daylight. With the current lift truck control panel, the operator is responsible for determining his position from the doorway and the distinction between ground and upper pallet staging levels.

- A come-along requiring less leverage is required and is currently under investigation. It may be necessary during recovery to lift the six-pack pallet (weighing approximately 1100 pounds) over the guide rail (6" from the floor plus necessary clearance).
- Additional lighting should be provided within the magazine during recovery operations to increase visibility for off-normal pallet pickup operations or to assure proper attachment of the come-along cable. Consider a portable power source with lights.
- Currently, all lift truck auxiliary equipment is on one circuit. Consider a separate circuit for lift truck lights.
- A pallet guide (with a triangular cross section) is planned to assist positioning on the pallet turner and to alleviate potential scraping.
- Steps should be taken to ensure that the pallet turner is level. Bubble levels may be needed on each of the ramp jacks, or on the two jacks supporting the pallet turner. If the pallet turner is not level, the pallet may scrape against the pallet turner sides.
- An enhancement to include an audible backup alarm on the shielded lift truck is underway. All of the light, heavy duty, and shielded lift trucks should have backup alarms.
- It is possible to position the equipment pedestal on the inventory pallet too far to the side so that it risks hitting the pallet turner or the staged pallets. There is a plan to put in stops on the guide track to allow only the camera-centered position for magazine inventory and the pallet storage position. An alternative preventive measure is to *mark* the two allowable positions on the pedestal guide track.
- An impact against the rear wall of a magazine could damage the inventory pallet. The inventory pallet itself extends past the electronic equipment on the leading side of the inventory pallet, as a protective measure. Two additional preventive measures are suggested. The first includes the use of a sensor to detect proximity to the rear wall, or installation of a cushioning bumper on the rear wall. (The current overrun chocks are positioned for staging the palletized drums.) Second, if absolute positioning is included in an enhancement of the lift truck control panel, the operator could easily tell when he has inventoried the pallets in the last position. The addition of a warning indicator could reinforce the information from the absolute positioning.

Training

Initial and recurrent lift truck operation/safety training have been shown to dramatically reduce accidents caused by operator error [FRI87, FEA89, CRO79, AND91]. Since

Pantex already has a training program, the recommendation here is for Pantex to ensure an active and interesting recurrent training and safety awareness program.

- The hazards of working around lift truck operations, especially electric lift trucks, should be identified for both operators and work area pedestrians. This training is necessary in Pantex's ongoing safety awareness programs.
- Operator training should simulate limited space operations requiring tight turns immediately prior to accurate fork placement.
- Safe lift truck practices should be discussed and practiced during training. Personnel need to be reminded that electric lift trucks are relatively quiet and may not be noticed if the person's attention is focused elsewhere.
- Special attention should be given during training to ensure a warning is sounded prior to backing up.
- Operator training should address acceptable traverse frame locations for attachment of the come-along cable during recovery. Two locations have been pointed out during operations demonstrations: a round opening for the hook attachment and a horizontal plate on the traverse frame. Optimal placement positions should be indicated on the traverse frame, if the cable is attached to the horizontal plate.
- Identify the staging ramp as a tripping hazard in ongoing safety awareness programs for personnel working in Zone 4.

General Procedures

The general procedures have been further grouped by process, as follows: procedures for working with or near lift trucks, operation checks and team operations, recovery procedures, inventory procedures, cab shield maintenance procedures, and procedures for equipment and pallet transportation.

Procedures for Working with or near Lift Trucks:

- Separate areas should be established for personnel movement and for lift truck movement. Some areas in the vicinity of the magazine should be designated "safe areas," *i.e.*, areas where lift trucks will not operate. Personnel in the area need to know where the safe areas are located and stay in those areas when possible. Lift truck operators must be aware of safe areas and not operate in them.
- Audible backup alarms should be used and should be operational. In addition, the operator should ensure that the lift truck path is clear of personnel during any lift truck movement.
- Operators should decrease the apron lift truck speed when approaching the pallet trailer or the pallet turner and inserting forks into pallets prior to unloading.
- A maximum safe speed limit should be determined for apron lift truck operations.
- Procedures should stipulate that pallet rotation occurs outside the magazine.
- Whenever two shielded lift trucks are located at Pantex Plant, it would be

preferable to use one of the two lift trucks with the boom attachment and the other one with the fork attachment. This also will minimize the number of attachment installations.

Operation Checks and Team Operations:

- A second person may be required to assist the lift truck operator during forking operations with the inventory pallet or with pallets at the pallet trailer or pallet turner.
- The boom attachment is removed (and subsequently reattached) whenever inventory is performed. It is important that procedures check and test for reattachment of all twelve bolts and reconnection of the circuit for the boom tip switch.
- Procedures for a check of the come-along connection by a second person or a second check by the operator who made the original attachment may be required.
- If the barrel handler is used during recovery, a second person check could be performed prior to closing the tongs.
- A second person should check cable attachments to the cab shield prior to the lift during maintenance. Also, a second person check should be made prior to the lift to ensure that outside and inside bolts/brackets have been removed, that the cab will not be impeded as it is raised, and that the door is secured.

Recovery Procedures:

- It should be decided if the barrel handler or the fork attachment on the shielded lift truck is more appropriate for recovery operations. The barrel handler may not be required unless a pallet has failed and its containers are no longer contained by the pallet.
- The operator may need to climb over two four-packs and the lift truck itself to get inside the magazine. The climb to the top of the lift truck may need to be done quickly and without a lead apron. The lead apron could then be handed to the person on the lift truck.

Inventory Procedures:

- Since the physical inventory pallet is a complex piece of equipment, care must be given to protect it from weather and radiation damage or from excessive vibration during transport.
- If the inventory pallet is damaged, any inventory should be delayed until necessary repairs are completed, to avoid performing inventory with hand scanners.
- There is a protective cover for the PINPAL, which should be readily accessible whenever the inventory pallet is being used.
- Make backup copies of all data. The diskette containing the input information for the inventory should never be the only source of that data. The inventory output information should be backed up or uploaded to another machine, after inventory completion.

Cab Shield Maintenance Procedures:

- Minimize the amount of direct handling of the cab shield as it is being lifted, lowered, or moved by the crane during maintenance.
- Since removal/replacement of the cab shield will occur infrequently and several tasks are required, a checklist should be used.
- Test cable equipment following non-routine maintenance, *e.g.*, repairs.

Procedures for Equipment and Pallet Transportation:

- The fork stork should be used to transport the shielded lift truck to and from the magazine to prevent damage.
- If feasible, movement of the pallets from the Zone 12 loading dock to the pallet trailer should be done by a lift truck at ground level.

Conclusion

This Stage Right operational safety analysis and Pantex personnel operations evaluation yielded no surprising results. The documentation does identify Stage Right processes and potential undesirable consequences and does include a section entitled *Summary of Recommendations*. It should be noted that costs have not been factored into the recommendations. Thus, it is possible that costs may be prohibitive compared to the benefits for some of the recommendations and should be considered prior to any implementation.

Another caveat is that this analysis evaluates safety of the Stage Right work processes for storage within the modified Richmond magazines only. Follow-on evaluation will be required for staging and interim storage of pits in the steel arch construction (SAC) magazines, or staging in the magazine center aisle. A comparison of the differences expected with the automated guided vehicle (AGV) is underway.

Appendix A:
The Method Used to Estimate
Human Failure Probabilities

The Method Used to Estimate Human Failure Probabilities

A modified version of the pre-accident screening portion of the Accident Sequence Evaluation Program Human Reliability Analysis Procedure (Swain, 1987) was used to estimate the total failure probability ($\text{Pr}(F)$) for each identified sequence of human actions (tasks) in which a human error could occur. In some cases the task consisted of only one action, e.g., inadvertently accelerate the forklift, and in other cases the task consisted of several human activities, e.g., perform brake maintenance.

For pre-accident screening, Swain recommended using a basic human error probability (BHEP) of .03. The BHEP of .03, which is the unmodified human error probability to use for an activity performed by one or more persons, combines the probability of an error of omission (.02) and the probability of an error of commission (.01). The BHEP can be raised because of poor administrative controls or other factors that result in poor ergonomics. The BHEP can never be less than .03. The $\text{Pr}(F)$, however, can be less than or greater than the BHEP. The $\text{Pr}(F)$ will be less than the BHEP if at least one opportunity exists for the human to recover from an error. Within- and between-person dependencies, the type of system (series or parallel), and the number of critical operator tasks also affect the estimated $\text{Pr}(F)$.

For this screening HRA, the BHEP of .03 was used in most cases in which either an error of omission or an error of commission could occur. If only an error of omission could be made (an error of commission was not possible) and only one critical human action could be omitted, then BHEP = .02 was used. If only an error of commission could be made (an error of omission was not possible) and only one critical human action could be in error, then BHEP = .01 was used.

When more than one activity can result in an error, dependence and system type are taken into account to estimate the $\text{Pr}(F)$ according to the following rules:

1. Human activities, whether performed by the same person or different people, can be completely independent or completely dependent.
2. System components can be in series or parallel.

Thus, if the BHEP = .03 and a human performs two critical activities to complete a task, the failure probability, unmodified by recovery factors, can have one of the following four estimated probabilities:

The human activities are independent and the components in series:

$$\text{Pr}(F) = 1 - (.97)^2 \cong .06$$

The human activities are completely dependent and the components in series:

$$\text{Pr}(F) = 1 - (.97)(1.0) = .03$$

The human activities are independent and the components in parallel:

$$\text{Pr}(F) = (.03)^2 = .0009$$

The human activities are completely dependent and the components in parallel:

$$\text{Pr}(F) = (.03)(1.0) = .03$$

Since this was a screening HRA and conservative estimates were desirable, $\text{Pr}(F) = .06$ was used in all cases where two critical human activities were performed to complete a task.

For maintenance tasks that involved several human activities that could cause a basic event to occur, but the exact number of critical activities was unknown, a very conservative approach was taken. The assumption was made that the number of critical human activities would not be greater than 12. Again, the activities were assumed to be independent and in series. In those cases, the BHEP was .03 and the probability of failure, unmodified by recovery factors, was $\text{Pr}(F) = .3$ ($\text{Pr}(F) = 1 - (.97)^{12} \approx .3$).

If recovery factors were identified, the unmodified failure probability was multiplied by .1 or .01 to obtain the $\text{Pr}(F)$, according to the following rules:

1. Credit was given for only one recovery factor even if more were identified.
2. The probability of failure of the recovery factor was .1, except for tests following maintenance or calibration which were assigned a probability of .01 (as recommended by Swain).

The following examples show how the BHEP estimates and recovery factors were used to generate human failure probability estimates.

Light lift truck operator rams the loaded pallet into the pallet turner.

Recovery: Pallet turner operator signals light forklift operator.

$$\text{Pr}(F) = .03 \times .1 = .003$$

Deck locks removed from one side of the trailer that carries the shielded lift truck but not from the other side.

Recovery: Second person check prior to lowering trailer; also, the problem should be detected as lowering begins.

$$\text{Pr}(F) = .02 \times .1 = .002$$

Inadequate installation of the bolts that secure the boom, especially, omission of one of the two sets of bolts.

Recovery: Check following installation.

$$\text{Pr}(F) = .03 \times .1 = .003$$

Appendix B:
Event Identification Description

Event Identification Description

Eight Character Coding Scheme:

1 2 3 4-5 6-7,8

P U O EQ FM[C]

				-----	Failure Mode + [Human/Equipment Category]
				-----	Equipment
				-----	Operation
				-----	Undesirable Event
				-----	Process/Subprocess

(1) Process/Subprocess

C	Zone 4: Setup/Close
H	Zone 4: Center Isle Staging/Removal
I	Zone 4: Inventory
O	Maintenance of Shielded Fork Lift
R	Zone 4: Recovery
S	Zone 4: Staging/Removal
T	Zone 4: Transport: Trailer to safe turnover on Pallet Turner
Z	Inter-zone Transportation

(2) Undesirable Event

A	D <u>A</u> amage Equipment
E	Br <u>E</u> ach Container
I	<u>I</u> njury to Personnel
O	Dr <u>O</u> p Loaded Pallet
U	<u>U</u> nreliability (Equipment Failure)

(3) Operation

A	Assemble/Setup
C	Close
D	Disassemble
F	Flip/Rotate
G	Package
H	Hoist/Raise/Lift
I	Insert
J	Retract
L	Load
N	Non-Specific
O	Open
P	Put Away
R	Retrieve
S	Position
T	Tuck
U	Unload
V	Inventory
W	Lower
X	Transport
Z	Secure

(4-5) Equipment

AD	ADB
AR	Alignment Ramp (12267-1)
BH	Barrel Handler
BL	Bubble Level
BO	Boom
BT	Battery
CA	Cable
CC	Come-a-long Cable
CD	3/8 in Cordless 12v Milwaukee Drill
CE	Cable Equipment
CH	Chain
DC	Drum Container (AL-R8)
FK	Fork Attachment (Shielded Fork)
FS	Fasteners
GR	Guide Rails
HF	30,000 lb. Forklift (ADB Mover)
HI	Hitch (12301)
HW	Handwheel (000-02-553)
IP	Inventory Pallet
LA	Light Forklift Alarm
LF	2,000 lb. Electric Fork
MA	Magazine
MS	Mast
NS	Non-Specific Equipment
PT	Pallet Turner (12266)
RM	Radiation Monitor
SD	Square Drive (000-02-552)
SF	Hyster Shielded Forklift with special boom
SP	Staging Pallet (4 or 6 Pac)
SR	Staging Ramp (12268)
SS	Sensors
TD	Tie Down
TG	Tongue (12281)
TL	Trailer
TS	Boom Tip Switch
TW	Sturtevant 0-150 ft-lb. Torque Wrench
WH	Wheels (12268)
TF	Traverse Frame

**(6-7) Failure Modes — Equipment
Conditions and Behavior**

Y Forks

- A Attachment not balanced during attachment
- C Hit container
- F Force during install
- I Inadequate insertion
- P Push against pallet
- S Structural failure
- T Tilt inadequate
- U Insert under pallet
- N Not installed correctly

F Forklift

- A Sudden acceleration
- B Brake failure
- C Not in control
- E Excessive acceleration
- F Feedback (Sensor) Failure-Shielded Hyster only
- H Hydraulic Failure
- I Fire
- L Load control failure
- M Motor failure
- N Non-specific
- O Pallet load, ram into object
- P Ram into pallet turner
- R Electrical Short
- S Fails to stop/Unsafe speed
- T Inadvertent tilt
- U Protective cab
- V Alarm failure

B Boom

- E Elevation too low (manual)
- F Feedback failure
- H Hydraulic failure
- I Inadequate insertion
- L Wrong level
- O L-R orientation wrong
- P Push against pallet
- S Structural failure

R Ramp/rail connection failure

- J Ramp jack failure
- R Ramp/rail connection failure

OP Obstacle in path

OM Immovable object in path

H Barrel handler

- L Lift with poor grip
- M Misalignment
- S Sufficient force for puncture

HU Human error

I Inventory Pallet

- B Off balance
- C Catches on obstacle
- R Radiation damage
- T Pallet catches on trailer
- V Vibration in transport
- W Weather damage

P Pallet

- B Off balance
- C Catches on obstacle
- F Fasteners fail
- H Carried too high
- M Misaligned at pallet turner
- S Structural failure
- T Not in tucked position
- W Welds fail
- X Wrong pallet (e.g., 6-Pac instead of 4-Pac)

D Tie down

- F Failure
- N Not present
- R Removed

LT Trailer

NP No protective clothing

M Mast

- A Sudden acceleration
- F Feedback failure
- H Hydraulic hoist failure
- S Structural failure

**(6-7) Failure Modes — Equipment
Conditions and Behavior - cont.**

V Vehicle
 A Sudden acceleration
 B Brake failure
 C Not in control
 E Excessive acceleration
 S Unsafe speed

TS Pallet turner

T Traverse
 H Hydraulic failure
 F Structural failure of frame

C Container
 C Integrity failure
 R Rim band fails
 S Sufficient force for puncture

CL Come-a-long cable failure

CP Crush pit

CH Chain failure

CE Cable equipment failure

CF Cable fails

AF ADB fails

**(8) Human/Equipment Category —
Human Task and Activity Categories**

A Assembly
C Calibration
I Inspection
M Maintenance
N Installation
O Operations
P Human presence necessary for
 accident to occur -- no human errors or
 unsafe behavior
S Safe operations (Human should not
 have been at that place at that time or
 performing those actions) *Unsafe
 Operations?*
T Test

E Equipment - General
K Catastrophic failure of equipment
 component
W Wearout of equipment component

Appendix C:
Probabilities of Equipment-Related
Events and Sources of Information

Probabilities of Equipment-Related Events and Sources of Information

Description	Probability	Source
Adjacent pallets "walk" toward each other	.25	Prob(walking in one direction)=0.5 P x P= prob(walking toward each other)
Boom height sensor failure	.038	Prob(sensor/detector failure-solid state) + prob(lamp fail). Ref. 1, pg. 19& 25. ($\lambda=2.12E-5$)+($\lambda=1.0E-5$)
Boom malfunction - Not due to inadequate maintenance, hits pallet or container	4.5E-7	Same as "Boom tip switch failure"
Boom tip switch failure	4.5E-7	Two switches ($\lambda=1.9E-5$, limit switches). Ref. 1, pg. 27
Brake temperature above hydraulic fluid ignition point	.001	Duty cycle of brakes for shielded fork "very low", speeds "very low" (< 2mph) Needs to be 400 degrees F (SAR, pg. D-18)
Bumper (Overrun Chock) fails to stop speeding Hyster (Fails or Hyster rolls over)	.02	$\lambda=1.5E-4$ Pins. Ref. 1, pg. 21
Cable breaks "high" above cab shield	1.3E-6	Prob(weak cable) x Faulty inspection ($1.3E-5 \times 0.1$)
Cable connections with lifting bracket on traverse weak	1.9E-3	$\lambda=1.5E-5$ Pins, mechanical. Ref. 1, pg. 21
Cable equipment component failure not due to inadequate maint	3.4E-4	$\lambda=2.7E-6$ Average of gears. Ref. 1
Cable too weak to support cab shield	1.3E-5	$\lambda=1.0E-7$ Derated Rod Hanger. Ref. 1, pg. 18
Come-a-long cable weakness	1.3E-5	$\lambda=1.0E-7$ Derated Hanger Rod. Ref. 1, pg. 18
Container deforms from impact pressure - Rim band falls off	.05	Likely
Container deforms from steady pressure - Rim band falls off	.05	Likely
Container fails - Impact pressure from Hyster	.5	10 x (Container fails - impact pressure)

Description	Probability	Source
Container/Pit pinned between boom tip and wall	2E-9	Boom center within 2cm of pit center = $(2 \times 2) / \pi r^2$ (drum) x prob(pit pushed against object lodged* between drum and wall): $0.002 \times 1E-6$ (extremely unlikely) * traverse travel alone not enough
Crane equipment breaks loose from ceiling supports, falls	2.5E-6	$\lambda = 2.0E-8$ Bolt. Ref. 1, pg. 11
Crane equipment fails -- not due to maintenance	2.4E-6	$\lambda = 1.0E-5$ Motor, general. Ref. 1, pg. 23 & $\lambda = 1.5E-5$ Pin (as safety latch). Ref. 1, pg. 21 ($1.2E-3 \times 2.0E-3$)
Eq. Failure: Sudden acceleration of traverse	.003	$\lambda = 2.55E-6$: Controller. Ref. 1, pg. 15
Equipment Error: Sudden acceleration	.003	Same as "Mechanical Failure: Causes excessive acceleration/speed"
Equipment failure of barrel handler	.027	Same as "Hyster hydraulic system failure"
Equipment Failure: Come-a-long cable fails	1.3E-5	Same as "Come-a-long cable weakness (will not support pallet, etc)"
Equipment Failure: Ramp jack failures causes sudden imbalance in ramp	1.6E-6	$\lambda = 1.0E-6$ Gears. Ref. 1, pg. 17 (2 jack must fail)
Equipment Failure: Ramp/Rail connection	3.5E-4	$\lambda = 1.5E-5$ Pins. Ref. 1, pg. 21 (both pins fail)
Equipment Failure: (Forklift*) Brakes	.005	Same as "Mechanical Failure: Brake failure"
Equipment Failure: Boom detached	2.0E-4	Same as "Mechanical Failure: Boom attachment separates from traverse"
Equipment Failure: Boom hydraulic failure	7.3E-4	Same as "Hydraulic failure & "Check Valve" failure causes carried pallet to drop too fast"
Equipment Failure: Boom structural failure	2.0E-4	Same as "Mechanical Failure: Boom attachment separates from traverse"
Equipment Failure: Drum closure (fails*) due to drop	.01	Same as "Rim band fails - Impact pressure" • Likely (but less that container deforming)
Equipment Failure: Drum closure due to Ram	.001	Same as "Rim band fails from steady pressure"

* Denotes variations of the descriptions in the fault trees, substitute or include as necessary

Description	Probability	Source
Equipment Failure: Drum closure due to short fall	.001	Use fraction (1/10) of "Equipment Failure: Drum closure due to drop (a drop or fall of more than 5 ft.).
Equipment Failure: Drum closure form pallet and barrel handler force	.001	Same as "Rim band fails from steady pressure"
Equipment Failure: Drum closure from pallet and ADB mover force	.005	5 x steady pressure force (from "Rim band fails from steady pressure")
Equipment Failure: Elevation indicator	.038	Same as "Boom height sensor failure"
Equipment Failure: Hoist speed	.027	Same as "Hyster hydraulic system failure"
Equipment Failure: Hydraulic system/control failure	.027	Same as "Hyster hydraulic system failure"
Equipment Failure: Mast hydraulic hoist/sudden acceleration to staging height	.027	Same as "Hyster hydraulic system failure"
Equipment Failure: Pallet structural fail. from ADB mover force against obstacle	.001	Same as "Pallet structural failure - Steady pressure"
Equipment Failure: Tilt control	.027	Treat as hydraulic failure $\lambda=2.2E-5$ (av. of high & low stressed hoses). Ref. 1, pg. 18
Equipment Failure: Sudden acceleration	.003	Same as "Mechanical Failure: Causes excessive acceleration/speed"
Horizontal position sensor(s) fail	.038	Prob(sensor/detector failure-solid state) + prob(lamp fail). Ref. 1, pg. 19 & 25. ($\lambda=2.12E-5$)+(1.0E-5)
Horn (alarm) fails	.038	Substitute horn for lamp. Prob(sensor/detector failure-solid state) + prob(lamp fail). Ref. 1, pg. 19 & 25. ($\lambda=2.12E-5$)+(1.0E-5)
Hydraulic failure & "Check Valve" failure causes carried pallet to drop too fast	7.3E-4	Double hydraulic failure $\lambda=2.2E-5$ (av. of high & low stressed hoses). Ref. 1, pg. 18 (single fail prob=.027)
Hyster hydraulic system failure	.027	$\lambda=2.2E-5$ (av. of high & low stressed hoses) Ref. 1, pg. 18
Hyster in Magazine	.5	Operations - Assume 50% of time in magazine
Impact back wall, damage (after drive through safety stops	.5	5 x prob(going through chock): $\lambda=7.5E-4$

Description	Probability	Source
Impact w/ narrow-edged or pointed object (e.g., rail + container)	.01	Prob(landing w/drum exposed) x prob(landing on rail) x prob(another pallet not in same location): $P(7 \text{ of } 18 \text{ edges/sides}) \times P(\text{land in } 5 \text{ of } 8 \text{ areas}) \times (1/22): 7/18 \times 5/8 \times 1/22$
(LF, SF*, HF*) brakes fail due to component failure	.005	Same as "Mechanical Failure: Brake failure"
LF alarm fails due to component failure	.038	Same as "Horn (Alarm) fails"
LF forks fail (2000 LB Electric Forklift)	6.0E-5	$\lambda=5.0E-8$ Worst case - Rigid Coupling. Ref. 1, pg. 15
Mechanical Failure -- boom breaks or falls	2.0E-4	Same as "Mechanical Failure: Boom attachment separates from traverse"
Mechanical Failure: Boom attachment separates from traverse	2.0E-4	Prob(4 bolts fail: top or bottom) + prob(boom plate weld fails): $\lambda=(1.5E-5)^4 + 1.6E-7$. Ref. 1, pg. 21& 38
Mechanical Failure: Brake failure	.005	Equipment Reliability $\lambda=4.3E-6$: Brakes, general. Ref. 1, pg. 11
Mechanical Failure: Causes excessive acceleration/speed	.003	Equipment Reliability $\lambda=2.55E-6$: Controller, electrical, proportional. Ref. 1, pg. 15
Pallet damaged during (fall, accident/fall*)	.001	Same as "Pallet structural failure - Steady pressure"
Pallet in intended position	6.8E-4	$1/44 \times \text{prob}(\text{previously, another pallet put in wrong position}): 1/44 \times .003$
Pallet structural failure - Impact pressure	.01	Likely
Pallet structural failure - Impact pressure from Hyster	.5	50 x (pallet fails from impact)
Pallet structural failure - Steady pressure	.001	1/10 of probability of impact pressure
Pallet turner structural / mechanical failure	5.0E-4	$\lambda=4.0E-7$ Hangers & Supports. Ref. 1, pg. 18

* Denotes variations of the descriptions in the fault trees, substitute or include as necessary

Description	Probability	Source
Pallet weld or bolt failure	.0001	Short fail. Use fraction of steady pressure fail prob
Person within 3 ft of pallet turner	.03	Operations
Protective cab fails in impact accident	.05	Likely
Puncture drum and pit with fork	5.0E-4	Ratio of 2x2cm to cross section pallet
Radiation inside magazine damage pinpal	1.3E-4	Estimated Unlikely: Computer (1.0E-5), recorders (1.5E-5), bar-code readers (1.5E-5)
Rim band fails - Impact pressure	.01	Likely (but less than container deforming)
Rim band fails from steady pressure	.001	1/10 of probability for container deformation
Safety stops fail	.02	$\lambda=1.5E-4$ Pins. Ref. 1, pg. 21
SF boom fails loaded -- Failure not due to inadequate maint	2.0E-4	Same as "Mechanical Failure: Boom attachment separates from traverse"
Spark from metal on metal contact-Pallets on metal	1.7E-4	Average of falling pallet (G20 & G29) from "Breach Container during Staging or Removal at Magazine" (2.0E-4+1.4E-4)/2
Sudden (forward, backward*) acceleration of (LF, SF*, HF*, LF due equipment failure*, SF equipment failure*)	.003	Same as "Mechanical Failure: Causes excessive acceleration/speed"
Tucked position sensors fail	.02	l=1.67E-5 Limit Switch. Ref. 1, pg. 27
Two pallets both "walk" > 1.5 ins	2.5E-3	Exponential distribution with $1/\lambda=0.5$ ins Both=[prob(one walking>1.5 ins)] ²

* Denotes variations of the descriptions in the fault trees, substitute or include as necessary

Reference 1. Component Failure-Rate Data with Potential Application to The Hot Experimental Facility, DPST-CFRP-80-113, E. I. du Pont de Nemours & Co., Savannah River Laboratory, December 1980.

Notes.

Boom Tip Force: 3586 lb.¹

Al-R8 Drum: 18 gauge carbon steel (0.0475 ins thick) O.D. = 20 ins., height = 30 ins.

Shear Force:

Lancing a 2" "vee" - ≈ 6400 LB. force

Tearing an opening - ≈ 2300 LB. force

Impact Force:

4-Pac falling 5 ft. (Impact dissipated in 0.1 sec) - ≈ 2900 LB. force

Elastic Deformation:

Bending the lid in the middle - ≈ 1500 LB.

Equipment:

Shielded Forklift, Pallet Turner @ 250 hrs/yr for 5 yrs: Prob Failure = $1 - R(t=1250) = 1 - e^{-1250\lambda}$

Maintenance @ 125hrs: Prob Failure = $1 - R(t=125) = 1 - e^{-125\lambda}$

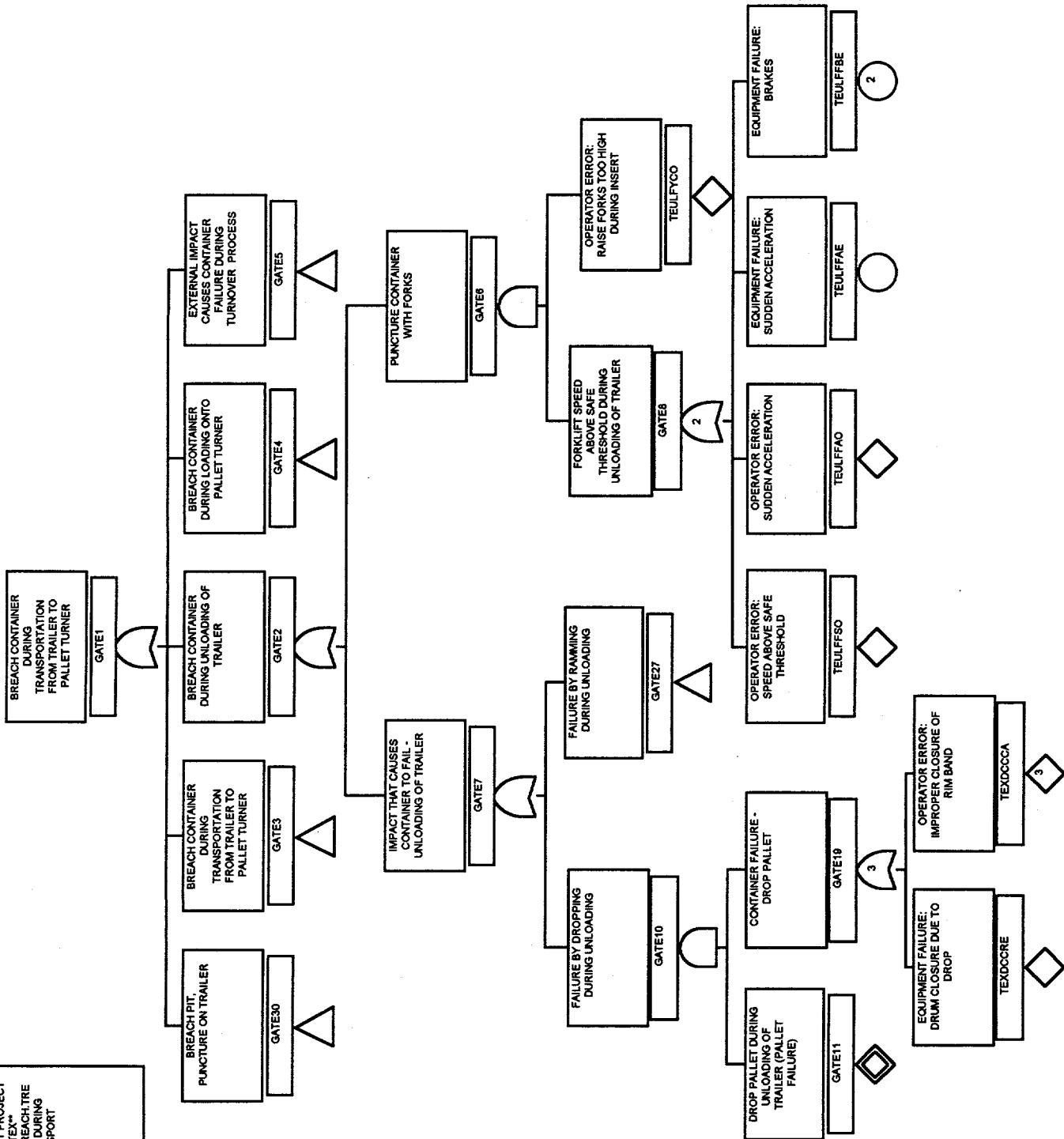
Come-a-long equipment @ 125 hrs: Prob Failure = $1 - R(t=125) = 1 - e^{-125\lambda}$

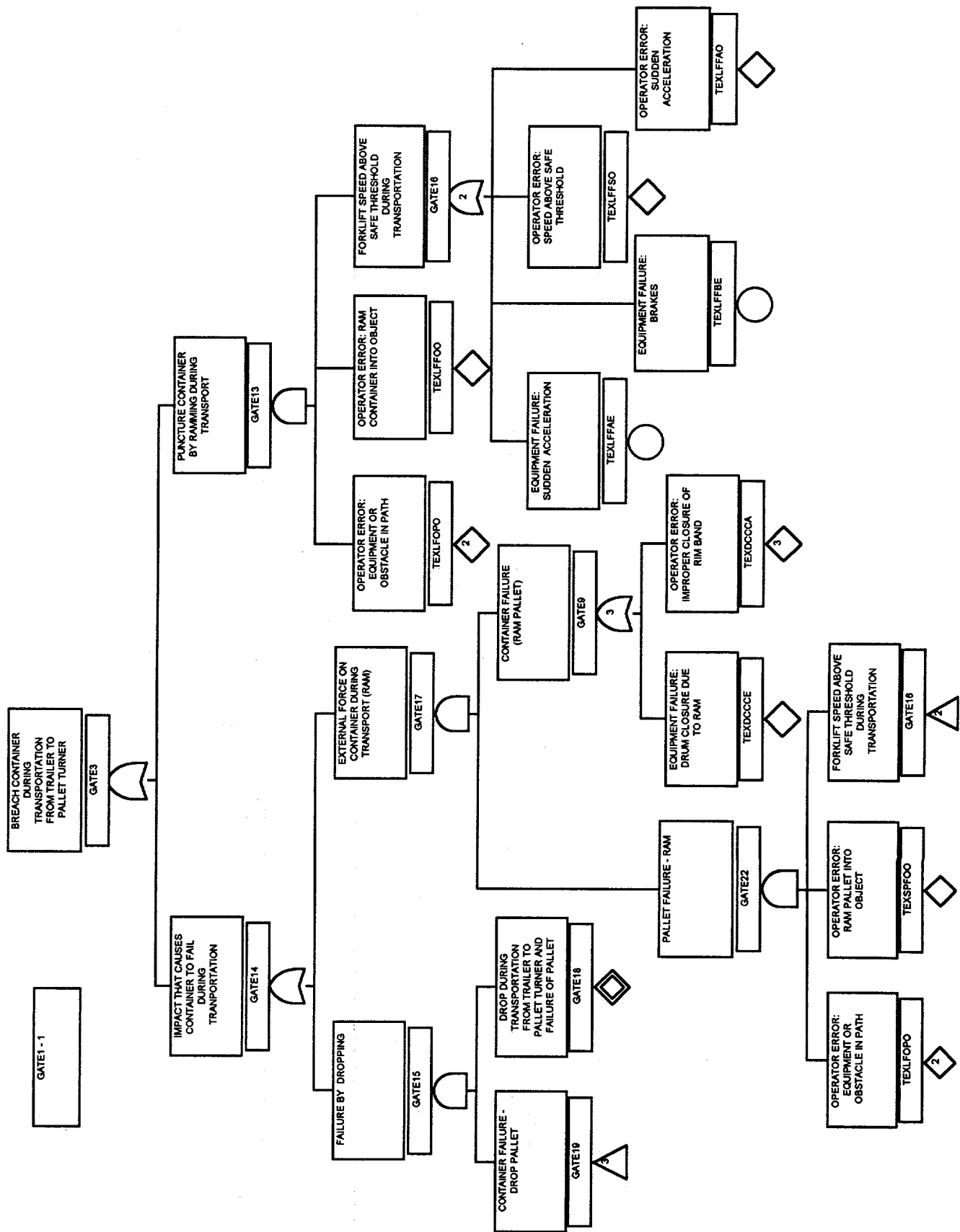
Pinpal @ 125 hrs: Prob Failure = $1 - R(t=125) = 1 - e^{-125\lambda}$

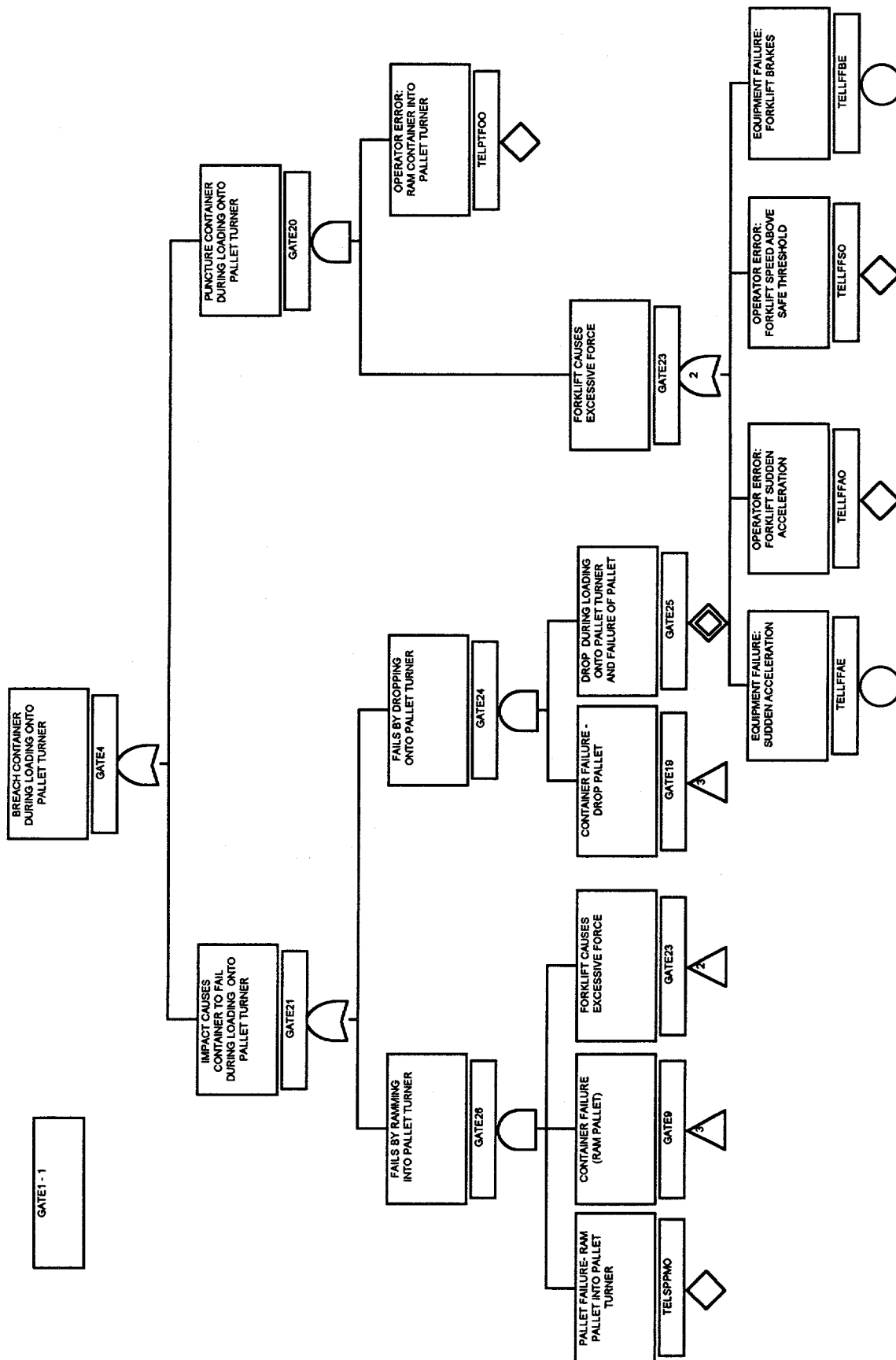
¹ Value obtained from Hyster

Appendix D:
Process Fault Trees
for
Transportation on Apron
From Pallet Trailer to Pallet Turner

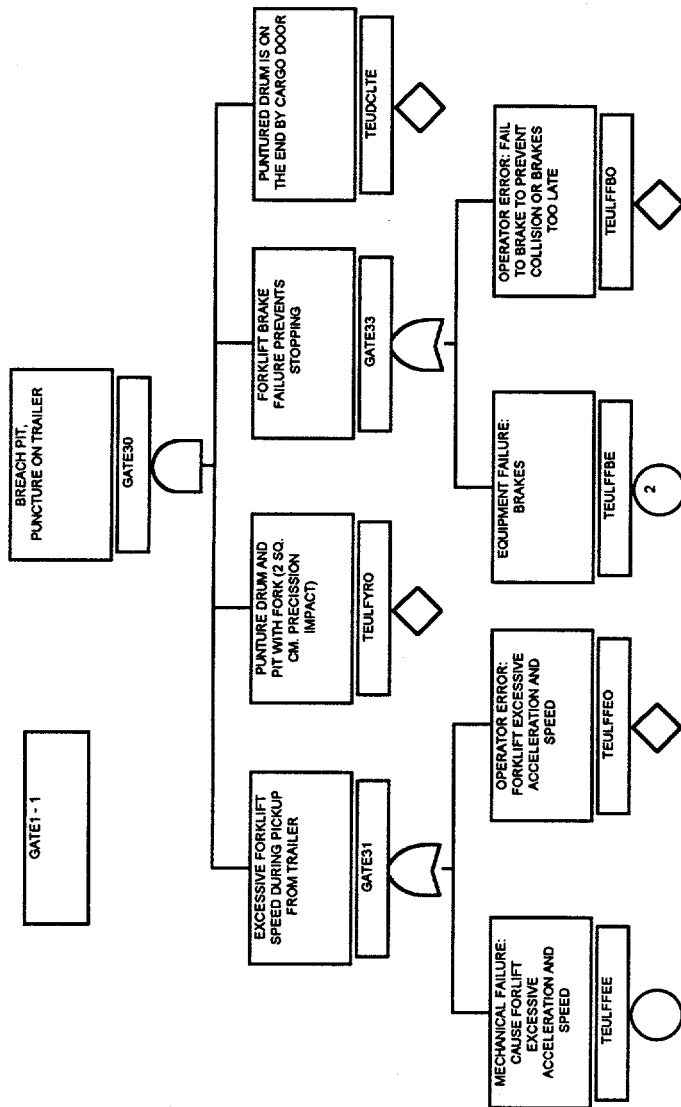
STAGE RIGHT PROJECT
PANTECH
C:\SIPRA\BREACH.TRE
BREACH DURING
TRANSPORT











FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM

BLOCK FILE: C:\SIPRA\BREACH.BLK

VALUE BLOCK FILE: C:\SIPRA\BREACH.VAL

WRITE FILE: NUL

EMS FILE: WINDRUN.EMS

SCRATCH FILE: WINDRUN.SCR

OUTPUT FILE: C:\SIPRA\BREACH.OUT

BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ BREACH.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1

FAULT TREE: BREACH

LOCATED: C:\SIPRA\BREACH.SET

NUMBER OF VALUE BLOCKS TO READ: 1

VALUE BLOCK: BREACH

LOCATED: C:\SIPRA\BREACH.TXT

OUTPUT FILE: C:\SIPRA\BREACH.OUT

BLOCK FILE: C:\SIPRA\BREACH.BLK

VALUE BLOCK FILE: C:\SIPRA\BREACH.VAL

PROGRAM: BREACH

USER BLOCK: TRBREACH

DATA PROC OPTIONS:

BEFORE ANALYSIS:

AFTER ANALYSIS:

COMPUTEBLOCK

COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:

TRUNCATION

TRUNC VALUE: 1E-12

TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (BREACH).

RDFT (BREACH).

DLTVALBLK (BREACH).

RDVALBLK (BREACH).

DLTBLK (TRBREACH).

DLTEON.

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GENFTEON (METHOD1\$ BREACH/ TRBREACH*
PROBABILITY/1E-12, BREACH).
LDBLK (TRBREACH).
COMPUTEBLOCK(PROBABILITY, BREACH).

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EXECUTE SETS USER PROGRAM BREACH

DLTBLK (BREACH).

STATEMENT EXECUTION REQUIRED 0.219 SECONDS FOR DLTBLK

RDFT (BREACH).

FAULTTREE\$BREACH.
OG\$ GATE1.
IN\$GATE30,GATE2,GATE3,GATE4,GATE5.
OG\$ GATE8.
IN\$TEULFFSO,TEULFFAO,TEULFFAE,TEULFFBE.
OUT\$GATE6,GATE12.
OG\$ GATE9.
IN\$TEXDCCCE,TEXDCCCA.
OUT\$GATE27,GATE17,GATE26.
OG\$ GATE16.
IN\$TEXLFFAE,TEXLFFBE,TEXLFFSO,TEXLFFAO.
OUT\$GATE13,GATE22.
OG\$ GATE23.
IN\$TELLFFAE,TELLFFAO,TELLFFSO,TELLFFBE.
OUT\$GATE20,GATE26.
AG\$ GATE6.
IN\$GATE8,TEULFYCO.
OUT\$GATE2.
AG\$ GATE13.
IN\$GATE16,TEXLFOPO,TEXLFFOO.
OUT\$GATE3.
AG\$ GATE20.
IN\$GATE23,TELPTFOO.
OUT\$GATE4.
UE\$ TEXDCCCA.
OUT\$GATE9,GATE32,GATE19.
UE\$ TEXLFOPO.
OUT\$GATE13,GATE22.
UE\$ TEXDCCRE.
OUT\$GATE19.
OG\$ GATE19.
IN\$TEXDCCRE,TEXDCCCA.
OUT\$GATE15,GATE24,GATE10.
BE\$ TEULFFBE.
OUT\$GATE8,GATE33.
OG\$ GATE2.
IN\$GATE7,GATE6.

OUT\$GATE1.
AG\$ GATE5.
IN\$TEFSPPSE,GATE32,TOLPTTSE.
OUT\$GATE1.
OG\$ GATE4.
IN\$GATE20,GATE21.
OUT\$GATE1.
OG\$ GATE3.
IN\$GATE14,GATE13.
OUT\$GATE1.
AG\$ GATE26.
IN\$TELSPPMO,GATE9,GATE23.
OUT\$GATE21.
BE\$ TELLFFBE.
OUT\$GATE23.
UE\$ TELLFFSO.
OUT\$GATE23.
UE\$ TELLFFAO.
OUT\$GATE23.
BE\$ TELLFFAE.
OUT\$GATE23.
UE\$ TELSPPMO.
OUT\$GATE26.
OG\$ GATE31.
IN\$TEULFFEE,TEULFFEO.
OUT\$GATE30.
UE\$ TEXSPFOO.
OUT\$GATE22.
AG\$ GATE15.
IN\$GATE18,GATE19.
OUT\$GATE14.
DE\$ GATE18.
OUT\$GATE15.
BE\$ TEXLFFAE.
OUT\$GATE16.
UE\$ TEXLFFAO.
OUT\$GATE16.
UE\$ TEXLFFSO.
OUT\$GATE16.
BE\$ TEXLFFBE.
OUT\$GATE16.
BE\$ TEULFFEE.
OUT\$GATE31.
UE\$ TEXLFFOO.
OUT\$GATE13.
UE\$ TELPTFOO.
OUT\$GATE20.
UE\$ TEXDCCCE.
OUT\$GATE9.
AG\$ GATE22.
IN\$TEXLFOPO,TEXSPFOO,GATE16.
OUT\$GATE17.

OG\$ GATE7.
 IN\$GATE10,GATE27.
 OUT\$GATE2.
 OG\$ GATE14.
 IN\$GATE15,GATE17.
 OUT\$GATE3.
 OG\$ GATE21.
 IN\$GATE26,GATE24.
 OUT\$GATE4.
 UE\$ TEULFFSO.
 OUT\$GATE8.
 BE\$ TEULFFAE.
 OUT\$GATE8.
 UE\$ TEULFFAO.
 OUT\$GATE8.
 UE\$ TEULFFEO.
 OUT\$GATE31.
 UE\$ TEFSPPE.
 OUT\$GATE5.
 UE\$ TEULFYCO.
 OUT\$GATE6.
 AG\$ GATE10.
 IN\$GATE11,GATE19.
 OUT\$GATE7.
 OG\$ GATE33.
 IN\$TEULFFBE,TEULFFBO.
 OUT\$GATE30.
 AG\$ GATE17.
 IN\$GATE22,GATE9.
 OUT\$GATE14.
 DE\$ TOLPTTSE.
 OUT\$GATE5.
 AG\$ GATE24.
 IN\$GATE19,GATE25.
 OUT\$GATE21.
 OG\$ GATE32.
 IN\$TEFDCCRE,TEXDCCCA.
 OUT\$GATE5.
 UE\$ TEULFFBO.
 OUT\$GATE33.
 DE\$ GATE25.
 OUT\$GATE24.
 DE\$ GATE11.
 OUT\$GATE10.
 UE\$ TEULFYRO.
 OUT\$GATE30.
 UE\$ TEFDCRE.
 OUT\$GATE32.
 UE\$ TEUDCLTE.
 OUT\$GATE30.
 AG\$ GATE27.
 IN\$GATE9,GATE12.

OUT\$GATE7.
AG\$ GATE12.
IN\$TEUSPYPO,GATE8.
OUT\$GATE27.
UE\$ TEUSPYPO.
OUT\$GATE12.
AG\$ GATE30.
IN\$GATE31,GATE33,TEULFYRO,TEUDCLTE.
OUT\$GATE1.

THERE ARE NO CYCLES IN BREACH

FAULT TREE BLOCK BREACH
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.941 SECONDS FOR RDFT

DLTVALBLK (BREACH).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTVALBLK

RDVALBLK (BREACH).

VALUE BLOCK\$BREACH.
CREATE VALUE BLOCK BREACH
1.0E-2 \$TEXDCCRE,TEULFFSO,TEULFFAO,TEXLFFSO,TEXLFFAO,TELLFFAO\$
1.0E-2 \$TELLFFSO,TEULFFEO,TEULFFBO\$
1.0E-3 \$TEXDCCCE,TEFDCCRE\$
5.0E-4 \$TEULFYRO\$
4.0E-1 \$TEUDCLTE\$
1.0E-4 \$TEFSPPSE,TOLPTTSE\$
3.0E-3 \$TEULFFAE,TEULFYCO,TEXLFFOO,TEXLFFAE,TEXSPFOO\$
3.0E-3 \$TELLFFAE,TELPTFOO,TELSPPMO,TEUSPYPO,TEULFFEE\$
3.0E-2 \$TEXLFOPO\$
5.0E-3 \$TEULFFBE,TEXLFFBE,TELLFFBE\$
6.0E-3 \$TEXDCCCA\$
1.0E-6 \$GATE11\$
7.0E-8 \$GATE18\$
9.0E-11 \$GATE25\$

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR RDVALBLK

DLTBLK (TRBREACH).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ BREACH/ TRBREACH* PROBABILITY/ 1E-12, BREACH).

TOP EVENTS OF BREACH

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (BREACH).
SUBINEON (GATE1, GATE1* STOP\$ GATE8, GATE16, GATE23,
GATE9, GATE19).
TRNTRMVAL (PROBABILITY/ 1E-12, BREACH* GATE1, GATE1*
EXCEPTNONCMP\$ GATE8, GATE16, GATE23,
GATE9, GATE19).
SUBINEON (GATE1, GATE1).
TRNTRMVAL (PROBABILITY/ 1E-12, BREACH* GATE1, GATE1).
FRMBLK (TRBREACH* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR GENFTEON

LDBLK (BREACH).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR LDBLK

SUBINEON (GATE1, GATE1* STOP\$ GATE8, GATE16, GATE23, GATE9, GATE19).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, BREACH* GATE1, GATE1* EXCEPTNONCMP\$
GATE8, GATE16, GATE23, GATE9, GATE19).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 15.

TERMS GENERATED BY EXPANSION
5 TERMS CONTAIN 2 VARIABLES
5 TERMS CONTAIN 3 VARIABLES
5 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS GENERATED 15.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
(THE SUM OF THE TERM VALUES IS 1.218110880000E-02)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
5 TERMS CONTAIN 2 VARIABLES
5 TERMS CONTAIN 3 VARIABLES
5 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS RETAINED 15.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL
SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR SUBINEON
TRNTRMVAL (PROBABILITY/ 1E-12, BREACH* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 48.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
22 TERMS CONTAIN 3 VARIABLES
12 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS GENERATED 46.

THERE WERE TERMS DELETED BECAUSE OF
TRUNCATION VALUES

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999920000E-05
(THE SUM OF THE TERM VALUES IS 1.717698910000E-04)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.063 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
12 TERMS CONTAIN 2 VARIABLES
22 TERMS CONTAIN 3 VARIABLES
12 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS RETAINED 46.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR TRNTRMVAL
FRMBLK (TRBREACH* ONLY\$ GATE1).

EQUATION BLOCK TRBREACH

HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR FRMBLK

LDBLK (TRBREACH).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, BREACH).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACH* GATE1).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACH* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 46.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
22 TERMS CONTAIN 3 VARIABLES
12 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS GENERATED 46.
EXPANSION TOOK 0.000 SECONDS.

*** VARIABLE OCCURRENCE TABLE ***

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
TEULFFSO	3		
TEULFFAO	3		
TEULFFAE	3		
TEULFFBE	5		
TEXDCCCE	12		
TEXDCCCA	15		
TEXLFFAE	3		
TEXLFFBE	3		
TEXLFFSO	3		
TEXLFFAO	3		
TELLFFAE	3		
TELLFFAO	3		
TELLFFSO	3		
TELLFFBE	3		
TEULFYCO	4		
TEXLFOPO	12		
TEXLFFOO	4		
TELPTFOO	4		

TEXDCCRE	2
TEFSPPSE	2
TOLPTTSE	2
TELSPPMO	8
TEULFFEE	2
TEULFFEO	2
TEXSPFOO	8
GATE18	2
GATE11	2
TEULFFBO	2
TEFDCCRE	1
TEULFYRO	4
TEUDCLTE	4
TEUSPYPO	8

THERE ARE 32 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

GATE1 =

1	3.0000E-05	TEULFFAO * TEULFYCO +
2	3.0000E-05	TEULFFSO * TEULFYCO +
3	3.0000E-05	TELLFFSO * TELPTFOO +
4	3.0000E-05	TELLFFAO * TELPTFOO +
5	1.5000E-05	TELLFFBE * TELPTFOO +
6	1.5000E-05	TEULFFBE * TEULFYCO +
7	9.0000E-06	TEULFFAE * TEULFYCO +
8	9.0000E-06	TELLFFAE * TELPTFOO +
9	9.0000E-07	TEXLFFAO * TEXLFOPO * TEXLFFOO +
10	9.0000E-07	TEXLFFSO * TEXLFOPO * TEXLFFOO +
11	4.5000E-07	TEXLFFBE * TEXLFOPO * TEXLFFOO +
12	2.7000E-07	TEXLFFAE * TEXLFOPO * TEXLFFOO +
13	1.8000E-07	TEXDCCCA * TELLFFSO * TELSPPMO +
14	1.8000E-07	TEXDCCCA * TELLFFAO * TELSPPMO +
15	1.8000E-07	TEULFFAO * TEXDCCCA * TEUSPYPO +

16 1.8000E-07 TEULFFSO * TEXTCCCA * TEUSPYPO +
 17 9.0000E-08 TEULFFBE * TEXTCCCA * TEUSPYPO +
 18 9.0000E-08 TEXTCCCA * TELLFFBE * TELSPPMO +
 19 5.4000E-08 TEULFFAE * TEXTCCCA * TEUSPYPO +
 20 5.4000E-08 TEXTCCCA * TELLFFAE * TELSPPMO +
 21 3.0000E-08 TEXTCCCE * TELLFFSO * TELSPPMO +
 22 3.0000E-08 TEXTCCCE * TELLFFAO * TELSPPMO +
 23 3.0000E-08 TEULFFAO * TEXTCCCE * TEUSPYPO +
 24 3.0000E-08 TEULFFSO * TEXTCCCE * TEUSPYPO +
 25 2.0000E-08 TEULFFEO * TEULFFBO * TEULFYRO * TEUDCLTE +
 26 1.5000E-08 TEXTCCCE * TELLFFBE * TELSPPMO +
 27 1.5000E-08 TEULFFBE * TEXTCCCE * TEUSPYPO +
 28 1.0000E-08 TEXTCCRE * GATE11 +
 29 1.0000E-08 TEULFFBE * TEULFFEO * TEULFYRO * TEUDCLTE +
 30 9.0000E-09 TEXTCCCE * TELLFFAE * TELSPPMO +
 31 9.0000E-09 TEULFFAE * TEXTCCCE * TEUSPYPO +
 32 6.0000E-09 TEXTCCCA * GATE11 +
 33 6.0000E-09 TEULFFEE * TEULFFBO * TEULFYRO * TEUDCLTE +
 34 5.4000E-09 TEXTCCCA * TEXTLFFAO * TEXTLFOPO * TEXTSPFOO +
 35 5.4000E-09 TEXTCCCA * TEXTLFFSO * TEXTLFOPO * TEXTSPFOO +
 36 3.0000E-09 TEULFFBE * TEULFFEE * TEULFYRO * TEUDCLTE +
 37 2.7000E-09 TEXTCCCA * TEXTLFFBE * TEXTLFOPO * TEXTSPFOO +
 38 1.6200E-09 TEXTCCCA * TEXTLFFAE * TEXTLFOPO * TEXTSPFOO +
 39 9.0000E-10 TEXTCCCE * TEXTLFFAO * TEXTLFOPO * TEXTSPFOO +
 40 9.0000E-10 TEXTCCCE * TEXTLFFSO * TEXTLFOPO * TEXTSPFOO +
 41 7.0000E-10 TEXTCCRE * GATE18 +

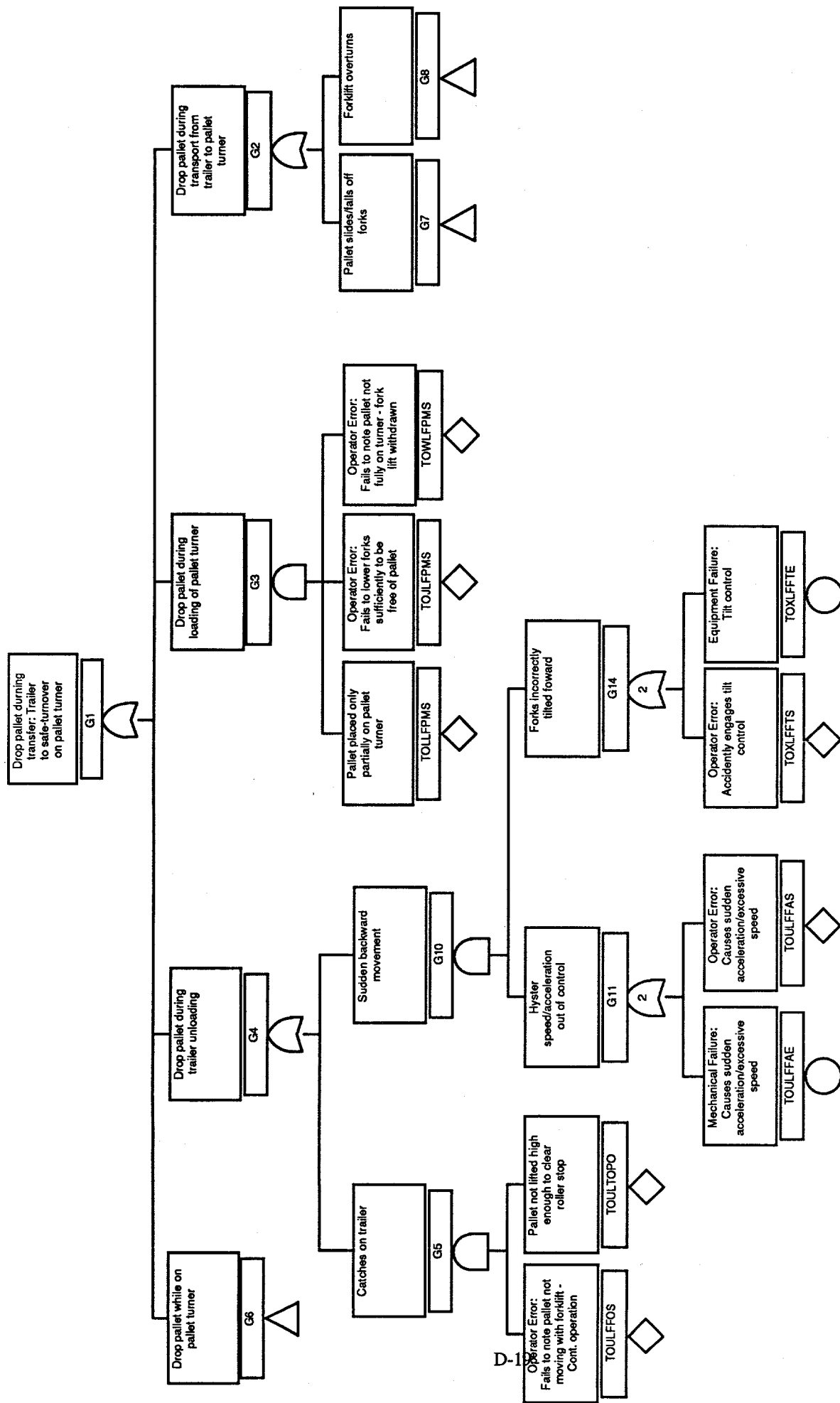
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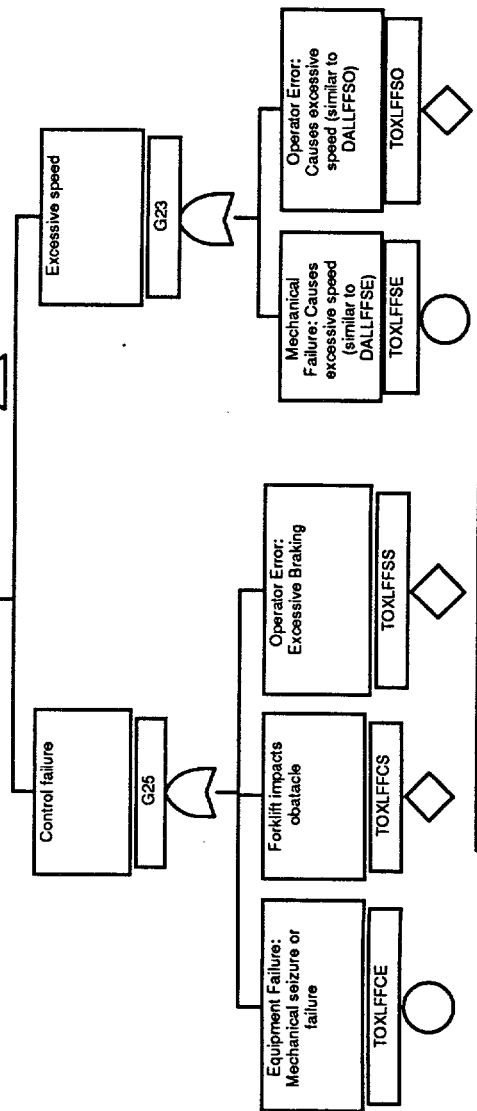
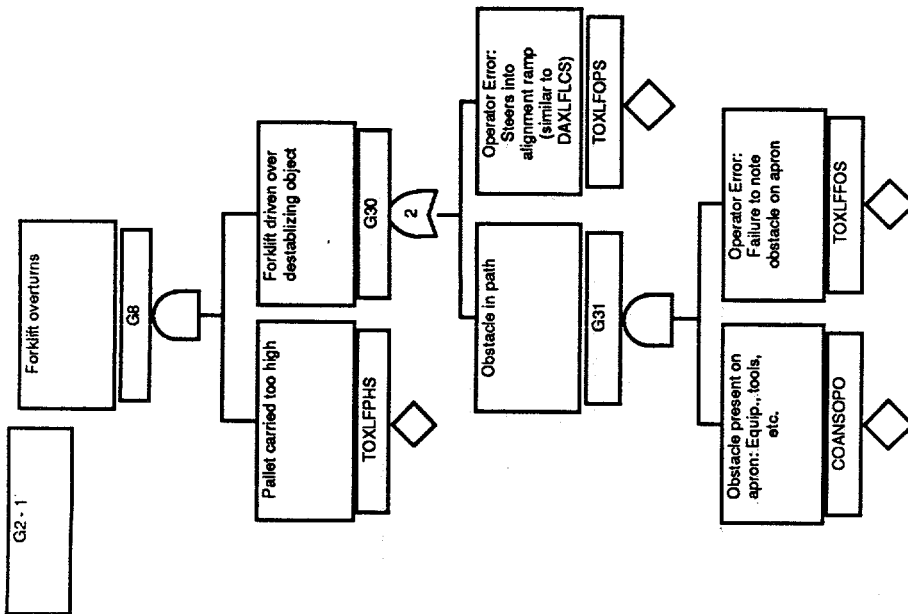
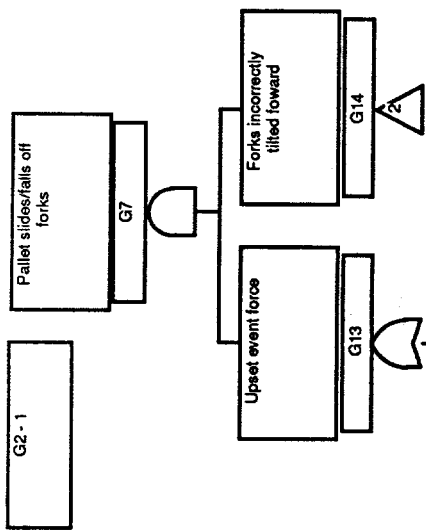
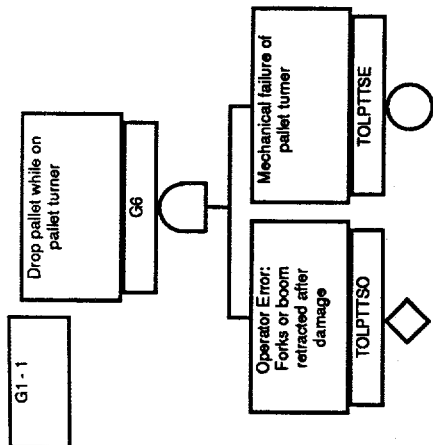
42 4.5000E-10 TEXDCCCE * TEXLFFBE * TEXLFOPO * TEXSPFOO +
43 4.2000E-10 TEXDCCCA * GATE18 +
44 2.7000E-10 TEXDCCCE * TEXLFFAE * TEXLFOPO * TEXSPFOO +
45 6.0000E-11 TEXDCCCA * TEFSPPPSE * TOLPTTSE +
46 1.0000E-11 TEFSPPPSE * TOLPTTSE * TEFDCCRE

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999920000E-05
(THE SUM OF THE TERM VALUES IS 1.717698910000E-04)

STATEMENT EXECUTION REQUIRED 0.168 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.





Drop Pallet during Transfer between Trailer and Pallet Turner.

Sheet 2 of 2

FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\DRPTRPT.BLK
VALUE BLOCK FILE: C:\SIPRA\DRPTRPT.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\DRPTRPT.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ DRPTRPT.
COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: DRPTRPT
LOCATED: C:\SIPRA\DRPTRPT.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: DRPTRPT
LOCATED: C:\SIPRA\DRPTRPT.TXT

OUTPUT FILE: C:\SIPRA\DRPTRPT.OUT

BLOCK FILE: C:\SIPRA\DRPTRPT.BLK

VALUE BLOCK FILE: C:\SIPRA\DRPTRPT.VAL

PROGRAM: DRPTRPT

USER BLOCK: TRDRPPT

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTE BLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (DRPTRPT).
RDFT (DRPTRPT).
DLTVALBLK (DRPTRPT).
RDVALBLK (DRPTRPT).
DLTBLK (TRDRPPT).
DLTEON.

GENFTEON (METHOD1\$ DRPTRPT/ TRDRPPT*
 PROBABILITY/1E-12, DRPTRPT).
 LDBLK (TRDRPPT).
 COMPUTEBLOCK(PROBABILITY, DRPTRPT).

EXECUTE SETS USER PROGRAM DRPTRPT

DLTBLK (DRPTRPT).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR DLTBLK

RDFT (DRPTRPT).

FAULTTREE\$DRPTRPT.
 OG\$ G1.
 IN\$G6,G4,G3,G2.
 OG\$ G30.
 IN\$TOXLFOPS,G31.
 OUT\$G8,G13.
 OG\$ G14.
 IN\$TOXLFFTS,TOXLFFTE.
 OUT\$G7,G10.
 OG\$ G11.
 IN\$TOULFFAE,TOULFFAS.
 OUT\$G10,G20.
 OG\$ G2.
 IN\$G7,G8.
 OUT\$G1.
 AG\$ G3.
 IN\$TOJLFPMS,TOLLFPMS,TOWLFPMS.
 OUT\$G1.
 OG\$ G13.
 IN\$G30,G20.
 OUT\$G7.
 UE\$ TOJLFPMS.
 OUT\$G3.
 BE\$ TOLPTTSE.
 OUT\$G6.
 UE\$ TOLLFPMS.
 OUT\$G3.
 UE\$ TOWLFPMS.
 OUT\$G3.
 OG\$ G4.
 IN\$G5,G10.
 OUT\$G1.
 UE\$ TOXLFFSO.
 OUT\$G23.
 AG\$ G5.
 IN\$TOULFFOS,TOULTOPO.
 OUT\$G4.
 AG\$ G10.
 IN\$G14,G11.

OUT\$G4.
 UE\$ TOULTOPO.
 OUT\$G5.
 UE\$ TOULFFOS.
 OUT\$G5.
 BE\$ TOULFFAE.
 OUT\$G11.
 UE\$ TOULFFAS.
 OUT\$G11.
 AG\$ G8.
 IN\$G30,TOXLFPHS.
 OUT\$G2.
 UE\$ TOXLFPHS.
 OUT\$G8.
 UE\$ COANSOPO.
 OUT\$G31.
 UE\$ TOXLFFOS.
 OUT\$G31.
 AG\$ G7.
 IN\$G13,G14.
 OUT\$G2.
 OG\$ G20.
 IN\$G11,G24.
 OUT\$G13.
 BE\$ TOXLFFSE.
 OUT\$G23.
 AG\$ G24.
 IN\$G25,G23.
 OUT\$G20.
 UE\$ TOXLFFSS.
 OUT\$G25.
 UE\$ TOXLFFCS.
 OUT\$G25.
 OG\$ G23.
 IN\$TOXLFFSE,TOXLFFSO.
 OUT\$G24.
 AG\$ G6.
 IN\$TOLPTTSE,TOLPTTSE.
 OUT\$G1.
 UE\$ TOLPTTSE.
 OUT\$G6.
 BE\$ TOXLFFTE.
 OUT\$G14.
 UE\$ TOXLFFTS.
 OUT\$G14.
 OG\$ G25.
 IN\$TOXLFFCE,TOXLFFCS,TOXLFFSS.
 OUT\$G24.
 BE\$ TOXLFFCE.
 OUT\$G25.
 AG\$ G31.
 IN\$COANSOPO,TOXLFFOS.

OUT\$G30.
UE\$ TOXLFOPS.
OUT\$G30.

THERE ARE NO CYCLES IN DRPTRPT

FAULT TREE BLOCK DRPTRPT
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.438 SECONDS FOR RDFT

DLTVALBLK (DRPTRPT).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTVALBLK

RDVALBLK (DRPTRPT).

VALUE BLOCK\$DRPTRPT.
CREATE VALUE BLOCK DRPTRPT
3.0E-2 \$COANSOPO\$
3.0E-3 \$TOJLFPMS,TOLLFPMS,TOULFFAE,TOXLFFCS,TOXLFFSE,TOXLFPMS,
TOLPTTSO\$
5.0E-4 \$TOLPTTSE\$
1.0E-2 \$TOULFFAS,TOULTOPO,TOXLFFOS,TOXLFFSO,TOXLFFSS,TOXLFOPS\$
1.0E-1 \$TOULFFOS,TOWLFPMS\$
2.5E-5 \$TOXLFFCE\$
2.7E-3 \$TOXLFFTE\$
1.0E-3 \$TOXLFFTS\$

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR RDVALBLK

DLTBLK (TRDRPPT).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ DRPTRPT/ TRDRPPT* PROBABILITY/ 1E-12, DRPTRPT).

TOP EVENTS OF DRPTRPT

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (DRPTRPT).
SUBINEON (G1, G1* STOP\$ G30, G14, G11).
TRNTRMVAL (PROBABILITY/ 1E-12, DRPTRPT* G1, G1*
EXCEPTNONCMP\$ G30, G14, G11).

SUBINEQN (G1, G1).
TRNTRMVAL (PROBABILITY/ 1E-12, DRPTRPT* G1, G1).
FRMBLK (TRDRPPT* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEON
LDBLK (DRPTRPT).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR LDBLK
SUBINEQN (G1, G1* STOP\$ G30, G14, G11).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN
TRNTRMVAL (PROBABILITY/ 1E-12, DRPTRPT* G1, G1* EXCEPTNONCMP\$ G30, G14,
G11).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 13.

TERMS GENERATED BY EXPANSION
6 TERMS CONTAIN 2 VARIABLES
7 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 13.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000000000E+00
(THE SUM OF THE TERM VALUES IS 3.004171850000E+00)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
5 TERMS CONTAIN 2 VARIABLES
7 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 12.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR TRNTRMVAL
SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN
TRNTRMVAL (PROBABILITY/ 1E-12, DRPTRPT* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 25.

TERMS GENERATED BY EXPANSION
9 TERMS CONTAIN 2 VARIABLES
16 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 25.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000050000E-03
(THE SUM OF THE TERM VALUES IS 1.120136700000E-03)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
9 TERMS CONTAIN 2 VARIABLES
16 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 25.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR TRNTRMVAL
FRMBLK (TRDRPPT* ONLY\$ G1).

EQUATION BLOCK TRDRPPT
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR FRMBLK
LDBLK (TRDRPPT).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK
COMPUTEBLOCK (PROBABILITY, DRPTRPT).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, DRPTRPT* G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMPUTEBLOCK
COMTRMVAL (PROBABILITY, DRPTRPT* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 25.

TERMS GENERATED BY EXPANSION
9 TERMS CONTAIN 2 VARIABLES
16 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 25.
EXPANSION TOOK 0.000 SECONDS.

* * * * VARIABLE OCCURRENCE TABLE * * * *

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
TOXLFOPS	3		
TOXLFFTS	10		
TOXLFFTE	10		
TOULFFAE	2		
TOULFFAS	2		
TOJLFPMS	1		
TOLLFPMS	1		
TOWLFPMS	1		
TOLPTTSE	1		
TOXLFFSO	6		
TOULFFOS	1		
TOULTOPO	1		
TOXLFPHS	2		
COANSOPO	3		
TOXLFFOS	3		
TOXLFFSE	6		
TOXLFFSS	4		
TOXLFFCS	4		
TOLPTTSO	1		
TOXLFFCE	4		

THERE ARE 20 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

1 1.0000E-03 TOULFFOS * TOULTOPO +
2 3.0000E-05 TOXLFOPS * TOXLFPHS +
3 2.7000E-05 TOXLFOPS * TOXLFFTE +
4 2.7000E-05 TOXLFFTE * TOULFFAS +
5 1.0000E-05 TOXLFOPS * TOXLFFTS +
6 1.0000E-05 TOXLFFTS * TOULFFAS +
7 8.1000E-06 TOXLFFTE * TOULFFAE +
8 3.0000E-06 TOXLFFTS * TOULFFAE +
9 1.5000E-06 TOLPTTSE * TOLPTTSO +

10	9.0000E-07	TOJLFPMS * TOLLFPMS * TOWLFPMS +
11	9.0000E-07	TOXLFPMS * COANSOPO * TOXLFFOS +
12	8.1000E-07	TOXLFFTE * COANSOPO * TOXLFFOS +
13	3.0000E-07	TOXLFFTS * COANSOPO * TOXLFFOS +
14	2.7000E-07	TOXLFFTE * TOXLFFSO * TOXLFFSS +
15	1.0000E-07	TOXLFFTS * TOXLFFSO * TOXLFFSS +
16	8.1000E-08	TOXLFFTE * TOXLFFSO * TOXLFFCS +
17	8.1000E-08	TOXLFFTE * TOXLFFSE * TOXLFFSS +
18	3.0000E-08	TOXLFFTS * TOXLFFSO * TOXLFFCS +
19	3.0000E-08	TOXLFFTS * TOXLFFSE * TOXLFFSS +
20	2.4300E-08	TOXLFFTE * TOXLFFSE * TOXLFFCS +
21	9.0000E-09	TOXLFFTS * TOXLFFSE * TOXLFFCS +
22	6.7500E-10	TOXLFFTE * TOXLFFSO * TOXLFFCE +
23	2.5000E-10	TOXLFFTS * TOXLFFSO * TOXLFFCE +
24	2.0250E-10	TOXLFFTE * TOXLFFSE * TOXLFFCE +
25	7.5000E-11	TOXLFFTS * TOXLFFSE * TOXLFFCE

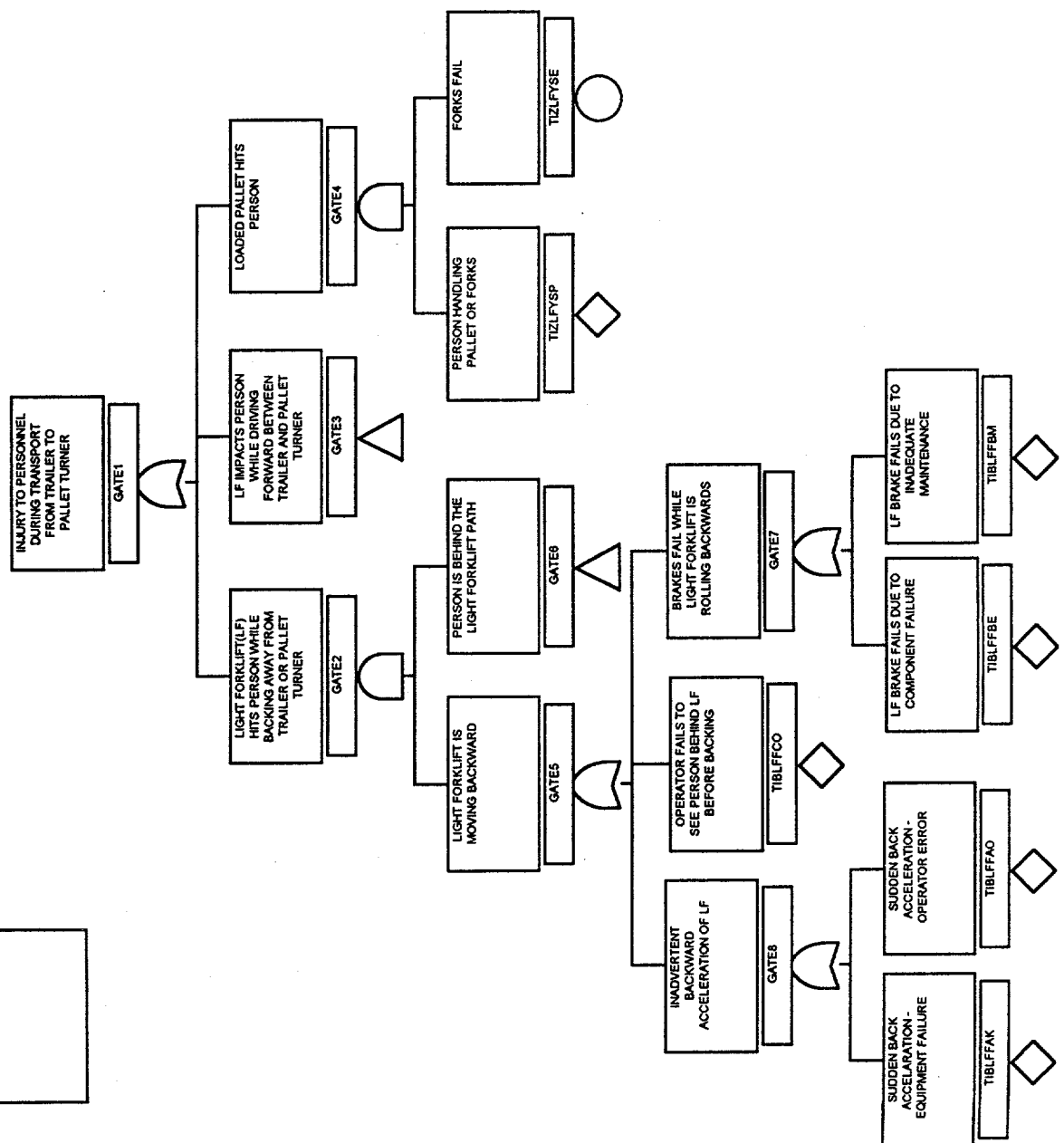
THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000050000E-03

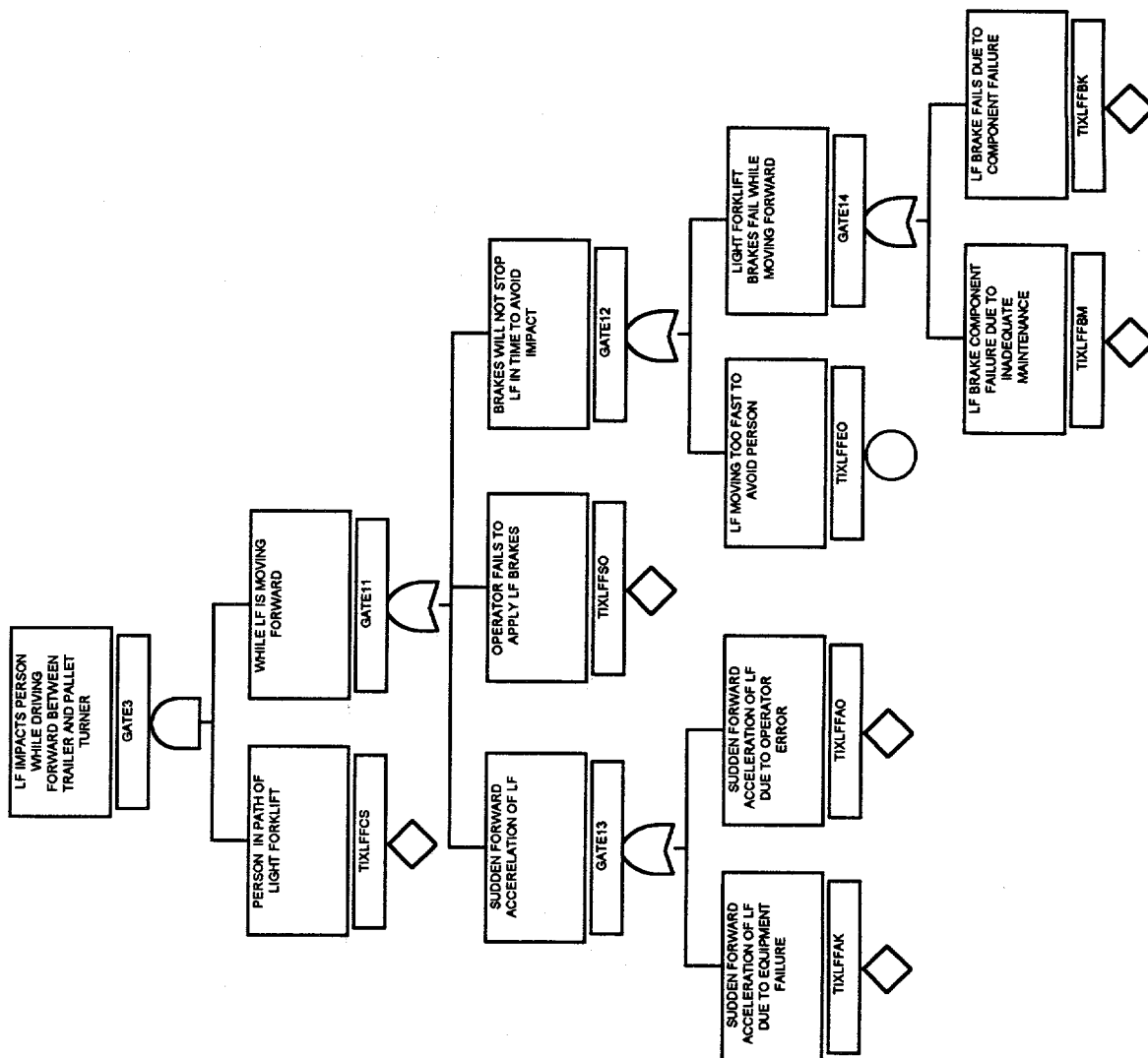
(THE SUM OF THE TERM VALUES IS 1.120136590000E-03)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

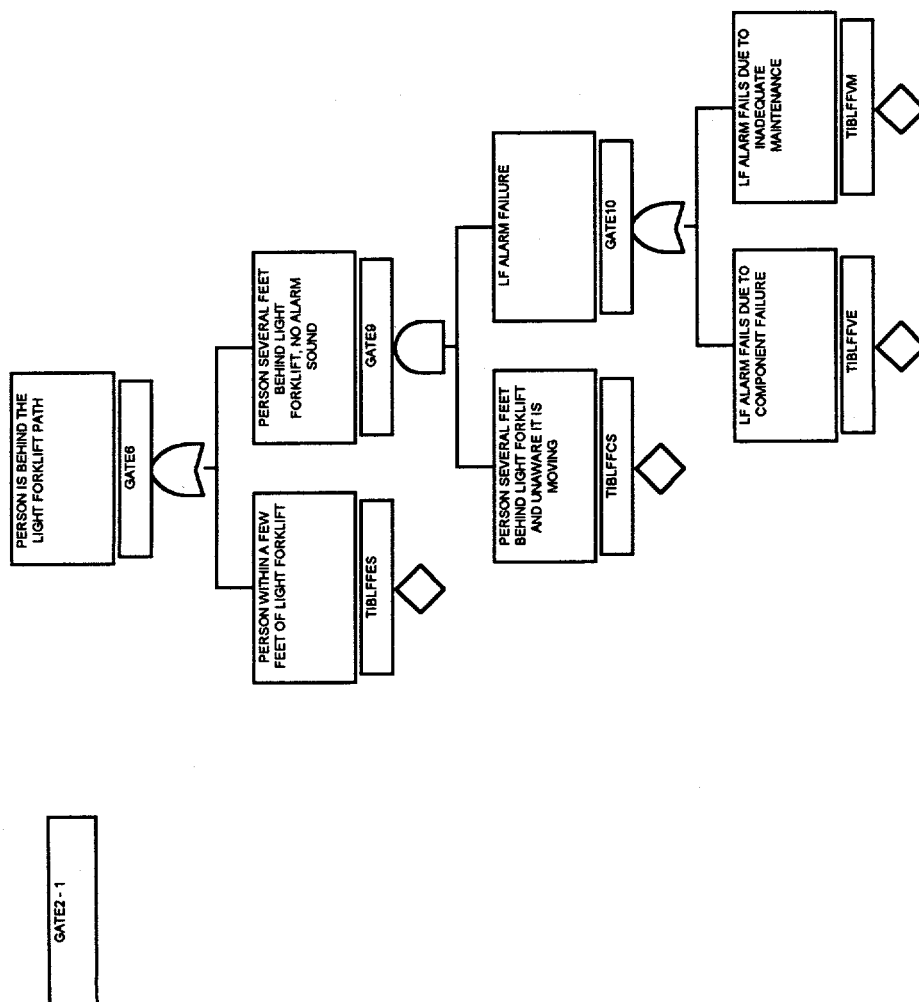
END EXECUTION OF SETS.

STAGE RIGHT PROJECT
 --PANTEX--
 C:\SPRAIN\INJURY TREE
 INJURY TO PERSONNEL
 DURING TRANSPORT





GATE1-1



SETS(07/06/93) 04/18/94 07:35:52.51 PAGE NO. 1

FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\INJURY.BLK
VALUE BLOCK FILE: C:\SIPRA\INJURY.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\INJURY.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ INJURY.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1

FAULT TREE: INJURY

LOCATED: C:\SIPRA\INJURY.SET

NUMBER OF VALUE BLOCKS TO READ: 1

VALUE BLOCK: INJURY

LOCATED: C:\SIPRA\INJURY.TXT

OUTPUT FILE: C:\SIPRA\INJURY.OUT

BLOCK FILE: C:\SIPRA\INJURY.BLK

VALUE BLOCK FILE: C:\SIPRA\INJURY.VAL

PROGRAM: INJURY

USER BLOCK: INURYPE

DATA PROC OPTIONS:

BEFORE ANALYSIS:

AFTER ANALYSIS:

COMPUTEBLOCK

COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:

TRUNCATION

TRUNC VALUE: 1E-12

TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (INJURY).

RDFT (INJURY).

DLTVALBLK (INJURY).

RDVALBLK (INJURY).

DLTBLK (INURYPE).

DLTEQN.

GENFTEQN (METHOD1\$ INJURY/ INURYPE*

PROBABILITY/1E-12, INJURY).

LDBLK (INURYPE).

COMPUTEBLOCK(PROBABILITY, INJURY).

EXECUTE SETS USER PROGRAM INJURY

DLTBLK (INJURY).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR DLTBLK

RDFT (INJURY).

FAULTTREE\$INJURY.

OG\$ GATE1.

IN\$GATE2,GATE3,GATE4.

AG\$ GATE2.

IN\$GATE5,GATE6.

OUT\$GATE1.

AG\$ GATE3.

IN\$TIXLFFCS,GATE11.

OUT\$GATE1.

AG\$ GATE4.

IN\$TIZLFYSP,TIZLFYSE.

OUT\$GATE1.

OG\$ GATE5.

IN\$TIBLFFCO,GATE8,GATE7.

OUT\$GATE2.

OG\$ GATE6.

IN\$TIBLFFES,GATE9.

OUT\$GATE2.

OG\$ GATE7.

IN\$TIBLFFBE,TIBLFFBM.

OUT\$GATE5.

UE\$ TIBLFFBM.

OUT\$GATE7.

UE\$ TIBLFFBE.

OUT\$GATE7.

UE\$ TIBLFFCO.

OUT\$GATE5.

OG\$ GATE8.

IN\$TIBLFFAK,TIBLFFAO.

OUT\$GATE5.

UE\$ TIBLFFAK.

OUT\$GATE8.

UE\$ TIBLFFAO.
OUT\$GATE8.
UE\$ TIBLFFES.
OUT\$GATE6.
AG\$ GATE9.
IN\$TIBLFFCS,GATE10.
OUT\$GATE6.
UE\$ TIBLFFCS.
OUT\$GATE9.
OG\$ GATE10.
IN\$TIBLFFVE,TIBLFFVM.
OUT\$GATE9.
BE\$ TIZLFYSE.
OUT\$GATE4.
UE\$ TIBLFFVE.
OUT\$GATE10.
UE\$ TIXLFFCS.
OUT\$GATE3.
OG\$ GATE11.
IN\$GATE13,TIXLFFSO,GATE12.
OUT\$GATE3.
UE\$ TIXLFFSO.
OUT\$GATE11.
OG\$ GATE12.
IN\$TIXLFFEO,GATE14.
OUT\$GATE11.
BE\$ TIXLFFEO.
OUT\$GATE12.
OG\$ GATE14.
IN\$TIXLFFBM,TIXLFFBK.
OUT\$GATE12.
UE\$ TIXLFFBM.
OUT\$GATE14.
UE\$ TIXLFFBK.
OUT\$GATE14.
OG\$ GATE13.
IN\$TIXLFFAK,TIXLFFAO.
OUT\$GATE11.
UE\$ TIXLFFAK.
OUT\$GATE13.
UE\$ TIXLFFAO.
OUT\$GATE13.
UE\$ TIZLFYSP.
OUT\$GATE4.

07:35:52.51 PAGE NO. 4
UE\$ TIBLFFVM.
OUT\$GATE10.

SETS(07/06/93) 04/18/94

THERE ARE NO CYCLES IN INJURY

FAULT TREE BLOCK INJURY
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.391 SECONDS FOR RDFT
DLTVALBLK (INJURY).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTVALBLK

RDVALBLK (INJURY).

VALUE BLOCK\$INJURY.

CREATE VALUE BLOCK INJURY

1.0E-3 \$TIZLFYSP\$

3.0E-2 \$TIBLFFCO,TIXLFFSO\$

2 . 0 E - 2

\$TIBLFFAO,TIXLFFCS,TIXLFFAO,TIXLFFEO,TIBLFFES,TIBLFFCS\$

3.0E-3 \$TIBLFFBM,TIXLFFBM,TIBLFFVM,TIBLFFAK,TIXLFFAK\$

6.5E-5 \$TIZLFYSE\$

5.0E-3 \$TIBLFFBE,TIXLFFBK\$

3.8E-3 \$TIBLFFVE\$

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR RDVALBLK

DLTBLK (INURYPE).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEQN

GENFTEON (METHOD1\$ INJURY/ INURYPE* PROBABILITY/ 1E-12, INJURY).
TOP EVENTS OF INJURY

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON
LDBLK (INJURY).

SUBINEON (GATE1, GATE1).

TRNTRMVAL (PROBABILITY/ 1E-12, INJURY* GATE1, GATE1).

FRMBLK (INURYPE* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEON
LDBLK (INJURY).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR LDBLK
SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR SUBINEON
TRNTRMVAL (PROBABILITY/ 1E-12, INJURY* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 22.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
10 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 22.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 5.999999700000E-04
(THE SUM OF THE TERM VALUES IS 2.848360690000E-03)

EXPANSION TOOK 0.049 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
12 TERMS CONTAIN 2 VARIABLES
10 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 22.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL
FRMBLK (INURYPE* ONLY\$ GATE1).

EQUATION BLOCK INURYPE
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.061 SECONDS FOR FRMBLK
LDBLK (INURYPE).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, INJURY).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, INJURY* GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMPUTEBLOCK
COMTRMVAL (PROBABILITY, INJURY* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 22.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
10 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 22.
EXPANSION TOOK 0.059 SECONDS.

* * * * VARIABLE OCCURRENCE TABLE * * * *

NUMBER OF OCCURRENCES	NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE
	TIXLFFCS	6	
	TIZLFYSP	1	
	TIZLFYSE	1	
	TIBLFFCO	3	
	TIBLFFES	5	
	TIBLFFBE	3	
	TIBLFFBM	3	
	TIBLFFAK	3	
	TIBLFFAO	3	
	TIBLFFCS	10	
	TIBLFFVE	5	
	TIBLFFVM	5	
	TIXLFFSO	1	
	TIXLFFEO	1	
	TIXLFFBM	1	
	TIXLFFBK	1	
	TIXLFFAK	1	
	TIXLFFAO	1	

THERE ARE 18 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

GATE1 =

1	6.0000E-04	TIXLFFCS * TIXLFFSO +
2	6.0000E-04	TIBLFFCO * TIBLFFES +
3	4.0000E-04	TIXLFFCS * TIXLFFE0 +
4	4.0000E-04	TIXLFFCS * TIXLFFAO +
5	4.0000E-04	TIBLFFES * TIBLFFAO +
6	1.0000E-04	TIBLFFES * TIBLFFBE +
7	1.0000E-04	TIXLFFCS * TIXLFFBK +
8	6.0000E-05	TIXLFFCS * TIXLFFAK +
9	6.0000E-05	TIBLFFES * TIBLFFBM +
10	6.0000E-05	TIBLFFES * TIBLFFAK +
11	6.0000E-05	TIXLFFCS * TIXLFFBM +
12	2.2800E-06	TIBLFFCO * TIBLFFCS * TIBLFFVE +
13	1.8000E-06	TIBLFFCO * TIBLFFCS * TIBLFFVM +
14	1.5200E-06	TIBLFFAO * TIBLFFCS * TIBLFFVE +
15	1.2000E-06	TIBLFFAO * TIBLFFCS * TIBLFFVM +
16	3.8000E-07	TIBLFFBE * TIBLFFCS * TIBLFFVE +
17	3.0000E-07	TIBLFFBE * TIBLFFCS * TIBLFFVM +
18	2.2800E-07	TIBLFFBM * TIBLFFCS * TIBLFFVE +

19 2.2800E-07 TIBLFFAK * TIBLFFCS * TIBLFFVE +

20 1.8000E-07 TIBLFFBM * TIBLFFCS * TIBLFFVM +

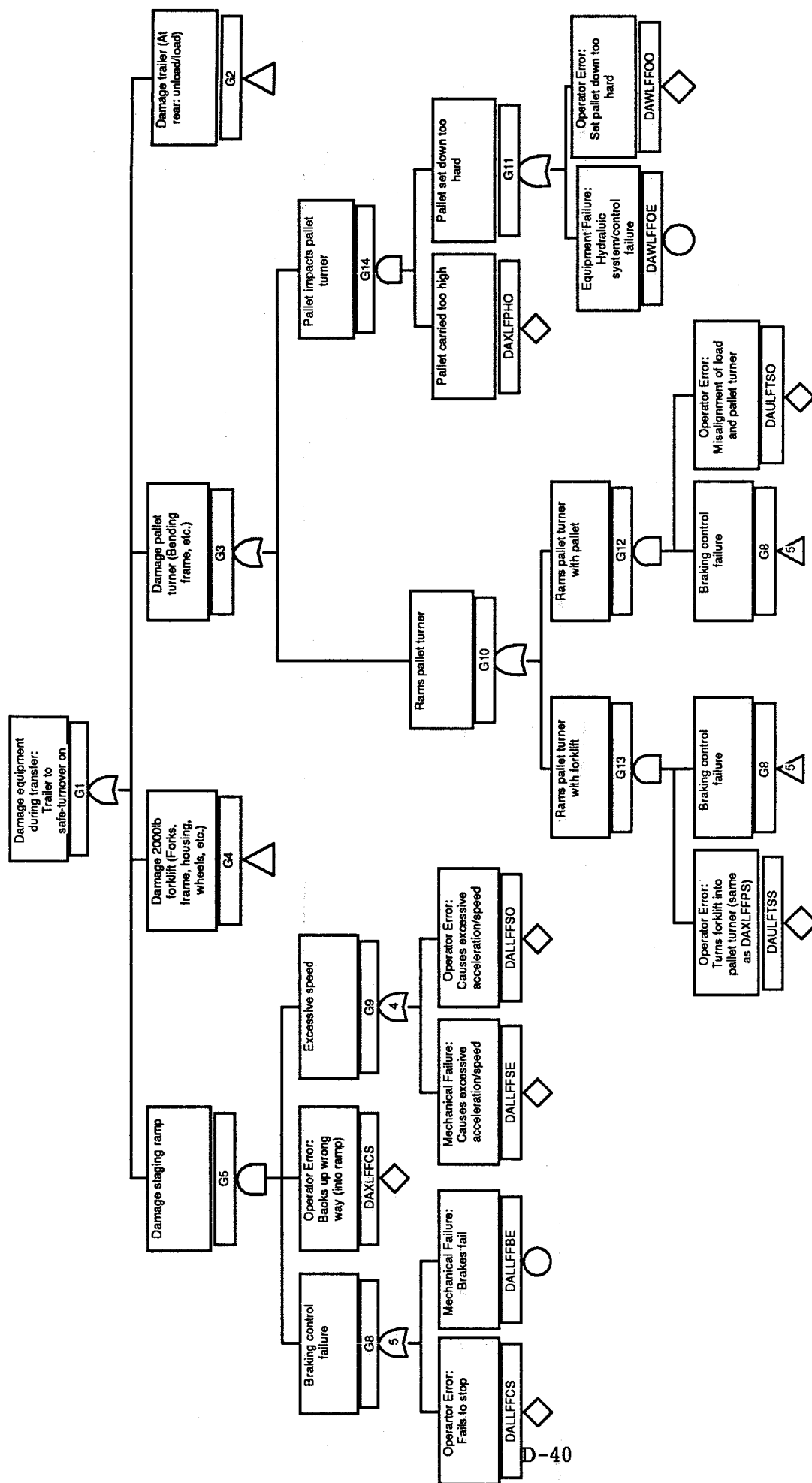
21 1.8000E-07 TIBLFFAK * TIBLFFCS * TIBLFFVM +

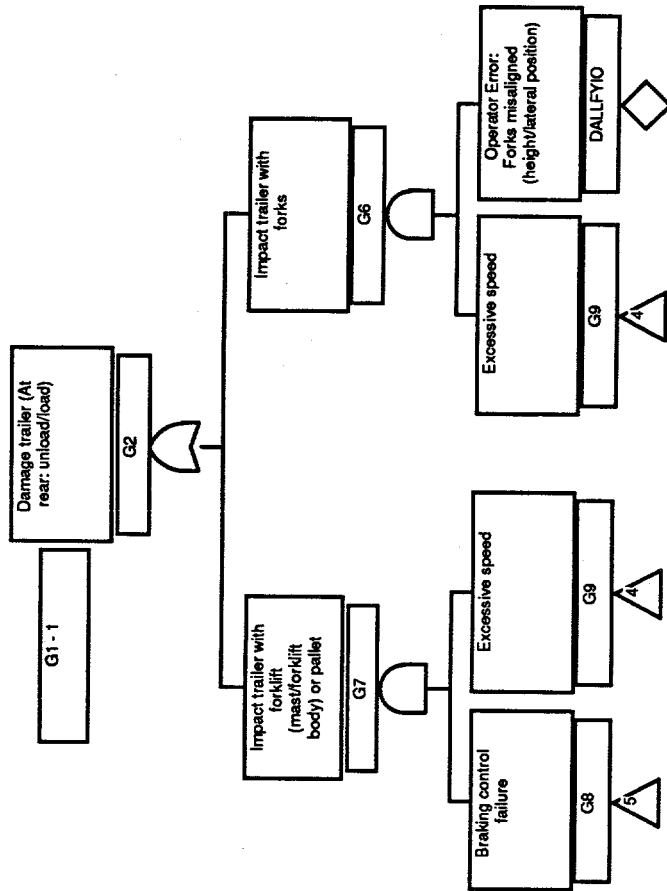
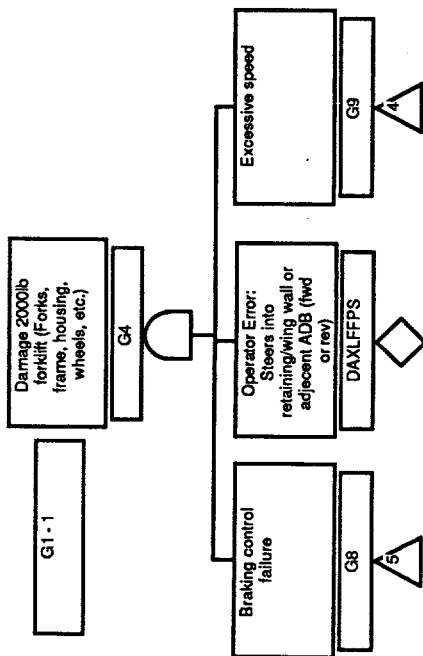
22 6.5000E-08 TIZLFYSP * TIZLFYSE

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 5.999999700000E-04
(THE SUM OF THE TERM VALUES IS 2.848360450000E-03)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.





FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\DETRPT.BLK
VALUE BLOCK FILE: C:\SIPRA\DETRPT.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\DETRPT.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ DETRPT.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1

FAULT TREE: DETRPT

LOCATED: C:\SIPRA\DETRPT.SET

NUMBER OF VALUE BLOCKS TO READ: 1

VALUE BLOCK: DETRPT

LOCATED: C:\SIPRA\DETRPT.TXT

OUTPUT FILE: C:\SIPRA\DETRPT.OUT

BLOCK FILE: C:\SIPRA\DETRPT.BLK

VALUE BLOCK FILE: C:\SIPRA\DETRPT.VAL

PROGRAM: DETRPT

USER BLOCK: DETRPT1

DATA PROC OPTIONS:

BEFORE ANALYSIS:

AFTER ANALYSIS:

COMPUTEBLOCK

COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:

TRUNCATION

TRUNC VALUE: 1E-12

TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (DETRPT).

RDFT (DETRPT).

DLTVALBLK (DETRPT).

RDVALBLK (DETRPT).

DLTBLK (DETRPT1).

DLTEON.

GENFTEON (METHOD1\$ DETRPT/ DETRPT1*
 PROBABILITY/1E-12, DETRPT).
 LDBLK (DETRPT1).
 COMPUTEBLOCK(PROBABILITY, DETRPT).

EXECUTE SETS USER PROGRAM DETRPT

DLTBLK (DETRPT).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR DLTBLK

RDFT (DETRPT).

FAULTTREE\$DETRPT.
 OG\$ G1.
 IN\$G5,G4,G3,G2.
 OG\$ G9.
 IN\$DALLFFSE,DALLFFSO.
 OUT\$G7,G4,G5,G6.
 OG\$ G8.
 IN\$DALLFFCS,DALLFFBE.
 OUT\$G7,G4,G5,G13,G12.
 OG\$ G2.
 IN\$G7,G6.
 OUT\$G1.
 OG\$ G3.
 IN\$G14,G10.
 OUT\$G1.
 AG\$ G4.
 IN\$G8,DAXLFFPS,G9.
 OUT\$G1.
 AG\$ G5.
 IN\$G8,DAXLFFCS,G9.
 OUT\$G1.
 AG\$ G6.
 IN\$G9,DALLFYIO.
 OUT\$G2.
 AG\$ G7.
 IN\$G8,G9.
 OUT\$G2.
 BE\$ DALLFFBE.
 OUT\$G8.
 UE\$ DALLFFCS.
 OUT\$G8.
 UE\$ DALLFYIO.
 OUT\$G6.
 BE\$ DAWLFFOE.
 OUT\$G11.
 UE\$ DAXLFFCS.
 OUT\$G5.
 UE\$ DAWLFFOO.
 OUT\$G11.

AG\$ G14.
 IN\$DAXLFPHO,G11.
 OUT\$G3.
 UE\$ DALLFFSO.
 OUT\$G9.
 UE\$ DAXLFFPS.
 OUT\$G4.
 UE\$ DAULFTSO.
 OUT\$G12.
 OG\$ G10.
 IN\$G13,G12.
 OUT\$G3.
 OG\$ G11.
 IN\$DAWLFFOE,DAWLFFOO.
 OUT\$G14.
 AG\$ G12.
 IN\$G8,DAULFTSO.
 OUT\$G10.
 AG\$ G13.
 IN\$G8,DAULFTSS.
 OUT\$G10.
 UE\$ DALLFFSE.
 OUT\$G9.
 UE\$ DAXLFPHO.
 OUT\$G14.
 UE\$ DAULFTSS.
 OUT\$G13.

THERE ARE NO CYCLES IN DETRPT

FAULT TREE BLOCK DETRPT
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.332 SECONDS FOR RDFT

DLTVALBLK (DETRPT).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTVALBLK

RDVALBLK (DETRPT).

VALUE BLOCK\$DETRPT.
 CREATE VALUE BLOCK DETRPT
 5.0E-3 \$DALLFFBE\$
 3.0E-2 \$DALLFFCS,DAWLFFOO\$
 3.0E-3 \$DALLFFSE,DALLFYIO,DAULFTSO,DAXLFPHO\$
 1.0E-2 \$DALLFFSO,DAULFTSS,DAXLFFCS,DAXLFFPS\$
 2.7E-3 \$DAWLFFOE\$

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR RDVALBLK

DLTBLK (DETRPT1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTEQN

GENFTEQN (METHOD1\$ DETRPT/ DETRPT1* PROBABILITY/ 1E-12, DETRPT).

TOP EVENTS OF DETRPT

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEQN

LDBLK (DETRPT).

SUBINEQN (G1, G1* STOP\$ G9, G8).

TRNTRMVAL (PROBABILITY/ 1E-12, DETRPT* G1, G1*
EXCEPTNONCMP\$ G9, G8).

SUBINEQN (G1, G1).

TRNTRMVAL (PROBABILITY/ 1E-12, DETRPT* G1, G1).

FRMBLK (DETRPT1* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEQN

LDBLK (DETRPT).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR LDBLK

SUBINEQN (G1, G1* STOP\$ G9, G8).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, DETRPT* G1, G1* EXCEPTNONCMP\$ G9, G8).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 8.

TERMS GENERATED BY EXPANSION
6 TERMS CONTAIN 2 VARIABLES
2 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 8.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000000000E+00
(THE SUM OF THE TERM VALUES IS 1.036098120000E+00)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
6 TERMS CONTAIN 2 VARIABLES

TOTAL TERMS RETAINED 6.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR TRNTRMVAL
SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR SUBINEQN
TRNTRMVAL (PROBABILITY/ 1E-12, DETRPT* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 12.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 12.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999850000E-04
(THE SUM OF THE TERM VALUES IS 1.047099940000E-03)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
12 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS RETAINED 12.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR TRNTRMVAL
FRMBLK (DETRPT1* ONLY\$ G1).

EQUATION BLOCK DETRPT1
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR FRMBLK
LDBLK (DETRPT1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK
COMPUTEBLOCK (PROBABILITY, DETRPT).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, DETRPT* G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, DETRPT* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 12.

TERMS GENERATED BY EXPANSION
12 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 12.
EXPANSION TOOK 0.000 SECONDS.

*** VARIABLE OCCURRENCE TABLE ***

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
DALLFFSE	3		
DALLFFSO	3		
DALLFFCS	4		
DALLFFBE	4		
DALLFYIO	2		
DAWLFFOE	1		
DAWLFFOO	1		
DAXLFPHO	2		
DAULFTSO	2		
DAULFTSS	2		

THERE ARE 10 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

1 3.0000E-04 DALLFFCS * DAULFTSS +
2 3.0000E-04 DALLFFSO * DALLFFCS +
3 9.0000E-05 DAWLFFOO * DAXLFPHO +
4 9.0000E-05 DALLFFCS * DAULFTSO +
5 9.0000E-05 DALLFFSE * DALLFFCS +
6 5.0000E-05 DALLFFSO * DALLFFBE +
7 5.0000E-05 DALLFFBE * DAULFTSS +
8 3.0000E-05 DALLFFSO * DALLFYIO +

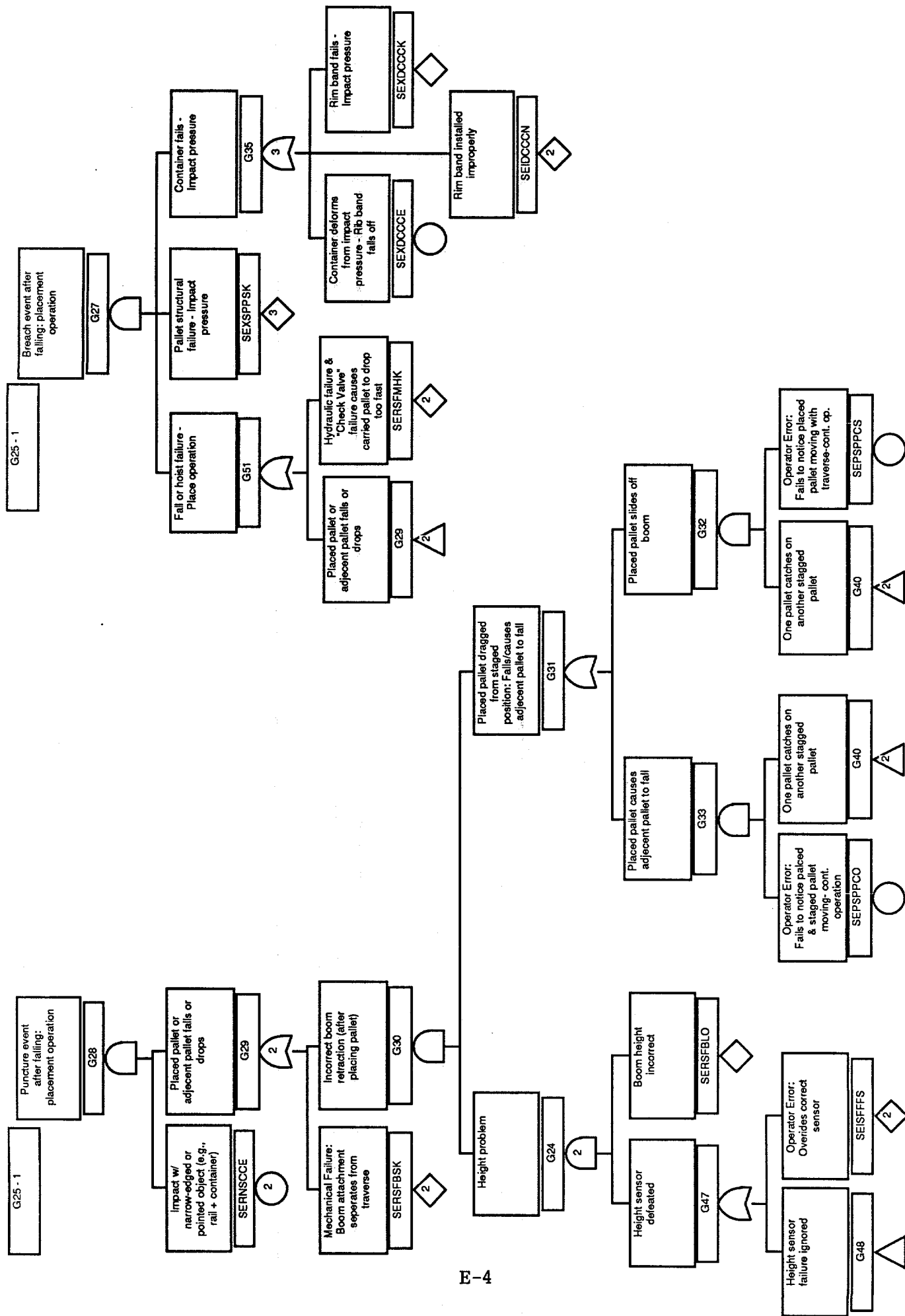
9 1.5000E-05 DALLFFBE * DAULFTSO +
10 1.5000E-05 DALLFFSE * DALLFFBE +
11 9.0000E-06 DALLFFSE * DALLFYIO +
12 8.1000E-06 DAWLFFOE * DAXLFPHO

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999850000E-04
(THE SUM OF THE TERM VALUES IS 1.047099820000E-03)

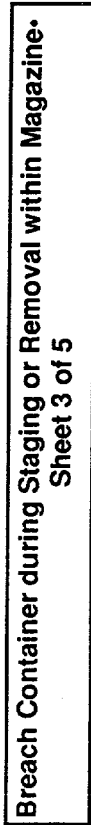
STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

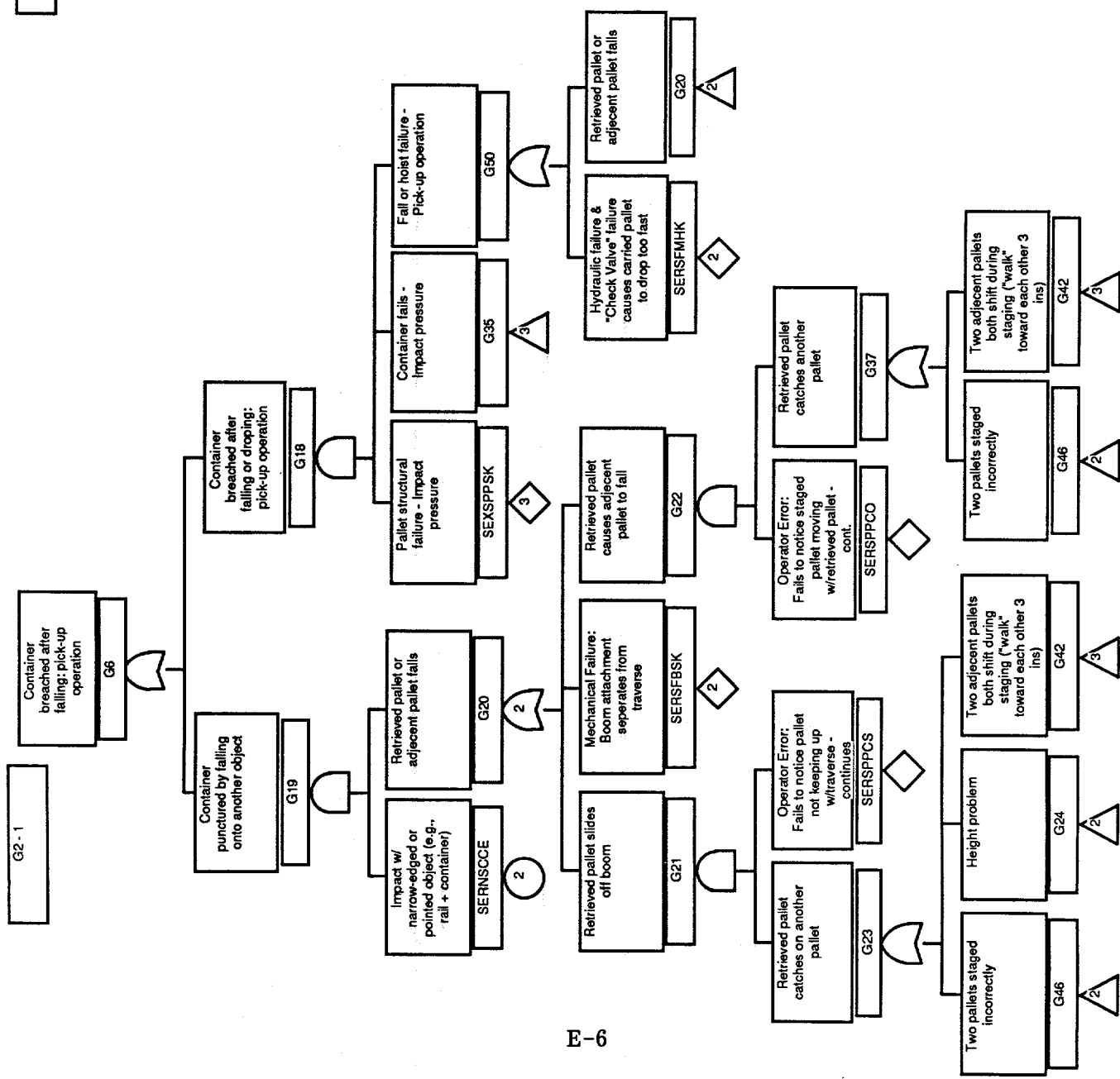
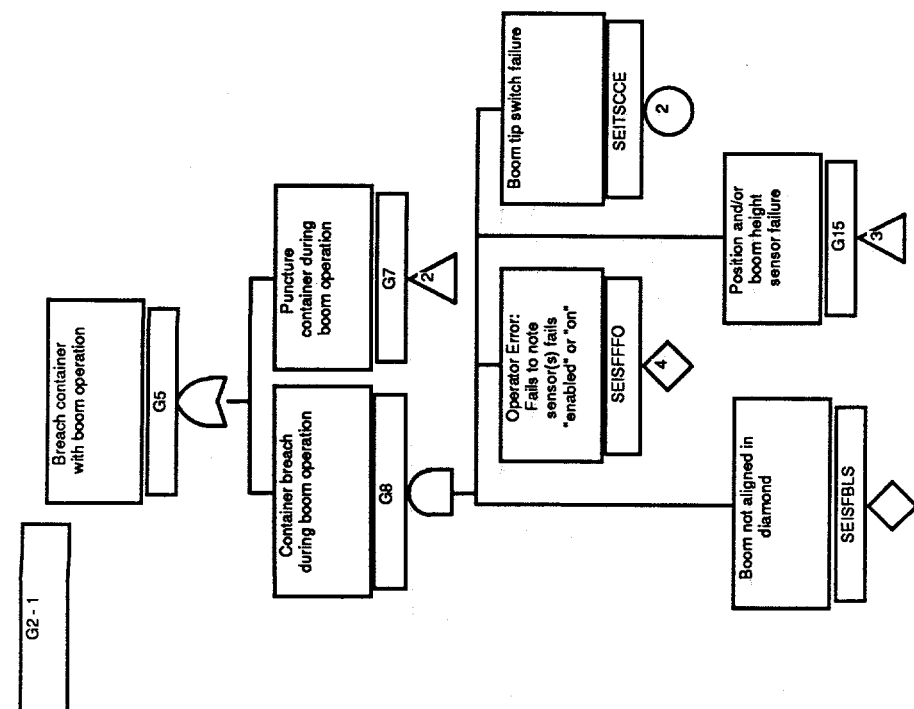
END EXECUTION OF SETS.

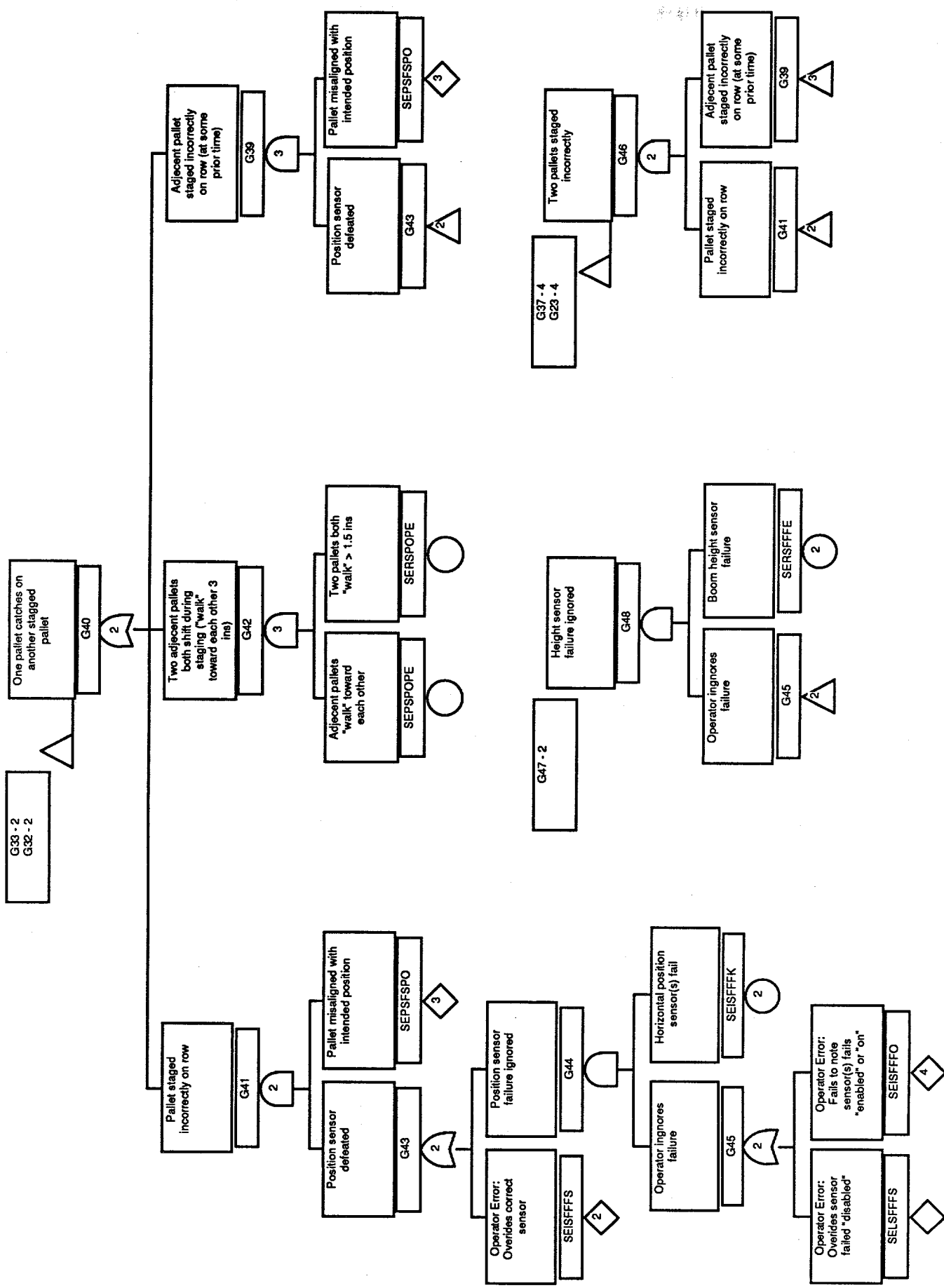
**Appendix E:
Process Fault Trees
for
Staging and Removal
Operations with Shielded Lift Truck**



Breach Container during Staging or Removal within Magazine.
Sheet 2 of 5







E-7

FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
 BLOCK FILE: C:\SIPRA\BREACHSR.BLK
 VALUE BLOCK FILE: C:\SIPRA\BREACHSR.VAL
 WRITE FILE: NUL
 EMS FILE: WINDRUN.EMS
 SCRATCH FILE: WINDRUN.SCR
 OUTPUT FILE: C:\SIPRA\BREACHSR.OUT
 BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ BREACHSR.
 COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
 FAULT TREE: BREACHSR
 LOCATED: C:\SIPRA\BR-S-R.SET

NUMBER OF VALUE BLOCKS TO READ: 1
 VALUE BLOCK: BREACHSR
 LOCATED: C:\SIPRA\BR-S-R.TXT

OUTPUT FILE: C:\SIPRA\BREACHSR.OUT

BLOCK FILE: C:\SIPRA\BREACHSR.BLK

VALUE BLOCK FILE: C:\SIPRA\BREACHSR.VAL

PROGRAM: BREACHSR

USER BLOCK: SRBREACH

DATA PROC OPTIONS:
 BEFORE ANALYSIS:
 AFTER ANALYSIS:
 COMPUTEBLOCK
 COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
 TRUNCATION
 TRUNC VALUE: 1E-12
 TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (BREACHSR).
 RDFT (BREACHSR).
 DLTVALBLK (BREACHSR).
 RDVALBLK (BREACHSR).
 DLTBLK (SRBREACH).
 DLTEON.
 GENFTEON (METHOD1\$ BREACHSR/ SRBREACH*
 PROBABILITY/1E-12, BREACHSR).
 LDBLK (SRBREACH).
 COMPUTEBLOCK(PROBABILITY, BREACHSR).

EXECUTE SETS USER PROGRAM BREACHSR

DLTBLK (BREACHSR).

RDFT (BREACHSR).

FAULTTREE\$BREACHSR.
OG\$ G1.
IN\$G34,G4,G3,G2.
OG\$ G15.
IN\$SERSFFFE,SEISFFFK.
OUT\$G7,G8,G17.
UE\$ SEISFFFO.
OUT\$G7,G8,G17,G45.
BE\$ SEITSCCE.
OUT\$G7,G8.
AG\$ G7.
IN\$G15,SEISFFFO,SEITSCCE,SEISFBLO.
OUT\$G5,G34.
UE\$ SEIDCCCN.
OUT\$G12,G35.
OG\$ G20.
IN\$SERSFBSK,G22,G21.
OUT\$G19,G50.
UE\$ SEXSPPSK.
OUT\$G18,G27,G10.
OG\$ G35.
IN\$SEXDCCE,SEXDCCK,SEIDCCCN.
OUT\$G18,G10,G27.
UE\$ SERSFMHK.
OUT\$G51,G50.
UE\$ SERSFBSK.
OUT\$G20,G29.
AG\$ G24.
IN\$G47,SERSFBLO.
OUT\$G30,G23.
OG\$ G40.
IN\$G42,G41,G39.
OUT\$G33,G32.
BE\$ SERNSCCE.
OUT\$G19,G28.
OG\$ G29.
IN\$G30,SERSFBSK.
OUT\$G28,G51.
UE\$ SEISPPSK.
OUT\$G26.
OG\$ G12.
IN\$SEIDCCCE,SEIDCCCK,SEIDCCCN.
OUT\$G26.
BE\$ SEISFFFK.
OUT\$G15,G44.
UE\$ SEPSFSPO.
OUT\$G17,G39,G41.
BE\$ SERSFFFE.
OUT\$G15,G48.
AG\$ G39.
IN\$G43,SEPSFSPO.
OUT\$G36,G46,G40.
AG\$ G42.
IN\$SEPSPOPE,SERSPOPE.
OUT\$G40,G23,G37.
OG\$ G43.
IN\$G44,SEISFFFS.
OUT\$G39,G41.
AG\$ G41.
IN\$G43,SEPSFSPO.

OUT\$G40,G46.
AG\$ G46.
IN\$G41,G39.
OUT\$G37,G23.
UE\$ SEISFFFS.
OUT\$G43,G47.
OG\$ G45.
IN\$SELSFFFS,SEISFFFO.
OUT\$G44,G48.
BE\$ SEISFBLO.
OUT\$G8,G7.
UE\$ SEXDCCCK.
OUT\$G35.
OG\$ G2.
IN\$G6,G5.
OUT\$G1.
OG\$ G3.
IN\$G10,G9.
OUT\$G1.
OG\$ G4.
IN\$G26,G25.
OUT\$G1.
OG\$ G5.
IN\$G8,G7.
OUT\$G2.
OG\$ G6.
IN\$G19,G18.
OUT\$G2.
AG\$ G8.
IN\$SEISFBLO,SEITSCCE,SEISFFFO,G15.
OUT\$G5.
UE\$ SEXSPPE.
OUT\$G9.
UE\$ SEIDCCCK.
OUT\$G12.
UE\$ SEIDCCCE.
OUT\$G12.
AG\$ G34.
IN\$SEIDCCPK,G7.
OUT\$G1.
UE\$ SEIDCCPK.
OUT\$G34.
AG\$ G18.
IN\$G50,SEXSPPSK,G35.
OUT\$G6.
AG\$ G19.
IN\$SERNSCCE,G20.
OUT\$G6.
BE\$ SEXDCCCE.
OUT\$G35.
AG\$ G21.
IN\$G23,SERSPPCS.
OUT\$G20.
AG\$ G22.
IN\$G37,SERSPPCO.
OUT\$G20.
UE\$ SERSPPCS.
OUT\$G21.
OG\$ G23.
IN\$G46,G42,G24.
OUT\$G21.
BE\$ SERSPOPE.
OUT\$G42.

UE\$ SERSFBLO.
OUT\$G24.
OG\$ G50.
IN\$SERSFMHK,G20.
OUT\$G18.
UE\$ SERSPPCO.
OUT\$G22.
AG\$ G9.
IN\$SEXGRFSE,SEXDCCCO,SEXSPPE,G11.
OUT\$G3.
AG\$ G10.
IN\$G13,SEXSPPSK,G35.
OUT\$G3.
OG\$ G11.
IN\$SEXSFEE,SEXSFEO.
OUT\$G9.
OG\$ G13.
IN\$G14,G16.
OUT\$G10.
AG\$ G32.
IN\$G40,SESPPCS.
OUT\$G31.
AG\$ G16.
IN\$SEXSFFFK,SEXSFEE,SEXSFEO.
OUT\$G13.
BE\$ SEXSFEE.
OUT\$G11.
UE\$ SEXSFEO.
OUT\$G11.
UE\$ SEXSFEO.
OUT\$G16.
BE\$ SEXSFEE.
OUT\$G16.
BE\$ SEXSFEE.
OUT\$G16.
OG\$ G14.
IN\$SEXSFBOO,SEXSFBO.
OUT\$G13.
UE\$ SEXSFBO.
OUT\$G14.
UE\$ SEXSFBO.
OUT\$G14.
OG\$ G25.
IN\$G28,G27.
OUT\$G4.
AG\$ G27.
IN\$G51,G35,SEXSPPSK.
OUT\$G25.
AG\$ G28.
IN\$G29,SENSCCE.
OUT\$G25.
AG\$ G30.
IN\$G31,G24.
OUT\$G29.
AG\$ G26.
IN\$G12,G36,SEISPPSK.
OUT\$G4.
BE\$ SEPSPPCO.
OUT\$G33.
AG\$ G33.
IN\$SEPSPPCO,G40.
OUT\$G31.
OG\$ G31.

IN\$G33,G32.
OUT\$G30.
BE\$ SEPSPPCS.
OUT\$G32.
OG\$ G36.
IN\$G38,G17,G39.
OUT\$G26.
AG\$ G17.
IN\$SEPSFSPO,G15,SEISFFFO.
OUT\$G36.
BE\$ SEPSPOPE.
OUT\$G42.
AG\$ G38.
IN\$SEPSFHUS,SEPSPPXO.
OUT\$G36.
UE\$ SEPSPPXO.
OUT\$G38.
UE\$ SEPSFHUS.
OUT\$G38.
OG\$ G47.
IN\$G48,SEISFFFS.
OUT\$G24.
OG\$ G37.
IN\$G46,G42.
OUT\$G22.
AG\$ G44.
IN\$G45,SEISFFFK.
OUT\$G43.
UE\$ SELSFFFS.
OUT\$G45.
AG\$ G48.
IN\$G45,SERSFFFE.
OUT\$G47.
OG\$ G51.
IN\$G29,SERSFMHK.
OUT\$G27.
UE\$ SEXDCCCO.
OUT\$G9.
UE\$ SEXGRFSE.
OUT\$G9.

THE FOLLOWING EVENTS ARE EQUIVALENT

1. G7
2. G8

THE FOLLOWING EVENTS ARE EQUIVALENT

1. G41
2. G39

THERE ARE NO CYCLES IN BREACHSR

FAULT TREE BLOCK BREACHSR
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 1.102 SECONDS FOR RDFT

DLTVALBLK (BREACHSR).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTVALBLK

RDVALBLK (BREACHSR).

VALUE BLOCK\$BREACHSR.
 CREATE VALUE BLOCK BREACHSR
 1.0E-2 \$SEIDCCCE,SEIRNSCCE,SEXDCCK,SEXSFEE\$
 1.0E-3 \$SEIDCCCK,SEISFBLO,SELSFFFS\$
 6.0E-3 \$SEIDCCCN\$
 4.0E-9 \$SEIDCCPK\$
 3.8E-2 \$SEISFFFK,SEISFFFE\$
 3.0E-2 \$SEISFFFO\$
 2.0E-3 \$SEISFFFS,SEPSFHUS,SEXSFFFK,SEXSFFFO\$
 1.0E-4 \$SEISPPSK\$
 4.5E-7 \$SEITSCCE\$
 3.0E-3 \$SEPSFPO,SEISFBLO,SEXSFBOO,SEXSFBO\$
 2.5E-1 \$SEPSPOPE\$
 1.0E-1 \$SEPSPPCO,SEPSPPCS,SEPSPPCO,SEPSPPCS,SEXDCCE,SEXSPPSK\$
 6.8E-4 \$SESPXO\$
 1.1E-5 \$SEISFBK\$
 7.3E-4 \$SEISFMHK\$
 2.5E-3 \$SEISPOPE\$
 2.0E-2 \$SEXSFIFE,SEXGRFSE\$
 5.0E-1 \$SEXSPPE,SEXDCCO\$

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR RDVALBLK

DLTBLK (SRBREACH).

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ BREACHSR/ SRBREACH* PROBABILITY/ 1E-12, BREACHSR).

TOP EVENTS OF BREACHSR

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (BREACHSR).
 SUBINEON (G1, G1* STOP\$ G7, G35, G39, G15, G20, G29).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1*
 EXCEPTNONCMP\$ G7, G35, G39, G15, G20, G29).
 SUBINEON (G1, G1* STOP\$ G15, G24, G42, G46, G43, G40).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1*
 EXCEPTNONCMP\$ G15, G24, G42, G46, G43,
 G40).
 SUBINEON (G1, G1* STOP\$ G42, G41, G39, G45).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1*
 EXCEPTNONCMP\$ G42, G41, G39, G45).
 SUBINEON (G1, G1* STOP\$ G43).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1*
 EXCEPTNONCMP\$ G43).
 SUBINEON (G1, G1* STOP\$ G45).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1*
 EXCEPTNONCMP\$ G45).
 SUBINEON (G1, G1).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1).
 FRMBLK (SRBREACH* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.172 SECONDS FOR GENFTEON

LDBLK (BREACHSR).

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR LDBLK

SUBINEQN (G1, G1* STOP\$ G7, G35, G39, G15, G20, G29).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1* EXCEPTNONCMP\$ G7, G35, G39, G15, G20, G29).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 23.

TERMS GENERATED BY EXPANSION
1 TERMS CONTAIN 1 VARIABLES
3 TERMS CONTAIN 2 VARIABLES
9 TERMS CONTAIN 3 VARIABLES
4 TERMS CONTAIN 4 VARIABLES
4 TERMS CONTAIN 5 VARIABLES
TOTAL TERMS GENERATED 21.

THERE WERE TERMS DELETED BECAUSE OF
TRUNCATION VALUES

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000000000E+00
(THE SUM OF THE TERM VALUES IS 1.220812680000E+00)

EXPANSION TOOK 0.059 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
1 TERMS CONTAIN 1 VARIABLES
2 TERMS CONTAIN 2 VARIABLES
8 TERMS CONTAIN 3 VARIABLES
4 TERMS CONTAIN 4 VARIABLES
4 TERMS CONTAIN 5 VARIABLES
TOTAL TERMS RETAINED 19.
SIMPLIFICATION TOOK 0.051 SECONDS.

FACTORIZATION TOOK 0.109 SECONDS.

STATEMENT EXECUTION REQUIRED 0.270 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1* STOP\$ G15, G24, G42, G46, G43, G40).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1* EXCEPTNONCMP\$ G15, G24, G42, G46, G43, G40).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 59.

TERMS GENERATED BY EXPANSION
2 TERMS CONTAIN 2 VARIABLES
20 TERMS CONTAIN 3 VARIABLES
25 TERMS CONTAIN 4 VARIABLES
12 TERMS CONTAIN 5 VARIABLES
TOTAL TERMS GENERATED 59.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000050000E-03
(THE SUM OF THE TERM VALUES IS 1.526355180000E-02)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

1 TERMS CONTAIN 2 VARIABLES

17 TERMS CONTAIN 3 VARIABLES

24 TERMS CONTAIN 4 VARIABLES

12 TERMS CONTAIN 5 VARIABLES

TOTAL TERMS RETAINED 54.

SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.332 SECONDS.

STATEMENT EXECUTION REQUIRED 0.551 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1* STOP\$ G42, G41, G39, G45).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1* EXCEPTNONCMP\$ G42, G41, G39, G45).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 105.

TERMS GENERATED BY EXPANSION

1 TERMS CONTAIN 2 VARIABLES

14 TERMS CONTAIN 3 VARIABLES

14 TERMS CONTAIN 4 VARIABLES

26 TERMS CONTAIN 5 VARIABLES

27 TERMS CONTAIN 6 VARIABLES

18 TERMS CONTAIN 7 VARIABLES

TOTAL TERMS GENERATED 100.

THERE WERE TERMS DELETED BECAUSE OF
TRUNCATION VALUES

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000050000E-03
(THE SUM OF THE TERM VALUES IS 8.785107170000E-03)

EXPANSION TOOK 0.063 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

1 TERMS CONTAIN 2 VARIABLES

14 TERMS CONTAIN 3 VARIABLES

14 TERMS CONTAIN 4 VARIABLES

26 TERMS CONTAIN 5 VARIABLES

27 TERMS CONTAIN 6 VARIABLES

18 TERMS CONTAIN 7 VARIABLES

TOTAL TERMS RETAINED 100.

SIMPLIFICATION TOOK 0.047 SECONDS.

FACTORIZATION TOOK 0.613 SECONDS.

STATEMENT EXECUTION REQUIRED 0.773 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1* STOP\$ G43).

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1* EXCEPTNONCMP\$ G43).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE

GENERATED BY EXPANSION IS 131.

TERMS GENERATED BY EXPANSION
1 TERMS CONTAIN 2 VARIABLES
12 TERMS CONTAIN 3 VARIABLES
10 TERMS CONTAIN 4 VARIABLES
26 TERMS CONTAIN 5 VARIABLES
12 TERMS CONTAIN 6 VARIABLES
20 TERMS CONTAIN 7 VARIABLES
10 TERMS CONTAIN 8 VARIABLES
TOTAL TERMS GENERATED 91.

THERE WERE TERMS DELETED BECAUSE OF
TRUNCATION VALUES

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 4.999999870000E-05
(THE SUM OF THE TERM VALUES IS 1.589873570000E-04)

EXPANSION TOOK 0.109 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
1 TERMS CONTAIN 2 VARIABLES
12 TERMS CONTAIN 3 VARIABLES
10 TERMS CONTAIN 4 VARIABLES
24 TERMS CONTAIN 5 VARIABLES
10 TERMS CONTAIN 6 VARIABLES
12 TERMS CONTAIN 7 VARIABLES
6 TERMS CONTAIN 8 VARIABLES
TOTAL TERMS RETAINED 75.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.660 SECONDS.

STATEMENT EXECUTION REQUIRED 0.930 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1* STOP\$ G45).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1* EXCEPTNONCMP\$ G45).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 97.

TERMS GENERATED BY EXPANSION
1 TERMS CONTAIN 2 VARIABLES
12 TERMS CONTAIN 3 VARIABLES
10 TERMS CONTAIN 4 VARIABLES
28 TERMS CONTAIN 5 VARIABLES
20 TERMS CONTAIN 6 VARIABLES
4 TERMS CONTAIN 7 VARIABLES
2 TERMS CONTAIN 8 VARIABLES
TOTAL TERMS GENERATED 77.

THERE WERE TERMS DELETED BECAUSE OF
TRUNCATION VALUES

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 4.999999870000E-05
(THE SUM OF THE TERM VALUES IS 1.465455570000E-04)

EXPANSION TOOK 0.109 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

1 TERMS CONTAIN 2 VARIABLES
 12 TERMS CONTAIN 3 VARIABLES
 10 TERMS CONTAIN 4 VARIABLES
 28 TERMS CONTAIN 5 VARIABLES
 20 TERMS CONTAIN 6 VARIABLES
 4 TERMS CONTAIN 7 VARIABLES
 2 TERMS CONTAIN 8 VARIABLES

TOTAL TERMS RETAINED 77.

SIMPLIFICATION TOOK 0.051 SECONDS.

FACTORIZATION TOOK 0.660 SECONDS.

STATEMENT EXECUTION REQUIRED 0.930 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHSR* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 85.

TERMS GENERATED BY EXPANSION

1 TERMS CONTAIN 2 VARIABLES
 12 TERMS CONTAIN 3 VARIABLES
 10 TERMS CONTAIN 4 VARIABLES
 30 TERMS CONTAIN 5 VARIABLES
 26 TERMS CONTAIN 6 VARIABLES
 4 TERMS CONTAIN 7 VARIABLES
 2 TERMS CONTAIN 8 VARIABLES

TOTAL TERMS GENERATED 85.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 4.999999870000E-05
 (THE SUM OF THE TERM VALUES IS 1.460683710000E-04)

EXPANSION TOOK 0.113 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

1 TERMS CONTAIN 2 VARIABLES
 12 TERMS CONTAIN 3 VARIABLES
 10 TERMS CONTAIN 4 VARIABLES
 30 TERMS CONTAIN 5 VARIABLES
 26 TERMS CONTAIN 6 VARIABLES
 4 TERMS CONTAIN 7 VARIABLES
 2 TERMS CONTAIN 8 VARIABLES

TOTAL TERMS RETAINED 85.

SIMPLIFICATION TOOK 0.047 SECONDS.

FACTORIZATION TOOK 0.551 SECONDS.

STATEMENT EXECUTION REQUIRED 0.770 SECONDS FOR TRNTRMVAL

FRMBLK (SRBREACH* ONLY\$ G1).

EQUATION BLOCK SRBREACH
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.172 SECONDS FOR FRMBLK

LDBLK (SRBREACH).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, BREACHSR).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACHSR* G1).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACHSR* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 85.

TERMS GENERATED BY EXPANSION

1 TERMS CONTAIN 2 VARIABLES

12 TERMS CONTAIN 3 VARIABLES

10 TERMS CONTAIN 4 VARIABLES

30 TERMS CONTAIN 5 VARIABLES

26 TERMS CONTAIN 6 VARIABLES

4 TERMS CONTAIN 7 VARIABLES

2 TERMS CONTAIN 8 VARIABLES

TOTAL TERMS GENERATED 85.

EXPANSION TOOK 0.059 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
SERSFFFE	14		
SEISFFFK	18		
SEISFFFO	20		
SEIDCCCN	21		
SERSFBSK	4		
SEXSPPSK	58		
SEXDCCCE	22		
SEXDCCCK	18		
SERSFMHK	3		
SERSFBLO	28		
SERNSCCE	18		
SEISPPSK	7		
SEIDCCCE	4		
SEPSFSPO	38		
SEPSPOPE	16		
SERSPOPE	16		
SEISFFFS	26		
SELSFFFS	12		
SEXSPPSE	2		
SERSPPCS	28		
SERSPPCO	16		
SEXGRFSE	2		
SEXDCCCO	2		
SEXSFFEE	1		
SEXSFFEO	1		
SEPSPPCS	8		
SEXSFFFK	3		
SEXSFFFE	3		
SEXSFFFO	3		
SEXSFBOO	3		
SEXSFBOS	3		
SEPSPPCO	8		
SEPSFHUS	1		
SEPSPPXO	1		

THERE ARE 34 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

```

1  5.0000E-05  SEXSPPE * SEXGRFSE * SEXDCCCO * SEXSFFEO +
2  3.0000E-05  SEXSPPSK * SEXDCCCE * SEXSFBOS +
3  3.0000E-05  SEXSPPSK * SEXDCCCE * SEXSFBOS +
4  1.5000E-05  SEXSPPE * SEXGRFSE * SEXDCCCO * SEXSFFEO +
5  7.3000E-06  SEXSPPSK * SEXDCCCE * SERSFMHK +
6  3.0000E-06  SEXSPPSK * SEXDCCCK * SEXSFBOS +
7  3.0000E-06  SEXSPPSK * SEXDCCCK * SEXSFBOS +
8  1.8000E-06  SEIDCCCN * SEXSPPSK * SEXSFBOS +
9  1.8000E-06  SEIDCCCN * SEXSPPSK * SEXSFBOS +
10 7.3000E-07  SEXSPPSK * SEXDCCCK * SERSFMHK +
11 6.2500E-07  SEXSPPSK * SEXDCCCE * SEPSPOPE * SERSPOPE * SERSPPCO +
12 6.2500E-07  SEXSPPSK * SEXDCCCE * SEPSPOPE * SERSPOPE * SERSPPCS +
13 6.2500E-07  SERNSCCE * SEPSPOPE * SERSPOPE * SERSPPCO +
14 6.2500E-07  SERNSCCE * SEPSPOPE * SERSPOPE * SERSPPCS +
15 4.3800E-07  SEIDCCCN * SEXSPPSK * SERSFMHK +
16 1.1000E-07  SERSFBSK * SEXSPPSK * SEXDCCCE +
17 1.1000E-07  SERSFBSK * SERNSCCE +
18 6.2500E-08  SEXSPPSK * SEXDCCCK * SEPSPOPE * SERSPOPE * SERSPPCS +
19 6.2500E-08  SEXSPPSK * SEXDCCCK * SEPSPOPE * SERSPOPE * SERSPPCO +
20 3.7500E-08  SEIDCCCN * SEXSPPSK * SEPSPOPE * SERSPOPE * SERSPPCS +
21 3.7500E-08  SEIDCCCN * SEXSPPSK * SEPSPOPE * SERSPOPE * SERSPPCO +
22 1.1000E-08  SERSFBSK * SEXSPPSK * SEXDCCCK +
23 6.6000E-09  SEIDCCCN * SERSFBSK * SEXSPPSK +
24 6.0000E-09  SEXSPPSK * SEXDCCCE * SEPSFSPO * SEISFFFS * SERSPPCO +
25 6.0000E-09  SEXSPPSK * SEXDCCCE * SEPSFSPO * SEISFFFS * SERSPPCS +
26 6.0000E-09  SEXSPPSK * SEXDCCCE * SERSFBLO * SEISFFFS * SERSPPCS +
27 6.0000E-09  SERNSCCE * SEPSFSPO * SEISFFFS * SERSPPCS +

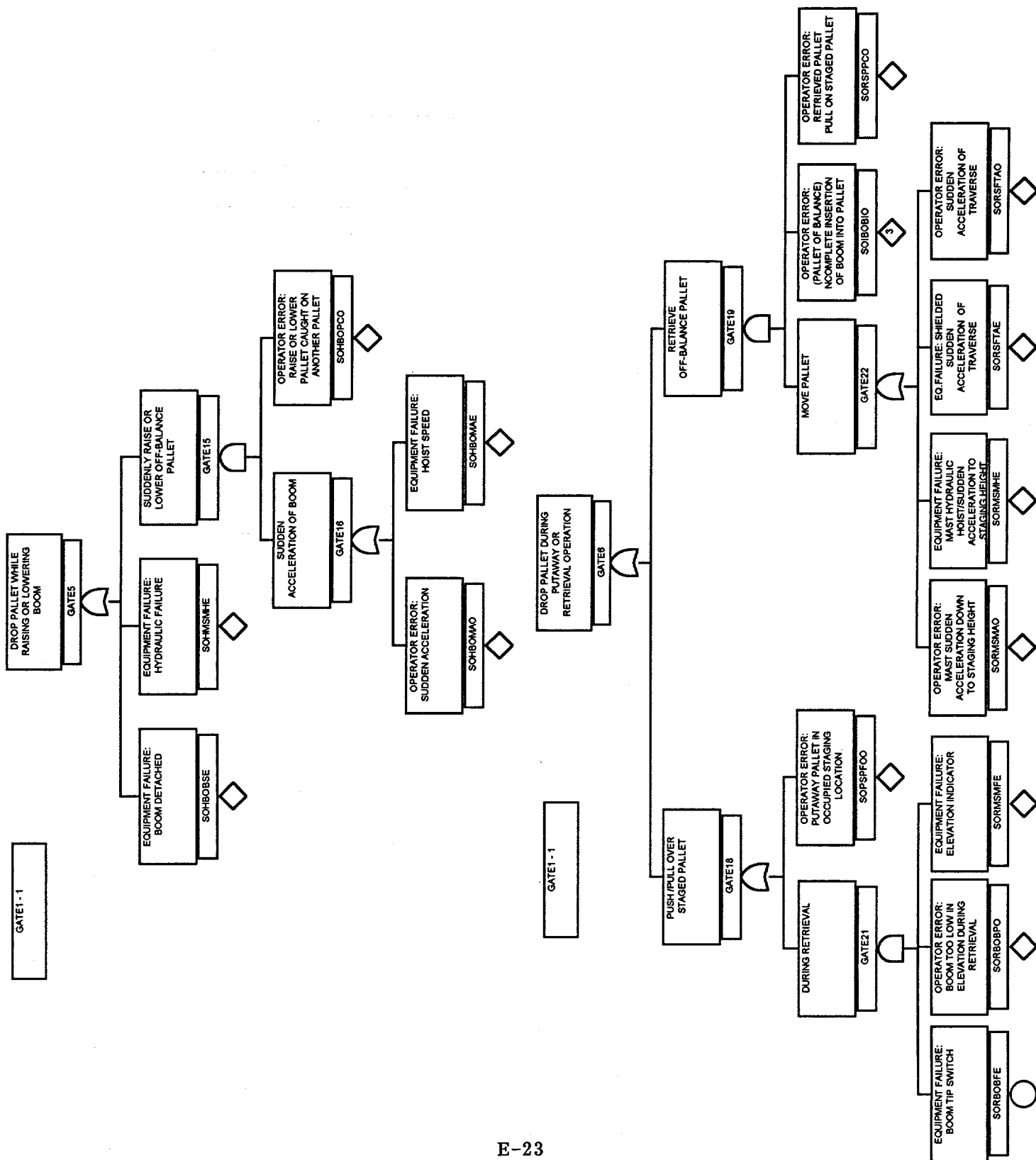
```

28 6.0000E-09 SERNSCCE * SEPSFSPO * SEISFFFS * SERSPPCO +
 29 6.0000E-09 SERSFBLO * SERNSCCE * SEISFFFS * SERSPPCS +
 30 3.4200E-09 SERSFFFE * SEISFFFO * SERSFBLO * SERNSCCE * SERSPPCS +
 31 3.4200E-09 SEISFFFK * SEISFFFO * SERNSCCE * SEPSFSPO * SERSPPCO +
 32 3.4200E-09 SEISFFFK * SEISFFFO * SERNSCCE * SEPSFSPO * SERSPPCS +
 33 3.4200E-09 SEISFFFK * SEISFFFO * SEXSPPSK * SEXDCCCE * SEPSFSPO * SERSPPCO +
 34 3.4200E-09 SEISFFFK * SEISFFFO * SEXSPPSK * SEXDCCCE * SEPSFSPO * SERSPPCS +
 35 3.4200E-09 SERSFFFE * SEISFFFO * SEXSPPSK * SEXDCCCE * SERSFBLO * SERSPPCS +
 36 8.0000E-10 SEXSPPSK * SEXDCCCE * SEXSFFFK * SEXSFFFE * SEXSFFFO +
 37 6.0000E-10 SEXSPPSK * SEXDCCCK * SEPSFSPO * SEISFFFS * SERSPPCS +
 38 6.0000E-10 SEXSPPSK * SEXDCCCK * SEPSFSPO * SEISFFFS * SERSPPCO +
 39 6.0000E-10 SEXSPPSK * SEXDCCCK * SERSFBLO * SEISFFFS * SERSPPCS +
 40 3.6000E-10 SEIDCCCN * SEXSPPSK * SEPSFSPO * SEISFFFS * SERSPPCO +
 41 3.6000E-10 SEIDCCCN * SEXSPPSK * SERSFBLO * SEISFFFS * SERSPPCS +
 42 3.6000E-10 SEIDCCCN * SEXSPPSK * SEPSFSPO * SEISFFFS * SERSPPCS +
 43 3.4200E-10 SEISFFFK * SEISFFFO * SEXSPPSK * SEXDCCCK * SEPSFSPO * SERSPPCO +
 44 3.4200E-10 SEISFFFK * SEISFFFO * SEXSPPSK * SEXDCCCK * SEPSFSPO * SERSPPCS +
 45 3.4200E-10 SERSFFFE * SEISFFFO * SEXSPPSK * SEXDCCCK * SERSFBLO * SERSPPCS +
 46 2.0520E-10 SEISFFFK * SEISFFFO * SEIDCCCN * SEXSPPSK * SEPSFSPO * SERSPPCO +
 47 2.0520E-10 SEISFFFK * SEISFFFO * SEIDCCCN * SEXSPPSK * SEPSFSPO * SERSPPCS +
 48 2.0520E-10 SERSFFFE * SEISFFFO * SEIDCCCN * SEXSPPSK * SERSFBLO * SERSPPCS +
 49 1.1400E-10 SEISFFFK * SEXSPPSK * SEXDCCCE * SEPSFSPO * SELSFFFS * SERSPPCO +
 50 1.1400E-10 SEISFFFK * SERNSCCE * SEPSFSPO * SELSFFFS * SERSPPCO +
 51 1.1400E-10 SELSFFFK * SEXSPPSK * SEXDCCCE * SEPSFSPO * SELSFFFS * SERSPPCS +
 52 1.1400E-10 SERSFFFE * SEXSPPSK * SEXDCCCE * SERSFBLO * SELSFFFS * SERSPPCS +
 53 1.1400E-10 SEISFFFK * SERNSCCE * SEPSFSPO * SELSFFFS * SERSPPCS +
 54 1.1400E-10 SERSFFFE * SERSFBLO * SERNSCCE * SELSFFFS * SERSPPCS +
 55 8.0000E-11 SEXSPPSK * SEXDCCCK * SEXSFFFK * SEXSFFFE * SEXSFFFO +
 56 4.8000E-11 SEIDCCCN * SEXSPPSK * SEXSFFFK * SEXSFFFE * SEXSFFFO +
 57 1.8000E-11 SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCS +
 58 1.8000E-11 SERSFBLO * SERNSCCE * SEPSFSPO * SEISFFFS * SEPSPPCS +

59 1.8000E-11 SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCO +
 60 1.8000E-11 SERSFBLO * SERNSCCE * SEPSFSPO * SEISFFFS * SEPSPPCO +
 61 1.1400E-11 SEISFFFK * SEXSPPSK * SEXDCCCK * SEPSFSPO * SELSFFFS * SERSPPCS +
 62 1.1400E-11 SEISFFFK * SEXSPPSK * SEXDCCCK * SEPSFSPO * SELSFFFS * SERSPPCO +
 63 1.1400E-11 SERSFFFE * SEXSPPSK * SEXDCCCK * SERSFBLO * SELSFFFS * SERSPPCS +
 64 6.8400E-12 SEISFFFK * SEIDCCCN * SEXSPPSK * SEPSFSPO * SELSFFFS * SERSPPCS +
 65 6.8400E-12 SEISFFFK * SEIDCCCN * SEXSPPSK * SEPSFSPO * SELSFFFS * SERSPPCO +
 66 6.8400E-12 SERSFFFE * SEIDCCCN * SEXSPPSK * SERSFBLO * SELSFFFS * SERSPPCS +
 67 6.0000E-12 SEISPPSK * SEIDCCCE * SEPSFSPO * SEISFFFS +
 68 3.7500E-12 SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSPOPE * SERSPOPE * SEISFFFS * SEPSPPCO +
 69 3.7500E-12 SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSPOPE * SERSPOPE * SEISFFFS * SEPSPPCS +
 70 3.7500E-12 SERSFBLO * SERNSCCE * SEPSPOPE * SERSPOPE * SEISFFFS * SEPSPPCO +
 71 3.7500E-12 SERSFBLO * SERNSCCE * SEPSPOPE * SERSPOPE * SEISFFFS * SEPSPPCS +
 72 3.6000E-12 SEIDCCCN * SEISPPSK * SEPSFSPO * SEISFFFS +
 73 3.4200E-12 SEISFFFK * SEISFFFO * SEISPPSK * SEIDCCCE * SEPSFSPO +
 74 3.4200E-12 SERSFFFE * SEISFFFO * SEISPPSK * SEIDCCCE * SEPSFSPO +
 75 2.1375E-12 SERSFFFE * SEISFFFO * SERSFBLO * SERNSCCE * SEPSPOPE * SERSPOPE * SEPSPPCO +
 76 2.1375E-12 SERSFFFE * SEISFFFO * SERSFBLO * SERNSCCE * SEPSPOPE * SERSPOPE * SEPSPPCS +
 77 2.1375E-12 SERSFFFE * SEISFFFO * SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSPOPE * SERSPOPE *
 SEPSPPCO +
 78 2.1375E-12 SERSFFFE * SEISFFFO * SEXSPPSK * SEXDCCCE * SERSFBLO * SEPSPOPE * SERSPOPE *
 SEPSPPCS +
 79 2.0520E-12 SERSFFFE * SEISFFFO * SEIDCCCN * SEISPPSK * SEPSFSPO +
 80 2.0520E-12 SEISFFFK * SEISFFFO * SEIDCCCN * SEISPPSK * SEPSFSPO +
 81 1.8000E-12 SEXSPPSK * SEXDCCCK * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCO +
 82 1.8000E-12 SEXSPPSK * SEXDCCCK * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCS +
 83 1.3600E-12 SEISPPSK * SEIDCCCE * SEPSFHUS * SEPSPPXO +
 84 1.0800E-12 SEIDCCCN * SEXSPPSK * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCO +
 85 1.0800E-12 SEIDCCCN * SEXSPPSK * SERSFBLO * SEPSFSPO * SEISFFFS * SEPSPPCS

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 4.999999870000E-05
 (THE SUM OF THE TERM VALUES IS 1.460683710000E-04)

STATEMENT EXECUTION REQUIRED 0.379 SECONDS FOR COMTRMVAL
 END EXECUTION OF SETS.



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\DROPALLE.BLK
VALUE BLOCK FILE: C:\SIPRA\DROPALLE.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\DROPALLE.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ DROPALLE.
COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: DROPALLE
LOCATED: C:\SIPRA\DROPALLE.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: DROPALLE
LOCATED: C:\SIPRA\DROPALLE.TXT

OUTPUT FILE: C:\SIPRA\DROPALLE.OUT

BLOCK FILE: C:\SIPRA\DROPALLE.BLK

VALUE BLOCK FILE: C:\SIPRA\DROPALLE.VAL

PROGRAM: DROPALLE

USER BLOCK: PALLETDR

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTEBLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (DROPALLE).
RDFT (DROPALLE).
DLTVALBLK (DROPALLE).
RDVALBLK (DROPALLE).
DLTBLK (PALLETDR).
DLTEQN.

GENFTEON (METHOD1\$ DROPALLE/ PALLETDR*
 PROBABILITY/1E-12, DROPALLE).
 LDBLK (PALLETDR).
 COMPUTEBLOCK(PROBABILITY, DROPALLE).

EXECUTE SETS USER PROGRAM DROPALLE

DLTBLK (DROPALLE).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK

RDFT (DROPALLE).

FAULTTREE\$DROPALLE.
 OG\$ GATE1.
 IN\$GATE5,GATE6,GATE3,GATE2.
 OG\$ GATE11.
 IN\$SOLSRRE,SOLSRRE.
 OUT\$GATE10,GATE12.
 UE\$ SOIBOBIO.
 OUT\$GATE8,GATE3,GATE19.
 UE\$ SOHBOPCO.
 OUT\$GATE15.
 AG\$ GATE2.
 IN\$GATE7,GATE8.
 OUT\$GATE1.
 OG\$ GATE7.
 IN\$SOLSFTAO,SOLSFTAE.
 OUT\$GATE2.
 UE\$ SOLSFTAO.
 OUT\$GATE7.
 BE\$ SOLSFTAE.
 OUT\$GATE7.
 OG\$ GATE8.
 IN\$SOLPTPMO,SOIBOBIO,GATE10.
 OUT\$GATE2.
 UE\$ SOFBOBSE.
 OUT\$GATE3.
 AG\$ GATE10.
 IN\$SOLBOPBO,GATE11.
 OUT\$GATE8.
 UE\$ SOLBOPBO.
 OUT\$GATE10.
 BE\$ SOLSRRE.
 OUT\$GATE11.
 UE\$ SOLSRRE.
 OUT\$GATE11.
 OG\$ GATE3.
 IN\$GATE12,SOFBOBHE,SOFBOBSE,SOIBOBIO.
 OUT\$GATE1.
 UE\$ SOFBOBHE.
 OUT\$GATE3.

AG\$ GATE12.
 IN\$SOFBOPBO,GATE11.
 OUT\$GATE3.
 UE\$ SOFBOPBO.
 OUT\$GATE12.
 UE\$ SOPSPFOO.
 OUT\$GATE18.
 OG\$ GATE5.
 IN\$SOHBOBSE,SOHMSMHE,GATE15.
 OUT\$GATE1.
 OG\$ GATE6.
 IN\$GATE18,GATE19.
 OUT\$GATE1.
 UE\$ SORSPPCO.
 OUT\$GATE19.
 UE\$ SOLPTPMO.
 OUT\$GATE8.
 AG\$ GATE15.
 IN\$SOHBOPCO,GATE16.
 OUT\$GATE5.
 OG\$ GATE16.
 IN\$SOHBOMAO,SOHBOMAE.
 OUT\$GATE15.
 UE\$ SOHBOMAO.
 OUT\$GATE16.
 UE\$ SOHBOMAE.
 OUT\$GATE16.
 UE\$ SOHBOBSE.
 OUT\$GATE5.
 UE\$ SOHMSMHE.
 OUT\$GATE5.
 OG\$ GATE18.
 IN\$GATE21,SOPSPFOO.
 OUT\$GATE6.
 AG\$ GATE21.
 IN\$SORBOBFE,SORBOBPO,SORMSMFE.
 OUT\$GATE18.
 BE\$ SORBOBFE.
 OUT\$GATE21.
 UE\$ SORBOBPO.
 OUT\$GATE21.
 UE\$ SORMSMFE.
 OUT\$GATE21.
 AG\$ GATE19.
 IN\$GATE22,SOIBOBIO,SORSPPCO.
 OUT\$GATE6.
 OG\$ GATE22.
 IN\$SORMSMAO,SORMSMHE,SORSFTAЕ,SORSFTAO.
 OUT\$GATE19.
 UE\$ SORMSMAO.
 OUT\$GATE22.
 UE\$ SORMSMHE.

OUT\$GATE22.
UE\$ SORSFTAЕ.
OUT\$GATE22.
UE\$ SORSFTAO.
OUT\$GATE22.

THERE ARE NO CYCLES IN DROPALLE

FAULT TREE BLOCK DROPALLE
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.438 SECONDS FOR RDFT

DLTVALBLK (DROPALLE).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR DLTVALBLK

RDVALBLK (DROPALLE).

VALUE BLOCK\$DROPALLE.
CREATE VALUE BLOCK DROPALLE
1.0E-2 \$SOLSFTAO,SOHBOMAO,SORSFTAO\$
1.0E-3 \$SORSPPCO,SORMSMAO\$
3.0E-3 \$SOIBOBIO,SOFBOPBO,SOLBOPBO,SOHBOPCO,SORBOBPO,SOPSPFOO,
SOLSFTAЕ,SORSFTAЕ\$
7.3E-4 \$SOFBOBHE,SOHMSMHE\$
2.0E-4 \$SOFBOBSE,SOHB0BSE\$
3.0E-2 \$SOLPTPMO\$
1.6E-6 \$SOLSRRJE\$
3.5E-4 \$SOLSRRRE\$
2.7E-2 \$SOHBOMAE,SORMSMHE\$
3.5E-7 \$SORBOBFE\$
3.8E-2 \$SORMSMFE\$

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR RDVALBLK

DLTBLK (PALLETDR).

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ DROPALLE/ PALLETDR* PROBABILITY/ 1E-12, DROPALLE).

TOP EVENTS OF DROPALLE

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (DROPALLE).
SUBINEON (GATE1, GATE1* STOP\$ GATE11).
TRNTRMVAL (PROBABILITY/ 1E-12, DROPALLE* GATE1,
GATE1* EXCEPTNONCMP\$ GATE11).
SUBINEON (GATE1, GATE1).
TRNTRMVAL (PROBABILITY/ 1E-12, DROPALLE* GATE1,
GATE1).
FRMBLK (PALLETDR* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR GENFTEON

LDBLK (DROPALLE).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR LDBLK

SUBINEON (GATE1, GATE1* STOP\$ GATE11).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, DROPALLE* GATE1, GATE1* EXCEPTNONCMP\$
GATE11).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 20.

TERMS GENERATED BY EXPANSION
6 TERMS CONTAIN 1 VARIABLES
7 TERMS CONTAIN 2 VARIABLES
7 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 20.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
(THE SUM OF THE TERM VALUES IS 1.143912410000E-02)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.059 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
6 TERMS CONTAIN 1 VARIABLES
5 TERMS CONTAIN 2 VARIABLES
3 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 14.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL

SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, DROPALLE* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 17.

TERMS GENERATED BY EXPANSION
6 TERMS CONTAIN 1 VARIABLES
6 TERMS CONTAIN 2 VARIABLES
5 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 17.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
(THE SUM OF THE TERM VALUES IS 8.362067860000E-03)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
6 TERMS CONTAIN 1 VARIABLES
6 TERMS CONTAIN 2 VARIABLES
5 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 17.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR TRNTRMVAL

FRMBLK (PALLETDR* ONLY\$ GATE1).

EQUATION BLOCK PALLETDR
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR FRMBLK

LDBLK (PALLETDR).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, DROPALLE).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, DROPALLE* GATE1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, DROPALLE* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 17.

TERMS GENERATED BY EXPANSION

6 TERMS CONTAIN 1 VARIABLES

6 TERMS CONTAIN 2 VARIABLES

5 TERMS CONTAIN 3 VARIABLES

TOTAL TERMS GENERATED 17.

EXPANSION TOOK 0.000 SECONDS.

* * * * VARIABLE OCCURRENCE TABLE * * * *

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
SOLSRRJE	3		
SOLSRRRE	3		
SOIBOBIO	1		
SOHBOPCO	2		
SOLSFTAO	3		
SOLSFTAE	3		
SOLPTPMO	2		
SOFBOBSE	1		
SOLBOPBO	4		
SOFBOBHE	1		
SOFBOPBO	2		
SOPSPFOO	1		
SOHBOBSE	1		
SOHMSMHE	1		
SOHBOMAO	1		
SOHBOMAE	1		
SORBOBFE	1		
SORBOBPO	1		
SORMSMFE	1		

THERE ARE 19 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

GATE1 =

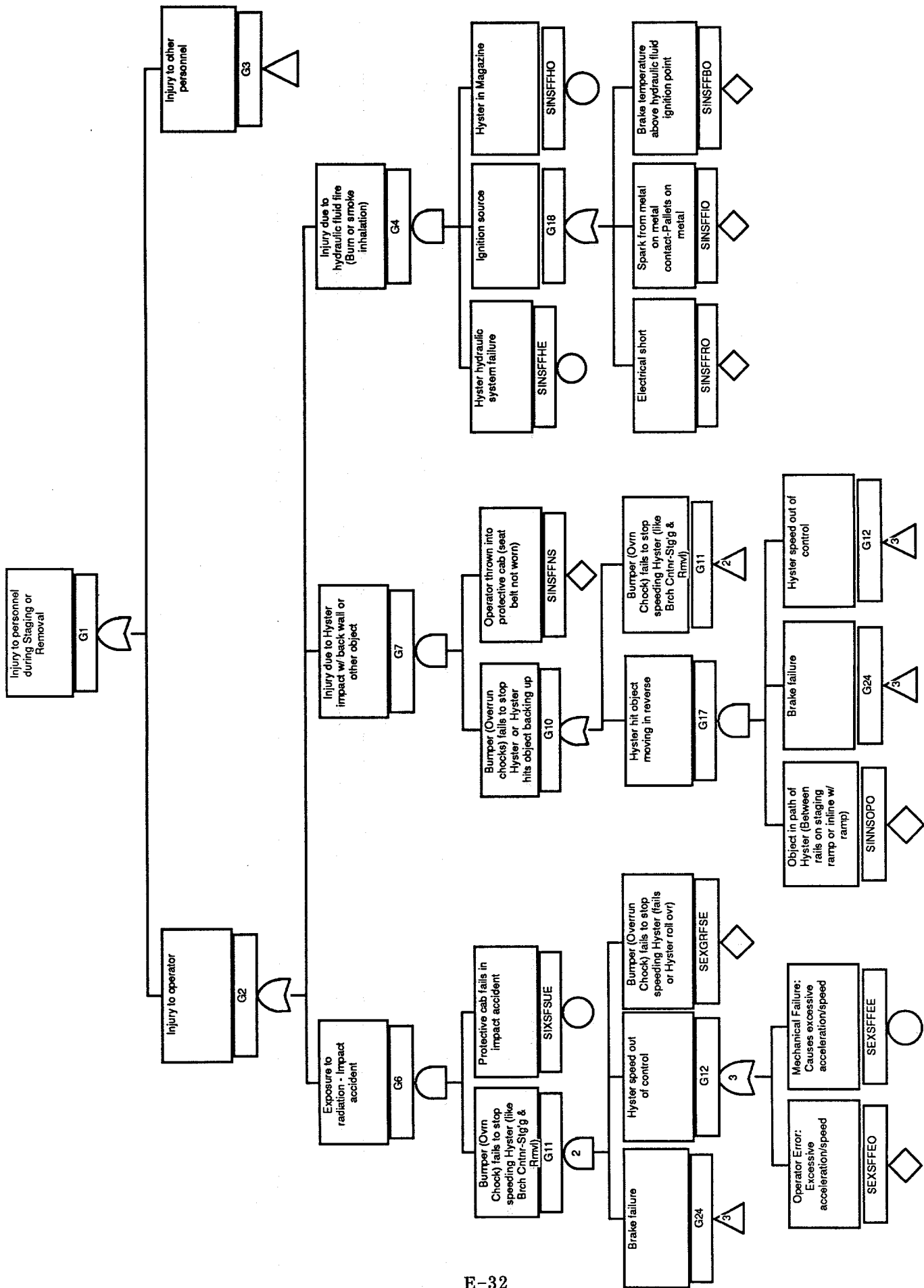
1 3.0000E-03 SOPSPFOO +
2 3.0000E-03 SOIBOBIO +
3 7.3000E-04 SOHMSMHE +

4 7.3000E-04 SOFBOBHE +
 5 3.0000E-04 SOLSFTAO * SOLPTPMO +
 6 2.0000E-04 SOHBOBSE +
 7 2.0000E-04 SOFBOBSE +
 8 9.0000E-05 SOLSFTAE * SOLPTPMO +
 9 8.1000E-05 SOHBOPCO * SOHBOMAE +
 10 3.0000E-05 SOHBOPCO * SOHBOMAO +
 11 1.0500E-06 SOLSRRRE * SOFBOPBO +
 12 1.0500E-08 SOLSRRRE * SOLSFTAO * SOLBOPBO +
 13 4.8000E-09 SOLSRRJE * SOFBOPBO +
 14 3.1500E-09 SOLSRRRE * SOLSFTAE * SOLBOPBO +
 15 4.8000E-11 SOLSRRJE * SOLSFTAO * SOLBOPBO +
 16 3.9900E-11 SORBOBFE * SORBOBPO * SORMSMFE +
 17 1.4400E-11 SOLSRRJE * SOLSFTAE * SOLBOPBO

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
 (THE SUM OF THE TERM VALUES IS 8.362067860000E-03)

STATEMENT EXECUTION REQUIRED 0.172 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
 BLOCK FILE: C:\SIPRA\SRINJ.BLK
 VALUE BLOCK FILE: C:\SIPRA\SRINJ.VAL
 WRITE FILE: NUL
 EMS FILE: WINDRUN.EMS
 SCRATCH FILE: WINDRUN.SCR
 OUTPUT FILE: C:\SIPRA\SRINJ.OUT
 BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ SRINJ.
 COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
 FAULT TREE: SRINJ
 LOCATED: C:\SIPRA\SRINJ.SET

NUMBER OF VALUE BLOCKS TO READ: 1
 VALUE BLOCK: SRINJ
 LOCATED: C:\SIPRA\SRINJ.TXT

OUTPUT FILE: C:\SIPRA\SRINJ.OUT

BLOCK FILE: C:\SIPRA\SRINJ.BLK

VALUE BLOCK FILE: C:\SIPRA\SRINJ.VAL

PROGRAM: SRINJ

USER BLOCK: INJURYSR

DATA PROC OPTIONS:
 BEFORE ANALYSIS:
 AFTER ANALYSIS:
 COMPUTEBLOCK
 COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
 TRUNCATION
 TRUNC VALUE: 1E-12
 TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (SRINJ).
 RDFT (SRINJ).
 DLTVALBLK (SRINJ).
 RDVALBLK (SRINJ).
 DLTBLK (INJURYSR).
 DLTEON.

GENFTEON (METHOD1\$ SRINJ/ INJURYSR*
 PROBABILITY/1E-12, SRINJ).
 LDBLK (INJURYSR).
 COMPUTEBLOCK(PROBABILITY, SRINJ).

EXECUTE SETS USER PROGRAM SRINJ

DLTBLK (SRINJ).
 STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR DLTBLK

RDFT (SRINJ).

FAULTTREE\$SRINJ.
 OG\$ G1.
 IN\$G2,G3.
 AG\$ G11.
 IN\$G24,SEXGRFSE,G12.
 OUT\$G10,G6.
 OG\$ G24.
 IN\$SIXSFFBE,SIXSFFBO.
 OUT\$G17,G25,G11.
 OG\$ G12.
 IN\$SEXSFFEO,SEXSFFEE.
 OUT\$G11,G25,G17.
 OG\$ G3.
 IN\$SINSROPS,G21,G20,G19.
 OUT\$G1.
 UE\$ SINSFFIO.
 OUT\$G18.
 OG\$ G2.
 IN\$G7,G6,G4.
 OUT\$G1.
 AG\$ G4.
 IN\$SINSFFHO,G18,SINSFFHE.
 OUT\$G2.
 AG\$ G6.
 IN\$G11,SIXSFSUE.
 OUT\$G2.
 AG\$ G7.
 IN\$SINSFFNS,G10.
 OUT\$G2.
 AG\$ G19.
 IN\$SIXSFHUO,SIXSFOPP,G25.
 OUT\$G3.
 AG\$ G20.
 IN\$TOLPTT\$SO,SINPTHUP,TOLPTTSE.
 OUT\$G3.
 AG\$ G21.
 IN\$SINNSHUO,SINNSHUP,SINNSNPS.
 OUT\$G3.
 UE\$ SINSROPS.
 OUT\$G3.
 BE\$ SINSFFHE.
 OUT\$G4.
 UE\$ SINSFFRO.
 OUT\$G18.
 UE\$ SEXGRFSE.
 OUT\$G11.
 UE\$ SINSFFNS.
 OUT\$G7.
 UE\$ SIXSFOPP.
 OUT\$G19.
 OG\$ G10.
 IN\$G17,G11.
 OUT\$G7.
 OG\$ G18.
 IN\$SINSFFBO,SINSFFRO,SINSFFIO.
 OUT\$G4.
 UE\$ TOLPTT\$SO.
 OUT\$G20.
 AG\$ G17.
 IN\$G12,G24,SINNSOPO.

OUT\$G10.
 UE\$ SIXSFFBO.
 OUT\$G24.
 BE\$ SIXSFFBE.
 OUT\$G24.
 BE\$ SEXSFFEE.
 OUT\$G12.
 UE\$ SEXSFFEO.
 OUT\$G12.
 UE\$ SINSFFBO.
 OUT\$G18.
 BE\$ SINSFFHO.
 OUT\$G4.
 UE\$ SINNSOPO.
 OUT\$G17.
 BE\$ SIXSFSUE.
 OUT\$G6.
 UE\$ SINNSNPS.
 OUT\$G21.
 UE\$ SINNSHUP.
 OUT\$G21.
 UE\$ SINNSHUO.
 OUT\$G21.
 BE\$ TOLPTTSE.
 OUT\$G20.
 UE\$ SINPTHUP.
 OUT\$G20.
 UE\$ SIXSFHUO.
 OUT\$G19.
 OG\$ G25.
 IN\$G12,G24,SIXSFHUS,SIXSFFVE.
 OUT\$G19.
 UE\$ SIXSFFVE.
 OUT\$G25.
 UE\$ SIXSFHUS.
 OUT\$G25.

THERE ARE NO CYCLES IN SRINJ

FAULT TREE BLOCK SRINJ
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.438 SECONDS FOR RDFT

DLTVALBLK (SRINJ).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTVALBLK

RDVALBLK (SRINJ).

VALUE BLOCK\$SRINJ.
 CREATE VALUE BLOCK SRINJ
 2.0E-1 \$SEXGRFSE\$
 3.0E-3 \$SEXSFFEE,TOLPTT\$
 1.0E-2 \$SEXSFFEO,SINNSHUO,SIXSFFBO,SIXSFOPP\$
 1.0E-3 \$SINNSHUP,SINSFFBO\$
 2.0E-3 \$SINNSNPS\$
 3.0E-2 \$SINNSOPO,SINPTHUP,SINSFFNS,SIXSFHUS\$
 2.7E-2 \$SINSFFHE\$
 5.0E-1 \$SINSFFHO\$
 1.7E-4 \$SINSFFIO\$
 4.0E-3 \$SINSFFRO\$
 5.0E-3 \$SIXSFFBE\$

3.8E-2 \$SIXSFFVE\$
 1.0E-1 \$SIXSFHUO\$
 5.0E-2 \$SIXSFSUE\$
 5.0E-4 \$TOLPTTSE\$
 1.0E-5 \$SINSROPS\$

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR RDVALBLK

DLTBLK (INJURYSR).

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEQN

GENFTEQN (METHOD1\$ SRINJ/ INJURYSR* PROBABILITY/ 1E-12, SRINJ).

TOP EVENTS OF SRINJ

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEQN

LDBLK (SRINJ).
 SUBINEQN (G1, G1* STOP\$ G11, G24, G12).
 TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1*
 EXCEPTNONCMP\$ G11, G24, G12).
 SUBINEQN (G1, G1* STOP\$ G24, G12).
 TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1*
 EXCEPTNONCMP\$ G24, G12).
 SUBINEQN (G1, G1).
 TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1).
 FRMBLK (INJURYSR* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR GENFTEQN

LDBLK (SRINJ).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

SUBINEQN (G1, G1* STOP\$ G11, G24, G12).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1* EXCEPTNONCMP\$ G11, G24,
 G12).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 13.

TERMS GENERATED BY EXPANSION

1 TERMS CONTAIN 1 VARIABLES
 2 TERMS CONTAIN 2 VARIABLES
 9 TERMS CONTAIN 3 VARIABLES
 1 TERMS CONTAIN 4 VARIABLES

TOTAL TERMS GENERATED 13.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 5.000000070000E-02

(THE SUM OF THE TERM VALUES IS 8.304786680000E-02)

EXPANSION TOOK 0.051 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

1 TERMS CONTAIN 1 VARIABLES
 2 TERMS CONTAIN 2 VARIABLES
 9 TERMS CONTAIN 3 VARIABLES
 1 TERMS CONTAIN 4 VARIABLES

TOTAL TERMS RETAINED 13.

SIMPLIFICATION TOOK 0.000 SECONDS.
 FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1* STOP\$ G24, G12).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1* EXCEPTNONCMP\$ G24, G12).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 13.

TERMS GENERATED BY EXPANSION
 1 TERMS CONTAIN 1 VARIABLES
 9 TERMS CONTAIN 3 VARIABLES
 3 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS GENERATED 13.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000070000E-02
 (THE SUM OF THE TERM VALUES IS 1.904786010000E-02)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
 1 TERMS CONTAIN 1 VARIABLES
 9 TERMS CONTAIN 3 VARIABLES
 3 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS RETAINED 13.
 SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL

SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, SRINJ* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 24.

TERMS GENERATED BY EXPANSION
 1 TERMS CONTAIN 1 VARIABLES
 11 TERMS CONTAIN 3 VARIABLES
 12 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS GENERATED 24.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 5.400000370000E-05
 (THE SUM OF THE TERM VALUES IS 1.791555260000E-04)

EXPANSION TOOK 0.059 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
 1 TERMS CONTAIN 1 VARIABLES
 11 TERMS CONTAIN 3 VARIABLES
 12 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS RETAINED 24.
 SIMPLIFICATION TOOK 0.000 SECONDS.
 FACTORIZATION TOOK 0.000 SECONDS.
 STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR TRNTRMVAL

FRMBLK (INJURYSR* ONLY\$ G1).

EQUATION BLOCK INJURYSR
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.102 SECONDS FOR FRMBLK

LDBLK (INJURYSR).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, SRINJ).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, SRINJ* G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, SRINJ* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 24.

TERMS GENERATED BY EXPANSION
1 TERMS CONTAIN 1 VARIABLES
11 TERMS CONTAIN 3 VARIABLES
12 TERMS CONTAIN 4 VARIABLES

TOTAL TERMS GENERATED 24.
EXPANSION TOOK 0.000 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
SEXGRFSE	8		
SIXSFFBE	7		
SIXSFFBO	7		
SEXSFFEO	7		
SEXSFFEE	7		
SINSROPS	1		
SINSFFIO	1		
SINSFFHO	3		
SINSFFHE	3		
SIXSFSUE	4		
SINSFFNS	8		
SIXSFHUO	6		
SIXSFOPP	6		
TOLPTTSO	1		
SINPTHUP	1		
TOLPTTSE	1		
SINNSHUO	1		
SINNSHUP	1		
SINNSNPS	1		
SINSFFRO	1		
SINSFFBO	1		
SINNSOPO	4		
SIXSFHUS	1		
SIXSFFVE	1		

THERE ARE 24 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

```

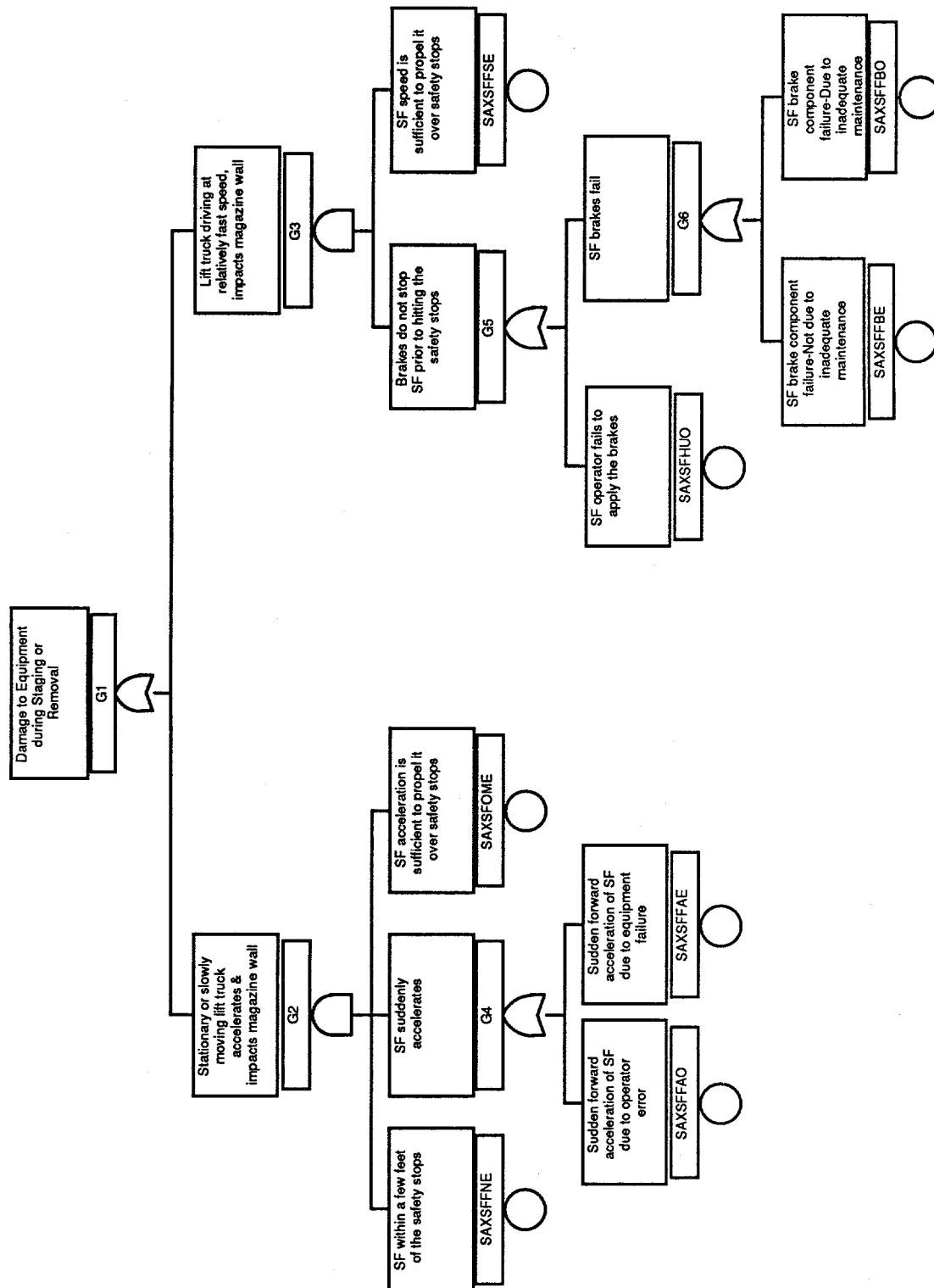
1  5.4000E-05  SINSFFHO * SINSFFHE * SINSFFRO +
2  3.8000E-05  SIXSFHUO * SIXSFOPP * SIXSFFVE +
3  3.0000E-05  SIXSFHUO * SIXSFOPP * SIXSFHUS +
4  1.3500E-05  SINSFFHO * SINSFFHE * SINSFFBO +
5  1.0000E-05  SEXSFFEO * SIXSFHUO * SIXSFOPP +
6  1.0000E-05  SIXSFFBO * SIXSFHUO * SIXSFOPP +
7  1.0000E-05  SINSROPS +
8  5.0000E-06  SIXSFFBE * SIXSFHUO * SIXSFOPP +
9  3.0000E-06  SEXSFFEE * SIXSFHUO * SIXSFOPP +
10 2.2950E-06  SINSFFIO * SINSFFHO * SINSFFHE +
11 1.0000E-06  SEXGRFSE * SIXSFFBO * SEXSFFEO * SIXSFSUE +
12 6.0000E-07  SEXGRFSE * SIXSFFBO * SEXSFFEO * SINSFFNS +
13 5.0000E-07  SEXGRFSE * SIXSFFBE * SEXSFFEO * SIXSFSUE +
14 3.0000E-07  SEXGRFSE * SIXSFFBE * SEXSFFEO * SINSFFNS +
15 3.0000E-07  SEXGRFSE * SIXSFFBO * SEXSFFEE * SIXSFSUE +
16 1.8000E-07  SEXGRFSE * SIXSFFBO * SEXSFFEE * SINSFFNS +
17 1.5000E-07  SEXGRFSE * SIXSFFBE * SEXSFFEE * SIXSFSUE +
18 9.0000E-08  SEXGRFSE * SIXSFFBE * SEXSFFEE * SINSFFNS +
19 9.0000E-08  SIXSFFBO * SEXSFFEO * SINSFFNS * SINNSOPO +
20 4.5000E-08  TOLPTTSE * SINPTTHUP * TOLPTTSE +
21 4.5000E-08  SIXSFFBE * SEXSFFEO * SINSFFNS * SINNSOPO +
22 2.7000E-08  SIXSFFBO * SEXSFFEE * SINSFFNS * SINNSOPO +
23 2.0000E-08  SINNSHUO * SINNSHUP * SINNSNPS +
24 1.3500E-08  SIXSFFBE * SEXSFFEE * SINSFFNS * SINNSOPO

```

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 5.400000370000E-05

(THE SUM OF THE TERM VALUES IS 1.791555410000E-04)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL
END EXECUTION OF SETS.



Damage to Equipment During Staging or Removal

<u>Basic Event</u>	<u>Prob.</u>
--------------------	--------------

SAXSFFNE	= 1E-1
SAXSFFAO	= 1E-2
SAXSFFAE	= 3E-3
SAXSFOME	= 5E-1
SAXSFHUO	= 3E-3
SAXSFFBE	= 5E-3
SAXSFFBO	= 3E-3
SAXSFFSE	= 5E-1

Cut Sets and Probabilities

$$\text{SAXSFFNE} \times \text{SAXSFFAO} \times \text{SAXSFOME} = 5\text{E-4}$$

$$\text{SAXSFFNE} \times \text{SAXSFFAE} \times \text{SAXSFOME} = 1.5\text{E-4}$$

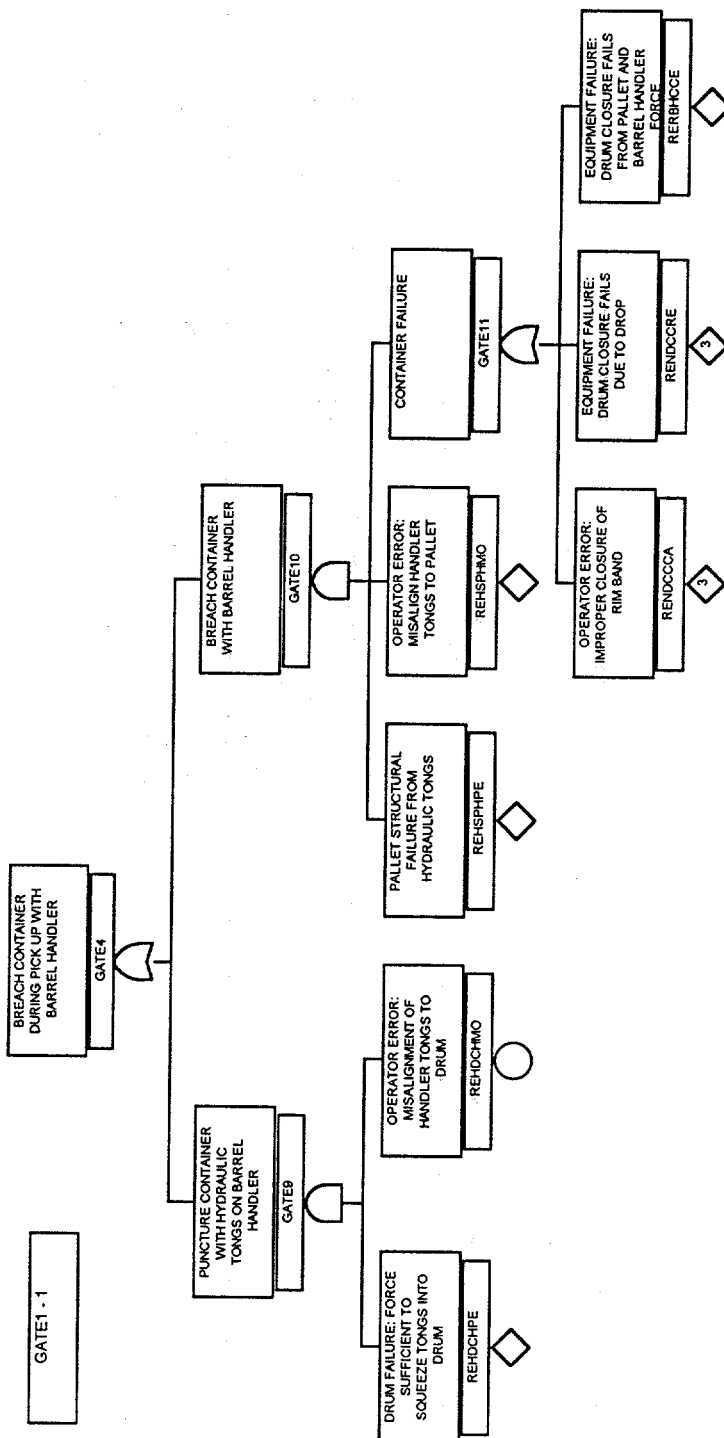
$$\text{SAXSFHUO} \times \text{SAXSFFSE} = 1.5\text{E-3}$$

$$\text{SAXSFFBE} \times \text{SAXSFFSE} = 2.5\text{E-3}$$

$$\text{SAXSFFBO} \times \text{SAXSFFSE} = 1.5\text{E-3}$$

Appendix F:
Process Fault Trees
for
Recovery Operations





FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\BREACHRE.BLK
VALUE BLOCK FILE: C:\SIPRA\BREACHRE.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\BREACHRE.OUT
BEGIN EXECUTION OF SETS.
READ SETS USER PROGRAM.

PROGRAM\$ BREACHRE.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: BREACHRE
LOCATED: C:\SIPRA\BREACHRE.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: BREACHRE
LOCATED: C:\SIPRA\BREACHRE.TXT

OUTPUT FILE: C:\SIPRA\BREACHRE.OUT

BLOCK FILE: C:\SIPRA\BREACHRE.BLK

VALUE BLOCK FILE: C:\SIPRA\BREACHRE.VAL

PROGRAM: BREACHRE

USER BLOCK: REBREACH

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTEBLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (BREACHRE).
RDFT (BREACHRE).
DLTVALBLK (BREACHRE).
RDVALBLK (BREACHRE).
DLTBLK (REBREACH).
DLTEQN.

GENFTEQN (METHOD1\$ BREACHRE/ REBREACH*
 PROBABILITY/1E-12, BREACHRE).
 LDBLK (REBREACH).
 COMPUTEBLOCK(PROBABILITY, BREACHRE).
 EXECUTE SETS USER PROGRAM BREACHRE

DLTBLK (BREACHRE).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR DLTBLK

RDFT (BREACHRE).

FAULTTREE\$BREACHRE.
 OG\$ GATE1.
 IN\$GATE2,GATE3,GATE4.
 UE\$ RENDCCCA.
 OUT\$GATE5,GATE11,GATE8.
 UE\$ RENDCCRE.
 OUT\$GATE5,GATE11,GATE8.
 AG\$ GATE2.
 IN\$REPSFPCK,REHCCPSE,GATE5.
 OUT\$GATE1.
 UE\$ REPSFPCK.
 OUT\$GATE2.
 BE\$ REHCCPSE.
 OUT\$GATE2.
 OG\$ GATE5.
 IN\$RENDCCRE,RENDCCCA.
 OUT\$GATE2.
 AG\$ GATE3.
 IN\$RERHFPSE,RERSFPTO,RERSPOPO,GATE8.
 OUT\$GATE1.
 UE\$ RERHFPSE.
 OUT\$GATE3.
 UE\$ RERSFPTO.
 OUT\$GATE3.
 UE\$ RERSPOPO.
 OUT\$GATE3.
 OG\$ GATE8.
 IN\$RERHFCCE,RENDCCCA,RENDCCRE.
 OUT\$GATE3.
 UE\$ RERHFCCE.
 OUT\$GATE8.
 OG\$ GATE4.
 IN\$GATE9,GATE10.
 OUT\$GATE1.
 AG\$ GATE9.
 IN\$REHDCHPE,REHDCHMO.
 OUT\$GATE4.
 UE\$ REHDCHPE.
 OUT\$GATE9.
 BE\$ REHDCHMO.

OUT\$GATE9.
 AG\$ GATE10.
 IN\$REHSPHPE,REHSPHMO,GATE11.
 OUT\$GATE4.
 UE\$ REHSPHPE.
 OUT\$GATE10.
 UE\$ REHSPHMO.
 OUT\$GATE10.
 OG\$ GATE11.
 IN\$RENDCCCA,RENDCCRE,RERBHCCE.
 OUT\$GATE10.
 UE\$ RERBHCCE.
 OUT\$GATE11.

THERE ARE NO CYCLES IN BREACHRE

FAULT TREE BLOCK BREACHRE
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.219 SECONDS FOR RDFT

DLTVALBLK (BREACHRE).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR DLTVALBLK

RDVALBLK (BREACHRE).

VALUE BLOCK\$BREACHRE.
 CREATE VALUE BLOCK BREACHRE
 1.0E-2 \$RENDCCRE,REHCCPSE\$
 6.0E-3 \$RENDCCCA\$
 1.0E-3 \$REPSFPCK,RERHFPSE,RERBHCCE\$
 2.0E-3 \$RERSFPTO\$
 1.0E-1 \$RERSPOPOS\$
 5.0E-3 \$RERHFCCE\$
 3.0E-1 \$REHDCHPE\$
 3.0E-3 \$REHDCHMO,REHSPHMO\$
 3.0E-2 \$REHSPHPE\$

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR RDVALBLK

DLTBLK (REBREACH).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEQN

GENFTEQN (METHOD1\$ BREACHRE/ REBREACH* PROBABILITY/ 1E-12, BREACHRE).

TOP EVENTS OF BREACHRE

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (BREACHRE).
 SUBINEQN (GATE1, GATE1).
 TRNTRMVAL (PROBABILITY/ 1E-12, BREACHRE* GATE1,
 GATE1).
 FRMBLK (REBREACH* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEON

LDBLK (BREACHRE).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

SUBINEQN (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, BREACHRE* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 9.

TERMS GENERATED BY EXPANSION
 1 TERMS CONTAIN 2 VARIABLES
 5 TERMS CONTAIN 3 VARIABLES
 3 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS GENERATED 9.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 9.000000430000E-04
 (THE SUM OF THE TERM VALUES IS 9.016942350000E-04)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
 IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
 EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.063 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
 1 TERMS CONTAIN 2 VARIABLES
 5 TERMS CONTAIN 3 VARIABLES
 3 TERMS CONTAIN 4 VARIABLES
 TOTAL TERMS RETAINED 9.
 SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR TRNTRMVAL

FRMBLK (REBREACH* ONLY\$ GATE1).

EQUATION BLOCK REBREACH
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR FRMBLK

LDBLK (REBREACH).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, BREACHRE).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACHRE* GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, BREACHRE* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 9.

TERMS GENERATED BY EXPANSION

1 TERMS CONTAIN 2 VARIABLES

5 TERMS CONTAIN 3 VARIABLES

3 TERMS CONTAIN 4 VARIABLES

TOTAL TERMS GENERATED 9.

EXPANSION TOOK 0.000 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
RENDCCCA	3		
RENDCCRE	3		
REPSFPCK	2		
REHCCPSE	2		
RERHFPSE	3		
RERSFPTO	3		
RERSPOPO	3		
RERHFCCE	1		
REHDCHPE	1		
REHDCHMO	1		
REHSPHPE	3		
REHSPHMO	3		
RERBHCCE	1		

THERE ARE 13 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

GATE1 =

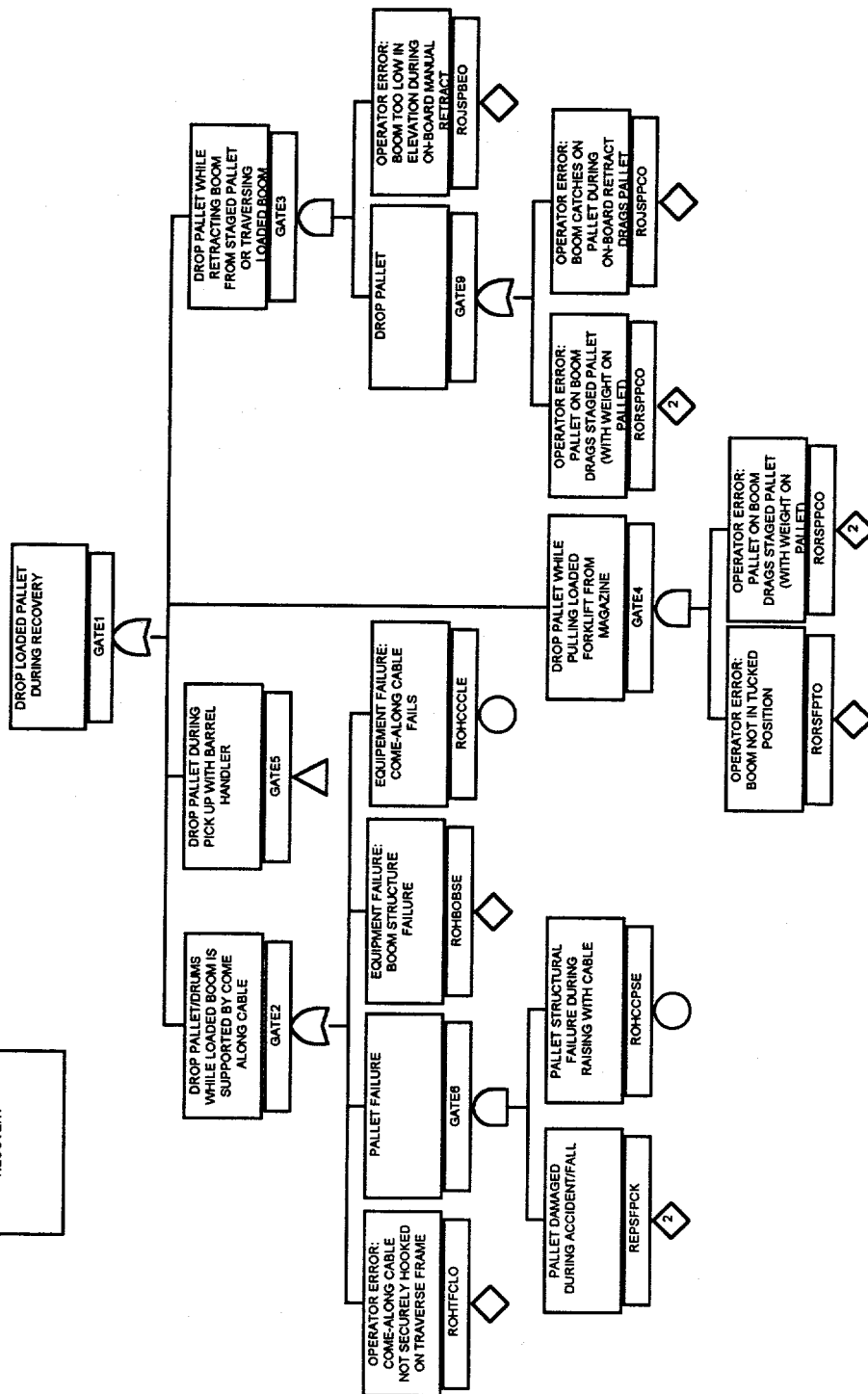
1 9.0000E-04 REHDCHPE * REHDCHMO +
2 9.0000E-07 RENDCCRE * REHSPHPE * REHSPHMO +
3 5.4000E-07 RENDCCCA * REHSPHPE * REHSPHMO +
4 1.0000E-07 RENDCCRE * REPSFPCK * REHCCPSE +
5 9.0000E-08 REHSPHPE * REHSPHMO * RERBHCCE +
6 6.0000E-08 RENDCCCA * REPSFPCK * REHCCPSE +
7 2.0000E-09 RENDCCRE * RERHFPSE * RERSFPTO * RERSPOPO +
8 1.2000E-09 RENDCCCA * RERHFPSE * RERSFPTO * RERSPOPO +
9 1.0000E-09 RERHFPSE * RERSFPTO * RERSPOPO * RERHFCCE

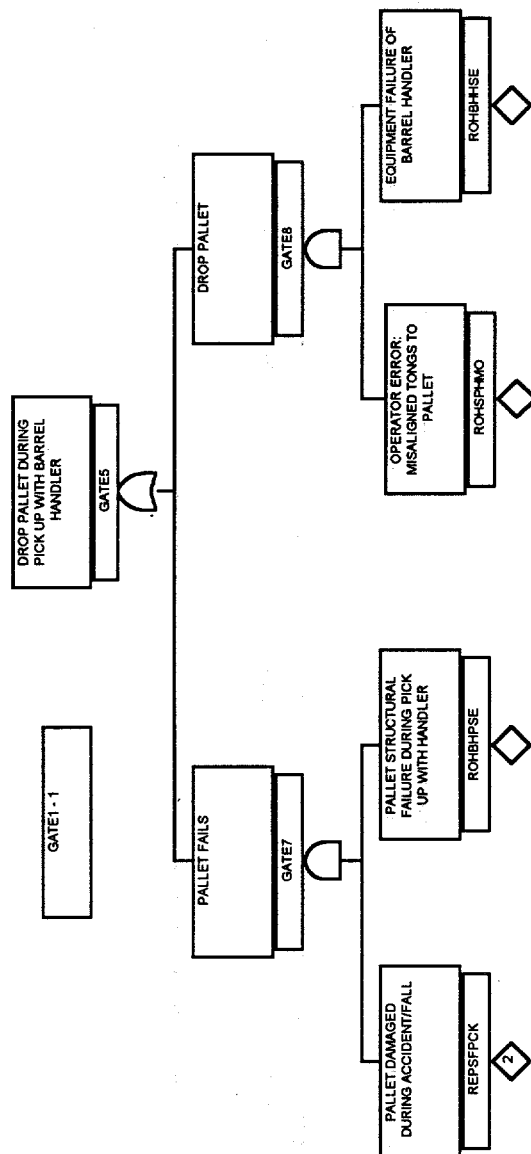
THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 9.000000430000E-04
(THE SUM OF THE TERM VALUES IS 9.016942350000E-04)

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

STAGE RIGHT PROJECT
 PANTEX
 C:\SI\PRADROP\ALRE.TRE
 DROP PALLET DURING
 RECOVERY





FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\DROPALRE.BLK
VALUE BLOCK FILE: C:\SIPRA\DROPPALRE.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\DROPALRE.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ DROPALRE.
COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: DROPALRE
LOCATED: C:\SIPRA\DROPALRE.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: DROPALRE
LOCATED: C:\SIPRA\DROPALRE.TXT

OUTPUT FILE: C:\SIPRA\DROPALRE.OUT

BLOCK FILE: C:\SIPRA\DROPALRE.BLK

VALUE BLOCK FILE: C:\SIPRA\DROPPALRE.VAL

PROGRAM: DROPALRE

USER BLOCK: DROPAREC

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTEBLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (DROPALRE).
RDFT (DROPALRE).
DLTVALBLK (DROPALRE).
RDVALBLK (DROPALRE).
DLTBLK (DROPAREC).
DLTEON.

GENFTEON (METHOD1\$ DROPALRE/ DROPAREC*
 PROBABILITY/1E-12, DROPALRE).
 LDBLK (DROPAREC).
 COMPUTEBLOCK(PROBABILITY, DROPALRE).

EXECUTE SETS USER PROGRAM DROPALRE

DLTBLK (DROPALRE).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTBLK

RDFT (DROPALRE).

FAULTTREE\$DROPALRE.
 OG\$ GATE1.
 IN\$GATE2,GATE4,GATE5,GATE3.
 UE\$ REPSFPCK
 OUT\$GATE6,GATE7.
 UE\$ RORSPPCO.
 OUT\$GATE9,GATE4.
 OG\$ GATE2.
 IN\$GATE6,ROHTFCLO,ROHBOBSE,ROHCCCLE.
 OUT\$GATE1.
 AG\$ GATE6.
 IN\$REPSFPCK,ROHCCPSE.
 OUT\$GATE2.
 BE\$ ROHCCPSE.
 OUT\$GATE6.
 UE\$ ROHTFCLO.
 OUT\$GATE2.
 UE\$ ROHBOBSE.
 OUT\$GATE2.
 BE\$ ROHCCCLE.
 OUT\$GATE2.
 AG\$ GATE3.
 IN\$ROJSPBEO,GATE9.
 OUT\$GATE1.
 UE\$ ROJSPBEO.
 OUT\$GATE3.
 OG\$ GATE9.
 IN\$RORSPPCO,ROJSPPCO.
 OUT\$GATE3.
 UE\$ ROJSPPCO.
 OUT\$GATE9.
 AG\$ GATE4.
 IN\$RORSFPTO,RORSPPCO.
 OUT\$GATE1.
 UE\$ RORSFPTO.
 OUT\$GATE4.
 OG\$ GATE5.
 IN\$GATE7,GATE8.
 OUT\$GATE1.

AG\$ GATE7.
IN\$REPSFPCK,ROHBHPSE.
OUT\$GATE5.
UE\$ ROHBHPSE.
OUT\$GATE7.
AG\$ GATE8.
IN\$ROHSPHMO,ROHBHHSE.
OUT\$GATE5.
UE\$ ROHSPHMO.
OUT\$GATE8.
UE\$ ROHBHHSE.
OUT\$GATE8.

THERE ARE NO CYCLES IN DROPALRE

FAULT TREE BLOCK DROPALRE
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.281 SECONDS FOR RDFT

DLTVALBLK (DROPALRE).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR DLTVALBLK

RDVALBLK (DROPALRE).

VALUE BLOCK\$DROPALRE.
CREATE VALUE BLOCK DROPALRE
1.0E-2 \$ROHTFCLO,ROHCCPSE,RORSPPCO,ROJSPPCO\$
1.0E-3 \$REPSFPCK\$
2.0E-3 \$RORSFPTO\$
2.0E-4 \$ROHBOBSE\$
1.3E-4 \$ROHCCCLE\$
3.0E-3 \$ROJSPBEO,ROHSPHMO\$
3.0E-2 \$ROHBHPSE\$
2.7E-2 \$ROHBHHSE\$

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR RDVALBLK

DLTBLK (DROPAREC).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ DROPALRE/ DROPAREC* PROBABILITY/ 1E-12, DROPALRE).

TOP EVENTS OF DROPALRE

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (DROPALRE).
SUBINEON (GATE1, GATE1).
TRNTRMVAL (PROBABILITY/ 1E-12, DROPALRE* GATE1,
GATE1).
FRMBLK (DROPAREC* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEON

LDBLK (DROPALRE).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, DROPALRE* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 9.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 1 VARIABLES
6 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 9.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 9.999999780000E-03
(THE SUM OF THE TERM VALUES IS 1.053099800000E-02)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.051 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
3 TERMS CONTAIN 1 VARIABLES
6 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS RETAINED 9.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL

FRMBLK (DROPAREC* ONLY\$ GATE1).

EQUATION BLOCK DROPAREC
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR FRMBLK

LDBLK (DROPAREC).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

COMTEBLOCK (PROBABILITY, DROPALRE).

SETS USER PROGRAM SEGMENT PRODUCED BY COMTEBLOCK

COMTRMVAL (PROBABILITY, DROPALRE* GATE1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMTEBLOCK

COMTRMVAL (PROBABILITY, DROPALRE* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 9.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 1 VARIABLES
6 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 9.
EXPANSION TOOK 0.000 SECONDS.

* * * * VARIABLE OCCURRENCE TABLE * * * *

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
REPSFPCK	2		
RORSPPCO	2		
ROHTFCLO	1		
ROHBOBSE	1		
ROHCCCLE	1		
ROHCCPSE	1		
ROJSPBEO	2		
ROJSPPCO	1		
RORSFPTO	1		
ROHBHPSE	1		
ROHSPHMO	1		
ROHBHHSE	1		

THERE ARE 12 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

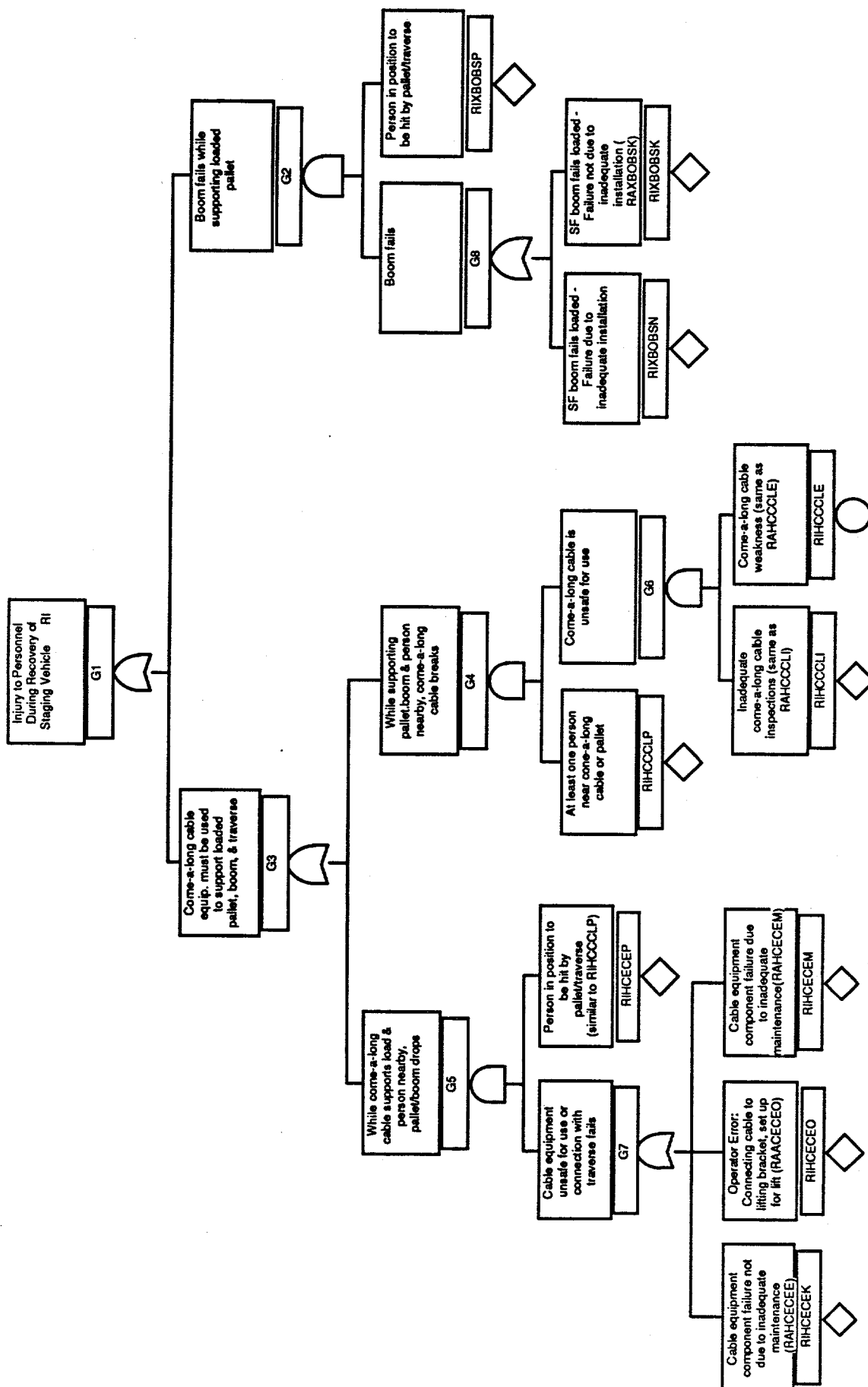
GATE1 =

1 1.0000E-02 ROHTFCLO +
2 2.0000E-04 ROHBOBSE +
3 1.3000E-04 ROHCCCLE +
4 8.1000E-05 ROHSPHMO * ROHBHHSE +
5 3.0000E-05 REPSFPCK * ROHBHPSE +
6 3.0000E-05 ROJSPBEO * ROJSPPCO +
7 3.0000E-05 RORSPPCO * ROJSPBEO +
8 2.0000E-05 RORSPPCO * RORSFPTO +
9 1.0000E-05 REPSFPCK * ROHCCPSE

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 9.999999780000E-03
(THE SUM OF THE TERM VALUES IS 1.053099890000E-02)

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.



Injury to Personnel During Recovery of Staging Vehicle

FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
 BLOCK FILE: C:\SIPRA\RECINJ.BLK
 VALUE BLOCK FILE: C:\SIPRA\RECINJ.VAL
 WRITE FILE: NUL
 EMS FILE: WINDRUN.EMS
 SCRATCH FILE: WINDRUN.SCR
 OUTPUT FILE: C:\SIPRA\RECINJ.OUT
 BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ RECINJ.
 COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
 FAULT TREE: RECINJ
 LOCATED: C:\SIPRA\RECINJ.SET

NUMBER OF VALUE BLOCKS TO READ: 1
 VALUE BLOCK: RECINJ
 LOCATED: C:\SIPRA\RECINJ.TXT

OUTPUT FILE: C:\SIPRA\RECINJ.OUT

BLOCK FILE: C:\SIPRA\RECINJ.BLK

VALUE BLOCK FILE: C:\SIPRA\RECINJ.VAL

PROGRAM: RECINJ

USER BLOCK: INJREC

DATA PROC OPTIONS:
 BEFORE ANALYSIS:
 AFTER ANALYSIS:
 COMPUTEBLOCK
 COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
 TRUNCATION
 TRUNC VALUE: 1E-12
 TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (RECINJ).
 RDFT (RECINJ).
 DLTVALBLK (RECINJ).
 RDVALBLK (RECINJ).
 DLTBLK (INJREC).
 DLTEON.

GENFTEON (METHOD1\$ RECINJ/ INJREC*
 PROBABILITY/1E-12, RECINJ).
 LDBLK (INJREC).
 COMPUTEBLOCK(PROBABILITY, RECINJ).

EXECUTE SETS USER PROGRAM RECINJ

DLTBLK (RECINJ).
 STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR DLTBLK

RDFT (RECINJ).

FAULTTREE\$RECINJ.
 OG\$ G1.
 IN\$G3,G2.
 AG\$ G2.
 IN\$RIXBOBSP,G8.
 OUT\$G1.
 OG\$ G3.
 IN\$G5,G4.
 OUT\$G1.
 AG\$ G4.
 IN\$RIHCCCLP,G6.
 OUT\$G3.
 AG\$ G5.
 IN\$RIHCECEP,G7.
 OUT\$G3.
 UE\$ RIHCCCLI.
 OUT\$G6.
 BE\$ RIHCCCLE.
 OUT\$G6.
 UE\$ RIHCECEM.
 OUT\$G7.
 UE\$ RIHCECEK.
 OUT\$G7.
 OG\$ G7.
 IN\$RIHCECEO,RIHCECEM,RIHCECEK.
 OUT\$G5.
 UE\$ RIHCECEO.
 OUT\$G7.
 AG\$ G6.
 IN\$RIHCCCLI,RIHCCCLE.
 OUT\$G4.
 UE\$ RIHCCCLP.
 OUT\$G4.
 OG\$ G8.
 IN\$RIXBOBSN,RIXBOBSK.
 OUT\$G2.
 UE\$ RIHCECEP.
 OUT\$G5.
 UE\$ RIXBOBSP.
 OUT\$G2.
 UE\$ RIXBOBSN.
 OUT\$G8.
 UE\$ RIXBOBSK.
 OUT\$G8.

THERE ARE NO CYCLES IN RECINJ

FAULT TREE BLOCK RECINJ
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR RDFT

DLTVALBLK (RECINJ).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTVALBLK

RDVALBLK (RECINJ).

VALUE BLOCK\$RECINJ.
 CREATE VALUE BLOCK RECINJ
 3.0E-3 \$RIXBOBSN,RIHCECEM\$
 5.0E-2 \$RIHCCCLP\$
 1.0E-1 \$RIHCCCLI\$
 1.0E-2 \$RIHCECEO\$
 2.0E-4 \$RIXBOBSK\$
 3.4E-4 \$RIHCECEK\$
 1.3E-5 \$RIHCCCLE\$
 1.0E-3 \$RIHCECEP,RIXBOBSP\$

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR RDVALBLK

DLTBLK (INJREC).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTEQN

GENFTEQN (METHOD1\$ RECINJ/ INJREC* PROBABILITY/ 1E-12, RECINJ).

TOP EVENTS OF RECINJ

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEQN

LDBLK (RECINJ).

SUBINEQN (G1, G1).
 TRNTRMVAL (PROBABILITY/ 1E-12, RECINJ* G1, G1).
 FRMBLK (INJREC* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR GENFTEQN

LDBLK (RECINJ).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, RECINJ* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION
 5 TERMS CONTAIN 2 VARIABLES
 1 TERMS CONTAIN 3 VARIABLES
 TOTAL TERMS GENERATED 6.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000070000E-05
 (THE SUM OF THE TERM VALUES IS 1.660499950000E-05)

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
 5 TERMS CONTAIN 2 VARIABLES
 1 TERMS CONTAIN 3 VARIABLES
 TOTAL TERMS RETAINED 6.
 SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR TRNTRMVAL

FRMBLK (INJREC* ONLY\$ G1).

EQUATION BLOCK INJREC
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR FRMBLK

LDBLK (INJREC).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, RECINJ).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RECINJ* G1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RECINJ* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION
 5 TERMS CONTAIN 2 VARIABLES
 1 TERMS CONTAIN 3 VARIABLES
 TOTAL TERMS GENERATED 6.
 EXPANSION TOOK 0.063 SECONDS.

**** VARIABLE OCCURRENCE TABLE ****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
RIXBOBSP	2		
RIHCCCLP	1		
RIHCECEP	3		
RIHCCCLI	1		
RIHCCCLE	1		
RIHCECEM	1		
RIHCECEK	1		
RIHCECEO	1		
RIXBOBSN	1		
RIXBOBSK	1		

THERE ARE 10 DIFFERENT VARIABLES IN THE
 EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

- 1 1.0000E-05 RIHCECEP * RIHCECEO +
- 2 3.0000E-06 RIXBOBSP * RIXBOBSN +
- 3 3.0000E-06 RIHCECEP * RIHCECEM +
- 4 3.4000E-07 RIHCECEP * RIHCECEK +
- 5 2.0000E-07 RIXBOBSP * RIXBOBSK +
- 6 6.5000E-08 RIHCCCLP * RIHCCCLI * RIHCCCLE

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.000000070000E-05
(THE SUM OF THE TERM VALUES IS 1.660500130000E-05)

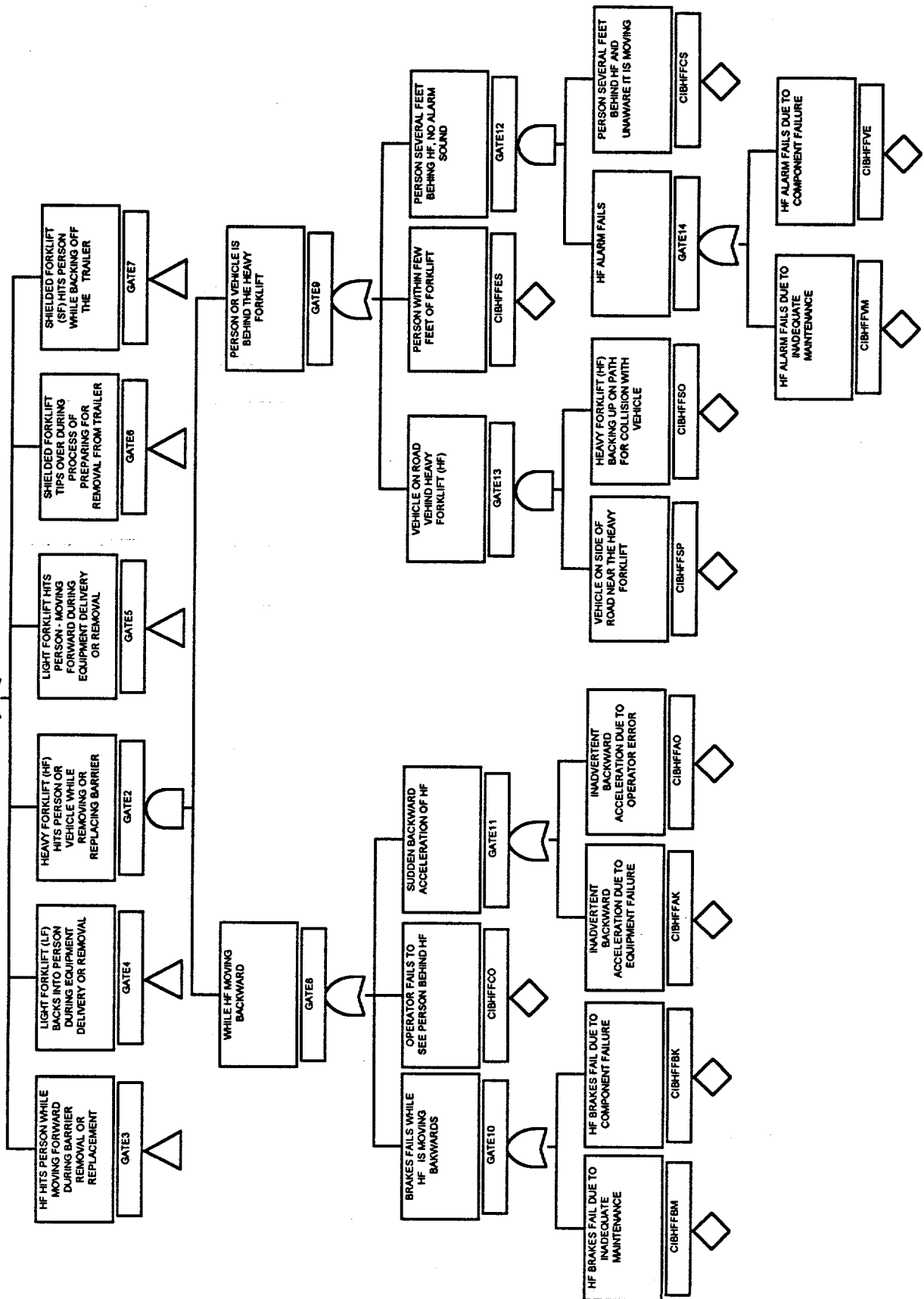
STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

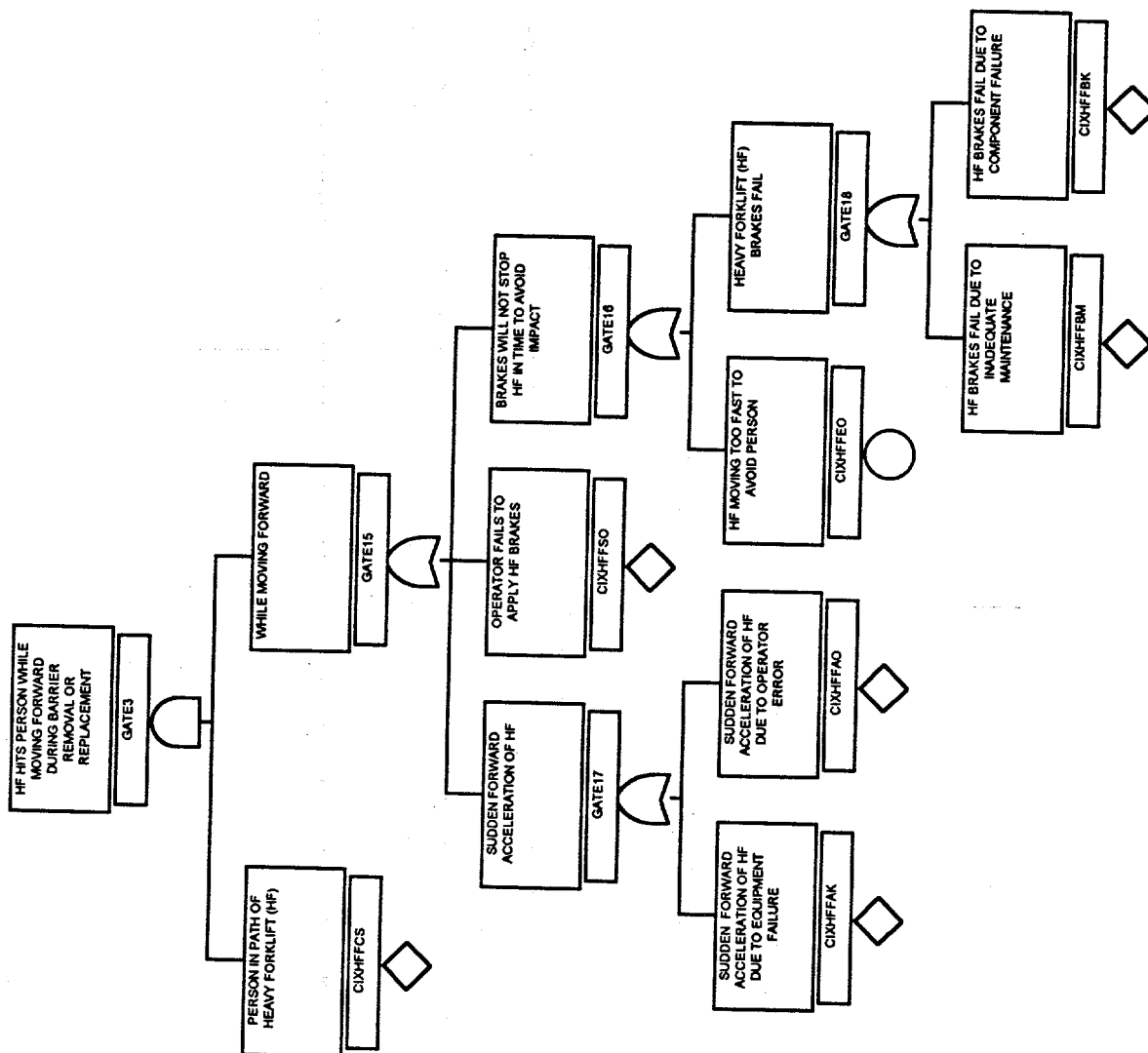
Appendix G:
Process Fault Trees
for
Setup and Close

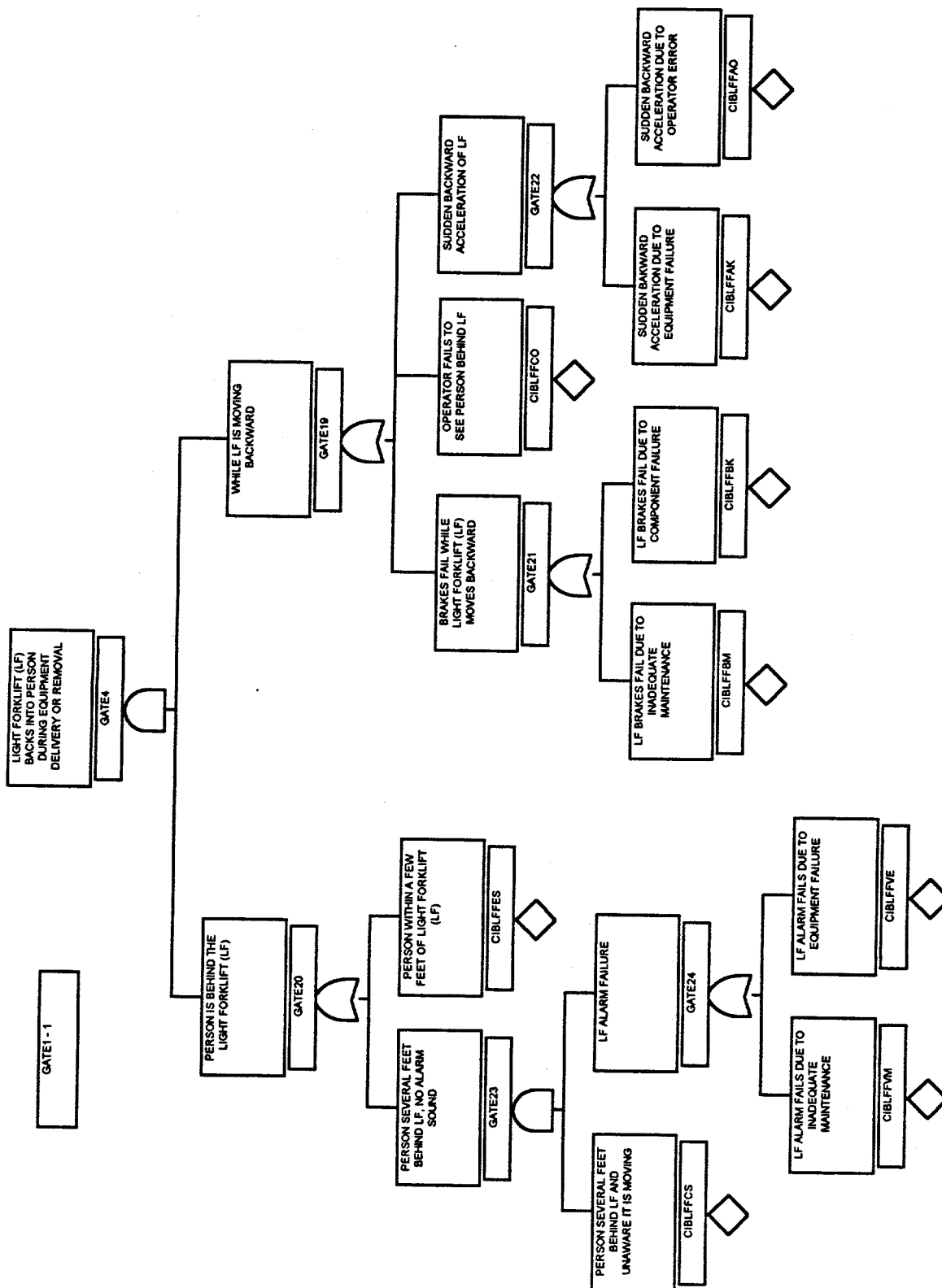
STAGE RIGHT PROJECT
 "PANTEX"
 C:\SPRAIN\INJURY\TREE
 INJURY TO PERSONNEL
 DURING
 SETUP\CLOSE-CI

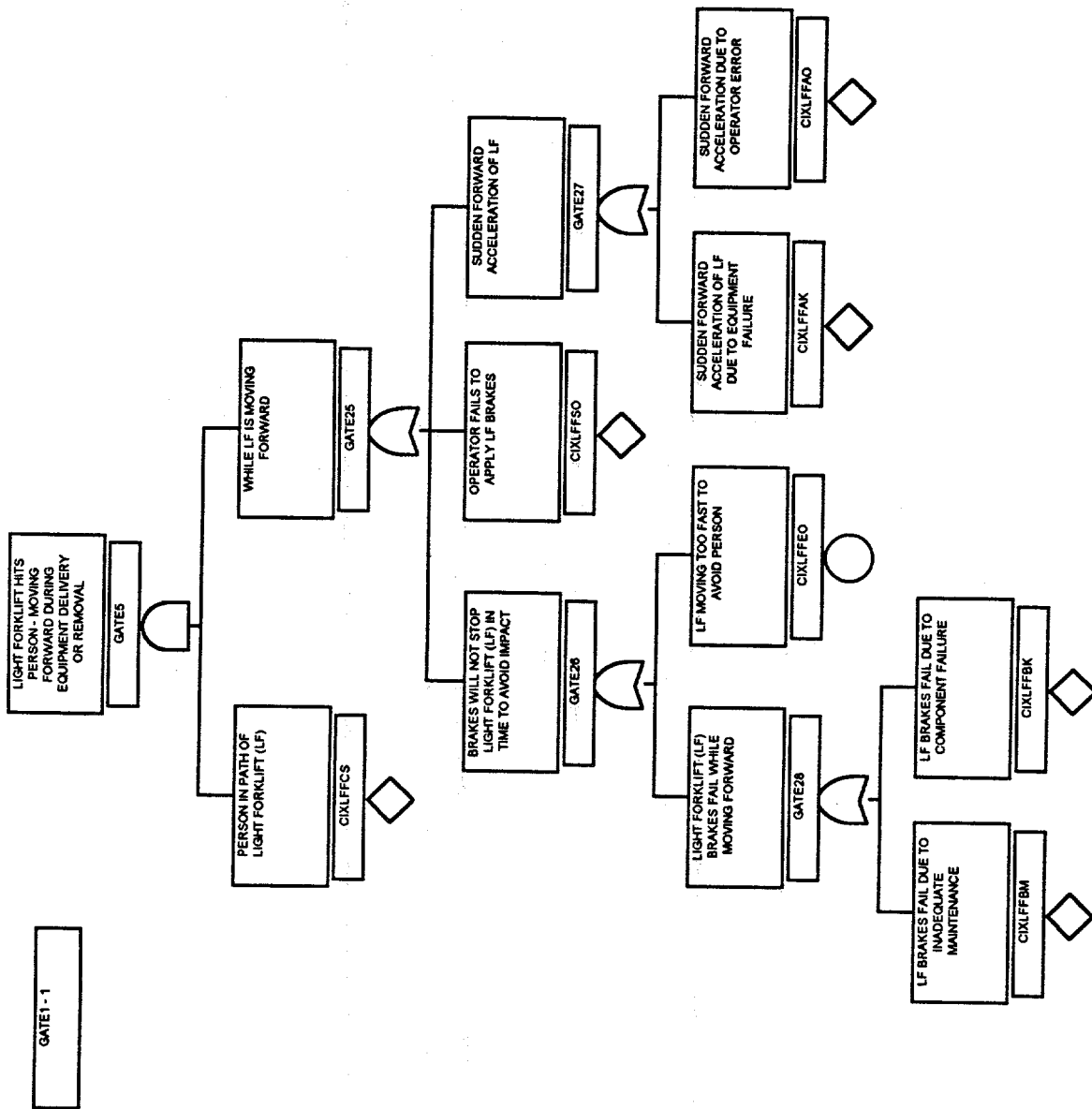
INJURY TO PERSONNEL
 DURING SETUP & CLOSE
 - CI



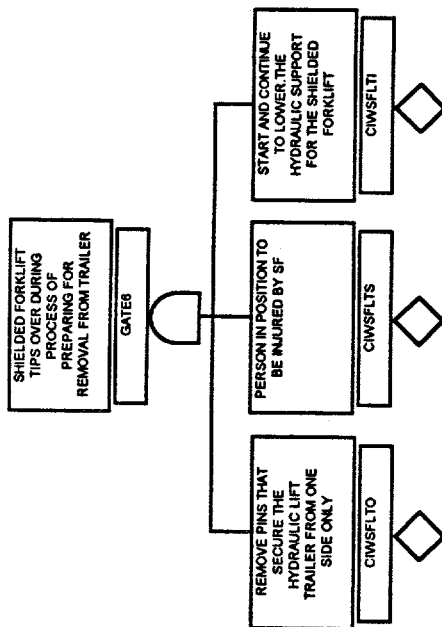
GATE1 - 1



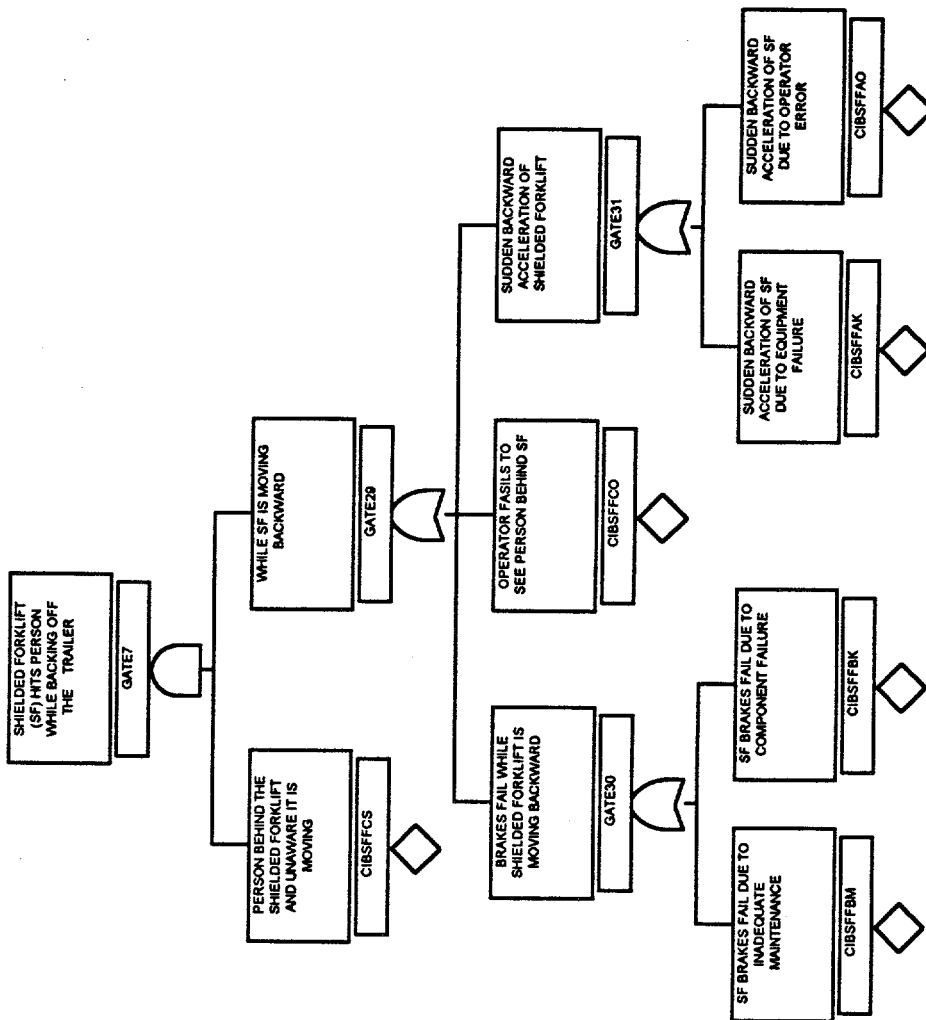




GATE1 - 1



GATE1 - 1



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
 BLOCK FILE: C:\SIPRA\INJURYCI.BLK
 VALUE BLOCK FILE: C:\SIPRA\INJURYCI.VAL
 WRITE FILE: NUL
 EMS FILE: WINDRUN.EMS
 SCRATCH FILE: WINDRUN.SCR
 OUTPUT FILE: C:\SIPRA\INJURYCI.OUT
 BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ INJURYCI.
 COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
 FAULT TREE: INJURYCI
 LOCATED: C:\SIPRA\INJURYCI.SET

NUMBER OF VALUE BLOCKS TO READ: 1
 VALUE BLOCK: INJURYCI
 LOCATED: C:\SIPRA\INJURYCI.TXT

OUTPUT FILE: C:\SIPRA\INJURYCI.OUT

BLOCK FILE: C:\SIPRA\INJURYCI.BLK

VALUE BLOCK FILE: C:\SIPRA\INJURYCI.VAL

PROGRAM: INJURYCI

USER BLOCK: CIINJURY

DATA PROC OPTIONS:
 BEFORE ANALYSIS:
 AFTER ANALYSIS:
 COMPUTEBLOCK
 COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
 TRUNCATION
 TRUNC VALUE: 1E-12
 TOP DOWN

END OF WINDOWS RUN INFORMATION \$
 DLTBLK (INJURYCI).
 RDFT (INJURYCI).
 DLTVALBLK (INJURYCI).
 RDVALBLK (INJURYCI).
 DLTBLK (CIINJURY).
 DLTEQN.

GENFTEQN (METHOD1\$ INJURYCI/ CIINJURY*
 PROBABILITY/1E-12, INJURYCI).
 LDBLK (CIINJURY).
 COMPUTEBLOCK(PROBABILITY, INJURYCI).

EXECUTE SETS USER PROGRAM INJURYCI

DLTBLK (INJURYCI).

STATEMENT EXECUTION REQUIRED 0.168 SECONDS FOR DLTBLK

RDFT (INJURYCI).

FAULTTREE\$INJURYCI.
OG\$ GATE1.
IN\$GATE3,GATE2,GATE4,GATE5,GATE6,GATE7.
AG\$ GATE2.
IN\$GATE8,GATE9.
OUT\$GATE1.
OG\$ GATE8.
IN\$CIBHFFCO,GATE10,GATE11.
OUT\$GATE2.
OG\$ GATE9.
IN\$GATE13,CIBHFFES,GATE12.
OUT\$GATE2.
UE\$ CIBHFFCO.
OUT\$GATE8.
OG\$ GATE10.
IN\$CIBHFFBM,CIBHFFBK.
OUT\$GATE8.
UE\$ CIBHFFBM.
OUT\$GATE10.
UE\$ CIBHFFBK.
OUT\$GATE10.
OG\$ GATE11.
IN\$CIBHFFAK,CIBHFFAO.
OUT\$GATE8.
UE\$ CIBHFFAK.
OUT\$GATE11.
UE\$ CIBHFFAO.
OUT\$GATE11.
UE\$ CIBHFFES.
OUT\$GATE9.
AG\$ GATE12.
IN\$CIBHFFCS,GATE14.
OUT\$GATE9.
UE\$ CIBHFFCS.
OUT\$GATE12.
OG\$ GATE14.
IN\$CIBHFFVM,CIBHFFVE.
OUT\$GATE12.
UE\$ CIBHFFVM.
OUT\$GATE14.
UE\$ CIBHFFVE.
OUT\$GATE14.
AG\$ GATE13.
IN\$CIBHFFSP,CIBHFFSO.
OUT\$GATE9.
UE\$ CIBHFFSP.
OUT\$GATE13.
UE\$ CIBHFFSO.
OUT\$GATE13.
AG\$ GATE3.
IN\$CIXHFFCS,GATE15.
OUT\$GATE1.
UE\$ CIXHFFCS.
OUT\$GATE3.
OG\$ GATE15.
IN\$GATE17,CIXHFFSO,GATE16.
OUT\$GATE3.
UE\$ CIXHFFSO.
OUT\$GATE15.
OG\$ GATE16.
IN\$CIXHFFEO,GATE18.

OUT\$GATE15.
BE\$ CIXHFFEO.
OUT\$GATE16.
OG\$ GATE18.
IN\$CIXHFFBM,CIXHFFBK.
OUT\$GATE16.
UE\$ CIXHFFBM.
OUT\$GATE18.
UE\$ CIXHFFBK.
OUT\$GATE18.
OG\$ GATE17.
IN\$CIXHFFAK,CIXHFFAO.
OUT\$GATE15.
UE\$ CIXHFFAK.
OUT\$GATE17.
UE\$ CIXHFFAO.
OUT\$GATE17.
AG\$ GATE4.
IN\$GATE20,GATE19.
OUT\$GATE1.
OG\$ GATE19.
IN\$CIBLFFCO,GATE21,GATE22.
OUT\$GATE4.
UE\$ CIBLFFCO.
OUT\$GATE19.
OG\$ GATE21.
IN\$CIBLFFBM,CIBLFFBK.
OUT\$GATE19.
UE\$ CIBLFFBM.
OUT\$GATE21.
UE\$ CIBLFFBK.
OUT\$GATE21.
OG\$ GATE22.
IN\$CIBLFFAK,CIBLFFAO.
OUT\$GATE19.
UE\$ CIBLFFAK.
OUT\$GATE22.
UE\$ CIBLFFAO.
OUT\$GATE22.
OG\$ GATE20.
IN\$CIBLFFES,GATE23.
OUT\$GATE4.
UE\$ CIBLFFES.
OUT\$GATE20.
AG\$ GATE23.
IN\$CIBLFFCS,GATE24.
OUT\$GATE20.
UE\$ CIBLFFCS.
OUT\$GATE23.
OG\$ GATE24.
IN\$CIBLFFVM,CIBLFFVE.
OUT\$GATE23.
UE\$ CIBLFFVM.
OUT\$GATE24.
UE\$ CIBLFFVE.
OUT\$GATE24.
AG\$ GATE5.
IN\$CIXLFFCS,GATE25.
OUT\$GATE1.
UE\$ CIXLFFCS.
OUT\$GATE5.
OG\$ GATE25.
IN\$CIXLFFSO,GATE26,GATE27.

OUT\$GATE5.
 UE\$ CIXLFFSO.
 OUT\$GATE25.
 OG\$ GATE26.
 IN\$CIXLFFEO,GATE28.
 OUT\$GATE25.
 OG\$ GATE27.
 IN\$CIXLFFAK,CIXLFFAO.
 OUT\$GATE25.
 BE\$ CIXLFFEO.
 OUT\$GATE26.
 OG\$ GATE28.
 IN\$CIXLFFBM,CIXLFFBK.
 OUT\$GATE26.
 UE\$ CIXLFFBM.
 OUT\$GATE28.
 UE\$ CIXLFFBK.
 OUT\$GATE28.
 UE\$ CIXLFFAK.
 OUT\$GATE27.
 UE\$ CIXLFFAO.
 OUT\$GATE27.
 AG\$ GATE6.
 IN\$CIWSFLT,CIWSFLTO,CIWSFLTI.
 OUT\$GATE1.
 UE\$ CIWSFLTO.
 OUT\$GATE6.
 UE\$ CIWSFLTI.
 OUT\$GATE6.
 AG\$ GATE7.
 IN\$CIBSFFCS,GATE29.
 OUT\$GATE1.
 UE\$ CIBSFFCS.
 OUT\$GATE7.
 OG\$ GATE29.
 IN\$CIBSFFCO,GATE30,GATE31.
 OUT\$GATE7.
 UE\$ CIBSFFCO.
 OUT\$GATE29.
 OG\$ GATE30.
 IN\$CIBSFFBM,CIBSFFBK.
 OUT\$GATE29.
 UE\$ CIBSFFBM.
 OUT\$GATE30.
 UE\$ CIBSFFBK.
 OUT\$GATE30.
 OG\$ GATE31.
 IN\$CIBSFFAK,CIBSFFAO.
 OUT\$GATE29.
 UE\$ CIBSFFAK.
 OUT\$GATE31.
 UE\$ CIBSFFAO.
 OUT\$GATE31.
 UE\$ CIWSFLT.
 OUT\$GATE6.

THERE ARE NO CYCLES IN INJURYCI

FAULT TREE BLOCK INJURYCI
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 1.320 SECONDS FOR RDFT

DLTVALBLK (INJURYCI).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTVALBLK

RDVALBLK (INJURYCI).

VALUE BLOCK\$INJURYCI.
 CREATE VALUE BLOCK INJURYCI
 3.0E-2 \$CIBHFFCO,CIXHFFSO,CIBLFFCO,CIXLFFSO,CIBSFFCO\$
 1.0E-3 \$CIBHFFES,CIBHFFCS,CIXHFFCS,CIBHFFSO\$
 3.0E-3 \$CIBHFFBM,CIBHFFVM,CIXHFFBM,CIBLFFVM,CIBLFFBM,CIXLFFBM,
 CIBSFFBM\$
 1.0E-1 \$CIWSFLT\$S\$
 1.0E-2 \$CIBHFFAO,CIXHFFAO,CIXHFFEO,CIBLFFES,CIBLFFCS,
 CIBLFFAO,CIXLFFCS,CIXLFFEO,CIXLFFAO,CIBSFFCS,CIBSFFAO\$
 5.0E-1 \$CIBHFFSP\$
 2.0E-3 \$CIWSFLT\$S\$
 1.0E-1 \$CIWSFLT\$S\$
 3.0E-3 \$CIBHFFAK,CIXHFFAK,CIBLFFAK,CIXLFFAK,CIBSFFAK\$
 5.0E-3 \$CIBHFFBK,CIXHFFBK,CIBLFFBK,CIXLFFBK,CIBSFFBK\$
 3.8E-2 \$CIBHFFVE,CIBLFFVE\$

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR RDVALBLK

DLTBLK (CIINJURY).

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR DLTBLK

DLTEQN.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEQN

GENFTEQN (METHOD1\$ INJURYCI/ CIINJURY* PROBABILITY/ 1E-12, INJURYCI).

TOP EVENTS OF INJURYCI

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEQN

LDBLK (INJURYCI).
 SUBINEQN (GATE1, GATE1).
 TRNTRMVAL (PROBABILITY/ 1E-12, INJURYCI* GATE1,
 GATE1).
 FRMBLK (CIINJURY* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR GENFTEQN

LDBLK (INJURYCI).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR LDBLK

SUBINEQN (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, INJURYCI* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
 GENERATED BY EXPANSION IS 53.

TERMS GENERATED BY EXPANSION

27 TERMS CONTAIN 2 VARIABLES
26 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 53.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999850000E-04
(THE SUM OF THE TERM VALUES IS 1.810500860000E-03)

EXPANSION TOOK 0.059 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

27 TERMS CONTAIN 2 VARIABLES
26 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 53.

SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR TRNTRMVAL

FRMBLK (CIINJURY* ONLY\$ GATE1).

EQUATION BLOCK CIINJURY
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR FRMBLK

LDBLK (CIINJURY).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, INJURYCI).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, INJURYCI* GATE1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, INJURYCI* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 53.

TERMS GENERATED BY EXPANSION
27 TERMS CONTAIN 2 VARIABLES
26 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 53.

EXPANSION TOOK 0.000 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
CIBHFFCO	4		
CIBHFFES	5		
CIBHFFBM	4		
CIBHFFBK	4		
CIBHFFAK	4		
CIBHFFAO	4		
CIBHFFCS	10		
CIBHFFVM	5		
CIBHFFVE	5		
CIBHFFSP	5		
CIBHFFSO	5		
CIXHFFCS	6		
CIXHFFSO	1		
CIXHFFEO	1		
CIXHFFBM	1		
CIXHFFBK	1		
CIXHFFAK	1		
CIXHFFAO	1		
CIBLFFCO	3		
CIBLFFBM	3		
CIBLFFBK	3		
CIBLFFAK	3		
CIBLFFAO	3		
CIBLFFES	5		
CIBLFFCS	10		
CIBLFFVM	5		
CIBLFFVE	5		
CIXLFFCS	6		
CIXLFFSO	1		
CIXLFFEO	1		
CIXLFFAK	1		
CIXLFFAO	1		
CIXLFFBM	1		
CIXLFFBK	1		
CIWSFLT	1		
CIWSFLT	1		
CIWSFLT	1		
CIBSFFCS	5		
CIBSFFCO	1		
CIBSFFBM	1		
CIBSFFBK	1		
CIBSFFAK	1		
CIBSFFAO	1		

THERE ARE 43 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

GATE1 =

1 3.0000E-04 CIBSFFCS * CIBSFFCO +
 2 3.0000E-04 CIXLFFCS * CIXLFFSO +
 3 3.0000E-04 CIBLFFCO * CIBLFFES +
 4 1.0000E-04 CIBSFFCS * CIBSFFAO +
 5 1.0000E-04 CIXLFFCS * CIXLFFAO +
 6 1.0000E-04 CIXLFFCS * CIXLFFEO +
 7 1.0000E-04 CIBLFFAO * CIBLFFES +
 8 5.0000E-05 CIBSFFCS * CIBSFFBK +
 9 5.0000E-05 CIXLFFCS * CIXLFFBK +
 10 5.0000E-05 CIBLFFBK * CIBLFFES +
 11 3.0000E-05 CIBHFFCO * CIBHFFES +
 12 3.0000E-05 CIXHFFCS * CIXHFFSO +
 13 3.0000E-05 CIXLFFCS * CIXLFFBM +
 14 3.0000E-05 CIBSFFCS * CIBSFFBM +
 15 3.0000E-05 CIXLFFCS * CIXLFFAK +
 16 3.0000E-05 CIBSFFCS * CIBSFFAK +
 17 3.0000E-05 CIBLFFAK * CIBLFFES +
 18 3.0000E-05 CIBLFFBM * CIBLFFES +
 19 2.0000E-05 CIWSFLTTS * CIWSFLTTO * CIWSFLTI +
 20 1.5000E-05 CIBHFFCO * CIBHFFSP * CIBHFFSO +
 21 1.1400E-05 CIBLFFCO * CIBLFFCS * CIBLFFVE +
 22 1.0000E-05 CIXHFFCS * CIXHFFEO +
 23 1.0000E-05 CIBHFFES * CIBHFFAO +
 24 1.0000E-05 CIXHFFCS * CIXHFFAO +
 25 5.0000E-06 CIBHFFES * CIBHFFBK +
 26 5.0000E-06 CIBHFFAO * CIBHFFSP * CIBHFFSO +
 27 5.0000E-06 CIXHFFCS * CIXHFFBK +
 28 3.8000E-06 CIBLFFAO * CIBLFFCS * CIBLFFVE +
 29 3.0000E-06 CIXHFFCS * CIXHFFBM +

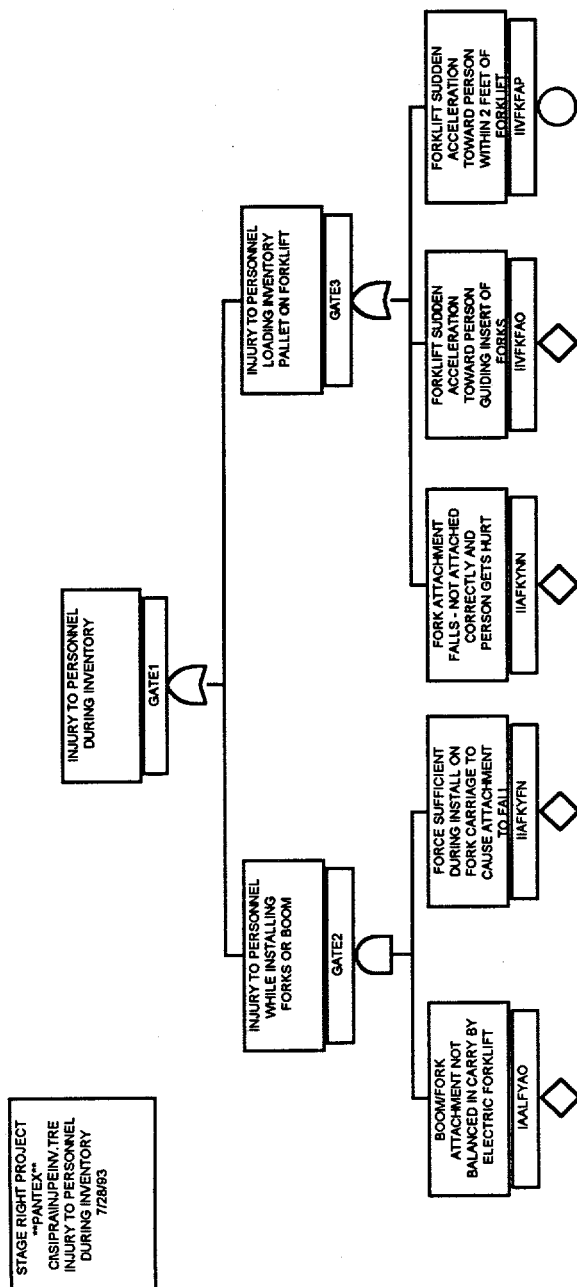
30 3.0000E-06 CIBHFFES * CIBHFFAK +
 31 3.0000E-06 CIBHFFES * CIBHFFBM +
 32 3.0000E-06 CIXHFFCS * CIXHFFAK +
 33 2.5000E-06 CIBHFFBK * CIBHFFSP * CIBHFFSO +
 34 1.9000E-06 CIBLFFBK * CIBLFFCS * CIBLFFVE +
 35 1.5000E-06 CIBHFFAK * CIBHFFSP * CIBHFFSO +
 36 1.5000E-06 CIBHFFBM * CIBHFFSP * CIBHFFSO +
 37 1.1400E-06 CIBHFFCO * CIBHFFCS * CIBHFFVE +
 38 1.1400E-06 CIBLFFBM * CIBLFFCS * CIBLFFVE +
 39 1.1400E-06 CIBLFFAK * CIBLFFCS * CIBLFFVE +
 40 9.0000E-07 CIBLFFCO * CIBLFFCS * CIBLFFVM +
 41 3.8000E-07 CIBHFFAO * CIBHFFCS * CIBHFFVE +
 42 3.0000E-07 CIBLFFAO * CIBLFFCS * CIBLFFVM +
 43 1.9000E-07 CIBHFFBK * CIBHFFCS * CIBHFFVE +
 44 1.5000E-07 CIBLFFBK * CIBLFFCS * CIBLFFVM +
 45 1.1400E-07 CIBHFFAK * CIBHFFCS * CIBHFFVE +
 46 1.1400E-07 CIBHFFBM * CIBHFFCS * CIBHFFVE +
 47 9.0000E-08 CIBHFFCO * CIBHFFCS * CIBHFFVM +
 48 9.0000E-08 CIBLFFAK * CIBLFFCS * CIBLFFVM +
 49 9.0000E-08 CIBLFFBM * CIBLFFCS * CIBLFFVM +
 50 3.0000E-08 CIBHFFAO * CIBHFFCS * CIBHFFVM +
 51 1.5000E-08 CIBHFFBK * CIBHFFCS * CIBHFFVM +
 52 9.0000E-09 CIBHFFAK * CIBHFFCS * CIBHFFVM +
 53 9.0000E-09 CIBHFFBM * CIBHFFCS * CIBHFFVM

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999850000E-04
 (THE SUM OF THE TERM VALUES IS 1.810500980000E-03)

STATEMENT EXECUTION REQUIRED 0.281 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

Appendix H:
Process Fault Trees
for
Inventory



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\INJPEINV.BLK
VALUE BLOCK FILE: C:\SIPRA\INJPEINV.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\INJPEINV.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ INJPEINV.
COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: INJPEINV
LOCATED: C:\SIPRA\INJPEINV.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: INJPEINV
LOCATED: C:\SIPRA\INJPEINV.TXT

OUTPUT FILE: C:\SIPRA\INJPEINV.OUT

BLOCK FILE: C:\SIPRA\INJPEINV.BLK

VALUE BLOCK FILE: C:\SIPRA\INJPEINV.VAL

PROGRAM: INJPEINV

USER BLOCK: PERINJINV

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTEBLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (INJPEINV).
RDFT (INJPEINV).
DLTVALBLK (INJPEINV).
RDVALBLK (INJPEINV).
DLTBLK (PERINJINV).
DLTEON.

GENFTEON (METHOD1\$ INJPEINV/ PERINJINV*
 PROBABILITY/1E-12, INJPEINV).
 LDBLK (PERINJINV).
 COMPUTEBLOCK(PROBABILITY, INJPEINV).

EXECUTE SETS USER PROGRAM INJPEINV

DLTBLK (INJPEINV).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

RDFT (INJPEINV).

FAULTTREE\$INJPEINV.
 OG\$ GATE1.
 IN\$GATE2,GATE3.
 AG\$ GATE2.
 IN\$IAALFYAO,IIAFKYFN.
 OUT\$GATE1.
 UE\$ IAALFYAO.
 OUT\$GATE2.
 UE\$ IIAFKYFN.
 OUT\$GATE2.
 OG\$ GATE3.
 IN\$IIAFKYNN,IIVFKFAO,IIVFKFAP.
 OUT\$GATE1.
 UE\$ IIAFKYNN.
 OUT\$GATE3.
 UE\$ IIVFKFAO.
 OUT\$GATE3.
 BE\$ IIVFKFAP.
 OUT\$GATE3.

THERE ARE NO CYCLES IN INJPEINV

FAULT TREE BLOCK INJPEINV
 HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR RDFT

DLTVALBLK (INJPEINV).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTVALBLK

RDVALBLK (INJPEINV).

VALUE BLOCK\$INJPEINV.
 CREATE VALUE BLOCK INJPEINV
 3.0E-2 \$IAALFYAO,IIAFKYFN\$
 6.0E-3 \$IIAFKYNN\$
 1.0E-3 \$IIVFKFAO,IIVFKFAP\$
 STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR RDVALBLK

DLTBLK (PERINJINV).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ INJPEINV/ PERINJINV* PROBABILITY/ 1E-12, INJPEINV).

TOP EVENTS OF INJPEINV

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (INJPEINV).

SUBINEON (GATE1, GATE1).

TRNTRMVAL (PROBABILITY/ 1E-12, INJPEINV* GATE1,
GATE1).

FRMBLK (PERINJINV* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR GENFTEON

LDBLK (INJPEINV).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, INJPEINV* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 4.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 1 VARIABLES
1 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 4.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 6.000000050000E-03

(THE SUM OF THE TERM VALUES IS 8.900000710000E-03)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION

3 TERMS CONTAIN 1 VARIABLES

1 TERMS CONTAIN 2 VARIABLES

TOTAL TERMS RETAINED 4.

SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR TRNTRMVAL

FRMBLK (PERINJINV* ONLY\$ GATE1).

EQUATION BLOCK PERINJINV

HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR FRMBLK

LDBLK (PERINJINV).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, INJPEINV).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, INJPEINV* GATE1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, INJPEINV* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 4.

TERMS GENERATED BY EXPANSION

3 TERMS CONTAIN 1 VARIABLES

1 TERMS CONTAIN 2 VARIABLES

TOTAL TERMS GENERATED 4.

EXPANSION TOOK 0.000 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
IAALFYAO	1		
IIAFKYFN	1		
IIAFKYNN	1		
IIVFKFAO	1		
IIVFKFAP	1		

THERE ARE 5 DIFFERENT VARIABLES IN THE
EQUATION FOR GATE1

TERM PROB.
NUMBER OF TERM

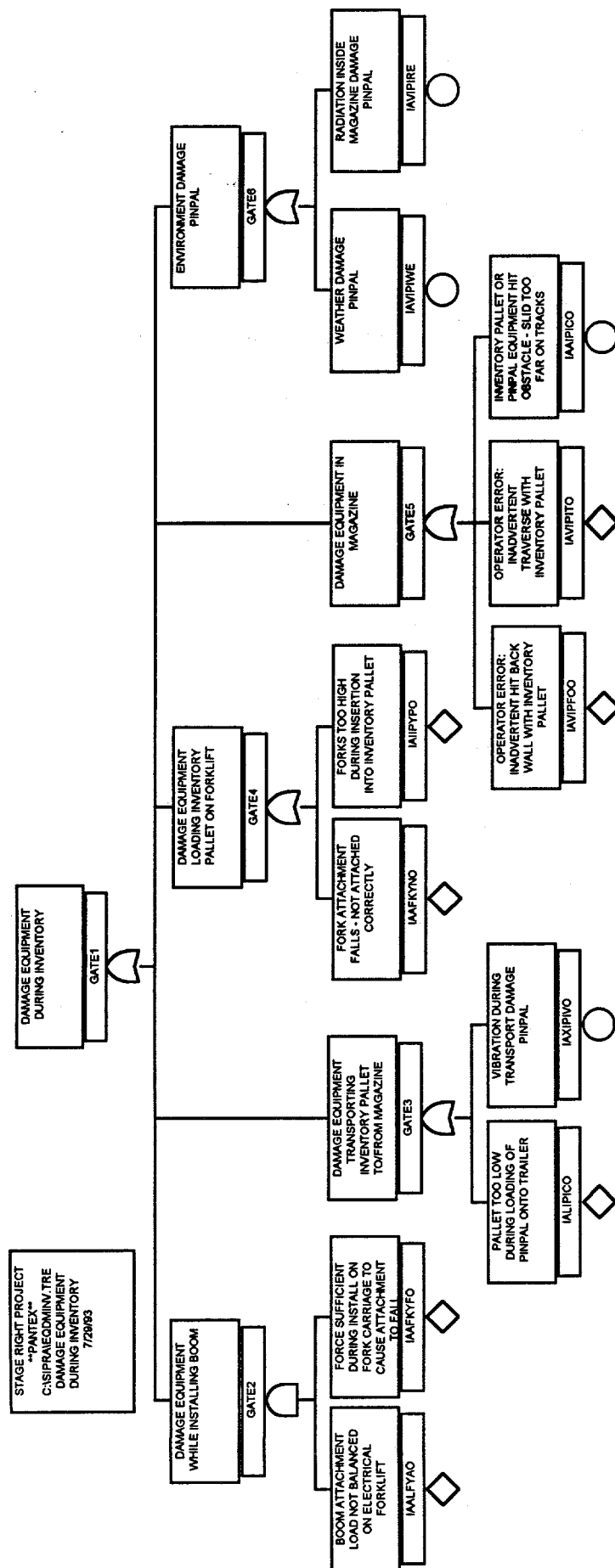
GATE1 =

- 1 6.0000E-03 IIAFKYNN +
- 2 1.0000E-03 IIVFKFAO +
- 3 1.0000E-03 IIVFKFAP +
- 4 9.0000E-04 IIALFYAO * IIAFKYFN

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 6.000000050000E-03
(THE SUM OF THE TERM VALUES IS 8.900000710000E-03)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\EODMINV.BLK
VALUE BLOCK FILE: C:\SIPRA\EODMINV.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\EODMINV.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ EODMINV.
COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1
FAULT TREE: EODMINV
LOCATED: C:\SIPRA\EODMINV.SET

NUMBER OF VALUE BLOCKS TO READ: 1
VALUE BLOCK: EODMINV
LOCATED: C:\SIPRA\EODMINV.TXT

OUTPUT FILE: C:\SIPRA\EODMINV.OUT

BLOCK FILE: C:\SIPRA\EODMINV.BLK

VALUE BLOCK FILE: C:\SIPRA\EODMINV.VAL

PROGRAM: EODMINV

USER BLOCK: DMEQINV

DATA PROC OPTIONS:
BEFORE ANALYSIS:
AFTER ANALYSIS:
COMPUTEBLOCK
COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:
TRUNCATION
TRUNC VALUE: 1E-12
TOP DOWN

END OF WINDOWS RUN INFORMATION \$
DLTBLK (EODMINV).
RDFT (EODMINV).
DLTVALBLK (EODMINV).
RDVALBLK (EODMINV).
DLTBLK (DMEQINV).
DLTEON.

GENFTEON (METHOD1\$ EODMINV/ DMEQINV*
 PROBABILITY/1E-12, EODMINV).
 LDBLK (DMEQINV).
 COMPUTEBLOCK(PROBABILITY, EODMINV).

EXECUTE SETS USER PROGRAM EODMINV

DLTBLK (EODMINV).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

RDFT (EODMINV).

FAULTTREE\$EODMINV.
 OG\$ GATE1.
 IN\$GATE2,GATE3,GATE4,GATE5,GATE6.
 AG\$ GATE2.
 IN\$IAALFYAO,IAAFKYFO.
 OUT\$GATE1.
 UE\$ IAALFYAO.
 OUT\$GATE2.
 UE\$ IAAFKYFO.
 OUT\$GATE2.
 OG\$ GATE3.
 IN\$IALIPICO,IAXIPIVO.
 OUT\$GATE1.
 UE\$ IALIPICO.
 OUT\$GATE3.
 BE\$ IAXIPIVO.
 OUT\$GATE3.
 OG\$ GATE4.
 IN\$IAAFKYNO,IAHPYPO.
 OUT\$GATE1.
 UE\$ IAAFKYNO.
 OUT\$GATE4.
 UE\$ IAHPYPO.
 OUT\$GATE4.
 OG\$ GATE5.
 IN\$IAVIPFOO,IAVIPITO,IAAIPICO.
 OUT\$GATE1.
 UE\$ IAVIPFOO.
 OUT\$GATE5.
 UE\$ IAVIPITO.
 OUT\$GATE5.
 BE\$ IAAIPICO.
 OUT\$GATE5.
 OG\$ GATE6.
 IN\$IAVIPIWE,IAVIPIRE.
 OUT\$GATE1.
 BE\$ IAVIPIWE.
 OUT\$GATE6.
 BE\$ IAVIPIRE.
 OUT\$GATE6.

THERE ARE NO CYCLES IN EODMINV

FAULT TREE BLOCK EODMINV
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.160 SECONDS FOR RDFT

DLTVALBLK (EODMINV).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTVALBLK

RDVALBLK (EODMINV).

VALUE BLOCK\$EODMINV.

CREATE VALUE BLOCK EODMINV

3.0E-2 \$IAALFYAO,IAAFKYFO,IAVIPFOO,IAAIPICO\$

3.0E-3 \$IALIPICO,IAXIPIVO,IAAFKYNO,IAIPYPO,IAVIPIWE\$

1.0E-3 \$IAVIPITO\$

1.3E-4 \$IAVIPIRE\$

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR RDVALBLK

DLTBLK (DMEQINV).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ EODMINV/ DMEQINV* PROBABILITY/ 1E-12, EODMINV).

TOP EVENTS OF EODMINV

1. GATE1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (EODMINV).

SUBINEON (GATE1, GATE1).

TRNTRMVAL (PROBABILITY/ 1E-12, EODMINV* GATE1, GATE1).

FRMBLK (DMEQINV* ONLY\$ GATE1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR GENFTEON

LDBLK (EODMINV).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

SUBINEON (GATE1, GATE1).

STATEMENT EXECUTION REQUIRED 0.113 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, EODMINV* GATE1, GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 10.

TERMS GENERATED BY EXPANSION
9 TERMS CONTAIN 1 VARIABLES
1 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS GENERATED 10.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.999999930000E-02
(THE SUM OF THE TERM VALUES IS 7.702999560000E-02)

*** WARNING *** THE SUM OF TERM VALUES WAS DERIVED BEFORE SIMPLIFICATION.
IF TERM(S) ARE REMOVED IN THE SIMPLIFICATION STEP BELOW, THEN THIS CUT SET
EXPRESSION SHOULD BE REQUANTIFIED TO OBTAIN THE CORRECT SUM OF TERM VALUES.

EXPANSION TOOK 0.000 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
9 TERMS CONTAIN 1 VARIABLES
1 TERMS CONTAIN 2 VARIABLES
TOTAL TERMS RETAINED 10.
SIMPLIFICATION TOOK 0.059 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR TRNTRMVAL

FRMBLK (DMEQINV* ONLY\$ GATE1).

EQUATION BLOCK DMEQINV
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR FRMBLK

LDBLK (DMEQINV).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, EODMINV).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, EODMINV* GATE1).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, EODMINV* GATE1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 10.

TERMS GENERATED BY EXPANSION
 9 TERMS CONTAIN 1 VARIABLES
 1 TERMS CONTAIN 2 VARIABLES
 TOTAL TERMS GENERATED 10.
 EXPANSION TOOK 0.051 SECONDS.

*** VARIABLE OCCURRENCE TABLE ***

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
IAALFYAO	1		
IAAFKYFO	1		
IALIPICO	1		
IAXIPIVO	1		
IAAFKYNO	1		
IAIPYPO	1		
IVIPFOO	1		
IVIPITO	1		
IAAIPICO	1		
IAPIWE	1		
IAPIRE	1		

THERE ARE 11 DIFFERENT VARIABLES IN THE
 EQUATION FOR GATE1

TERM PROB.
 NUMBER OF TERM

GATE1 =

- 1 3.0000E-02 IAAIPICO +
- 2 3.0000E-02 IAVIPFOO +
- 3 3.0000E-03 IAPIWE +
- 4 3.0000E-03 IAIPYPO +
- 5 3.0000E-03 IAAFKYNO +
- 6 3.0000E-03 IAXIPIVO +
- 7 3.0000E-03 IALIPICO +
- 8 1.0000E-03 IAVIPITO +
- 9 9.0000E-04 IAALFYAO * IAAFKYFO +
- 10 1.3000E-04 IAPIRE

SETS(07/06/93) 11/05/93 11:53:54.35 PAGE NO. 7

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 2.9999999300000E-02
(THE SUM OF THE TERM VALUES IS 7.7029988200000E-02)

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

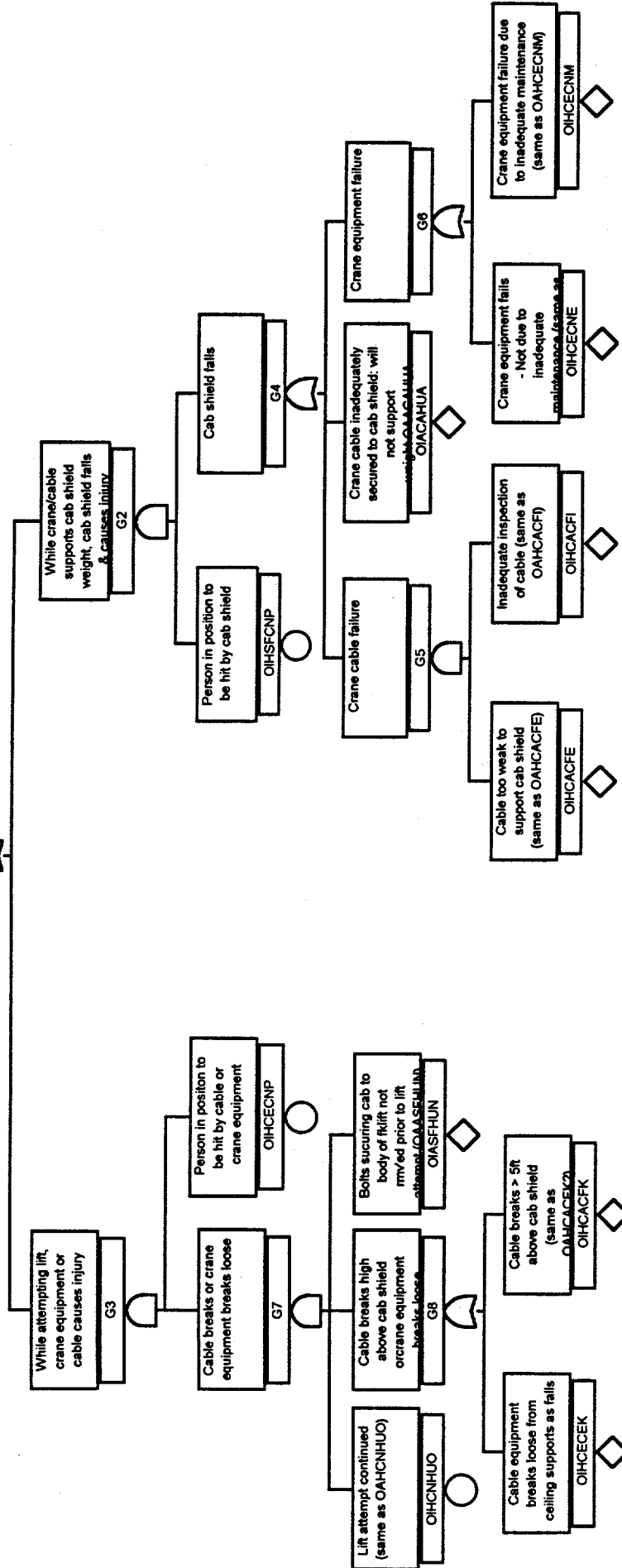
Appendix I:
Process Fault Trees for
Inter-Zone Transportation

(none included)

Appendix J:
Process Fault Trees
for
Maintenance on Shielded Lift Truck:
Removal of Protective Cab

Stage Right Project
 Pantex
 r_cb_in.tr
 Injury to personnel during
 removal/replacement of
 the forklift cab shield

Injury to personnel
 during
 removal/replacement
 of forklift cab shield
 G1



FILES BEING USED FOR THIS SETS RUN ARE:

SETS PROGRAM FILE: WINDRUN.PGM
BLOCK FILE: C:\SIPRA\RRCBIN.BLK
VALUE BLOCK FILE: C:\SIPRA\RRCBIN.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\RRCBIN.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ RRCBIN.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1

FAULT TREE: RRCBIN

LOCATED: C:\SIPRA\RRCBIN.SET

NUMBER OF VALUE BLOCKS TO READ: 1

VALUE BLOCK: RRCBIN

LOCATED: C:\SIPRA\RRCBIN.TXT

OUTPUT FILE: C:\SIPRA\RRCBIN.OUT

BLOCK FILE: C:\SIPRA\RRCBIN.BLK

VALUE BLOCK FILE: C:\SIPRA\RRCBIN.VAL

PROGRAM: RRCBIN

USER BLOCK: INJRRCB

DATA PROC OPTIONS:

BEFORE ANALYSIS:

AFTER ANALYSIS:

COMPUTEBLOCK

COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:

TRUNCATION

TRUNC VALUE: 1E-12

TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (RRCBIN).

RDFT (RRCBIN).

DLTVALBLK (RRCBIN).

RDVALBLK (RRCBIN).

DLTBLK (INJRRCB).

DLTEON.

GENFTEON (METHOD1\$ RRCBIN/ INJRRCB*
 PROBABILITY/1E-12, RRCBIN).
 LDBLK (INJRRCB).
 COMPUTEBLOCK(PROBABILITY, RRCBIN).

EXECUTE SETS USER PROGRAM RRCBIN

DLTBLK (RRCBIN).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK

RDFT (RRCBIN).

FAULTTREE\$RRCBIN.
 OG\$ G1.
 IN\$G3,G2.
 AG\$ G2.
 IN\$G4,OIHSFCNP.
 OUT\$G1.
 AG\$ G3.
 IN\$OIHCECNP,G7.
 OUT\$G1.
 UE\$ OLASFHUN.
 OUT\$G7.
 BE\$ OIHCNHUO.
 OUT\$G7.
 AG\$ G7.
 IN\$OLASFHUN,OIHCNHUO,G8.
 OUT\$G3.
 UE\$ OIHCECEK.
 OUT\$G8.
 UE\$ OIHCACFK.
 OUT\$G8.
 BE\$ OIHSFCNP.
 OUT\$G2.
 OG\$ G4.
 IN\$OLACAHUA,G5,G6.
 OUT\$G2.
 OG\$ G6.
 IN\$OIHCECNE,OIHCECNM.
 OUT\$G4.
 UE\$ OIHCECNE.
 OUT\$G6.
 UE\$ OIHCECNM.
 OUT\$G6.
 UE\$ OIHCACFE.
 OUT\$G5.
 UE\$ OIHCACFI.
 OUT\$G5.
 AG\$ G5.
 IN\$OIHACAFE,OIHCACFI.
 OUT\$G4.

UE\$ OIACAHUA.
OUT\$G4.
OG\$ G8.
IN\$OIHCECEK,OIHCACFK
OUT\$G7.
BE\$ OIHCECNP.
OUT\$G3.

THERE ARE NO CYCLES IN RRCBIN

FAULT TREE BLOCK RRCBIN
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.219 SECONDS FOR RDFT

DLTVALBLK (RRCBIN).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTVALBLK

RDVALBLK (RRCBIN).

VALUE BLOCK\$RRCBIN.
CREATE VALUE BLOCK RRCBIN
1.0E-1 \$OIHCHUO,OIHCACFI\$
2.0E-3 \$OIASFHUN\$
2.0E-1 \$OIHCECNP\$
4.0E-1 \$OIHSCNP\$
3.0E-3 \$OIACAHUA,OIHCECNM\$
2.5E-6 \$OIHCECEK\$
1.3E-6 \$OIHACACFK\$
1.3E-5 \$OIHACACFE\$
2.4E-6 \$OIHCECNE\$

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR RDVALBLK

DLTBLK (INJRRCB).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTBLK

DLTEON.

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR DLTEON

GENFTEON (METHOD1\$ RRCBIN/ INJRRCB* PROBABILITY/ 1E-12, RRCBIN).

TOP EVENTS OF RRCBIN

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON

LDBLK (RRCBIN).
SUBINEQN (G1, G1).
TRNTRMVAL (PROBABILITY/ 1E-12, RRCBIN* G1, G1).
FRMBLK (INJRRCB* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR GENFTEQN

LDBLK (RRCBIN).

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR LDBLK

SUBINEQN (G1, G1).

STATEMENT EXECUTION REQUIRED 0.047 SECONDS FOR SUBINEQN

TRNTRMVAL (PROBABILITY/ 1E-12, RRCBIN* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 2 VARIABLES
1 TERMS CONTAIN 3 VARIABLES
2 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS GENERATED 6.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.200000060000E-03
(THE SUM OF THE TERM VALUES IS 2.401479990000E-03)

EXPANSION TOOK 0.063 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
3 TERMS CONTAIN 2 VARIABLES
1 TERMS CONTAIN 3 VARIABLES
2 TERMS CONTAIN 4 VARIABLES
TOTAL TERMS RETAINED 6.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.063 SECONDS FOR TRNTRMVAL

FRMBLK (INJRRCB* ONLY\$ G1).

EQUATION BLOCK INJRRCB
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR FRMBLK

LDBLK (INJRRCB).

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, RRCBIN).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RRCBIN* G1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RRCBIN* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 2 VARIABLES
1 TERMS CONTAIN 3 VARIABLES
2 TERMS CONTAIN 4 VARIABLES

TOTAL TERMS GENERATED 6.

EXPANSION TOOK 0.000 SECONDS.

***** VARIABLE OCCURRENCE TABLE *****

NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE	NUMBER OF OCCURRENCES
OIHSFCNP	4		
OIHCECNP	2		
OIASFHUN	2		
OIHCHNUO	2		
OIHCECEK	1		
OIHCACFK	1		
OIACAHUA	1		
OIHCECNE	1		
OIHCECNM	1		
OIHCACFE	1		
OIHCACFI	1		

THERE ARE 11 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

- 1 1.2000E-03 OHSFCNP * OIHCECNM +
- 2 1.2000E-03 OHSFCNP * OIACAHUA +
- 3 9.6000E-07 OHSFCNP * OIHCECNE +
- 4 5.2000E-07 OHSFCNP * OIHCACFE * OIHCACFI +
- 5 1.0000E-10 OIHCECNP * OIASFHUN * OIHCHNUO * OIHCECEK +
- 6 5.2000E-11 OIHCECNP * OIASFHUN * OIHCHNUO * OIHCACFK

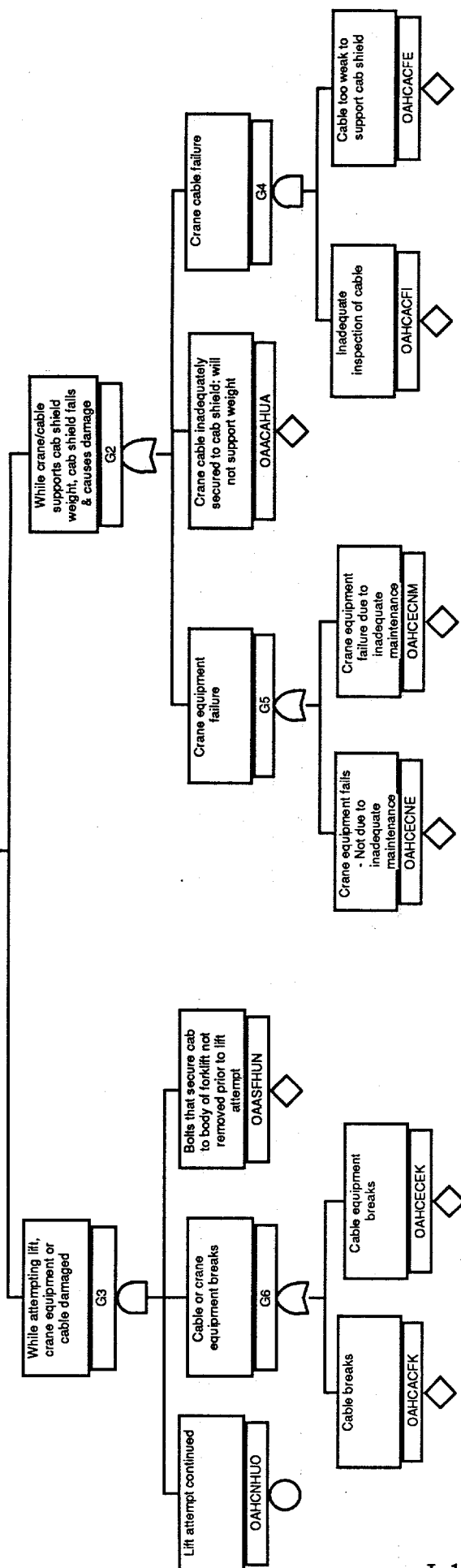
THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 1.200000060000E-03
(THE SUM OF THE TERM VALUES IS 2.401479990000E-03)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

Stage Right Project
"Partex"
Damage to equipment
during
removal/replacement of
the forklift cab shield

Damage to equipment
during
removal/replacement
of forklift cab shield
G1



FILES BEING USED FOR THIS SETS RUN ARE:
SETS PROGRAM FILE: WINDRUN.PGM

BLOCK FILE: C:\SIPRA\RRCBDE.BLK
VALUE BLOCK FILE: C:\SIPRA\RRCBDE.VAL
WRITE FILE: NUL
EMS FILE: WINDRUN.EMS
SCRATCH FILE: WINDRUN.SCR
OUTPUT FILE: C:\SIPRA\RRCBDE.OUT
BEGIN EXECUTION OF SETS.

READ SETS USER PROGRAM.

PROGRAM\$ RRCBDE.

COMMENT\$ BEGINNING OF WINDOWS RUN INFORMATION

NUMBER OF FAULT TREES TO READ: 1

FAULT TREE: RRCBDE

LOCATED: C:\SIPRA\RRCBDE.SET

NUMBER OF VALUE BLOCKS TO READ: 1

VALUE BLOCK: RRCBDE

LOCATED: C:\SIPRA\RRCBDE.TXT

OUTPUT FILE: C:\SIPRA\RRCBDE.OUT

BLOCK FILE: C:\SIPRA\RRCBDE.BLK

VALUE BLOCK FILE: C:\SIPRA\RRCBDE.VAL

PROGRAM: RRCBDE

USER BLOCK: EODMRR

DATA PROC OPTIONS:

BEFORE ANALYSIS:

AFTER ANALYSIS:

COMPUTEBLOCK

COMPUTE OPTIONS: PROB

FAULT TREE OPTIONS:

TRUNCATION

TRUNC VALUE: 1E-12

TOP DOWN

END OF WINDOWS RUN INFORMATION \$

DLTBLK (RRCBDE).

RDFT (RRCBDE).

DLTVALBLK (RRCBDE).

RDVALBLK (RRCBDE).

DLTBLK (EODMRR).

DLTEQN.

GENFTEON (METHOD1\$ RRCBDE/ EODMRR*

PROBABILITY/1E-12, RRCBDE).

LDBLK (EODMRR).

COMPUTEBLOCK(PROBABILITY, RRCBDE).

EXECUTE SETS USER PROGRAM RRCBDE

DLTBLK (RRCBDE).

STATEMENT EXECUTION REQUIRED 0.061 SECONDS FOR DLTBLK

RDFT (RRCBDE).

FAULTTREE\$RRCBDE.

OG\$ G1.

IN\$G3,G2.

OG\$ G2.

IN\$G5,G4,OAACAHUA.

OUT\$G1.

AG\$ G3.

IN\$G6,OAHCNHUO,OAASFHUN.

OUT\$G1.

UE\$ OAASFHUN.

OUT\$G3.

BE\$ OAHCNHUO.

OUT\$G3.

OG\$ G6.

IN\$OAHCACFK,OAHCECEK.

OUT\$G3.

UE\$ OAHCECEK.

OUT\$G6.

UE\$ OAHCACFK.

OUT\$G6.

UE\$ OAACAHUA.

OUT\$G2.

AG\$ G4.

IN\$OAHCACFI,OAHCACFE.

OUT\$G2.

OG\$ G5.

IN\$OAHCECNE,OAHCECNM.

OUT\$G2.

UE\$ OAHCECNM.

OUT\$G5.

UE\$ OAHCECNE.

OUT\$G5.

UE\$ OAHCACFE.
OUT\$G4.
UE\$ OAHCACFI.
OUT\$G4.

THERE ARE NO CYCLES IN RRCBDE

FAULT TREE BLOCK RRCBDE
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.270 SECONDS FOR RDFT

DLTVALBLK (RRCBDE).

STATEMENT EXECUTION REQUIRED 0.061 SECONDS FOR DLTVALBLK

RDVALBLK (RRCBDE).

VALUE BLOCK\$RRCBDE.
CREATE VALUE BLOCK RRCBDE
1.0E-1 \$OAHCNHUO,OAHCACFI\$
2.0E-3 \$OAASFHUN\$
3.0E-3 \$OAHCECNM,OAACAHUA\$
2.5E-6 \$OAHCECEK\$
1.3E-6 \$OAHCACFK\$
1.3E-5 \$OAHCACFE\$
2.4E-6 \$OAHCECNE\$

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR RDVALBLK

DLTBLK (EODMRR).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR DLTBLK
DLTEON.

STATEMENT EXECUTION REQUIRED 0.059 SECONDS FOR DLTEON
GENFTEON (METHOD1\$ RRCBDE/ EODMRR* PROBABILITY/ 1E-12, RRCBDE).

TOP EVENTS OF RRCBDE

1. G1

SETS USER PROGRAM SEGMENT PRODUCED BY GENFTEON
LDBLK (RRCBDE).
SUBINEON (G1, G1).
TRNTRMVAL (PROBABILITY/ 1E-12, RRCBDE* G1, G1).
FRMBLK (EODMRR* ONLY\$ G1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR GENFTEON
LDBLK (RRCBDE).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR LDBLK

SUBINEON (G1, G1).

STATEMENT EXECUTION REQUIRED 0.061 SECONDS FOR SUBINEON

TRNTRMVAL (PROBABILITY/ 1E-12, RRCBDE* G1, G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION
3 TERMS CONTAIN 1 VARIABLES
1 TERMS CONTAIN 2 VARIABLES
2 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS GENERATED 6.

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
(THE SUM OF THE TERM VALUES IS 6.003701130000E-03)

EXPANSION TOOK 0.049 SECONDS.

TERMS RETAINED BY SIMPLIFICATION
3 TERMS CONTAIN 1 VARIABLES
1 TERMS CONTAIN 2 VARIABLES
2 TERMS CONTAIN 3 VARIABLES
TOTAL TERMS RETAINED 6.
SIMPLIFICATION TOOK 0.000 SECONDS.

FACTORIZATION TOOK 0.000 SECONDS.

STATEMENT EXECUTION REQUIRED 0.049 SECONDS FOR TRNTRMVAL
FRMBLK (EODMRR* ONLY\$ G1).

EQUATION BLOCK EODMRR
HAS BEEN ADDED TO THE BLOCK FILE

STATEMENT EXECUTION REQUIRED 0.061 SECONDS FOR FRMBLK
LDBLK (EODMRR).

STATEMENT EXECUTION REQUIRED 0.051 SECONDS FOR LDBLK

COMPUTEBLOCK (PROBABILITY, RRCBDE).

SETS USER PROGRAM SEGMENT PRODUCED BY COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RRCBDE* G1).

STATEMENT EXECUTION REQUIRED 0.000 SECONDS FOR COMPUTEBLOCK

COMTRMVAL (PROBABILITY, RRCBDE* G1).

THE MAXIMUM NUMBER OF TERMS THAT CAN BE
GENERATED BY EXPANSION IS 6.

TERMS GENERATED BY EXPANSION

3 TERMS CONTAIN 1 VARIABLES

1 TERMS CONTAIN 2 VARIABLES

2 TERMS CONTAIN 3 VARIABLES

TOTAL TERMS GENERATED 6.

EXPANSION TOOK 0.000 SECONDS.

* * * * VARIABLE OCCURRENCE TABLE * * * *

NUMBER OF OCCURRENCES	NONCOMPLEMENT VARIABLE	NUMBER OF OCCURRENCES	COMPLEMENT VARIABLE
	OAACAHUA	1	
	OAHCNHUO	2	
	OAASFHUN	2	
	OAHCACFK	1	
	OAHCCECEK	1	
	OAHCACFI	1	
	OAHCACFE	1	
	OAHCCECNE	1	
	OAHCCECNM	1	

THERE ARE 9 DIFFERENT VARIABLES IN THE
EQUATION FOR G1

TERM PROB.
NUMBER OF TERM

G1 =

1 3.0000E-03 OAACAHUA +
2 3.0000E-03 OAHCECNM +
3 2.4000E-06 OAHCECNE +
4 1.3000E-06 OAHCACFI * OAHCACFE +
5 5.0000E-10 OAHCNHUO * OAASFHUN * OAHCECEK +
6 2.6000E-10 OAHCNHUO * OAASFHUN * OAHCACFK

THE MAXIMUM TERM VALUE FOR COMPUTATION 1 IS 3.000000030000E-03
(THE SUM OF THE TERM VALUES IS 6.003701130000E-03)

STATEMENT EXECUTION REQUIRED 0.109 SECONDS FOR COMTRMVAL

END EXECUTION OF SETS.

Appendix K:
SETS Computer Code

Appendix K: SETS Computer Code

Computer codes have been used to evaluate the fault trees and to use boolean algebra and reduction to obtain the smallest groups of events (cut sets) which may lead to an undesirable incident. These groups of events are then ranked from highest probability of occurrence to lowest. Cut sets with probabilities below a determined threshold are not considered viable. Outputs from these codes, for every fault tree, have been included in the appendices. A very simple discussion follows to explain that information.

The first page or two gives a written hierarchical representation of all event descriptions included in the graphical fault tree. Contributing event descriptions are indented, similar to subtopic items in an outline.

The next one to five pages are the graphical fault tree output. The top event, generally labeled Gate1, gives the process and the undesirable event described in the fault tree. Events are connected with AND and OR gates (horseshoes with flat or peaked bottoms), and sometimes transfer gates (triangles). The lowest level events are either basic events (circles) or undeveloped events (diamonds).

Output from the SETS code follows the graphical output. It lists the input/output files and the program options selected. The section beginning with RDFT (filename) looks for cycling or loops in the fault tree. Each AND (AG\$) and OR (OR\$) gate is examined. Gates and events feeding up and into that gate are listed (IN\$), as well as the gates which break down and include the gate being examined (OUT\$). Single and multiple occurrences of low level events (UE\$ undeveloped events and BE\$ basic events) are traced up to their higher level gates (OUT\$). Multiple occurrences of low level events and transfers are indicated with a number in the graphical fault tree.

The section beginning with RDVALBLK (filename) listed the probabilities of occurrence that were input for each of the basic and undeveloped events. After some program execution statements, the calculated output begins.

In the TRNTRMVAL statement, the cut set cutoff value PROBABILITY/ 1E-12 is given. This means that cut sets with values smaller than 1.0×10^{-12} are eliminated during the algebraic expansion process. EXCEPTNONCMP\$ GATE_x means that events feeding into GATE_x should not be expanded and computed. During the simplification process, the rules of boolean algebra are applied to reduce the numbers of terms by elimination of cut sets that are not minimal. The entire algebraic expression is requantified to determine the SUM OF THE TERM VALUES. This sum is the probability of one occurrence of the top gate in the fault tree and is equivalent to the sum of all the minimal cut set probabilities. The number of term retained after simplification gives the number of minimal cut sets and the breakdown by number of variables in each minimal cut set. The Variable Occurrence Table gives the number of minimal cut sets in which each low level event (variable) appears. The last section of the output numbers all of the remaining minimal cut sets, gives the cut set probability (PROB. OF TERM), and lists the events in each cut set (under the GATE1 = header).

The SETS Code Document [WOR78] gives more detail on the options and outputs of the SETS code. The Fault Tree Handbook (NUREG-0492, January 1981) discusses fault trees

and solution methods in general, and is an excellent source.

Appendix L:
Terminology / Definitions / Acronyms

Appendix L: Terminology / Definitions / Acronyms

- ADB - access denial blocks or barriers. These are the two-piece concrete blocks placed in front of the closed magazine doors. They are informally referred to as the big rocks.
- ADB mover - The heavy-duty 30,000 pound capacity lift truck for moving the access denial blocks in front of the magazine doors.
- AGV - automated guided vehicle
- ALARA - As Low As Reasonably Achievable. Current federal regulations call for exposures to be ALARA.
- AL-R8 pit container - The pit is held in place on a wire frame/rack and is surrounded with Celetex insulation (a high-density wooden pressboard). The pit drums are fairly light in weight for their size.
- boom - The attachment for the shielded lift truck (and the AGV) used for staging palletized drums in the Stage Right configuration.
- bumpers - overrun chocks within the magazines at the end of the center guide rails
- container - The AL-R8 pit container.
- drum - The AL-R8 pit container.
- drum closure - Consists of a band around the upper lips of the drum, secured with a bolt.
- lift truck - Lift trucks may have either the boom attachment or the fork with fork carriage. No Zone 4 lift trucks may be gasoline powered. The heavy-duty lift truck for the access denial blocks is permitted to be diesel, but must remain over 25 feet from opened magazine doors. All other lift trucks must be electric.
- mast - The portion of the magazine lift truck that provides hydraulic hoisting and lowering of the loaded pallet. The traverse frame attaches to the mast. In turn, the pivot boom travels along the traverse frame and has the rotator attached at its end. Either the fork carriage or the boom attachment can be attached to the rotator.
- overrun chocks - A 2.5 inch barrier installed to prevent the magazine lift truck from traveling too far and impacting the magazine rear wall.
- pallet - The frame that is used to hold AL-R8s in either the four-pack or the six-pack configuration. The boom attachment is inserted into a diamond-tube at the top of the pallet. The pallet also has forking tubes for use by forked lift trucks.
- pallet trailer - The low-to-the-ground-level transport vehicle for pallet transfer between zones at Pantex Plant.
- pallet turner - The assembly attached to the staging ramp for pallet turnover from / to the vertical drum position used by apron lift trucks to the horizontal drum

- position used by the shielded lift truck within the magazine. Sometimes called the turnover assembly.
- magazine - The storage repository for the pit containers. It is sometimes referred to as an igloo.
- SAR - Safety Analysis Report
- shielded lift truck - The lift truck with the boom attachment and added radiation shielding for use within the magazine.
- stage - To place in an storage location for an interim period of time.
- tie down - Straps to secure material or drums for transport.
- trailer - The vehicle that is used to transport pit containers from Zone 12 to Zone 4. The current trailer is a transport with a support trailer. It requires a lift truck and a turning turret on the support trailer for unloading, as well as an apron lift truck. The new pallet trailer is a lowboy, which requires only the apron lift truck.
- tucked position - When the shielded lift truck is in the tucked position, the boom is fully retracted and in its home position in front of the lift truck. The boom may be in a raised or lowered position and still be in the tucked position.

Appendix M: References

Appendix M: References

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