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FEMA/RAM Analysis for the Multi-Canister Overpack Handling Machine

*Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management*

*Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200*

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P.O. Box 1000
Richland, Washington

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FEMA/RAM Analysis for the Multi- Canister Overpack Handling Machine

C. E. Swenson
Fluor Hanford


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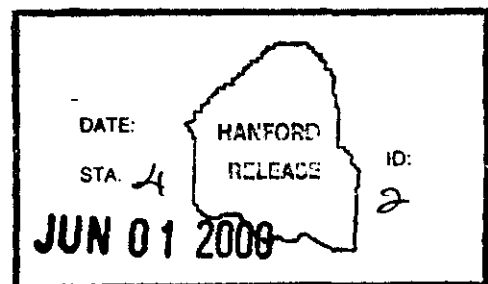
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**FMEA/RAM ANALYSIS FOR THE MULTI-CANISTER
OVERPACK HANDLING MACHINE**

Prepared for

DE&S HANFORD
Purchase Order MAA-SLB-A06272
Report No. 974502-002
Revision 0

September 23, 1997

Prepared by

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Applied Research & Engineering Sciences

97RL0924

September 23, 1997

Mr. Craig Swenson
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**SUBJECT: DE&S HANFORD, INC., PURCHASE ORDER MAA-SLB-A06272 -
TRANSMITTAL OF THE FAILURE MODES AND EFFECTS ANALYSIS
AND RELIABILITY, AVAILABILITY, AND MAINTAINABILITY
ANALYSIS FOR THE MULTI-CANISTER OVERPACK HANDLING
MACHINE**

Dear Craig:

Attached are five copies of the final ARES Corporation Report 974502-002, Rev. 0,
FMEA/RAM Analysis for the Multi-Canister Overpack Handling Machine. Transmittal of this
report completes all activities associated with this task.

Thank you for the opportunity to complete this work. If you have any questions, please contact
me at 946-3300.

Sincerely,

A handwritten signature in black ink, appearing to read "R. L. Frits".

Robert L. Frits, Vice President and
Manager, Richland Operations

RLF/lci

cc: Tony Anguiano

FMEA/RAM ANALYSIS FOR THE MHM

Report No. 974502-002, Rev. 0
September 23, 1997

FMEA/RAM ANALYSIS FOR THE MULTI-CANISTER OVERPACK HANDLING MACHINE

Prepared for

DE&S HANFORD
Purchase Order MAA-SLB-A06272
Report No. 974502-002
Revision 0

September 23, 1997

Prepared by: Mr. Robert Gauger
Dr. Amitava Ghose
Mr. Bruce Groth

Approved by:


Robert L. Fritz

Date: 9-23-97

EXECUTIVE SUMMARY

The Failure Modes and Effects Analysis and the Reliability, Availability, and Maintainability Analysis performed for the Multi-Canister Overpack Handling Machine (MHM) has shown that the current design provides for a safe system, but the reliability of the system (primarily due to the complexity of the interlocks and permissive controls) is relatively low.

No specific failure modes were identified where significant consequences to the public occurred, or where significant impact to nearby workers should be expected. The overall reliability calculation for the MHM shows a 98.1 percent probability of operating for eight hours without failure, and an availability of the MHM of 90 percent. The majority of the reliability issues are found in the interlocks and controls. The availability of appropriate spare parts and maintenance personnel, coupled with well written operating procedures, will play a more important role in successful mission completion for the MHM than other less complicated systems.

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ACRONYMS

CM	Corrective Maintenance
CSB	Canister Storage Building
DESH	Duke Engineering and Services Hanford
FMEA	Failure Modes and Effects Analysis
HEPA	High Efficiency Particulate Air
IEEE	Institute of Electrical and Electronics Engineers
MCO	Multi-Canister Overpack
MDT	Mean Down Time
MHM	MCO Handling Machine
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
PM	Preventive Maintenance
RAM	Reliability, Availability and Maintainability

1.0 GENERAL

The Canister Storage Building (CSB) Multi-Canister Overpack (MCO) Handling Machine (MHM) is designed for handling MCOs at the Hanford Site Spent Nuclear Fuel Canister Storage Building. The MHM is a large complex piece of machinery that is required to perform its mission and functions in a safe and reliable manner. This report describes the results of a Failure Modes and Effects Analysis (FMEA) and a Reliability, Availability, and Maintainability (RAM) Analysis conducted on the MHM by ARES Corporation under contract with Duke Engineering and Services Hanford [(DESH) 1997].

1.1 Purpose

The FMEA was conducted as a means to evaluate the designed safety features of the MHM and identify any undesirable failure modes which should be mitigated or eliminated. The RAM was conducted to determine if the overall reliability of the MHM would be sufficient to safely meet the required throughput rate of the MCOs to be delivered to and stored in the CSB.

1.2 System Definition

The MHM is essentially a crane system designed for the mission of transporting MCOs within the CSB from a receiving station to storage tubes, and vice versa, in an inert and shielded environment. Several functions are involved in performance of this mission, such as:

- Collecting an MCO from the MCO service station or storage tube,
- Depositing an MCO into a storage tube,
- Delivering an MCO to the Hot Conditioning Facility,
- Collecting an MCO from the Hot Conditioning Facility,
- Transferring an impact absorber from the exchange facility to a storage tube,
- Transferring an impact absorber from a storage tube to the exchange facility, and
- Replacing a tube plug.

A brief description of the subsystems which comprise the MHM system follows.

1.2.1 MHM Description

The MHM consists of two main structures, the crane system and the shielded turret system. The Crane System consists of the trolley and control panel, girders, end ties, wheel trucks and seismic clamps. The shielded turret or cask system includes the MCO cask body, MCO hoist, ventilation and inert gas system, tube plug hoist, TV navigation

cameras, shield skirt and turntable.

- The crane has a bridge that provides travel in the North-South direction and a trolley that provides travel in the East-West direction.
- The shielded turret system is mounted on the trolley and has a turntable to align one of three cavities (TV navigation, tube plug hoist, and MCO hoist) with the shield skirt port that is aligned with a storage tube or other MCO handling location.
- The TV navigation camera cavity contains two closed circuit television cameras that are used by the operator to navigate the MHM to the desired location and closely align it over a storage tube.
- The tube plug hoist cavity contains a lead screw type hoist and grapple for lifting, temporarily storing, and reinstalling a storage tube shield plug. The MCO hoist cavity provides a shielded cask for temporary storage of the MCO during transport, and a double reeving cable hoist and grapple system for raising and lowering an MCO in a storage tube. All three cavities and the shield skirt area are actively ventilated and maintained in an inert atmosphere by a helium purge from the ventilation and inert gas system. All exhaust paths in the ventilation system contain two High Efficiency Particulate Air (HEPA) filters to maintain control of airborne radioactive particulates.

1.3 Scope

The FMEA and RAM conducted for this report only considered the systems described above. It specifically did not address the supporting utility systems, such as electrical power, or the structure within which the MHM is located. Also, the studies were conducted at a major component level as opposed to a piece and part level for the analysis to be at a sufficiently macroscopic level to be of maximum benefit. Even so, at the level at which the study was conducted, over 500 individual components were addressed.

1.4 Objectives

The objective of the studies was to make recommendations for improvements to the MHM for safety and reliability considerations. More specifically, these recommendations were to be based on determining whether there are any failure modes that could be identified that had the potential to result in undesirable consequences from a safety standpoint, and whether the MHM was

reliable enough to meet required throughput rates.

2.0 ANALYSIS METHODS

2.1 Designation of the Subsystems for Analysis

In order to conduct the FMEA and RAM analyses, the MHM was first broken down into the following subsystems. These subsystems closely follow the description provided above and the subsystems described in the 90 Percent Design Report (GEC 1997a). A notable exception was that for the purposes of the FMEA, a separate subsystem for the controls is not defined. Rather, the controls were described as associated with each mechanical subsystem. This method was chosen so that a "book-keeping" method would be available to determine the effects of individual control components failing. However, for the RAM analysis the control system is considered as a whole for reasons that are described in Section 2.4. The subsystems and their description are:

- **Bridge Travel**

This subsystem provides the bridge that supports the MHM and MHM trolley, controls the allowable movement of the bridge unit, and provides indication showing movement status. The bridge provides North-South movement of the MHM.

- **Trolley Travel**

This subsystem supports the MHM and allows for trolley movement in the East-West direction.

- **Turret and Turntable Assembly**

This subsystem provides a turret assembly for the MHM that can be rotated to one of three positions to align the requisite MHM cavity over the corresponding turret opening. The three positions are the MCO hoist cavity, the tube plug hoist cavity, and the navigation camera cavity.

- **Tube Plug Hoist and Grapple**

This subsystem supplies the hoist and grapple necessary to remove the plug at the top of the MCO storage tube, and temporarily store this plug in an MHM turret cavity for

subsequent operations.

- **Nose Unit, Shield Skirt, Sealing System**

This subsystem supplies radiation shielding and an integral seal between the MHM and the MCO storage tube while raising or lowering an MCO.

- **MCO Hoist and Enclosure**

This subsystem provides a hoist for raising and lowering of an MCO from the MHM to the storage tube. This hoist is also used for handling the impact absorbers that are placed in the storage tube.

- **MCO Grapple**

This subsystem provides a grapple for the MCO hoist for both the MCO and the impact absorbers that are placed in the storage tube.

- **Navigation System**

This subsystem provides two navigation cameras on the MHM for accurately aligning the turret opening over a storage tube.

- **Ventilation and Inerting System**

This subsystem provides exhaust ventilation on the MHM for control of any MCO offgas. In addition, the inerting system maintains an inert atmosphere in the MHM to prevent possible deflagration in the event that hydrogen is relieved through an MCO pressure relief valve.

2.2 Method Used for FMEA

An FMEA is a flexible design analysis tool that is useful for providing input to design from component concept through development. The extent of effort and sophistication of approach used in the FMEA is dependent upon the specific requirements of an individual program. This makes it necessary to tailor the requirements and conduct of an FMEA to each program. Therefore, the methods used to perform the MHM FMEA are described here in some detail. Further information can also be obtained from the references cited. In general, the guidelines of MIL-STD-1629A (DOD 1980) were used in conducting the FMEA.

A typical FMEA systematically reviews the one-line drawings (e.g., P&IDs) to identify failure modes associated with the system. However, for the MHM the only one-line drawings available were for the ventilation & inert gas system. Therefore, a combination of mechanical drawings, control logic diagrams, electrical elementary drawings, design reports, and an Interlock Requirements Schedule (GEC 1997b) were the primary sources of information used. A complete list of all documentation provided is contained in Appendix A. It should be noted here that complete updated elementary diagrams were not received until a majority of the analysis had been completed using the control logic diagrams. The consistency of information between the updated elementaries and the completed analysis was reviewed, and where needed, the elementaries were used to enhance the information in the FMEA worksheets prepared using the control logic diagrams.

The performance of the FMEA can best be described by the manner in which the FMEA worksheet utilized for this analysis was developed. An example of the worksheet used, along with a more detailed description of the information contained in each column, is included in Appendix B. The various components (switches, relays, contacts, instruments, etc.) necessary for each subsystem to operate were identified and recorded on the individual FMEA worksheets. The principal failure modes of interest for these components were determined from such sources as FMD-91 (RAC 1991), engineering experience, and engineering judgement. The effects (or consequences) of a failure mode for each component was determined from both a local standpoint and a system wide standpoint (end effect) and recorded. In addition to the effects of the failure, features of the design that mitigate the effects were also recorded. Mitigating features include redundant systems that lessen the probability of a failure occurring, or features that limit the severity of the consequences should the failure occur. Both failure effects and mitigating features were evaluated through documentation review, conversations with engineers and maintenance personnel, and past engineering experience. Finally, methods of identifying the failure were determined and a severity class was assigned. Further information on failure modes and effects is contained in sections 2.3.1 and 2.3.2, respectively.

For this FMEA, the means of identifying the failure was included only if it was explicit. In many cases, whether or not a failure is detected is based upon how the system is being operated at the time. If the component may not have been in use at the time of failure, and there was no clear indication to the operator that it had failed, then the means of identifying the failure was listed as "None". This does not mean that the failure cannot be detected at all, but that it may only be found during certain operations or during maintenance.

The severity class was assigned to provide a qualitative measure of the worst potential consequences resulting from component failure. Using the guidelines of MIL-STD-1629A and the needs of the project, the following severity classifications were used.

- **Category I**

Catastrophic - A failure which may cause death, offsite toxic or radiological consequences, or system loss (MHM) of greater than one month. Offsite is considered outside the Hanford Site boundaries.

- **Category II**

Critical - A failure which may cause severe injury, major property damage, toxic or radiological consequences outside the CSB (onsite), or system loss (MHM) of greater than one week.

- **Category III**

Marginal - A failure which may cause minor injury, minor property damage, toxic or radiological consequences confined to the CSB, or system loss (MHM) of greater than 24 hours.

- **Category IV**

Minor - A failure not serious enough to cause injury, property damage, toxic or radiological consequences, and system loss (MHM) is less than 24 hours.

The consequences were based on engineering judgement and experience. The end effects noted for the consequences were also based on the governing item that determined the severity class.

2.2.1 Consideration of Failure Modes

All predictable failure modes for components analyzed were considered. Where failure modes resulted in the same effect, they were usually considered under one failure mode. For example, a motor failing to start or failing to run had the same consequences in most cases and the failure mode was listed as motor fails to start/run. The potential failure modes were determined by examination of the item in assembly and one-line drawings. To assure that a complete analysis was performed, FMD-91 (RAC 1991) was used and the general modes shown below were considered by the analysts in all cases. Only those failure modes deemed to be of interest by the analyst were recorded on the FMEA worksheets.

- Premature operation,
- Failure to operate at a prescribed time,
- Intermittent operation,
- Failure to cease operation at a prescribed time,
- Loss of output or failure during operation,
- Degraded output or operational capability, and
- Other unique failure conditions, as applicable, based upon system characteristics and operational requirements or constraints.

2.2.2 Consideration of Failure Effects

The consequences of each assumed failure recorded were identified, evaluated, and recorded on the FMEA worksheet. For this FMEA, the consequences were described in terms of local and end effects. Local effects concentrated specifically on the impact an assumed failure has on the operation and function at the level under consideration. The purpose of defining "local" effects is to provide a basis for evaluating compensating or mitigating provisions and recommending corrective actions. It is possible for the local effect to be the failure mode itself.

End effects represent and define the total effect an assumed failure has on the operation, function, or status of the uppermost system (i.e. the MHM). For the FMEA all end effects considered only the failure described and not double failures. Double failures were considered to be beyond the scope of this effort and have been addressed and will continued to be addressed by safety analysis. The end effects also documented the primary consequence that drove the severity classification. For example, if a component failure caused the MHM to shutdown and the repair took greater than 24 hours, this would be noted in the end effects column of the FMEA worksheet, and a severity class of III was assigned.

2.3 Method Used for Reliability and Availability Analysis

Several methods of reliability analysis could have been selected including:

- **Fault-tree analysis** - uses a process or system analysis technique based on a detailed logic model that represents the status and conditions for an undesirable top event to occur.
- **Event tree analysis** - a method of displaying a large number of accident sequences in a systematic manner. The analysis starts with an initiating event and then

displays the alternate subsequent events, often with their numerical probability.

- **Failure mode and effect analysis** - a process for identifying and documenting causes and modes of each component failure and the consequences of such failure.
- **Reliability block diagram analysis** - uses an analysis technique in which the logical and sequential arrangement of blocks and lines depict the effect of a failure on the overall process or system. The block diagram closely resembles a typical single-line or process flow diagram so that it is easily constructed and understood. This analysis provides a convenient basis for proceeding to one of the other more specialized analyses shown above.

2.3.1 Use of the Reliability Block Diagram Method

The reliability and availability analyses of the MHM system were developed using an RBDA+ reliability block diagram analysis program. The advantages of use of such a computerized program are that the results provide the following:

- A means of developing an easily-changed block diagram reliability or availability model that represents both essential and critical functions of the system.
- The basis for calculating both the availability and the probability of success of the system.

This model can be modified or expanded, thereby providing the capability to analyze the reliability of alternative configurations and equipment in any follow-on studies.

For a more detailed discussion of the capabilities of the RBDA+ analysis program as well as guidelines for understanding the model, see Appendix C.

2.3.2 Steps in Preparing the Reliability and Availability Analysis

An introduction to reliability analysis is provided in Appendix C. The following paragraphs detail the specific reliability analysis process utilized in this report.

As a first step, the system and subsystems were defined and the method of operation reviewed. Using this, the FMEAs were developed for nine of the subsystems. Each of the reliability block diagrams was developed directly from the FMEAs.

Actually, two models were developed for each subsystem. One model included the controls and logic elements that must function for success of that particular subsystem. Because many of the sensors and switches that determine success affect more than one subsystem, they are shown on each of the subsystem diagrams. If these data were combined and used for system calculations, it would be overly conservative.

In order to provide data for a more exact calculation of system reliability, a second model was prepared for each subsystem. This model did not include any of the limit switches, relays, or logic elements. Using the elementary diagrams, these items were counted separately at the system level and included in one group for the entire system. The count of the control and logic elements and the failure rates/down time information for appropriate elements has been included as Appendix D.

In the first analysis, all the control elements were included at the subsystem level. In the second analysis, the control and logic components were excluded at the subsystem level and calculated separately at the system level. This provided data for a more detailed analysis of the impact of the controls on system operation.

2.3.3 Failure Modes

The FMEA shows the more likely failure modes for each component. Though not all failure modes would result in an immediate failure of the system, a more careful analysis showed that almost all of the failure modes would prevent the system from completing its full cycle--estimated at eight hours. An example is the X and Y channels. In a few cases, such as for the nose and cask extraction units, the two control systems were found to be redundant and have been modeled that way. In most cases, it was found that the X and Y channels were redundant as far as protection (system shutdown) is concerned, but that the failure of either the X or Y channels would subsequently prevent the system from accomplishing its mission. In these cases, the X and Y channels were modeled in series.

The FMEA also shows the failure effects of each component at both the local and subsystem level. With few exceptions this has resulted in system failure.

The notable exception is some of the emergency components, such as the handwheel. These are strictly for safety and not needed for operation. As a result, they have not been included in the reliability model.

2.3.4 Redundancy

A review of the system showed many applications in which the X and Y channel controls and logic were redundant for shutdown and safety concerns but were not redundant for operation. It was noted that a failure in either the X or Y channel would subsequently cause a system failure that would prevent completion of the mission. Where this was the case, all blocks were modeled in series.

In those cases (such as the nose and cask extraction systems) where the system could operate on either channel, they have been modeled as redundant.

2.3.5 Operational Mode

It was realized that certain of the component failures would not cause an immediate shutdown if they were not currently in use. These component failures were considered system failures if they would subsequently prevent the MHM from completing its total mission.

2.4 References and Data Sources Used for the Analysis

The basic system data was provided by DESH and prepared by GEC Alsthom and Ederer Cranes. This data was supplemented by discussion with DESH personnel on functionality, downtime estimates, and maintenance philosophy. These personnel had operating experience under similar conditions. In a few cases, industry standard figures were available. Utility surveys and Army-sponsored surveys have provided data for some of the more common components. It should be noted that repair and restoration times vary widely and depend on the maintenance policy and spares policy at each site.

Component failure rate data was available from many sources, including IEEE Std-500, IEEE Std 493-1990, Reliability Analysis Center (RAC) NPRD-95, RAC NPRD-3, NPRD-91, RAC EPRD-97, and other military and utility data sources.

Because of the special nature of many of the components, published failure rate data was not available. In these cases, expert opinion and comparison with similar items were used. See Appendix E for a more complete listing of the published reference data.

2.5 Assumptions Made in Modeling

Several assumptions were mentioned earlier, including the assumption that all failure modes would subsequently result in system failure.

More basic assumptions include:

- The system will have been thoroughly checked before use and is operational at time zero.
- All failures are random.
- No wear out will be experienced during the relatively short time the equipment is required to operate.
- Repair personnel are available on call, 24 hours a day. Repair time estimates allow for a maximum response time of two hours.

Most items are available as spares in a nearby warehouse. If this is not true, the mean down time shown may need to be modified unless specifically discussed in the FMEA worksheet.

For the control and interlock systems, it was assumed that each limit switch or contact operated a relay and the failure rate assumed included both the contact and the relay coil.

Assumptions were also made as to the complexity and failure rates of items that could not be further identified. These included the hydraulic power unit, the variable speed controls, the resolvers, and the brakes.

2.5.1 Factors Specifically Not Included

It should be noted that the following factors may have a significant impact on the system reliability or availability, but have not been included in this analysis:

- Human reliability - Particularly during the early period, operator error could be significant. The same will be true after the system has not been used for many years. Until such time as operating procedures, training programs, operator qualifications, etc., are established, the impact of operator error cannot be calculated.
- Software Reliability - This is normally a major contributor to system reliability

calculation. Relatively little new or non-standard software is used here, so this will not be a major factor.

- Availability of offsite utilities, such as electric power. The reliability of electric power onsite is understood to be very high; therefore, this contribution should be minimal.
- Availability of main-line helium. This supply should be very reliable, and the impact of this item should be minimal.

2.5.2 Assumptions Regarding Certain Failure Rates

In several cases, no data could be found that related directly to special components, such as the festoon and the grapple and jaws. No industry survey to find where similar items had maintained and repaired was performed as part of this report. Interviews with local personnel and the gathering of expert opinion was utilized and should provide acceptable model input.

2.6 Development of Models

As noted earlier, the complete reliability and availability models were developed directly from the FMEA diagrams, and therefore, they follow the FMEA, block-by-block.

The initial models included all control and logic and predicted the reliability and availability of each individual subsystem. It was often difficult to determine whether all the components were included only once in the model particularly for the control and interlock systems.

Because of the commonality and sharing of the logic between subsystems, it was necessary to prepare a second system-level calculation in which all logic was grouped together. This had the advantage that it showed the failure contribution by all logic and controls and assured that an overall accurate calculation of reliability could be obtained.

3.0 FINDINGS FROM THE ANALYSES

3.1 Results of the Failure Modes and Effects Analysis

The complete FMEA worksheets for the MHM are located in Appendix F. The results of the FMEA show that there are very few potential system failure modes that could result in a

significant safety hazard. All failure modes that were identified as having a severity classification of II were either failures of variable speed drives that were identified as taking greater than one week to replace, or gross structural failures of major load bearing components which are highly unlikely to fail. In order to assure that these structural components are unlikely to fail, it is recommended that the design and fabrication criteria be closely reviewed for appropriate safety margins and quality assurance requirements. The structural components identified were:

- MCO grapple structural load path components,
- Tube plug grapple structural load path components, and
- Tube plug hoist lead screw.

Another result of the FMEA is that nearly all of the failures investigated will require component replacement action to correct. It is, therefore, very important that spare parts lists are accurate and that the spares are maintained in a ready inventory. A number of the same components are used in several places so the total number of spare items can be reduced.

A final result of the FMEA is the observation that the MHM system is complex, and when failures occur, they may be difficult to diagnose. It will be very important to thoroughly train both operations and maintenance personnel to be familiar with the likely failure modes, some of the indications of those failures and procedures to trouble shoot based on the indications.

3.2 Results of the Reliability and Availability Analysis

The 18 RBDA reliability and availability analysis models and their calculations are shown in Appendix G. Assistance in interpreting the models can be found in Appendices C and D.

Note that data is provided regarding the failure rate, restore time or mean down time (MDT), availability, and unavailability of every component, each subsystem, and the overall MHM system. In addition, grouping of the failure rates permits estimating the portion of the failures and down time that are attributed to control and logic components.

Probably the best summary of the reliability and availability calculations can be seen in Figures 1, 2, and 3. Figure 1 shows the relative frequency of failure of the subsystems. The frequency of failure is shown in failures per hour. If mean time between failures (MTBFs) is needed, the MTBF is the reciprocal of the failure rate.

Because much of the control system and logic is shared by several systems, the individual system results cannot be combined directly to provide a system reliability result. To show this, a

separate calculation is required. The results of this calculation are shown in Figures 2 and 3. For these displays, the control system and logic failure rate have been removed from each system and displayed as one slice of the pie.

Examination of the data shows that the control systems and logic account for approximately 50 percent of all system failures. It may be noted that the turret and turntable assembly is the major contributor to the longest bar in the frequency of failures display shown in Figure 1, yet the turret is not a major contributor to the failure causes or outage time shown in Figures 2 and 3. This is due to two factors. First, the major failure causes for the turret and turntable are the controls and logic. In Figures 2 and 3, the controls and logic have been removed for the turret segment and included as part of the controls. The second factor is that the mean down time for the turntable and turret assembly is relatively low, as controls and logic can be replaced or repaired in less time than other components. However, because this system can be repaired rather quickly, it accounts for only approximately 28 percent of the system down time.

The data provided allows for many useful calculations. Findings that may be particularly useful in subsequent calculations are:

- As an operating system the MHM has an availability of about 90 percent. This means that if the MHM is operated continually, it can be expected to require maintenance about 870 hours per years.
- As an operating system, the MHM has an estimated failure rate of 2,880 failure per million hours.

If all systems are operating at the start, there is a 98 percent probability that the system will operate successfully for the next eight hours.

3.3 Open Items

The FMEA and RAM analyses were conducted with the design of the MHM at the 90 percent complete level. Therefore, open items have been documented to assure that future design changes and design completion consider the findings of these analyses.

- The MCO hoist subsystem design was not yet at the 90 percent level, and the analyses were performed to the level of detail available. Because of the lack of design details, it was not clear whether there were any mitigating circumstances for an MCO hoist brake failure. Some mitigation, such as a backup brake, needs to be added in order to prevent an MCO load drop if the primary brake should fail.

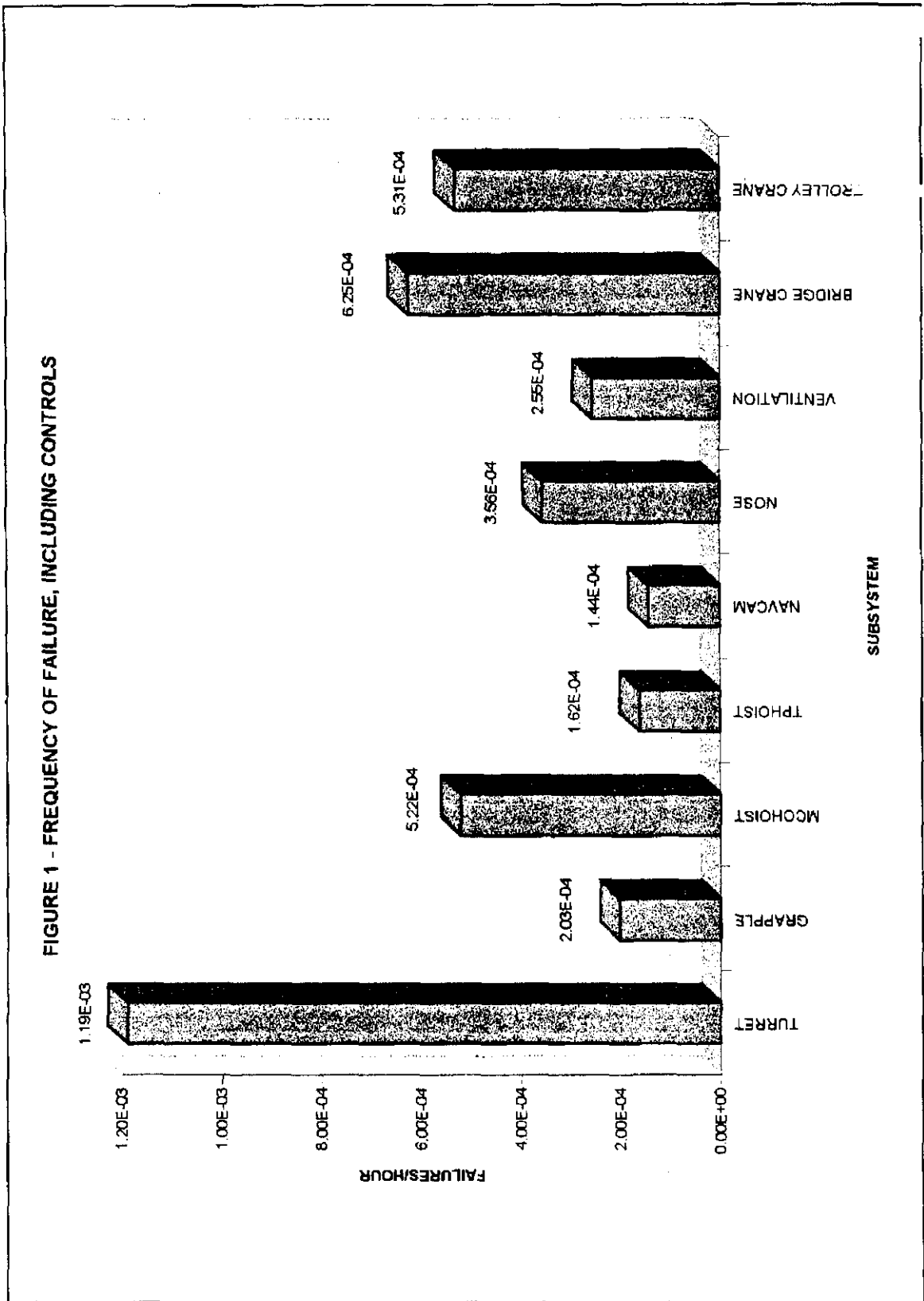


FIGURE 2 - COMPARISON OF FAILURE CAUSES

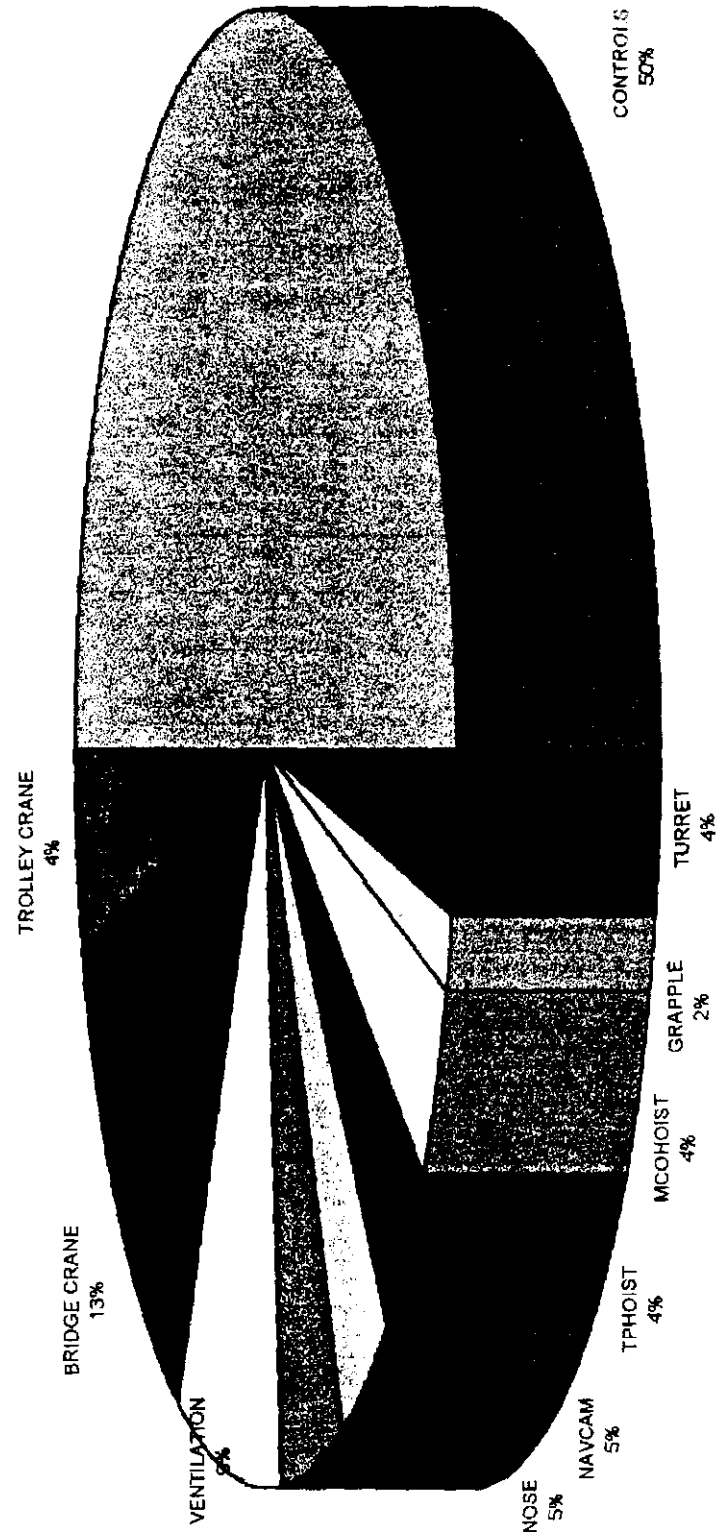
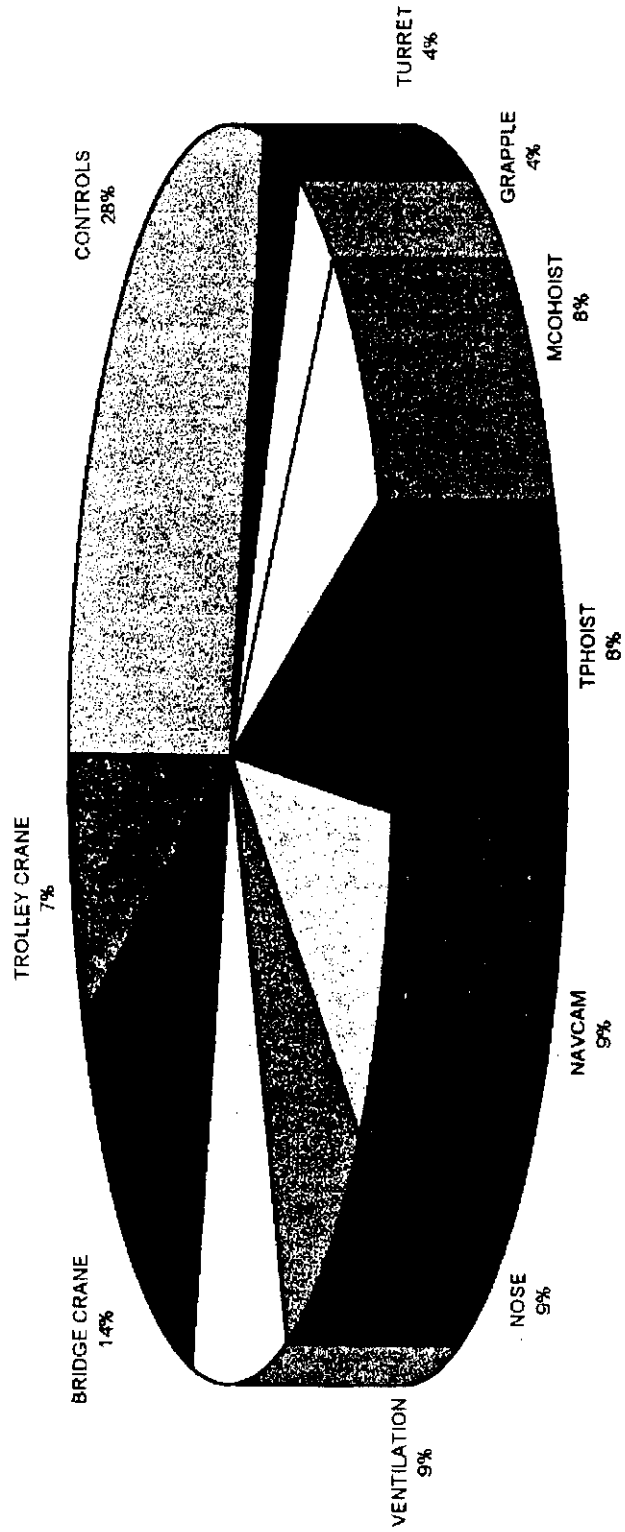


FIGURE 3 - COMPARISON OF OUTAGE TIME



- Operating scenarios for the MHM are still being developed. The RAM models for this report assumed an eight hour operating period for receiving and depositing an MCO in a storage tube. Changes to this number will affect the calculated probability of success.
- Revised elementary diagrams were not received until the RAM analysis was nearly complete. The control logic diagrams were used to estimate the number of switches, and relays involved in various control commands. This technique should be sufficiently accurate for the purposes of this report. At such time as final elementaries are available, a review of changes can be made to see if any changes to this report are warranted.

4.0 RECOMMENDATIONS

The MHM is designed to be a very safe system and the FMEA reflects this. However, to provide this level of safety, active interlock controls are used which affect the overall system reliability and availability. The following are recommendations for improving the reliability and availability if it is deemed appropriate.

- The control system is designed to be redundant from a safety aspect, but not from a reliability aspect. A thorough review of the safety needs should be conducted to determine if the number of control interlocks can be reduced. Additional redundancy could be provided for reliability, but this would be costly at the current state of project completion.
- The ability to maintain and repair the MHM will be very important in the availability of the MHM. Thorough training of both maintenance and operations personnel is encouraged. Spare parts must be reviewed and adequate inventory maintained in an available location.
- Initial startup and restart procedures need to be detailed and thorough to minimize the probability of failures occurring during operations.
- Operators should be thoroughly trained to reduce failures due to operator error. They should also be trained in the manual alternatives available for MHM operations.
- Although the vent system by itself is comparatively reliable, deletion of the inerting system that has been proposed would improve the reliability by reducing the number of interlocks that are associated with other subsystems.

5.0 REFERENCES

- DESH 1997, *Statement of Work for Engineering Technical Services for Spent Nuclear Fuel Canister Storage Building*, FAX Transmittal, July 7, 1997, Anthony Anguiano (DESH) to Bob Fritz (ARES), DE&S Hanford, Inc., Richland, Washington.
- DOD 1980, *Procedures for Performing a Failure Mode, Effects and Criticality Analysis*, MIL-STD-1629A, U.S. Department of Defense, Washington D.C.
- GEC 1997a, *Hanford MHM - Phase III (90%) Design Submission Report, Design File Ref. 4683/471/100*, ESL/R(96)065, rev. C, June 6, 1997, GEC ALSTHOM, Leicester, England.
- GEC 1997b, *Hanford MCO Handling Machine Interlock Requirements Schedule*, ESL/R(97)8, rev. B, June 30, 1997, GEC ALSTHOM, Leicester, England.

Appendix A
MHM Documentation Provided by DESH

FMEA/RAM ANALYSIS FOR THE MHM

Report No. 974502-002, Rev. 0
September 23, 1997

Document No.	Sheet Number	Revision	Document/ Drawing Type	Title
ESL/R(97)8	N/A	B	Report	Hanford MCO Handling Machine Interlock Requirements Schedule (revised 8/13/97)
ESL/R(96)065	N/A	C	Report	Hanford MHM Project 90% Design Submission Report - 6 June 1997
ESL 1506/2D	N/A	A	Spec.	Hanford MHM Control System Requirements Specification - Technical Specification
ESL/R(96)065	N/A	C	Drawings	Mechanical Drawings - 90% Design Submission - 6 June 1997 (Includes all drawings on index)
ESL/R(96)065	N/A	C	Drawings	Electrical Drawings - 90% Design Submission - 6 June 1997 (Includes all drawings on index)
ESL/R(96)065	N/A	C	Spec.	Specifications - 90% Design Submission - 6 June 1997 (Includes all specifications on list)
C-34650	-	B	Drawing	Seismic Restrain Assay
C-34680	-	B	Drawing	Bridge Drive Assay
C-34966	-	-	Drawing	Seismic Restrain Uplift Trolley
C-35188	-	A	Drawing	Trolley Drive Assay
C-35570	-	-	Drawing	Rail Detail Bridge Festoon
C-35625	-	-	Drawing	Support (Trolley Festoon)
C-35626	-	-	Drawing	Pusher Arm (Trolley)
EB-33056	I	E	Drawing	Crane Control Elementary Drawings - Title and Index (includes all drawings on index - rev. c and rev. d were also provided)
EB-33056	IA	A	Drawing	Crane Control Elementary Drawings - Title and Index Continued (includes all drawings on index - initial rev. was also provided)
363A0038	N/A	A	Drawing	Hanford MHM Control and Interlock Logic Diagram
HNF-S-0468	N/A	3	Spec.	Canister Storage Building Integrated MCO Handling Machine Specification
N/A	N/A	2	Comments	MHM 80% Design Review Comments
ESL/R(96)083	N/A	I	Report	Hanford MHM Project Seismic Analysis of the MCO Handling Machine

FMEA/RAM ANALYSIS FOR THE MHM

Report No. 974502-002, Rev. 0
September 23, 1997

Document No.	Sheet Number	Revision	Document/ Drawing Type	Title
ESL/R(96)99	N/A	B	Report	Hanford MCO Handling Machine Design Calculations
ESL/R(96)085	N/A	A	Report	Hanford MHM Phase III Shielding Assessment
ESL/R(97)9	N/A	-	Report	Hanford MHM Phase III Thermal Assessment
D-34964	-	-	Drawing	MHM Rotate Gear Guard
D-34968	-	A	Drawing	Turret Festoon Arrangement
D-34969	-	A	Drawing	Festoon Rail Beam
D-34970	-	A	Drawing	Vertical Supports
D-35571	-	-	Drawing	Bridge Festoon Assembly
D-35263	-	-	Drawing	Trolley Conductor Assembly (Festoon)
D-35624	-	-	Drawing	Rail (Trolley Festoon)
B-35266	-	A	Drawing	Hanger Carrier
B-35288	-	-	Drawing	Hose Clamps Top & Bottom
B-35569	-	-	Drawing	Pusher Arm (Bridge Festoon)
B-35618	-	-	Drawing	Intermediate Shaft Hex Adapter
B-35636	-	-	Drawing	Splice Guard and Step
D-35205	-	A	Drawing	Bridge Erection Drawing MHM Gantry Crane
C-35662	1	-	Drawing	Shipping Control Drawing (Bridge)
D-34960	-	A	Drawing	Trolley Arrangement
L-34597	1 thru 2	C	BOM	Bill of Material - Bridge List
L-34598	1 thru 9	A	BOM	Bill of Material - Walkway Access and Electrical List
L-34604	1	B	BOM	Bill of Material - Main Trolley List
L-34605	1 thru 3	B	BOM	Bill of Material - Trolley Wheel and Drive
1510-088	-	-	Letter	MCO Handling Machine Purchase Order MDK-SDX-452656
FRF-2825	-	-	Report	Fault Tree Analysis for MHM System - June 7, 1996
97-SFD-141	-	-	Document	Attachment 1, IRP Questions and Assignments (Informal draft provided)

FMEA/RAM ANALYSIS FOR THE MHM

Report No. 974502-002, Rev. 0
September 23, 1997

Document No.	Sheet Number	Revision	Document/ Drawing Type	Title
-	-	-	Document	MHM System Outline (Informal draft provided)
-	N/A	-	Vendor Info	GEMCO Quik-Set III, Programmable Limit Switch
-	N/A	-	Vendor Info (FAX)	General Purpose Relays
05092	N/A	-	Vendor Info	Troubleshooting the Drive

Appendix B
FMEA Worksheet Description

An example of the FMEA worksheets utilized in this report is shown on Page B-4. The worksheet is used to tabulate various information necessary to perform the FMEA. A description of the information in each column is provided as follows.

Subcomponent/Subsystem - This column provides a further breakdown of the system by defining a subcomponent or subsystem.

Component ID - This column provides the actual component whose failure is to be analyzed. Where possible, the component is identified by an existing component numbering system. If the component is not assigned a unique identifier, such descriptions as part numbers and noun names are used.

Component Fail Rate/Hr - This column provides the failure rate per hour chosen for the component. Generic sources of information as well as component specific information may be used.

Failure Mode - This column provides the modes in which the component may fail that were analyzed.

Alpha - This column provides the probability that the failure was in the mode specified in the previous column.

Local Effects - This column is used to describe the local effects of the failure. Local effects concentrate specifically on the impact an assumed failure has on the operation and function at the level under consideration. The purpose of defining "local" effects is to provide a basis for evaluating compensating or mitigating provisions and recommending corrective actions. It is possible for the "local" effect to be the failure mode itself.

End Effects - This column is used to describe the total effect an assumed failure has on the operation, function, or status of the uppermost system (i.e. the MHM). The end effects also documented the primary consequence that drove the severity classification. For example, if a component failure caused the MHM to shutdown and the repair took greater than 24 hours, this would be noted in the "end" effects column of the FMEA worksheet, and a Severity Class of III was assigned.

Failure Detection Method - This column is used to describe the ways in which a failure may be detected. The information is not required in the statement of work for this report, but may be useful where provided.

FMEA/RAM ANALYSIS FOR THE MHM

Report No. 974502-002, Rev. 0
September 23, 1997

Mitigation - This column is used to describe the mitigating features of the failure described. It may include redundant systems that lessen the probability of a failure occurring, or features that limit the severity of the consequences should the failure occur.

Severity Class - The severity class is a means of prioritizing failure modes as a function of probability of occurrence and the severity of the consequences. The following categories were used:

- **Category I** - Catastrophic - A failure which may cause death, offsite toxic or radiological consequences, or system loss (MHM) of greater than one month. Offsite is considered outside the Hanford Site boundaries.
- **Category II** - Critical - A failure which may cause severe injury, major property damage, toxic or radiological consequences outside the CSB (onsite), or system loss (MHM) of greater than one week.
- **Category III** - Marginal - A failure which may cause minor injury, minor property damage, toxic or radiological consequences confined to the CSB, or system loss (MHM) of greater than 24 hours.
- **Category IV** - Minor - A failure not serious enough to cause injury, property damage, toxic or radiological consequences, and system loss (MHM) is less than 24 hours.

The severity class assignments were based on engineering judgement and experience and not on detailed accident analysis.

Maintenance Action - This column briefly defines whether a component should be repaired or replaced in order to correct the failure. If an item is not planned to be carried in spares it is noted. In many instances where replacement has been noted, it is recognized that for some failures, repair may be possible in lieu of replacement. The most difficult maintenance action--usually replace--was noted in this column.

Remarks - This column contains additional remarks to clarify any information provided on the worksheet.

SYSTEM.
Reference Drawing:
Mission/Function:

Date:
Compiled by:
Reviewed by:

Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					

Appendix C
Introduction to Reliability Analysis

C.1 INTRODUCTION TO RELIABILITY ANALYSIS

Reliability analysis provides a formal method for evaluating a process or system from a RAM viewpoint.

- It involves the development of logical and/or mathematical models which represent the interaction among various processes, systems, and components for the occurrence of a specified system state (i.e., working, failed, etc.). Though the analysis may be qualitative or quantitative, the quantitative analyses are desired. A quantitative solution of the model requires relevant failure data, repair data, experience data, and minimum operational requirements.

There are a number of objectives that may be realized from such analysis. These can be to:

- Compare alternate system configuration from a reliability viewpoint.
- Confirm the ability of the process/system design to meet its reliability requirements.
- Identify critical areas for improvements.
- Provide input to trade-off studies, including consideration of spares.
- Provide input to maintenance and operational procedures and policies.
- Identify reliability goals for systems/processes.
- Evaluate consequences of failure.
- Satisfy regulatory requirements.

Though there are several techniques that can be used, a reliability block diagram analysis is the technique most often used for an operating process or system in which system availability and reliability is a major concern. Fortunately, a reliability block diagram closely resembles a flow diagram, a schematic, or a functional block diagram.

The reliability block diagram is really a logic chart and the arrangement of blocks and lines shows the relationship among system processes and components to indicate which components (blocks) of the system must operate successfully for the process to accomplish its intended function. It is developed through the analysis of the function relationships among the components. Each component is represented by a block. Removal of the block from the diagram

represents the failure of the components represented by the block. The blocks for redundant components are shown in parallel. Blocks representing components whose failure cause a process or system failure are shown in series. Once the reliability block diagram is constructed, the success paths of the process can be identified and reliability/unreliability of the system can be calculated.

A system is said to be a series system, from a reliability viewpoint, if all system components (blocks) must work for system success or only one needs to fail for system failure.

A system is said to be a parallel system, from a reliability viewpoint, if only one path (block) needs to be working for system success or all must fail for system failure.

The reliability of simple series and parallel circuits can be readily calculated by hand, particularly if the failure rates are low and approximations are used. Comprehensive diagrams, such as those for the MHM, are best analyzed with the use of a computer program, such as RBDA+.

C.2 HOW TO READ A RELIABILITY BLOCK DIAGRAM

For ease of illustration, the model has been constructed as a block diagram using the arrangement of the blocks to show functional or equipment relationships. The success path in the block diagram is indicated by an unbroken chain of successes or blocks from start to finish. The probability of failure (and usually the frequency of failure and restoration time) are typically indicated by the numbers shown on the corners of each block.

Blocks representing functions that cause a system failure are shown in series with the other blocks.

Most blocks in the reliability block diagram have been arranged in about the same position that they would be in a functional block diagram, although mathematically, it is not necessary to do this. This makes the reliability block diagram easier to follow and compare with the functional diagram.

The reliability and availability analysis of the MHM has been based on the following:

- Developing a series of block diagram reliability models that represent the functions of the system.
- Calculating both the unavailability and probability of success.

For ease of illustration, the model has been constructed as a block diagram that uses a block arrangement to show the interrelationship and redundancy of the equipment functions represented by the blocks. Success is indicated by a path through an unbroken chain of blocks from start to finish. The probability of failure (and usually the frequency of failure and restoration time) are typically indicated by the numbers shown on the corners of each block. The failure codes are defined below.

Corner Where Information Appears	Failure Code Information
Upper right	Availability of the component
Upper left	Unavailability (also the probability of failure)
Lower left	Failure rate per hour
Lower right	Mean down time (MDT) or mean time to restore operation, in hours

Blocks representing components or functions that cause a system or process failure are shown in series with the other blocks. For the MHM system, there is little redundancy, so most blocks are in series.

Blocks shown with the upper corners clipped are further subdivided. Another drawing shows the components that are included.

C.3 RELIABILITY AND AVAILABILITY DEFINITIONS

Availability - The probability that a process or function is in an operable state and can function if required. It is also a measure of the fraction of the time that an item or process is functioning during a period.

Component - Often used interchangeably with equipment for a definable or replaceable element in an equipment or process. In some applications, a component is a part of an equipment.

Corrective Maintenance (CM) - Unscheduled maintenance that cannot be deferred until the next scheduled maintenance period. Such unscheduled maintenance is normally considered to be a failure.

Equipment - Often used interchangeably with component for a definable or replaceable element in an equipment or process. In some applications, a component is a part of an equipment.

Failure - Basically, the inability of an item or process to perform its required function. Where redundancy is involved, an item may fail, but the process or system can continue to perform all of its required functions until a repair is made or a second failure occurs.

Failure Rate - The failures per unit of time. For this prediction, it is the probability of a failure per hour.

Item - A generic term that can include components, equipments, or a collection of them.

Lambda - Used in the RBDA printouts to represent failure rate. Normally shown in failures per hour.

Maintainability - A measurement of the ease with which a process or system can be restored to operation. Typically, it is measured in the hours of mean down time (MDT) following a failure. Consideration needs to be given to total down time and not just the active repair time.

MDT (Mean down time) - This is often interchangeable with MTTR. MDT always includes all administrative and other contributors to down time.

MTBF - The mean or average time between failures. It is the reciprocal of failure rate.

MTTR - The mean or average time to repair (or restore) the item for service.

PM - Preventive maintenance that is scheduled for keeping an item in operating condition or restoring it to original condition. This is normally scheduled in an off period and has not been included in the MHM calculations as it will have little impact on overall reliability.

Probability of Failure - Used in the RBDA printout with a value that is (1 - probability of success). It represents the probability that an item or system is in the failed state.

Probability of Success - Used in the RBDA printout and has essentially the same meaning as availability.

Redundancy - The existence of one or more means (not necessarily identical) for accomplishing a given function.

Reliability - The probability that an item (which may be a single component or a complete system) to perform its required function under stated conditions for a specified time interval.

System - an assembly of components or equipment needed to accomplish a function. In this respect, it is similar to the definition for a process, but the term system tends to be used for functions where no linear movement or flow is involved. For this analysis, the MHM is considered to be a system.

Subsystem - For this analysis, the subsystems described are portions of the overall system or essentially various discrete groups of components necessary to perform a portion of the overall process. These subsystems include bridge travel, trolley travel, turret and turntable assembly, tube plug hoist and grapple, nose unit/shield skirt/sealing system, MCO hoist and enclosure, MCO grapple, navigation system, and ventilation and inerting system.

Unavailable - The status of an item or major piece of equipment which renders it inoperable because of a failure or other adverse condition.

Appendix D
Logic Element Count and Failure Rates and Down Time Information

LOGIC COUNT FOR PAGES 1 THROUGH 63 OF ELEMENTARY DIAGRAM EB - 33056

SHEET	RELAY	PUSH	CIRCUIT	POWER	OVER	THERMAL	LIMIT	PROX	RELAY	VALVE	RESOL	TRIP PT	FLOW	PRESS	ELECT
No.	CONTACTS	BUTTONS	BREAKERS	CONTACTS	LOADS	SWITCHES	SWITCHES	SWITCHES	COILS	SOLENOIDS	VERS	RELAYS	SESNORS	SENSORS	MODULES
1	5	8		1					4						1
2	2	4							2						2
2A			1												
3		1													
4	2	7							7						
5			1	2											
6	7				1				3						
7	14								4						
7A	4	6						4	8						
8	46	1				1			9						
9											3				5
10	11						1		13						
11	10								8			1			2
12	10								3			1			2
13	10	2						3	6						
13A							12		12						
13B	2						6		6						
14	2	1	1						2						
15	24	3							7						
15A							7		7						
16			1	4	1										
17	4						4		6						
17A	1						6	2	10						
18	8	2			1				3						
19	7		1	2	1		2		2						
20	4			1				5	8						
21	17	1				1	2		4						
21A	6								1						
21B							2		2						
22	8		1	2	1				2						2
22A	8				1				3						2
23	5	1							4						
24	22	1				2	2		4						
24A	7								1						
24B							8		8						
25	22	3							6						
25A	31	5							8						
26	9						3		12						

LOGIC COUNT FOR PAGES 1 THROUGH 63 OF ELEMENTARY DIAGRAM EB - 33056																
SHEET	RELAY	PUSH	CIRCUIT	POWER	OVER	THERMAL	LIMIT	PROX	RELAY	SOLENOIDS	VALVE	RESOL	TRIP PT	FLOW	PRESS	ELECT
No.	CONTACTS	BUTTONS	BREAKERS	CONTACTS	LOADS	SWITCHES	SWITCHES	SWITCHES	COILS	SOLENOIDS	VALVE	VERS	RELAYS	SENSORS	SENSORS	MODULES
26A	4						1		5							2
27	7		1	2	1				3							
28	24	2							6							
28A	6	4						3	7							
29			1	4	1											
30	23								6							
30A	2							3	5							
31	4	2							1							
32	18	4							6							
32A	6		1	4	1				2							
33	2						12		6							
33A							1		3							
34	10	2							6						4	
35								4	6							
35A			2	4	2				2							
36	19	3							8							
36A	22	5							8							
37							12		12							
38			1	3	1				3							
38A				3	1				1							
39	1								2							
40			1	3	1		6		7							
40A				3	1				1							
41	2	1					3		3	2						
42	4	1					6		7	1						
43	5	6							9	4			4	4		
44	7	11							9							
44A	21	4							6							
45	6	3							9							
46A	8	2					4		6							
47	16	8	2	4	2				12				4	4		
48	5						2		9						4	
49	17	8	2	4	1				12							
50	3						3		3							
51	45								6							
52	30								7							
53	17								5							
54	17								4							

LOGIC COUNT FOR PAGES 1 THROUGH 63 OF ELEMENTARY DIAGRAM EB - 33056

SHEET No.	RELAY CONTACTS	PUSH BUTTONS	CIRCUIT BREAKERS	POWER CONTACTS	OVER LOADS	THERMAL SWITCHES	LIMIT SWITCHES	PROX SWITCHES	RELAY COILS	VALVE SOLENOIDS	RESOL VERS	TRIP PT RELAYS	FLOW SENSORS	PRESS SENSORS	ELECT MODULES
55	12								8						
56	15								6						
57	23								2						
58	23	23							6						
59	18	18							6						
60	17	17							4						
61	25	25							7						
62	25	25							5						
63	3	3							1						
TOTAL	820	223	17	47	18	4	112	17	443	7	3	10	8	8	18

**Failure Rates and Down Times Used
for the Calculation**

CODE FOR PROGRAM	UNIT OF COMPONENTS	FAILURE RATE/HOUR	MTBF (YEARS)	MEAN DOWN TIME (HOURS)	COMMENTS AND DATA SOURCES USED
AO	GAS-OPERATED VALVE, INCLUDING OPERATOR	9.00E-06	12.7	48	From IEEE Std 500-1984 and other sources
BB	BEARING	9.00E-08	1268.4	168	NPRD-95 was the primary data source
BE	BELLOWS	1.00E-05	11.4	168	NPRD-95 was the primary data source
BE NU	BELLOWS FOR NOSE UNIT	1.60E-06	71.3	168	NPRD-95 was the primary data source
BE TP	BELLOWS FOR TUBE PLUG HOIST	1.60E-06	71.3	168	NPRD-95 was the primary data source
BK	BREAKER	1.20E-06	95.1	12	Based on data shown in IEEE Std 493-1990
BR 51	BRAKING RESISTOR FOR MOTOR	1.00E-06	114.2	12	Based on a prediction using MIL HDBK-217F
BU	BRAKE UNIT FOR HOIST MOTORS	1.15E-05	9.9	24/48	NPRD-95 was the primary data source
CA	CABLE, INCLUDING THE CONNECTORS.	3.00E-06	38.1	24	From IEEE Std 493-1990
CF	CENTRIFUGAL FAN	8.00E-06	14.3	48	NPRD-95 and other data
CM 01	VIDEO CAMERA #1	5.00E-05	2.3	72	Experience with similar units as obtained from discussions with responsible on-site personnel
CM 02	VIDEO CAMERA #2	5.00E-05	2.3	72	Experience with similar units as obtained from discussions with responsible on-site personnel
CO	LINE CONTACTOR FOR MOTOR	4.12E-06	27.7	24	Based on data shown in IEEE Std 493-1990
CR	HOIST ELECTRICAL CABLE AND REEL	1.00E-05	11.4	80	Engineering estimates
DM	MECHANICAL DAMPER	1.00E-08	11415.5	168	NPRD-95 and other data
DU	DUCT FOR EXTRACTION SYSTEM	9.00E-07	126.8	24/48	Expert opinion
EN	ENCODER, RESOLVER & CARD	2.00E-05	5.7	40	IEEE Std 500 and NPRD-95
FE	FESTOONS FOR TROLLEY	3.60E-05	3.2	48/72	IEEE Std-500 data for cables with a multiplier estimated for this application
FS	FLOW TRANSMITTER	3.90E-06	29.3	24	From IEEE Std 500-1984 and other sources
FU	FUSE	1.50E-07	761.0	4	Based on data shown in IEEE Std 493-1990
FU 04	FOUR FUSES, ONE FAILS	6.00E-07	190.3	4	Based on data shown in IEEE Std 493-1990
GA	GRAPPLE ASSEMBLY	2.50E-05	4.6	48	Engineering estimates
GR	GEARBOX FOR TROLLEY DRIVE	2.00E-05	5.7	72	NPRD-95 was the primary data source
GR HW	HANDWIND CRANK OR GEARS	2.50E-06	45.7		NPRD-95 was the primary data source
GR TU	GEARING FOR TURRET DRIVE	2.00E-05	5.7	168	NPRD-95 was the primary data source
HB	HELIUM BOTTLE	1.60E-06	71.3	8	NPRD-95 was the primary data source
HC	HOIST CABLE FOR MCO HOIST	1.00E-05	11.4		Engineering estimates
HE	MAINLINE HELIUM SUPPLY	5.00E-06	22.8	36	Engineering estimates
HF	HEPA FILTER	3.00E-06	38.1	48	CRBRP estimates
HO	FLEXIBLE HOSE FOR HELIUM	9.00E-06	12.7	24	Engineering estimates

CODE FOR PROGRAM	UNIT OF COMPONENTS	FAILURE RATE/HOUR	MTBF (YEARS)	MEAN DOWN TIME (HOURS)	COMMENTS AND DATA SOURCES USED
HP	HYDRAULIC POWER UNIT FOR SEISMIC CLAMP	1.00E-04	1.1	24	Shown on Drawing D-35205 but further details are not available. Has been assumed to include an electrically-powered gear-type hydraulic pump, 3 valves, a supply tank, and two hoses. Failure rates used are for commercial equipment as listed in NPDR-95. The 24-hour MDT assumes an assembled unit is maintained as a spare.
HR	HELIUM HOSE AND REEL (MCO HOIST)	1.00E-05	11.4	80	NPDR-95 and engineering estimate
IA	JACK MECHANISM FAILS	5.00E-06	22.8	24	NPDR-95 and engineering estimate
JK 01	FAILURE OF ONE JACK	5.70E-06	20.0	24	NPDR-95 and engineering estimate
JK 03	SHIELD JACKS OR MOTOR	1.25E-05	9.1	24	NPDR-95 and engineering estimate
JW	GRAPPLE JAWS	5.00E-05	2.3	80	Engineering Estimate
LO 01	LOGIC COMPONENTS FOR PERMIT SKIRT RAISE	8.30E-05	1.4	12	Based on a prediction using MIL HDBK-217F
LO 04	LOGIC COMPONENTS	8.70E-06	13.1	12	Based on a prediction using MIL HDBK-217F
LO 06	MCOH LOGIC COMPONENTS - HOIST SPEED CONTROL	4.00E-05	2.9	12	Based on a prediction using MIL HDBK-217F
LO 07	LOGIC COMPONENTS	1.77E-05	6.4	12	Based on a prediction using MIL HDBK-217F
LO 13	LOGIC COMPONENTS FOR LOWER SHIELD SKIRT	2.00E-05	5.7	12	Based on a prediction using MIL HDBK-217F
LO 20	ALL OTHER LOGIC COMPONENTS REQUIRED	8.90E-05	1.3	12	Based on a prediction using MIL HDBK-217F
LO 22	LOGIC FOR LOWER MCO HOIST	9.60E-05	1.2	12	Based on a prediction using MIL HDBK-217F
LO 24	LOGIC FOR LOWER TUBE PLUG HOIST	2.40E-05	2.7	12	Based on a prediction using MIL HDBK-217F
LO 25	LOGIC COMPONENTS	7.51E-05	1.5	12	Based on a prediction using MIL HDBK-217F
LO 29	LOGIC COMPONENTS	1.41E-04	0.8	12	Based on a prediction using MIL HDBK-217F
LO 31	LOGIC COMPONENTS	9.76E-05	1.2	12	Based on a prediction using MIL HDBK-217F
LO 36	LOGIC COMPONENTS	4.20E-05	2.7	12	Based on a prediction using MIL HDBK-217F
LO 40	LOGIC FOR PERMIT TUBE PLUG HOIST TO RAISE	9.70E-05	1.2	12	Based on a prediction using MIL HDBK-217F
LO 42	LOGIC COMPONENTS FOR RAISE SHIELD SKIRT	8.60E-05	1.3	12	Based on a prediction using MIL HDBK-217F
LO 47	LOGIC FOR RAISE TUBE PLUG HOIST	1.10E-04	1.0	12	Based on a prediction using MIL HDBK-217F
LO 54	LOGIC ELEMENTS	9.30E-05	1.2	12	Based on a prediction using MIL HDBK-217F
LO 77	LOGIC COMPONENTS	1.34E-04	0.9	12	Based on a prediction using MIL HDBK-217F
LO 80	LOGIC FOR ENGAGE LOCKING PIN	3.40E-05	3.4	12	Based on a prediction using MIL HDBK-217F
LO 81	MCOH LOGIC COMPONENTS	1.58E-04	0.7	12	Based on a prediction using MIL HDBK-217F
LO 89	LOGIC COMPONENTS AND CONTROLS FOR NOSE	1.50E-04	0.8	12	Based on a prediction using MIL HDBK-217F
LO DB	LOGIC FOR PERMIT DISENGAGE BASE LOCKING PIN	1.41E-04	0.8	12	Based on a prediction using MIL HDBK-217F
LO DL	LOGIC FOR DISENGAGE BASE LOCKING PIN	1.41E-04	0.8	12	Based on a prediction using MIL HDBK-217F
LO DT	LOGIC FOR DISENGAGE TURRET LOCKING PIN	1.41E-04	0.8	12	Based on a prediction using MIL HDBK-217F
LO ET	LOGIC FOR ENABLE TURRET ROTATE	2.48E-04	0.5	12	Based on a prediction using MIL HDBK-217F
LO	LOGIC FOR ENGAGE BASE LOCKING PIN	3.43E-05	3.3	12	Based on a prediction using MIL HDBK-217F

CODE FOR PROGRAM	UNIT OF COMPONENTS	FAILURE RATE/HOUR	MTBF (YEARS)	MEAN DOWN TIME (HOURS)	COMMENTS AND DATA SOURCES USED
LO	LOGIC FOR ENABLE TURRET ROTATE	8.30E-05	1.4	12	Based on a prediction using MIL HDBK-217F
LO	LOGIC FOR LOGIC FOR BASE PIN LOCKING	1.80E-04	0.6	12	Based on a prediction using MIL HDBK-217F
LO	LOGIC FOR PERMIT TURRET LOCKING PIN	1.80E-04	0.6	12	Based on a prediction using MIL HDBK-217F
LO	LOGIC FOR ENGAGE TURRET LOCKING PIN	3.43E-05	3.3	12	Based on a prediction using MIL HDBK-217F
LO	LOGIC FOR TURRET ROTATE DIRECTION	8.17E-05	1.4	12	Based on a prediction using MIL HDBK-217F
LP 01	LAMP FOR VIDEO POSITIONING FAILS	5.00E-04	0.2	6	NPRD-95 plus engineering estimates
LP 02	LAMP (FAILS IN STANDBY) FOR VIDEO POSITION	5.00E-05	2.3	6	NPRD-95 plus engineering estimates
LS	LEAD SCREW	1.00E-08	11415.5	48	NPRD-95 plus engineering estimates
MD	ELECTRONIC MODULE	1.30E-06	87.8	8	From IEEE Std 500-1984 and other sources
ML	MECHANICAL LOCK OR PIN	2.60E-09	43905.9	48	NPRD-95
MN	MONITOR FAILS TO SHOW POSITION OF HOIST	2.00E-05	5.7	12	From IEEE Std 493-1990
MO	FAN DRIVE MOTOR	5.00E-06	22.8	24/48	IEEE Std 493-1990 data
MO 15	MOTOR DRIVE	5.00E-06	22.8	48	From IEEE Std 493-1990
MO ST	MOTOR STARTER	1.60E-06	71.3	24	Based on data shown in IEEE Std 493-1990
NR	NON-RETURN DAMPER	2.60E-06	43.9	48	NPRD-95
OR	ORIFICE PLUGS	1.00E-09	114155.3	24/48	NPRD-95
OS	O-RING	1.00E-05	11.4	24/48	NPRD-95
PA	PNEUMATIC ACTUATOR FOR GRAPPLE	1.10E-05	10.4	48	Based on pneumatic actuator data from NPRD95
PF	FLOW MONITOR	1.30E-06	87.8	24/48	Note that units are redundant
PG	PRESSURE GAUGE	1.00E-05	11.4	24	From IEEE Std 500-1984 and other sources
PI	PIN AND DRIVE MECHANISM	5.00E-06	22.8	24	From IEEE Std 500-1984 and other sources
PL	PLANETARY GEAR	5.00E-07	228.3	168	NPRD-95
PS	POWER SUPPLY FOR MODULES OR CAMERAS	2.00E-06	57.1	16	Manufacturer's data
PS SW	PRESSURE SWITCH FAILS	1.70E-06	67.2	16	IEEE Std 500
PX	PROXIMITY SENSOR FAILS	3.00E-06	38.1	12	IEEE Std 500
RE	RELAY OR THE POWER INPUT (SERIES OF C	1.10E-06	103.8	24	From IEEE Std 500-1984 and other sources
RG	MULTISTAGE PRESSURE REGULATING VALVE	5.00E-06	22.8	24	IEEE Std 500 and CRBRP
RL	REEL FOR HOSE OR CABLE	1.14E-05	10.0	80	Engineering estimates
SH	SHIELD FAILURE	1.14E-07	1001.4	72	Engineering Estimate
SI	SILENCER @@@@ FAILS, BLOCKING GAS FLOW	1.00E-09	100000.0	36	NPRD-95 and estimate
SL	SEAL @@@@ REQUIRES REPLACEMENT	5.70E-05	2.0	48/72	NPRD-95 and CRBRP
SR	PRESSURE RELIEF SAFETY VALVE	5.00E-06	22.8	24	From IEEE Std 500-1984 and other sources
SV	PILOT VALVE WITH MONITOR	5.00E-06	22.8	24	Calculated from MIL HDBK-217F
SW	SWITCH	7.00E-07	163.1	12	Based on a prediction using MIL HDBK-217F
SW 07	VIDEO SWITCHING UNIT	5.80E-06	19.7	12	Based on a prediction using MIL HDBK-217F
SW LI	LIMIT SWITCH OR ASSOCIATED SPST RELAY	1.80E-06	63.4	12	Based on a prediction using MIL HDBK-217F

CODE FOR PROGRAM	UNIT OF COMPONENTS	FAILURE RATE/HOUR	MTBF (YEARS)	MEAN DOWN TIME (HOURS)	COMMENTS AND DATA SOURCES USED
SW RO	ROTARY SWITCH	6.60E-06	17.3	12	Based on a prediction using MIL HDBK-217F
SW RY	SWITCH AND SERIES RELAY	1.80E-06	63.4	12	Based on a prediction using MIL HDBK-217F
SY	RESOLVER, SYNCHRO, OR ELECTRONIC MODULES	7.00E-06	16.3	24	Based on a prediction using MIL HDBK-217F and NPRD-95
TB	TROLLEY BRAKE RELAY FAIL	1.00E-06	114.2	24	NPRD-95
TR	POWER TRANSFORMER	1.00E-06	114.2	48	Based on data shown in IEEE Std 493-1990
TU	TUBE FOR HELIUM	1.00E-07	1141.6	48/72	NPRD-95
UN	UNIBALANCE	1.00E-08	11415.5	168	Engineering estimates
VA	GAS OPERATED VALVE WITH MONITOR AND OP	5.00E-06	22.8	48	From IEEE Std 500-1984 and other sources
VACK	CHECK VALVE FAILS	2.30E-06	49.6	48	From IEEE Std 500-1984 and other sources
VAGA	GATE VALVE FAILS	4.50E-06	25.4	48	From IEEE Std 500-1984 and other sources
VAGL	GLOBE VALVE FAILS	5.60E-06	20.4	48	From IEEE Std 500-1984 and other sources
VASO	SOLENOID VALVE	2.00E-05	5.7	48	From IEEE Std 500-1984 and other sources
VS	VARIABLE SPEED DRIVE AND ENCODER UNIT	2.00E-05	5.7	168	From NPRD 95 and engineering estimates
WD	LOAD CELL WEIGHING DEVICE FOR LOAD	1.00E-05	11.4	48	Engineering estimates

NOTES:

A double entry in the mean downtime hours provides the estimated down time for a component located in either an uncontaminated or a contaminated area.

Appendix E
Reliability Data References

DOD 1990, *Military Handbook Reliability Prediction of Electronic Equipment*, MIL-HDBK-217F, U.S. Department of Defense, Washington D.C.

IEEE 1984, *Reliability Data for Nuclear Power Generating Stations*, Std 500-1984, Institute of Electrical and Electronic Engineers, New York, New York.

IEEE 1990, *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*, IEEE Std 493-1990, Institute of Electrical and Electronics Engineers, Inc., New York, New York.

RAC 1985, *Nonelectronic Parts Reliability Data*, NPRD-3, Reliability Analysis Center, 201 Mill Street, Rome, New York.

RAC 1995, *Nonelectronic Parts Reliability Data*, NPRD-95, Reliability Analysis Center, 201 Mill Street, Rome, New York.

RAC 1997, *Electronic Parts Reliability Data*, EPRD-97, Volumes 1 and 2, Reliability Analysis Center, Rome, New York.

U.S. Army 1994, *Power Reliability Enhancement Program (PREP)*, A06631, Volume 1, Reliability Analysis Center, Rome, New York.

Appendix F
FMEA Worksheets

FM-4 WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below
Move MCO to Desired Location

Date: 22-Sep-97
Completed by: R. Gauger / A. Ghose
Reviewed by: BD Groth

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Subcomponent / Subsystem Editor Dwg No. D-35205 Rev A	Component ID	Component Fail Rate/Hours	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
	Mechanical Gear Box for Motor 1	2.00E-05	Freeze/jam	0.98	Can't move crane	Suspend operation. Repairs ~ 72 hrs.	Status light indicator	None	III	Replace	
			Run free	0.02	No hold	Coast to stop. Potential facility damage. Repairs ~ 72 hrs.	Status light indicator	None	III	Replace	
	Bridge Motor 1, 7.5 HP EB33056-22	5.00E-06	Fail to run	1.00	Can't move crane	Suspend operation. Repairs ~ 8 hrs.	Status light indicator	None	III	Replace	
	BOL 1 Bridge Motor Overload Switch EB33056-22	4.12E-06	Fails open	0.98	Motor will not run	Suspend operation. Repairs ~ 8 hrs.	Visual	Reset switch	IV	Replace	
			Fails shorted	0.02	No trip on overload	Damage to motor, suspend operation. Repairs ~ 72 hrs.	None	None	IV	Replace	
	BLC Bridge Line Contactor EB 33058-22	4.12E-06	Fails open	0.80	No power to Bridge	Suspend operation. Repairs ~ 8 hrs.	Status light indicator	None	IV	Replace	
			Fails shorted	0.20	Can't turn power off	Repairs ~ 8 hrs.	None	None	IV	Replace	
	Mechanical Gear Box for Motor 2	5.00E-07	Freeze/jam	0.98	Can't move crane	Suspend operation. Repairs ~ 72 hrs.	Status light indicator	None	III	Replace	
			Run free	0.02	No hold	Suspend operation. Repairs ~ 72 hrs.	Status light indicator	None	III	Replace	
	Bridge Motor 2, 7.5 HP EB 33056-22A	5.00E-06	Fail to run	1.00	No bridge travel	Suspend operation. Repairs ~ 72 hrs.	Status light indicator	None	III	Replace	
BMC1 BMC2 Bridge Motor Control EB-33056-22, 22A	BOL 2 Bridge Motor Overload Switch EB33056-22A	4.12E-06	Fails open	0.98	Motor will not run	Suspend operation. Repairs ~ 8 hrs.	Visual	Reset switch	IV	Replace	
			Fails shorted	0.02	No trip on overload	Damage to motor, suspend operation. Repairs ~ 8 hrs.	None	None	IV	Replace	
	Encoder Interface Card EB-33056-22, 22A	5.00E-06	Motor fails to run	1.00	Motor will not run	Suspend operation. Repairs ~ 8 hrs.	Visual	None	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:

Reference Drawing:

Mission/Function:

Bridge Travel

See below

Move MCO to Desired Location

Date:

Compiled by:

Reviewed by:

22-Sep-97

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R. Gauger / A. Ghose

BD Groth

Subcomponent (Subsystem)	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Local effects	Failure Effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
	Bridge AC Disk Brakes (2)	5.00E-06	Fails to Brake	0.98	Cannot stop bridge crane within travel limits	Reduced control of bridge travel. Repairs ~ 24 hrs.	Visual	Manual control	Replace	III		
			Fails to release	0.02	Bridge Crane operation shutdown	Suspend operation. Repairs ~ 24 hrs.	Visual	None	Replace	III		
	BDB1, BDB2 Braking Resistors	1.00E-06	Fails open	0.98	No braking	Overtravel. Repairs ~ 24 hrs.	None	None	Replace	III		
			Fails shorted	0.02	Short on line	Suspend operations. Repairs ~ 24 hrs.	None	None	Replace	III		
	Bridge Variable Speed Drive (2) EB-33056-22, 22A	1.90E-05	Fails to operate	0.50	No Bridge travel	Cannot operate. Repairs ~ 1 week	Status light indication	None	Replace	II		
			Loss of speed control	0.50	No speed control	Cannot operate. Repairs ~ 1 week.	Status light indication	None	Replace	II		
	TC-GIF-5 Control Interface Card - 1, & -2 EB-33056-22, 22A	1.30E-06	Fails to operate	1.00	No Bridge travel	Cannot operate. Repairs ~ 8 hrs	Visual	None	Replace	IV		
	BCB Bridge Circuit Breaker, QWG 33056 SHI 22	1.20E-06	Fails open	0.90	No power to Bridge	Suspend operation. Repairs ~ 8 hrs.	Status light indication	None	Replace	IV		
			Fails shorted	0.20	No trip on overload	Damage to motor, suspend operation. Repairs ~ 24 hrs.	None	None	Replace	III		
	BBR1 Bridge Brake Relay 1, Dwg 33056 SHI 22	4.00E-06	Fails open	0.90	Brakes do not release	Shutdown. Repairs ~ 8 hrs.	Alarm	None	Replace	IV		
			Fails closed	0.10	Tends to release brake	Unsafe operation. Repairs ~ 8 hrs.	None	None	Replace	IV		
	BBR2 Bridge Brake Relay 2, Dwg 33056 SHI 22A	4.00E-06	Fails open	0.90	Brakes do not release	Shutdown. Repairs ~ 8 hrs.	Alarm	None	Replace	IV		

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
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Bridge Travel
See below
Move MCO to Desired Location

Date: 22-Sep-97
Complied by: R. Gauger / A. Ghose
Reviewed by: BD Groth
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Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
	BFL11 Bridge Fault Relay 1 Dwg 33056 SH 22	1.10E-06	Fails open	0.90	Tends to release brake	Shutdown. Repairs ~ 8 hrs	None	None	IV	Replace	
	BFL12 Bridge Fault Relay 2 Dwg 33056 SH 22A	1.10E-06	Fails open	0.90	Prevents brake release	Shutdown. Repairs ~ 8 hrs	None	None	IV	Replace	
	BTA - Overtemp Relay EB-33056-24	1.00E-06	Fails closed	0.10	Allows brake release	Cannot operate. Repairs ~ 8 hrs	None	Other controls in series	IV	Replace	
	BR - Bridge Run relay EB-33055-24	1.10E-06	Fails open	0.9	Stops bridge	Cannot operate. Repairs ~ 8 hrs	None	None	IV	Replace	
	BBC - Bridge Brake Release relay EB-33055-24	1.10E-06	Fails open	0.9	Loss of temp protection	Repairs ~ 8 hrs	None	None	IV	Replace	
			Fails closed	0.1	Unable to operate bridge	Cannot operate. Repairs ~ 8 hrs	None	None	IV	Replace	
			Fails closed	0.1	Bridge may operate inadvertently	Repairs ~ 8 hrs	None	Other controls in series	IV	Replace	
			Fails open	0.9	Bridge brake not released indicated, does not permit release of seismic clamps	Cannot operate. Repairs ~ 8 hrs	None	None	IV	Replace	
			Fails closed	0.1	Permits release of seismic clamps, with Bridge brakes not released	Cannot operate. Repairs ~ 8 hrs	None	Other controls in series	IV	Replace	
	LSTTRFX Bridge Rail Frog Aligned (X) LS (NC)	7.00E-07	Fails open	0.90	Erroneously indicates Rail Frog at North end	Does not release Crane Bridge brakes, can not operate. Repairs ~ 8 hrs.	Visual	None	IV	Replace	
			Fails Shorted	0.10	May permit Crane travel over misaligned Rail Frog	Potential derailment?	Visual	Manual control	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below

Move MCO to Desired Location

Date: 22-Sep-97
Compiled by: R. Gauger / A. Ghose
Reviewed by: BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate/hour	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
LSLTNLX' MHM Crane Bridge Travel not at North End of Travel (X) US (NC)		7.00E-07	Falls open	0.90	Erroneously indicates Crane at North End, does not permit Crane Br. Travel	Cannot operate. Repairs ~ 8 hrs.	Visual	None - fails safe	IV	Replace	
			Falls Shorted	0.10	Fails to stop Crane at North End limit, impacts North end buffer	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
			Falls open	0.90	Permits only slow speed Crane Br. travel	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
LSLTSLX' MHM Crane Bridge Travel not at South End of Travel (X) US (NC)		7.00E-07	Falls Shorted	0.10	Does not enforce slow speed at North end, may overshoot North end limit and impact buffer at fast speed	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
			Falls open	0.90	Erroneously indicates Crane at South End, does not permit Crane Br. Travel	Cannot operate. Repairs ~ 8 hrs.	Visual	None - fails safe	IV	Replace	
			Falls Shorted	0.10	Fails to stop Crane at South End limit, impacts South end buffer	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
LSLTSSX' MHM Crane Bridge Travel not at South End Slow Speed Zone (X) US (NC)		7.00E-07	Falls open	0.90	Permits only slow speed Crane Br. travel	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
			Falls Shorted	0.10	Does not enforce slow speed at South end, may overshoot South end limit and impact buffer at fast speed	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
			Falls Shorted	0.10	Does not enforce slow speed at South end, may overshoot South end limit and impact buffer at fast speed	Limited operation. Repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below
Move MCO to Desired Location

Date: 22-Sep-87
Compiled by: R. Gauger / A. Ghose
Reviewed by: BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Local effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
	LSBHCFX MHM Crane Bridge Travel in Hot Conditioning Facility (X) US	7.00E-07	Fails open	0.90	Indicates in HCF all the time. Limited operation, only in HCF, may permit Turret rotation, TLP and BLP disengaging, and lowering of the MCO hoist	Shutdown for repairs ~ 8 hrs.	Visual	LSBHCFX is redundant component for channel Y permissive	IV	Replace	
			Fails Shorted	0.10	Fails to indicate in HCF. May not permit MCO Cask extract fans to run	Shutdown for repairs ~ 8 hrs.	Visual	None	IV	Replace	
	LSBHCFY MHM Crane Bridge Travel in Hot Conditioning Facility (Y) US	7.00E-07	Fails open	0.90	Indicates in HCF all the time. Limited operation, only in HCF, may permit Turret rotation, TLP and BLP disengaging, and lowering of the MCO hoist	Shutdown for repairs ~ 8 hrs.	Visual	LSBHCFY is redundant component for channel X	IV	Replace	
	LLTSFX MHM Crane Bridge Travel in the Exchange Facility Zone (X) US	7.00E-07	Fails open	0.90	Indicates in the exchange facility zone all the time. Limited operation, only in Exchange Facility Zone	Shutdown for repairs ~ 8 hrs.	Visual	LLTSFY is redundant component for channel Y permissive	IV	Replace	
			Fails Shorted	0.10	Fails to indicate in Exchange Facility zone	Shutdown for repairs ~ 8 hrs.	Visual	Manual control	IV	Replace	
	LLTSFY MHM Crane Bridge Travel in the Exchange Facility Zone (Y) US	7.00E-07	Fails open	0.90	Indicates in the exchange facility zone all the time. Limited operation, only in Exchange Facility Zone	Shutdown for repairs ~ 8 hrs.	Visual	None	IV	Replace	
			Fails Shorted	0.10	Fails to indicate in Exchange Facility zone	Shutdown for repairs ~ 8 hrs.	Visual	LLTSFX is redundant component for channel X	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below

Move MCO to Desired Location

Date: 22-Sep-97

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Compiled by: R. Gauger / A. Ghose

Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Local effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
Bridge Seismic Clamps Elevator Dwg. D-35205, Rev A	LMSCZY NMM Crane Bridge Travel is South of the Overlap Zone (Y) U/S	7.00E-07	Fails open	0.90	May permit Crane Bridge Travel, with resulting collision with Receiving Crane, provided anti-collision detection is overridden and other conditions are met	Shutdown for repairs - 8 hrs.	Conflict with redundant U/S	Manual operation with anti-collision detect override	IV	Replace	
	LMSCZY NMM Crane Bridge Travel is Not South of the Overlap Zone (Y) U/S (NC)	7.00E-07	Fails Shorted	0.10	Indicates crane South of the overlap zone all the time	Limited operation. Repairs - 8 hrs.	Conflict with redundant U/S	Manual operation	IV	Replace	
			Fails open	0.90	Will not permit Crane Bridge Travel	Cannot operate. Repairs - 8 hrs.	Conflict with redundant U/S	None - fails safe.	IV	Replace	
			Fails Shorted	0.10	May permit Crane Bridge Travel, with resulting collision with Receiving Crane, provided anti-collision detection is overridden and other conditions are met	Limited operation. Repairs - 8 hrs.	Conflict with redundant U/S	Manual control	IV	Replace	
Bridge Seismic Clamps Elevator Dwg. D-35205, Rev A	VFBSO1 Bridge East Seismic Clamp Pump Motor EB-33056-35A	5.00E-06	Fails to run	1.00	Seismic clamps cannot be released	Cannot operate bridge Crane. Repairs - 24 hrs.	Visual	None - fails safe	III	Replace	
	BS101 Bridge Seismic Clamp Motor Overload Switch EB-33056-35A	4.12E-06	Fails open	0.98	Motor will not run. Seismic clamps cannot be released	Suspend operation. Repairs - 8 hrs.	Visual	Reset switch	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:

Bridge Travel

Reference Drawing:

See below

Mission/Function:

Move MCO to Desired Location

Date:

22-Sep-97

01:01 PM

Compiled by:

R. Gauger / A. Ghose

Reviewed by:

BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Local effects	Failure Effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
			Fails shorted	0.02	No trip on overload	Damage to motor, suspend operation. Repairs ~ 24 hrs.		None	None - fails safe	III	Replace	
	BSCB1 Bridge Seismic Clamp Circuit Breaker Dwg 33056 Sht. 35A	1.20E-06	Fails open	0.80	No power to Bridge Clamp Motor. Seismic clamps can not be released	Suspend operation. Repairs 8 hrs.		Unable to operate - visual	None - fails safe	IV	Replace	
			Fails shorted	0.20	No trip on overload	Damage to motor, suspend operation. Repairs 24 hrs		None	None - fails safe	III	Replace	
	BS1, BSD1 Bridge Seismic Clamp Line Connectors EB 33056-35A	1.10E-06	Fails open	0.80	No power to Bridge Clamp Motor. Seismic clamps can not be released	Suspend operation. Repairs ~ 8 hrs.		Visual	None - fails safe	IV	Replace	
			Fails shorted	0.20	Can't turn power off	Repairs ~ 8 hrs.		Visual	None	IV	Replace	
	Bridge #1 Seismic Clamp Hydraulic Power Unit D-35205- Rev A	5.00E-06	Fails to pressurize	1.00	Seismic clamps cannot be released	Cannot operate Bridge Crane. Repairs ~ 72 hrs		Visual	None - fails safe	III	Replace	
	MFBS02 Bridge West Seismic Clamp Pump Motor EB-33056-35A	4.12E-06	Fails to run	1.00	Seismic clamps not operable	Cannot operate Bridge Crane. Repairs ~ 24 hrs		Visual	None - fails safe	III	Replace	
	BS20L Bridge Seismic Clamp Motor Overload Switch EB-33056-35A	1.20E-06	Fails open	0.98	Motor will not run	Suspend operation. Repairs ~ 8 hrs		Visual	Reset switch	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below
Move MCO to Desired Location

Date: 22-Sep-97
Compiled by: R. Gauger / A. Ghose
Reviewed by: BD Groth

01:01 PM

Subcomponent / Subsystem	Component ID	Component Fail Rate/Year	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
			Fails shorted	0.02	No trip on overload	Damage to motor need for clamp, suspend operation. Repairs ~ 24 hrs	None	None	III	Replace	
	BSC82 Bridge Seismic Clamp Circuit Breaker Dwg 33056 Sht 35A	4.12E-06	Fails open	0.80	No power to Bridge Clamp Motor. Seismic clamps can not be released	Suspend operation. Repairs ~ 8 hrs.	Visual	None	IV	Replace	
			Fails shorted	0.20	No trip on overload	Damage to motor, suspend operation. Repairs 24 hrs.	None	None	III	Replace	
	BS2, BSD2 Bridge Seismic Clamp Line Contactors EB 33056-35A	1.10E-06	Fails open	0.80	No power to Bridge Clamp Motor. Seismic clamps can not be released	Suspend operation. Repairs ~ 8 hrs	Visual	None	IV	Replace	
			Fails shorted	0.20	Can't turn power off	Repairs ~ 8 hrs	None	None	IV	Replace	
	Bridge #2 Seismic Clamp Hydraulic Power Unit D-35205- Rev A	1.00E-04	Fails to pressurize	1.00	Seismic clamps can not be released	Cannot operate bridge crane. Repairs ~ 72 hrs.	Visual	None	III	Replace	
Logic for Crane Br. Travel Motor Dwg 363A0038 Issue A Sht 2	Equivalent to 31 signals, 48 Relays, 2 TPU's	9.76E-05	Open	0.90	Does not allow Br. Crane Travel	Repairs ~ 8 to 24 hrs.	Various	None-fails safe	III	Replace	For MHM RAM: 21 Signals, 33 Relays, 2 TPUs
			Short	0.10	Erroneous crane operation	Repairs ~ 8 to 24 hrs.	Various	Other permissives	III	Replace	
Logic for "Permit Crane Br. Travel" (Y) Dwg 363A0038 Issue A Sht 2	Equivalent to 25 signals, 41 Relays, 1 TPU	7.51E-05	Short	0.10	Permits Br. Crane travel with fault	Repairs ~ 8 to 24 hrs.	Various	Other permissives	III	Replace	For MHM RAM: 8 Signals, 19 Relays
			Open	0.90	Stops all Br. Crane Travel	Repairs ~ 8 to 24 hrs.	Various	None-fails safe	III	Replace	

FML WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

Bridge Travel
See below
Move MCO to Desired Location

Date: 22-Sep-97 01:01 PM
Compiled by: R. Gauger / A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate/Hour	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
Logic for Release Bridge East and West Seismic Clamps Dwg 363A0038 Issue A Sht 4	Equivalent to 7 U.S. Relays	1.77E-06	Short	0.10	Permits Br. Crane travel with fault	Repairs - 8 to 24 hrs.	Various	Other permissives	III	Replace	For MHHM RAM: 6 Signals, 10 Relays
Logic for "All Seismic Clamps Applied" Dwg 363A0038 Issue A Sht 4	Equivalent to 4 U.S. Relays	8.70E-06	Short	0.10	Stops all Br. Crane Travel	Repairs - 8 to 24 hrs.	Various	None-fails safe	III	Replace	
			Open	0.90	Permits Br. Crane travel with fault	Repairs - 8 to 24 hrs.	Various	Other permissives	III	Replace	For MHHM RAM: 2 Signals, 3 Relays
			Open	0.90	Stops all Br. Crane Travel	Repairs - 8 to 24 hrs.	Various	None-fails safe	III	Replace	
Bridge Festoon Assembly	Bridge Festoon Assembly	3.60E-06	Assembly becomes entangled	1.00	Power disconnect	Cannot operate. Repairs - 8 to 24 hrs	Visual	None	III	Replace	

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FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM: TROLLEY TRAVEL

Reference Drawing: See drawings listed below
 Mission/Function: Position MCO as Required.

22-Sep-97 01:03:11 PM

R. Gauger

BD Groth

Date:

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Subcomponent/ Subsystem	Component ID	Component Fail Rate/Hr	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Trolley Drive Assembly/ Encoder Dwg. A6 C35188 Rev A	Gearbox	2.00E-05	Freeze/jam	0.98	Can't move crane	Repair ~ 72 hours	Can't move crane	None	III	Replace	
	Trolley motor, 15 HP EB33056 - 19	5.00E-06	Run free Fail to start/run	0.02 1	Loss control Can't move crane	Repair ~ 72 hours Repair ~ 72 hours	Visual Can't move crane	None None	II III	Replace Replace	
	TBU AC Brake Unit (on the motor) EB33056 - 19	1.15E-05	Fail to brake	0.7	Over travel	Repair ~ 24 hrs	Visual	Manual control	III	Replace	
	Encoder interface card EB33-56 - 19	1.30E-06	Fail to release	0.3	Can't move crane	Repair ~ 24 hrs	Can't move crane	None	III	Replace	
	Encoder EB33056 - 19	1.30E-06	Motor fail to run	1	Can't move crane	Repair ~ 24 hrs	Can't move crane	None	III	Replace	
	TBR Trolley Brake relay EB33056-19	1.10E-06	Fails open	0.9	Brakes don't release	Repair ~ 8 hrs	Can't move crane	None	IV	Replace	
Trolley Motor Control TMC			Fails closed	0.1	Tends to release brake	Repair ~ 8 hrs	Can't move crane	Other controls in series	IV	Replace	
	TF LT Trolley Fault Relay EB33056 - 19	1.10E-06	Fails open	0.9	Shut down	Repair ~ 8 hrs	Can't move crane	None	IV	Replace	
			Fails closed	0.1	Can't operate	Repair ~ 8 hrs	Can't move crane	None	IV	Replace	
	TE Trolley East Relay EB33056 - 20	1.10E-06	Fails open	0.9	Can't operate	Repair ~ 8 hrs	Can't move crane	Other controls in series	IV	Replace	
			Fails closed	0.1	Can't operate	Repair ~ 8 hrs	None	Other controls in series	IV	Replace	
	TW Trolley West Relay EB33056 - 19	1.10E-06	Fails open	0.9	Can't operate	Repair ~ 8 hrs	Can't move crane	Other controls in series	IV	Replace	
Trolley Drive Assembly/ Encoder Dwg. A6 C35188 Rev A			Fails closed	0.1	Allows travel past west limit	Repair ~ 8 hrs	Alarm	Other controls in series	IV	Replace	
	Variable Speed Drive EB33056 - 20	1.90E-05	Fail to operate	0.5	No trolley travel	Repair ~ 1 week	Can't move crane	None	II	Replace	
			Loss of speed control	0.5	No speed control	Repair ~ 1 week	Erratic crane movement	Full manual control	II	Replace	
	TBDR, Braking Resistor EB33056 - 19	1.00E-06	Fails open	0.98	No braking	Repair ~ 24 hrs	None	Other controls in series	III	Replace	
			Shorted	0.02	Short on line	Repair ~ 24 hrs	None	None	III	Replace	
	TFA Trolley overtemp relay EB33056 - 21	2.00E-06	Fails open	0.9	Stops trolley	Repair ~ 8 hrs	Visual	None	IV	Replace	
Trolley Drive Assembly/ Encoder Dwg. A6 C35188 Rev A			Fails closed	0.1	Loss of temp protection	Repair ~ 8 hrs	None	None	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: TROLLEY TRAVEL
Reference Drawing: See drawings listed below
Mission/Function: Position MCO as Required.

Date: 22-Sep-97
Compiled by: R. Gauger
Reviewed by: BD Groth

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Sub-component/ Subsystem	Component ID	Component Fail Rate/Hr	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	TR Trolley Run Relay EB33056 - 21	1.10E-06	Fail open	0.9	Can't operate	Repair - 8 hrs	Visual	Other controls in series	IV	Replace	
	TBC Trolley Brake Release	1.10E-06	Fail closed	0.1	Inadvertent operation	Repair - 8 hrs	Visual	Other controls in series	IV	Replace	
			Fail open	0.9	Loss of braking	Repair - 24 hrs	None	Other controls in series	III	Replace	
			Fail closed	0.1	Can't move - brakes locked	Repair - 24 hrs	Visual	Other controls in series	III	Replace	
	TLC Trolley Line Contactor EB33056 - 21A	4.12E-06	Fail open	0.8	No power to Trolley	Repair - 8 hrs	No power	Other controls in series	IV	Replace	
			Fail closed	0.2	Can't turn power off	Repair - 8 hrs	None	Other controls in series	IV	Replace	
	TBC Circuit Breaker	1.20E-06	Fail open	0.5	No power	Repair - 8 hrs	No power	None	IV	Replace	
			Short	0.5	No power	Repair - 8 hrs	None	None	IV	Replace	
	LSC TELX Limit switch, and relays trolley not at E end of travel EB33056 - 19	1.80E-06	Fail open	0.9	Stops travel though not at E end	Repair - 8 hrs	Alarm	Travel west manual control	IV	Replace	
			Fail closed	0.1	Fails to limit travel at east end of travel	Repair - 8 hrs	None	Defect bumper	IV	Replace	
	LSC TWSX Limit switch and relays travel not in West end slow speed zone. Opens in zone. EB33056-19	1.80E-06	Fail open	0.9	Slows crane travel, all zones	Repair - 8 hrs	Visual	None - fails safe	IV	Replace	
			Fail closed	0.1	Fails to slow travel in West end zone	Repair - 8 hrs	Visual	Manual control	IV	Replace	
	LCTSPX Limit switch and relays	1.80E-06	Fail open	0.9	Fails to indicate exch zone	Repair - 8 hrs	Can't move crane	Other series sensors/controls limit travel	IV	Replace	
			Fail closed	0.1	Indicates in zone all the time	Repair - 8 hrs	Can't move crane	Other series sensors/controls limit travel	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: TROLLEY TRAVEL
Reference Drawing: See drawings listed below
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Date: 22-Sep-97
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Subcomponent/ Subsystem	Component ID	Component Fail Rate/Hr	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Logic for crane travel trolley motor 363A0038; See 4th 3	LCTSPY Limit switch, and relays travel in each zone Y	1.80E-06	Fails open	0.9	Fails to indicate each zone	Repair ~ 8 hrs	Can't move crane	None - fails safe	IV	Replace	
	Trolley Motor Thermal Switch #1, EB33056-21	1.80E-06	Fails closed	0.1	False indication of each zone	Repair ~ 8 hrs	Can't move crane	Other series sensors/controls limit travel	IV	Replace	
	TOL Trolley Motor Overload EB33056-19	4.12E-06	Fails open	0.9	False shutdown	Repair ~ 8 hrs	Can't move crane	None	IV	Replace	
	Equivalent to 62 spst switches, and 77 relays	1.16E-04	Fails closed	0.1	Loss of overtemp protection	Repair ~ 8 hrs	None	None	IV	Replace	
Logic for "permit crane travel" (Y) sh1 3	Equivalent to 30 spst switches, 36 relays, & trip point unit	5.96E-05	Fails open	0.9	Can't operate the crane	Repair ~ 8 hrs	Can't move crane	None - fails safe	IV	Replace	
	Equivalent to 31 spst switches, 36 relays, & trip point unit	5.96E-05	Fails open	0.9	Does not allow crane to travel	Repair ~ 8 hrs	Can't move crane	None - fails safe	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails short	0.1	May allow inadvertent crane travel	Repair ~ 8 hrs	Various	Other relays in series	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails short	0.1	Failure could allow travel	Repair ~ 8 hrs	Alarm lights	Other relays in series	IV	Replace	
Logic for north trolley seismic restraint 363A0038 -sh1 2	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails open	0.9	Stops all crane travel	Repair ~ 8 hrs	Can't move crane	None - fails safe	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails open	0.9	May allow restraint pin retraction	Repair ~ 8 hrs	Alarm lights	Other relays in series	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails open	0.9	Will prevent restraint pin retraction	Repair ~ 8 hrs	Can't move crane	None - fails safe	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails short	0.1	May allow restraint pin retraction	Repair ~ 8 hrs	Alarm lights	Other relays in series	IV	Replace	
Logic for south trolley seismic restraint 363A0038 -sh1 3	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails open	0.9	Will prevent restraint pin retraction	Repair ~ 8 hrs	None	None - fails safe	IV	Replace	
	Equivalent to 30 spst switches, 34 relays, and a timing unit	7.60E-05	Fails open	0.9	Will prevent restraint pin retraction	Repair ~ 8 hrs	None	None - fails safe	IV	Replace	
Fusions	One wire open	1.40E-04	One wire open	0.5	Will prevent trolley travel	Repair ~ 72 hrs	Visual	None - fails safe	III	Replace	
	Short in wiring	1.40E-04	Short in wiring	0.5	Will prevent trolley travel	Repair ~ 72 hrs	Visual	None - fails safe	III	Replace	

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FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING

SYSTEM:
Reference Drawing:
Mission/Function:

Turret and Turntable Assembly

See below

Position Hoists and Navigation Camera

Date:

Compiled by:

Reviewed by:

22-Sep-97

A. Ghose

BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Turret Rotate Drive (Dwg. 362A0552)	MFTR - Turret Rotate Motor	5.00E-06	Fails to run	1.00	Can not rotate turret	Repairs ~ 24 hrs	Status light indicator	Manual Hand Wind	III	Replace	
	TRQL Turret Rotate Motor Overload Switch EB-33056-27	1.00E-06	Fails open	0.98	Motor will not run	Repairs ~ 8 hrs	Visual	Reset switch	IV	Replace	
	BFTR - Turret Rotate Brake	5.00E-06	Fails shorted	0.02	No trip on overload	Repairs ~ 8 hrs	None		IV	Replace	
			Fails to Brake	0.98	Can not stop turret within travel limits	Repairs ~ 24 hrs	Visual	Manual control	III	Replace	
TRBC Turret Rotate Brake Contactor EB-33056-27			Fails to release	0.02	Turret operation shutdown	Repairs ~ 24 hrs	Visual	None	III	Replace	
		1.00E-06	Fails open	0.98	No braking	Repairs ~ 48 hrs	Visual	None	III	Replace	
			Fails shorted	0.02	Short on line	Repairs ~ 48 hrs	None	None	III	Replace	
TRMC Turret Motor Control 7.5HP Variable Frequency Drive EB-33056-27		2.00E-05	Motor fails to run	1.00	Cannot rotate turret	Repairs ~ 1 week	Status indicator	None	II	Replace	
			Fails open	0.98	No braking	Repairs ~ 24 hrs	Visual	None	III	Replace	
TRCB Turret Rotate Circuit Breaker EB-33056-27		1.00E-06	Fails open	0.98	No power to Turret Rotate Motor, Suspend operation	Repair ~ 24 hrs	Visual	None	III	Replace	
			Fails shorted	0.02	No trip on overload	Repair ~ 24 hrs	None	None	III	Replace	

FME - WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING

SYSTEM:
Reference Drawing:
Mission/Function:

Turret and Turntable Assembly

See below
Position Hoists and Navigation Camera

Date: 22-Sep-97 01:06 PM

Completed by: A. Ghose

Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	TRBR	Turret Rotate Brake Relay 1 Dwg 33056 Sht 27	Fails open	0.90	Brakes do not release	Repair ~ 24 hrs	Visual	None	III	Replace	
	TRFLT	Turret Rotate Fault Relay 1 Dwg 33056 Sht 27	Fails closed	0.10	Tends to release brake	Repair ~ 24 hrs	None	None	III	Replace	
			Fails open	0.90	Prevent turret rotation	Repair ~ 8 hrs	Visual	None	IV	Replace	
			Fails closed	0.10	May permit inadvertent turret rotation	Repair ~ 8 hrs	None	None	IV	Replace	
		Ball Bearing Slewing Ring (362A0552 ref. no. 64)	Fails structurally		Cannot operate turret	Repair > 1 week	Visual	None	II	Repair/Replace No spare kept	
	LTFRMHPY - Turret at MCO Hoist Position (Y) LUS (NC)		Fails shorted	0.10	Cannot stop turret at MCO Hoist position, can not engage Turret and Base Locking pins	Repair ~ 8 hr	None	P34X - Turret aligned relay	IV	Replace	
			Fails open	0.90	Erroneously indicates turret at MCO Hoist position, may permit Turret and Base Locking pins to engage, or may permit MCO Hoist operation if other conditions are met	Repair ~ 8 hr	None	None - fails safe	IV	Replace	
	LTFRNPPY - Turret at Navigation Camera Position (Y) LUS (NC)		Fails shorted	0.10	Cannot stop turret at Navigation camera position, can not engage Turret and Base Locking pins	Repair ~ 8 hr	None	P34X - Turret aligned relay	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING

SYSTEM:
Reference Drawing:
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Turret and Turntable Assembly
See below
Position Hoists and Navigation Camera

Date: 22-Sep-97 01:05 PM
Complied by: A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Fails open	0.90	Erroneously indicates turret at Navigation camera position, may permit Turret and Base Locking pins to engage	Repair ~ 8 hr	None	None - fails safe	IV	Replace	
	LFTRHPV - Turret not at Navigation Camera Position (Y) L/S (NO)	7.00E-07	Fails shorted	0.10	Erroneously indicates turret not at Navigation camera position, may short Turret and Base Locking pins disengaging if other conditions are met. May permit turret rotate	Repair ~ 8 hr	None	Several other conditions must be met	IV	Replace	
			Fails open	0.90	Erroneously indicates turret not at Navigation camera position, may permit Turret and Base Locking pins to disengage if other conditions are met. May not permit turret rotate	Repair ~ 8 hr	None	Other conditions must be met. Fails safe	IV	Replace	
	LFTRHPV - Turret at Tube Plug Hoist Position (Y) L/S (NC)	7.00E-07	Fails shorted	0.10	Permits engage Turret and Base Locking pins	Repair ~ 8 hr	None	P34X - Turret aligned relay	IV	Replace	
			Fails open	0.90	Unable to permit Turret and Base Locking pins to engage	Repair ~ 8 hr	None	Fails safe - other conditions must be met	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING – MCO HANDLING

SYSTEM:
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Turret and Turntable Assembly
See below
Position Hoists and Navigation Camera

Date: 22-Sep-97
Complied by: A. Ghose
Reviewed by: BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Position Resolver	BFRX - Turret Rotate Position (X) Resolver/ Digitizer	7.00E-06	Fails to record position	1.00	Cannot determine turret position, turret rotate operation shutdown	Repair - 24 hrs	Visual	None	III	Replace	
Logic for Turret Rotate Direction & Speed Control (Dwg. 363A0038 Sht 16 Issue Status A)	Equivalent to 18 signals, 43 relays, 2 trip point units	8.17E-06	Failure of a single device in logic	1.00	Does not allow turret motor control	Repair 8 to 24 hrs	Various	None	IV	Replace	
Logic for Enable Turret Rotate (Dwg. 363A0038 Sht 15 Issue Status A)	Equivalent to 66 signals, 120 relays, 6 trip point units	8.30E-05	Failure of a single device in logic	1.00	Does not allow turret to rotate	Repair 8 to 24 hrs	Various	None	IV	Replace	
Turret Fastoon	Turret Fastoon Assembly Ederer Dwg. D-54860 Rev A	3.60E-05	Assembly becomes entangled or disconnects	1.00	Power disconnect	Repair - 72 hrs	Visual	None	III	Replace	
Turret Locking Pin (Dwg. 362A0553)	MFTLP - Turret Locking Pin Motor	5.00E-06	Fails to run	1.00	Cannot move TLP	Repair - 24 hrs	Visual	Use handwheel	III	Replace	
	BFTLP - Turret Locking Pin Brake	1.15E-05	Fails to brake	0.50	Cannot stop TLP movement	Repair - 24 hrs	Visual	None	III	Replace	
	Inverted Screw Jactuator (362P0553, ref No. 20)	5.00E-06	Fails to release	0.50	Cannot move TLP	Repair - 24 hrs	Visual	None	III	Replace	
			Fails structurally or jams	1.00	Cannot move TLP	Repair - 24 hrs	Visual	None	III	Replace	
	PFTLPEX - TLP Fully Engaged (X) Proximity Sensor (NC)	3.00E-06	Fails shorted	0.10	TLP fully engaged (false indication, and permits base locking pin (BLP) engage when TLP is not fully engaged	Repair - 24 hrs	Status indication	PFTLPEX is redundant component for channel Y permissive	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING – MCO HANDLING

SYSTEM:
Reference Drawing:
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Turret and Turntable Assembly
 See below
Position Hoists and Navigation Camera

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Compiled by: A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
PFTLPEY - TLP Not Fully Engaged (X) Proximity Sensor (NC)		3.00E-06	Fails open	0.90	Inhibits TLP engaging	Repair ~ 24 hrs	None	None - fails safe	III	Replace	
			Fails shorted	0.10	Attempt to engage TLP which is already fully engaged, TLP may impinge on locating plate (bearing spigot) and trip TLP motor overload	Repair ~ 24 hrs	Status indication	PFTLPEY is redundant component for channel Y permissive	III	Replace	
			Fails open	0.90	Will not permit TLP to engage	Repair ~ 24 hrs	None	None - fails safe	III	Replace	
PFTLPEY - TLP Fully Engaged (Y) Proximity Sensor (NC)		3.00E-06	Fails shorted	0.10	May erroneously indicate TLP fully engaged, and permit MHM functions that require both TLP and BLP to be fully engaged	Repair ~ 24 hrs	None	PFTLPEY is redundant component for channel X	III	Replace	
			Fails open	0.90	Will not permit Bridge travel, Trolley travel, raising Shield skirt, Operating Shield Plug hoist, or MCO hoist	Repair ~ 24 hrs	None	None - fails safe	III	Replace	
			Fails shorted	0.10	TLP fully disengaged false indication	Repair ~ 24 hrs	Status indication	None	III	Replace	
PFTLPDX - TLP Fully Disengaged (X) Proximity Sensor		3.00E-06	Fails open	0.90	Fails to indicate that TLP is fully disengaged	Repair ~ 24 hrs	None	None - fails safe	III	Replace	
			Fails shorted	0.10	Continues disengage TLP when not fully disengaged	Repair ~ 24 hrs	Status indication	None - fails safe	III	Replace	
			Fails open	0.90	Inhibits full disengagement of TLP	Repair ~ 24 hrs	None	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING

SYSTEM:
Reference Drawing:
Mission/Function:

Turret and Turntable Assembly
See below
Position Hoists and Navigation Camera

Date: 22-Sep-97
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01:05 PM

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
Logic for Permit Turret Locking Pin Disengage(Y) (Dwg. 363A0038 Sht 14 Issue Status A)	Equivalent to 48 signals, 74 relays, 6 trip point units	1.80E-04	Short	0.10	Local effects: May allow inadvertent disengagement of the locking pin. End effects: Repair - 8 to 24 hrs.	Various	Numerous other shorts would have to occur	IV	Replace	
Logic for Engage Turret Locking Pin (X) (Dwg. 363A0038 Sht 14 Issue Status A)	Equivalent to 7 signals, 17 relays, 1 trip point unit	3.43E-05	Short	0.10	Local effects: May allow inadvertent engagement of the locking pin. End effects: Repair - 8 to 24 hrs.	Various	Numerous other shorts would have to occur	IV	Replace	
Logic for Disengage Turret Locking Pin (X) (Dwg. 363A0038 Sht 14 Issue Status A)	Equivalent to 48 signals, 84 relays, 1 trip point unit	1.41E-04	Short	0.10	Local effects: May allow inadvertent disengagement of the locking pin. End effects: Repair - 8 to 24 hrs.	Various	Numerous other shorts would have to occur	IV	Replace	
Base Locking Pin (Dwg. 362A0554)	MFBLP - Base Locking Pin Motor	5.00E-06	Fails to run	1.00	Local effects: Will prevent disengaging the locking pin. End effects: Repair - 8 to 24 hrs.	Visual	None - fails safe	III	Replace	
	BFBLP - Base Locking Pin Brake	1.15E-05	Fails to brake	0.50	Local effects: Cannot engage or disengage locking pin. End effects: Repair - 24 hrs.	None	None	III	Replace	
			Fails to release	0.50	Local effects: Cannot move BLP. End effects: Repair - 24 hrs.	None	None	III	Replace	
	PFBLPDX - BLP Fully Disengaged Proximity Sensor	3.00E-06	Fails shorted	0.10	Local effects: BLP fully disengaged false indication. End effects: Repair - 24 hrs.	Status indication	None - fails safe	III	Replace	
			Fails open	0.90	Local effects: Fails to indicate that BLP is fully disengaged. End effects: Repair - 24 hrs.	None	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING

SYSTEM:
Reference Drawing:
Mission/Function:

Turret and Turntable Assembly
See below
Position Hoists and Navigation Camera

Date: 22-Sep-97 01:05 PM
Compiled by: A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	PFBLPEX - BLP Fully Engaged (X) Proximity Sensor	3.00E-06	Fails shorted	0.10	BLP Fully engaged, false indication, and may permit release of Turret brake when BLP is not fully engaged	Repair ~ 24 hrs	Status indication	PFBLPEX is redundant component for channel Y permissive	NI	Replace	
			Fails open	0.90	Inhibits Turret operation	Repair ~ 24 hrs	None	None - fails safe	III	Replace	
	PFBLPEX - BLP Fully Engaged (Y) Proximity Sensor	3.00E-06	Fails shorted	0.10	May erroneously indicate BLP fully engaged, and permit MHHM functions that require both TLP and BLP to be fully engaged	Repair ~ 24 hrs	None	PFBLPEX is redundant component for channel X	III	Replace	
Logic for Permit Base Locking Pin Disengage (Y) (Dwg. 363A0038 Sht. 14 Issue Status A)			Fails open	0.90	Will not permit Bridge travel, Trolley travel, raising Shield skirt, Operating Shield Plug hoist, or MCO hoist	Repair ~ 24 hrs	None	None - fails safe	IV	Replace	
		1.41E-08	Short	0.10	May allow inadvertent disengagement of the base locking pin	Repair ~ 8 to 24 hrs.	Various	Numerous other shorts would have to occur	IV	Replace	
			Open	0.90	Will prevent disengaging the base locking pin	Repair ~ 8 to 24 hrs.	Various	None - fails safe	IV	Replace	
Logic for Engage Base Locking Pin (X) (Dwg. 363A0038 Sht. 14 Issue Status A)			Short	0.10	May allow inadvertent engagement of the base locking pin	Repair ~ 8 to 24 hrs.	Various	Numerous other shorts would have to occur	IV	Replace	
			Open	0.90	Will prevent engaging the base locking pin	Repair ~ 8 to 24 hrs.	Various	None - fails safe	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING

SYSTEM:
Reference Drawing:
Mission/Function:

Turret and Turntable Assembly
See below
Position Hoists and Navigation Camera

Date: 22-Sep-97 01:06 PM
Compiled by: A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
Logic for Disengage Base Locking Pin (X) (Dwg. 353A0038 Sht 14 Issue Status A)	Equivalent to 48 signals, 84 relays, 1 trip point unit	1 41T-04	Short	0.10	Local effects	End effects	Various	Numerous other shorts would have to occur	IV	Replace	
			Open	0.9	May allow inadvertent disengagement of the base locking pin	Repair - 8 to 24 hrs.					
					Will prevent disengaging the base locking pin	Repair - 8 to 24 hrs.	Various	Nine - fails safe	IV	Replace	

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FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-87
Completed by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
				Local effects	End effects					
Hoist Motor and Gearbox	MFPH - Hoist Motor 3 HP & Gearbox Unit	5.50E-06	Motor Fails to Start/Run	Cannot raise or lower Tube Plug by motor	Shutdown for repairs ~ 24 hours	Status light indicator	Use of handwheel for manual application	III	Replace	
	BFPH - Tube Plug Hoist Brake	1.15E-05	Fails	Potential for tube plug drop (see note)	Shutdown for repairs ~ 24 hours. If tube plug drops then shutdown > 1 week.	None	None	III (II if plug drops)	Replace	
	PHOL - Tube Plug Hoist Motor Overload Switch EB3056-16	4.12E-06	Fails open	Motor will not run	Shutdown for repairs for ~ 8 hrs	Status light indicator	Manual handwind	IV	Replace	
	PHL - PHH - Tube Plug Hoist Contactors Dwg 33056 Sht 16	4.12E-06	Fails open	No trip on overload	Shutdown for repairs for ~ 8 hrs	None	Manual handwind	IV	Replace	
Tube Plug Hoist Redundant Contactors Dwg 33056 Sht 16	PHL - PHH - Tube Plug Hoist Contactors Dwg 33056 Sht 16	4.12E-06	Fails open	No power to Tube Plug Hoist	Shutdown for repairs for ~ 24 hrs	Status light indicator	Manual handwind	III	Replace	
	PHLY - PHHY - Tube Plug Hoist Redundant Contactors Dwg 33056 Sht 16	4.12E-06	Fails open	Short on line	Shutdown for repairs for ~ 24 hrs	None	Manual handwind	III	Replace	
	PHLY - PHHY - Tube Plug Hoist Redundant Contactors Dwg 33056 Sht 16	4.12E-06	Fails open	No power to Tube Plug Hoist	Shutdown for repairs for ~ 24 hrs	Status light indicator	Manual handwind	III	Replace	
	PHLY - PHHY - Tube Plug Hoist Redundant Contactors Dwg 33056 Sht 16	4.12E-06	Fails open	Short on line	Shutdown for repairs for ~ 24 hrs	None	Manual handwind	III	Replace	
Tube Plug Hoist Circuit Breaker Dwg 33056 Sht 16	PHCB - Tube Plug Hoist Circuit Breaker Dwg 33056 Sht 16	1.20E-06	Fails open	No power to Tube Plug Hoist	Shutdown for repairs for ~ 24 hrs	Status light indicator	Manual handwind	III	Replace	
	PHCB - Tube Plug Hoist Circuit Breaker Dwg 33056 Sht 16	1.20E-06	Fails open	Short on line	Shutdown for repairs for ~ 24 hrs	None	Manual handwind	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 382A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	LFPHCTX - Tube Plug Hoist Not Torque Limited	7.00E-07	Short	0.20	No trip on overload	Shutdown for repairs for ~ 24 hrs	None	Manual handwind	III	Replace	
				0.10	Potential overtorquing of the motor. Failure to stop if travel limit fails	Shutdown for repairs ~ 8 hours	None	Normally controlled by High Limit Switch. Also motor overload relay.	IV	Replace	
			Open	0.50	Prevents raising of tube plug when desired	Shutdown for repairs ~ 5 hours	Alarm - Tube Plug Hoist Torque Limit	Handwind operation is still possible	IV	Replace	
	Plug Hoist Screw Jack Worm Drive Seal	1.00E-05	Leaks	1.00	If leak is significant, proper latching is prevented	Shutdown for repairs ~ 24 hours	Failure to pass leak test	None	III	Replace	
			Short	0.10	Jack screw fails to stop when fully raised	Shutdown for repairs ~ 48 hours	Lack of fully raised indication	Limit torque	III	Replace	
Hoist Jack Screw	LFPHFRX - Tube Plug Hoist Not Fully Raised (X) L/S	7.00E-07	Open	0.50	Hoist stops prior to being fully raised	Shutdown for repairs ~ 48 hours	Lack of fully raised indication	Manual handwheel actuation	III	Replace	
			Short	0.10	Will allow crane trolley travel without hoist being fully raised	Shutdown for repairs ~ 48 hours	Tube Plug Grapple Fully Raised Indication	LFPHFRY, P2X, P2Y, LFSFRX, and others must also be actuated.	III	Replace	
					May enable turret rotate/disengage locking pin	Shutdown for repairs ~ 48 hours	Tube Plug Grapple Fully Raised indication	LFPHFRY, P2X, P2Y, and P2YX must also be actuated.	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0657
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
					May indicate tube plug is in storage	Shutdown for repairs - 48 hours	Tube Plug Grapple Fully Raised Indication	LFPHERY, LFPHERX, PESSPY, LFPGOX and others must also be actuated.	III	Replace	
					May allow crane bridge travel.	Shutdown for repairs - 48 hours	Tube Plug Grapple Fully Raised Indication	LFPHERY, P6X, P2X, LESSERX, and others must also be actuated.	III	Replace	
					May allow release of mode select lock.	Shutdown for repairs - 48 hours	Tube Plug Grapple Fully Raised Indication	Channel Y, Other conditions	III	Replace	
			Open	0.90	Will not permit crane trolley travel, turret rotate, or indicate Tube Plug is in storage even if the hoist is fully raised. Prevents mode select release.	Shutdown for repairs - 48 hours	Lack of Tube Plug Grapple Fully Raised Indication	None - fails safe	III	Replace	
	LFPHERY - Tube Plug Hoist Fully Raised (Y) L/S	7.00E-07	Short	0.10	Will indicate Tube Plug in Storage Tube when it may not be.	Shutdown for repairs - 48 hours	None	LFPHERX, LFPGOX and PESSPY and others must also be actuated.	III	Replace	
					May permit crane bridge travel	Shutdown for repairs - 48 hours	None	LFPHERX, P2Y, P6Y, LSMCSZY and other must also be actuated.	III	Replace	
					May enable turret rotation/disengage locking pin	Shutdown for repairs - 48 hours	None	LFPHERX, P6Y, P21Y, and P27Y must also be actuated.	III	Replace	
					May permit shield skirt raise	Shutdown for repairs - 48 hours	None	LFPHERX, P2Y, P6Y, and others must also be actuated.	III	Replace	
					May allow release of mode select lock.	Shutdown for repairs - 48 hours	None	Channel X, Other conditions	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Will not provide indication that Tube Plug is in storage, even if it is. Will not permit crane bridge travel. Prevents mode select release.	Shutdown for repairs - 48 hours	None	None - fails safe	II	Replace	
	Hoist Screw	1.00E-08	Fails structurally	0.10	Unable to raise or lower tube plug. Potential drop of tube plug	Shutdown for repairs - 24 hours. If tube plug drops then shutdown > 1 week.	Various - Plug height limit switches	None	III (if plug drops)	Replace	
	LFPHSZX - Tube Grapple within Sealing Zone (X) LS	7.00E-07	Short	0.10	Allows hoist to be raised and grapple jaws opened without grapple in sealing zone if other conditions are met.	Shutdown for repairs - 48 hours	Status indicator	LFPHSZY is redundant component for channel Y permissive	III	Replace	
			Open	0.90	May allow running MCO Cask extract fan if inerting system is operating.	Shutdown for repairs - 48 hours	Status indicator	LFPMSV10X and LFPMSV20X	III	Replace	
			Open	0.90	Unable to raise hoist or open jaws unless jaws are closed and locked, or are fully open	Shutdown for repairs - 48 hours	None	None - fail safe condition	III	Replace	
	LFPHSZY - Tube Grapple within Sealing Zone (Y) LS	7.00E-07	Short	0.10	Allows hoist to be raised and grapple jaws opened without grapple in sealing zone if other conditions are met.	Shutdown for repairs - 48 hours	None	LFPHSZX is redundant component for channel X	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Unable to raise hoist or open jaws unless jaws are closed and locked, or are fully open	Shutdown for repairs ~ 48 hours	None	None - fair safe condition	III	Replace	
	LFPFLX - Tube Plug Hoist Not Fully Lowered (X) L/S	7.00E-07	Short	0.10	Will allow hoist to lower when plug is already seated if grapple is not supported and other conditions are met.	Shutdown for repairs ~ 48 hours	None	Plug Hoist Motor Overload (OVR), Tube Plug Grapple not Fully Supported (LFPGSX)	III	Replace	
			Open	0.90	Will not allow hoist to be lowered even if the hoist is not fully lowered.	Shutdown for repairs ~ 48 hours	None	None	III	Replace	
	Telescoping Bellows	1.00E-08	Leaks		Large leak could result in loss of inerting capabilities, which in turn would result in a loss of the ability to raise the plug	Shutdown for repairs ~ 48 hours	Failure to pass leak test	None - fails safe.	III	Replace	
Tube Plug Grapple	LFPGLX - Tube Plug Grapple Jaws Locked (X) L/S	7.00E-07	Short	0.10	Allows raising of hoist without grapple jaws being locked if grapple jaws are fully closed.	Shutdown for repairs ~ 48 hours	Tube Plug Grapple Jaws Locked indication	LFPGLX - Grapple jaws fully closed and LFPGLY - Grapple Jaws Locked ch. Y.	III	Replace	
					May provide erroneous indication of tube plug in storage tube.	Shutdown for repairs ~ 48 hours	Tube Plug Grapple Jaws Locked indication	Channel Y, LFPGLX, PESSPX, and others must also be actuated.	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Holst and Grapple
Reference Drawing: 362A0667
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fat Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Will prevent raising of Tube Plug Holst with Jaws Fully Open. May prevent indication of tube plug in storage tube.	Shutdown for repairs - 48 hours	None	Hand Wind. Also fails safe	III	Replace	
	LFPGLX - Tube Plug Grapple Jaws Not Locked (X) / US	7.00E-07	Short	0.10	May allow opening grapple jaws without them being locked if other conditions are met.	Shutdown for repairs - 48 hours	None	Other conditions must be satisfied - grapple supported, within seating zone, and turrel at tube plug holst.	III	Replace	
			Open	0.90	Will not allow tube plug grapple jaws to be opened.	Shutdown for repairs - 48 hours	None	None - fail safe conditions	III	Replace	
	LFPGLY - Tube Plug Grapple Jaws Locked (Y) / US	7.00E-07	Short	0.10	Same as LFPGLX above for the ch. Y permissive.	Shutdown for repairs - 48 hours	None	LFPGOY - Grapple jaws fully closed and LFPGLX - Grapple Jaws Locked ch. Y.	III	Replace	
					May provide erroneous indication of tube plug in storage tube.	Shutdown for repairs - 48 hours	None	Channel X. LFPGOY, PESSPY, and others must also be actuated.	III	Replace	
			Open	0.90	Same as LFPGLX above for the ch. Y permissive	Shutdown for repairs - 48 hours	None	None - fails safe	III	Replace	
	LFPGOX - Tube Plug Jaws Fully Open (X) / US	7.00E-07	Short	0.10	Allows raising Tube Plug Holst without jaws fully open or fully closed if all other conditions are met.	Shutdown for repairs - 48 hours	Tube Plug Grapple Jaws Open indication	LFPGOY must also short for this to occur.	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
					May provide erroneous indication of tube plug in storage tube	Shutdown for repairs - 48 hours	Tube Plug Grapple Jaws Open indication	Channel Y P2 Interlock. LFPHFRX and PESSPY must also be actuated, as well as other conditions met.	III	Replace	
					May allow operation of the Cask Extract Fan operation in the HCF with the Tube Plug removed.	Shutdown for repairs - 48 hours	Tube Plug Grapple Jaws Open indication	Operator action to indication	III	Replace	
					May allow release of mode select lock.	Shutdown for repairs - 48 hours	Tube Plug Grapple Jaws Open indication	Channel Y. Other conditions.	III	Replace	
			Open	0.90	Will prevent raising of Tube Plug Hoist with Jaws Fully Open. May prevent indication of tube plug in storage tube. May prevent operation of Cask Extract Fan if no other conditions are met.	Shutdown for repairs - 48 hours	None	None for raising of tube hoist or Cask Extract Fan. Channel Y for tube plug in storage tube.	III	Replace	
	LFGGV - Tube Plug Jaws Fully Open (Y) US	7.00E-07	Short	0.10	Same as LFGGV above for Tube Plug Hoist for channel Y permissive.	Shutdown for repairs - 48 hours	None	LFGGV must also short for this to occur	III	Replace	
					May provide erroneous indication of tube plug in storage tube.	Shutdown for repairs - 48 hours	None	Channel X LFGGV PESSPY, and others must also be actuated.	III	Replace	
					May allow release of mode select lock.	Shutdown for repairs - 48 hours	None	Channel X Other conditions.	III	Replace	

FAILURE WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Deflection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Same as LFPGSX above for Tube Plug Hoist for channel Y permissive. Will prevent indication of tube plug in storage tube. Prevents release of mode select.	Shutdown for repairs - 48 hours	None	None for raising of tube hoist. Channel X for tube plug in storage tube.	III	Replace	
	LFPGSX - Tube Plug Grapple Not Supported (X) L/S	7.00E-07	Short	0.10	Will allow hoist to be lowered with grapple being supported if other conditions are met	Shutdown for repairs - 48 hours	None	Other conditions must be met - Hoist not fully lowered (LFPHFLX), etc	III	Replace	
			Open	0.90	Will not allow hoist to be lowered even if grapple is not supported.	Shutdown for repairs - 48 hours	None	None - fails safe	III	Replace	
	LFPGSX - Tube Plug Grapple Supported (unlocked) (X) L/S	7.00E-07	Short	0.10	May allow grapple jaws to be opened without the grapple being supported.	Shutdown for repairs - 48 hours	Status light	LFPGSV - channel Y L/S must also be satisfied.	III	Replace	
			Open	0.90	Will prevent grapple jaws from being opened	Shutdown for repairs - 48 hours	None	None - fails safe	III	Replace	
	LFPGSV - Tube Plug Grapple Supported (unlocked) (Y) L/S	7.00E-07	Short	0.10	May allow grapple jaws to be opened without the grapple being supported.	Shutdown for repairs - 48 hours	None	LFPGSX - channel X L/S must also be satisfied.	III	Replace	
			Open	0.90	Will prevent grapple jaws from being opened	Shutdown for repairs - 48 hours	None	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R Gauger

01:07 PM

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
LEPGCY - Tube Plug Grapple Jaws Fully Closed (X) LS		7.00E-07	Short	0.10	Will allow hoist to be raised without grapple jaws fully open or fully closed.	Shutdown for repairs - 48 hours.	Status light	LEPGCY - Channel Y Jaws Fully Closed must also be shorted.	III	Replace	
					May permit turret rotate	Shutdown for repairs - 48 hours.	Status light	LEPGCY and PESSPX must also be actuated.	III	Replace	
					May provide erroneous tube plug in storage indication.	Shutdown for repairs - 48 hours.	Status light	LEPGCY, PESSPX, and others must also be actuated.	III	Replace	
					Will not allow hoist to be raised unless jaws are locked. Will prevent turret rotate	Shutdown for repairs - 48 hours.	None	None - fails safe	III	Replace	
LEPGCY - Tube Plug Grapple Jaws Fully Closed (Y) LS		7.00E-07	Short	0.10	Same as LEPGCY above for channel Y permissive.	Shutdown for repairs - 48 hours.	None	Same as above for channel Y.	III	Replace	
					Same as LEPGCY above for channel Y permissive. Will not allow turret rotate.	Shutdown for repairs - 48 hours.	None	None - fails safe	III	Replace	
AFPG - Tube Plug Grapple Actuator Motor		5.00E-06	Fails to Start/Run	1.00	Unable to engage or disengage grapple.	Shutdown for repairs - 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
					Motor will not run	Shutdown for repairs - 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
PGOL - Tube Plug Grapple Motor Overload Switch EB33056-18		4.12E-06	Fails open	0.98	No trip on overload	Shutdown for repairs - 24 hours.	None	Manual hand wind.	III	Replace	
					Fails shorted	Shutdown for repairs - 24 hours.	None	Manual hand wind.	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING – MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 382A0567
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	PGO - Tube Plug Grapple Open Contactor Dwg 33056 Sht 16	4.12E-06	Fails open	0.80	No power to Tube Plug Grapple	Shutdown for repairs ~ 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
	PGC - Tube Plug Grapple Close Contactor Dwg 33056 Sht 16	4.12E-06	Fails open	0.80	No power to Tube Plug Grapple	Shutdown for repairs ~ 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
	PGCB - Tube Plug Grapple Circuit Breaker Dwg 33056 Sht 18	1.20E-06	Fails open	0.80	No power to Tube Plug Grapple	Shutdown for repairs ~ 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
	PGODY - Tube Plug Grapple Open Disable Contactor Dwg 33056 Sht 16	4.12E-06	Fails open	0.80	No power to Tube Plug Grapple	Shutdown for repairs ~ 24 hours.	Unable to grapple	Manual hand wind.	III	Replace	
			Fails shorted	0.20	No trip on overload	Shutdown for repairs ~ 24 hours.	None	Manual hand wind.	III	Replace	
			Fails shorted	0.20	No power to Tube Plug Grapple	Shutdown for repairs ~ 24 hours.	None	Manual hand wind.	III	Replace	
			Fails shorted	0.20	Short on line	Shutdown for repairs ~ 24 hours.	None	Manual hand wind.	III	Replace	
			Fails structurally	1.00	Unable to engage grapple. May be unable to disengage if already engaged. Potential tube plug drop	Shutdown for repairs ~ 45 hours. If plug drops shutdown > 1 week.	Unable to grapple	None	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 382A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Controls	SW - Open Tube Plug Grapple Jaws	5.60E-06	Short	0.20	Grapple jaws will open inadvertently if other conditions are met	Shutdown for repairs ~ 8 hours	Status light	Grapple jaws not locked, grapple within seating zone, and turret in tube hoist positions must all be satisfied.	IV	Replace	
			Open	0.80	Grapple jaws can not be opened if desired.	Shutdown for repairs ~ 8 hours	Unable to operate	Hand wind - see note	IV	Replace	
	SW - Close Tube Plug Grapple Jaws	7.00E-07	Short	0.20	Grapple jaws will close inadvertently if other conditions are met	Shutdown for repairs ~ 8 hours	Status light	Grapple jaws not locked and grapple supported, must be satisfied.	IV	Replace	
			Open	0.80	Grapple jaws can not be closed if desired.	Shutdown for repairs ~ 8 hours	Unable to operate	Hand wind - see note	IV	Replace	
PB - Stop Tube Plug Hoist		7.00E-07	Short	0.10	Will allow the hoist to continue being raised or lowered after the stop command	Shutdown for repairs ~ 8 hours	Status light	Limit torque. Hoist not fully lowered	IV	Replace	
			Open	0.90	Will stop the hoist even if not desired.	Shutdown for repairs ~ 8 hours	Unable to stop	None - fails safe. May use hand wind.	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 302A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

01:07 PM

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
PB - Start Lower Tube Plug Hoist	PB - Start Lower Tube Plug Hoist	7.00E-07	Short	0.10	Hoist will lower inadvertently if other conditions are met	Shutdown for repairs - 8 hours.	Status light	Tube plug hoist not fully lowered, tube plug grapple not supported, turret at tube plug position, shield skirt seated, seismic clamps applied, and base locking pin engaged must all be satisfied.	IV	Replace	
					Hoist can not be lowered	Shutdown for repairs - 8 hours.	Unable to operate	Hand wind	IV	Replace	
					Hoist will raise inadvertently if other conditions are met	Shutdown for repairs - 8 hours.	Status light indication	Tube plug hoist not fully lowered, tube plug grapple not supported, turret at tube plug position, shield skirt seated, seismic clamps applied, and base locking pin engaged must all be satisfied.	IV	Replace	
PB - Start Raise Tube Plug Hoist	PB - Start Raise Tube Plug Hoist	7.00E-07	Open	0.90	Hoist can not be raised	Shutdown for repairs - 8 hours.	Unable to operate	Hand wind	IV	Replace	
					Will permit inadvertent raising of the tube plug hoist	Shutdown for repairs - 8 to 48 hours	Various	Channel X must also short	III	Replace	

Failure Worksheet
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Tube Plug Hoist and Grapple
Reference Drawing: 362A0557
Mission/Function: Install/Remove Tube Plug

Date: 22-Sep-97
Completed by: BD Groth
Reviewed by: R Gauger

01:07 PM

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Will prevent raising the tube plug hoist	Shutdown for repairs ~ 8 to 48 hours	Various	None - fails safe	III	Replace	
	Raise Tube Plug Hoist (X) - modeled as 28 switches, 47 relays, 2 limiters and 4 trip point units	1.10E-04	Short	0.10	Will inadvertently raise the tube plug hoist	Shutdown for repairs ~ 8 to 48 hours	Various	Channel Y must also short	III	Replace	
			Open	0.90	Will prevent raising the tube plug hoist	Shutdown for repairs ~ 8 to 48 hours	Various	None - fails safe	III	Replace	
	Lower Tube Plug Hoist (X) - modeled as 13 switches, 19 relays, and 1 resolver	2.40E-05	Short	0.10	Will inadvertently lower the tube plug hoist	Shutdown for repairs ~ 8 to 48 hours	Various	Several shorts must occur due to the & logic	III	Replace	
			Open	0.80	Will prevent lowering the tube plug hoist	Shutdown for repairs ~ 8 to 48 hours	Various	None - fails safe	III	Replace	

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FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
362A0566 and 362A0661
Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:08 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Retractable Nose Unit Assembly	Inflatable Seal (Inner)	5.70E-05	Leaks	1.00	Failure to pass leak test. If failure after leak testing, may prevent adequate inerting	Shutdown for repairs ~ 72 hours	Interspace leak check prior to operation. Inerting system pressure will indicate large leaks. Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	Inflatable Seal (Outer)	5.70E-05	Leaks	1.00	Failure to pass leak test. If failure after leak testing, may prevent adequate inerting	Shutdown for repairs ~ 72 hours	Interspace leak check prior to operation. Inerting system pressure will indicate large leaks. Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	O-Ring (inner) - PIN 24	1.00E-05	Leaks	1.00	Failure to pass leak test. If failure after leak testing, may prevent adequate inerting	Shutdown for repairs ~ 72 hours	Interspace leak check prior to operation. Inerting system pressure will indicate large leaks. Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	O-Ring (outer) - PIN 35	1.00E-05	Leaks	1.00	Failure to pass leak test. If failure after leak testing, may prevent adequate inerting	Shutdown for repairs ~ 72 hours	Interspace leak check prior to operation. Inerting system pressure will indicate large leaks. Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	Belows Assembly - PIN 1	1.60E-06	Fails	1.00	Leak through bellows wall, or inadequate sealing on sealing surface prevents adequate inerting.	Shutdown for repairs ~ 72 hours	Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	Inner Tube - PIN 2	Negligible for leak	Fails	1.00	Leak through tube wall may prevent adequate inerting.	Shutdown for repairs ~ 72 hours	Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	Outer Tube - PIN 3	Negligible for leak	Fails	1.00	Leak through tube wall may prevent adequate inerting.	Shutdown for repairs ~ 72 hours	Alarm - Nose Seal Leak Check Healthy	Ventilation system will compensate for small leaks.	III	Replace	
	SSJL - Shield Skirt Motor Overload Switch E-1133056 32A	4.12E-06	Fails open	0.98	Motor will not run	Shutdown for repairs ~ 8 hours	Visual indication	Manual hand wind	IV	Replace	
			Fails shorter	0.02	No trip on overload	Shutdown for repairs ~ 8 hours	Visual indication	Manual hand wind	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
362A0658 and 362A0581
Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:08 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
				Local effects	End effects					
SSRY - SSL - Shield Skirt Raise & Lower Contactors Dwg 33058 SHI 32A	SSRY - SSL - Shield Skirt Raise & Lower Contactors Dwg 33058 SHI 32A	4.12E-06	0.80	No power to Shield Skirt for corresponding operation	Shutdown for repairs ~ 24 hours	Visual indication	Manual hand wind	III	Replace	
				Short on line	Shutdown for repairs ~ 24 hours	None	Manual hand wind	III	Replace	
				No power to Shield Skirt for corresponding operation	Shutdown for repairs ~ 24 hours	Unable to raise or lower	Manual hand wind	III	Replace	
SSCB - Shield Skirt Circuit Breaker Dwg 33058 SHI 32A	SSCB - Shield Skirt Circuit Breaker Dwg 33058 SHI 32A	1.20E-06	0.80	Short on line	Shutdown for repairs ~ 24 hours	None	Manual hand wind	III	Replace	
				No power to Shield Skirt	Shutdown for repairs ~ 24 hours	Unable to operate	Manual hand wind	III	Replace	
				No trip on overload	Shutdown for repairs ~ 24 hours	None	Manual hand wind	III	Replace	
LFSSX1 - Shield Skirt Fully Seated 1 (X) L/S	LFSSX1 - Shield Skirt Fully Seated 1 (X) L/S	7.00E-07	0.50	Will indicate shield skirt is sealed when it may not be.	Shutdown for repairs ~ 8 hours	LFSSFLX - Shield skirt fully lowered, and other sealed limit switches.	Other limit switches do not indicate skirt is sealed.	IV	Replace	
				Will prevent shield skirt fully sealed indication, even when properly sealed	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
				Will indicate shield skirt is sealed when it may not be.	Shutdown for repairs ~ 8 hours	LFSSFLX - Shield skirt fully lowered, and other sealed limit switches.	Other limit switches do not indicate skirt is sealed.	IV	Replace	
LFSSX2 - Shield Skirt Fully Seated 2 (X) L/S	LFSSX2 - Shield Skirt Fully Seated 2 (X) L/S	7.00E-07	0.50	Will prevent shield skirt fully sealed indication, even when properly sealed.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
				Will indicate shield skirt is sealed when it may not be.	Shutdown for repairs ~ 8 hours	LFSSFLX - Shield skirt fully lowered, and other sealed limit switches.	Other limit switches do not indicate skirt is sealed.	IV	Replace	
				Will indicate shield skirt is sealed when it may not be.	Shutdown for repairs ~ 8 hours	LFSSFLX - Shield skirt fully lowered, and other sealed limit switches.	Other limit switches do not indicate skirt is sealed.	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
Reference Drawing: 362A0656 and 362A0661
Mission/Function: Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:08 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.50	Will prevent shield skirt fully sealed indication, even when properly sealed.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSSY1 - Shield Skirt Fully Sealed 1 (Y) US	7.00E-07	Short	0.50	Will permit MFM inserted indication when it isn't. Will permit turret locking pin to disengage. Will permit turret rotate.	Shutdown for repairs ~ 8 hours	Leak Check	LFSSY2 and 3. Leak Check, other limit switches (LFPHRY)	IV	Replace	
					May permit turret rotate.	Shutdown for repairs ~ 8 hours	Leak Check	Same as above.	IV	Replace	
					May permit turret locking pin to disengage.	Shutdown for repairs ~ 8 hours	Leak Check	Same as above.	IV	Replace	
					May permit healthy leak check.	Shutdown for repairs ~ 8 hours	Leak Check	Same as above.	IV	Replace	
					May permit tube plug hoist raise.	Shutdown for repairs ~ 8 hours	Leak Check	Same as above.	IV	Replace	
					May permit mode select lock release.	Shutdown for repairs ~ 8 hours	Leak Check	Same as above.	IV	Replace	
			Open	0.50	Will not permit MFM inserted indication. Will not permit turret locking pin to disengage. Will not allow leak check to pass. Will not allow tube plug hoist raise. Will not allow mode select lock release.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSSY2 - Shield Skirt Fully Sealed 2 (Y) US	7.00E-07	Short	0.50	Same as LFSSSY1	Shutdown for repairs ~ 8 hours	Same as LFSSSY1	Same as LFSSSY1	IV	Replace	
			Open	0.50	Same as LFSSSY1	Shutdown for repairs ~ 8 hours	Same as LFSSSY1	Same as LFSSSY1	IV	Replace	
	LFSSSY3 - Shield Skirt Fully Sealed 3 (Y) US	7.00E-07	Short	0.50	Same as LFSSSY1	Shutdown for repairs ~ 8 hours	Same as LFSSSY1	Same as LFSSSY1	IV	Replace	
			Open	0.50	Same as LFSSSY1	Shutdown for repairs ~ 8 hours	Same as LFSSSY1	Same as LFSSSY1	IV	Replace	
	LFSSFLX - Shield Skirt Fully Lowered (X) US	7.00E-07	Short	0.50	Will indicate shield skirt is fully lowered when it may not be.	Shutdown for repairs ~ 8 hours	Alarm - Shield Skirt Not Sealed (if in conjunction with LFSSFSX indication)	LFSSSY1, 2, and 3 - Shield skirt fully sealed.	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
Reference Drawing: 382A0558 and 382A0561
Mission/Function: Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:08 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.50	Will prevent shield skirt fully lowered indication, even when properly lowered.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSFLX - Shield Skirt Not Fully Lowered (X) L/S	7.00E-07	Short	0.50	Will indicate shield skirt is not fully lowered when it may be. Will allow further lowering of shield skirt	Shutdown for repairs ~ 8 hours	LFSSFLX indicates opposite	LFSSCTX - Shield skirt not torque limited prevents further lowering past a hard stop.	IV	Replace	
			Open	0.50	Will prevent shield skirt not fully lowered indication, even when shield skirt is raised. Will prevent further lowering of shield skirt	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSFRX - Shield Skirt Fully Raised (X) L/S	7.00E-07	Short	0.50	Will provide indication to the operator that the shield skirt is fully raised when it may not be.	Shutdown for repairs ~ 8 hours	Status light indication	LFSSFRY is redundant. P2X, P6X, and LFPHFRX interlocks must also be met.	IV	Replace	
					May enable crane trolley travel motor.	Shutdown for repairs ~ 8 hours	Status light indication	Same as above	IV	Replace	
					May allow North and South trolley restraint pin to be retracted.	Shutdown for repairs ~ 8 hours	Status light indication	Same as above	IV	Replace	
			Open	0.50	Will prevent indication to the operator that the shield skirt is fully raised. Will also prevent retraction of North and South Trolley Restraint Pin. Trolley Restraint Pin and operation of the crane trolley travel motor.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSFRX - Shield Skirt Not Fully Raised (X) L/S	7.00E-07	Short	0.50	Will allow raising the shield skirt when it is already fully raised, provided other conditions are met.	Shutdown for repairs ~ 8 hours	None	P2X - Tube Plug in Storage Tube, P6X - MCO Host at correct upper limit, LFPHFRX - Tube Plug Hoist Fully Raised, etc.	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
362A0566 and 362A0581
Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

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Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.50	Will prevent shield skirt from being raised in any condition.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSFRY - Shield Skirt Fully Raised (Y) L/S	7.00E-07	Short	0.50	Permits bridge East and West seismic clamp release without skirt raised.	Shutdown for repairs ~ 8 hours	None	LFSSFRX is redundant	IV	Replace	
					May permit crane bridge travel.	Shutdown for repairs ~ 8 hours	None	LFSSFRX P2Y, P6Y and others must also be actuated.	IV	Replace	
					May permit crane trolley travel.	Shutdown for repairs ~ 8 hours	None	LFSSFRX P2Y, P6Y and others must also be actuated.	IV	Replace	
					Permits trolley South Restraint to retract	Shutdown for repairs ~ 8 hours	None	None	IV	Replace	
			Open	0.50	Will not allow release of seismic clamps with skirt raised. Will not allow bridge travel, will not allow trolley restraint to retract.	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	LFSSCTX - Shield Skirt Jack Not Torque Limited (X) L/S	7.00E-07	Short	0.50	Will prevent shield skirt being raised or lowered, even if the jack is not torque limited.	Shutdown for repairs ~ 8 hours	Alarm - Shield Skirt Torque Limit	None - fails safe	IV	Replace	
			Open	0.50	Will prevent the shield skirt jack from being stopped on high torque as long as other conditions are met.	Shutdown for repairs ~ 8 hours	None	OVR - motor overload, LFSSFLX - Shield skirt not fully lowered, LFSSFRX - Shield skirt not fully raised, etc.	IV	Replace	
	LFSS - Shield Skirt Jack Motor	5.00E-06	Fails to Start/Run	1.00	Will prevent shield skirt from being raised by the motor.	Shutdown for repairs ~ 24 hours	Lack of Shield Skirt Raising or Lowering Indication	Manual hand wind	III	Replace	
	BFSS - Shield Skirt Jack Brake	1.15E-05	Fails to brake	1.00	Would permit jack overtravel.	Shutdown for repairs ~ 24 hours	Lack of Shield Skirt Raising or Lowering Indication	None	III	Replace	
	Jack 1 - P/N 145	5.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to lifting.	Shutdown for repairs ~ 24 hours	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Jack 2 - P/N 146	5.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to lifting.	Shutdown for repairs ~ 24 hours	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	

FL. WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

01:08 PM

22-Sep-97

Date: **BD Groth**
 Compiled by: **R. Gauger**
 Reviewed by:

NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
362A0556 and 362A0561
Shielding/Sealing

SYSTEM:
Reference Drawing:
Mission/Function:

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
	Jack 3 - P/N 147	5.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Drive Shaft (quantity 2) - P/N 151	1.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Drive Shaft (quantity 2) - P/N 152	1.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Bevel Gearbox (motor end) - P/N 149	5.00E-07	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Bevel Gearbox (drive shaft end) - P/N 150	5.00E-07	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	III	Replace	
	Dowel Pin (quantity 8) - P/N 74	3.00E-06	Fails mechanically	1.00	Prevents shield skirt from being raised or lowered. May bind skirt due to tilting.	Lack of Shield Skirt Raising or Lowering Indication	Limit Torque will stop motor if skirt binds.	IV	Replace	
	PB - Raise Shield Skirt	7.00E-07	Short	0.10	May inadvertently raise shield skirt if other conditions are met.	Shield Skirt Raising Indication	P2X, P6X, and other switches/interlocks must also be actuated.	IV	Replace	
			Open	0.90	Will prevent shield skirt from being raised.	Lack of Shield Skirt Raising Indication	Manual Hand Wind	IV	Replace	
	PB - Stop Shield Skirt (NIC)	7.00E-07	Short	0.10	Will prevent stopping the shield skirt if in motion.	Shield Skirt Raising or Lowering Indication stays on	Limit Torque. Position limit switches (LSSFRX). Operator deenergizes.	IV	Replace	
			Open	0.90	Will stop the shield skirt if in motion.	Shield Skirt Raising or Lowering Indication turns off	Manual hand wind.	IV	Replace	
	PB - Lower Shield Skirt	7.00E-07	Short	0.10	May inadvertently lower the shield skirt if other conditions are met.	Shield Skirt Lowering Indication	Limit Torque. Position limit switches (LSSFLX). Operator deenergizes.	IV	Replace	
			Open	0.90	Will prevent lowering the shield skirt.	Lack of Shield Skirt Lowering Indication	Manual hand wind.	IV	Replace	

F1 WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM: NOSE UNIT, SHIELD SKIRT, AND SEALING SYSTEM
Reference Drawing: 362A0556 and 362A0581
Mission/Function: Shielding/Sealing

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:08 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	Permit Shield Skirt Raise (Y) - modeled as 25 switches, 42 relays, 1 trip pint unit and 1 resolver	1.89E-04	Short	0.10	May permit shield skirt to be raised if several switches or relays are shorted	Shutdown for repair - 8 to 48 hours	Various	Would require several shorts to occur. Highly unlikely failure mode	III	Replace	
	Raise Shield Skirt (X) - modeled as 28 switches, 42 relays, 1 trip pint unit and 1 resolver	1.89E-04	Open	0.90	A single failure would prevent skirt from being raised.	Shutdown for repair - 8 to 48 hours	Various	None - fails safe	III	Replace	
	Raise Shield Skirt (X) - modeled as 28 switches, 42 relays, 1 trip pint unit and 1 resolver	1.89E-04	Short	0.10	May permit shield skirt to be raised if several switches or relays are shorted	Shutdown for repair - 8 to 48 hours	Various	Would require several shorts to occur. Highly unlikely failure mode	III	Replace	
	Lower Shield Skirt - modeled as 7 switches and 13 relays	2.00E-05	Open	0.90	A single failure would prevent skirt from being raised.	Shutdown for repair - 8 to 48 hours	Various	None - fails safe	III	Replace	
			Short	0.10	May lower shield skirt inadvertently if several switches or relays are shorted.	Shutdown for repair - 8 to 48 hours	Various	Would require several shorts to occur. Highly unlikely failure mode	III	Replace	
			Open	0.90	A single failure will prevent the shield skirt from being lowered.	Shutdown for repair - 8 to 48 hours	Various	None - fails safe. An unlikely event would consider the shield skirt being raised inadvertently and then failing to be lowered, but this is highly unlikely	III	Replace	

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FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

22-Sep-97 01:21 PM

BD Groth

Date:

Compiled by:

R. Gauger

Reviewed by:

MCO HOIST AND ENCLOSURE

362A0545/546

Raise/lower MCO Grapple, Maintaining Confinement of the MHM

SYSTEM:

Reference Drawing:

Mission/Function:

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
Drum and External Drive Assembly	MFHM - MCO Hoist Motor 10HP	5.00E-06	Fails to Start/ Run	1.00	Local effects Unable to raise or lower hoist	Lack of Various Indications (sealing zone, raising, lowering, etc.)	Manual Hand Wind	III	Replace	
	MHOL - MCO Hoist Motor Overload Switch EB33056-8	4.12E-06	Fails open	0.98	Motor will not run	Visual	Reset switch	III	Replace	
			Fails shorted	0.02	No trip on overload	None	None	III	Replace	
	MHLC - MCO Hoist Line Contactor EB 33056-5	4.12E-06	Fails open	0.80	No power to Hoist	Visual	None	III	Replace	
			Fails shorted	0.20	Can't turn power off	None	None	III	Replace	
	HMC - MCO Hoist Motor Variable Speed Drive EB-33056-6	2.00E-06	Motor fails to run	1.00	Prevents motor from starting or running	Visual	None	II	Replace	
	Planetary Gear	5.00E-07	Broken	0.50	Unable to raise or lower hoist	Lack of Various Indications (sealing zone, raising, lowering, etc.)	None	III	Replace	
			Binding/ Sticking	0.50	Unable to raise or lower hoist, or degraded performance	Lack of Various Indications (sealing zone, raising, lowering, etc.)	None	III	Replace	
	BFMH - Mechanical Load D.C. Shoe Brake (includes transformer and rectifier)	1.15E-05	Fails	1.00	Fails to prevent overtravel	None	None	III	Replace	
	MHBR - MCO Hoist Brake Relay 1/B 33056 -6	4.00E-06	Fails open	0.90	Brakes do not release	Alarm	None	IV	Replace	
			Fails closed	0.10	Tends to release brake	None	None	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:

Reference Drawing:

Mission/Function:

MCO HOIST AND ENCLOSURE

382A0645/646

Raise/lower MCO Grapple, Maintaining Confinement of the MHM

Date:

22-Sep-97

01:21 PM

Complied by:

BD Groth

Reviewed by:

R. Gauger

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
MHFLT - MCO Hoist Fault Relay EB-33056-6		1.10E-06	Fails open	0.90	Prevents hoist use	Repairs ~ 8 hrs	None	None	IV	Replace	
			Fails closed	0.10	Allow inadvertent hoist use	Repairs ~ 8 hrs	Alarm	Other contacts in series	IV	Replace	
MHDB Dynamic Braking Resistors EB-33056-6		1.00E-06	Fails open	0.98	No braking	Repairs ~ 24 hrs	None	None	III	Replace	
			Fails shorted	0.02	Short on line	Repairs ~ 24 hrs	None	None	III	Replace	
MHCB MCO Hoist Brake Circuit Breaker EB-33056-5		1.20E-06	Fails open	0.80	No power to Brake	Repair ~ 24 hrs	None	None	III	Replace	
			Fails shorted	0.20	No trip on overload	Repair ~ 24 hrs	None	None	III	Replace	
MHL C MCO Hoist Brake Line Connector EB 33056-5		1.10E-06	Fails open	0.80	No power to Brake	Repair ~ 24 hrs	None	None	III	Replace	
			Fails shorted	0.20	Can't turn power off	Repair ~ 24 hrs	None	None	III	Replace	
LFMBB1X - MCO Hoist Balance Beam rope 1 not slack (X) / S		7.00E-07	Short	0.50	Indicates hoist is not slack even if it is. Potential to attempt to raise an unbalanced load	Shutdown for repairs ~ 48 hours	MCO Hoist Rope Imbalance Tripped Alarm.	LFMBB2X must also indicate no slack. Damping cylinders ensure overbalance motion is within ASME-NOG-1 guidelines	III	Replace	
			Open	0.50	Will prevent raising of the hoist due to slack rope indicators	Shutdown for repairs ~ 48 hours	None	None - fails safe	III	Replace	
LFMBB2X - MCO Hoist Balance Beam rope 2 not slack (X) / S		7.00E-07	Short	0.50	Indicates hoist is not slack even if it is. Potential to attempt to raise an unbalanced load	Shutdown for repairs ~ 48 hours	MCO Hoist Rope Imbalance Tripped Alarm.	LFMBB1X must also indicate no slack. Damping cylinders ensure overbalance motion is within ASME-NOG-1 guidelines	III	Replace	
			Open	0.50	Will prevent raising of the hoist due to slack rope indicators	Shutdown for repairs ~ 48 hours	None	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE
Reference Drawing: 362A0646/546
Mission/Function: Raise/lower MCO Grapple, Maintaining Confinement of the NMIM

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

01:21 PM

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
			Open	0.50	Will prevent raising of the hoist due to slack rope indications	Shutdown for repairs ~ 48 hours	None	None - fails safe	III	Replace	
	LFMRMX - MCO Hoist Rope Not Misreave (X) US	7.00E-07	Short	0.50	Provides indication that the hoist rope is not misreaved when it may be. Hoist may be raised with a misreaved rope causing potential damage to the rope.	Shutdown for repairs ~ 48 hours. If damage to hoist rope, then shutdown for > 1 week.	MCO Hoist Misreave Alarm	None	III (If rope is damaged)	Replace	
			Open	0.50	Prevents raising of hoist even if rope is not misreaved.	Shutdown for repairs ~ 48 hours	None	None - fails safe	III	Replace	
	RSVMGHX - MCO Grapple Height (X) resolver	7.00E-07	Fails open - no output	1.00	Incorrect grapple height output. No operation of height limits	Shutdown for repairs ~ 48 hours	Inconsistent with channel Y	RVSIMGHY	III	Replace	
	RSVMGHY - MCO Grapple Height (Y) resolver	7.00E-06	Fails open - no output	1.00	Incorrect grapple height output. No operation of height limits	Shutdown for repairs ~ 48 hours	Inconsistent with channel X	RVSIMGHX	III	Replace	
	SMRHY - MCO Hoist Not Overspeed (Y)	7.00E-06	Tripped (Short)	0.50	Will prevent hoist from being raised.	Shutdown for repairs ~ 48 hours	MCO Hoist Overspeed Alarm	None - fails safe	III	Replace	
			Untripped (open)	0.50	Will allow hoist to be raised even if the hoist is overspeed.	Shutdown for repairs ~ 48 hours	None	None	III	Replace	
	Hoist Electrical Cable	3.00E-06	Fails open	0.55	Open indication for all MCO Grapple limit switches	Shutdown for repairs ~ 80 hours	Lack of raising or lowering indication	See MCO Grapple System	III	Replace	
			Short to ground	0.45	Shut indication for all MCO Grapple limit switches	Shutdown for repairs ~ 80 hours	Lack of raising or lowering indication	See MCO Grapple System	III	Replace	
	Operational Gas Hose	9.00E-08	Fails	1.00	Loss of ability to open the grapple jaws	Shutdown for repairs ~ 80 hours	Lack of Grapple Jaws Open indication	Emergency gas hose	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE

Reference Drawing:

352A0546/546

Mission/Function:

Raiselower MCO Grapple, Maintaining Confinement of the MHM

Date:

22-Sep-97

01:21 PM

Compiled by:

BD Groth

Reviewed by:

R. Gauger

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Hoist Upper Assembly	Emergency Gas Hose	9.00E-06	Fails	1.00	Loss of ability to open the grapple jaws via the emergency helium	Shutdown for repairs ~ 80 hours	Lack of Grapple Jaws Open indication	Normal (operational) gas hose	III	Replace	
	Operational Hose Reel	1.14E-05	Fails to unwind (jams)	0.50	Possible damage to the hose. Loss of ability to open the grapple	Shutdown for repairs ~ 80 hours	Lack of Grapple Jaws Open indication	Hose can be disconnected and grapple operated by emergency helium	III	Replace	
			Fails to retract	0.50	Possible interference of the hose with the hoist	Shutdown for repairs ~ 80 hours	None	None	III	Replace	
	Emergency Hose Reel	1.14E-05	Fails to unwind (jams)	0.50	Possible damage to the hose. Loss of ability to open the grapple by the emergency system	Shutdown for repairs ~ 80 hours	Lack of Grapple Jaws Open indication	None - assuming the emergency system is only used if the operational system fails.	III	Replace	
MCO Hoist Cable			Fails to retract	0.50	Possible interference of the hose with the hoist.	Shutdown for repairs ~ 80 hours	None	None	III	Replace	
	Cable Reel	1.15E-05	Fails to unwind (jams)	0.50	Possible damage to the cable. Loss of grapple associated limit switch indication.	Shutdown for repairs ~ 80 hours	Lack of Grapple Jaws Open indication	None	III	Replace	
			Fails to retract	0.50	Possible interference of the cable with the hoist	Shutdown for repairs ~ 80 hours	None	None	III	Replace	
	Cable 1	1.00E-05	Fails	1.00	Will cause the load to become unbalanced.	Shutdown for repairs > 1 week	Alarm - MCO Hoist Rope imbalance Tripped	Cable 2: Damping cylinders ensure overbalance motion is within ASME NOG-1 guidelines	II	Replace	

FMIA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

MCO HOIST AND ENCLOSURE
362A064S/546

Raise/lower MCO Grapple, Maintaining Confinement of the MHM

Date:
Compiled by:
Reviewed by:

22-Sep-97
BD Groth
R. Gauger

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Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	Cable 2	1.00E-05	Fails	1.00	Will cause the load to become unbalanced.	Shutdown for repairs > 1 week	Alarm - MCO Hoist Rope Imbalance Tripped	Cable 1. Dumping cylinders ensure overbalance motion is within ASME-NOG-1 guidelines	II	Replace	
	LCMHR1X - MCO Hoist Rope 1 Load Cell (X). Also includes strain meter and volt relay	1.00E-05	Degraded Output	0.56	Spurious operation. Could result in any of the three failure effects described below.	Shutdown for repairs ~ 48 hours	Erratic operation	LCMHR1Y	III	Replace	
			High	0.19	Allows lowering of MCO hoist no matter what load is on the hoist. See note 1.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Overweight Tripped	LCMHR1Y - prevents this from occurring only in the case where weight is less than grapple weight.	III	Replace	
			Low	0.12	Allows raising of MCO hoist no matter what load is on the hoist. See note 2.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Undersize Tripped	LCMHR1Y - prevents this from occurring only in the case where weight is greater than grapple weight, and is not engaged on a grapple.	III	Replace	
			As-Is	0.13	Could raise or lower in various modes with incorrect weight. See notes 1 and 2 for all possible scenarios	Shutdown for repairs ~ 48 hours	Inconsistent with other load cells	LCMHR1Y	II	Replace	
	LCMHR2X - MCO Hoist Rope 2 Load Cell (X). Also includes strain meter and volt relay	1.00E-05	Degraded Output	0.56	Spurious operation. Could result in any of the three failure effects described below.	Shutdown for repairs ~ 48 hours	Erratic operation	LCMHR2Y	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE
Reference Drawing: 362A0545/546
Mission/Function: Raise/Lower MCO Grapple, Maintaining Confinement of the MHM

Date: 22-Sep-97 01:21 PM
Compiled by: BD Groth
Reviewed by: R. Gauger

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			High	0.19	Allows lowering of MCO hoist no matter what load is on the hoist. See note 1.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Overweight Tripped	LCMHR2Y - prevents this from occurring only in the case where weight is less than grapple weight.	III	Replace	
			Low	0.12	Allows raising of MCO hoist no matter what load is on the hoist. See note 2.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Underweight Tripped	LCMHR2Y - prevents this from occurring only in the case where weight is greater than grapple weight, and is not engaged on a grapple.	III	Replace	
			As-Is	0.13	Could raise or lower in various modes with incorrect weight. See notes 1 and 2 for all possible scenarios	Shutdown for repairs ~ 48 hours	Inconsistent with other load calls	LCMHR2Y	III	Replace	
	LCMHR1Y - MCO Hoist Rope 1 Load Cell (Y). Also includes strain meter and volt relay	1.00E-05	Degraded Output	0.56	Spurious operation. Could result in any of the three failure effects described below.	Shutdown for repairs ~ 48 hours	Erratic operation	LCMHR1X	III	Replace	
			High	0.19	May allow operation of hoist with less than min Grapple weight.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Overweight Tripped	LCMHR1X	III	Replace	
			Low	0.12	May allow operation of hoist with above grapple only weight and jaws open.	Shutdown for repairs ~ 48 hours	Alarm - MCO Hoist Underweight Tripped	LCMHR1X, and Grapple Jaws US LFMJCY	III	Replace	
			As-Is	0.13	Could allow either of the two failure effects above	Shutdown for repairs ~ 48 hours	Inconsistent with other load calls	LCMHR1X	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE
Reference Drawing: 382A0545/546
Mission/Function: Raise/lower MCO Grapple, Maintaining Confinement of the MHM

Date: 22-Sep-97
Compiled by: BD Groth
Reviewed by: R. Gauger

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Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Controls	LCMHR2V - MCO Hoist Rope 1 Load Cell (Y). Also includes strain meter and volt relay	1.00E-05	Degraded Output	0.56	Spurious operation. Could result in any of the three failure effects described below.	Shutdown for repairs - 48 hours	Erratic operation	LCMHR2X	III	Replace	
			High	0.19	May allow operation of hoist with less than min. Grapple weight.	Shutdown for repairs - 48 hours	Alarm - MCO Hoist Overweight Tripped	LCMHR2X	III	Replace	
			Low	0.12	May allow operation of hoist with above grapple only weight and jaws open.	Shutdown for repairs - 48 hours	Alarm - MCO Hoist Underweight Tripped	LCMHR2X, and Grapple Jaws US LFMJCY	III	Replace	
			As-Is	0.13	Could allow either of the two failure effects above	Shutdown for repairs - 48 hours	Inconsistent with other load cells	LCMHR2X	III	Replace	
	PB - Start Raise MCO Hoist	7.00E-07	Short	0.10	Inadvertent raising of the MCO hoist if in Auto and other conditions are met.	Shutdown for repairs - 8 hours	MCO Hoist Raising Indication	Other hoist raise interlocks. Must be in auto.	IV	Replace	
			Open	0.90	Prevents raising of MCO Hoist in Auto	Shutdown for repairs - 8 hours	Lack of MCO Hoist Raising Indication	Manual hand wind	IV	Replace	
	PB - Stop MCO Hoist (MCO)	7.00E-07	Short	0.10	Fails to stop hoist if moving	Shutdown for repairs - 8 hours	MCO Hoist Raising or Lowering Indication still on	Hoist position limit switches. Operator deenergizes.	IV	Replace	
			Open	0.90	Stops hoist	Shutdown for repairs - 8 hours	Lack of MCO Hoist Raising or Lowering Indication	Manual hand wind	IV	Replace	
	SW - MCO Hoist Control Switch at Auto Positions	8.60E-06	Short	0.20	Allows inadvertent auto operation of the MCO Hoist	Shutdown for repairs - 8 hours	None	Switch needs to be actuated by operator	IV	Replace	
			Open	0.80	Prevents auto operation of MCO Hoist	Shutdown for repairs - 8 hours	None	Can be operated manually.	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE
Reference Drawing: 362A0545/546
Mission/Function: Raise/Lower MCO Grapple, Maintaining Confinement of the MHM

Date: 22-Sep-87
Compiled by: BD Groth
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Sub-component/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	SW - MCO Hoist Raise/Lower Joystick Control	Included in overall VSD failure rate (2E-05)	Short	0.20	May allow inadvertent manual raising or lowering of the MCO Hoist	Shutdown for repairs ~ 8 hours	MCO Hoist Raising or Lowering Indication	MCO Hoist Control Switch must be in manual position	IV	Replace	
			Open	0.80	Prevents manual operation of the MCO hoist	Shutdown for repairs ~ 8 hours	Lack of MCO Hoist Raising or Lowering Indication	Can be operated in the auto mode.	IV	Replace	
	SW - MCO Hoist Control Switch at Manual Position	6.60E-06	Short	0.20	Allows inadvertent manual operation of the MCO Hoist	Shutdown for repairs ~ 8 hours	None	Still needs to be actuated by operator	IV	Replace	
			Open	0.80	Prevents manual operation of MCO Hoist	Shutdown for repairs ~ 8 hours	None	Can be operated in the auto mode.	IV	Replace	
	PB - Start Lower MCO Hoist	7.00E-07	Short	0.10	Inadvertent lowering of the MCO hoist in Auto and other conditions are met.	Shutdown for repairs ~ 8 hours	MCO Hoist Lowering Indication	Numerous other conditions must be met	IV	Replace	
			Open	0.90	Prevents lowering of MCO Hoist in Auto	Shutdown for repairs ~ 8 hours	Lack of MCO Hoist Lowering Indication	Can be lowered in the manual mode	IV	Replace	
	SW - MHM in MCO Mode	6.60E-06	Short	0.20	May allow inadvertent operation of the MHM in the MCO Mode	Shutdown for repairs ~ 8 hours	None	None	IV	Replace	
			Open	0.80	Will not allow operation of the MHM in the MCO Mode	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	
	SW - MHM in Impact Absorber Exchange Mode	6.60E-06	Short	0.20	May allow inadvertent operation of the MHM in the Impact Absorber Exchange Mode	Shutdown for repairs ~ 8 hours	None	None	IV	Replace	
			Open	0.80	Will not allow operation of the MHM in the Impact Absorber Exchange Mode	Shutdown for repairs ~ 8 hours	None	None - fails safe	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:

Reference Drawing:

Mission/Function:

MCO HOIST AND ENCLOSURE

382A0545/546

Raise/Lower MCO Grapple, Maintaining Confinement of the MHM

Date:

Complied by:

Reviewed by:

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22-Sep-97

BD Groth

R. Gauger

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
Raise MCO Hoist Command -	SW - MHM in Tube Plug Exchange Mode	6.80E-06	Short	0.20	May allow inadvertent operation of the MHM in the Tube Plug Exchange Mode	Shutdown for repairs - 8 hours	None	None	IV	Replace	
			Open	0.80	Will not allow operation of the MHM in the Tube Plug Exchange Mode	Shutdown for repairs - 8 hours	None	None - fails safe	IV	Replace	
Lower MCO Hoist Command -	Modeled as 36 switches, 81 relays, 2 load cells, 2 trip point units, and 1 resolver	1.58E-04	Short	0.10	May allow for inadvertent raising of the hoist	Shutdown for repairs - 8 to 48 hours	Various	Numerous shorts would need to occur. Low probability of this failure	III	Replace	
			Open	0.80	Will prevent raising of the hoist	Shutdown for repairs - 8 to 48 hours	Various	None - fails safe	III	Replace	
MCO Hoist Speed Control -	Modeled as 29 switches, 71 relays, 2 load cells, 2 resolvers and 2 trip point units	1.41E-04	Short	0.10	May allow for inadvertent lowering of the hoist	Shutdown for repairs - 8 to 48 hours	Various	Numerous shorts would need to occur. Low probability of this failure	III	Replace	
			Open	0.80	Will prevent lowering of the hoist	Shutdown for repairs - 8 to 48 hours	Various	None - fails safe	III	Replace	
			Short	0.10	May allow inadvertent raising or lowering of the hoist	Shutdown for repairs - 8 to 48 hours	Various	Numerous shorts would need to occur. Low probability of this failure	III	Replace	
			Open	0.80	Will prevent raising or lowering of the hoist	Shutdown for repairs - 8 to 48 hours	Various	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO HOIST AND ENCLOSURE **Date:** 22-Sep-97 **01:21 PM**
Reference Drawing: 362A0546/546 **Compiled by:** BD Groth
Mission/Function: Raise/lower MCO Grapple, Maintaining Confinement of the MHM **Reviewed by:** R. Gauger

Subcomponent/ Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					

NOTES:

1. If hoist has less than minimum grapple only weight, effects could be slack rope with potential for MCO grapple to break free and drop.
 If hoist has less than minimum grapple + impact absorber weight when carrying an impact absorber - could result in a jammed impact absorber breaking free and dropping.
 If hoist is carrying an MCO with weight below grapple + MCO weight - could result in a jammed MCO possibly breaking free and dropping.
 If hoist is carrying a Tube Plug with weight below grapple + tube plug weight - could result in a jammed tube plug, possibly breaking free and dropping.
2. If hoist has greater than minimum grapple only weight and is not engaged on a load -grapple could snag with potential damage for MCO or Tube Plug.
 If hoist has greater than grapple + MCO weight when raising - could result in damage to hoist or grapple, or damage to the MCO or Storage Tube.
 If hoist has greater than grapple + impact absorber weight when in impact absorber exchange mode - could inadvertently lift an MCO with potential for damage to impact absorber or Storage Tube.
 If hoist has greater than grapple + tube plug weight when raising in the Tube Plug Exchange mode - could inadvertently lift an MCO with potential for damage to a Tube Plug or Storage Tube.

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FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO Grapple
Reference Drawing: 362A0563
Mission/Function: Engage MCOs and Impact Absorbers

Date: 22-Sep-97
Compiled by: A. Ghose
Reviewed by: BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
MCO Grapple Body	Operating Cylinder	1.10E-05	Cylinder leaks	Alpha	Failure Effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
				Alpha	Local effects	End effects	Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
				0.50	Cylinder inoperable. Cannot open grapple jaws.	Repairs ~ 8 hrs.	Visual	Redundant component emergency cylinder	IV	Replace	
				0.50	Cylinder inoperable. Cannot open grapple jaws.	Repairs ~ 8 hrs.	Visual	Redundant component emergency cylinder	IV	Replace	
Emergency Cylinder	Emergency Cylinder	1.10E-05	Cylinder leaks	0.50	Cylinder inoperable. Cannot open grapple jaws.	Repairs ~ 8 hrs.	Visual	This is a backup system.	IV	Replace	
				0.50	Cylinder inoperable. Cannot open grapple jaws.	Repairs ~ 8 hrs.	Visual	This is a backup system.	IV	Replace	
				0.10	Falsely indicates MCO Grapple is in contact with load.	Repairs ~ 48 hrs.	Status indication	LFMCOCY is redundant component for channel Y permissive	III	Replace	
				0.90	Falls to indicate status that Grapple load is not an MCO, with LFMCOMX tripped.	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	
LFMCOCY MCO Grapple NOT in Contact w/ Load (X) I/S	LFMCOCY MCO Grapple NOT in Contact w/ Load (X) I/S	7.00E-07	Short	0.10	Will allow opening of MCO Grapple jaws when in contact with a load but not sealed, and may satisfy P80 to release mode select lock	Repairs ~ 48 hrs.	Status indication	LFMCOCY is redundant component for channel Y permissive. Other conditions must be met.	III	Replace	
				0.90	Will not allow opening of MCO Grapple jaws except with MCO Grapple sealed	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:

MCO Grapple

Reference Drawing:

362A0563

Mission/Function:

Engage MCOs and Impact Absorbers

Date:

22-Sep-97

01:21 PM

Compiled by:

A. Ghose

Reviewed by:

BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
LFMCOMY MCO Grapple Load is not Contact w/ Load (Y) L/S	LFMCOMY	7.00E-07	Short	0.10	Will permit inadvertent MCO Hoist operation, or Shield Skirt raise, if other conditions are met	Repairs ~ 48 hrs.	Status indication	Other conditions must be met e.g. Turret at MCO Hoist, Tube plug Hoist fully raised, etc.	III	Replace	
			Open	0.90	Will not permit MCO hoisting, or Shield Skirt raise, even with other conditions met.	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	
LFMCOMX MCO Grapple Load is MCO (X) L/S	LFMCOMX	7.00E-07	Short	0.10	False status indication that MCO Grapple load is MCO, when jaws are closed and locked	Repairs ~ 48 hrs.	Status indication	LFMCOMY is redundant component for channel Y permissive	III	Replace	
			Open	0.90	Cannot detect MCO Grapple load is MCO.	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	
LFMCOMX MCO Grapple Load is not MCO (X) L/S	LFMCOMX	7.00E-07	Short	0.10	False status indication that MCO Grapple load is not MCO.	Repairs ~ 48 hrs.	Status indication	LFMCOMY is redundant component for channel Y permissive	III	Replace	
			Open	0.90	Cannot detect MCO Grapple load is not MCO.	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	
LFMCOMY MCO Grapple Load is not MCO (Y) L/S	LFMCOMY	7.00E-07	Short	0.10	Will permit MCO Hoist raising and lowering a MCO when MCO not inserted or Nose Seals are not leak free.	Repairs ~ 48 hrs.	Status indication	LFMCOMX is redundant component for channel X	III	Replace	
			Open	0.90	Will not permit Hoist operation for a load that is not MCO	Repairs ~ 48 hrs.	None	None - fails safe	III	Replace	
LFMGSX1 MCO Grapple Seated 1 (X) Limit Switch	LFMGSX1	7.00E-07	Short	0.10	Will permit opening MCO Grapple jaws without MCO Grapple seated	Repairs ~ 48 hrs.	None	MCO Grapple will be seated if any two of three L/S give correct indication	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

MCO Grapple
382A0863

Engage MCOs and Impact Absorbers

Date: 22-Sep-97

Compiled by: A. Ghose

Reviewed by: BD Groth

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Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.90	Will not permit opening MCO Grapple jaws with MCO Grapple sealed	Repairs - 48 hrs.	None	None - fails safe	III	Replace	
	LFMGSX2 MCO Grapple Sealed 2 (X) Limit Switch	7.00E-07	Short	0.10	Will permit opening MCO Grapple jaws without MCO Grapple sealed	Repairs - 48 hrs.	None	MCO Grapple will be sealed if any two of three L/S give correct indication	III	Replace	
			Open	0.90	Will not permit opening MCO Grapple jaws with MCO Grapple sealed	Repairs - 48 hrs.	None	None - fails safe	III	Replace	
	LFMGSX3 MCO Grapple Sealed 3 (X) Limit Switch	7.00E-07	Short	0.10	Will permit opening MCO Grapple jaws without MCO Grapple sealed	Repairs - 48 hrs.	None	MCO Grapple will be sealed if any two of three L/S give correct indication	III	Replace	
			Open	0.90	Will not permit opening MCO Grapple jaws with MCO Grapple sealed	Repairs - 48 hrs.	None	None - fails safe	III	Replace	
	LFMGUDX MCO Grapple Not at Upper Datum (X) L/S	7.00E-07	Short	0.10	MCO Grapple Hoist raised past upper datum - possible damage to hoist, or jamming of hoist	Repairs - 48 hrs.	Status indication	Other conditions must be met, e.g. MCO Hoist below ultimate upper limit (P57)	III	Replace	
			Open	0.90	MCO Grapple Hoist cannot be raised to upper limit position	Repairs - 48 hrs.	No Operation	None - fails safe	III	Replace	
			Fails Structurally	0.05	Unable to engage or disengage MCO Grapple. May cause MCO drop if several jaws fail	Suspend operation. Repairs - 48 hrs.	Load cell indication	None	III (II if MCO drops)	Replace Entire Assembly	
MCO Grapple Jaws	MCO Grapple Jaw Assembly	Negligible (<1E-8 for structural failure of jaws)	Link mechanism freezes	0.95	Unable to engage or disengage MCO Grapple	Suspend operation. Repairs - 48 hrs.	Grapple limit switch indications	None	III	Replace Entire Assembly	

BD Groth

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FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

MCO Grapple
382A0563
Engage MCOs and Impact Absorbers

Date: 22-Sep-97 01:21 PM
Compiled by: A. Ghose
Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.30	Does not permit MCO Hoist operation	Repairs ~ 48 hrs.	No operation	None - fails safe	III	Replace	
	LFMJLX MCO Grapple Jaws Locked (X) L/S	7.00E-07	Short	0.10	False Status indication that MCO Grapple jaws locked	Repairs ~ 48 hrs.	Status indication	LFMJLY is redundant component for ch. Y permissive	III	Replace	
			Open	0.30	Inability to indicate whether or not MCO Grapple is MCO	Repairs ~ 48 hrs.	Lack of indication	None - fails safe	III	Replace	
	LFMJLY MCO Grapple Jaws Locked (Y) L/S	7.00E-07	Short	0.10	May permit operation with MCO Grapple jaws not locked	Repairs ~ 48 hrs.	Status indication	LFMJLX is redundant component	III	Replace	
			Open	0.30	Does not permit MCO Hoist operation	Repairs ~ 48 hrs.	No operation	None - fails safe	III	Replace	
	LFMJOX MCO Grapple Jaws Open (X) L/S	7.00E-07	Short	0.10	False Status indication that MCO Grapple jaws open	Repairs ~ 48 hrs.	Status indication	LFMJLY is redundant component for ch. Y permissive	III	Replace	
			Open	0.30	Inability to indicate whether or not MCO Grapple is MCO	Repairs ~ 48 hrs.	Lack of indication	None - fails safe	III	Replace	
	LFMJYJ MCO Grapple Jaws Open (Y) L/S	7.00E-07	Short	0.10	May permit operation with MCO Grapple jaws not open	Repairs ~ 48 hrs.	Status indication	LFMJOX is redundant component	III	Replace	
			Open	0.30	Does not permit MCO Hoist operation	Repairs ~ 48 hrs.	No operation	None - fails safe	III	Replace	
	LFMJUX MCO Grapple Jaws Unlocked (X) L/S	7.00E-07	Short	0.10	Opening of Grapple jaws may be initiated while jaws are not unlocked if other conditions are met	Repairs ~ 48 hrs.	Incorrect operation	Other conditions must be met, i.e. MCO Grapple is within a seating zone (P56)	III	Replace	

FMEA WORKSHEET CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO Grapple
 Reference Drawing: 382A0583
 Mission/Function: Engage MCOs and Impact Absorbers

Date: 22-Sep-97 01:21 PM
 Compiled by: A. Ghose
 Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
			Open	0.80	Grapple jaws cannot be opened even though Grapple is in a sealing zone. The turret is at MCO Hoist position, and Grapple supply pressure is high	Repairs - 48 hrs.	Lack of operation	None - fails safe	III	Replace	
PB	Open MCO Jaws Pushbutton	7.00E-07	Short	0.10	Will open Grapple jaws, without operating pushbutton when other conditions are met	Repairs - 8 hrs	Visual	Conditions of P88, P87, and P89 must be met	IV	Replace	
			Open	0.80	Cannot open Grapple jaws	Repairs - 8 hrs	Lack of operation	None - fails safe	IV	Replace	
PB	Close MCO Jaws Pushbutton	7.00E-07	Short	0.10	Will close Grapple jaws, without operating pushbutton when other conditions are met	Repairs - 8 hrs	Visual	Conditions of P88 must be met	IV	Replace	
			Open	0.80	Cannot close Grapple jaws	Repairs - 8 hrs	Unable to operate	None - fails safe	IV	Replace	
MCO Grapple Mechanical lock		Negligible for structural failure	Fails structurally - shears on one of six jaws	1.00	Grapple jaw (one of six) cannot be locked	Suspend operation. Repairs - 48 hrs	Visual	Mechanical lock on five other jaws functioning, and Grapple jaw mechanism does not permit jaws opening in loaded condition. Operator action, suspend operation	III	Replace	

FM... WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: MCO Grapple Date: 22-Sep-97 01:21 PM
 Reference Drawing: 362A0563 Compiled by: A. Ghose
 Mission/Function: Engage MCOs and Impact Absorbers Reviewed by: BD Groth

Subcomponent / Subsystem	Component ID	Component Fail Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks
					Local effects	End effects					
	Proximity probe and spring	3.00E-06	Sticks in spring-compromised position	1.00	Fails to trip proximity limit switches that indicate (a) whether load is MCO or Impact Absorber, or (b) that Grapple has separated from load	Repairs -- 48 hrs	Visual, limit switches do not trip as expected while MCO hoist is being raised or lowered	None	III	Replace	

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FIG. A WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Navigation Cameras, and Alignment
Reference Drawing: 362A0558
Mission/Function: Accurate Positioning of the MHM

Date: 22-Sep-97
Compiled by: R. Gauger
Reviewed by: BD Groth

01:30 PM

Subcomponent / Subsystem	Component ID	Component	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation	Severity Class	Maintenance Action	Remarks Notes
					Local effects	End effects					
Navigation	M1 - Main power contactor	4.12E-06	Fail open	0.9							
	M1 - Main power contactor	4.12E-06	Fail open	0.9							
	CAMS video switcher	5.80E-06	Fail to switch	0.1	Local effects Unable to align with tube plug	End effects Repairs ~ 24 hrs	Visual - Monitor	Use camera 2 if possible	Class III	Replace	Notes
	Camera #1 and lens	5.00E-05	Fail to operate	0.5	Minimal - may prevent overload protection.	Repairs ~ 24 hrs	None	Operate with difficulty	III	Replace	
	Camera #2 and lens	5.00E-05	Degraded	0.5	Must use only coarse or fine adjustment	Repairs ~ 24 hrs	Visual - Monitor	Use camera 2	III	Replace	
	Camera #2 and lens	5.00E-05	Fail to	0.5	Must use only fine adjustment	Repairs ~ 72 hrs	Visual - Monitor	Use camera 2	III	Replace	
	Camera #2 and lens	5.00E-05	Degraded	0.5	Must use only coarse adjustment	Repairs ~ 72 hrs	Visual - Monitor	Operate with difficulty	III	Replace	
	LP1 - Lamp	5.00E-04	Fails in use	0.5	Must use only coarse adjustment	Repairs ~ 72 hrs	Visual - Monitor	Use camera 1 - less accuracy	III	Replace	
	LP2 - Standby lamp	5.00E-04	Fails while lamp is off	0.5	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	More use of camera 1	III	Replace	
	CA - Cable for light	3.00E-06	Fails in use	0.5	Potential loss of navigation	Repairs ~ 72 hrs	None	Use Lamp 2	III	Replace	
Navigation	CA - Cable for video #1	3.00E-06	Fails while lamp is off	0.5	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Use Lamp 2	III	Replace	
	CA - Cable for video #1	3.00E-06	Open	0.9	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	None if LP1 has failed	III	Replace	
	CA - Cable for video #1	3.00E-06	Short	0.1	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	None if LP1 has failed	III	Replace	
	CA - Cable for video #1	3.00E-06	Open	0.9	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Use other light	III	Replace	
	CA - Cable for video #1	3.00E-06	Short	0.1	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Use other light	III	Replace	
	CA - Cable for video #2	3.00E-06	Open	0.9	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Limited use of other camera	III	Replace	
Navigation	CA - Cable for video #2	3.00E-06	Short	0.1	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Limited use of other camera	III	Replace	
	CA - Cable for video #2	3.00E-06	Short	0.1	Potential loss of navigation	Repairs ~ 72 hrs	Visual - Monitor	Limited use of other camera	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING -- MCO HANDLING MACHINE

SYSTEM: Navigation Cameras, and Alignment
Reference Drawing: 362A0558
Mission/Function: Accurate Positioning of the M/HM

Date: 22-Sep-97
Compiled by: R. Gauger
Reviewed by: BD Groth

01:38 PM

Subcomponent / Subsystem	Component ID	Component	Failure Mode	Alpha	Failure Effects		Failure Detection		Mitigation	Severity	Maintenance	Remarks
					Local effects	End effects	Method	Class				
Navigation	M1 - Main power connector	4.12E-06	Fail open	0.9	Potential loss of navigation	Repairs - 72 hrs	None	limited use of other camera	Replace	III	Replace	
	CA - Cable for 12 VDC Power	3.00E-06	Open	0.9	Potential loss of navigation	Repairs - 72 hrs	Visual - Monitor	Replace	Replace	III	Replace	
	PSV - power supply 120 VAC to 12 VDC	2.00E-06	No output	0.5	Potential loss of navigation	Repairs - 72 hrs	None	Replace	Replace	III	Replace	
	SW - Camera Switch EB33056	5.80E-06	Open	0.5	Potential loss of navigation	Repairs - 24 hrs	Visual - Monitor	Replace	Replace	III	Replace	
	Monitor	2.00E-05	Fail to operate	0.5	Potential loss of navigation	Repairs - 24 hrs	Visual - Monitor	Replace	Replace	III	Replace	
	TVCB Circuit Breaker	1.20E-06	Fails to open	0.9	Potential loss of navigation	Repairs - 8 hrs	Visual - Monitor	Replace	Replace	IV	Replace	
	AFU3 - Fuse	1.50E-07	Open/blown	1	Potential equipment damage	Repairs - 24 hrs	None	Replace	Replace	III	Replace	
	TR 480/120 V transformer	1.00E-06	Fails open	0.1	Potential loss of navigation	Repairs - 8 hrs	Visual - Monitor	Replace	Replace	IV	Replace	
	AFU1 & AFU2 Fuses	1.50E-07	Open/blown	0.1	Potential equipment damage	Repairs - 24 hrs	Visual - Monitor	Replace	Replace	III	Replace	
					Potential loss of navigation	Repairs - 8 hrs	Visual	Replace	Replace	IV	Replace	

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FMEA WORKSHEET CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:

Reference Drawing:

Mission/Function:

VENTILATION SYSTEM AND INERTING SYSTEM

362A0526 362A0570

Provide Active Confinement for MCO Cask

Date:

Compiled by:

Reviewed by:

22-Sep-97

R. Gauger

BD Groth

01:37 PM

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Nose Active Extract System	SRV5 - Pressure Relief Damper - 362A0526 - 362A570-2	5.00E-06	Fails to release pressure	0.08	Low exhaust flow	Repair with alternate system operating	Flow Monitor PFNE2X and Y	Change to other channel	IV	Replace	
	SRV6 - Pressure Relief Damper - 362A0526 - 362A570-2	5.00E-06	Release at low pressure	0.92	Permits backflow to nose	Repair with alternate system operating	Flow Monitor PFNE2X and Y	None - run fan	IV	Replace	
			Fails to release pressure	0.08	Low exhaust flow	Repair with alternate system operating	Flow Monitor PFNE1X and Y	Change to other channel	IV	Replace	
	V21 Valve - Isolates Pressure Gauge - 362A0526	5.60E-08	Release at low pressure	0.92	Permits backflow to nose	Repair with alternate system operating	Flow Monitor PFNE1X and Y	None - run fan	IV	Replace	
			Fails to close	1.00	Can not isolate pressure gauge for calibration/replace ment	Repair with alternate system operating	Visual during maintenance	Use alternate channel	IV	Replace	
	V22	Same as V21									
	V23	Same as V21									
	V24	Same as V21									
	V25	Same as V21									
	V26	Same as V21									
PG17 - Pressure Gauge - 362A0526	V27	Same as V21									
	V28	Same as V21									
	PG17 - Pressure Gauge - 362A0526	1.00E-05	No reading	0.5	Can't monitor filter DP	Repair with alternate system operating	Visual	Use alternate channel	IV	Replace	
	PG18	Same as PG 17	Erroneous reading	0.5	Falsely indication of filter DP	Repair with alternate system operating	Visual	Use alternate channel	IV	Replace	
	PG19	Same as PG 17									
	PG20	Same as PG 17									
	HF4 - HEPA Filter - 362A0526 - 362A570-1	3.00E-06	Leaks	0.5	Possible release of particulate	Repair with alternate system operating	Flow Monitor	Use alternate channel	IV	Replace	
	HF5 - HEPA Filter	Same as HF4	Plugged	0.5	Can't exhaust nose	Repair with alternate system operating	Flow Monitor, DP gage	Use alternate channel	IV	Replace	
	HF9 - HEPA Filter	Same as HF4									
	HF10 - HEPA Filter	Same as HF4									

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:

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VENTILATION SYSTEM AND INERTING SYSTEM

362A0526 362A0570

Provide Active Confinement for MCO Cask

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Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
	FS3 - Ultrasonic Vortex Flow Transmitter - 362A0526	1.30E-06	No output	0.17	Loss of data output	Repair with alternate system operating	Error signal and alarm	Use alternate channel	IV	Replace	
	FS4	Same as FS3	Erroneous output	0.83	Causes operator error	Repair with alternate system operating	Error in output to operator	Use alternate channel	IV	Replace	
	PFNEFY - Flow Meter - 362A0526	1.30E-06	No output	0.17	No input to logic	Repair with alternate system operating	Error signal and alarm	Use alternate channel	IV	Replace	
	PFNEF2Y	Same as PFNEFY	Erroneous output	0.83	Wrong input to logic error	Repair with alternate system operating	Error in output to operator	Use alternate channel	IV	Replace	
	OR3 - Orifice - 362A0526	1.00E-09	Plug partially	1	Flow not balanced	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	OR4	Same as OR3									
	NF1 - Fan and fan belt - 362A0526 - 362A570-1	8.00E-06	No output flow	1	Fail to exhaust nose	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	NF2 - Fan and Belt - 362A0526 - 362A570-1	Same as NF1									
	MFNF1 - Motor for fan - 362A0526 - 362A570-1	5.00E-06	Fails to run	1	Fail to exhaust nose	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	MFNF2 - Motor for fan	Same as for MFNF1									
	FS6 - Ultrasonic Vortex Flow Transmitter - 362A0526	1.30E-06	No output	0.17	False indication of no flow	Repair with alternate system operating	Error signal and alarm	Use alternate channel	IV	Replace	
	FS7 - Ultrasonic Vortex Flow Transmitter - 362A0526	Same as FS6	Erroneous output	0.83	Erroneous flow indication	Repair with alternate system operating	Error in output to operator	Use alternate channel	IV	Replace	
	PFNEFY - Flow Monitor - 362A0526	1.30E-06	No output	0.17	No input to logic	Repair with alternate system operating	Error signal and alarm	Use alternate channel	IV	Replace	
	PFNEFX - Flow Monitor - 362A0526	Same as PFNEFY	Erroneous output	0.83	Erroneous flow indication	Repair with alternate system operating	Error in output to operator	Use alternate channel	IV	Replace	
	PFNEF2X - Flow Monitor - 362A0526	Same as PFNEFX1									

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
 Reference Drawing:
 Mission/Function:

VENTILATION SYSTEM AND INERTING SYSTEM
 362A0526 362A0670
 Provide Active Confinement for MCO Cask

Date: 22-Sep-97
 Compiled by: R. Gaugier
 Reviewed by: BD Groth
 01:37 PM

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects Local Effects	Failure Effects End Effects	Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
Cask Active Exhaust System	SL3 - Muffler - 362A0526	1.00E-09	Plugged	0.5	No exhaust	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	SL4 - Muffler	Same as SL3	Broken	0.5	Minor	Repair with alternate system operating	None	Use alternate channel	IV	Replace	
	OR5 - Orifice - 362A0526	1.00E-09	Plug partially	1	Flow not balanced	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	OR6 - Orifice	Same as OR5									
	OR7 - Orifice	Same as OR5									
	OR8 - Orifice	Same as OR5									
	NRV18 - Check Valve Damper - 362A0526	2.60E-06	Partially plugged	0.5	Restricts flow	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
			Fails to close completely	0.5	Permits backflow	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	NRV19 - Check Valve Damper	Same as NRV 18									
	Tuning - PV-SS-1 1/2 (both channels) - 362A0526	9.00E-07	Break/leak	1	Release He	Repair - 24 hrs	Flow monitor	None	III	Replace	
	V3 - Valve (NO) - 362A0526	2.60E-06	Fails to close	0.5	Can't change filters	Repair with alternate system operating	Visual during maintenance	Use alternate channel	IV	Replace	
			Fails to open	0.5	Can't use channel	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	V4 Valve	Same as V3									
	V5 - Valve (NO) - 362A0526	Same as V3									
HF2 - HEPA Filter HF6 HEPA Filter HEPA7 - HEPA Filter	V6 Valve	Same as V3									
	HF1 - HEPA Filter - 362A0526 - 362A0570-1	3.00E-06	Leak	0.5	Contribute to particulate release	Repair with alternate system operating	None	Use alternate channel	IV	Replace	
			Partially plugged	0.5	Limits use	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
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VENTILATION SYSTEM AND INERTING SYSTEM
362A0526 362A0570
Provide Active Confinement for MCO Cask

Date: 22-Sep-97
Completed by: R. Gauger
Reviewed by: BD Groth
01:37 PM

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
V13, V14, V15, V16 valves - 362A0526	V13, V14, V15, V16 valves - 362A0526	2.60E-06	Fail to close	1	Can not isolate pressure gage for calibration/replace ment	Repair with alternate system operating	Visual during maintenance	Use alternate channel	IV	Replace	
	V17, V18, V19, V20 valves	Same as V13, 14, 15, 16 valves									
	FS1 Ultrasonic Vortex Flow Transmitter - 362A0526	1.30E-06	No output	0.17	Loss of flow data	Repair with alternate system operating	Alarm	Use alternate channel	IV	Replace	
	FS2 Ultrasonic Vortex Flow Transmitter	Same as FS1	Erroneous output	0.83	Wrong input to logic error	Repair with alternate system operating	Inconsistent with other flow monitor	Use alternate channel	IV	Replace	
PFCEFY - Flow Monitor - 362A0526	PFCEFY - Flow Monitor - 362A0526	1.30E-06	No output	0.17	No data out	Repair with alternate system operating	Alarm	Use alternate channel	IV	Replace	
	PFCEFY - Flow Monitor	Same as PFCEFY	Erroneous output	0.83	Wrong data output	Repair with alternate system operating	Inconsistent with other flow monitor	Use alternate channel	IV	Replace	
	GF1 - Centrifugal Fan and belt - 362A0526	8.00E-06	No output	1	Fail to exhaust the cask	Repair with alternate system operating	Alarm	Use alternate channel	IV	Replace	
	GF2 - Centrifugal Fan and belt	Same as GF1									
MFCF1 - Motor for Fan - 362A0526	MFCF1 - Motor for Fan - 362A0526	5.00E-06	Fail to run	1	Fail to exhaust cask	Repair with alternate system operating	Alarm - flow monitor	Use alternate channel	IV	Replace	
	MFCF2 - Motor for Fan	Same as MFCF1									
	FS5 - Ultrasonic Flow Transmitter - 362A0526	1.30E-06	No output	0.17	Loss of data output	Repair with alternate system operating	Alarm - flow monitor	Use alternate channel	IV	Replace	
	FS6 - Ultrasonic Flow Transmitter	Same as FS5	Erroneous output	0.83	Cause operator error	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
PFCEFX - Flow Monitor - 362A0526	PFCEFX - Flow Monitor - 362A0526	1.30E-06	No output	0.17	Error signal to logic	Repair with alternate system operating	Alarm - flow monitor	Use alternate channel	IV	Replace	
	PFCEFX - Flow Monitor	Same as PFCEFX	Erroneous output	0.83	Erroneous flow indication	Repair with alternate system operating	Flow monitor	Use alternate channel	IV	Replace	
	PFCEFX - Flow Monitor	Same as PFCEFX									
	PFCEFX - Flow Monitor	Same as PFCEFX									

FMEA WORKSHEET

CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

VENTILATION SYSTEM AND INERTING SYSTEM
362A0526 362A0670
Provide Active Confinement for MCO Cask

Date: 22-Sep-97 01:37 PM
Compiled by: R. Gauger
Reviewed by: BD Groth

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Cask Pressure	NRV7 - Non-return Valve - 362A0526 - 362A0570-4	2.60E-06	Partially plugged	0.5	Low exhaust flow	Repair with alternate system operating	Alarm - flow monitor	Use alternate channel	IV	Replace	
	NRV8 - Non-return Valve	Same as NRV7	Fail to close completely	0.5	Could permit backflow	Repair with alternate system operating	Flow monitor	NRV 18 is in series	IV	Replace	
	SIL1, SIL2 - Silencer Muffler - 362A0526	1.00E-09	Partially plugged	0.5	No exhaust	Repair with alternate system operating	Alarm - flow monitor	Use alternate channel	IV	Replace	
	HF3 - HEPA Filter - 362A0526 - 362A0570-1	3.00E-06	Broken leaks to air	0.5	Leaks to atmosphere	Repair with alternate system operating	Visual	Use alternate channel	IV	Replace	
Cask Pressure	HF3 - HEPA Filter - 362A0526 - 362A0570-1	3.00E-06	Leaks, loss of filtering	0.5	Loss of filtering by this unit	Repair during downtime if HF8 Operating	None	Second unit in series	IV	Replace	
	HF8 - HEPA Filter - 362A0526	Same as HF3	Partially plugged	0.5	Restricts output	Repair - 24 hrs	Flow monitor - DP gage	None	III	Replace	
	SRV1 - Pressure Relief Damper - 362A0526	5.00E-06	Fail to relieve	0.08	Limited flow on overpressure	Repair during downtime - SRV4 is redundant	Pressure monitor	Second valve in parallel	IV	Replace	
	SRV4 - Pressure Relief Damper	Same as SRV1	Release at low pressure	0.92	Permit backflow to cask	Repair - 24 hrs	Flow monitor	None	III	Replace	
Main Line Helium	AOV4 - SV4 Gas Activated Valve and Operator - 362A0526	1.40E-05	Fail to open on command	0.5	Can't get He from main line supply	Suspend operations. Use emergency He. Repair - 24 hrs.	Limit switch	None	III	Replace	
	AOV14 and SV14	Same as AOV4 and SV4	Fail to close on command	0.5	Loss backup for He shut-off	Repair during downtime	Limit switch	Back-up valve is in series	IV	Replace	
	He SS-1/2" Flexible Hose - 362A0526	9.00E-07	Leak	1	Loss He, take in air	Suspend operations. Use emergency He. Repair - 24 hrs.	Pressure monitor	Change to alternate channel	III	Replace	
	RG2 - Multi-stage Pressure Regulator - 362A0526	5.00E-06	Cask & nose pressure high	0.5	Pressure too high for seals	Suspend operations. Use emergency He. Repair - 24 hrs.	Pressure monitor, alarm	Use emergency He system	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
Reference Drawing:
Mission/Function:

VENTILATION SYSTEM AND INERTING SYSTEM
362A0526 362A0570

Provide Active Confinement for MCO Cask

22-Sep-97

Date:

Compiled by:

Reviewed by:

R. Gaugler

BD Groth

01:37 PM

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Cask Inert Gas	ADV1 - SV1 - Gas activated valve and operator - 362A0526	1.40E-05	Cask & nose pressure low	0.5	Not enough He in cask/hose	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Pressure monitor, alarm	Under specified conditions, bottled He will be supplied	III	Replace	
			Fails to close on command	0.5	He pressure in cask too high	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Limit switch	Bottled He is available	III	Replace	
			Fails to open on command	0.5	He pressure in cask too low	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Limit switch	Bottled He is available	III	Replace	
			Restricts flow	0.5	Not enough He is allowed in	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Pressure monitor	Use emergency He system	III	Replace	
			Fails to close	0.5	Permits backflow	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Pressure Monitor	Use emergency He system	III	Replace	
	PS17 - Ultrasonic Vortex Flow Transmitter - 362A0526	1.30E-06	Reads too high	0.17	Does not agree with other unit	Repair with PS18 on line	Alarm	Back-up unit on line	IV	Replace	
			Fails to read or too low	0.83	Does not agree with other unit	Repair with PS18 on line	Alarm	Back-up unit on line	IV	Replace	
			Same as PS17								
			PFCHSHX - Flow Monitor - 362A0526	1.30E-06	Does not agree with other unit	Repair with PFCHSHY on line	Alarm	Back-up unit on line	IV	Replace	
			Reads low or no output	0.83	Does not agree with other unit	Repair with PFCHSHY on line	Alarm	Back-up unit on line	IV	Replace	
Cask Inert Gas	OR11 - Orifice plate - 362A0526	1.00E-09	Partial restriction	1	Limits He to cask	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Pressure and flow monitors	Bottle emergency He	III	Replace	
			Restricted flow	0.5	Low He flow	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Pressure and flow monitors	Bottle emergency He	III	Replace	
			Closure not complete	0.5	He flow does not stop	Repair during downtime	Pressure and flow monitors	Bottle emergency He	IV	Replace	
			Same as NRV1								
			NRV2								
Cask Inert Gas	OR11 - Orifice plate - 362A0526	1.00E-09	Partial restriction	1	Loss of Emergency He	Repair ~ 24 hrs	Cask pressure	Only on line if main He fails	IV	Replace	

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SYSTEM:
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VENTILATION SYSTEM AND INERTING SYSTEM
362A0526 362A0670
Provide Active Confinement for MCO Cask

Date:
Compiled by:
Reviewed by:

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R. Gauger
BD Groth

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Nose Inert Gas Purge System	ADV3 & SV3 Gas isolated valve and operator - 362A0526	1.40E-05	Fails to open on command	0.5	Excess He Plug Flask	Suspend operations. Use emergency He. Repair - 24 hrs.	Limit switch	Overpressure relief	III	Replace	
	NRV3 - Non-return valve - 362A0526	2.80E-06	Fails to open on command	0.5	No He to plug flask	Suspend operations. Use emergency He. Repair - 24 hrs.	Limit switch	None	III	Replace	
	NRV3 - Non-return valve - 362A0526	2.80E-06	Restricted flow	0.5	Lack of He to plug flask	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	ORP2 - Orifice - 362A0526	1.00E-09	Closure not complete	0.5	Permits backflow	Repair after shutdown	Alarm	None	IV	Replace	
	ORP2 - Orifice - 362A0526	1.00E-09	Restricted flow	1	Flow restricted	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	Flexible tubing - 362A0526	9.00E-07	Leak	1	He to atmosphere	Suspend operations. Use emergency He. Repair - 24 hrs.	Loss of flow	None	III	Replace	
	NRV12 - Non Return Valve - 362A0526	2.60E-06	Restricted Flow	0.5	He pressure too low to initiate seals	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	NRV12 - Non Return Valve - 362A0526	2.60E-06	Closure not complete	0.5	Permits backflow	Repair after shutdown	Alarm	None	IV	Replace	
	V8 - Valve (NO) - 362A0526	2.60E-06	Fails to close	0.5	Can't isolate the subsystem	Repair after shutdown	Visual during operation	None	IV	Replace	
	V8 - Valve (NO) - 362A0526	2.60E-06	Fails to open	0.5	No He to seals	Suspend operations. Use emergency He. Repair - 24 hrs.	Visual during operation	Emergency He	III	Replace	
Inertable Seals Pressurization System	RGS - Multistage Pressure Regulator - 362A0526	5.00E-08	Pressure too high	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	Regulation by series valve	III	Replace	
	RGS - Multistage Pressure Regulator - 362A0526	5.00E-08	Pressure too low or off	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	SRV3 - Pressure Relief Valve - 362A0526	5.00E-06	Pressure too high	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	Regulation by series valve	III	Replace	
	SRV3 - Pressure Relief Valve - 362A0526	5.00E-06	Pressure too low	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	SV8 - Valve - 362A0126	2.60E-08	Fails to close on command	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	SV8 - Valve - 362A0126	2.60E-08	Fails to open on command	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	

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					Local Effects	End Effects					
	F12 - HEPA Filter 362A0526	3.00E-06	Leaks internally	0.5	Particulate may reach seals	Suspend operations. Use emergency He. Repair - 24 hrs.	None	None	III	Replace	
	AOV6 & SV6 - Gas Activated Valve an Operator - 362A0526	1.40E-05	Partially plugged	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
			Fails to open on command	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
			Fails to close on command	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	AOV7 & SV7 - Gas Activated Valve and Operator - 362A0526	1.40E-05	Fails to open on command	0.5	Seal pressure too low	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
			Fails to close on command	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	OR9 - Orifice - 362A0526	1.00E-09	Partially plugged	1	Flow not balanced	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
			Fails to close on command	0.5	Seal pressure too high	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	OR10 - Orifice - 362A0526	1.00E-09	Partially plugged	1	Flow not balanced	Suspend operations. Use emergency He. Repair - 24 hrs.	Alarm	None	III	Replace	
	PS9 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Fail to alarm on over pressure	Repair with PS10 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Set too low	0.5	Nuisance alarm.	Repair with PS10 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFC5IMX - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error	Repair with PFC5IMY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Erroneous output	0.83	Wrong input to logic, causes error	Repair with PFC5IMY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS10 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Fail to alarm on over pressure	Repair with PS9 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Set too low	0.5	Nuisance alarm.	Repair with PS9 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFC5IMY - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error	Repair with PFC5IMX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	

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Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Inertable Seals: Inter-Space Integrity Check System	PS11 - Pressure Switch - 362A0526	1.70E-06	Erroneous output	0.83	Wrong input to logic, causes error on line	Repair with PFCS1MX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS12 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Fail to alarm on over pressure	Repair with PS12 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCS2MX - Pressure Monitor - 362A0526	1.30E-06	Set too low	0.5	Nuisance alarm	Repair with PS12 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCS2MX - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error on line	Repair with PFCS2MY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS12 - Pressure Switch - 362A0526	1.70E-06	Erroneous output	0.83	Wrong input to logic, causes error on line	Repair with PFCS2MY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS12 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Fail to alarm on over pressure	Repair with PS11 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS12 - Pressure Switch - 362A0526	1.70E-06	Set too low	0.5	Nuisance alarm	Repair with PS11 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCS2LX - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error on line	Repair with PFCS2MY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCS2LX - Pressure Monitor - 362A0526	1.30E-06	Erroneous output	0.83	Wrong input to logic, causes error on line	Repair with PFCS2MY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	V8 - Isolation Valve (NO) - 362A0526	2.60E-06	Fails to close	0.5	Can't isolate the subsystem	Repair if needed for isolation	Visual during operation	None	IV	Replace	
	RG6 - Pressure Regulator - 362A0526	5.00E-06	Fails to reopen	0.5	No tie to seals	Suspend operations. Repair ~ 24 hrs	Visual during operation	None	III	Replace	
	RG6 - Pressure Regulator - 362A0526	5.00E-06	Set too high	0.5	Seal pressure too high	Suspend operations. Repair ~ 24 hrs	Alarm	None	III	Replace	
AOV8 & SV 8 - Gas Activated Valve and Operator - 362A0526	AOV8 & SV 8 - Gas Activated Valve and Operator - 362A0526	1.40E-05	Set too low	0.5	Seal pressure too low	Suspend operations. Repair ~ 24 hrs	Alarm	None	III	Replace	
	AOV8 & SV 8 - Gas Activated Valve and Operator - 362A0526	1.40E-05	Fails to open on command	0.5	Seal pressure too low	Suspend operations. Repair ~ 24 hrs	Alarm	None	III	Replace	
	PS7 - Pressure Switch - 362A0526	1.70E-06	Fails to close on command	0.5	Seal pressure too high	Suspend operations. Repair ~ 24 hrs	Alarm	Regulation by series valve.	III	Replace	
PS7 - Pressure Switch - 362A0526	PS7 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Fail to alarm on over pressure	Repair with PS8 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PS7 - Pressure Switch - 362A0526	1.70E-06	Set too low	0.5	Nuisance alarm	Repair with PS8 on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	

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Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
O Ring Seals - Inter Space Integrity Check System	PS5 - Pressure Switch - 362A0526	1.70E-08	Set too high	0.5	Fail to alarm on over pressure	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCSLCHX Pressure Monitor - 362A0526	1.30E-06	Set too low	0.5	Nuisance alarm	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			No output	0.17	Wrong input to logic, causes error	Repair with PFCSLCHY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Erroneous	0.83	Wrong input to logic, causes error	Repair with PFCSLCHY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCSLCHY Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error	Repair with PFCSLCHX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Erroneous	0.83	Wrong input to logic, causes error	Repair with PFCSLCHX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	NRV10 - Non return Valve - 362A0526	2.60E-06	Reverse forward flow	0.5	Insufficient leak check	Suspend operations. Repair - 24 hrs	Alarm	Regulation by series valves.	III	Replace	
			Fail to stop backflow	0.5	Seal pressure too high	Suspend operations. Repair - 24 hrs	Alarm	Regulation by series valves	III	Replace	
	V10 - Isolation Valve - 362A0526	2.60E-06	Fail to close	0.5	Fails to isolate if required	Repair when shutdown	Visual during operation	None	IV	Replace	
			Fail to open	0.5	System won't work	Suspend operations. Repair - 24 hrs	Visual during operation	None	III	Replace	
AOVS & SVS - Gas Activated Valve and Operator - 362A0526	RG4 - Pressure Regulator - 362A0526	5.00E-06	Pressure too high	0.5	Seal pressure too high.	Suspend operations. Repair - 24 hrs	Alarm	None	III	Replace	
			Pressure too low	0.5	Seal pressure too low.	Suspend operations. Repair - 24 hrs	Alarm	None	III	Replace	
			Fails to open on command	0.5	Seal pressure too low.	Suspend operations. Repair - 24 hrs	Redundant switches and indicator.	Redundant switches and indicator.	III	Replace	
			Fails to close on command	0.5	Seal pressure too high.	Suspend operations. Repair - 24 hrs	Redundant switches and indicator.	Redundant switches and indicator.	III	Replace	
PS5 - Pressure Switch - 362A0526		1.70E-06	Set too high	0.5	Seal pressure too high.	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Set too low	0.5	Seal pressure too low.	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	

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Reviewed by: BD Groth

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Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
Grapple Gas Supply	PS5 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	Seal pressure too high.	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Set too low	0.5	Seal pressure too low	Repair with PSS on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCSHLCX - Pressure Monitor - 362A0526	1.30E-08	No output	0.17	Wrong input to logic, causes error.	Repair with PFCSHLCY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Erroneous output	0.83	Wrong input to logic, causes error.	Repair with PFCSHLCY on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	PFCSHLCY - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error.	Repair with PFCSHLCX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
			Erroneous output	0.83	Wrong input to logic, causes error.	Repair with PFCSHLCX on line	Redundant switches and indicator.	Redundant switches and indicator.	IV	Replace	
	V12 - Isolation Valve (NO) - 362A0526	2.60E-06	Fail to close	0.5	Can't isolate the subsystem	Repair when shutdown	Visual during operation	Use emergency He	IV	Replace	
			Fail to open	0.5	Can't operate system	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Visual during operation	Use emergency He	III	Replace	
	RG7 - Multi-Stage Regulator - 362A0526	5.00E-08	Pressure too high	0.5	May not operate	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Visual	Use emergency system and bottled He.	III	Replace	
			Pressure too low	0.5	May not operate	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Visual	Use emergency system and bottled He.	III	Replace	
Grapple Open	PS15 - Pressure Switch - 362A0526	1.70E-06	Set too high	0.5	May not operate	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Alarm	Redundant switches and indicator.	III	Replace	
			Set too low	0.5	May not operate	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Alarm	Redundant switches and indicator.	III	Replace	
	PFCSHX - Pressure Monitor - 362A0526	1.30E-06	No output	0.17	Wrong input to logic, causes error	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Alarm	Can't operate the subsystem.	III	Replace	
			Erroneous output	0.83	Wrong input to logic, causes error	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Alarm	Use emergency system and bottled He.	III	Replace	
			Restricted flow	0.5	He pressure too low	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Grapple limit switches	Use emergency system and bottled He.	III	Replace	
	NRV16 - Non return Valve - 362A0526	2.60E-06	Fail to fully close	0.5	May permit backflow	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Grapple limit switches	Shut V12. Use emergency He	III	Replace	

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					Local Effects	End Effects					
MCO Emergency Open	SV18 - Solenoid Actuated Spool Valve - 362A0526	9.00E-06	Fails to close	0.5	Unable to close grapple	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Grapple limit switches	None	III	Replace	
			Fails to open	0.5	Unable to open grapple	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Grapple limit switches	None	III	Replace	
	NRV17 - Non return Valve - 362A0526	2.60E-06	Restricted flow	0.5	He pressure too low	Suspend operations and repair	Grapple limit switches	Can only occur if emergency He is needed	IV	Replace	
			Fail to fully close	0.5	May permit backflow	Suspend operations and repair	Grapple limit switches	Can only occur if emergency He is needed	IV	Replace	
	SV17 - Push-button Spool Valve - 362A0526	2.60E-06	Fails to close	0.5	Unable to close grapple	Suspend operations and repair	Grapple limit switches	Can only occur if emergency He is needed	IV	Replace	
			Fails to open	0.5	Unable to open grapple	Suspend operations and repair	Grapple limit switches	Can only occur if emergency He is needed	IV	Replace	
	GCV1 - Disconnect - 362A0526	Negligible	Fail to connect	1	Unable to operate emergency He	Suspend operations and repair	Visual during operation	Can only occur if emergency He is needed	IV	Replace	
	V31 - Isolation Valve (NC) - 362A0526	2.60E-06	Fail to open on command	0.5	Can't operate grapple on emergency He	Suspend operations and repair	Alarm	Can only occur if emergency He is needed	IV	Replace	
			Fail to close on command	0.5	Can't isolate the subsystem	Suspend operations and repair	Alarm	Turn off bottled He.	IV	Replace	
	NRV20 - Non-return Valve - 362A0526	2.60E-06	Restricted flow	0.5	Can't operate grapple on emergency He	Suspend operations and repair	Grapple limit switches	Can only occur if emergency He is needed	IV	Replace	
Actuated Valves Gas Supply System			Fail to fully close	0.5	May permit backflow	Repair when shutdown	Grapple limit switches	Shut V31	IV	Replace	
	V11 - Isolation Valve (NO) - 362A0526	2.60E-06	Fail to close	0.5	Unable to isolate	Repair when shutdown	Visual during operation	Isolate main line He	IV	Replace	
			Fail to open	0.5	Unable to operate on main line He	Suspend operations. Use emergency He. Repair ~ 24 hrs.	Visual during operation	None	III	Replace	
	RGB - Multi-stage Pressure Regulator - 362A0526	5.00E-06	Output too high	0.5	May be able to operate if needed but at high pressure.	Suspend operations. Use emergency He Repair ~ 24 hrs.	Erratic valve operation	Use Emergency He	III	Replace	
Bottled Helium Supply System			Output too low	0.5	Probably cannot operate	Suspend operations. Use emergency He Repair ~ 24 hrs.	Erratic valve operation	Use Emergency He	III	Replace	
	Bottle of Helium (2) - 362A0526	1.60E-06	He low	1	Loss of emergency supply	Replace bottle - 8 hrs	Alarm	Two bottles	IV	Replace	

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	NRV13 & NRV14 - Non-return Valves for He - 362A0526	2.60E-06	Restricted flow	0.5	Limits system use	Repair when shutdown	Pressure gage	Other bottle	IV	Replace	
	RG1 - Multi-stage Pressure Regulator - 362A0526	5.00E-06	Failure to fully close	0.5	Can't isolate the subsystem	Repair when shutdown	Alarm	Other bottle	IV	Replace	
			Output too high	0.5	He pressure too high	Repair when shutdown	Alarm	None	IV	Replace	
			Output too low	0.5	Flow restricted	Repair when shutdown	Alarm	None	IV	Replace	
	SRV12 - Pressure Relief Valve - 362A0526	5.00E-06	Fails to relieve	0.08	He overpressure	Shutdown and repair	Alarm	None	IV	Replace	
	KIV1 - Valve (NC) - 362A0526	2.60E-06	Leak by at low pressure	0.92	Loss of emergency He	Shutdown and repair ~ 24 hrs	Alarm	None	III	Replace	
			Fails open	0.5	Can't isolate the subsystem	Repair when shutdown	Visual during operation	None	IV	Replace	
			Fails closed	0.5	No emergency He	Shutdown and repair ~ 24 hrs	Visual, pressure gage	None	III	Replace	
	LFBMNOX - Limit switch - 362A0526	7.00E-07	No display	1	Wrong indication of KIV1 valve position	Replace ~ 8 hrs	Visual	None	IV	Replace	
	AOV12 & SV12 - Gas Activated Valve and Operator - 362A0526	1.40E-05	Fail to open on command	0.5	Can't operate system	Repair when shutdown	Limit switches	AOV16 and SV16 redundant	IV	Replace	
Other	AOV16 & SV16 - Gas Activated Valve and Operator - 362A0526	1.40E-05	Fail to close on command	0.5	He pressure too high	Repair when shutdown	Limit switches	AOV16 and SV16 redundant	IV	Replace	
			Fail to open on command	0.5	Can't operate system	Repair when shutdown	Limit switches	AOV12 and SV12 redundant	IV	Replace	
			Fail to close on command	0.5	He pressure too high	Repair when shutdown	Limit switches	AOV12 and SV12 redundant	IV	Replace	
	Tubing - He-SS-1/2" - 362A0526	9.00E-07	Leaks	1	Loss of He	Repair ~ 24 hrs	Pressure gage	None	III	Replace	
	F11 - HEPA Filter - 362A0526	3.00E-06	Leaks internal	0.5	Particulate may reach seals	Repair when shutdown	None	None	IV	Replace	
			Partially plugged	0.5	Flow restricted	Shutdown and repair	Pressure gage	None	III	Replace	

FMEA WORKSHEET
CANISTER STORAGE BUILDING - MCO HANDLING MACHINE

SYSTEM:
 Reference Drawing:
 Mission/Function:

VENTILATION SYSTEM AND INERTING SYSTEM
 362A0528 362A0570
 Provide Active Confinement for MCO Cask

Date:
 Compiled by:
 Reviewed by:

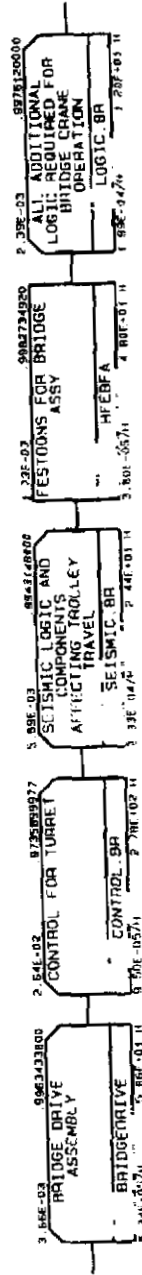
22-Sep-97 01:37 PM
 R. Gauger
 BD Groth

Subcomponent/ Subsystem	Component ID	Component Failure Rate	Failure Mode	Alpha	Failure Effects		Failure Detection Method	Mitigation Action	Severity Class	Maintenance	Remarks
					Local Effects	End Effects					
	RG3 - Multi-stage Pressure Regulator - 362A0528	5.00E-06	Pressure set too high	0.5	He pressure too high	Shutdown and repair	Pressure gage	None	III	Replace	
			Pressure set too low or no output	0.5	He pressure too low	Shutdown and repair	Pressure gage	None	III	Replace	

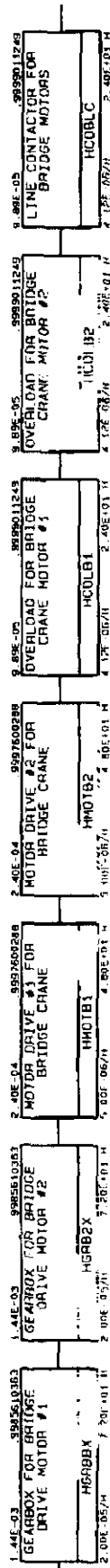
Appendix G
MHM Reliability Block Diagrams

**Bridge Travel Subsystem
With Controls**

Module : BRIDGE
 Prob. Failure : 3.98E-02
 Prob. Success : .9601875D22
 MOT : 6.37E+01 H
 Lambda : 6.35E-04 / H
 Description : BRIDGE: TRAVEL



Module	Prob.	Failure
Prob.	Success	
MDT		
Lambda		
Description		



Module : CONTROL BR
 Prob. Failure : 29745000077
 MDY : Success : 2780003 H
 Lambda : 9.50E-05/H
 Description : CONTROL FOR TURRET

4.80E-04 ENCODER, RESOLVER & CARD HE NCOB 2.40E-05/H	2.78E-04 BRIDGE BRAKE UNIT 1 HOUNB1 1.15E-05/H	2.78E-04 BRIDGE BRAKE UNIT 2 HOUNB2 1.15E-05/H	1.20E-05 BRAKING RESISTOR FOR BRIDGE MOTOR 1 HROB1S1 1.00E-06/H	2.40E-05 BRAKING RESISTOR FOR TROLLEY MOTOR 2 HROB2S1 1.00E-06/H	3.30E-03 VARIABLE SPEED DRIVE FOR BRIDGE MOTOR FAILS HVSBD 2.00E-05/H	1.04E-05 CONTROL INTERFACE CARD GIP FAILS HMOGIF 1.30E-06/H
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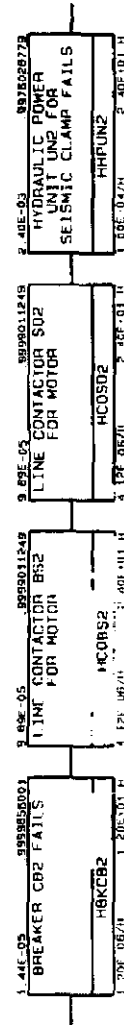
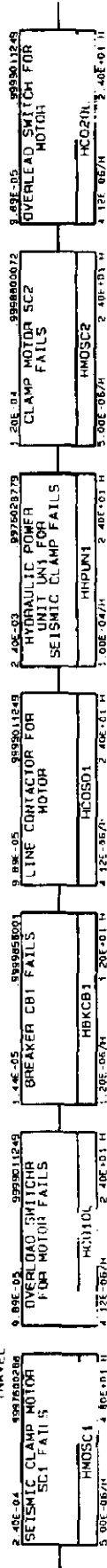
1.44E-05 BREAKER RCB FAILS HKBKCB 1.20E-05/H	2.64E-05 RELAY BR1 FAILS, BRAKE RELAY 1 HREBR1 1.07E-06/H	2.64E-05 RELAY BR2 FAILS, BRAKE RELAY 2 HREBR2 1.10E-06/H	2.64E-05 RELAY LT1 BRIDGE FAULT RELAY FAILS HRELT1 1.10E-06/H	2.64E-05 RELAY LT2 BRIDGE FAULT RELAY FAILS HRELT2 1.10E-06/H	2.64E-05 RELAY OT BRIDGE OVERTEMP FAILS HRCOT 1.10E-06/H	2.64E-05 RELAY BRIDGE RUN FAILS HREBRUN 1.10E-06/H
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2.64E-05 RELAY BR1 BRIDGE BRAKE RELAYS - FAILS HREBRH 1.10E-06/H	2.18E-05 LIMIT SWITCH REF OR ASSOCIATED SPST RELAY FAILS HSMRFXL1 1.80E-06/H	2.18E-05 LIMIT SWITCH NLP OR ASSOCIATED SPST RELAY FAILS HSMNPL1 1.80E-06/H	2.18E-05 LIMIT SWITCH NSP OR ASSOCIATED SPST RELAY FAILS HSMNSPL1 1.80E-06/H	2.18E-05 LIMIT SWITCH SLP OR ASSOCIATED SPST RELAY FAILS HSMSLPL1 1.80E-06/H	2.18E-05 LIMIT SWITCH SSP OR ASSOCIATED SPST RELAY FAILS HSMSSPL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFXL1 1.80E-06/H
---	---	--	---	---	---	---

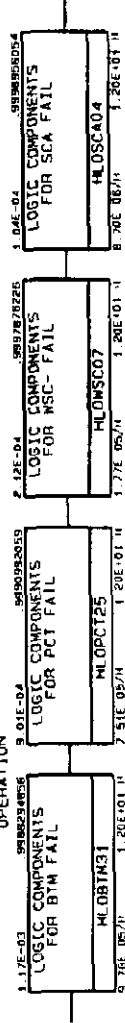
2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H	2.18E-05 LIMIT SWITCH CFX OR ASSOCIATED SPST RELAY FAILS HSMCFYL1 1.80E-06/H
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Module
Prob. Failure
Mod. Success
Lambda
Description

SEISMIC BH
9.69E-03
994314600
2.40E-01/H
2.3E-04/H
SEISMIC LOGIC AND
COMPONENTS
AFFECTING TROLLEY
TRAVEL

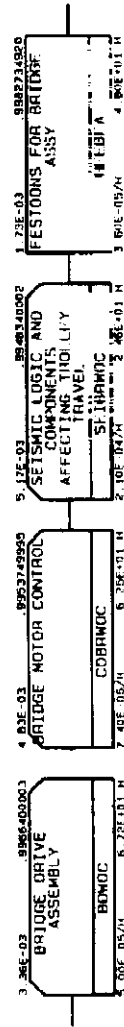


Module : LOGIC BR
 Prob. Failure : 2.39E-03
 Prob. Success : .9976120000
 NOT : 1.20E+01 H
 Lambda : 1.99E-04/H
 Description : ALL ADDITIONAL
 LOGIC REQUIRED FOR
 BRIDGE CRANE
 OPERATION

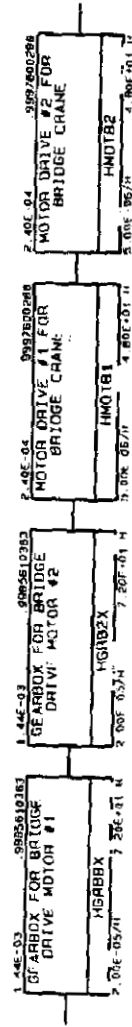


**Bridge Travel Subsystem
Without Controls**

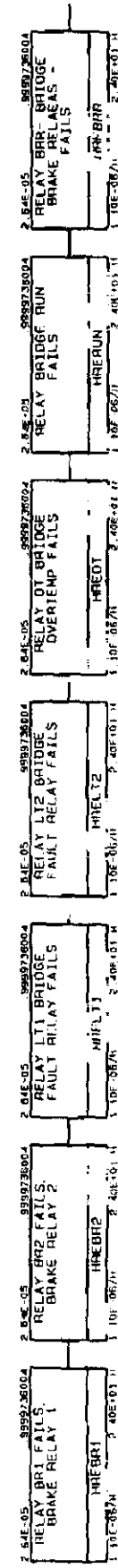
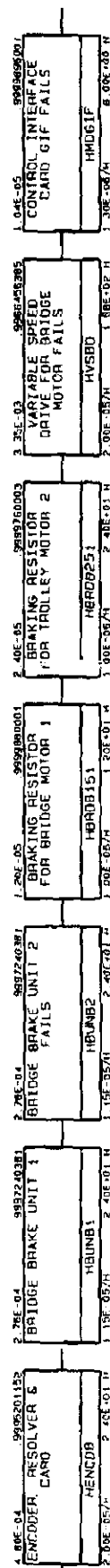
Module : BRIDGE
 Prob: Failure
 Prob: Success
 MDY : 4 02E+01 H
 Lambda : 3.70E-04/H
 Description : BRIDGE TRAVEL

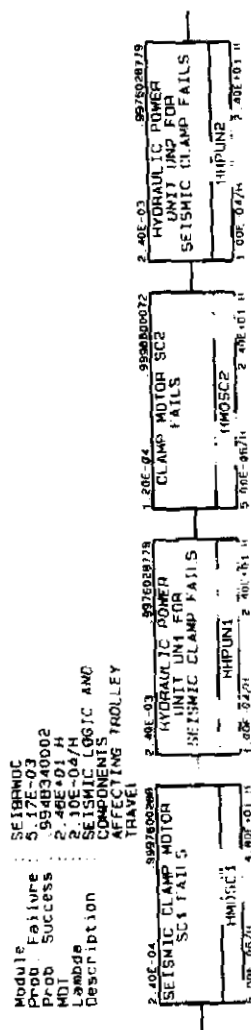


Module : BMDIC
 Prob. Failure : 3.75E-03
 Prob. Success : 9999999999999999
 MOT : 6.72E+01 H
 Lambda : 5.00E-05/H
 Description : BRIDGE DRIVE
 ASSEMBLY



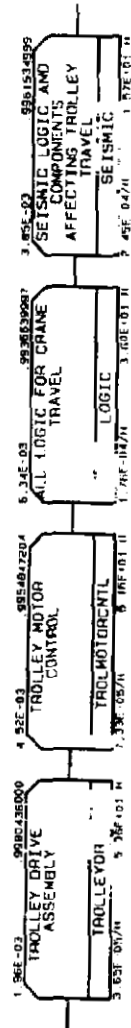
Module : CUBANOC
 Prob. Failure : 4.53E-03
 Prob. Success : .995374995
 MOT : 6.25E+01 H
 Lambda : 7.48E-05/H
 Description : BRAISE MOTOR CONTROL



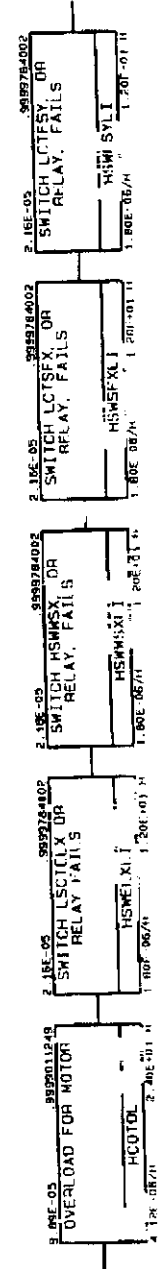
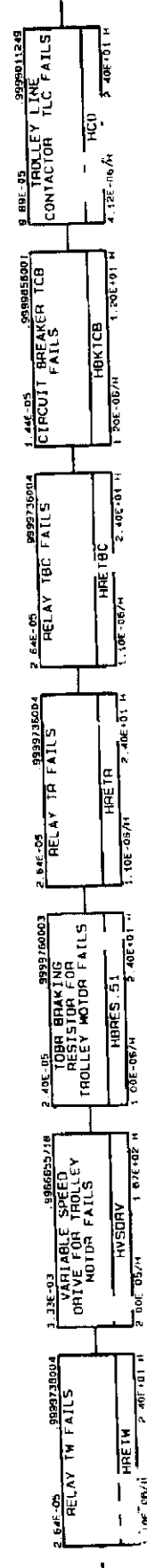
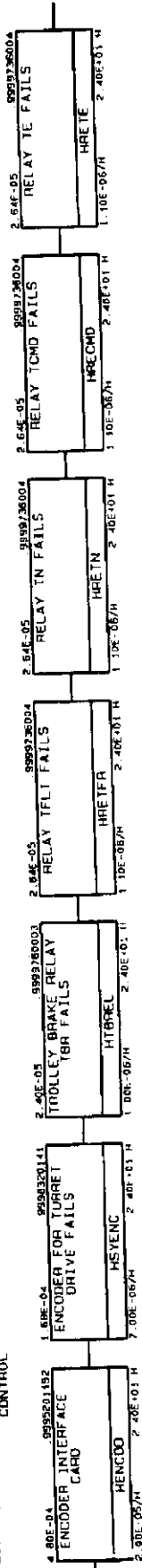


**Trolley Travel Subsystem
With Controls**

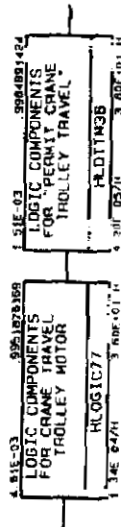
Module Failure : TROLLEY
 Prod. Success : 1825-02990
 MDG : 5825-03990
 Lambda : 5-31E-04/H
 Description : TROLLEY TRAVEL



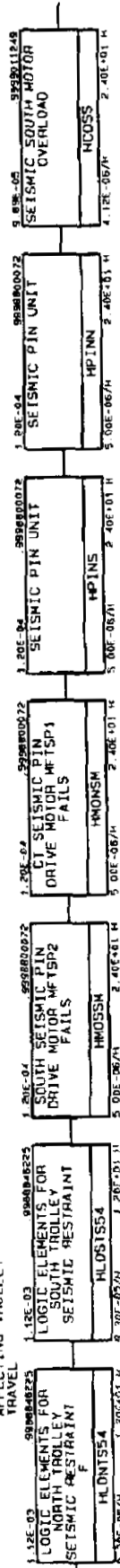
Module: TROL MOTORCNTRL
 Prob: 4 52E-03
 MOD: Success 9954947204
 Lambda: 6 16E+01 H
 Description: 7 33E-05/H
 TROLLEY MOTOR CONTROL



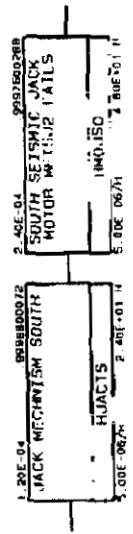
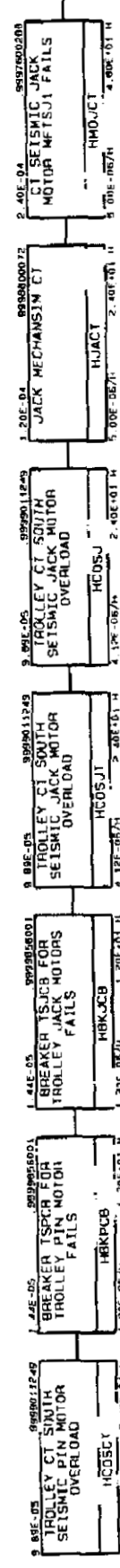
Module : LOGIC
 Prob Failure : 6.34E-03
 Wty Success : 99.999997
 Wty : 1.0E-04/H
 Lambda : 1.0E-04/H
 Description : ALL LOGIC FOR CRANE TRAVEL



Module SEISMIC
 Prob. Failure 3.85E-03
 Prob. Success .99961534999
 MOT 1.57E+01 H
 Lambda 2.45E-04/H
 Description SEISMIC LOGIC AND
 COMPONENTS
 AFFECTING TROLLEY
 TRAVEL

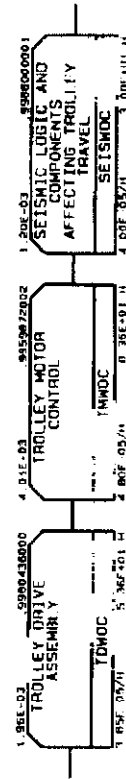


G-17

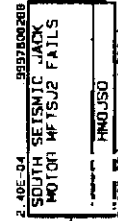
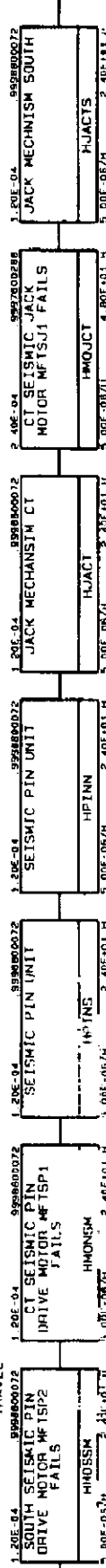


**Trolley Travel Subsystem
Without Controls**

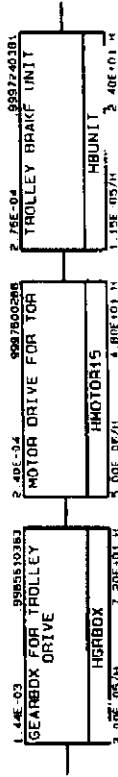
Module : TROLWOC
 Prob : Failure
 Prob : Success
 WPN : 992799997
 Lmbda : 0.00E+01 M
 Description : TROLLY TRAVEL



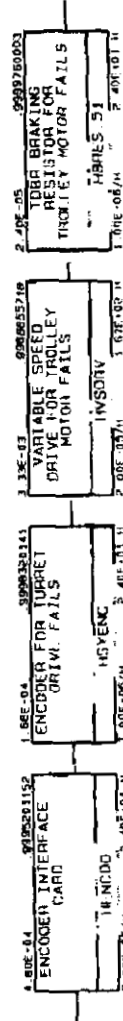
Module : SEISNDC
 Prob. Failure : 1.20E-03
 Prob. Success : .9980000001
 MTD : 3.00E+01 H
 Description : SEISMIC LOGIC AND
 COMPONENTS
 AFFECTING TROLLEY
 TRAVEL



Module IDWOC
 Prod. Failure 1 05E-03
 Prod. Success 9980438000
 M01 5 36E+01 H
 Lambda 3 65E-05/H
 Description TROLLEY DRIVE
 ASSEMBLY

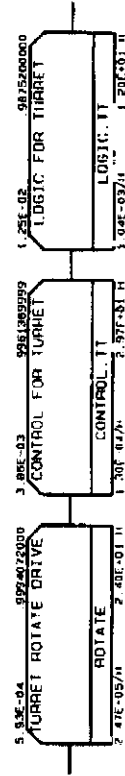


Module THWOC
 Prod. Failure 4 01E-03
 Prod. Success 9 98E-02/2002
 Qty 6 38E-01/H
 Vendor 4 80E-05/H
 Description TADLEY MOTOR
 CONTROL

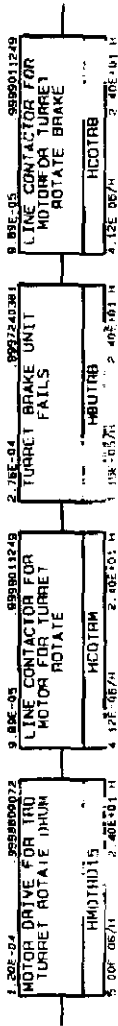


**Turret and Turntable Assembly Subsystem
With Controls**

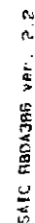
Module : TURRET
 Prob. Failure : 1.65E-02
 Prob. Success : 9.931019994
 MDA : 1.42E-01/H
 Lambda : 1.15E-03/H
 Description :



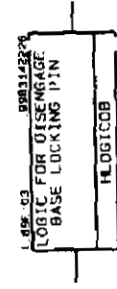
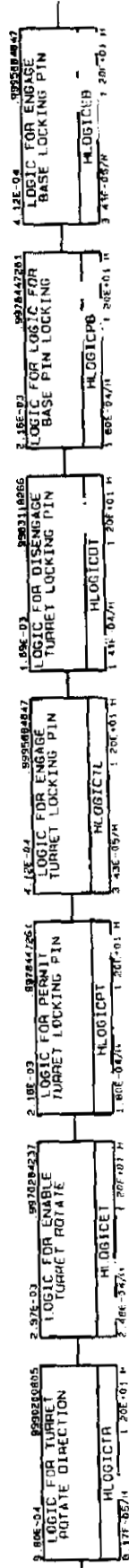
Module : ROTATE
P100 : Failure
P101 : Success
MDT : 598023000
Lambda : 2.40E-01/H
Description : TURRET ROTATE DRIVE



Mod.	Control, IT
Prob.	3

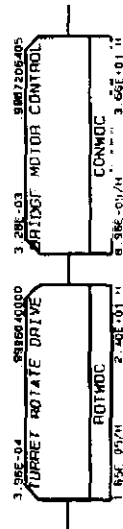


Module : LOGIC 11
 Prod. Failure : 1.25E-02
 Prod. Success : 9875200000
 MDT : Success : 1.20E+01 H
 Lambda : 1.04E-03/H
 Description : LOGIC FOR TURRET

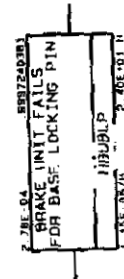
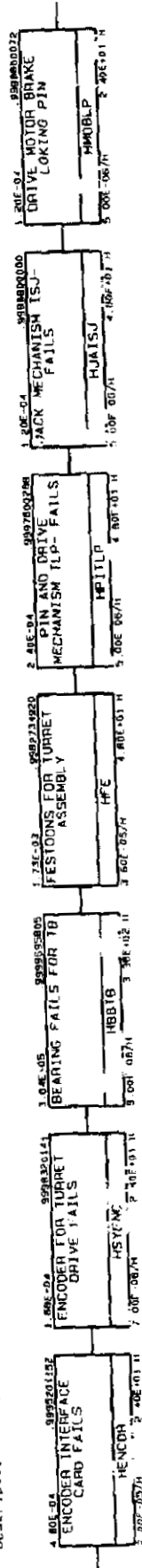


**Turret and Turntable Assembly Subsystem
Without Controls**

Module TURRET
 Prod. Failure 3 57-03
 Prod. Success 996324005
 MDT 3 45E+01 H
 Lambda 1 05E-04/H
 Description :



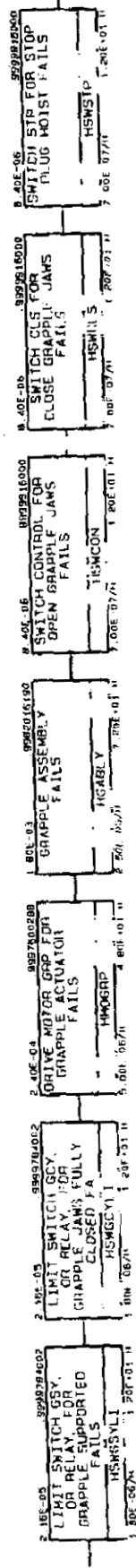
Module Failure : COMADC
 Prob : Success : 3.26E-03
 M01 : 3.66E-01 H
 Lambda : 8.96E-05/H
 Description : BRIDGE MOTOR CONTROL

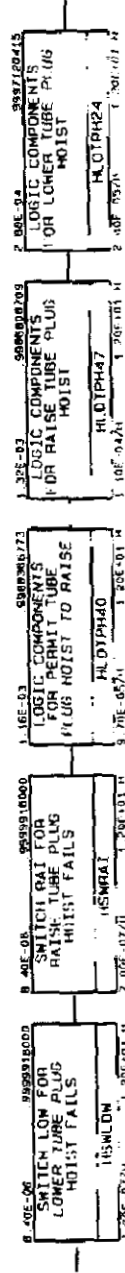


Module : ROTMOC
 Prob. Failure : 5.85E-04
 Prob. Success : 9.9994140000
 H0000 : 2.40E+01 H
 H0000 : 1.65E-05/H
 Description : TURRET ROTATE DRIVE



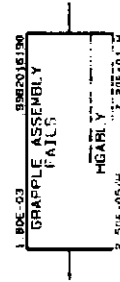
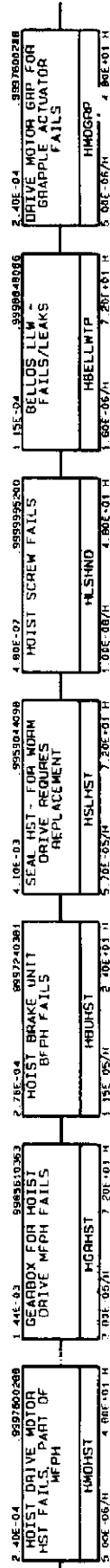
**Tube Plug Hoist and Grapple Subassembly
With Controls**





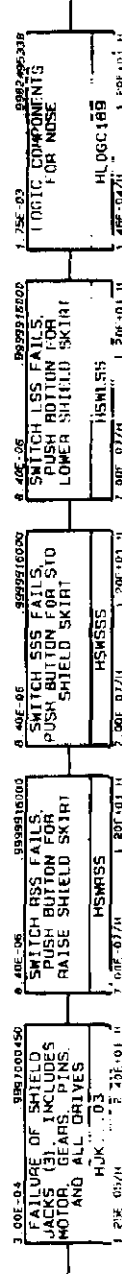
**Tube Plug Hoist and Grapple Subassembly
Without Controls**

Module : TPI, MOC
 Prod. Failure : 9-21E-03
 Prod. Success : 9917874937
 MOT : 5-57E+01 H
 Lambda : 1-25E-04/H
 Description : TUBE PILING HOIST AND GRAPPLE



**Nose Unit, Shield Skirt, Sealing System
With Controls**



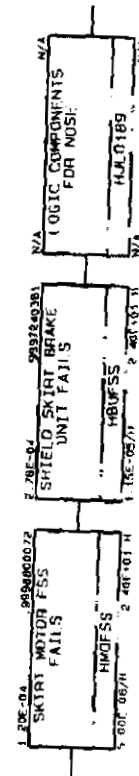
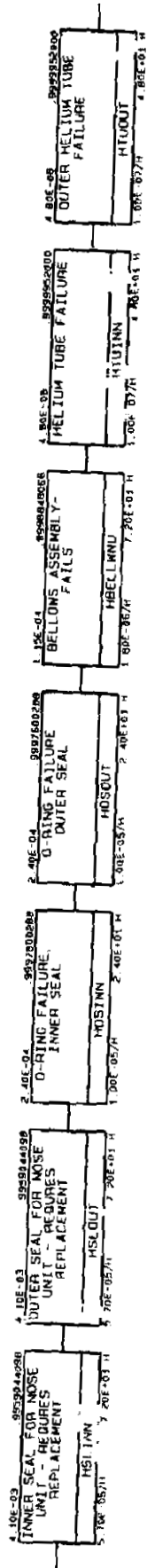


**Nose Unit, Shield Skirt, Sealing System
Without Controls**

Module
 Prob. Failure
 Prob. Success
 MDT
 Lambda
 Description

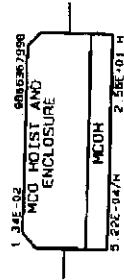
NUMOC
 955344288
 955344288
 6.05E-04/H
 1.52E-04/H

NOSE UNIT, SHIELD
 SKIRT AND SEALING
 SYSTEM



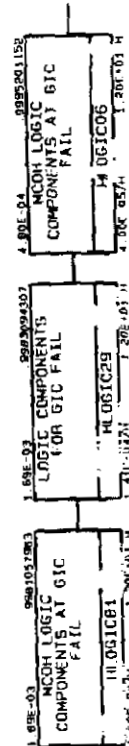
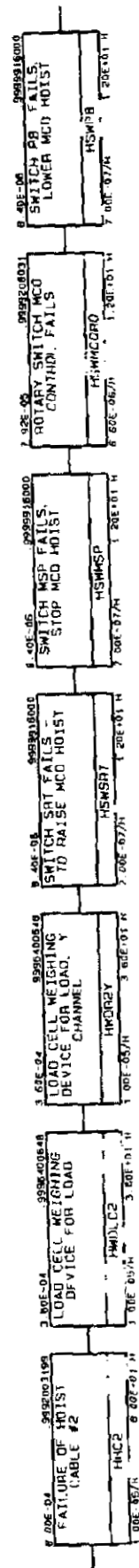
MCO Hoist and Enclosure Subsystem With Controls

Module : MCDHOIST
 Prod : 1.34E-02
 Prod : Success
 M01 : 9808967998
 Lambda : 2.58E-01 H
 Description : 5.22E-04/H



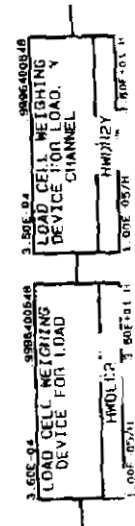
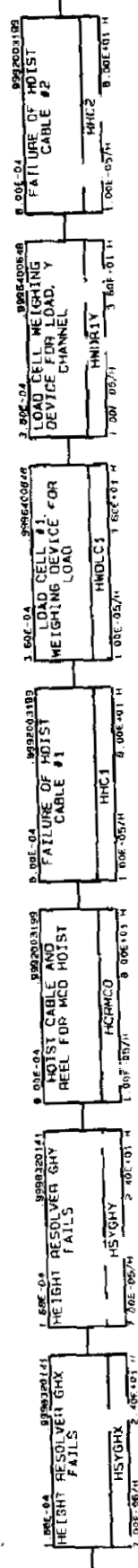
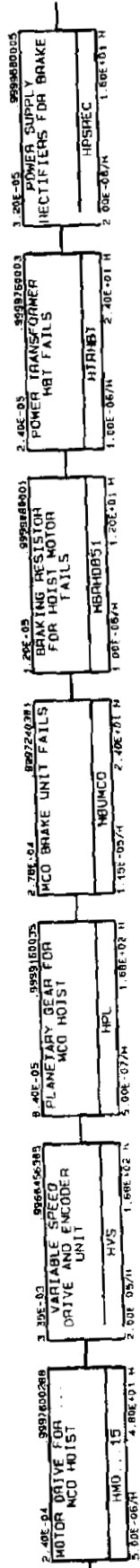
Mod. Title : MCOH
 Prob. Success : 1.34E-02
 MDT : 2.58E+01 H
 Load : 3.22E+04 H AND
 Description : MCOH TEST AND
 ENCLOSURE





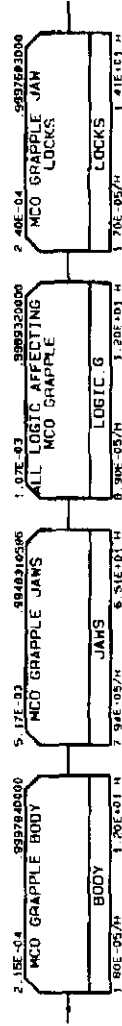
**MCO Hoist and Enclosure Subsystem
Without Controls**

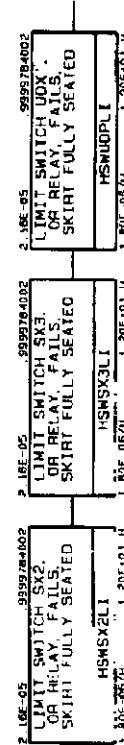
Module	Prob.	Failure
WCDMA0CC	8.20E-03	
WCDMA0CC	9.918000000	
WCDMA0CC	5.55E+01 H	
WCDMA0CC	1.25E-04/H	



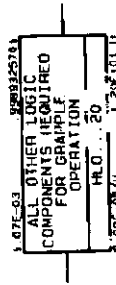
MCO Grapple Subsystem With Controls

Module : GRAPPLE
 Prob. Failure : 6.68E-03
 Prob. Success : .9933213000
 MTTF : 3.29E+01 H
 Lambda : 2.03E-04/H
 Description :

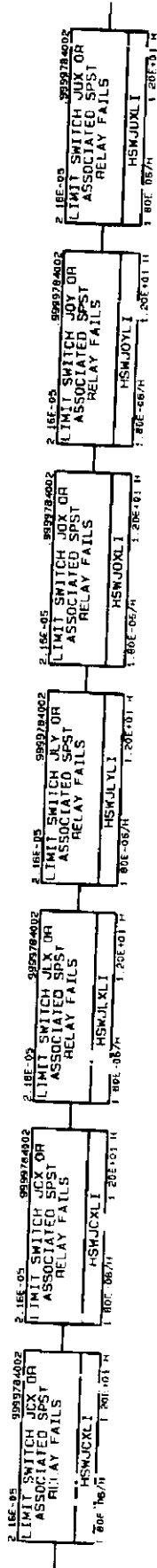




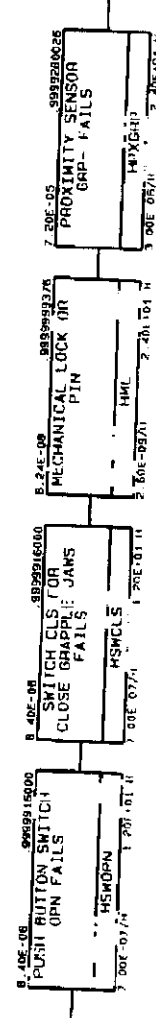
Module : LOGIC G
 Prob. Failure : 1.07E-03
 Prob. Success : 9989320000
 MDT : 1.0E+02 H
 Lambda : ALL LOGIC AFFECTING
 Description : MED GRAPHIC



Module : LOCKS
 Prob. Failure : 2.40E-04
 Prob. Success : 1.99E-063000
 MDT : 1.70E-05/H
 Lambda : 1.70E-05/H
 Description : MCD GRAPPLE JAW
 LOCKS

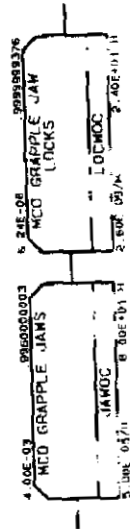


G-53

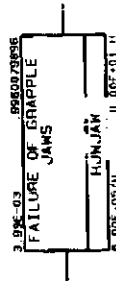


**MCO Grapple Subsystem
Without Controls**

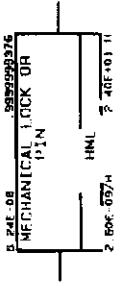
Module GRAPWOC
 Prob Failure 4.00E-03
 Prob Success 9.999999999
 MDI 8.00E+01/H
 Lmode 5.00E-05/H
 Description



Module : JAMDC
 Prob. Failure : 4.00E-03
 Prob. Success : .9960000003
 MDT : 8.00E+01 H
 Lambda : 3.00E-01 H
 Description : MCD GRAPPLI JANS

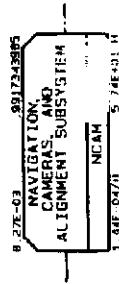


Module : LCMDC
Prob. Failure : 6.24E-08
Prob. Success : 9999999375
MDT : 2.40E+01 H
Lambda : 2.60E-09/H
Description : MCD GRAPHIC JAW
LOCKS

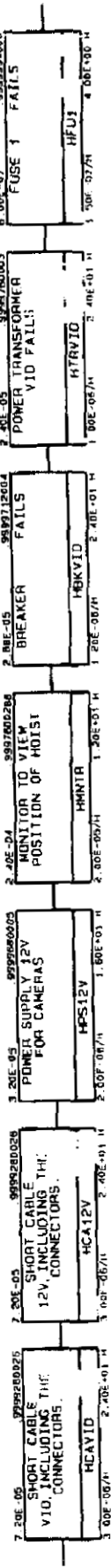
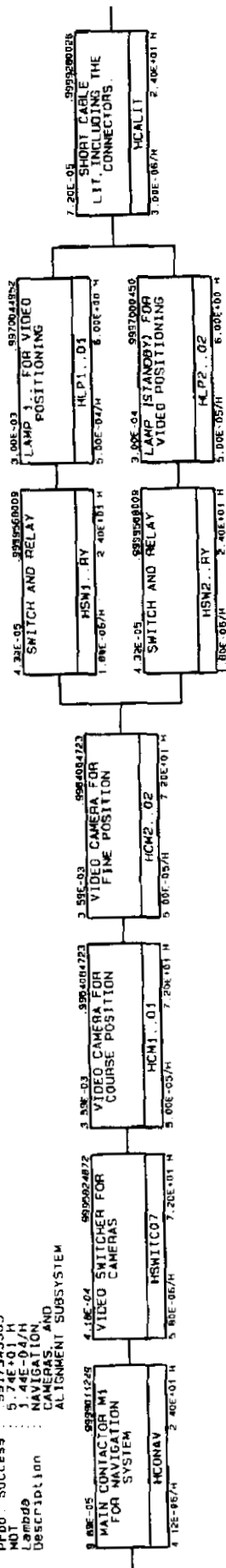


**Navigation Subsystem
With Controls**

Module : NAVCAM
 Prob. Failure : B 27E-03
 Prob. Success : 9917343985
 MUI : 5.74E+01
 Lambda : 1.44E-04/11
 Description :

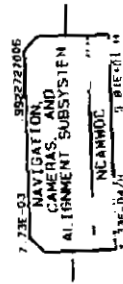


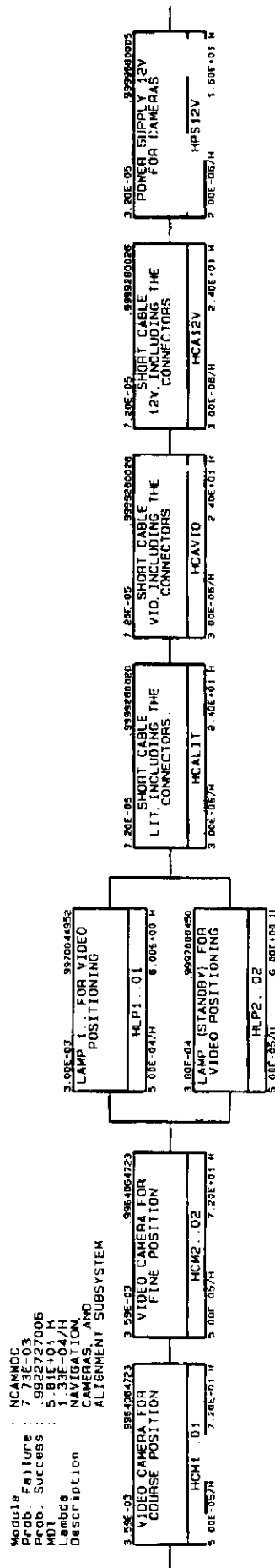
Module Failure
 Prob. Success
 69517343985
 1.44E-04/H
 1.44E-04/H
 Navigation, and
 Alignment Subsystem



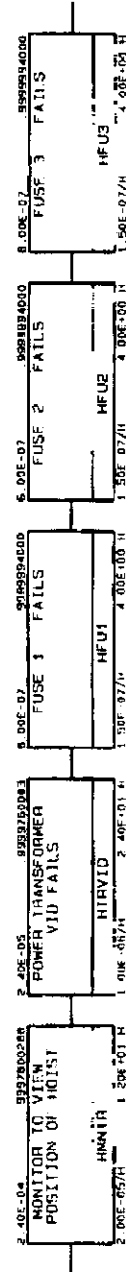
Navigation Subsystem Without Controls

Module NAVMOC
 Prob. Failure 7.72E-03
 Prob. Success 9.99E-06
 MDI 9.99E-04
 Load 1.33E-04
 Description





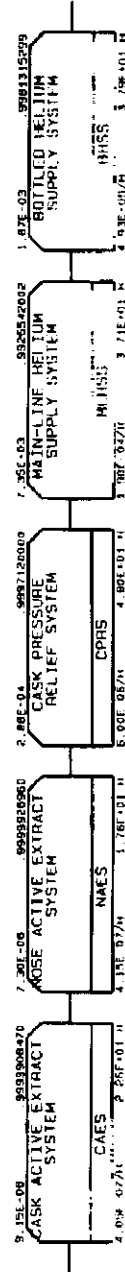
G-63



Ventilation and Inerting Subsystem With Controls

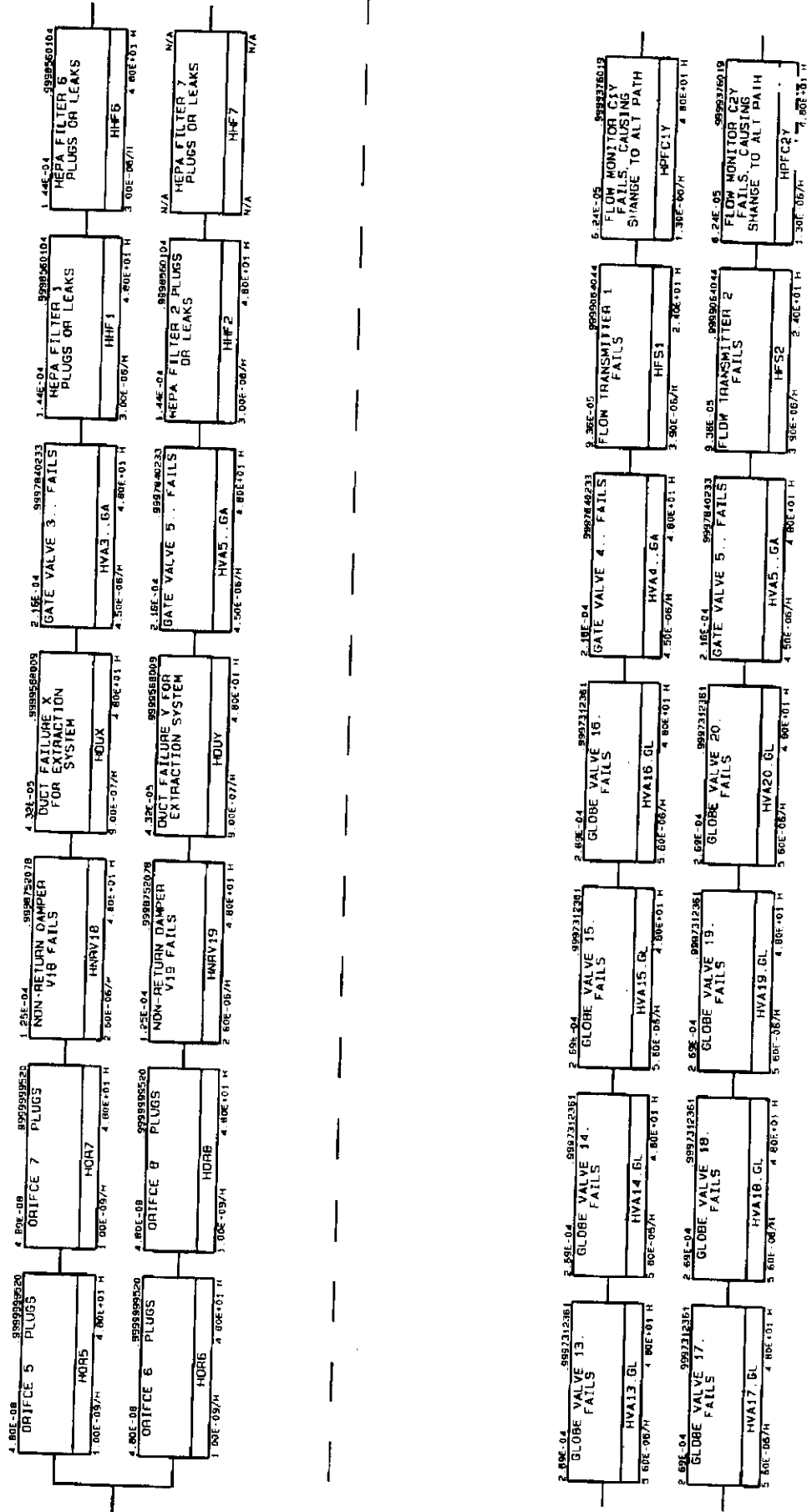
**Note: Ventilation and Inerting Subsystem without Controls provides
same quantitative results.**

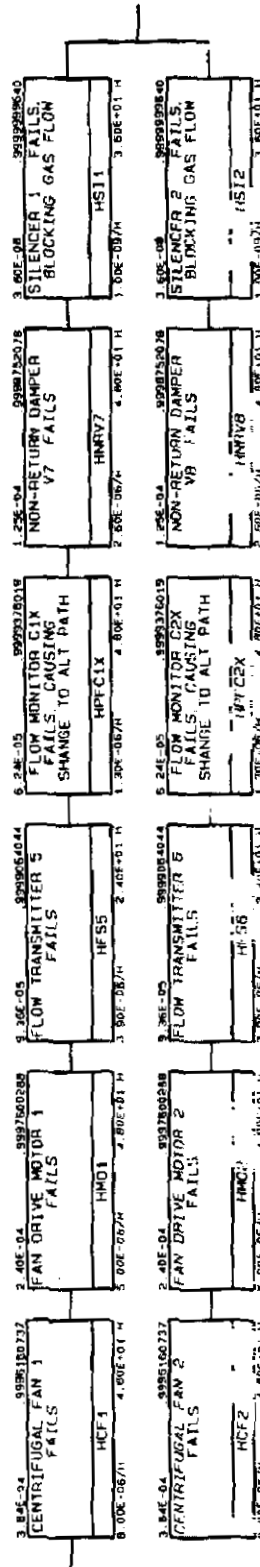
Module : VENT
 Prob. Failure : 9.53E-03
 Prob. Success : 999474999
 Mode : 3.53E-04
 Mode : 3.53E-04
 Description : VENTILATING SYSTEM
 AND INERTING SYSTEM



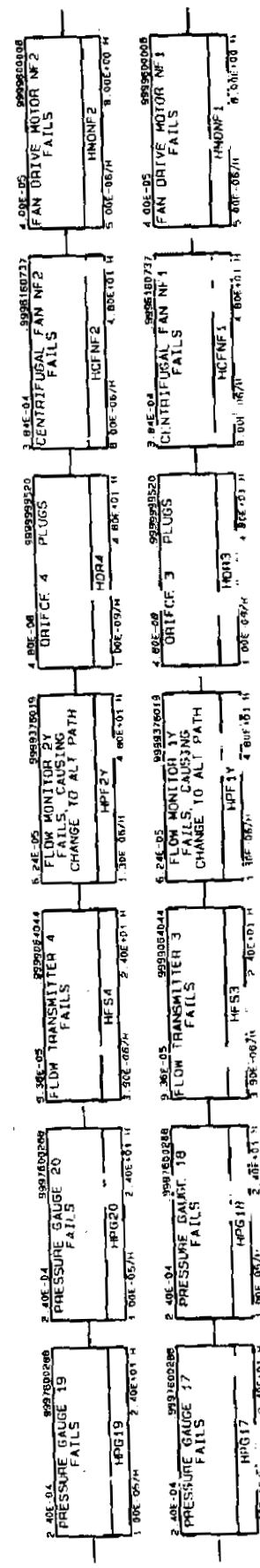
G-65

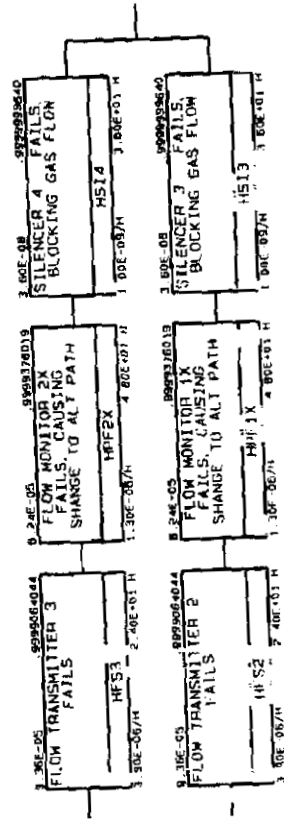
Module Failure : CAES
 Prod. Success : 9.15E-06
 MOD. Success : 9.999908470
 Lambda : 2.00E-01 H
 Description : CASK ACTIVE EXTRACT
 SYSTEM

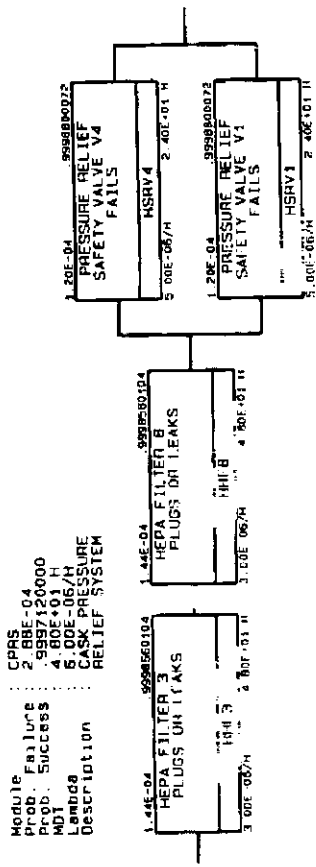




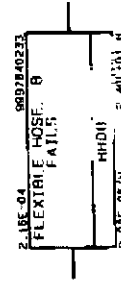
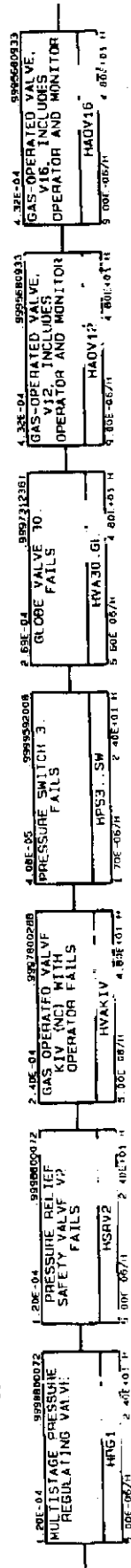
G-67



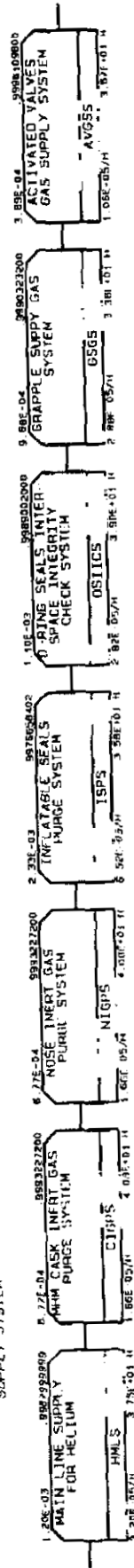


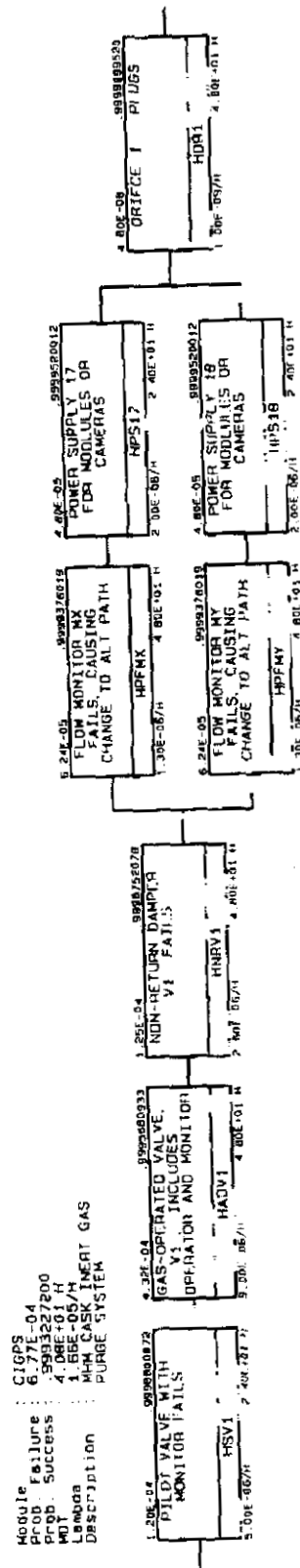


Module : BHSS
 Prob : 1. B7E-03
 Prob : 9901315299
 WOT : 3.79E+01 H
 Lambda : 4.93E-05/H
 Description : BOTTLED HELIUM
 SUPPLY SYSTEM



Module : MLHSS
 Prob. Failure : 7.35E-03
 Prob. Success : 9.928542002
 MTD : 3.77E+04 H
 Lambda : 1.08E+04 H
 Description : MAIN LINE HELIUM
 SUPPLY SYSTEM

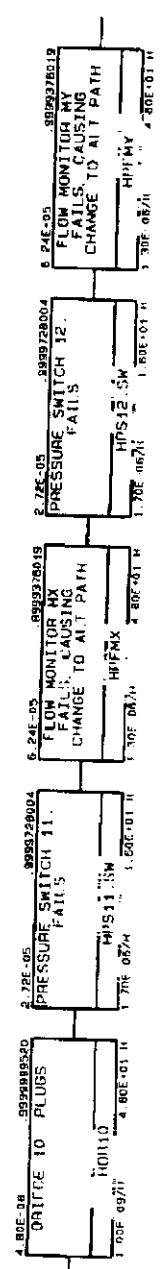
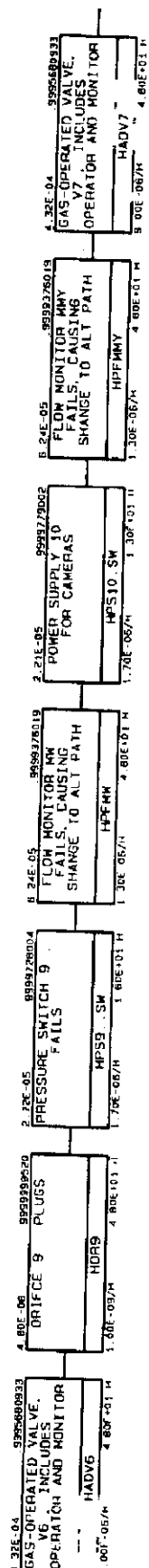
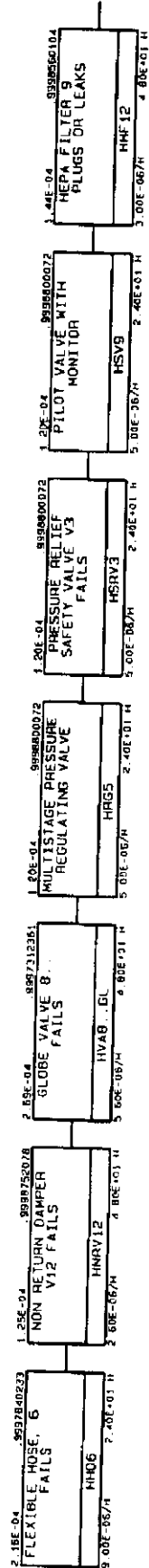




Module NISPS
 Prob. Failure 5 37E-04
 Prob. Success 4 95B327200
 Module 4 0BE-01 H
 Module 1 5EE-05/H
 Description NOSE INERT GAS
 PURGE SYSTEM



Module : IPS
 Prob. Failure : 2.33E-03
 Prob. Success : 9978658402
 MDT : 8.15E-01 H
 Lambda : 1.50E-01 H
 Description : INTERLOCK SEALS
 PURGE SYSTEM

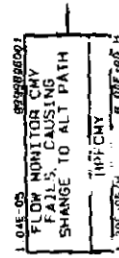
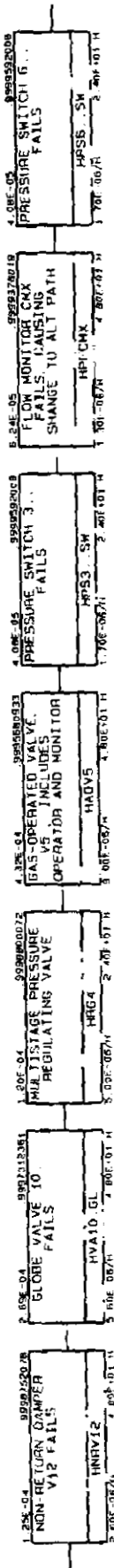


Module
Pr-06 Failure
Pr-06 Success
Lambda
Description
SPACE INTEGRITY
CHECK SYSTEM

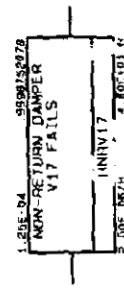
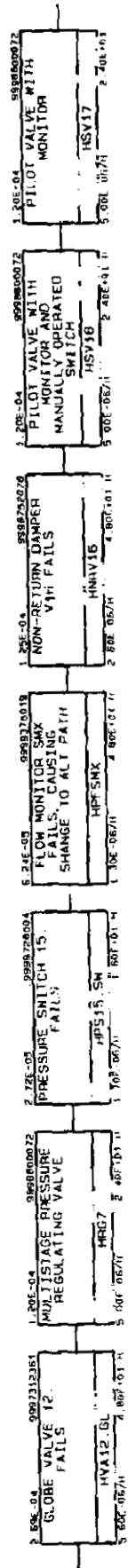
OSICS

1.00E-03
9999002000
3.00E+01 H
2.00E-04/H
D-RING SEALS INTER-

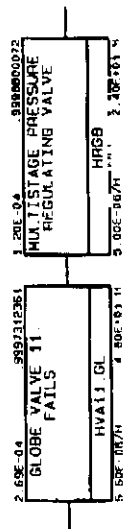
SPACE INTEGRITY
CHECK SYSTEM



Module : 6565
 Prob. Failure : 9.68E-04
 Prob. Success : 9.990323200
 WOT : 3.35E+01 H
 Lambda : 2.88E-05/H
 Description : GRAPPLE SUPPLY GAS SYSTEM



Module	AVGSS
Prob. Failure	3.89E-04
Prob. Success	.9996109800
NOT	3.67E+01 H
Lambda	1.06E-05/H
Description	ACTIVATED VALVES GAS SUPPLY SYSTEM



Appendix H
FMEA/RAM Preparers

Robert H. Gauger

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

Specialty

Consulting assignments that utilize technical and problem solving capabilities in reliability engineering, electronics, and related fields.

**Professional
Experience**

INDEPENDENT CONSULTANT, IRVINE, CA 1990 to date
Providing reliability consulting and risk analysis for clients, including Fluor Daniel, Holmes & Narver, PLG Inc, and Precision Controls & Instrumentation.

HOLMES & NARVER, Orange, CA 1974 to 1990
Manager of Reliability Engineering - Responsible for all reliability, availability, and maintainability (RAM) engineering programs and services provided by Holmes & Narver. This included analyses of control systems, process systems, chemical plants, pharmaceutical plants, power plants, wastewater plants, and military bases. The programs used techniques such as failure mode analyses (FMEAs), failure mode effect and criticality analyses, (FMECAs), reliability modeling, accessibility analyses, fault tree analyses (FTAs), event trees, accident scenarios, hazard analyses, and identification of problem areas. In all cases, quantitative reports were provided, and design changes resulted.

Recent programs included:

- o A failure mode, effect, and criticality analysis for a NASA test facility for hydrogen storage tanks.
- o A failure mode and effect analysis for a compactor for hazardous waste.
- o An ethylene oxide plant that required a high integrity shutdown system. The analyses used FTAs and FMECAs.
- o Several programs for high-reliability communications systems, including networks, emergency systems, satellite communications, and fiber optics.
- o Clinch River Breeder Reactor Plant, using availability analyses, risk assessments, FMECAs, FTAs, and predictions.

- o Uranium enrichment facility with FMEAs and predictions used to satisfy availability and safety concerns.
- o Southern California Edison, including the development of an advanced data acquisition, monitoring, and diagnostic system based on expert systems.
- o Consolidated Space Operations Center, RAM analyses and controls to meet the critical requirements regarding the availability and distribution of electric power.
- o National Test Facility, again with critical power requirements, but based on a combination of backup power systems.
- o Security system for military bases having reliability and availability requirements.
- o A pharmaceutical plant that required a quantitative hazard evaluation and FTAs in order to obtain approval for plant construction.

SINGER KEARFOTT, Little Falls, N.J.

1970-1974

Reliability Program Manager - Established a series of sequential reliability tests and programs for the company's electrical and mechanical guidance components.

HAZELTINE CORPORATION, Greenlawn, N.Y.

1949-1970

Division Head - Directed all reliability, availability, maintainability, components, and standards activities for a multiplant military electronics company.

**Educational/
Affiliation**

BSEE, Iowa State University
 MEE, Polytechnic Institute of Brooklyn
 IEEE, Life Senior Member
 ASQC Certified Quality Engineer
 ASQC Certified Reliability Engineer
 Professional Engineer, Quality, California
 Professional Engineer, New York
 Institute for the Advancement of Engineering, Fellow
 Presented and published more than 30 papers on availability, maintainability, and reliability.

RESUME OF AMITAVA GHOSE

EDUCATION

Ph.D.	Structural Engineering, University of California, Berkeley
M.S.	Structural Engineering, University of California, Berkeley
B.Tech.	Civil Engineering, Indian Institute of Technology

PROFESSIONAL REGISTRATIONS

Registered Professional Engineer, State of California, Reg. No. CE-26202

PROFESSIONAL AFFILIATIONS / PUBLICATIONS

Member, American Society of Civil Engineers

Co-author: ASCE Standard 4-86, "Seismic Analysis of Safety Related Nuclear Structures"

PROFESSIONAL EXPERIENCE

ARES Corporation

Vice President and one of the founders of ARES Corporation. Some areas in which the firm provides services include:

- Seismic evaluation and retrofit design of power plant, transportation, industrial, and commercial structures;
- Design of high level radioactive waste underground storage facilities;
- Performance of third-party design and construction reviews of plant systems;
- Development of design basis and licensing basis documents for plant-wide design criteria manual;
- Development of safety analyses for plant modifications; and
- Development of methodology for the basis for the justification for continued operation of plants.

AMITAVA GHOSE

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Some recent projects in which Dr. Ghose had major involvement include:

- Development of Design Basis Document for PG&E's Diablo Canyon plant. DBD development activity included writing, reviewing, enhancing, and revising a comprehensive set of DBDs encompassing the Civil/Structural/Piping disciplines. His breadth of experience is exemplified by the following partial list of DBDs worked on: Seismic Analysis; Containment Building; Containment Interior Structure; Fuel Handling Building; Seismic Qualification of Equipment; Pipe Break (HELB, MELB) and missiles; Control of Heavy Loads; etc.
- Development of Alternate Analysis Techniques for Arkansas Nuclear One's Isometric Update Project. A comprehensive set of plant-specific simplified evaluation techniques were developed, eliminating undue conservatism, for the cost-efficient documentation update of the plant's small-bore piping systems and supports. The ANO staff engineers and field personnel were trained in the effective use of these procedures;
- Vibration analysis for suppression pool components for boiling water reactor under seismic and hydrodynamic loads; and
- Evaluation of the effects of long duration seismic loading on the performance of reinforced concrete bridge columns.

Cygna Group, Inc.

As Section Manager for Advanced Seismic/Structural Analysis, technical direction and management were provided for the following key projects:

- Development of design basis documents, and numerous plant design modifications including seismic/structural design of a major plant building expansion at Pacific Gas & Electric's Diablo Canyon Nuclear Generating Station;
- Comprehensive research and rewrite of the Updated Final Safety Analysis Report for Commonwealth Edison Company's Quad Cities Nuclear Generating Station, reflecting all design basis modifications and resolving any existing inconsistencies; and
- Performance of a series of seismic parametric studies for the California Department of Transportation, to verify and improve the seismic modeling, evaluation techniques, and design specifications used by

AMITAVA GHOSE

Page 3

Caltrans for single and double-deck elevated freeways. Presentations were made, based upon these studies, to groups of Caltrans senior design engineers, and to Caltrans' distinguished seismic advisory board. Numerous results and conclusions from these studies have been incorporated into the Caltrans procedures.

Independent Seismic/Structural Consultant

Independent consultation on seismic design and review of industrial structures. Utilized computer-based as well as conventional solutions to the application of earthquake loads on large complex structures, and evaluated the integrity of their designs. The majority of the consultation was in the Power Industry. Specific projects included:

- Design review of the seismic design of Category I structures, dynamic evaluation of safety class components and critical piping systems and their supporting structures, and evaluation of pipewhip and jet interactions, for the Comanche Peak Nuclear Plant.
- Seismic evaluation of the interfacing cable tray and conduits and their supports associated with a control panel design modification at the Diablo Canyon Nuclear Generating Station.
- Review of computer models and codes for Nuclear Power Structural Evaluations (NASTRAN, STARDYNE, GTSTRUDL, SUPERPIPE) and Computer Codes for Repository Design Models (ADINA, DOT, MATLOC, SALT4, VISCOT, HEATING6, STEALTH2D), for an NRC/DOE Project.

Cygna Corporation, San Francisco

As Manager of Product Development, Dr. Ghose produced definition and design of a structural engineering system for the interactive design of commercial and industrial buildings. Development of a demonstration system utilized C-programming language, in a UNIX environment. Responsibilities included technical direction and management of the development group.

Impell Corporation, San Francisco

As Senior Technical Specialist, key responsibility was the development of the Interactive Structural Design module for Impell's Computer-Aided Engineering product. Significant contributions were made in conceptual planning and in:

AMITAVA GHOSE

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directing the development team; efficient design of data structures; implementation of 3-D interactive graphics; and design of interfaces with Structural Analysis software.

As a Manager of the Advanced Structural Analysis Section, provided technical management of a group of 20 engineering personnel within the Advanced Analysis Division. Responsibilities included technical direction, client interface, personnel hiring, evaluation and development. The technical areas covered included the application of computer analysis techniques to the design and analysis of complex structural systems, reactor components and equipment. Dynamic analysis codes using finite element methods were developed and applied. Design verifications were performed of Category I structures in U.S. and overseas nuclear power plants.

Selected project areas included:

- Supervision and technical direction of structural dynamics problems for power plant structures and components. Some sample project involvement were the following:
 - seismic analysis of Category I structures and development of amplified in-structure response spectra for Allen's Creek, Douglas Point, Hope Creek, and South Texas Project.
 - seismic analysis studies, including fluid-structure interaction effects, of the proposed Atlantic Generating Nuclear Station floating power plant.
 - nonlinear dynamic analysis of generic PWR model with asymmetric loads for the evaluation of the reactor vessel, saddle supports, pedestal and shield walls.
 - dynamic analysis and component/equipment evaluation and retrofit design for BWR Mark I suppression pool hydrodynamic loads for Cooper Nuclear Station.
 - dynamic analyses for the correlation of General Electric's Full Scale Test Facility results for the development of chugging loads in BWR Mark I containments.
 - seismic analysis of a BWR Mark III containment building axisymmetric model including fluid-structure interaction effects of the pressure suppression pool.
 - dynamic time-history analyses for the evaluation of steam-hammer and water-hammer effects on main steam lines and safety/relief valve lines on Duke Power Company's McGuire and Catawba Plants and TVA's Sequoyah and Watts Bar Nuclear Plants.

AMITAVA GHOSE

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- Supervision of technical work for site seismic ground motion development and soil-structure interaction analysis. Some specific project experience includes:
 - site analysis, seismic design criteria development, spectrum-compatible ground motion computation, and generic soil-structure interaction studies in support of the Early Site Review Report (ESRR) for the proposed San Joaquin Nuclear Plant for LA Department of Water and Power.
 - soil-structure interaction analyses in support of Preliminary Safety Analysis Report (PSAR) for Allen's Creek, Douglas Point, and South Texas Project.
 - soil-structure interaction studies for General Electric's BWR Standard Reactor Island Design (STRIDE) project.
 - soil-structure interaction studies including nonlinear soil-gap properties for Tihange 2, Electrobelt, Belgium.
- Direction of the enhancement developments, testing, and documentation of the company's two major engineering software modules: SUPERPIPE and EDSSAP.

Madigan-Hyland Inc., New York

Analysis, design, and refurbishment of steel and reinforced concrete bridges in the State Highway system of New York and New Jersey.

RESUME OF BRUCE D. GROTH

EDUCATION

B.S., Chemistry, Willamette University, Salem, Oregon

B.S., Mathematics, Willamette University, Salem, Oregon

Progress towards M.S., Chemical Engineering, Washington State University-Tri Cities,
Richland, WA

Over 30 hours of continuing education in project management.

PROFESSIONAL EXPERIENCE

ARES Corporation, Richland, Washington

Mr. Groth is a senior engineer responsible for conducting engineering studies, conceptual design reports and estimating, and performing design reviews, in addition to other engineering duties.

Westinghouse Hanford Company, Richland, Washington

While working as a Tank Farm Characterization and Monitoring Systems Design Engineer, Mr. Groth performed engineering studies, conceptual design, and detailed design for systems to characterize and monitor waste in high level radioactive waste storage tanks on the Hanford Site.

As a Project Engineer on Multi-Function Waste Tank Facility, Mr. Groth performed project engineering functions on a new \$435 million tank farm for the storage of radioactive and hazardous waste from concept through detailed design. Responsibilities included Safety Analysis Report preparation, Systems Engineering, design oversight, preparation of design baseline criteria, risk management, cost and schedule control, and NEPA documentation support.

As a Tank Farm Process Engineer, Mr. Groth was involved in process support, equipment design, development of design criteria, maintenance, and operation of instrumentation, data acquisition, electrical, and mechanical systems in Nuclear Waste Storage Tank Farms. Primarily worked on developing, fabricating, installing and operating new gas monitoring systems for both process control and analytical purposes in tanks with safety concerns.

U.S. Navy

Main Propulsion Assistant onboard USS Texas (CGN-39) - Duties involved supervision of all mechanical system maintenance, operation, testing, and training on TEXAS' two Nuclear Propulsion Plants. Responsible for completion of all repairs and alterations as specified on ships drawings from the planning phase through the completion of satisfactory testing. Supervision of a staff of two Lieutenants, five Chief Petty Officers, and sixty enlisted personnel.

BRUCE D. GROTH

Page 2

Assistant to the Chief Engineer onboard USS TEXAS (CGN-39) - Coordinated maintenance with outside repair activities, assisted in implementing a Quality Assurance Program in the Engineering Department, and significantly upgraded the mechanical training program.

Machinery Division Officer onboard USS TEXAS (CGN-39) - Experience involved operation, preventive maintenance, and repair of all Reactor and Steam Plant Mechanical Systems. Qualified as Engineering Officer of the watch of TEXAS' Nuclear Propulsion Plants as well as Engineering Duty Officer and Nuclear Quality Assurance Inspector. These duties involved direct supervision of 35 personnel.

Surface Warfare Officers School, San Diego, California - Comprehensive training on all aspects of Naval Surface Ship Operations, Weapons, Engineering, and Administration.

Naval Nuclear Propulsion Training - Six months of formal training in Reactor and Steam plant theory, mathematics, physics, electrical engineering, materials, chemistry, and reactor design at Naval Nuclear Power School, Orlando, Florida. Seven months of operational training at A1W nuclear prototype reactor in Idaho Falls, Idaho.

CLEARANCE: DOD Top Secret Security Clearance

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