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Technical Support for:
Lawrence Livermore Laboratory

**Retrieval System for Emplaced
Spent Unreprocessed Fuel (SURF)
in Salt Bed Depository**

MASTER

**ACCIDENT EVENT ANALYSIS
AND MECHANICAL FAILURE PROBABILITIES**

G. Bhaskaren and J.E. McCleery
L.O. Hannah, Editor

Copy 8 of 30

FINAL REPORT

October 1979

This work was prepared
by International
Engineering Company
under subcontract No.
5488909 with Lawrence
Livermore Laboratory.

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1.0 ABSTRACT

This report provides support in developing an accident prediction event tree diagram, with an analysis of the baseline design concept for the retrieval of emplaced spent unprocessed fuel (SURF) contained in a degraded Canister. The report contains an evaluation check list, accident logic diagrams, accident event tables, fault trees/event trees and discussions of failure probabilities for the following subsystems as potential contributors to a failure:

- a) Canister extraction, including the "core" and "ram" units;
- b) Canister transfer at the hoist area;
- c) Canister hoisting.

This report is the second volume of a series. It continues and expands upon the report "Retrieval System for Emplaced Spent Unprocessed Fuel (SURF) in Salt Bed Depository: Baseline Concept Criteria Specifications and Mechanical Failure Probabilities"⁽¹⁾, submitted to Lawrence Livermore Laboratory in May 1979. This report draws upon the baseline conceptual specifications contained in the first report.

2.0 SUMMARY

A Failure Mode and Effects Analysis (FMEA) of an applicant's design of the SURF retrieval equipment is required to determine:

- a) Probability of radiation release due to equipment failure.
- b) Critical or governing components, subassemblies or assemblies which have potentially high failure rates which cause either hazardous midmode failures or undesireably low equipment availability rates.
- c) Design acceptability based on overall failure intensity parameters.
- d) Potential constraints imposed on human operations or mine spatial conditions.

The sample FMEA demonstrated in this report consists of the creation of a fault tree/event tree. The methodology for this FMEA is demonstrated in Sections 3 to 8 of this report. Failure rates and their implications for the logic diagrams are discussed in Section 9. Data acquisition procedures for failure intensity derivations are presented in Section 10.

2.1 Definitions

To assist in understanding the presentation/derivation methodology presented in this report, the basic definitions, abbreviations and equipment nomenclature are herein summarized.

The failure intensity or failure rate is the expected number of failures, by either catastrophic, degraded or incipient causes, per item, in a given time interval (or given number of operating cycles, for cyclic parts). The failure intensity rates are expressed in units of failure per 10^6 hours (or per 10^6 cycles) and are represented universally by the greek letter, lamda: λ

The failure intensity of an assembly is defined as the summation of the failure rates of the individual devices in series. The failure of any device in the series results in a failure of the assembly. The addition of redundant devices (failure of one identical device does not inhibit operation) is discussed in Subsection 9.1.

The failure intensity of an assembly is expressed by: $\lambda_A = \sum \lambda$

2.2 Abbreviations

The following abbreviations are used in this report:

BWR - boiling water reactors
CET - canister extraction/transporter
COT - canister overcore transporter
CTB - canister transport basket
CWB - canister waste basket
CWC - canister waste cage
CWSRS - canister waste subsurface receiving station
DOE - Department of Energy
FF - Floor Flange
FFG - Floor Flange Gate
FMEA - Failure Mode and Effects Analysis
GIDEP - Government - Industry Data Exchange Program
LLL - Lawrence Livermore Laboratory
mph - miles per hour
MTBF - mean time before failure
NRC - Nuclear Regulatory Commission
NWM - Nuclear waste management
POM - plug overcore machine
PRM - plug removal machine
PWR - pressurized water reactor
SHT - Sheet
SURF - spent unreprocessed fuel
vs - versus

2.3 Equipment Nomenclature

The subassemblies of the retrieval equipment are identified on Figures 2.1 through 2.5 inclusive. Figure 2.1 depicts the canister extraction/transporter (CET) unit with subassemblies. The lifting device nomenclature of all retrieval equipment are also presented to enable ready identification of common and discrete assemblies. Figures 2.2 through 2.5 show the discrete assemblies of the plug overcore machine (POM) and canister overcore transporter unit (COT).

Figure 2.1
RETRIEVAL EQUIPMENT SUBASSEMBLY NOMENCLATURE

Figure 2.2
POM AND PLUG LIFTING DEVICE NOMENCLATURE

Figure 2.3
POM AND OVERCORE DEVICE NOMENCLATURE

Figure 2.4

POM AND SLEEVE CUTTING AND REMOVAL DEVICE NOMENCLATURE

Figure 2.5

COT SUBASSEMBLY NOMENCLATURE

3.0 INTRODUCTION

"The Nuclear Regulatory Commission (NRC) has the Nuclear Waste Management (NWM) responsibility for developing high-level and spent-fuel waste regulations, regulatory guides and licensing requirements in a timely manner consistent with the Department of Energy (DOE) NWM needs. The Lawrence Livermore Laboratory (LLL) Waste Management Project is developing macroscopic element simulation models to evaluate the risks involved. The models developed need to be validated against data bases."⁽²⁾

NWM is a complex problem requiring storage of spent unprocessed fuel (SURF) from pressurized water reactors (PWR) and boiling water reactors (BWR). The design base for this report is the sealing of SURF in a steel canister and emplacing it in a deep geologic halite deposit. In situ salt bed emplacement tests have been conducted in the United States, and a wealth of data has been obtained establishing the feasibility of salt mine emplacement.⁽³⁾ Additional tests are being performed.⁽⁴⁾

The storage concept requires the development of an efficient and reliable emplacement and retrieval system. An effective retrieval method is essential if the stored nuclear waste must be removed from the depository for any reason. During emplacement operations, degraded canisters may have to be removed, repackaged and reemplaced to avoid contamination leading to premature cessation of emplacement operations.

One of the integral elements of the Nuclear Waste Management Program is the material handling task of retrieving canisters containing spent unprocessed fuel from their emplacement in a deep geologic salt bed depository. A study defining baseline concept criteria specifications and mechanical failure probabilities of SURF retrieval equipment⁽¹⁾ predicted this report.

As discussed in that report, a sleeve protects the emplaced canister from the pressures due to salt creep⁽⁵⁾ and from corrosion by salt and brine.⁽²⁾ This sleeve must be designed to permit the retrieval of the canister by the emplacement machinery or by special retrieval equipment. In the event that the sleeve fails in its function to protect the canister, the retrieval of a degraded canister from a degraded sleeve will require a technique different from the procedures for ordinary retrieval of degraded canisters from intact sleeves.

The previous volume in the series:

- a) Presented various concepts for the retrieval of the degraded canister from an intact sleeve and a degraded sleeve;
- b) Evaluated the different concepts;
- c) Evolved a baseline retrieval concept;
- e) Predicted the failure probability for the major system components.

Using the above mentioned failure probabilities, this report develops an evaluation check list, block diagrams, event tables and fault trees/event trees to provide an accident analysis methodology for the following SURF canister retrieval subsystems:

- a) Canister extraction from both intact and degraded sleeves;
- b) Canister transfer at the hoist area;
- c) Canister hoisting.

To assist the NRC in developing defensible regulations and designs for SURF canister retrieval, this report evaluates hazard risks evolving from mechanical subsystem failure and lists requirements necessary to reduce accident risk.

Failure probabilities for the major canister retrieval subsystems along with the formula derivations and discussions of the rationale behind the formulas are included in Section 4. A discussion of failure governing subassembly design analysis is contained in Section 5. The block diagrams for the operation sequence of the retrieval subsystems are shown in Section 6. Accident event tables developed on the basis of potential mechanical subsystem failure are presented in Section 7. The fault trees/event trees for the accident analyses are based on these tables; they are presented in Section 8. Sections 9 and 10 discuss failure probability and fault tree/event tree gate number derivation, respectively.

4.0 EVALUATION CHECK LIST

The evaluation check list provides the reviewer with a concise and convenient form by which to evaluate submitted retrieval equipment designs. The check list as formulated is based on the previous report "Retrieval System for Emplaced Spent Unreprocessed Fuel (SURF) in Salt Bed Depository: Baseline Concept Criteria Specifications and Mechanical Failure Probabilities".⁽¹⁾ It is obvious that the designs will deviate from the baseline design depicted on Figures 2.1 through 2.5 inclusive. The check list presented herein is intended to show a methodology for assembling requisite facts relative to the equipment by subassembly division and recordation. The equipment shall be designed such that it can be easily maneuvered in the emplacement rooms and the corridors.

For purposes of this report, "yes" answers to all questions are assumed. The development of a weighted answer for each yes or no value is beyond the scope of this report.

Surveying, reaming, and Floor Flange placement are requisite for successful retrieval operations, and are assumed in this report to have been completed. The reviewer of an applicant's design should verify that similar procedures are incorporated. For a complete discussion of these procedures, refer to Section 10 of the previous baseline specifications report.⁽¹⁾

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

4.1 PLUG REMOVAL MACHINE (PRM)

The principal systems and major components of the PRM will be:

1. Cask
2. Cask elevating mechanism
3. Cask tilt mechanism
4. Cask gate mechanism
5. Plug lifting device
6. Plug lifting device elevating/lowering mechanism
7. Power system - transporter
8. Power system - retrieval
9. Power system - emergency
10. Power system - hydraulic
11. Chassis
12. Cab
13. Transporter drive
14. Steering, automatic guidance system
15. Automatic indexing system
16. Controls
17. Monitors
18. Communication to control center
19. Communication to other vehicles
20. Emergency equipment
21. Shielding including cab
22. Lighting

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

	<u>Yes</u>	<u>No</u>
1. <u>CASK</u>		
a) Will the travel position of the cask be horizontal?		
b) Will the retrieval position of the cask be vertical?		
c) Will vehicle operate in an emplacement room of 18 feet wide by 30 feet high?		
d) Is access for inspection, service and decontamination provided?		
2. <u>CASK ELEVATING MECHANISM</u>		
a) Does design provide that failure of mechanism to go into retrieval position prevents plug removal operation?		
b) Does failure of mechanism to unlatch from retrieval position prevent the cask from lowering to the transport position?		
c) Must cask lock in travel position before PRM can travel?		
d) Will power or control failure lock elevating mechanism?		

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

3. CASK TILT MECHANISM

Yes

No

- a) Will mechanism position cask accurately plus/minus one half degree?
- b) Will mechanism tilt cask in any direction (within 2 radians) ten degrees (10^0) from vertical?
- c) Have position monitoring and out of position alarm systems been provided?
- d) Is hydraulic system including cylinders and pump provided?
- e) Are supply lines and cask penetration seals of other than elastomeric compounds?
- f) Do cask penetrations form an integral "s" to prevent a path for radiation release?

4. CASK GATE MECHANISM

- a) Is pressure test seal of cask gate to Floor Flange provided?
- b) Is cask gate devised to prevent opening if seal is faulty?
- c) Must cask open or close fully to permit next operation?
- d) Will cask gate key latch operate the Floor Flange Gate?
- e) Are controls provided to prevent disengagement from Floor Flange if cask gate fails to close and lock?
- f) Will jam while opening or closing cause gate to return to previous position?
- g) Is gate mechanism accessible for repair?
- h) Does design provide for gate seals to wipe the sealing surface free of debris?
- i) Is mechanism electric motor powered?

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

5. PLUG LIFTING DEVICE

Yes No

- a) Is the plug lifting device of a collet design provided?
- b) Does design assure positive engagement between plug lifting fixture and plug lifting ram?
- c) Does design include provision for prevention of hoisting in the event that the lifting device does not fully close?
- d) Is a pawl latch or equivalent provided to lock plug lift ram in position at time of power control failure?

6. PLUG LIFTING DEVICE ELEVATING/LOWERING MECHANISM

- a) Will power or control failure lock the plug lifting device into position at the time of failure?

7. POWER SYSTEM - TRANSPORTER

- a) Is a mine locomotive battery power system provided?
- b) Is storage capacity of the batteries sufficient for six round trips of 6500 feet each way with full load?
- c) Direct power for retrieval operation is required. For this purpose, is a cable reel with plug provided onboard the vehicle to allow connection to a mine power distribution panel?
- d) Is a recharging system onboard the vehicle provided to charge batteries whenever the machine is plugged into the station power supply at either the retrieval site or the CWSRS?

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

	<u>Yes</u>	<u>No</u>
8. <u>POWER SYSTEM - RETRIEVAL</u>		
a) Does system plug into station power supply at retrieval site and CWSRS?		
b) When retrieval power system is plugged in, is transporter travel power system locked out?		
9. <u>POWER SYSTEM - EMERGENCY</u>		
a) Does a separate battery system exist with capability to provide power for air conditioned cab, lighting, communication, and vehicle controls for a minimum of four hours?		
10. <u>POWER SYSTEM - HYDRAULIC</u>		
a) Is a medium pressure system of approximately 2500 psi operating pressure provided?		
b) Are supply lines and cask penetration seals of other than elastomeric compounds?		
c) Do cask penetrations form an integral "s" to prevent a path for radiation release?		
11. <u>CHASSIS</u>		
a) Is chassis custom designed and fabricated?		
b) Are stabilizer jacks at each corner of the vehicle provided?		
12. <u>CAB</u>		
a) Is cab air conditioned?		
b) Is an emergency exit door provided?		

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

13. TRANSPORTER DRIVE

Yes No

- a) During corridor travel is drive speed continuously variable 0 to 10 mph?
- b) During emplacement room travel is drive speed continuously variable 0 to 5 mph?
- c) Is transporter drive battery powered mine locomotive type?
- d) Are heavy duty pneumatic rubber tires used for wheels?

14. STEERING, AUTOMATIC GUIDANCE CONTROL

- a) Does automatic vehicle steering system follow wire plus/minus one inch from centerline of wire embedded in drift floor?
- b) Do error detectors monitor steering and stop the machine in event of deviation from prescribed path (wire)?
- c) Will failure of steering mechanism components stop the machine?
- d) Are all mechanisms and controls failsafe?
- e) Will failure of guidance control signal stop the vehicle?

STEERING, MANUAL OVERRIDE

- a) Does power steering exist to assist vehicle operator?
- b) Do error detectors warn operator of deviation from prescribed path (wire)?
- c) Will component failures stop the machine?

PHOTOCELL OR SONAR CONTROL

- a) Will approach to wall stop the machine?
- b) Will approach of another vehicle stop the machine?

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

15. AUTOMATIC INDEXING SYSTEM

Yes

No

- a) Does design position vehicle accurately plus/minus one inch from the theoretical centerline of canister?
- b) Are position monitoring and alarm systems provided?
- c) Is feedback of alignment position data for alignment confirmation provided?
- d) Do interlocks prevent next operation when non-alignment exists?

16. CONTROLS

- a) Is corridor travel control manual with operator in cab?
- b) Is emplacement room travel control automatic guidance with manual override from remote control station in corridor?
- c) When indexing PRM over the canister does design provide for automatic indexing with manual override from remote control station in corridor?
- d) During engagement to Floor Flange does design provide for manual operation from remote control station in corridor?
- e) Is manual operation from remote control station in corridor provided for cask gate and Floor Flange Gate?
- f) During plug removal does design provide for manual operation from remote control station in corridor?

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

	<u>Yes</u>	<u>No</u>
17. <u>MONITORS</u>		
a) Are cab radiation detectors provided?		
b) Does design provide gas leakage detector in cab?		
c) In photocell, sonar or other range detection systems, are monitors of collision conditions provided?		
d) Are remote vision aids provided?		
e) Are fire and smoke alarms provided?		
18. <u>COMMUNICATION TO CONTROL CENTER</u>		
a) Is telemetry provided?		
19. <u>COMMUNICATION TO OTHER VEHICLES</u>		
a) Is two-way radio provided?		
20. <u>EMERGENCY EQUIPMENT</u>		
a) Does design provide manual fire extinguisher for use in cab only?		
b) Does fire control equipment on vehicle for remote operation exist?		
c) Is first aid kit provided?		
d) Is portable breathing apparatus with 30 minute oxygen supply provided?		
e) Is radiation suit provided?		
f) Is regenerative air supply provided?		
g) Will an emergency power plug-in be provided to provide power for transporter, retrieval and hydraulic systems?		

EVALUATION CHECK LIST
PLUG REMOVAL MACHINE (PRM)
(REFERENCE FIGURE 2.1)

21. SHIELDING

Yes

No

a) Is shielding provided for:

- cask gate?
- cask?
- cab?

22. LIGHTING

- a) Is cab interior lighting provided?
- b) Are machine driving lights provided?
- c) Will exterior area be illuminated?
- d) Is TV camera lighting provided?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

4.2 CANISTER EXTRACTION/TRANSPORTER (CET)

The principal systems and major components of the CET will be:

1. Cask
2. Cask elevating mechanism
3. Cask tilt mechanism
4. Cask gate mechanism
5. Canister overpack
6. Ram elevating/lowering mechanism
7. Ram
8. Power system - transporter
9. Power system - retrieval
10. Power system - emergency
11. Power system - hydraulic
12. Chassis
13. Cab
14. Transporter drive
15. Steering, automatic guidance system
16. Automatic indexing system
17. Controls
18. Monitors
19. Communication to control center
20. Communication to other vehicles
21. Emergency equipment
22. Shielding including cab
23. Lighting

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

	<u>Yes</u>	<u>No</u>
1. <u>CASK</u>		
a) Will the travel position of the cask be horizontal?		
b) Will the retrieval position of the cask be vertical?		
c) Will vehicle operate in an emplacement room of 18 feet wide by 30 feet high?		
d) Is access for inspection, service and decontamination provided?		
2. <u>CASK ELEVATING MECHANISM</u>		
a) Does design provide that failure of mechanism to go into retrieval position prevents canister retrieval operation?		
b) Does failure of mechanism to unlatch from retrieval position prevent the cask from lowering to the transport position?		
c) Must cask lock in travel position before CET can travel?		
d) Will power or control failure lock elevating mechanism?		

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

3. CASK TILT MECHANISM

Yes

No

- a) Will mechanism position cask accurately plus/minus one half degree?
- b) Will mechanism tilt cask in any direction (within 2 radians) ten degrees (10°) from vertical?
- c) Have position monitoring and out of position alarm systems been provided?
- d) Is hydraulic system including cylinders and pump provided?
- e) Are supply lines and cask penetration seals of other than elastomeric compounds?
- f) Do cask penetrations form an integral "s" to prevent a path for radiation release?

4. CASK GATE MECHANISM

- a) Is pressure test seal of cask gate to Floor Flange provided?
- b) Is cask gate devised to prevent opening if seal is faulty?
- c) Must cask gate open or close fully to permit next operation?
- d) Will cask gate key latch operate the Floor Flange Gate?
- e) Are controls provided to prevent disengagement from Floor Flange if cask gate fails to close and lock?
- f) Will jam while opening or closing cause gate to return to previous position?
- g) Is gate mechanism accessible for repair?
- h) Does design provide for gate seals to wipe the sealing surface free of debris?
- i) Is mechanism electric motor powered?
- j) Are controls provided to prevent the cask gate from closing if the CET ram fails in midmode?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

5. CANISTER OVERPACK

Yes

No

- a) Is canister overpack designed to slip between the canister outside diameter and the sleeve inside diameter?
- b) Are bearings guided by the interior of the sleeve?
- c) Is a latch for the concrete collar provided in the bottom of the sleeve?

6. RAM ELEVATING/LOWERING MECHANISM

- a) Is a mechanical screw jack with cross head and guides provided?
- b) Is the hydraulic piston designed to extend the ram reach to below the bottom of the canister?
- c) Can the mechanism travel sufficiently to overpack the canister and latch onto the concrete collar in the bottom of the sleeve?
- d) Is manual crank provided for stuck ram?

7. RAM

- a) Is a quick detachable connection to the canister overpack provided?
- b) Is an operator controlled redundant disconnect joint provided above the detachable connection and is it compatible with the telescoping cylinder?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

Yes No

8. POWER SYSTEM - TRANSPORTER

- a) Is a mine locomotive battery power system provided?
- b) Is storage capacity of the batteries sufficient for six round trips of 6500 feet each way with full load?
- c) Direct power for retrieval operation is required. For this purpose, is a cable reel with plug provided onboard the vehicle to allow connection to a mine power distribution panel?
- d) Is a recharging system onboard the vehicle provided to charge batteries whenever the machine is plugged into the station power supply at either the retrieval site or CWSRS?

9. POWER SYSTEM - RETRIEVAL

- a) Does system plug into station power supply at retrieval site and CWSRS?
- b) Is transporter travel locked out when retrieval power system is plugged in?

10. POWER SYSTEM - EMERGENCY

- a) Does a separate battery system exist with capability to provide power for air conditioned cab, lighting, communication, and vehicle controls?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

Yes No

11. POWER SYSTEM - HYDRAULIC

- a) Is a medium pressure system of approximately 2500 psi operating pressure provided?
- b) Are supply lines and cask penetration seals of other than elastomeric compounds?
- c) Do cask penetrations form an integral "s" to prevent a path for radiation release?

12. CHASSIS

- a) Is chassis custom designed and fabricated?
- b) Are stabilizer jacks provided at each corner of the vehicle?

13. CAB

- a) Is cab air conditioned?
- b) Is an emergency exit door provided?

14. TRANSPORTER DRIVE

- a) During corridor travel is drive speed continuously variable 0 to 10 mph?
- b) During emplacement room travel is drive speed continuously variable 0 to 5 mph?
- c) Is transporter drive battery powered mine locomotive type?
- d) Are heavy duty pneumatic rubber tires used for wheels?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

Yes No

15. STEERING, AUTOMATIC GUIDANCE CONTROL

- a) Does automatic vehicle steering system follow wire plus/minus one inch from centerline of wire embedded in drift floor?
- b) Do error detectors monitor steering and stop the machine in event of deviation from prescribed path (wire)?
- c) Will failure of steering mechanism components stop the machine?
- d) Are all mechanisms and controls failsafe?
- e) Will failure of guidance control system stop the vehicle?

STEERING, MANUAL OVERRIDE

- a) Does power steering exist to assist vehicle operator?
- b) Do error detectors warn operator of deviation from prescribed path (wire)?
- c) Will component failures stop the machine?

PHOTOCELL OR SONAR CONTROL

- a) Will approach to wall stop the machine?
- b) Will approach of another vehicle stop the machine?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

16. AUTOMATIC INDEXING SYSTEM

Yes

No

- a) Does design position vehicle accurately plus/minus one inch from the theoretical centerline of canister?
- b) Are position monitoring and alarm systems provided?
- c) Is feedback of alignment position data for alignment confirmation provided?
- d) Do interlocks prevent next operation when non-alignment exists?

17. CONTROLS

- a) Is corridor travel control manual with operator in cab?
- b) Is emplacement room travel control automatic guidance with manual override from remote control station in corridor?
- c) When indexing CET over the canister does design provide for automatic indexing with manual override from remote control station in corridor?
- d) During engagement to Floor Flange does design provide for manual operation from remote control station in corridor?
- e) Is manual operation from remote control station in corridor provided for cask gate and Floor Flange Gate?
- f) During canister removal does design provide for manual operation from remote control station in corridor?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

18. MONITORS

Yes

No

- a) Are cab radiation detectors provided?
- b) Does design provide gas leakage detector in cab?
- c) In photo cell, sonar or other range detection systems, are monitors of collision conditions provided?
- d) Are remote vision aids provided?
- e) Are fire and smoke alarms provided?

19. COMMUNICATION TO CONTROL CENTER

- a) Is telemetry provided?

20. COMMUNICATION TO OTHER VEHICLES

- a) Is two-way radio provided?

21. EMERGENCY EQUIPMENT

- a) Does design provide manual fire extinguisher for use in cab only?
- b) Does fire control equipment on vehicle for remote operation exist?
- c) Is first aid kit provided?
- d) Is portable breathing apparatus with 30 minute oxygen supply provided?
- e) Is radiation suit provided?
- f) Is regenerative air supply provided?
- g) Will an emergency power plug-in be provided for transporter, retrieval and hydraulic power systems?

EVALUATION CHECK LIST
CANISTER EXTRACTION/TRANSPORTER (CET)
(REFERENCE FIGURE 2.1)

22. SHIELDING

Yes

No

a) Is shielding provided for:

- cask gate?
- cask?
- cab?

23. LIGHTING

- a) Is cab interior lighting provided?
- b) Are machine driving lights provided?
- c) Will exterior area be illuminated?
- d) Is TV camera lighting provided?

EVALUATION CHECK LIST
TRANSFER TO HOIST AT CANISTER WASTE SUBSURFACE
RECEIVING STATION (CWSRS)

4.3 TRANSFER TO HOIST AT CWSRS

The principal systems and major components of the transfer will be:

1. Basket port
2. Basket port gate
3. Canister transport basket (CTB)
4. Basket (CTB) transfer mechanism

EVALUATION CHECK LIST
TRANSFER TO HOIST AT CANISTER WASTE SUBSURFACE
RECEIVING STATION (CWSRS)

Yes No

1. BASKET PORT

- a) Does design provide for pressure test seal of cask gate to basket port such that the basket port will not open if the seal is faulty?

2. BASKET PORT GATE

- a) Is basket port gate operated by cask gate?
- b) Does basket port gate open or close fully before permitting the next operation to take place?
- c) Does a jam while opening or closing the gate cause the gate to return to previous open or closed position?
- d) Does the design provide that the basket port gate be fully closed before cask gate disengages from Floor Flange?
- e) Is the gate mechanism accessible for repair?

3. CANNISTER TRANSPORT BASKET (CTB)

- a) Is the CTB large enough to accommodate the canister overpack?
- b) Does design provide for a CTB capacity of four canisters in overpack?

4. BASKET (CTB) TRANSFER MECHANISM

- a) Does remote manually operated mechanism move CTB on rails between basket port and CWC?

EVALUATION CHECK LIST
HOISTING

4.4 HOISTING

The principal systems and major components of the hoisting will be:

1. Telescoping track section
2. Canistered waste cage (CWC) loading door
3. Canistered waste cage
4. Canistered waste cage hoist

EVALUATION CHECK LIST
HOISTING

Yes No

1. TELESCOPING TRACK SECTION

- a) Does design provide that the track section must be locked in place before CTB can be moved in or out of the CWC?
- b) Must the track section be retracted from the CWC before the CWC loading door will close?
- c) Does the design provide that the track section must be in fully retracted position and the CWC loading door closed before the hoist raises or lowers the CWC?
- d) Does the design assure that the CWC is in place and the CWC loading door is open before the telescoping track section can be extended?

2. CANISTERED WASTE CAGE (CWC) LOADING DOOR

- a) Does design assure that the failure of door to open prevents the loading or unloading operation from commencing?
- b) Will failure of door to close prevent the hoist operation from occurring?

3. CANISTERED WASTE CAGE (CWC)

- a) Does the design provide for a minimum capacity of four baskets?

4. CWC HOIST

- a) Does the design assure that a safety device will stop the cage in the event of excessive speed?
- b) Are buffers provided to absorb shock in the event that the cage falls free?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

4.5 PLUG OVERCORE MACHINE (POM)

The principal systems and major components of the POM will be:

1. Cask
2. Cask tilt mechanism
3. Cask gate mechanism
4. Assembly rotation drive
5. Cask lowering mechanism
6. Plug lift ram
7. Overcore drill
8. Sleeve cutter/remover
9. Debris removal system
10. Power system - transporter
11. Power system - retrieval
12. Power system - emergency
13. Power system - hydraulic
14. Chassis
15. Cab
16. Transporter drive
17. Steering, automatic guidance
18. Automatic indexing control
19. Controls
20. Monitors
21. Communication to control center
22. Communication to other vehicles
23. Emergency equipment
24. Shielding
25. Lighting

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

1. <u>CASK</u>	<u>Yes</u>	<u>No</u>
a) Will the travel position of the cask be vertical?		
b) Will the retrieval position of the cask be vertical?		
c) Will vehicle operate in an emplacement room of 18 feet wide by 30 feet high?		
d) Is access for inspection, service and decontamination provided?		
-
2. <u>CASK TILT MECHANISM</u>		
a) Will mechanism position cask accurately plus/minus one half degree?		
b) Will mechanism tilt cask in any direction (within 2 radians) ten degrees (10^0) from vertical?		
c) Have position monitoring and out of position alarm systems been provided?		
d) Is hydraulic system including cylinders and pump provided?		
e) Are supply lines and cask penetration seals of other than elastomeric compounds?		
f) Do cask penetrations form an integral "s" to prevent a path for radiation release?		

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

3. CASK GATE MECHANISM

- a) Is pressure test seal of cask gate to Floor Flange provided?
- b) Is cask gate devised to prevent opening if seal is faulty?
- c) Must cask gate open or close fully to permit next operation?
- d) Will cask gate key latch operate the Floor Flange Gate?
- e) Are controls provided to prevent disengagement from Floor Flange if cask gate fails to close and lock?
- f) Will jam while opening or closing cause gate to return to previous position?
- g) Is gate mechanism accessible for repair?
- h) Does design provide for gate seals to wipe the sealing surface free of debris?
- i) Is mechanism electric motor powered?
- j) Are controls provided to prevent the cask gate from closing if the POM ram fails in midmode?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

4. ASSEMBLY ROTATION DRIVE

Yes

No

- a) Are the following index positions provided for:
 - Plug lift ram?
 - Overcore drill?
 - Sleeve cutter/remover?
- b) Are stops provided to accurately align index positions over cask gate?
- c) Are position monitoring and alarm system provided?
- d) Are feedback controls for assembly position, verifying alignment provided?
- e) Are interlock switches provided to prevent next operation if nonalignment exists?
- f) Is electric gear motor provided for rotation drive?

5. CASK LOWERING MECHANISM

- a) Are down travel limit switches provided to stop cask at maximum lowering position?
- b) Are up travel limit switches provided to stop cask at transport position?
- c) Is an overspeed detector to retard cask travel provided?
- d) Are proximity switches provided (redundant to 5a above) to stop down travel when cask contacts Floor Flange?
- e) Is a hydraulic system provided for raising or lowering?
- f) Are supply lines and cask penetration seals of other than elastomeric compounds provided?
- g) Do cask penetrations form an integral "s" to prevent a path for radiation release?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

6. PLUG LIFTING RAM

Yes

No

- a) Is the plug lifting device of a collet design provided?
- b) Does design assure positive engagement between plug lifting fixture and plug lifting ram?
- c) Does design include provision for prevention of hoisting in the event that the lifting device does not fully close?
- d) Is a pawl latch or equivalent provided to lock plug lift ram in position at time of power control failure?

7. OVERCORE DRILL

- a) Are replaceable carbide drill teeth provided?
- b) Is a sleeve grab device provided?
- c) Do sleeve holding pawls operate automatically?
- d) Is a variable speed drill drive for 0 to 800 feet per minute surface speed of drill provided?
- e) Is a variable speed drill feed drive provided?
- f) Does the drill feed drive include electric motor-driven mechanical screw jacks?
- g) Does jamming of the drill stop the drilling operation?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

8. SLEEVE/CUTTER REMOVER

Yes

No

- a) Is a plasma arc cutting torch furnished?
- b) Will sleeve grab device grab and hold upper sleeve during cutoff and removal?
- c) Is an electric motor-powered variable speed cutter rotation drive provided?
- d) Are separate hydraulic down/up travel drives for sleeve grab and cutting torch provided?

9. DEBRIS REMOVAL SYSTEM

- a) Does system remove by air only?
- b) Are cyclone separator, fan, debris hopper with discharge valve and return hose provided?

10. POWER SYSTEM - TRANSPORTER

- a) Is a mine locomotive battery power system provided?
- b) Is storage capacity of the batteries sufficient for six round trips of 6500 feet each way with full load?
- c) Direct power for retrieval operation is required. For this purpose, is a cable reel with plug provided onboard the vehicle to allow connection to a mine power distribution panel?
- d) Is a recharging system onboard the vehicle provided to charge batteries whenever plugged into the station power supply at each end of travel?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

	<u>Yes</u>	<u>No</u>
11. <u>POWER SYSTEM - RETRIEVAL</u>		
a) Does system plug into station power supply at retrieval site and CWSRS?		
b) Is transporter travel locked out when retrieval power system is plugged in?		
12. <u>POWER SYSTEM - EMERGENCY</u>		
a) Does a separate battery system exist with capability to provide power for air conditioned cab, lighting, communication, and vehicle controls for a minimum of four hours?		
13. <u>POWER SYSTEM - HYDRAULIC</u>		
a) Is a medium pressure system of approximately 2500 psi operating pressure provided?		
b) Are supply lines and cask penetration seals of other than elastomeric compounds?		
c) Do cask penetrations form an integral "s" to prevent a path for radiation release?		
14. <u>CHASSIS</u>		
a) Is chassis custom designed and fabricated?		
b) Are stabilizer jacks provided at each corner of the vehicle?		
15. <u>CAB</u>		
a) Is cab air conditioned?		
b) Is an emergency exit door provided?		

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

16. TRANSPORTER DRIVE

Yes

No

- a) During corridor travel is drive speed continuously variable 0 to 10 mph?
- b) During emplacement room travel is drive speed continuously variable 0 to 5 mph?
- c) Is transporter drive battery powered mine locomotive type?
- d) Are heavy duty pneumatic rubber tires used for wheels?

17. STEERING, AUTOMATIC GUIDANCE CONTROL

- a) Does automatic vehicle steering system follow wire plus/minus one inch from centerline of wire embedded in drift floor?
- b) Do error detectors monitor steering and stop the machine in event of deviation from prescribed path (wire)?
- c) Will failure of steering mechanism components stop the machine?
- d) Are all mechanisms and controls failsafe?
- e) Will failure of guidance system stop the machine?

STEERING, MANUAL OVERRIDE

- a) Does power steering exist to assist vehicle operator?
- b) Do error detectors warn operator of deviation from prescribed path (wire)?
- c) Will component failures stop the machine?

PHOTOCELL OR SONAR CONTROL

- a) Will approach to wall stop the machine?
- b) Will approach of another vehicle stop the machine?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

18. AUTOMATIC INDEXING CONTROL

Yes

No

- a) Does design position vehicle accurately plus/minus one inch from the theoretical centerline of canister?
- b) Are position monitoring and alarm systems provided?
- c) Is feedback of alignment position data for alignment confirmation provided?
- d) Do interlocks prevent next operation when non-alignment exists?

19. CONTROLS

- a) Is corridor travel control manual with operator in cab?
- b) Is emplacement room travel control automatic guidance with manual override from remote control station in corridor?
- c) When indexing POM over the canister does design provide for automatic indexing with manual override from remote control station in corridor?
- d) During engagement to Floor Flange does design provide for manual operation from remote control station in corridor?
- e) Is manual operation from remote control station in corridor provided for cask gate and Floor Flange Gate?
- f) During plug removal does design provide for manual operation from remote control station in corridor?
- g) During sleeve cutoff and removal does design provide for manual operation from remote control station in corridor?
- h) In debris removal system does design provide for manual operation from remote control station in corridor?

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

	<u>Yes</u>	<u>No</u>
20. <u>MONITORS</u>		
a) Are cab radiation detectors provided?		
b) Does design provide gas leakage detector in cab?		
c) In photocell, sonar or other range detection systems, are monitors of collision conditions provided?		
d) Are remote vision aids provided?		
e) Are fire and smoke alarms provided?		
21. <u>COMMUNICATION TO CONTROL CENTER</u>		
a) Is telemetry provided?		
22. <u>COMMUNICATION TO OTHER VEHICLES</u>		
a) Is two-way radio provided?		
23. <u>EMERGENCY EQUIPMENT</u>		
a) Does design provide manual fire extinguisher for use in cab only?		
b) Does fire control equipment on vehicle for remote operation exist?		
c) Is first aid kit provided?		
d) Is portable breathing apparatus with 30 minute oxygen supply provided?		
e) Is radiation suit provided?		
f) Is regenerative air supply provided?		
g) Will an emergency power plug-in receptacle be provided for transporter, retrieval and hydraulic power systems?		

EVALUATION CHECK LIST
PLUG OVERCORE MACHINE (POM)
(REFERENCE FIGURES 2.2, 2.3, 2.4)

24. SHIELDING

Yes

No

a) Is shielding provided for:

- cask gate?
- cask?
- cab?

25. LIGHTING

- a) Is cab interior lighting provided?
- b) Are machine driving lights provided?
- c) Will exterior area be illuminated?
- d) Is TV camera lighting provided?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

4.6 CANISTER OVERCORE TRANSPORTER (COT)

The principal systems and major components of the COT will be:

1. Cask
2. Cask elevating mechanism
3. Cask tilt mechanism
4. Cask gate mechanism
5. Overcore drill barrel
6. Telescoping drill unit
7. Debris removal system
8. Power system - transporter
9. Power system - retrieval
10. Power system - emergency
11. Power system - hydraulic
12. Chassis
13. Cab
14. Transporter drive
15. Steering, automatic guidance system
16. Automatic indexing system
17. Controls
18. Monitors
19. Communication to control center
20. Communication to other vehicles
21. Emergency equipment
22. Shielding including cab
23. Lighting

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

Yes No

1. CASK

- a) Will the travel position of the cask be horizontal?
- b) Will the retrieval position of the cask be vertical?
- c) Will vehicle operate in an emplacement room of 18 feet wide by 30 feet high?
- d) Is access for inspection, service and decontamination provided?

2. CASK ELEVATING MECHANISM

- a) Does design provide that failure of mechanism to go into retrieval position prevents canister retrieval operation?
- b) Does failure of mechanism to unlatch from retrieval position prevent the cask from lowering to the transport position?
- c) Must cask lock in travel position before COT can travel?
- d) Will power or control failure lock elevating mechanism?

3. CASK TILT MECHANISM

- a) Will mechanism position cask accurately plus/minus one half degree?
- b) Will mechanism tilt cask in any direction (within 2 radians) ten degrees (10^0) from vertical?
- c) Have position monitoring and out of position alarm systems been provided?
- d) Is hydraulic system including cylinders and pump provided?
- e) Are supply lines and cask penetration seals of other than elastomeric compounds?
- f) Do cask penetrations form an integral "s" to prevent a path for radiation release?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

Yes No

4. CASK GATE MECHANISM

- a) Is pressure test seal of cask gate to Floor Flange provided?
- b) Is cask gate devised to prevent opening if seal is faulty?
- c) Must cask gate open or close fully to permit next operation?
- d) Will cask gate key latch operate the Floor Flange Gate?
- e) Are controls provided to prevent disengagement from Floor Flange if cask gate fails to close and lock?
- f) Will jam while opening or closing cause gate to return to previous position?
- g) Is gate mechanism accessible for repair?
- h) Does design provide for gate seals to wipe the sealing surface free of debris?
- i) Is mechanism electric motor powered?
- j) Are controls provided to prevent cask gate closing if COT ram is stuck midway?

5. OVERCORE DRILL BARREL

- a) Are replaceable carbide drill teeth provided?
- b) Is variable drill speed drive for 0 to 800 feet per minute surface speed of drill provided?
- c) Is variable speed drill feed drive provided?
- d) Does the drill feed drive include electric motor driven mechanical screw jacks?
- e) Is an undercutting device provided to undercut and close around the bottom of the sleeve?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

Yes No

6. TELESCOPING DRILL UNIT

- a) Is quick disconnect coupling at top of overcore barrel provided?
- b) Is a mechanical screw jack with cross head and guides provided?
- c) Is standby operator controlled disconnect joint compatible with the telescoping cylinder provided?
- d) Is the reach of the unit 27 feet below the floor?

7. DEBRIS REMOVAL SYSTEM

- a) Does design provide for removal of debris by air only?
- b) Are cyclone separator, fan, debris hopper with discharge valve and return hose provided?

8. POWER SYSTEM - TRANSPORTER

- a) Is a mine locomotive battery power system provided?
- b) Is storage capacity of the batteries sufficient for six round trips of 6500 feet each way with full load?
- c) Direct power for retrieval operation is required. For this purpose, is a cable reel with plug provided onboard the vehicle to allow connection to a mine power distribution panel?
- d) Is a recharging system onboard the vehicle provided to charge batteries whenever the machine is plugged into the station power supply at either the retrieval site or CWSRS?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

Yes No

9. POWER SYSTEM - RETRIEVAL

- a) Does system plug into station power supply at retrieval site and CWSRS?
- b) Is transporter travel locked out when retrieval power system is plugged in?

10. POWER SYSTEM - EMERGENCY

- a) Does a separate battery system exist with capability to provide power for air conditioned cab, lighting, communication, and vehicle controls for a minimum of four hours?

11. POWER SYSTEM - HYDRAULIC

- a) Is a medium pressure system of approximately 2500 psi operating pressure provided?
- b) Are supply lines and cask penetration seals of other than elastomeric compounds?
- c) Do cask penetrations form an integral "s" to prevent a path for radiation release?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

	<u>Yes</u>	<u>No</u>
12. <u>CHASSIS</u>		
a) Is chassis custom designed and fabricated?		
b) Are stabilizer jacks provided at each corner of the vehicle?		
13. <u>CAB</u>		
a) Is cab air conditioned?		
b) Is an emergency exit door provided?		
14. <u>TRANSPORTER DRIVE</u>		
a) During corridor travel is drive speed continuously variable 0 to 10 mph?		
b) During emplacement room travel is drive speed continuously variable 0 to 5 mph?		
c) Is transporter drive battery powered mine locomotive type?		
d) Are heavy duty pneumatic rubber tires used for wheels?		

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

Yes

No

15. STEERING, AUTOMATIC GUIDANCE CONTROL

- a) Does automatic vehicle steering system follow wire plus/minus one inch from centerline of wire embedded in drift floor?
- b) Do error detectors monitor steering and stop the machine in event of deviation from prescribed path (wire)?
- c) Will failure of steering mechanism components stop the machine?
- d) Are all mechanisms and controls failsafe?
- e) Will failure of the guidance control signal stop the vehicle?

STEERING, MANUAL OVERRIDE

- a) Does power steering exist to assist vehicle operator?
- b) Do error detectors warn operator of deviation from prescribed path (wire)?
- c) Will component failures stop the machine?

PHOTOCELL OR SONAR CONTROL

- a) Will approach to wall stop the machine?
- b) Will approach of another vehicle stop the machine?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

16. AUTOMATIC INDEXING SYSTEM

Yes

No

- a) Does design position vehicle accurately plus/minus one inch from the theoretical centerline of canister?
- b) Are position monitoring and alarm systems provided?
- c) Is feedback of alignment position data for alignment confirmation provided?
- d) Do interlocks prevent next operation when non-alignment exists?

17. CONTROLS

- a) Is corridor travel control manual with operator in cab?
- b) Is emplacement room travel control automatic guidance with manual override from remote control station in corridor?
- c) When indexing COT over the canister does design provide for automatic indexing with manual override from remote control station in corridor?
- d) During engagement to Floor Flange does design provide for manual operation from remote control station in corridor?
- e) Is manual operation from remote control station in corridor provided for cask gate and Floor Flange Gate?
- f) During canister removal does design provide for manual operation from remote control station in corridor?
- g) During overcore drilling and retrieval does design provide for manual operation from remote control station in corridor?
- h) In debris removal system does design provide for manual operation from remote control station in corridor?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

18. MONITORS

Yes

No

- a) Are cab radiation detectors provided?
- b) Does design provide gas leakage detector in cab?
- c) In photocell, sonar or other range detection systems, are monitors of collision conditions provided?
- d) Are remote vision aids provided?
- e) Are fire and smoke alarms provided?

19. COMMUNICATION TO CONTROL CENTER

- a) Is telemetry provided?

20. COMMUNICATION TO OTHER VEHICLES

- a) Is two-way radio provided?

21. EMERGENCY EQUIPMENT

- a) Does design provide manual fire extinguisher for use in cab only?
- b) Does fire control equipment on vehicle for remote operation exist?
- c) Is first aid kit provided?
- d) Is portable breathing apparatus with 30 minute oxygen supply provided?
- e) Is radiation suit provided?
- f) Is regenerative air supply provided?
- g) Will an emergency power plug-in be provided for transporter, retrieval and hydraulic power systems?

EVALUATION CHECK LIST
CANISTER OVERCORE TRANSPORTER (COT)
(REFERENCE FIGURE 2.5)

22. SHIELDING

Yes

No

- a) Is shielding provided for:
- cask gate?
 - cask?
 - cab?

23. LIGHTING

- a) Is cab interior lighting provided?
- b) Are machine driving lights provided?
- c) Will exterior area be illuminated?
- d) Is TV camera lighting provided?

5.0 FAILURE GOVERNING SUBASSEMBLY DESIGN ANALYSIS

The sequence diagrams were reviewed and the subassemblies evaluated herein were adjudged as failure governing in the equipment operation. Midmode failure can neither be corrected nor repaired without risk of radiation exposure, and equipment is statically frozen (abandoned) until exceptional repairs are instituted. Discreet alternative designs of the following failure governing subassemblies were evaluated and will suffice to demonstrate also the evaluation methodology to use for alternative subassembly concepts presented in license application submittals. The criteria used in this report to determine acceptability of alternative subassembly designs are (in decreasing order of importance):

- a) Reliability
- b) Maintainability
- c) Operability
- d) Simplicity
- e) Economy

A numeric scale of 1 (poor) to 10 (superior) is herein applied to the competing designs.

The figures in this and the subassembly reliability derivation sections of this report depicting subassembly designs are deliberately shown in cartoon form to demonstrate the overview procedure. Obviously, no item could be fabricated from these simplistic sketches. However, it is not intended to present designs for fabrication in this report. Only sufficient detail is shown to enable the reliability derivation to be performed in a consistent manner. The overview precept is lost if detail analysis is emphasized in the review procedures.

Designs depicted herein are for exemplary purposes only. They are not intended to present favored or required subassemblies. Only subassembly designs listed in this report and shown in the fault tree/event tree as possible causes of radiation release need be reviewed in detail.

In demonstrating the methodology for subsystem design critique, superior designs to the unit depicted in earlier reports and used as baseline designs have been discovered. The text and reliability calculations in this report have been changed to reflect this reversal.

Optimizing of subsystem design is not the intent of this report. However, where repair of the failed part could lead to radiation release or create a machine abandonment scenario, the reliability of the device must be vindicated by the applicant. This methodology of design critique is a simple procedure which an applicant could use to demonstrate design optimization, and a reviewer could use to confirm applicant claims.

5.1 Floor Flange and Cask Gate Assemblies

A round gate surrounded by an oval frame as shown on Figure 5.2, utilizing the same opening mechanism and seal, and bearing support concepts as shown on Figure 5.1 and entitled "baseline", is considered. The primary differences between the baseline and alternative design are:

- a) Method of support - four point vs. two point (tangential).
- b) Seating arrangement - semicircular vs. three sided (2/3 peripheral).

The baseline and alternative designs were evaluated according to the five criteria discussed in the preceeding subsection. They were adjudged in words to reflect a creditable overview procedure. The design evaluation is summarized as follows:

CRITERIA	BASELINE DESIGN, Figure 5.1		ALTERNATIVE DESIGN, Figure 5.2	
	Judgement - words	Points	Judgement - words	Points
Reliability	More bearing points and seal face contact surface area; reliability lower.	5	Seal equivalent to gate valves in service; confidence level of reliability higher.	8
Maintainability	Lower MTBF due to seal wear yields higher maintenance.	5	Point to semicircular seal contact yields higher MTBF of seal. May require time to replace seal.	7
Operability	Probability of binding is much greater.	3	Geometry of Floor Flange Gate improves cask positioning.	8
Simplicity	No comment.	N/A	No comment.	N/A
Economy	No comment.	N/A	More difficult to construct, but difference negligible in quantities anticipated.	N/A
TOTAL		13		23

The oval gate configuration, entitled "Alternative Design" is superior to the rectangular gate, which was the "Baseline Design". Consequently in this report the failure intensity calculations are based on the Alternative Design depicted in detail on Figures 5.2 and 5.3.

5.2 PRM Plug Lifting Device

The method of plug grapple is the primary failure governing feature of the plug extraction process. Two distinct designs of the plug lift pin and corresponding PRM Plug Lifting Device are shown on Figures 5.4 and 5.5, and are entitled "Lifting Eye Design" and "Lifting Ball Design". The evaluation of the two designs are summarized as follows:

CRITERIA	LIFTING EYE DESIGN, Figure 5.4		LIFTING BALL DESIGN, Figure 5.5	
	Judgement - Words	Points	Judgement - Words	Points
Reliability	Tongs would have to be pre-aligned to mate with lifting eye. Such procedure is subject to human error. Linkage subject to increase failure in part due to misalignment.	1	No dependance on alignment. Mechanical screw drive arrangement is more reliable.	8
Maintainability	Few moving parts to maintain	6	Coiled expansion spring is suspected to be a high maintenance item . All other parts are long live components.	3
Operability	Alignment dependant	2	Positive engagement and grapple latch assured.	8
Simplicity	Few parts	8	More complex	5
Economy		<u>8</u>		<u>4</u>
TOTAL		25		28

The Lifting Ball design, Figure 5.5, is selected for the reason of higher reliability and the failure intensity calculations are based on this design.

5.3 CET Ram Unit Assembly

The canister bottom latching is by means of identification, the system whose failure governs the success of the canister extraction. Four alternative latching mechanisms were considered, three use guided push rods and one uses bearing mounted rotating rods, and are shown on Figures 5.6, 5.7, 5.8 and 5.9. The evaluation of these designs is summarized in the following table:

Criteria	Points Assessment Only				
	Figure 5.6	Figure 5.7	Figure 5.8	Figure 5.9	Figure 5.10
Reliability	3	3	2	4	6
Maintainability	5	2	3	4	7
Operability	1	1	3	3	5
Simplicity	5	2	2	2	8
Economy	<u>4</u>	<u>2</u>	<u>2</u>	<u>1</u>	<u>7</u>
TOTAL	18	10	12	14	33

In all of these alternative designs, the push rods and guides will be an impediment to lowering the overpack between the sleeve and the canister walls. The operability and reliability of these designs is adjudged extremely low due to the probability of contact of the bearing or guide housing with the sleeve wall and in Figures 5.6 and 5.7 with the contact of the canister.

The failure intensity calculations are based on the design depicted on Figure 5.10.

5.4 POM Sleeve Sutter-Remover Assembly and COT Overcore Drill Barrel

Discrete baseline designs of these assemblies were developed in a similar manner to the subassemblies discussed in the previous paragraphs. The baseline designs are shown on Figures 5.11 and 5.12.

NOTE: Upper Flange of Floor Flange Frame and Lower Flange of Cask Gate must be studied. Deflection of these mating flanges will cause gate binding, therefore affecting gate opening and seal reliability (assumed adequate for this report).

Figure 5.1
BASELINE DESIGN OF
CASK GATE ASSEMBLY

NOTE: Upper Flange of Floor Flange Frame and Lower Flange of Cask Gate must be studied. Deflection of these mating flanges will cause gate binding, therefore affecting gate opening and seal reliability (assumed adequate for this report).

Figure 5.2
ALTERNATIVE DESIGN OF
CASK GATE ASSEMBLY

Figure 5.3
CASK GATE AND FLOOR FLANGE
ASSEMBLY CROSS SECTIONS

Figure 5.4
 LIFTING EYE DESIGN AND
 PLUG LIFTING DEVICE DESIGN

Figure 5.5
LIFTING BALL DESIGN
AND PLUG LIFTING DEVICE DESIGN

Figure 5.6
TRIANGULAR LATCHING MECHANISM

Figure 5.7
RACK AND PINION
LATCHING MECHANISM

Figure 5.8
CRANK ACTION
LATCHING MECHANISM

Figure 5.6 thru 5.8
ALTERNATIVE CET RAM LATCH ASSEMBLIES

Figure 5.9
ALTERNATIVE CET RAM

Detail of latch in forced collapsed position

- Note: 1. Latch assembly designed to be spring loaded in open (as shown) position.
2. Bottom rest arm has a high strength stop to limit rotation to 90° and coiled spring to keep open.

Figure 5.10
CET RAM UNIT
ASSEMBLY

Figure 5.11
POM SLEEVE CUTTER REMOVER

Figure 5.12
 COT TELESCOPING
 DRILL UNIT

6.0 BLOCK DIAGRAMS

The block diagrams for the sequence of operations for the major SURF retrieval subsystems are shown on Figures 6.1 to 6.6. They include listings of possible accidents or failures which could occur at each stage of the operation of each piece of equipment. Block diagrams are used to:

- a) Show sequential operational modes, thereby indentifying major failures or accident occurrences governing design and procedures.
- b) Establish understanding of equipment by function as opposed to design study.
- c) Revise the evaluation check list and if necessary develop discrete designs to reduce subsystem failure potentials.

BLOCK DIAGRAM I - PLUG REMOVAL MACHINE (PRM)

* Cask gate shall couple to PFG through a positive link for simultaneous open/close operations.

BLOCK DIAGRAM I - PLUG REMOVAL MACHINE (PRM) (Cont'd)

FIGURE 6.1
Sheet 2 of 2

Possible Accidents/Failures

BLOCK DIAGRAM II - CANISTER EXTRACTION/TRANSPORTER (CET)

BLOCK DIAGRAM II - CANISTER EXTRACTION/TRANSPORTER (CET) (Cont'd)

CASRS

Possible Accidents/Failures

BLOCK DIAGRAM III - CANISTER TRANSPORT BASKET (CTB)

Canistered Waste Building

Possible Accidents/Failures

1. Lower the basket (CTB) with empty overcars from the canister storage and feed room to the shaft transfer room
2. Open the loading door of the cage (CWC)
3. Roll the basket (CTB) into the cage (CWC)
4. Close the cage (CWC) loading door
5. Lower the cage (CWC) to the CWSRS

Basket drops
Basket will not lower

Door will not open

Basket derails
Basket roller drive failure

Door will not close

Hoist fails, cage drops, cage derails

CWSRS

6. Open the cage (CWC) loading door
7. Roll the basket (CTB) out of the cage (CWC)
8. Pick up the basket (CTB) with the CWSRS overhead crane
9. Position the basket (CTB) under the basket door

Door will not open

Basket derails
Basket roller drive failure

Crane pickup fails, dropping basket
Crane malfunction and crash

Faulty basket position

CTB Retrieval
See Block Dia. 11,
11-17 thru 11-37

10. Pick up the basket (CTB) with the CWSRS overhead crane
11. The overhead crane lowers the basket (CTB) onto rails for transfer to the cage (CWC)
12. Roll the basket (CTB) into the cage (CWC)
13. Close the cage (CWC) loading door
14. Hoist the cage (CWC) to the canistered waste building

Crane pickup fails, dropping basket
Crane malfunction and crash

Crane drops the basket

Basket derails

Door will not close

Hoist fails, basket drops
Cage derails

Canistered Waste Building

15. Open the cage (CWC) loading door
16. Roll the basket (CTB) out of the cage (CWC) into the shaft transfer room
17. Raise the basket (CTB) with canisters into the storage and feed room

Loading door will not open

Basket derails
Basket roller drive failure

Basket drops
Basket cannot be raised

BLOCK DIAGRAM IV - PLUG OVERCORE MACHINE (POM)

* Cask gate shall couple to FFB through a positive link for simultaneous open/close operations.

BLOCK DIAGRAM IV - PLUG OVERCORE MACHINE (POM) (Cont'd)

After this operation, the backfill machine is placed over emplacement and the hole is backfilled by outside salt.

BLOCK DIAGRAM V - CANISTER OVERCORE TRANSPORTER (COT)

Travel (Empty)

1. COT departs DWSRS
2. Corridor travel
3. Emplacement room travel

Collision
Jibsec
Guidance control failure
Power failure
Tunnel collapse

Retrieval

4. Locate COT over emplacement
5. Connect COT power cable to electric power
6. Raise COT cask to retrieval position
7. Seal COT cask to Floor Flange
8. Open COT cask gate
9. Open Floor Flange Gate
10. Lower overcore drill barrel by means of overcore drill drive shaft to 26 feet below floor line
11. Undercut the bottom of the sleeve and extend the lifting fingers on the bottom of the overcore drill barrel
12. Break the bond between the sleeve and the salt
13. Raise overcore drill barrel with canister into the COT cask
14. Close the COT cask gate
15. Close the Floor Flange Gate
16. Disengage COT from Floor Flange
17. Lower COT cask to travel position
18. Disconnect COT power cable from electric power center

Motive power failure
COT hits Floor Flange
Guidance control failure

Electric power failure

Cask hits Floor Flange
Cask will not raise
Cask drops, damaging cask/vehicle

Seal failure

Gate will not open

Gate will not open

Overcore drill will not lower
Overcore drill breaks
Overcore drill hits obstruction

Undercut will not work
Lifting fingers will not extend

Bond will not break

Overcore drill will not raise

Gate will not close

Gate will not close

COT will not disengage

Cask hits Floor Flange
Cask will not lower
Cask gate fails, dropping canister
Cask drops, damaging cask/vehicle

* Cask gate shall couple to FFG through a positive link for simultaneous open/close operations.

BLOCK DIAGRAM 1 - CANISTER OVERCORE TRANSPORTER (COT) RETRIEVAL (Cont.)

Travel Loaded

BLOCK DIAGRAM 7 - CANISTER OVERCORE TRANSPORTED COT - Cont'd

Cases

BLOCK DIAGRAM #1 - CANISTER "PASSENGER" BASKET (CTB)

Canistered Waste Building

Possible Accidents/Failures

7.0 ACCIDENT EVENT TABLES

The accident event tabulations for the SURF retrieval equipment have been developed on the basis of potential mechanical subsystem failure. At this point, environmental or human factors are not considered. Accident event tabulations for the equipment are based on the block diagrams showing the sequence of equipment operations as shown on Figures 6.1 through 6.6. Procedure numbers in the first column of the accident event tables correspond to the respective numbered blocks in the block diagrams. For each operational procedure (Column 1), possible accident events (Column 3) are forecast, along with the contributing events or causes (Column 2) leading to the accident event. The accident event tables also list the immediate (Column 4) and final (Column 5) consequences of the accident event, and remarks and mitigation measures to reduce the potential consequences of the accident event (Column 6). Columns 2 through 5 of the tables are organized sequentially from left to right as they would appear from bottom to top should a fault tree/event tree be constructed for each final consequential event in the table.

Tables 7.1 through 7.6 on the following pages present the accident event tables for the major SURF retrieval subsystems. Tables 7.1, 7.2 and 7.3 present tabulations for machinery based on "Concept F" in the baseline concept criteria report.⁽¹⁾ "Concept F" is a retrieval scenario involving a degraded canister package and an intact sleeve. Tables 7.4, 7.5 and 7.6 tabulate accident events based on "Concept A", a retrieval scenario involving both a degraded sleeve and canister.

When there are multiple entries to Columns 2 or 6 or both, bullets (•) are used to so indicate. Block numbers (Column 1) marked with an asterisk (*) indicate that the cask gate shall couple to FFG through a positive link for simultaneous open/close operations. The symbol # preceding Column 6 indicates that human entry to the emplacement area is required.

Block Diagram I-Block No. 14, Block Diagram II-Block No. 17, and Block Diagram V-Block No. 18 consequential events consider also the worst case scenario of the failure of either the quick disconnect coupling or latch and the destruction of the gate occurring simultaneously. This accident is the worst case whereby irradiated matter could be broadcast within the subsurface environment.

TABLE 7.1
Sheet 1 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
2	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine.	None.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

Note: Block numbers marked on the following pages with an asterisk (*) indicate that cask gate shall couple to FFG through a positive link for simultaneous open/close operations.

TABLE 7.1
Sheet 2 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
4	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.
5	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. • Seal failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if plug is leaky.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Plug leakage shall be detected and corrected before placement of Floor Flange. • Floor Flange, if damaged, can be replaced and operation resumed. • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before plug removal is started. • Design of seal shall include self cleaning concept. Seal shall be performance tested.

TABLE 7.1
Sheet 3 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Event, (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
6*	<ul style="list-style-type: none"> Floor Flange Gate link failure. Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	None.	Controls for gate shall be designed so that gate can be manually closed.
7*	<ul style="list-style-type: none"> Cask gate opening mechanism failure. Power/control failure. Defective gate. Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	None.	Defect can be rectified by moving the PRM to the subsurface decontamination repair area.
8	<ul style="list-style-type: none"> Hoist defect. Control failure. Hydraulic failure. Power failure. 	Plug lifting device fails in midmode while lowering.	Operation stoppage.	None.	Not critical before plug removal. Hoist can be repaired at subsurface decontamination area.

TABLE 7.1
Sheet 4 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
9	Engagement mechanism failure.	Nonengagement to lift fixture.	Operation stoppage.	None.	Not critical before plug removal. Can be repaired or a new PRM can be substituted.
10	<ul style="list-style-type: none"> • Lift fixture or engagement mechanism failure. • Lift fixture or engagement mechanism failure. • Structural failure of plug. 	<ul style="list-style-type: none"> • Plug lift fixture does not engage. • Plug drops while lifting. • Plug cracks while lifting. 	<ul style="list-style-type: none"> • Operation stoppage, if plug is not lifted. • Possible damage to sleeve plug or cask or both. • Plug becomes leaky. 	<ul style="list-style-type: none"> • None. • Possible radiation release. • Possible radiation release to interior of cask only. 	<ul style="list-style-type: none"> • PRM to be shifted and other means sought for lifting. • Plug lift fixture design shall be thoroughly investigated before emplacement. • Design shall be reviewed. • A Q. A. program during emplacement shall be established and shall include destruct testing of prototypes to assure plug longevity.

TABLE 7.1
Sheet 5 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> ● Hoist defect. ● Power failure. ● Control failure. ● Hydraulic failure. 	Plug lifting device midmode failure.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> ● Operation can be resumed if control or power problem is rectified. ● Redundant manually operated hoist system shall be required.
11*	<ul style="list-style-type: none"> ● Cask gate closing mechanism failure. ● Power failure. ● Control failure. ● Defective gate. ● Hydraulic failure. ● Seal failure. 	Cask gate stuck open.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> ● Design of seal needs to be tested. ● Operation can be resumed if power or control problem is rectified. ● Failsafe design of seal and gate is required. ● Design of seal shall include self cleaning concept. Seal shall be performance tested.

TABLE 7.1
Sheet 6 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
12*	<ul style="list-style-type: none"> Floor Flange Gate link failure. Defective gate. 	Floor Flange Gate stuck.	Operation stoppage.	Unknown.	Failsafe design of seal and gate shall be required.
13	<ul style="list-style-type: none"> Cask orientation mechanism defect. Power failure. Control failure. 	Cask fails to disenagage.	Operation stoppage.	Unknown.	Operation can be resumed if power or control problem is rectified.
14	<ul style="list-style-type: none"> Cask tilting mechanism failure. Power failure. Control failure. Hydraulic failure. 	Cask will not lower to travel position.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> Operation can be resumed if power or control problem is rectified. External repairs are possible on cask tilting mechanism.

TABLE 7.1
Sheet 7 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-I)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
16 thru 32	• Gate lock mechanism failure.	Cask gate damage.	Plug drops.	Possible radiation leakage.	• Design of cask gate shall be such that it will fail in the closed position.
	• Cask tilting mechanism failure.	Cask drops.	Damage to vehicle. Damage to cask. Damage to plug.	Possible radiation release.	• Redundant support device for plug such as bottom swing out platform shall be provided.
		Accident events during reinstallation of the plug are repetitions but are treated separately for demonstrative purposes.			• All controls shall be designed to fail in safe position.

TABLE 7.1
Sheet 8 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
17	<ul style="list-style-type: none"> ● Guidance control failure. ● Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown.	<ul style="list-style-type: none"> ● Manual override of automatic controls is required. ● Guidance control system shall be designed to be failsafe. ● Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
18	<ul style="list-style-type: none"> ● Guidance control failure. ● Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine.	None.	<ul style="list-style-type: none"> ● Manual override of automatic controls is required. ● Position monitoring and alarm systems shall be provided. ● Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

TABLE 7.1
Sheet 9 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-I)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
20	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.
21	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. • Seal failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor Flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if plug is leaky.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Plug leakage shall be detected and corrected before placement of Floor Flange. • Floor Flange, if damaged, can be replaced and operation resumed. • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before plug removal is started. • Design of seal shall include self cleaning concept. Seal shall be performance tested.

TABLE 7.1
Sheet 10 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
22*	<ul style="list-style-type: none"> Floor Flange Gate link failure. Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	None.	Controls for gate shall be designed so that gate can be manually closed.
23*	<ul style="list-style-type: none"> Cask gate opening mechanism failure. Power/control failure. Defective gate. Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	None.	Defect can be rectified by moving the PRM to the subsurface decontamination repair area.
24	<ul style="list-style-type: none"> Lift fixture engagement mechanism failure. Structural failure of plug. 	Plug drops while lowering. Plug cracks while lowering.	Possible damage to sleeve plug or cask or both. Operation stoppage.	Possible radiation release. Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> Design shall be reviewed. A Q. A. program during emplacement shall be established and shall include destruct testing of prototypes to assure plug longevity.

TABLE 7.1
Sheet 11 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-I)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
25	Engagement mechanism failure.	Lifting fixture does not disengage.	Operation stoppage.	Unknown.	
26	<ul style="list-style-type: none"> • Hoist defect. • Control failure. • Hydraulic failure. • Power failure. 	Plug lifting device fails in midmode while raising.	Operation stoppage.	Unknown.	
27*	<ul style="list-style-type: none"> • Cask gate closing mechanism failure. • Power failure. • Control failure. • Defective gate. • Hydraulic failure. 	Cask gate stuck open.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Design of seal needs to be tested. • Operation can be resumed if power or control problem is rectified. • Failsafe design of seal and gate shall be required.

TABLE 7.1
Sheet 12 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
28*	<ul style="list-style-type: none"> ● Floor Flange Gate link failure. ● Defective gate. 	Floor Flange Gate stuck.	Operation stoppage.	Unknown.	Failsafe design of seal and gate shall be required.
29	<ul style="list-style-type: none"> ● Cask orientation mechanism defect. ● Power failure. ● Control failure. 	Cask fails to disenagage.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> ● Operation can be resumed if power or control problem is rectified. ● Design needs review.
30	<ul style="list-style-type: none"> ● Cask tilting mechanism failure. ● Power failure. ● Control failure. ● Hydraulic failure. ● Cask tilting mechanism failure. 	Cask will not lower to travel position.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> ● Operation can be resumed if power or control problem is rectified. ● External repairs are possible on cask tilting mechanism.
		Cask drops.	Damage to vehicle.	Unknown.	<ul style="list-style-type: none"> ● All controls shall be designed to fail in safe position.
			Damage to cask.		

TABLE 7.1
Sheet 13 of 13

PLUG REMOVAL MACHINE (PRM)
(REF: BLOCK DIAGRAM-1)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
32	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.

TABLE 7.2
Sheet 1 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1, 2 3	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown. Possible radiation release, if FFG is damaged.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
4	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine. Damage to Floor Flange	None. Possible radiation release if FFG is damaged.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

Note: Block numbers marked on the following pages with an asterisk (*) indicate that cask gate shall couple to FFG or basket port gate through a positive link for simultaneous open/close operations.

The symbol # in Column 6 indicates that human entry to the emplacement area to perform corrective repairs is required.

TABLE 7.2
Sheet 2 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
6	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.
7	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. • Seal failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor Flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if FFG is damaged.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before canister removal is started. • Design of seal shall include self cleaning concept. Seal shall be performance tested.

TABLE 7.2
Sheet 3 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-11)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
8*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	
9*	<ul style="list-style-type: none"> • Floor Flange Gate link failure. • Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> • Controls for gate shall be designed so that gate can be manually closed. • See notes on special repairs at the end of Table 7.6.
10	<ul style="list-style-type: none"> • Hoist defect. • Control failure. • Hydraulic failure. 	CET ram fails in midmode while lowering.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • If failure is due to external troubles outside cask, repairs can be done without much difficulty. • See notes on special repairs at the end of Table 7.6.

TABLE 7.2
Sheet 4 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> Power failure. 				# • Human entry to the area is required.
	<ul style="list-style-type: none"> Canister degradation. 	Ram breaches canister.	Possible operation stoppage.	Radiation release to interior of cask only.	<ul style="list-style-type: none"> Retrieval will depend on nature of damage of the canister. If canister damage is severe the operation has to be abandoned and the hole sealed back.
	<ul style="list-style-type: none"> Misalignment of of CET. 	Ram breaches sleeve.	Possible operation stoppage.	Unknown.	<ul style="list-style-type: none"> Depending on the extent of damage, the retrieval may need abandonment. Sleeve position should be monitored before start of operations.
	<ul style="list-style-type: none"> Sleeve shifts position. 				
	<ul style="list-style-type: none"> Same causes as above. 	Ram breaches canister and sleeve.	Possible operation stoppage.	Unknown.	<ul style="list-style-type: none"> Same remarks as above.

TABLE 7.2
Sheet 5 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
11	Engagement latch failure.	Ram fails to latch the concrete support block.	Operation stoppage.	None.	Raise the ram and check the latching mechanism and repair as necessary.
12	<ul style="list-style-type: none"> Engagement latch failure. Concrete block failure. Hoist defect Power failure. Hydraulic failure. Control failure. 	Canister drops while lifting. CET ram fails in midmode while lifting.	Operation stoppage. Possible damage to canister. Operation stoppage.	Possible radiation release to interior of cask only. Unknown.	<ul style="list-style-type: none"> Redundant means of holding the canister should be investigated. If failure is due to external troubles outside the cask, repairs can be made without difficulty. See notes on special repairs at end of Table 7.6. # Human entry to the area is required.

TABLE 7.2
Sheet 6 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-11)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
13*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	Controls for gate shall be designed so that gate can be closed manually.
14*	<ul style="list-style-type: none"> • Floor Flange Gate link failure. • Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	Possible radiation release to interior of cask.	<ul style="list-style-type: none"> • Controls for gate shall be designed so that gate can be manually closed. • See notes on special repairs at the end of Table 7.6.
15	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage.	Unknown.	# Human entry to the area is required.

TABLE 7.2
Sheet 7 of 13
CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
16	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into travel position.	Operation stoppage.	Unknown.	# Human entry to the area is required.
17	Cask gate and engagement latch failures.	Overpack with canister drops.	Cask gate damage. Cask damage. Overpack damage. Floor Flange Gate damage.	Possible radiation release.	<ul style="list-style-type: none"> • This is a major problem requiring special attention and repair procedure. # • Human entry is required. • See notes on special repairs at the end of Table 7.6.
18 thru 37		Accident events during the CET travel with canister overpack to the CWSRS and transferring the overpack to the CTB are repetitious, but are treated separately for demonstrative purposes.			

TABLE 7.2
Sheet 8 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
18, 19, 20	• Guidance control failure.	Erratic travel of machine.	Collision against walls.	Unknown.	• Manual override of automatic controls is required.
	• Manual control failure.		Damage to Floor Flange.	Possible radiation release, if FFG or basket port gate is damaged.	• Guidance control system shall be designed to be failsafe. • Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
21	• Guidance control failure.	Improper placement of machine.	Nonaligned machine.	None.	• Manual override of automatic controls is required.
	• Automatic indexing control failure.		Damage to basket port.	Possible radiation release if basket port is damaged.	• Position monitoring and alarm system shall be provided. • Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

TABLE 7.2
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CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
23	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.
24	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. 	Cask hits basket port.	Damage to Floor Flange.	Possible radiation release, if basket port gate is damaged.	<ul style="list-style-type: none"> • Radiation monitors shall be provided.
		Faulty sealing of cask to Floor Flange.	Leakage.	Possible radiation release.	<ul style="list-style-type: none"> • Proximity of cask to Floor Flange shall be detected before further operations are begun.

TABLE 7.2
Sheet 10 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
25*	<ul style="list-style-type: none"> ● Basket port gate link failure. ● Defective gate. 	Partially open basket port gate.	Operation stoppage.	Possible radiation release to interior of Cask only.	<ul style="list-style-type: none"> ● Controls for gate shall be designed so that gate can be closed manually. ● See notes on special repairs at the end of Table. 7.6.
26*	<ul style="list-style-type: none"> ● Cask gate opening mechanism failure. ● Power/control failure. ● Defective gate. ● Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	
27	<ul style="list-style-type: none"> ● Hoist defect. ● Control failure. ● Hydraulic failure. ● Power failure. 	CET ram fails in midmode while lowering.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> ● If failure is due to external troubles outside cask, repairs can be done without much difficulty. ● If troubles are inside the cask the repairs are of a special nature. # ● Human entry to the area is required.

TABLE 7.2
Sheet 11 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-11)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
28	Engagement latch failure.	Ram fails to unlatch the concrete support block.	Operation stoppage.	None.	See notes on special repairs at the of Table 7.6.
29	Hoist failure.	CET ram fails in midmode while raising.	Operation stoppage.	Unknown.	If failure is due to external troubles outside cask, repairs can be done without much difficulty.
30	Gate failure.	Improper positioning of overpack.	Operation stoppage.	None.	Failure does not result in radiation release.
31	Hoist failure.	CET ram fails in midmode while lowering.	Operation stoppage.	Unknown.	If failure is due to external troubles outside cask, repairs can be done without much difficulty.
32	Engagement latch failure.	Ram fails to latch the empty overpack.	Operation stoppage.	None.	Raise the ram and check the latching mechanisms and repair as necessary.
33	● Engagement latch failure.	Overpack drops while lifting.	Operation stoppage	Possible radiation release to interior of cask only.	● Redundant means of holding the overpack should be investigated.
	● Hoist defect.	CET ram fails in midmode while lifting.	Operation stoppage.	Unknown.	● If failure is due to external troubles outside the cask, repairs can be made without difficulty.

TABLE 7.2
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CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> Power failure. Hydraulic failure. 				<ul style="list-style-type: none"> See notes on special repairs at end of Table 7.6. # Human entry to the area is required.
34*	<ul style="list-style-type: none"> Cask gate opening mechanism failure. Power/control failure. Defective gate. Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	Controls for gate shall be designed so that gate can be manually closed.
35*	<ul style="list-style-type: none"> Basket port gate link failure. Defective gate. 	Partially open basket port gate.	Operation stoppage.	Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> Controls for gate shall be designed so that gate can be closed manually. See notes on special repairs at the end of Table 7.6.

TABLE 7.2
Sheet 13 of 13

CANISTER EXTRACTION/TRANSPORTER (CET)
(REF: BLOCK DIAGRAM-II)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
36	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage	Unknown.	# Human entry to the area is required.

TABLE 7.3
Sheet 1 of 2

CANISTER TRANSPORT BASKET (CTB)
(REF: BLOCK DIAGRAM-III)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1 thru 9					<p>These operations refer to moving a CTB with empty overpack from the storage and feed room down to CWSRS, and are not critical during this sequence.</p> <p>However, when CTB is filled with retrieved canisters, the reverse operations are critical and are dealt with further.</p>
10, 11, 17	<ul style="list-style-type: none"> Crane hoist failure. Hoist hook failure. 	CTB drops while lifted.	Operation stoppage.	Possible radiation release, if the basket is damaged.	<ul style="list-style-type: none"> The basket and the hoisting devices shall be designed to be failsafe. See notes on special repairs at the end of Table 7.6.
12	<ul style="list-style-type: none"> Guidance control failure. 	CTB derails.	Operation stoppage.	Possible radiation release if the basket is damaged.	<ul style="list-style-type: none"> Guidance control and the handling systems shall be designed to be failsafe. See notes on special repairs at the end of Table 7.6.

TABLE 7.3
Sheet 2 of 2

CANISTER TRANSPORT BASKET (CTB)
(REF: BLOCK DIAGRAM-III)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
13	Door closing mechanism failure.	Cage door fails to close or open.	Operation stoppage.	None.	-
14	Hoist mechanism failure.	Cage hoist fails.	Operation stoppage.	None, if CTB is intact. If CTB damaged, possible radiation release.	- See notes on repairs at the end of Table 7.6.

TABLE 7.4
Sheet 1 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
2	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine.	None.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

Note: Block numbers marked on the following pages with an asterisk (*) indicate that cask gate shall couple to FFG through a positive link for simultaneous open/close operations.

TABLE 7.4
Sheet 2 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-[V])

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
4	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. • Seal failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor Flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if plug is leaky.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Plug leakage shall be detected and corrected before placement of Floor Flange. • Floor Flange, if damaged, can be replaced and operation resumed. • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before plug removal is started. • Design of seal shall include self cleaning concept. Seal shall be performance tested.
5*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	<p>Partially open cask gate.</p>	<p>Operation stoppage.</p>	<p>None.</p>	<p>Defect can be rectified by moving the POM to the subsurface decontamination repair area.</p>

TABLE 7.4
Sheet 3 of 12

PUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
6*	<ul style="list-style-type: none"> Floor Flange Gate link failure. Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	None.	Controls for gate shall be designed so that gate can be manually closed.
7	Automatic indexing control failure.	Improper indexing of ram.	Nonaligned machine.	None.	Indexing shall be checked before removal of plug.
8	<ul style="list-style-type: none"> Hoist defect Power failure. Control failure. 	Plug lift ram midmode failure.	Operation stoppage.	None.	Not critical before plug removal. Hoist can be repaired at subsurface decontamination area.
9	Engagement mechanism failure.	Nonengagement to lift fixture.	Operation stoppage.	None.	Not critical before plug removal. Can be repaired or a new POM can be substituted.
10	<ul style="list-style-type: none"> Lift fixture or engagement mechanism failure. 	Plug lift fixture does not engage.	Operation stoppage, if plug is not lifted.	None.	<ul style="list-style-type: none"> POM to be shifted and other means sought for lifting. Plug lift fixture design shall be thoroughly investigated before emplacement.

TABLE 7.4
Sheet 4 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> • Lift fixture or engagement mechanism failure. • Structural failure of plug. • Hoist failure. 	<ul style="list-style-type: none"> • Plug drops while lifting. • Plug cracks while lifting. • Plug lift fixture mid-mode failure. 	<ul style="list-style-type: none"> • Possible damage to sleeve plug or cask or both. • Plug becomes leaky. • Operation stoppage. 	<ul style="list-style-type: none"> • Possible radiation release. • Possible radiation release to interior of cask only. • Unknown. 	<ul style="list-style-type: none"> • Design shall be reviewed. • A. Q. A. program during emplacement shall be established and shall include destruct testing of prototypes to assure plug longevity. • Operation can be resumed if control or power problem is rectified. • Redundant manually operated hoist system shall be required.
11	Automatic indexing control failure.	Improper indexing of overcore drill.	Nonaligned machine.	None.	<ul style="list-style-type: none"> • Indexing shall be accurate and shall be checked before start of operations. • Position monitoring and alarm system shall be provided. • Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven. • Manual override of automatic controls is required.

TABLE 7.4
Sheet 5 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
12	<ul style="list-style-type: none"> Overcore drill raising/lowering device failure. Kelley bar tube (drill drive shaft) system failure. Overcore drill hits sleeve. 	Overcore drill midmode failure.	Operation stoppage.	None.	<ul style="list-style-type: none"> See notes on special repairs at the end of Table 7.6.
13	Debris collection system failure.	Debris cannot be removed.	Operation stoppage.	Possible radiation release to interior of cask if the sleeve and canister are degraded.	See notes on special repairs at the end of Table 7.6.
14	<ul style="list-style-type: none"> Overcore drill lowering/raising device failure. Kelly bar tube (drill drive shaft) system failure. 	Overcore drill midmode failure.	Operation stoppage.	Unknown.	See notes on special repairs at the end of Table 7.6.
15	Automatic indexing control failure.	Improper indexing of sleeve grab and cutting torch.	Nonaligned machine.	None.	Indexing shall be checked before start of operations.

TABLE 7.4
Sheet 6 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
16	Sleeve grab mechanism failure.	Sleeve grab stuck halfway.	Operation stoppage.	None.	See notes on special repairs at end of the Table 7.6.
17	Cutting torch lowering mechanism failure.	Cutting torch stuck halfway.	Operation stoppage.	None.	See notes on special repairs at end of Table 7.6.
18	<ul style="list-style-type: none"> • Torch rotating device failure. • Torch flame extinguished. 	Cutting torch will not operate.	Operation stoppage.	None.	<ul style="list-style-type: none"> • See notes on special repairs at the end of Table 7.6. • See notes on special repairs at end of Table 7.6.
19	Cutting torch lowering mechanism failure.	Cutting torch stuck halfway.	Operation stoppage.	None.	See notes on special repairs at the end of Table 7.6.
20	Cutting torch lowering mechanism failure.	Cutting torch stuck halfway.	Operation stoppage.	None.	See notes on special repairs at the end of Table 7.6.

TABLE 7.4
Sheet 7 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
21*	<ul style="list-style-type: none"> • Cask gate closing mechanism failure. • Power failure. • Control failure. • Defective gate. • Hydraulic failure. 	Cask gate stuck open.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Design of seal needs to be tested. • Operation can be resumed if power or control problem is rectified. • Failsafe design of seal and gate shall be required.
22*	<ul style="list-style-type: none"> • Floor Flange Gate link failure. • Defective gate. 	Floor Flange Gate stuck.	Operation stoppage.	Unknown.	Failsafe design of seal and gate shall be required.
23	<ul style="list-style-type: none"> • Cask orientation mechanism defect. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage.	Unknown.	Operation can be resumed if power or control problem is rectified.

TABLE 7.4
Sheet 8 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
25 thru 43		Accident events during reinstallation of the plug and cut sleeve are repetitious but are treated separately for demonstrative purposes.			
26	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine.	None.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
28	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor Flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if gate is damaged.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before start of operations.
29	Automatic indexing control failure.	Improper indexing of ram.	Nonaligned machine.	None.	Indexing shall be checked before start of operations.
30*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	None.	Defect can be rectified by moving the POM to the subsurface decontamination repair area.

TABLE 7.4
Sheet 10 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
31*	<ul style="list-style-type: none"> Floor Flange Gate link failure. Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	None.	Controls for gate shall be designed so that gate can be manually closed.
32, 33	Sleeve grab mechanism failure.	Sleeve grab stuck halfway.	Operation stoppage.	None.	See notes on special repairs at the end of the Table 7.6.
34	Debris collection system failure.	Debris cannot be removed.	Operation stoppage.	Possible radiation release to interior of cask.	See notes on special repairs at the end of Table 7.6.
35	<ul style="list-style-type: none"> Hoist defect. Power failure. Control failure. 	Plug lift ram midmode failure.	Operation stoppage.	None.	See notes on special repairs at the end of Table 7.6.
36	Engagement mechanism failure.	Lift fixture does not release the plug.	Operation stoppage.	None.	See notes on special repairs at the end of Table 7.6.
37	Automatic indexing control failure.	Improper indexing of sleeve grab and cutting torch.	Nonaligned machine.	None.	Indexing shall be checked before start of operations.

TABLE 7.4
Sheet 11 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
39*	<ul style="list-style-type: none"> • Cask gate closing mechanism failure. • Power failure. • Control failure. • Defective gate. • Hydraulic failure. 	Cask gate stuck open.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Design of seal needs to be tested. • Operation can be resumed if power or control problem is rectified. • Failsafe design of seal and gate is required.
40*	<ul style="list-style-type: none"> • Floor Flange Gate link failure. • Defective gate. 	Floor Flange Gate stuck.	Operation stoppage.	Unknown.	Failsafe design of seal and gate shall be required.
41	<ul style="list-style-type: none"> • Cask orientation mechanism defect. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage.	Unknown.	Operation can be resumed if power or control problem is rectified.

TABLE 7.4
Sheet 12 of 12

PLUG OVERCORE MACHINE (POM)
(REF: BLOCK DIAGRAM-IV)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
43	<ul style="list-style-type: none"> ● Guidance control failure. ● Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown.	<ul style="list-style-type: none"> ● Manual override of automatic controls is required. ● Guidance control system shall be designed to be failsafe. ● Proximity sensors shall be provided to prevent collision against walls and Floor Flange.

TABLE 7.5
Sheet 1 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1, 2 3	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls. Damage to Floor Flange.	Unknown. Possible radiation release, if FFG is damaged.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.
4	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine. Damage to Floor Flange	None. Possible radiation release if FFG is damaged.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.

Note: Block numbers marked on the following pages with an asterisk (*) indicate that cask gate shall couple to FFG or basket port gate through a positive link for simultaneous open/close operations.

The symbol # in Column 6 indicates that human entry to the emplacement area is required.

TABLE 7.5
Sheet 2 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
6	<ul style="list-style-type: none"> • Cask elevating mechanism failure. • Power failure. • Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.
7	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. • Seal failure. 	<p>Cask hits Floor Flange.</p> <p>Faulty sealing of cask to Floor Flange.</p>	<p>Damage to Floor Flange.</p> <p>Leakage.</p>	<p>Possible radiation release, if FFG is damaged.</p> <p>Possible radiation release.</p>	<ul style="list-style-type: none"> • Radiation monitors shall be provided. • Proximity of cask to Floor Flange shall be detected before Canister removal is started. • Design of seal shall include self cleaning concept. Seal shall be performance tested.

TABLE 7.5
Sheet 3 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
8*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	
9*	<ul style="list-style-type: none"> • Floor flange Gate link failure. • Defective gate. 	Partially open Floor Flange Gate.	Operation stoppage.	Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> • Controls for gate shall be designed so that gate can be manually closed. • See notes on special repairs at the end of Table 7.6.
10	<ul style="list-style-type: none"> • Hoist defect. • Control failure. • Hydraulic failure. • Power failure. 	Drill drive shaft fails in midmode while lowering.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • If failure is due to external troubles outside cask, repairs can be done without much difficulty. • See notes on special repairs at the end of Table 7.6.

TABLE 7.5
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CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
11	<ul style="list-style-type: none"> • Power failure • Control failure. • Hydraulic failure. 	<p>Undercut will not work.</p> <p>Lifting fingers will not extend.</p>	<p>Operation stoppage.</p> <p>Operation stoppage.</p>	<p>None.</p> <p>None.</p>	<ul style="list-style-type: none"> • Operation can be resumed after power/control problems are resolved. • The drill drive shaft can be lifted and the COT moved to the subsurface decontamination area for repairs.
13	<ul style="list-style-type: none"> • Hoist defect. • Control failure. • Hydraulic failure. 	<p>Drill drive shaft fails in midmode while lifting.</p>	<p>Operation stoppage.</p>	<p>Unknown.</p>	<p>See notes on special repairs at the end of Table 7.6.</p>

TABLE 7.5
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CANISTER OVERLORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
14*	<ul style="list-style-type: none"> • Cask gate closing mechanism failure. • Power failure. • Control failure. • Defective gate. • Hydraulic failure. 	Cask gate stuck open.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Design of seal needs to be tested. • Operation can be resumed if power/control problem is rectified. • Failsafe design of seal and gate shall be required.
15*	<ul style="list-style-type: none"> • Floor Flange Gate link failure. • Defective gate. 	Floor Flange Gate stuck open.	Operation stoppage.	Unknown.	Failsafe design of seal and gate shall be required.
16	<ul style="list-style-type: none"> • Cask orientation mechanism defect. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Operation can be resumed if power or control problem is rectified. # • Human entry to the area is required.

TABLE 7.5
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CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
17	<ul style="list-style-type: none"> • Cask tilting mechanism failure. • Power failure. • Control failure. • Hydraulic failure. • Cask tilting mechanism failure. 	<p>Cask will not lower to travel position.</p> <p>Cask drops.</p>	<p>Operation stoppage.</p> <p>Damage to vehicle.</p> <p>Damage to cask.</p>	<p>Unknown.</p> <p>Unknown.</p>	<ul style="list-style-type: none"> • Operation can be resumed if power or control problem is rectified. • External repairs are possible on cask tilting mechanism. • All controls shall be designed to be failsafe.
18	Cask gate latch fails.	Overcore drill barrel with canister drops.	<p>Cask gate damage.</p> <p>Cask damage.</p> <p>Floor Flange Gate damage.</p>	Possible radiation release.	<ul style="list-style-type: none"> • This is a major problem requiring special attention and repair procedure. # • Human entry is required.

TABLE 7.5
Sheet 7 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
19 thru 40		Accident events during the COT travel with overcore drill barrel with canister to the CWSRS and transferring the same to the CTB are repetitious, but are treated separately for demonstrative purposes.			
19, 20, 21	<ul style="list-style-type: none"> Guidance control failure. Manual control failure. 	Erratic travel of machine.	Collision against walls.	Unknown.	<ul style="list-style-type: none"> Manual override of automatic controls is required.
			Damage to Floor Flange.	Possible radiation release, if FFG or basket port gate is damaged.	<ul style="list-style-type: none"> Guidance control system shall be designed to be failsafe. Proximity sensors shall be provided to prevent collision against walls and Floor Flange.

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CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
22	<ul style="list-style-type: none"> Guidance control failure. Automatic indexing control failure. 	Improper placement of machine.	Nonaligned machine. Damage to basket port.	None. Possible radiation release if basket port gate is damaged.	<ul style="list-style-type: none"> Manual override of automatic controls is required. Position monitoring and alarm system shall be provided. Interlocks shall be provided so that the next step of operation cannot take place until proper alignment is proven.
25	<ul style="list-style-type: none"> Cask elevating mechanism failure. Power failure. Control failure. 	Cask fails to go into retrieval position.	Operation stoppage.	None.	Means could be provided to allow an alternative method to elevate casks using alternative mechanism and power source such as portable, specially designed, manually actuated jacks.

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
26	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Automatic indexing control failure. • Limit switch failure. 	Cask hits basket port.	Damage to basket port.	Possible radiation release, if basket port gate is damaged.	<ul style="list-style-type: none"> • Radiation monitors shall be provided.
		Faulty sealing of cask to basket port.	Leakage.	Possible radiation release.	<ul style="list-style-type: none"> • Proximity of cask to basket port shall be detected before further operations.
28*	<ul style="list-style-type: none"> • Cask gate opening mechanism failure. • Power/control failure. • Defective gate. • Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	

TABLE 7.5
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CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> Basket port gate link failure. Defective gate. 	Partially open basket port gate.	Operation stoppage.	Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> Controls for gate shall be designed so that gate can be closed manually. See notes on special repairs at the end of Table. 7.6.
29	<ul style="list-style-type: none"> Hoist defect. Control failure. Hydraulic failure. Power failure. 	Overcore drill shaft fails in midmode while lowering.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> If failure is due to external troubles outside cask, repairs can be done without much difficulty. If troubles are inside the cask the repairs are of a special nature. # • Human entry to the area is required.

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CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
30	Quick disconnect coupling failure.	Overcore drill barrel does not disengage from overcore drill drive shaft.	Operation stoppage.	None.	• See notes on special repairs at end of Table 7.6.
		Overcore drill barrel with canister drops.	Operation stoppage. Possible damage to cask. Possible damage to cask gate. Possible damage to CTB.	Possible radiation release.	• See notes on special repairs at the end of Table 7.6.
31	Hoist failure.	Drill drive shaft fails in midmode while raising.	Operation stoppage.	Unknown.	If failure is due to external troubles outside cask, repairs can be done without much dif- ficulty.
33	Hoist failure.	Drill drive shaft fails in midmode while lowering.	Operation stoppage.	Unknown.	If failure is due to external troubles outside cask, repairs can be done without much dif- ficulty.

TABLE 7.5
Sheet 12 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
34	Quick disconnect coupling failure.	Overcore drill drive shaft does not engage to overcore drill barrel.	Operation stoppage.	None.	Repairs can be done by moving the COT to the subsurface decontamination repair area.
35	<ul style="list-style-type: none"> Quick disconnect coupling failure. Hoist defect. Hydraulic failure. Power failure. Control failure. 	<ul style="list-style-type: none"> Overcore drill barrel drops. Drill drive shaft fails in midmode. 	<ul style="list-style-type: none"> Operation stoppage. Operation stoppage. 	<ul style="list-style-type: none"> None. None. 	<ul style="list-style-type: none"> See notes on special repairs at the end of Table 7.6. # Human entry to the area is required.
36*	<ul style="list-style-type: none"> Cask gate closing mechanism failure. Power/control failure. Defective gate. Hydraulic failure. 	Partially open cask gate.	Operation stoppage.	Possible radiation release to interior of cask only.	<ul style="list-style-type: none"> Controls for gate shall be designed so that gate can be manually closed.

TABLE 7.5
Sheet 13 of 13

CANISTER OVERCORE TRANSPORTER (COT)
(REF: BLOCK DIAGRAM-V)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
	<ul style="list-style-type: none"> • Basket port gate link failure. • Defective gate. 	Partially open basket port gate.	Operation stoppage.	Possible radiation release to interior of cask.	<ul style="list-style-type: none"> • Controls for gate shall be designed so that gate can be closed manually. • See notes on special repairs at the end of Table 7.6.
38	<ul style="list-style-type: none"> • Cask orientation mechanism failure. • Power failure. • Control failure. 	Cask fails to disengage.	Operation stoppage	Unknown.	# Human entry to the area is required.
39	<ul style="list-style-type: none"> • Cask tilting mechanism failure. • Power failure. • Control failure. • Hydraulic failure. • Cask tilting mechanism failure. 	Cask will not lower to travel position.	Operation stoppage.	Unknown.	<ul style="list-style-type: none"> • Operation can be resumed if power or control problem is rectified. • External repairs are possible on cask tilting mechanism.
		Cask drops.	Damage to vehicle.	Unknown.	<ul style="list-style-type: none"> • All controls shall be designed to be failsafe.
			Damage to cask.		

TABLE 7.6
Sheet 1 of 2

CANISTER TRANSPORT BASKET (CTB)
(REF: BLOCK DIAGRAM-VI)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
1 thru 9					<p>These operations refer to moving a CTB with empty overcore drill tubes from the storage and feed room down to CWSRS, and are not critical during this sequence.</p> <p>However when CTB is filled with retrieved canisters, the reverse operations are critical and are dealt with further.</p>
10, 11, 17	<ul style="list-style-type: none"> Crane hoist failure. Hoist hook failure. 	CTB drops while lifted.	Operation stoppage.	Possible radiation release, if the basket is damaged.	<ul style="list-style-type: none"> The basket and the hoisting devices shall be designed to be failsafe. See notes on special repairs at the end of this Table.
12, 16	Guidance control failure.	CTB derails.	Operation stoppage.	Possible radiation release, if the basket is damaged.	<ul style="list-style-type: none"> The guidance control and the handling systems shall be designed to be failsafe. See notes on special repairs at the end of this Table.

TABLE 7.6
Sheet 2 of 2

CANISTER TRANSPORT BASKET (CTB)
(REF: BLOCK DIAGRAM-VI)

(1) Block No.	(2) Contributing Events (Causes)	(3) Accident Events	(4) Resulting Event	(5) Final Consequential Event	(6) Remarks/Compensating Procedures
13	Door closing mechanism failure.	Cage door fails to close or open.	Operation stoppage.	None.	-
14	Hoist mechanism failure.	Cage hoist fails.	Operation stoppage.	None, if CTB is intact. If CTB damaged, possible radiation release.	- See notes on special repairs at the end of this Table.

TABLE 7.7
Sheet 1 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Floor Flange or Cask
Gate Closure Failure

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

After attempts have failed to manually close the gate by means of force applied to the exterior handwheel (see Figure 5.2), special repair procedures should be instituted as follows:

- a) Install a portable radiation shield around the base of the equipment. Raise the equipment upward inside the shield and visually inspect the gates through an observation port in the shield.
- b) If deemed possible, attempt to close cask gate by acuating drive or by manual operation of exposed handwheel.
- c) Attempt to force Floor Flange Gate closed by use of a manipulator arm.
- d) Install temporary cover plate over gate.
- e) Abandon emplacement hole if Floor Flange Gate cannot be closed or covered and backfill hole through shield.

Radiation Shield Equipment Description:

The portable radiation shield, designed to envelope the base of the PRM, CET, POM or COT and allow visual inspection, should be of sufficient height to allow insertion of the radiation cover over either the Floor Flange or the equipment cask gate. The shield should be equipped with a manipulation arm designed to:

- a) Push the floor flange gate closed,
- b) Attach the cover to either of the affected gates or do crosshead demolition by plasma torch cutting.

TABLE 7.7
Sheet 2 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

Hoist Defect - Causing
Midmode Failure

The shield should accommodate the storage of gate coverplates within the enclosure, be equipped with view port and a gate to allow hole backfill).

Hoisting mechanism shall be equipped with an extension shaft protruding through the cask enclosure (with adequate seal provided so that ancillary outboard power can be applied to the hoist). If the hoist cannot be raised (or lowered) by power applied to the extension shaft, install the portable radiation shield, raise cask within the enclosure limits and determine elevation of hoist.

If hoist has failed at or near the bottom of its stroke the following special procedures are necessary:

- a) Disengage quick disconnect coupling solenoid, abandoning cask with overpack and retract hydraulic ram.
- b) Attempt to raise hoist.
- c) Cut off crosshead using manipulator arm with plasma torch (preinstalled).
- d) Lower cask, backfill if applicable*, close gates and dispatch disabled unit to decontamination area for repair.

*If the hoist failure occurs on the CET, the retrieval of the canister can be performed utilizing a POM and a COT. If the hoist fails on either a POM or COT unit, the emplacement must be temporarily abandoned. Modifications to a POM and a COT to equip the units with larger core drills designed to over bore the abandoned and backfilled holes would be required. The alternative would be complete abandonment.

TABLE 7.7
Sheet 3 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

If the hoist cannot be raised from a mid-position, the special procedures may be simplified as follows:

After the solenoid quick disconnect coupling is disengaged, the hydraulic ram is retracted, and raising the hoist is attempted, determine if the bottom of the ram will clear the inside of the cask gate. If clearance is assured, skip Step c); if not, Step c) must be performed.

CET Quick Disconnect
Solenoid Coupling or En-
gagement Latch Midmode
Failure

The hydraulic ram should be mounted to a load cell which in turn is connected to the crosshead. The remote reading dial should be graduated to indicate weight of hydraulic ram, overpack and canister. An alarm circuit should be provided, set upon canister pickup and triggered by loss of canister weight. Should this event occur, as indicated to the operator as a loss of weight supported at the crosshead, the applicable procedures outlined below should be instituted:

- a) Solenoid quick disconnect coupling failure during lifting at the emplacement hole:

Cease operation and dispatch CET to decontamination area for repair and replace plug using PRM. Reschedule retrieval operation using POM and COT units. If the plug cannot be replaced (i.e. - the overpacked canister is stuck at midway) attempts using the repaired CET to reattach to the overpack should first be performed. If this attempt fails then utilization of the POM and COT will be required and the plug contained in the PRM will have to be safely deposited in an empty hole. (Note: An empty hole with only a cover plate over it should be provided in each chamber for this and for monitoring purposes).

TABLE 7.7
Sheet 4 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

b) Latch failure during lifting:

Dispatch CET to CWSRS and deposit defective overpack into CTB and pick up new overpack. Attempt to retrieve with a CET with a different overpack. If this attempt fails, assign retrieval chore to POM/COT combination.

c) Latch or engagement coupling failure in transit:

Decision must be reached to either continue to CWSRS and drop overpacked canister into CTB or into an empty hole for future POM/COT combo retrieval. The decision will be based on prior simulation tests.

POM or COT Solenoid
Disconnect Coupling,
Engagement Latch or
Sleeve Clamp Failures

If the failure occurs during retrieval operations, the procedures outlined for the CET should basically be followed. To summarize:

a) Solenoid quick disconnect failure:

Cease operation, dispatch disabled unit to repair area (after depositing drill debris in an empty hole), attempt to raise dropped plug/drill assembly or canister drill assembly using repaired unit. If this attempt fails, a modified unit with larger core drill will have to be employed or the hole abandoned.

b) COT engagement latch failure during lifting:

Attempt to retrieve sleeve/canister using new overcore drill unit obtained at CWSRS (after depositing failed core drill into CTB). Failure to retrieve by second unit will necessitate using a modified COT with larger core drill or abandonment, including backfill of emplacement hole.

TABLE 7.7
Sheet 5 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event (From Tables 7.2 through 7.6 inclusive)	Procedures and Equipment Required to Effect Temporary In Situ Repairs, Midmode Failure
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- c) Failure of COT engagement latch or quick disconnect coupling in transit:

As previously discussed, decision must be made to either drop canister/sleeve/core drill unit into CTB or special hole provided for the purpose. Again, simulated drop tests will assist decision making.

- d) Failure of POM subassemblies have little effect on operations; i.e. continue processing until plug and cutting debris is redeposited into emptied hole then dispatch unit to repair area for cask gate inspection or repair.

Simultaneous Engagement Latch or Solenoid Coupling Release and Cask Gate Failure or Collision Accident (WORST CASE RETRIEVAL ACCIDENT SCENARIO)

1. If event occurs while machine is still in position over the emplacement hole, the overpack will likely fall back into the hole.

The first procedure shall be to close the Floor Flange and cover the cask gate by employing the portable radiation shield and following the procedures outlined for Floor Flange/cask gate failure. Attempts should then be instituted to retrieve the dropped item utilizing a similar unit. If this does not work assign retrieval task to either POM/COT combo, modified COT or abandon and backfill hole.

2. WORST CASE: If event occurs while machine is travelling in transit to the CWSRS, the following procedures are outlined.

If the overpacked canister falls on the emplacement room or corridor floor:

A radiation shielded fork lift described in Reference 1 and an empty

TABLE 7.7
Sheet 6 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

CET or COT shall be dispatched to the scene of the accident. The fork lift should be remotely controlled and specially fitted to lift the overpack (in horizontal position) and insert it into a CET or COT (as applicable) cask. A radiation shielded floor and wall sweeper should be dispatched to clean all spilled material. This procedure of using a sweeper should be followed even though no damage to the overpack is apparent. The CET or COT with the overpack has since proceeded to the CWSRS. Isolation of the accident area by altering the ventilation system by pressurizing the adjacent zones to mitigate irradiated particulate transport should be the subject of additional study. Description of Equipment Needed:

Fork Lift:

Unit should have radiation shielded cab and be arranged for operator control as near the scene as safety will allow and remote control at the vicinity. The fork lift should be equipped with a side push off device to slide the retrieval overpack into the transport canister. The fork lift should also be equipped with a manipulator arm whose principal duty will be to install a cover plate over the cask opening so that the disabled vehicle can be transferred to the repair area.

Floor/Wall Sweeper:

A self-propelled vacuum device device with rotary brushes and a cylindrical (canister-shaped) debris collection container, all enclosed in a

TABLE 7.7
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NOTES ON SPECIAL REPAIRS

<u>Contributing Event (From Tables 7.2 through 7.6 inclusive)</u>	<u>Procedures and Equipment Required to Effect Temporary In Situ Repairs, Midmode Failure</u>
	radiation shield, should be provided. One of the brushes should be designed to clean the walls of particulate splatter and should also be enclosed in a radiation shield and mounted on a telescoping arm.
CWSRS Crane Subassembly Failures	<p>The design of the CWSRS should include a provision for allowing access to the crane from a safe area at the mounting elevation of the crane.</p> <p>Properly suited and monitored personnel can then perform necessary repairs within the crane antichamber adjacent to or within the CTB chamber (after decontamination procedures have been performed).</p>
CTB Derailment Combined with Radiation Release (WORST CASE SCENARIO)	<ol style="list-style-type: none"> 1. Attempt to rerail the unit by means of the overhead crane. 2. Use the aforementioned fork lift to rerail or place the CTB into the CWC. Then sweep area with floor sweeper as described above. <p>Note: The design of the CWSRS may not require the use of an overhead crane for normal transfer (CTB to CWC) function. Nevertheless, the crane should be installed to service the CTB.</p>
Canistered Waste Cage (CWC) Hoist Failure with Radiation Release (WORST CASE SCENARIO)	<p>The hoist drum and drive mechanism is normally contained in a separate room. The dividing wall should also serve as a radiation shield.</p> <p>The hoist reeving should be designed such that the weight of a fully loaded CWC can be supported by half the strands and the breakage of one cable will not affect raising. The CWC can then be raised to the surface emptied, decontaminated and then repaired.</p> <p>Note: Redundant hoisting cables are the absolute minimum safeguard.</p>

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Sheet 8 of 9

NOTES ON SPECIAL REPAIRS

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

POM Sleeve Crab and Cutting Torch Failures

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

The following position and force instrumentation should be provided with remote reading indicators at the operating control panel:

- a) Load cells on each sleeve crab cylinder to indicate force applied to sleeve wall.
- b) Proximity switch on down and up positions of cutting torch raising/lowering mechanism to indicate torch position.
- c) A cutting gap measuring device positioned behind torch to confirm sleeve severance.
- d) A rotation indicator to indicate location and sweep distance traversed by the cutting torch.

With the above indications, the operator will know the current position of each sub-assembly and can react to any failure. None of these failures leads to radiation release. The corrective action is to simply replace the disabled POM with another POM to continue the operation. Both POM's would remain near the emplacement until the cutting debris, sleeve and plug have been redeposited in the emplacement hole.

Overcore Drill of POM
or COT Hits Sleeve

Unless the sleeve is degraded at the point of impact or bent at an incline angle, the drill will not penetrate the sleeve. A drill progression indicator at the operation control panel should be provided and will indicate a no change in drill depth situation.

The procedure to attempt to correct for a broached sleeve or a drill penetration resistance condition is as follows:

TABLE 7.7
Sheet 9 of 9

NOTES ON SPECIAL REPAIRS^{FE}

Contributing Event
(From Tables 7.2 through
7.6 inclusive)

Procedures and Equipment Required to Effect
Temporary In Situ Repairs, Midmode Failure

- a) Raise the drill and reverse rotation of drill and restart.
- b) Attempt retrieval using a different machine.
- c) Use machine equipped with larger diameter core drill.
- d) Abandon hole and backfill.

8.0 ACCIDENT EVENT TREES (FAULT TREES)

8.1 Accident Event Tree Analysis (Fault Tree Analysis)

A fault tree/event tree, referred to hereafter as an accident event tree or event tree, is in essence a logic diagram by which the relationship between contributing events (causes) and a final consequential event (usually an undesired event) is analyzed. Once the final consequential event (in this study it is radiation release) has been selected, it becomes necessary to determine the contributing events leading to it. These contributing events are then broken down into their causes, and so on. A tree diagram records the events as they are identified. When completed, the fault tree/event tree provides a graphic display of all potential causes to the final consequential event.

Event tree analysis as an accident prevention technique is based on the following principles^(7,8):

- a) The consequential event results from interacting contributing events within the system or subsystem.
- b) The consequential event can be separated into basic contributing events.
- c) Solutions are possible which will reduce or eliminate contributing events or potential failures leading to the consequential event.

The event tree graphically depicts the logical development of the final consequential or TOP event from the contributing events. In the following subsection the TOP event (radiation release) is examined in relationship to the primary or contributing events (causes) of:

- a) Failure of Canister extraction subsystem.
- b) Failure of Canister transfer subsystem.
- c) Failure of Canister hoisting subsystem.

In fault tree/event tree construction, symbols are used to represent contributing and TOP events and to describe the relationship between the events. Two basic types of symbols are contained in an event tree: logic gates and event symbols. A description of these symbols along with their respective graphic examples are presented in Section 8.3.

8.2 Accident Event Tree Construction

The accident event tree for the final consequential event of radiation release is presented in two parts. Each part reflects one of the two selected retrieval concepts discussed in the previous baseline concept criteria specification report⁽¹⁾. Event trees showing "Concept F" for a retrieval scenario involving a degraded Canister package and an intact sleeve are shown on pages 8 - 7 through 8 - 35 of this section. Event trees describing "Concept A" for a scenario involving both a degraded sleeve and Canister are shown on pages 8 - 35 through 8 - 65 of this section.

These accident event trees were constructed based on the accident event tables, Tables 7.1-7.6. A branch event tree was constructed for each accident event resulting in either radiation release or in an unknown final consequential event (Column 5 of the accident event table). For example, sheets 8 - 12 through 8 - 19 are branch trees for accident events resulting in either radiation release or in an unknown result. These branch trees were grouped by suitable logic gates to indicate their interaction to produce each output event which then further produced the TOP event of radiation release.

The final accident event tree was constructed from the starting point of the final consequential event - radiation release. Then reasoning deductively, the major contributing events to radiation release in the subsystems under study (Canister retrieval, Canister transport and transfer, Canister hoist) were listed. Each of these contributing events were then further broken down and linked together into branches of the tree through the use of logic gates.

For purposes of this report, the event tree has been presented in individual pages. Each page refers to its immediate predecessor for matching points against the transfer symbol. Later, when all input data are finalized, the event tree can be transferred to one large size drawing.

The fault trees/event trees representing retrieval "Concepts F and A" are shown on the following pages.

8.3 Accident Event Tree - Introduction

8.3a Logic Gates

In accident event tree analysis, logic gates are used to show the interconnection of contributing events needed to produce an event at a higher branch of the tree. The logic gates most frequently used in this development of an event tree are the AND and the OR gates.

8.3b The "and" Gate

The AND gate represents a condition in which only a combination of all contributing events leads to the occurrence of the consequential or output event. In other words, the AND gate requires the coexistence of all inputs shown below the gate in order to produce an output.

8.3c The or Gate

The OR gate depicts a condition in which the presence of any of the contributing events leads to the occurrence of the output event. Or put another way, the OR gate provides an output if at least one input shown below the gate is present.

8.3d Events

Event symbols depict types and characteristics of various events. In accident event tree analysis there are four basic types of events:

- a) Output events
- b) Independent events
- c) Normal events
- d) Undeveloped events

A different symbol indicates each type of event.

8.3e Output Events

Output events are events usually resulting from a combination of more-basic events, and are those events which should be further examined to determine how they transpire. They are represented on an event tree by rectangles. The rectangle is the only figure on an event tree with contributing events under it acting through a logic gate. It is also the only event symbol to be used in the inner parts of the event tree. It is never used at the end of branches. The rectangle is thus used to show the TOP event of the event tree and also the major consequential events to be examined and analyzed, and then reduced to their component parts. Except when it represents the TOP events, the rectangle serves as an input to another output event.

8.3 Accident Event Tree - Introduction (Continued)

<p>8.3f <u>Independent Events</u></p> <p>Independent events can exist apart from other components within a system or subsystem. They are generally basic system component failures which are clearly defined and need no further analysis in themselves. Independent events are represented by circles at the lower levels of the event trees. Circles designate those events which are independent of all other events.</p>	<p>* - Indicates empirically derived failure intensity number</p> <p>High) Medium) Failure Intensity Low) number generally empirical</p>
<p>8.3g <u>Normal Events</u></p> <p>Normal events are those which should occur during the operation of a system or subsystem. They are naturally occurring events which need not be further reduced into component parts. Normal events are represented by houses, and like circles are found at the lower levels of the event tree. Houses are useful as trigger events for a logic structure change within the event tree.</p>
<p>8.3h <u>Undeveloped Events</u></p> <p>Undeveloped events are represented by diamonds. Undeveloped events are those at which an event tree branch is terminated due to:</p> <ol style="list-style-type: none"> Insufficient information about the event to allow for its further analysis, or The insignificance of the event. <p>In the case of b, the event could be divided further to show how it is caused by more basic failures but is not developed because of the lack of significance in such basic faults.</p>	<p>10.12 - Table 10.1 Reference Number</p> <p>* - Indicates empirically derived number</p> <p>High) Failure intensity Medium) number cycle time Low) corrected. See Note 6 page 8-6 and 8-36</p>
<p>8.3i <u>The Transfer Symbol</u></p> <p>A transfer symbol is a triangle used to signify the transfer of a branch of the event tree to another part of the tree. Use of this symbol eliminates the need to repeat a complete sequence of events common to different sections of the tree. A line from the side of the triangle denotes an event transfer to another section of the tree. A line from the apex of the triangle signifies an event transfer into that section of the tree. Thus, triangles always appear in sets of at least two. When more than one set of transfer symbols is needed, each set is identified with a notation indicating its transfer-in and transfer-out points.</p>

Accident Event Trees for Retrieval
Concept "F": Retrieval of a Degraded
Canister from an Intact Sleeve

NOTES:

1. This analysis covers radiation release occurring outside casks or shielding in the working areas including emul. cement rooms, corridors, CUSPS and canister waste building.
2. Radiation release is assumed to occur during exposure of either the contaminated concrete plug or the fuel canister.
3. The canisters are assumed to be degraded.
4. Event trees for each branch shown above are developed in the following sheets.
5. Word 'failure' implies complete failure or malfunction.
6. Except for the Canister Transfer Basket (CTB), the failure rates appearing under each event are adjusted by the ratio of the time the device operates divided by the time the equipment operates. Therefore, these values (except for the CTB) are expressed in terms of units of 10^{-6} equipment operating hours. To determine the failure intensity after a duration of time, follow the methodology demonstrated in Reference 13.

PLUG REMOVAL MACHINE - BLOCK DIAGRAM 1

NOTE: Sheets 8-12 through 8-19 are backup sheets.

PLUG REMOVAL UNCLUTTE - BLOCK DIAGRAM 1

PLUM REMOVAL MACHINE - BLOCK DIAGRAM 1

PLUG REMOVAL MACHINE - BLOCK DIAGRAM I

PLUG REMOVAL MACHINE - BLOCK DIAGRAM 1

PLUS REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCK -1

NOTE: PAPERWORK
WORKSHEET
FOR REFERENCE
ONLY

PLUS REMOVAL MACHINE - BLOCK DIAGRAM 1
BLOCKS = 5, 21

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

PLUG REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCKS 6, 12

NOTE: BACKUP
WORKSHEET
FOR REFERENCE

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON UH-47 DIAGRAM

PLUG REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCKS # 7 & 11

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

PLUG REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCK # 10

NOTE: BACKUP
APPROPRIATE
FOR PLUGGING
ONLY

PLUS REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCK # 10

NOTE: DRAWING
NOT TO SCALE
FOR REFERENCE
ONLY

THIS DOCUMENT
IS UNCLASSIFIED
DATE 11-11-2001
BY 1045

PLUG REMOVAL MACHINE - BLOCK DIAGRAM 1
BLOCK # 14

NOTE: BACKUP
WITH SHUTT
FOR RECOVERY
ONLY

THIS EVENT DOES
NOT LEAD TO
CONTAINER FAILURE
AND IS NOT A
CRITICAL FAILURE

PLUG REMOVAL MACHINE - BLOCK DIAGRAM I
BLOCK #14

NOTE: BACKUP
DISPOSABLE
FOR PRESENCE
ONLY

CANISTER EXTRACTION/TRANSPORTED - BLOCK DIAGRAM II

NOTE: Sheets 8-26 thru 8-32 are backup sheets.

CASK/STRETCHER/TRANSPORTER - BLOCK DIAGRAM 11

CANISTER EXTRACTOR/TRANSPORTER - BLOCK DIAGRAM II

CANISTER EXTRACTOR/TRANSPORTER - BLOCK DIAGRAM II

CANISTER EXTRACTION/TRANSFER - BLOCK DIAGRAM II

CANISTER EXTRACTOR/TRANSPORT - BLOCK DIAGRAM 11

CANISTER EXTRACTOR/EXPORTER - BLOCK DIAGRAM II

BLOCK #1, 2 3, 16, 19, 20

NOTE: DISC'D
W/PL. 11"
FOR 11" CASE
SL 1

BLOCKS #4, 6, 7, 21, 23, 24

CANISTER EXTRACTOR/TWIN PORTER - BLOCK DIAGRAM 11
BLOCK 19, 1A, 35

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS DRAWING IS
NOT TO BE
REPRODUCED OR
TRANSMITTED IN
ANY FORM OR BY
ANY MEANS.

CONTAINER EXTRACTOR TRANSPORTER - BLOCK SYSTEM II
BLOCKS #10, 12, 27

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS CHART DOES
NOT LEAD TO
ANALYSIS OF
AND DOES NOT
GIVE RECOMMENDATIONS.

CONVEXITY EXTRACTION SYSTEM - BLOCK DIAGRAM 11
BLOCKS #12, 16, 23, 27

NOTE: BACKUP
WIPES-111
FOR REFERENCE
JAN 1

CANISTER EXTRACTOR/TRANSPORTER - BLOCK DIAGRAM 17

BLOCKS #8, 17, 25, 34

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT AFFECT
OTHER DIAGRAMS.

CRACKER EXTRACTION/RECOVERY - BLOCK DIAGRAM 11
BLOCK 125

NOTE: BACKUP
WITH MEET
FOR GATE FAILURE
ALMA

CANISTER TRANSPORT BASKET - BLOCK DIAGRAM III

CANISTER 100% INSPECTION - BLOCK DIAGRAM III

CONTAINER TRANSPORT SYSTEM - LOGIC DIAGRAM 111

Accident Event Trees for Retrieval
Concept "A": Retrieval of a Degraded
Canister from a Degraded Sleeve

GENERAL

NOTES:

1. This analysis covers radiation release occurring outside casks or shielding in the working areas including emplacement rooms, corridors, CHSRS and canister waste building.
2. Radiation release is assumed to occur during exposure of either the contaminated concrete plug or the fuel canister.
3. The canisters are assumed to be degraded.
4. Event trees for each branch shown above are developed in the following sheets.
5. Word 'failure' implies complete failure or malfunction.
6. Except for the Canister Transfer Basket (CTB), the failure rates appearing under each event are adjusted by the ratio of the time the device operates divided by the time the equipment operates. Therefore, these values (except for the CTB) are expressed in common units of 10^{-6} equipment operating hours. To determine the failure intensity after a duration of time, follow the methodology demonstrated in Reference 13.

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV

NOTE: Sheets 8-42 thru 8-49 are backup sheets.

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV

NOTE: SINCE BASELINE DESIGN DOES NOT REQUIRE ROTATION OF CASK, POSSIBILITY OF CASK WALL DAMAGE IS REDUCED.

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV
BLOCK #1

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV
BLOCK 44

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV
BLOCKS 46, 22

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

PLUG OVERCODE MACHINE - BLOCK DIAGRAM IV
BLOCK #14

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

PLUG OVERCORE MACHINE

BLOCKS #10, 14, 20

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV
BLOCK #20

NOTE: Sheets 8-55 thru 8-62 are backup sheets.

PLUS OVERCODE MACHINE - BLOCK DIAGRAM IV
BLOCK #21

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

PLUG OVERCORE MACHINE - BLOCK DIAGRAM IV
BLOCK 125

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V

NOTE: Sheets 8-55 thru 8-62 are backup sheets.

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCK #6

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V

BLOCK #1, 16, 17, 18

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCK #1, 4

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCKS 16, 12

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCKS #11, 23, 29, 43, 51

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
MAGNETIC RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCKS #9, 28, 44

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V
BLOCK 8, 10, 25, 28

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

CANISTER OVERCORE TRANSPORTER - BLOCK DIAGRAM V

BLOCK #3, 14, 32, 40, 54

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

THIS EVENT DOES
NOT LEAD TO
RADIATION RELEASE
AND DOES NOT APPEAR
ON OTHER DIAGRAMS.

CANISTER OVERCODE TRANSPORTER - BLOCK DIAGRAM Y
BLOCK #32

NOTE: BACKUP
WORKSHEET
FOR REFERENCE
ONLY

CANISTER TRANSPORT BASKET - BLOCK DIAGRAM VI

CANISTER TRANSPORT BASKET - BLOCK DIAGRAM VI

CANISTER TRANSPORT BASKET - BLOCK DIAGRAM VI

9.0 RELIABILITY AND FAILURE PROBABILITY

The mechanical failure probabilities of the major canister retrieval subsystems were calculated and discussed in the previous report "Retrieval System for Emplaced Spent Fuel (SURF) in Salt Bed Depository: Baseline Concept Criteria Specifications and Mechanical Failure Probabilities"⁽¹⁾. Section 12 of that report also included the derivation of the formula for the probable reliability of the subsystems along with the rationale and assumptions behind the use and selection of the formula. Concerning mechanical retrieval subsystem failure, the previous report concluded:

- a) Most mechanical failures can be controlled by design, testing, quality control, inspection, maintenance, operator training and sound operational procedures.
- b) Midmode failure of the mechanical systems during canister retrieval is unlikely, but cannot be completely ruled out. In such cases the retrieval vehicle may have to be abandoned, and/or emergency procedures applied as discussed in detail at the end of Table 7.6.
- c) A shielded forklift with a grabbing device to clamp onto the overcan shall be used to pick up a dropped canister should such an event take place.

The failure probability of the retrieval equipment was found to be as shown in Table 9.1, which is extracted from the report cited above.

The present study report includes the retrieval equipment (or subsystems) assembly and component failure probability estimates (see Appendixes A and B) and derivations of assembly cyclic failure rates (see Table 10.1). Failure probability estimates of the subsystem assemblies and components in this report have been compared with generic component failure test reports from the Government - Industry Data Exchange Program (GIDEP). The aforementioned calculations are for specific assemblies evidenced

TABLE 9.1

EQUIPMENT SYMBOL	EQUIPMENT	LEVEL OF FAILURE INTENSITY	HOURS OF OPERATION		
			1000	3000	5000
CET	Canister Extraction/Transporter	Low	.00846	.02539	.04232
		Medium	.04150	.12451	.20752
		High	.0932	.27979	.46632
PRM	Plug Removal Machine	Low	.00316	.00948	.01580
		Medium	.01535	.04605	.07675
		High	.03459	.10377	.17295
CTB	Canister Transport Basket	Low	.00052	.0015	.00262
		Medium	.0109	.03271	.05452
		High	.03282	.09845	.16408
CWC	Canister Waste Cage (Hoist)	Low	.00356	.0107	.0178
		Medium	.01427	.0428	.07135
		High	.0369	.1108	.1848
COT	Canister Overcore Transporter	Low	.00516	.01547	.02579
		Medium	.03767	.1130	.18834
		High	.09443	.28328	.47214
POM	Plug Overcore Machine	Low	.00757	.02272	.03787
		Medium	.03195	.09506	.15977
		High	.08188	.24565	.40941

in the event tables, Tables 7.1 through 7.6 inclusive, as failure governing. The cyclic failure probability predictions so derived are entered in the event trees at the relevant event gate.

The following impacts on the reliability figures expressed in Table 9.1 and the failure intensity tabulations and calculations of this report need to be studied when sensitivity analysis to the above is required:

- a) Environmental
- b) Nuclear radiation effects
- c) Effects of time

- d) Human factors
- e) Degree of certainty
- f) Factors of safety used in the design of the components.

9.1 Failure Intensity Data Acquisition Rate (λ)

Failure intensity values for the SURF retrieval subsystems have been extracted from the data sources indicated on the calculation sheets. The values were then compared with generic component failure test records procured from the Government - Industry Data Exchange Program (GIDEP).

The GIDEP Policies and Procedures Manual⁽⁹⁾ defines GIDEP as "a cooperative data exchange among Government and Industry participants seeking to reduce or eliminate expenditures of time and money and improve system reliability by making maximum use of existing knowledge. The program provides a means to automatically exchange certain types of data essential in the research, design, development, production, and operational life cycle of systems and equipment."

GIDEP is managed and funded by the federal government. Participants to GIDEP submit pertinent technical data generated as a result of government-financed work. The submitted data is then indexed, computerized and placed on microfilm. The microfilmed information is then available to GIDEP participants through remote computer terminal access. Participants in GIDEP are provided access to four data banks: engineering, meteorology, failure experience and reliability - maintainability. GIDEP data helps assure accurate SURF retrieval subsystem failure rates.

In general, the minimum and maximum values given in the References and Bibliography and used in this report are averages of individual values obtained from experts. As such, they are to be interpreted as ranges, not as specific confidence bounds. In analyzing failure rate estimates, the analytical techniques should be no more sophisticated than the esti-

mates presented. The majority of data obtained used the Delphi method of polling of expert opinion and a simple unweighted geometric averaging procedure.

The heuristic technique is useful in Delphi pollings where a consensus is sought on several properties of a randomly distributed variable. The Delphi method deals in part with opinion, as opposed to exclusively factual information. As such, Delphi procedures are not purely statistical.

The heuristic technique also has the advantage of flexibility in the utilization of relevant data as it becomes available. Minimum, best and maximum estimates may have to be revised. A procedure for doing so is outlined in the following section and can be used to verify the accuracy of empirical data using GIDEP records. The method of converting field data and GIDEP test reports into homogeneous failure rate classes is a given in Equation 1 of the following section.

9.2 Conversion of Field Tests and GIDEP Reports into Failure Intensity Values

If the failure intensity data come from a single population with a failure rate λ (exponentially distributed times to failure), twice the accumulated test hours (T^*) times λ (or $2\lambda T^*$) has a χ^2 distribution with $2n$ degrees of freedom, as shown here.⁽¹⁰⁾ The confidence interval on λ for fixed time censored data is expressed⁽¹¹⁾:

$$\text{Equation 1} = \frac{\chi^2_{\alpha/2; 2n}}{2T^*} < \lambda < \frac{\chi^2_{1-\alpha/2; 2n+2}}{2T^*}$$

where: n = number of observed failures

α = 1- desired confidence level

λ = n/T^* is the recommended value of λ

This means that upper and lower confidence bounds are expressed as

$$\lambda L = \frac{\chi^2_{\alpha/2; 2n}}{2T^*} \text{ and } \lambda U = \frac{\chi^2_{1-\alpha/2; 2n+2}}{2T^*}$$

Where: λL = the lower bound
 λU = the upper bound.

The value of χ^2 can be easily obtained from standard tabulations⁽¹²⁾ for cases where the problem degrees of freedom, often denoted by "v", are less than 30. For degrees of freedom over 30, the following approximation is used:

$$\chi^2 = \frac{1}{2} [(2v-1)^{1/2} + Z]^2$$

Where: Z = the standard normal variable at the desired confidence integral;
 $v = 2n$ = the number of degrees of freedom for the lower bounds;
 $v = 2n + 2$ = the number of degrees of freedom for the upper bounds.

9.3 Reliability Derivation

In this section, the term component or device means a single item which combines in series with other components to comprise an assembly; i.e. a bearing supporting a drive shaft is a component. Also in this report, the terms "failure rate" and "failure intensity" are synonymous.

The reliability function for components which fail at constant rate is an exponential distribution:

$$R = e^{-\lambda t}$$

This expression assumes that components or subassemblies of the SURF retrieval subsystems will fail at a constant rate. In this and the previous report⁽¹⁾ "t" is the number of hours the components are used and the symbol "λ" signifies the failure intensity and in practice is generally expressed per 10⁶ hours.

For an assembly consisting of n number of devices, where the failure of any device results in failure of the assembly to accomplish its intended function, the assembly reliability is expressed:

$$R(\text{Assembly}) = \prod_{i=1}^n R_i$$

Where: $R(\text{Assembly})$ = Reliability of the Assembly

R_i = Reliability of the i^{th} device

$\prod$ = Product symbol

n = Number of devices in the Assembly

The equation can also be expressed as follows:

$$R(\text{Assembly}) = e^{-\sum \lambda_i t_i}$$

Where: t_i = Operating time (cycles) of the individual devices

λ_i = Failure rate of the individual devices

When the operating time (cycles) of individual devices are equal to the total operating time of the assemblies the equation becomes:

$$R(\text{Assembly}) = e^{-t_A \sum \lambda_i}$$

Where: t_A = Assembly operating time.

9.4 Failures Occur According to a Poisson Process

Classical Reliability analysis assumes that failures occur according to a Poisson process. When making this assumption certain implications should be carefully noted.

The following four assumptions sufficiently demonstrate that the failure process is indeed a Poisson process. Let $N(t)$ be the number of failure events observed in a fixed time interval t .

1. The increments are independent, i.e. the random variable $N(t_1) - N(t_0)$ is independent of the random variable $N(t_3) - N(t_2)$.
2. There is a finite probability of a failure event occurring in a finite interval, i.e.:

$$0 < P[N(t) > 0] < 1$$

3. For sufficiently small intervals, the probability of 1 event approaches 0.

$$\lim_{h \rightarrow 0} P[N(t+h) - N(t) > 0] = 0$$

4. The process is stationary, i.e. the failure rate is constant as a function of time.
 $N(t) - N(s)$ is identically distributed as $N(t+h) - N(s+h)$ for arbitrary h .

Assumption (4) is valid if the failure rate remains constant with time, i.e. the process is homogeneous. Intuitively one would think that when components wear, failure rates would increase rather than remain stationary, i.e. the process due to aging is actually nonhomogeneous. Practice has shown, however that failure rates of many kinds of components do remain approximately constant during the normal useful life of the component. Consequently failure rates can be modeled by piecewise homogeneous poisson processes.

Define $P_n(t) = P[N(t) = n]$ i.e. probability that n events will be observed in time t . It can be shown⁽¹²⁾ that:

$$P_n(t) = e^{-\lambda t} \frac{(\lambda t)^n}{n!}$$

Now having derived a probability density function for the number of events which occur in a fixed time interval t , it is interesting to derive the probability distribution of time required to reach the n^{th} event.

$$\text{Let } F_{w_n}(t) = P[w_n \leq t] = \int_0^t f_{w_n}(x) dx$$

$F_{w_n}(t)$ is the distribution function of the waiting time to the n^{th} event.

$$1 - F_{w_n}(t) = P[w_n > t] = P[n(t) < n]$$

The probability that the waiting time to the n^{th} event is greater than t is equal to the probability that less than n events have occurred in time t .

$$\text{But: } P[n(t) < n] = \sum_{i=0}^{n-1} P_n(t) = \sum_{i=0}^{n-1} \frac{e^{-\lambda t} (\lambda t)^i}{i!} = 1 - F_{w_n}(t)$$

$$Fw_n(t) = 1 - e^{-\lambda t} \left(1 + \lambda t + \frac{(\lambda t)^2}{2} + \frac{(\lambda t)^3}{3!} + \dots + \frac{(\lambda t)^{n-1}}{(n-1)!} \right)$$

$$f_{w_n}(t) = \frac{d}{dt} Fw_n(t) = \frac{\lambda (\lambda t)^{n-1} e^{-\lambda t}}{(n-1)!}$$

thus

$$f_{w_n}(t) = \frac{\lambda}{(n-1)!} (\lambda t)^{n-1} e^{-\lambda t}$$

To get confidence intervals for w_n

$$\text{Define } \chi^2 = 2\lambda w_n$$

$$\text{Substitute } w_n = \frac{U}{2\lambda}$$

$$f_U(u) = \frac{1}{2(n-1)!} \left(\frac{u}{2}\right)^{n-1} e^{-u/2} = \chi^2 \text{ in } \frac{n}{2} \text{ degrees of freedom in variate } U$$

so $(1-\alpha)$ confidence intervals for $2 w_n$ are:

$$\chi^2_{/2, 2n} \leq 2\lambda w_n \leq \chi^2_{1-\alpha/2, 2(n+1)}$$

10.0 ACCIDENT EVENT TREE GATE NUMBER DERIVATION

A logic diagram is a simple means of performing the basic Failure Mode and Effects Analysis (FMEA). The required accuracy of the numeric values of failure intensity rates need not be precise for the first level of effort, that of determining the overall possibility of radiation release. The purpose of the FMEA (consisting of the creation of an accident event tree and the computation of failure probability) is to:

- a) Determine the probability of radiation release resulting from equipment failure.
- b) Discover which critical components, subassemblies or assemblies may have high failure rates (resulting in hazardous midmode failure or inadequate equipment availability rates).
- c) Decide upon the acceptability of equipment design based on available failure intensity parameters.
- d) Discern potential constraints imposed on human operations or mine spatial conditions.

10.1 Data Acquisition

Appropriate failure rate data bases (8, 9, 10, 12, 13) are available to the designer and are used in this report. The interpretation of a most valuable source, the GIDEP data base, is discussed in Subsections 9.1 and 9.2 of this report. Equation 1 in Subsection 9.2 can be used to convert test data into failure bounds.

10.2 Event Tree Gate Number Derivation

Failure governing assemblies or components are those whose failure could lead to a catastrophic event or require heroic or high risk repair procedures. The methodology for the examination of subsystems or equipment for identification of the failure governing elements is the premier procedure in preparing a FMEA and in this report culminates in Section 7. Subjunctively, alternative designs of failure governing assemblies were prepared and analyzed in Section 5 to mitigate failures and thereby improve the equipment reliability.

The failure governing subassembly failure intensity rates are derived in Appendixes A and B, based on the discrete designs evolved in Section 5. The intensity values of the subassembly components were extracted from the data base references indicated in Appendix D. As shown in Section 9, the failure rate of a subassembly is the sum of the failure intensities of all individual components. The methodology for the summation of component failure intensities is demonstrated in the aforementioned appendixes.

The subassemblies of a subsystem operate for a fraction of the equipment operating (or cycle) time. Since the failure rates are time dependent, they are corrected in Table 10.1 to reflect this factor. The rates derived in Table 10.1 are entered in the event trees at the end of Section 8.

10.3 Numeric Value Deviations

The numeric values for subassemblies given in Table 10.1 of this report differ from those reported in the baseline specifications report.⁽¹⁾ The original derivations of subsystem failure intensity were based on abstract subassembly designs. However, the calculations performed herein are based on the discrete designs shown on Figures 5.2, 5.3, 5.5, 5.10, 5.11, 5.12, and A-1. Subassembly failure intensity values are sensitive to the extent

of knowledge of the design. In fact, their accuracy varies in direct proportion to the extent that details of the design are known. The deviation in values shown in both reports reflects this variation in accuracy.

10.4 Failure Rate Data Submission Requirements for License Application

The license applicant should submit predictive failure rates of components, subassemblies and assemblies which, in the opinion of the reviewer, have potentially critical or governing failure modes. Components and subassemblies of the baseline design with these characteristics are identified on the accident event trees in Section 8.

Factual operating failure rate data reported on Federal forms DD2000 and DD2001 in accordance with GIDEP requirements should be mandatory. Tests of prototype assemblies and reports of results by the SURF retrieval equipment manufacturer should be mandatory and made available to the license reviewer.

TABLE 10.1
Sheet 1 of 4
DERIVATION AND TABULATION OF FAILURE PROBABILITY OF
RETRIEVAL EQUIPMENT SUBASSEMBLIES

Ref. No.	Subassembly Description	Operation	Failure Intensity Under Continuous Operation x 10 ⁶ Hours			Time Assembly Operates (Min. ^{1/})	No. of Times Assembly Works ^{2/}	Equipment Cycle Time (Min. ^{3/})	Fraction of Total Cycle Time	Failure Intensity-6 of Subassembly x 10 ⁶ Equip. Operating Hours			Failure Probability Calculation References
			High	Medium	Low					High	Medium	Low	
10.1	PRM Cask Elevating Mechanism	Raise or Lower Cask	133.227	63.733	15.257	0.5	4	60	0.0333	4.441	2.124	0.509	Fig. A-1 and Table A-1
10.2	PRM Cask Positioning Mechanism	Orient Cask	250.912	122.473	24.622	1.0	2	60	0.0333	8.364	4.082	0.821	Fig. A-1 and Table A-1
10.3	PRM Limit Switch	Stop/Start	0.660	0.175	0.118	1.5	6	60	0.1500	0.099	0.026	0.018	Ref. 13
10.4	PRM Cask Gate Operating Mechanism	Open/Close	138.171	66.691	12.675	0.5	4	60	0.0333	4.606	2.223	0.422	Figs. 5.2, 5.3 and Table A-2
10.5	PRM Plug Engagement Mechanism	Raise or Lower Plug	190.639	86.308	19.212	2.0	2	60	0.0667	12.709	5.754	1.281	Fig. 5.5 and Table A-3
10.6	PRM Plug Engagement Mechanism	Holding Plug	76.200	19.000	6.502	38.0	N/A	60	0.6333	48.260	12.033	4.118	Fig. 5.5 and Table A-3
10.7	PRM Auto. Guidance System	Locating Unit	43.272	20.880	5.375	2.5	2	60	0.0833	3.606	1.740	0.448	Table B-2
10.8	PRM Auto. Index Control System	Locate Over hole	43.272	20.880	5.375	1.0	2	60	0.0333	1.442	0.696	0.179	Table B-2
10.9	PRM Power Steering System	Steer Unit	241.838	104.408	19.035	2.5	2	60	0.0667	16.123	6.961	1.269	Table A-4

^{1/} Value is expressed as the amount of time required for the assembly to perform a single operation.

^{2/} Value is number of times assembly performs described operation during each equipment cycle.

^{3/} Refer to Reference 1, Appendix 3 for equipment operating time studies and Appendix 6 for methodology for deriving equipment reliability estimates.

TABLE 10.1
Sheet 2 of 4
DERIVATION AND TABULATION OF FAILURE PROBABILITY OF
RETRIEVAL EQUIPMENT SUBASSEMBLIES

Ref. No.	Subassembly Description	Operation	Failure Intensity Under Continuous Operation x 10 ⁻⁶ Hours			Time Assembly Operates (Min. ^{1/})	No. of Times Assembly Works ^{2/}	Equipment Cycle Time (Min. ^{3/})	Fraction of Total Cycle Time	Failure Intensity of Subassembly x 10 ⁻⁶ Equip. Operating Hours			Failure Probability Calculation References
			High	Medium	Low					High	Medium	Low	
10.10	CET Cask Elevating Mechanism	Raise or Lower Cask	133.227	63.733	15.257	0.5	6	120	0.025	3.331	1.593	0.381	Fig. A-1 and Table A-1
10.11	CET Cask Positioning Mechanism	Orient Cask	250.912	122.473	24.622	1.0	3	120	0.025	6.273	3.062	0.616	Fig. A-1 and Table A-1
10.12	CET Limit Switch	Stop/Start	0.660	0.175	0.118	1.5	6	120	0.075	0.050	0.013	0.009	Ref. 13
10.13	CET Cask Gate Operating Mechanism	Open/Close	138.171	66.691	12.675	0.5	6	120	0.025	3.454	1.667	0.317	Figs. 5.2, 5.3 and Table A-2
10.14	CET Ram Unit Assembly	Raise or Lower Canister	198.943	100.390	30.031	15.5	N/A	120	0.129	25.697	12.967	3.879	Fig. 5.10 and Table A-5
10.15	CET Ram Unit Assembly	Holding Canister	67.200	40.500	19.800	34.5	N/A	120	0.088	19.320	11.644	5.693	Fig. 5.10 and Table A-5
10.16	CET Auto. Guidance System	Locating Unit	43.272	20.880	5.375	24.5	N/A	120	0.204	8.835	4.263	1.097	Table B-2
10.17	CET Auto. Index Control System	Locate Over hole	43.272	20.880	5.375	2.5	3	120	0.063	2.705	1.305	0.336	Table B-2
10.18	CET Power Steering	Steer Unit	241.838	104.408	19.035	50.5	N/A	120	0.421	101.774	43.938	8.011	Table A-4

^{1/} Value is expressed as the amount of time required for the assembly to perform a single operation.

^{2/} Value is number of times assembly performs described operation during each equipment cycle.

^{3/} Refer to Reference 1, Appendix 3 for equipment operating time studies and Appendix 6 for methodology for deriving equipment reliability estimates.

TABLE 10.1

Sheet 3 of 4

DERIVATION AND TABULATION OF FAILURE PROBABILITY OF
RETRIEVAL EQUIPMENT SUBASSEMBLIES

Ref. No.	Subassembly Description	Operation	Failure Intensity Under Continuous Operation x 10 ⁻⁶ Hours			Time Assembly Operates (Min.)	No. of Times Assembly Works ^{2/}	Equipment Cycle Time (Min.) ^{3/}	Fraction of Total Cycle Time	Failure Intensity of Subassembly x 10 ⁻⁶ Equip. Operating Hours			Failure Probability Calculation References
			High	Medium	Low					High	Medium	Low	
10.19	POM Cask Positioning Mechanism	Orient Cask	250.912	122.473	24.622	2.5	4	144	0.069	17.424	8.505	1.710	Fig. A-1 and Table A-1
10.20	POM Limit Switch	Stop/Start	0.660	0.175	0.118	1.5	8	144	0.083	0.055	0.015	0.010	Ref. 13
10.21	POM Cask Gate Operating Mechanism	Open/Close	138.171	66.691	12.675	0.5	4	144	0.014	1.919	0.926	0.176	Figs. 5.2, 5.3 and Table A-2
10.22	POM Plug Engagement Mechanism	Raise or Lower Plug	190.639	86.308	19.212	2.0	2	144	0.028	5.296	2.397	0.534	Fig. 5.5 and Table A-3
10.23	POM Plug Engagement Mechanism	Holding Plug	76.200	19.000	6.502	415.5 ^{4/}	N/A	144	2.885	219.869	54.823	18.761	Fig. 5.5 and Table A-3
10.24	POM Sleeve Engagement Mechanism	Raise or Lower Sleeve	274.448	130.813	27.739	2.0	2	144	0.028	7.624	3.634	0.771	Fig. 5.11 and Table A-6
10.25	POM Sleeve Engagement Mechanism	Holding Sleeve	155.073	76.877	18.098	323.5 ^{4/}	N/A	144	2.247	348.376	172.706	40.658	Fig. 5.11 and Table A-6
10.26	POM Auto. Guidance System	Locating Unit	43.272	20.880	5.375	2.5	4	144	0.069	3.005	1.450	0.373	Table B-2
10.27	POM Auto. Index Control System	Locate Over hole	43.272	20.880	5.375	1.0	2	144	0.014	0.601	0.290	0.075	Table B-2
10.28	POM Power Steering	Steer Unit	241.838	104.408	19.035	2.5	4	144	0.069	16.794	7.251	1.322	Table A-4

1/ Value is expressed as the amount of time required for the assembly to perform a single operation.

2/ Value is number of times assembly performs described operation during each equipment cycle.

3/ Refer to Appendix C for equipment operating time studies and Reference 1, Appendix 6 for methodology for deriving equipment reliability estimates.

4/ Includes dwell time.

TABLE 10.1
Sheet 4 of 4
DERIVATION AND TABULATION OF FAILURE PROBABILITY OF
RETRIEVAL EQUIPMENT SUBASSEMBLIES

Ref. No.	Subassembly Description	Operation	Failure Intensity Under Continuous Operation x 10 ⁻⁶ (hours)			Time Assembly Operates (Min. ^{1/})	No. of Times Assembly Works ^{2/}	Equipment Cycle Time (Min. ^{3/})	Fraction of Total Cycle Time	Failure Intensity ⁶ of Subassembly x 10 ⁻⁶ Equip. Operating Hours			Failure Probability Calculation References
			High	Medium	Low					High	Medium	Low	
10.29	COT Cask Elevating Mechanism	Raise or Lower	133.227	63.733	15.257	0.5	6	388	0.008	1.030	0.493	0.118	Fig. A-1 and Table A-1
10.30	COT Cask Positioning Mechanism	Orient Cask	250.912	122.473	24.622	2.5	3	388	0.019	4.850	2.367	0.476	Fig. A-1 and Table A-1
10.31	COT Limit Switch	Stop/Start	0.660	0.175	0.118	1.5	6	388	0.023	0.015	0.004	0.003	Reference 13
10.32	COT Cask Gate Operating Mechanism	Open/Close	138.171	66.691	12.675	0.5	6	388	0.008	1.068	0.516	0.098	Fig. 5.2, 5.3 and Table A-2
10.33	COT Drill Barrel Operating Mech.	Raise or Lower Canister	241.473	118.794	28.892	1.1	N/A	388	0.003	0.685	0.337	0.082	Fig. 5.12 and Table A-7
10.34	COT Drill Barrel Operating Mech.	Holding Canister	110.925	52.857	13.202	46.5	N/A	388	0.120	13.294	6.335	1.582	Fig. 5.12 and Table A-7
10.35	COT Auto. Guidance System	Locating Unit	43.272	20.880	5.375	29.5	N/A	388	0.076	3.290	1.588	0.409	Table B-2
10.36	COT Auto. Index Control System	Locate Overhole	43.272	20.880	5.375	2.5	3	388	0.019	0.836	0.404	0.104	Table B-2
10.37	COT Power Steering	Steer Unit	241.838	104.408	19.035	50.5	N/A	388	0.130	31.476	13.589	2.477	Table A-4

^{1/} Value is expressed as the amount of time required for the assembly to perform a single operation.

^{2/} Value is number of times assembly performs described operation during each equipment cycle.

^{3/} Refer to Appendix C for equipment operating time studies and Reference 1, Appendix 6 for methodology for deriving equipment reliability estimates.

Figure A-1

Schematic Design of Cask Orientation System

- Note: 1. Cask Orientation System for PRM, CET and COT consists of three mechanism assemblies: a) Elevating, b) Tilting and c) Alignment
2. Cask positioning mechanisms are the tilting and alignment mechanisms combined.
3. Item (3) Hydraulic Piping System not shown for clarity.

TABLE A-1
FAILURE PROBABILITY CALCULATION
CASK ORIENTATION SYSTEM

REFERENCE DESIGN: FIGURE A-1

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$) Hours					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
CASK ELEVATING MECHANISM								
1	2	Mechanical Pin Connections	2.600	5.200	1.625	3.250	0.650	1.300
2	1	Hydraulic Piston (Table B-1)	10.797	10.797	5.508	5.508	0.516	0.516
3	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
4	1	Orientation Control System (Table B-2)	43.270	43.270	20.880	20.880	5.375	5.375
Total - Cask Elevation Mechanism				133.227		63.733		15.257
CASK TILTING MECHANISM								
5	8	Hoist Direct Connections	0.700	5.600	0.175	1.400	0.015	0.120
2	4	Hydraulic Pistons (Table B-1)	10.797	43.188	5.508	22.032	0.516	2.064
CASK ALIGNMENT MECHANISM								
1	3	Mechanical Pin Connections	2.600	7.800	1.625	4.875	0.650	1.950
5	1	Hoist Direct Connections	0.700	0.700	0.175	0.175	0.015	0.015
2	2	Hydraulic Pistons (Table B-1)	10.797	21.594	5.508	11.016	0.516	1.032
6	8	Rollers	6.850 ^{1/}	54.800	3.500 ^{1/}	28.000	0.750 ^{1/}	6.000
3	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
4	1	Orientation Control System (Table B-2)	43.270	43.270	20.880	20.880	5.375	5.375
Total - Tilting and Alignment Mechanism which Combined Equal the Positioning Mechanism				250.912		122.473		24.622

^{1/} Estimated values; all other values from Appendix B or Reference 13.

^{2/} Refer to Reference 1, Appendix 3 for operating time studies and Appendix 6 for methodology for deriving equipment reliability estimates.

TABLE A-2
FAILURE PROBABILITY CALCULATION
CASK GATE OPERATING MECHANISM

REFERENCE DESIGN: FIGURES 5.2 AND 5.3

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$) Hours					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	1	Operating Link	1.960	1.960	0.020	0.020	0.011	0.011
2	1	Screw Mechanism	4.300 ^{1/}	4.300	2.175 ^{1/}	2.175	0.087 ^{1/}	0.087
3	8	Bearings	3.530	28.240	1.800	14.400	0.072	0.576
4	2	Springs	0.221	0.441	0.113	0.226	0.004	0.008
5	2	Slides	0.700 ^{1/}	1.400	0.300 ^{1/}	0.600	0.100 ^{1/}	0.200
6	2	Ball Bearings	3.530	7.060	1.800	3.600	0.072	0.144
7	2	Control Switches	0.660	1.320	0.175	0.350	0.118	0.236
8	1	Hydraulic Motor	7.150	7.150	4.300	4.300	1.450	1.450
9	1	Pin	2.600	2.600	1.625	1.625	0.650	0.650
10	1	Gear Reducer	4.300	4.300	2.175	2.175	0.087	0.087
11	1	Connecting Link to Floor Flange	2.600	2.600	1.625	1.625	0.650	0.650
12	1	Floor Flange Pocket	0.600	0.600	0.100	0.100	0.010	0.010
13	2	Seals	1.120	2.240	0.700	1.400	0.250	0.500
14	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
Total - Cask Gate Operating Mechanism				138.171		66.691		12.675

^{1/} Assumed values; all other values from Reference 13.

TABLE A-3
FAILURE PROBABILITY CALCULATION
PLUG ENGAGEMENT MECHANISM

REFERENCE DESIGN: FIGURE 5.5

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$) Hours					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	1	Lifting Device (Table B-3)	129.975	129.975	58.986	58.986	10.199	10.199
2	1 each	Thrust and Guide Bearing	3.530	7.060	1.800	3.600	0.072	0.144
3	1	Screw	4.300	4.300	2.175	2.175	0.174	0.174
4	8	Frame Connections	0.700	5.600	0.175	1.400	0.015	0.120
5	1	Screw to Stern Connection	2.600	2.600	1.625	1.625	0.650	0.650
6	1	Electric Motor	7.500	7.500	0.625	0.625	0.150	0.150
7	1	Collet Housing	3.000 ^{1/}	3.000	1.750 ^{1/}	1.750	1.000 ^{1/}	1.000
8	4	Pivot Pins	2.600	10.400	1.625	6.500	0.650	2.600
9	4	Springs	0.221	0.884	0.113	0.452	0.004	0.016
10	4	Tongs	3.000 ^{1/}	12.000	1.750 ^{1/}	7.000	1.000 ^{1/}	4.000
11	1	Operating (Screw) Link	1.960	1.960	0.020	0.020	0.011	0.011
12	1	Electrical Connection	4.700	4.700	2.000	2.000	0.030	0.030
13	1	Overtravel Limit Switch	0.660	0.660	0.175	0.175	0.118	0.118
Total - Plug Engagement Mechanism, Operating				190.639		86.308		19.212
14	3	Mechanical Screw Jacks	4.300 ^{1/}	12.900	2.175 ^{1/}	6.525	0.174 ^{1/}	0.522
15	1	Cross Head and Guide	1.400 ^{1/}	1.400	0.600 ^{1/}	0.600	0.200 ^{1/}	0.200
16	1	Latch	0.600 ^{1/}	0.600	0.100 ^{1/}	0.100	0.010 ^{1/}	0.010
17	4	Tongs	3.000 ^{1/}	12.000	1.750 ^{1/}	7.000	1.000 ^{1/}	4.000
18	1	Collet Housing	3.000 ^{1/}	3.000	1.750 ^{1/}	1.750	1.000 ^{1/}	1.000
19	4	Pivot Pins	2.600	10.400	1.625	6.500	0.650	2.600
20	8	Frame Connections	0.700	5.600	0.175	1.400	0.015	0.120
Total - Plug Engagement Mechanism, Static				45.900		23.875		8.452

^{1/} Assumed values; all other values from Reference 13.

TABLE A-4
FAILURE PROBABILITY CALCULATION
POWER STEERING ASSEMBLY

REFERENCE DESIGN: LARGE TRUCK INDUSTRY TYPICAL DESIGNS

Item No.	No. of items	Item Description	λ = Failure Intensity ($\times 10^{-6}$) Hours					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	4	Seals	3.000	12.000	0.345	1.380	0.140	0.560
2	1	Piston	0.350	0.350	0.200	0.200	0.080	0.080
3	3	Piston Rings	0.350	1.050	0.200	0.600	0.080	0.240
4	1	Cylinder	0.120	0.120	0.008	0.008	0.005	0.005
5	6	Hydraulic Connection	1.348	8.088	0.690	4.140	0.027	0.162
6	4	Flexible Connection	5.220	20.880	3.940	15.760	0.157	0.628
7	1	Hydraulic Piping	0.040 ^{1/}	0.040	0.020 ^{1/}	0.020	0.010 ^{1/}	0.010
8	1	Pressure Switch	0.660 ^{1/}	0.660	0.175 ^{1/}	0.175	0.118 ^{1/}	0.118
9	3	Valves	7.700	23.100	4.600	13.800	1.110	3.330
10	1	Pump	27.400	27.400	13.500	13.500	2.900	2.900
11	1	Motor	7.500	7.500	0.625	0.625	0.150	0.150
12	2	Check Valves	16.200	32.400	6.500	13.000	1.980	3.960
13	1	Control Valve	19.800	19.800	8.500	8.500	1.680	1.680
14	2	Gears	4.300	8.600	2.175	4.350	0.087	0.174
15	4	Bearings	3.530	14.120	1.870	7.200	0.072	0.288
16	6	Mechanical Connections	2.600	15.600	1.625	9.750	0.650	3.900
17	1	Control System	2.130	2.130	1.400	1.400	0.370	0.370
18	4	Universal Joints	12.000	48.000	2.500	10.000	0.120	0.480
Total - Power Steering Assembly				241.838		104.408		19.035

^{1/} Assumed values, all other values from Reference 13.

TABLE A-5
FAILURE PROBABILITY CALCULATION
ASSEMBLY: CET RAM UNIT

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$ hours)					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	1	Lifting Device	129.975	129.975	58.986	58.986	10.199	10.199
2	12	Pivot Pins (latch assembly)	2.600	31.200	1.625	19.500	0.650	7.800
3	8	Springs	0.221	1.768	0.113	0.904	0.004	0.032
4	12	Arms (latch assembly)	3.000 ^{1/}	36.000	1.750 ^{1/}	21.000	1.000 ^{1/}	12.000
TOTAL CET RAM UNIT (operating)				198.943		100.390		30.031
5	12	Pivot Pins	2.600	31.200	1.625	19.500	0.650	7.800
6	12	Arms	3.000 ^{1/}	36.000	1.750 ^{1/}	21.000	1.000 ^{1/}	12.000
TOTAL CET RAM UNIT (static)				67.200		40.500		19.800

^{1/} Assumed values, all other values from Reference 13.

TABLE A-6
FAILURE PROBABILITY CALCULATION
ASSEMBLY: POM SLEEVE ENGAGEMENT MECHANISM
REFERENCE DESIGN: FIGURE 5.11

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$ hours)					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	1	Lifting Device (Table B-3)	129.975	129.975	58.986	58.986	10.199	10.199
2	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
3	4	Hydraulic Pistons (Table B-1)	10.797	43.188	5.508	22.032	0.516	2.064
4	4	Hoist Direct Connections	0.700	2.800	0.175	0.700	0.015	0.060
5	4	Mechanical Pin Connections	2.600	10.400	1.625	6.500	0.650	2.600
6	4	Grabs (Tongs, Table A-3)	3.000 ^{1/}	12.000	1.750 ^{1/}	7.000	1.000 ^{1/}	4.000
7	1	Housing	2.125 ^{1/}	2.125	1.500 ^{1/}	1.500	0.750 ^{1/}	0.750
TOTAL, SLEEVE ENGAGEMENT MECHANISM OPERATING			274.448		130.813		27.739	
8	2	Mechanical Screw Jacks	4.300	8.600	2.175	4.350	0.174	0.348
9	1	Cross Head and Guide	1.400 ^{1/}	1.400	0.600 ^{1/}	0.600	0.200 ^{1/}	0.200
10	1	Latch	0.600 ^{1/}	0.600	0.190 ^{1/}	0.190	0.010 ^{1/}	0.010
11	4	Grabs	3.000 ^{1/}	12.000	1.750 ^{1/}	7.000	1.000 ^{1/}	4.000
12	1	Housing	2.125 ^{1/}	2.125	1.500 ^{1/}	1.500	0.750 ^{1/}	0.750
13	4	Hydraulic Pistons (Table B-1)	10.797	43.188	5.508	22.032	0.516	2.064
14	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
15	4	Hoist Direct Connections	0.700	2.800	0.175	0.700	0.015	0.060
16	4	Mechanical Pin Connections	2.600	10.400	1.625	6.500	0.650	2.600
TOTAL, SLEEVE ENGAGEMENT MECHANISM STATIC			155.073		76.877		18.098	

^{1/} Assumed values, all other values from Reference 13.

TABLE A-7
FAILURE PROBABILITY CALCULATION
ASSEMBLY: COT DRILL BARREL OPERATING MECHANISM
REFERENCE DESIGN: FIGURE 5.12

Item No.	No. of Items	Item Description	λ = Failure Intensity ($\times 10^{-6}$ hours)					
			High		Medium		Low	
			Each	Total	Each	Total	Each	Total
1	1	Mechanical Screw Assembly (Table B-4)	41.968	41.968	17.638	17.638	0.956	0.956
2	2	Telescoping Kelly Bar and Enclosing Shield	5.220 ^{1/}	10.440	3.940 ^{1/}	7.880	0.157 ^{1/}	0.314
3	3	Telescoping Cylinders (Table B-1)	10.797	32.391	5.508	16.524	0.516	1.548
4	1	Hydraulic Piping System (Table B-1)	73.960	73.960	34.095	34.095	8.066	8.066
5	1	Solenoid Quick Disconnect	0.550	0.550	0.050	0.050	0.036	0.036
6	6	Bearings	3.530	21.180	1.800	10.800	0.072	0.432
7	2	Coupling Gear and Worm Gear	4.300	8.600	2.175	4.350	0.087	0.174
8	1	Lifting Ball	8.000 ^{1/}	8.000	4.500 ^{1/}	4.500	3.200 ^{1/}	3.200
9	4	Springs	0.221	0.884	0.113	0.452	0.004	0.016
10	16	Diamond Tipped Cutters	1.500 ^{1/}	24.000	0.930 ^{1/}	14.880	0.625 ^{1/}	10.000
11	1	Electric Motor	7.500	7.500	0.625	0.625	0.150	0.150
12	4	Tongs	3.000 ^{1/}	12.000	1.750 ^{1/}	7.000	1.000 ^{1/}	4.000
COT DRILL BARREL MECHANISM (OPERATING)				241.473		118.794		28.892
13	4	Latch	0.600	2.400	0.100	0.400	0.010	0.040
14	8	Springs	0.221	1.768	0.113	0.904	0.004	0.032
15	2	Mech. Screw Jacks	4.300	8.600	2.175	4.350	0.174	0.348
16	1	Cross Head and Guide	1.400	1.400	0.600	0.600	0.200	0.200
17	4	Tongs	3.000	12.000	1.750	7.000	1.000	4.000
18	1	Telescoping Cylinder and Hydraulic Piping System (Table B-1)	84.757	84.757	39.603	39.603	8.582	8.582
TOTAL DRILL BARREL MECH. (STATIC)				110.925		52.857		13.202

^{1/}Assumed value, all other values from Reference 13.

TABLE B-1
FAILURE PROBABILITY CALCULATION
TYPICAL HYDRAULIC PISTON AND HYDRAULIC SYSTEM

Item No.		Item Description	Failure Intensity x 10 ⁻⁶ Hours		
			High	Medium	Low
<u>TYPICAL HYDRAULIC PISTON</u>					
1	Hoist 'cem	0.200 ^{1/}	0.020 ^{1/}	0.006 ^{1/}	
2	Hoist Seals	3.000	0.345	0.140	
3	Hoist Piston Connection	0.049	0.025	0.001	
4	Hoist Piston	0.350	0.200	0.080	
5	Hoist Piston Rings	0.350	0.200	0.080	
6	Hoist Cylinder	0.120	0.008	0.005	
7	Hoist Hydraulic Connection	1.348	0.690	0.027	
8	Hoist Cylinder Head	0.160 ^{1/}	0.080 ^{1/}	0.020 ^{1/}	
9	Flexible Metal Hose Including Pipe Connection	5.220	3.940	0.157	
Total - Single, Typical Hydraulic Piston			10.797	5.508	0.516
<u>TYPICAL HYDRAULIC PIPING SYSTEM</u>					
10	Hydraulic Piping	0.040 ^{1/}	0.020 ^{1/}	0.010 ^{1/}	
11	Solenoid Valve	0.660 ^{1/}	0.175 ^{1/}	0.118 ^{1/}	
12	Pressure Switches	0.660 ^{1/}	0.175 ^{1/}	0.118 ^{1/}	
13	Valve (Ball)	7.700	4.600	1.110	
14	Pump	27.400	13.500	2.900	
15	Motor	7.500	0.625	0.150	
16	Check Valve	10.200	6.500	1.980	
17	Control Valve	19.800	8.500	1.680	
Total - Typical Hydraulic Piping System			73.960	34.095	8.066

^{1/} Assumed values; all other values from Reference 13.

TABLE B-2
FAILURE PROBABILITY CALCULATION
AUTOMATIC INDEX CONTROL SYSTEM
GUIDANCE CONTROL SYSTEM

Item No.	Item Description	Failure Intensity $\times 10^{-6}$ Hours		
		High	Medium	Low
1	Position Switch	2.290	1.340	0.585
2	Potentiometric Switch	2.290 ^{1/}	1.340 ^{1/}	0.585 ^{1/}
3	Radiation Type Switch	2.290 ^{1/}	1.340 ^{1/}	0.585 ^{1/}
4	Sonic Type Switch	2.290 ^{1/}	1.340 ^{1/}	0.585 ^{1/}
5	Speed Switch	1.732	0.870	0.195
6	Power Supply	8.370	5.880	0.100
7	Bistable	10.000	2.980	0.300
8	Signal Modifiers	9.750 ^{1/}	3.490 ^{1/}	1.440 ^{1/}
9	Transducers Signal Conditioners	4.260 ^{1/}	2.300 ^{1/}	1.000 ^{1/}
Total		43.272	20.880	5.375

^{1/} Assumed values; all other values from Reference 11.

TABLE B-3
FAILURE PROBABILITY CALCULATION
TYPICAL LIFTING DEVICE

REFERENCE DESIGN: FIGURE 2.1 AND FIGURE 6.3.2⁽¹⁾

Item No.	Item Description	Failure Intensity $\times 10^{-6}$ Hours		
		High	Medium	Low
1	Electric Motor	7.500	0.625	0.150
2	Gear Reducer	4.300	2.175	0.087
3	Screws (2 units)	8.600 ^{1/}	4.350 ^{1/}	0.174 ^{1/}
4	Electrical Connection	4.700	2.000	0.030
5	Cross Head and Guide	1.400 ^{1/}	0.600 ^{1/}	0.200 ^{1/}
6	Drive Shaft Connection (Mechanical)	1.348	0.688	0.027
7	Drive Shaft Bearings (4 units)	14.120	7.200	0.288
8	Latch (Reference Figure 6.3.2 ^[1])	0.600 ^{1/}	0.100 ^{1/}	0.010 ^{1/}
9	Hoist Connection	0.050	0.020	0.001
10	Latch to Stem Connection	2.600	1.625	0.650
11	Hydraulic Piston (Table B-1)	10.797	5.508	0.516
12	Hydraulic Piping (Table B-1)	73.960	34.095	8.066
Total - Lifting Device		129.975	58.986	10.199

^{1/} Assumed values; all other values from Reference 13.

TABLE B-4
FAILURE PROBABILITY CALCULATION
TYPICAL MECHANICAL SCREW JACK ASSEMBLY

Item No.	Item Description	Failure Intensity $\times 10^{-6}$ Hours		
		High	Medium	Low
1	Electric Motor	7.500	0.625	0.150
2	Gear Reducer	4.300	2.175	0.087
3	Screws (2 Units)	8.600 ^{1/}	4.350 ^{1/}	0.174 ^{1/}
4	Electrical Connection	4.700	2.000	0.030
5	Cross Head and Guide	1.400 ^{1/}	0.600 ^{1/}	0.200 ^{1/}
6	Drive Shaft Connection (Mechanical)	1.348	0.688	0.027
7	Drive Shaft Bearings (4 Units)	14.120	7.200	0.288
TOTAL MECHANICAL SCREW JACK ASSEMBLY		41.968	17.638	0.956

^{1/} Assumed value, all other values from Reference 13.

APPENDIX C

CANISTER EXTRACTION AND TRANSPORT TIME ESTIMATES

Retrieval using a concrete plug handling and sleeve removal machine and a sleeve and canister extraction/transporter machine.

Estimated time to retrieve a canister

A. Plug Overcore Machine (POM), Reference 1, Figures 6a, 6b, 6c, 8a and 8b

<u>Sleeve and Plug Removal</u>	<u>Minutes per Operation, Maximum</u>
1. Locate overhole	2.5
2. Engage shielding port - exit operator from POM	2.5
3. Open port	0.5
4. Engage sleeve plug, remove plug	2.0
5. Rotate plug and locate overcore drill over hole	3.0
6. Overcore around upper portion of sleeve	80.0
7. Retract overcore drill, rotate and locate sleeve cutter-remover over hole	2.5
8. Lower sleeve cutter-remover, clamp and cut upper sleeve	15.0
9. Raise sleeve cutter-remover with sleeve portion retained	2.0
10. Close port and pause for operator entry	2.0
11. Disengage shielding port	2.5
12. Back off and stop for COT positioning	<u>2.5</u>
Subtotal	117.0
13. Dwell time and exit operator (CET positioned at hole) (Includes 6 minute delays for shut- down and restart of POM)	(296.0)

<u>Backfill of Empty Emplacement</u>	<u>Minutes per Operation, Maximum</u>
14. Locate over hole	2.5
15. Engage shielding port	2.5
16. Open port	0.5
17. Lower sleeve cutter-remover and release upper portion of sleeve	2.0
18. Raise sleeve cutter-remover and rotate to locate plug over port	2.5
19. Lower plug into hole and release	2.0
20. Raise plug lift ram	2.0
21. Release core drill cutting debris	6.0
22. Close port	2.0
23. Disengage shielding port	2.5
24. Proceed to next hole	<u>2.5</u>
TOTAL (Dwell time excluded)	144.0

B. Canister Overcore Transporter Machine (COT), Reference 1,
Figures 7a, 7b and 7c

Travel

1. Transporter departs from CWSRS	0
2. Corridor travel 4600 ft @ 440 fpm	10.5
3. Room travel 1800 ft @ 220 fpm (rounded up)	<u>8.5</u>
Subtotal	19.0

Extract

4. Locate over hole	2.5
5. Engage shielding port	2.5

<u>Extract (Continued)</u>	<u>Minutes per Operation, Maximum</u>
6. Open port	0.5
7. Lower telescoping drill unit 10 feet @ 5 fpm	2.0
8. Overcore around lower portion of sleeve	260.0
9. Reverse engaging retrieval latches	1.5
10. Raise telescoping drill unit into trans- porter 30 feet @ 5 fpm	6.0
11. Release core drill cutting debris	12.0
12. Close port	0.5
13. Disengage shielding port	<u>2.5</u>
Subtotal	290.0

Travel

14. Room travel 1800 ft @ 220 fpm (rounded up)	8.5
15. Corridor travel 4600 ft @ 440 fpm	<u>10.5</u>
Subtotal	19.0

At Canister Waste Subsurface Receiving Station (CWSRS), Reference 1, Figure 9

16. Locate over shielding	5.0
17. Engage shielding port	2.5
18. Open Canister Transport Basket (CTB) gate and shielding gate	5.0
19. Lower drill unit overpack with canister 25 ft @ 5 fpm	5.0
20. Disengage drill unit and raise ram lift apparatus into COT	5.0
21. Close CTB gate and shielding port gate	5.0

<u>At Canister Waste Subsurface Receiving Station</u> <u>(CWSRS), Reference 1, Figure 9 (Continued)</u>	<u>Minutes per</u> <u>Operation, Maximum</u>
22. Disengage from shielding port	2.5
23. Locate over drill overpack storage port	5.0
24. Engage drill overpack storage port	2.5
25. Open drill overpack storage port gate and CET gate	5.0
26. Lower ram lift apparatus and engage new drill unit	5.0
27. Raise drill unit into transporter	5.0
28. Close drill overpack storage port gate	5.0
29. Disengage drill overpack storage port	2.5
30. Transporter departs CWSRS	-
Subtotal	60.0
TOTAL COT ELAPSED OPERATING TIME	388.0
TOTAL POM/COT CYCLE TIME (See Figure C-1)	440.0

Appendix C Sketch of Time Sequence of Retrieval for Plug Overcore Machine and Canister
Overcore/Transporter

Figure C-1
 Time Sequence for One POM and One COT Cycle

440 Minutes
 POM /COT Cycle

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