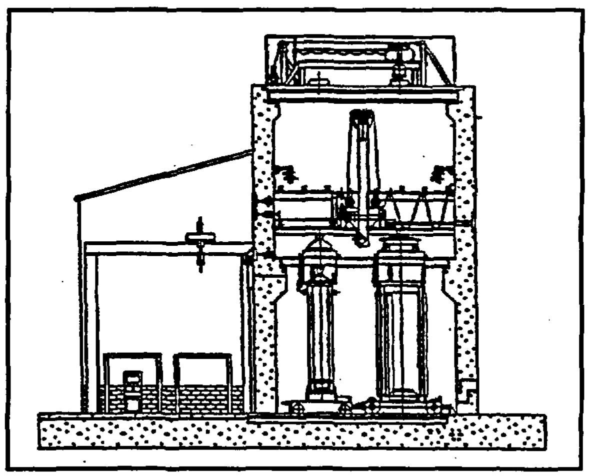
Dry Transfer System Topical Safety Analysis Report

Volume 2



U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

Printed with soy ink on recycled paper

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

CHAPTER 2
SITE CHARACTERISTICS

CHAPTER 3
PRINCIPAL DESIGN CRITERIA

CHAPTER 4
INSTALLATION DESIGN

CHAPTER 5
OPERATION SYSTEMS

APPENDIX 5A
TECHNICAL REPORT FOR THE CONTROL SUBSYSTEM OF THE DRY TRANSFER SYSTEM

CHAPTER 6
SITE GENERATED WASTE CONFINEMENT AND MANAGEMENT

CHAPTER 7
RADIATION PROTECTION

APPENDIX 7A
SHIELDING EVALUATION OF THE DRY TRANSFER SYSTEM

CHAPTER 8
ACCIDENT ANALYSIS

APPENDIX 8A.1
STRUCTURAL ANALYSIS OF DTS

APPENDIX 8A.2
CASK TRANSFER SUBSYSTEM ANALYSIS

APPENDIX 8A.3
RECEIVING AND SOURCE CASK MATING SUBSYSTEM

APPENDIX 8A.4
SHIELD PLUG AND SOURCE CASK LID HANDLING SUBSYSTEM ANALYSIS

APPENDIX 8A.5
FUEL HANDLING CRANE ANALYSIS

APPENDIX 8A.6
DOSE ASSESSMENT FROM OFF-NORMAL CONDITIONS

CHAPTER 9
CONDUCT OF OPERATIONS

CHAPTER 10
OPERATING CONTROLS AND LIMITS

CHAPTER 11
QUALITY ASSURANCE

APPENDIX 11A
TRANSNUCLEAR QUALITY ASSURANCE PROGRAM

LIST OF TABLES

TABLE PAGE

CHAPTER 1

CHAPTER 3

CHAPTER 4

CHAPTER 5

APPENDIX 5A

CHAPTER 6

CHAPTER 7

APPENDIX 7A

CHAPTER 8

APPENDIX 8A.1

APPENDIX 8A.2

APPENDIX 8A.4

APPENDIX 8A.5

APPENDIX 8A.6

CHAPTER 9

CHAPTER 10

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

CHAPTER 3

CHAPTER 4

CHAPTER 5

APPENDIX 5A

CHAPTER 7

APPENDIX 7A

CHAPTER 8

APPENDIX 8A.1

APPENDIX 8A.2

APPENDIX 8A.3

APPENDIX 8A.4

APPENDIX 8A.5

APPENDIX 11A

E-13887
Rev. 0

TECHNICAL REPORT

FOR THE

CONTROL SUBSYSTEM

OF

THE DRY TRANSFER SYSTEM

PROJECT 1051

This document, the property of TRANSNUCLEAR, INC., is furnished subject to return and on demand and on the condition that the information and technology embodied herein shall not be disclosed or used and the document shall not be reproduced or copied whole or in part except as previously authorized by TRANSNUCLEAR, INC.

TRANSNUCLEAR, INC.
TWO SKYLINE DRIVE
HAWTHORNE, NEW YORK 10532

REVISION CONTROL SHEET

Rev No	Effective Date	Affected Sections	Affected Pages	Prepared By	Approval		
					Project Engineer	QA Engineer	Chief Engineer
0	07/27/95	1.0-7.0 App. A	i,vii, 1-142, A-1-A-2	[illegible]	[illegible]	VRP for ED	[illegible]

TABLE OF CONTENTS

LIST OF TABLES

FLOW CHARTS

FLOW CHARTS (Continued)

FLOW CHARTS (Continued)

1.0 REFERENCES

1.1 E-13679, Design Criteria for the Control Subsystem of the Dry Transfer System, Rev. 0.

1.2 Operating Instructions, Cask Transfer Subsystem Specifications (Final Design), NF 00321 22 0004, Rev. A.

1.3 Operating Instructions, TC Cask Mating Subsystem Specifications (Final Design), NF 00321 22 0002, Rev. A.

1.4 Operating Instructions, Transfer Confinement Port/Shield & Lid/Shield Plug Handling Subsystem (Final Design), NF 00321 22 0003, Rev. A.

1.5 Operating Instructions, Fuel Assembly Handling Subsystem Specifications (Final Design), NF 00321 22 0001, Rev. A.

1.6 Procurement Specification for the Closed Circuit Television and Lighting Subsystems of the DTS, E-13738, Rev. 0.

1.7 Transnuclear Design Drawing TN 1051-15, Dry Transfer System HVAC Subsystem Control Schematics

1.8 Transnuclear Design Drawing TN 1051-42, Dry Transfer System Main Control Panel

1.9 Transnuclear Design Drawing TN 1051-43, Dry Transfer System Preparation Area and Lower Access Area Control Panels

1.10 Transnuclear Design Drawing TN 1051-41, Dry Transfer System CCTV & Lighting Subsystems

Notes: See Referenced Document 1.1 for additional references.
See Section 1.2.6 for the correspondence between referrenced Drawings and 3039 series.

2.0 DEFINITIONS

2.1 Introduction

As specified in the referenced document 1.1, the purpose of the Control Subsystem is:

- to allow the control and monitoring of the mechanical equipment including the following subsystems:
  - Cask Transfer Subsystem
  - Transfer Confinement Mating Subsystem
  - Transfer Confinement Port Shield Subsystem
  - MPC Shield Plug and Source Cask Lid Handling Subsystem
  - Fuel Assembly Handling Subsystem
- to allow the control and monitoring of the HVAC Subsystem equipment
- to allow the monitoring of the Radiation Monitoring Subsystem
- to manage the interfaces and interlocks, internal and external to the equipment and subsystems.
- to allow communication between the DTS and the Control Center

2.2 Scope

This report covers the design of the monitoring and control equipment (both hardware and software) of the DTS. The monitoring and control system includes the control panels, equipment used to process information from the sensors on the operating equipment, HVAC system, sliding and roll up doors, Radiation Monitoring equipment, the alarm systems. The sensors and cables for equipment are considered part of the equipment.

The DTS transfer cycle operations can be broken down into three levels:

- Macro-operation level: Opening of a cask...
- Operation level: opening of a port cover, lowering of a grapple...
- Micro-operation level: brake activation, speed regulation...

The Control Subsystem covers the logic of the two first levels providing macro-operation and operation sequences, origin and usage of information for the verification of the conditions to allow each operation processing. These levels have been analyzed for a safe control and monitoring of the operations during normal operating conditions. For the off-normal operating conditions, this document identifies the different alarm levels, their causes and consequences.

3.0 STRUCTURE

3.1 Introduction

This section presents the structure of the Control Subsystem. It describes the human/machine interfaces which are the control and monitoring equipment used by the operator to safely perform a transfer cycle. It shows the different levels in which information is processed, the type of equipment used to process the information and the communication links between the equipment.

The Instrumentation and Control Structural Diagram (see Appendix A) provides a schematic view of the Control Subsystem structure.

3.2 Human/Machine interface locations

As shown in the structural diagram, the human/machine interfaces for the control and monitoring of the equipment are located in three areas:

- the Control Center which is located in a trailer outside the DTS building
- the Preparation Area
- the Lower Access Area

The locally controlled and monitored operations are those involving:

- the Cask Transfer Subsystem (transfer trolleys entry/positioning/removal and locking/unlocking operations)
- the Structural Subsystem (sliding door opening/closing operations)

During all the other operations, workers are not in the DTS building and means are provided to safely control and monitor the operations remotely from the Control Center.

3.3 Local control and monitoring means

Two identical control panels are located in the Lower Access Area and in the Preparation Area (referenced document 1.9) to control the Cask Transfer Subsystem during normal operating conditions. A unique key activates the control panel, in order to give the control to a unique operator. Entry, positioning and removal of the receiving and source casks transfer trolleys are controlled by these panels.

The control of the sliding door is performed using specific control panels located in the Lower Access Area and in the Preparation Area.

Communication means are provided to enable communication between the Control Center and the Preparation Area or the Lower Access Area.

3.4 Remote control and monitoring means

The following instrumentation is provided to remotely control and monitor operations during normal conditions:

- a video system (2 CCTV displays, Intensity Control Units and Camera Control Units) (referenced document 1.6)
- one main control panel (referenced document 1.8)
- a personal computer (PC)
- a monitoring display
- an audio system

The operating cycle is completely controlled by the operator. Each operation is controlled independently and there is no automatic sequence. The main control panel permits the operator to control every remote operation by use of pushbuttons and joysticks and to control the power of each equipment group (locking device and motorization for example).

A monitoring display animated by a monitoring software (supervisor) provides a schematic representation of all the equipment status, motions and positions which are necessary to monitor the process and validate operations in order to safely control the process. It provides information for the monitoring of the HVAC Subsystem and the Radiation Monitoring Subsystem too. In addition, an Instruction Guide listing the steps to be completed by the operator is displayed, based on the monitoring information.

Two CCTV displays provide viewing of the Lower Access Area, of the Transfer Confinement Area and of the upper part of the cask baskets. They permit the operator to validate different operations and transition conditions, and also to help him to position the transfer tube above a cell, to check the correct entry of a fuel assembly in a cask and to detect either physical problems on equipment or abnormal process conditions.

The computer also enables the operator to set the coordinates of the target position of the fuel transfer tube to activate its automatic positioning (see Section 5.2.5).

The audio system provides another monitoring means for the operations which occur in the Transfer Confinement Area.

3.5 Between control request and operation processing

The control panel and the PC are linked to two Programmable Logic Controllers (PLC). One PLC controls all the mechanical equipment, while the other controls the sliding door and the HVAC equipment. The PLC controlling the sliding door is linked to the Radiation Monitoring equipment. The PLCs and the PC are linked by a local network.

When a control is requested (control panel), the PLC checks all the safety conditions allowing the operation processing, and the request is transmitted to the electronic cabinets which manage the interface between the Power Subsystem and the equipment. In the other direction, the sensors provide information to the PLC on the different status and positions of the equipment, which transmits it to the PC to animate the supervisor and to update the process data of the instruction guide software.

Concerning the HVAC equipment, the PLC task is esssentially a regulation and alarms task (see Section 5.4).

Concerning the Radiation Monitoring equipment, the PLC task is essentially to check values and transmit them to the supervisor.

3.6 Alarms

The alarms are always directly activated by the detecting equipment. So, the equipment, the instrumentation, the PLC and the PC are linked to the alarm system.

4.0 ANALYSIS OF THE TRANSITION CONDITIONS

4.1 Introduction

As specified in the Referenced Document 1.1, a function of the Control Subsystem is to prevent unsafe control of the transfer operations. The compliance with the operating sequence is achieved through the administrative procedure; there is no automatic checking of the sequence.

The safety of the complete operating cycle depends on the control of each operation. The safety criteria is based on maintaining the integrity of the fuel assemblies, preventing damage to the source cask lid and receiving cask shield plug which would prevent proper closure, keeping radiation exposure to a minimum and ensuring that there is a means to recover from any failure of equipment. The safe control of an operation is achieved by the automatic checking of the iniation conditions which are important to safety. During an operation process, safety is guaranteed by the design of the alarms and by the design of each equipment.

4.2 Nomenclature

All the operation (or macro-operation) results or equipment status are used as conditions to allow the initiation of other operations (or macro-operations). These conditions are identified throughout this document using their acronym.

The condition's acronym, in the case of an operation result, is based on the operation's acronym (cf Referenced Document 1.1) that achieves the condition, using the extension "x" for executed.

Example : Condition : Source Cask Trolley locked
Operation : TCL-*SC*
Condition's acronym : TCL-*SC*-x

The table 4.2.α lists all the equipment status acronyms, linking the equipment, its status, the operations that can influence it and the acronym.

Table 4.2.α
Equipment Status Acronyms

Equipment	Status	Operation	Acronym
TC Cask Mating Subsystem Mating Flange	in upper position	MFLO MFLI	MF-up
	in proper mated position	MFLO MFLI	MF-mp
Source Cask Lid / Receiving Cask Shield Plug Grapple	in upper position	LSPGLO LSPGLI	LSPG-up
	above TC port cover	LSPGLO LSPGLI SCLLI SCLLO SPLI SPLO	LSPG-p1
	at the TC port cover level (MPC shield plug or source cask lid on the TC port cover) Note: These levels are not the same for the Source and the Receiving Casks	LSPGLO LSPGLI SCLLO SCLLI SPLO SPLI	LSPG-p2
	at the cask level Note: These levels are not the same for the Source and the Receiving Casks	LSPGLO LSPGLI SCLLO SCLLI SPLO SPLI	LSPG-p3
	in gripping position	SCLG SCLGD SPG SPGD	LSPG-g

Table 4.2.α (Continued)
Equipment Status Acronyms

Equipment	Status	Operation	Acronym
Source Cask Lid / Receiving Cask Shield Plug Grapple (continued)	in disengaged position	SCLG SCLGD SPG SPGD	LSPG-d
Source Cask Lid / Receiving Cask Shield Plug Handling Subsystem handling cables	not loaded	SCLLO SCLLI SPLO SPLI	LSPHC-nl
Fuel Assembly Handling Subsystem Grapple	in upper z position	FAGLO FAGLI FALO FALI	FAG-up
	in gripping / disengagement z position	FAGLO FALO	FAG-p
	fingers in disengaged position	FAGC FAGD	FAG-d
Fuel Assembly Handling Subsystem handling cable	not loaded	FAGLO FAGLI FALO FALI	FAHC-nl

4.3 Analysis

This section presents the results of the analysis of the transition conditions. The table 4.3.α shows the conditions which are necessary to pass from the operating process step n to n+1. These conditions are classified as internal if the device or system at their source is a part of the same subsystem as the operation to process. Otherwise, they are classified as external. This classification permits one to see the interactions between the different Subsystems.

A transition condition can be necessary to process consecutive operations. The first validation, the administrative control and the interlocks (if applicable) guarantee the validation for the consecutive operations. The Column '↓' provides the index of the last operation depending on this transition (without discontinuity).

Each transition is classified in the Column O/S according to its importance to safety :

- if the transition condition is only necessary for the operating process, it is classified as Operating (O).
- if the transition condition is important to safety, it is classified as Safety (S).

This table doesn't show the operating sequence (cf Referenced Document 1.1) but only the transitions. When extensions exist for an operation that are not specified with the name of the operation to process, it means that the transition is available for a same system (usually Source or Receiving Cask) whatever it is. This table doesn't show the transitions which occur during the processing of two identical macro-operations (for example, the entering and mating of the source and receiving casks).

Table 4.3.α
Transition Conditions

#	Operation to Process	Internal Transition Conditions	↓ #	OS	External Transition Conditions	↓ #	O S
0	TCE	TCU-x	0	0	TCSPC -*(RC & SC)*-x MF-up SDO-x	9 1 3	0 0 0
1	TCP	TCE-x	1	0			
2	TCL	TCP-x	2	0			
3	SDC						
4	SDL	SDC-x		0			
5	MFLO				TCL-x SDL-x	55 53	S 0
6	UCP	USPC- *(RC & SC)*-x LSPG-up	6 9	0 S	Mating successful	52	S
7	USPU	UCP-x	19	S	Radiation level low FAHC-nl	8 22	SS
8	USPO	USPU-x	8	0			
9	TCSPO				USPO-x SDL-x	19	0 S
10	LSPGLO				TCSPO- *(RC & SC)*-x CCP- *PP*-x	13 21	0 S
11	SPGC / SCLGC	LSPG-p3 LSPHC-nl	11 11	0 0			
12	SPLI/SCLLI	LSPG-g	15	S			
13	TCSPOC / TCSPC				LSPG-p1	13	S
14	SPLO / SCLLO				TCSPOC-x / TCSPC- *SC*-x	17 17	0 0
15	SPGD / SCLGD	LSPG-p2 LSPHC-nl	15 15	S S			
16	LSPGLI	LSPG-d	16	S			
17	TCSPC				LSPG-p1	17	0
18	LSPGLI	TCSPC-x	21	0			
19	USPC	LSPG-up	19	0			

Table 4.3.α (Continued)
Transition Conditions

#	Operation to Process	Internal Transition Conditions	↓ #	OS	External Transition Conditions	↓ #	O S
20	USPL	USPC-x	40	S			
21	TCSPO -*(RC & SC)*-x				USPL- *(RC & SC)*-x	40	S
22	TCSPL- *(RC & SC)*	TCSPO- *(RC & SC)*-x	22	0			
23	CCP- *SC* & RPP	CRCC-x FAG-up FAG-d	23 24 25	S S 0	TCSPL- *(RC & SC)*-x	36	S
24	CRCO	CCP- *SC*-x & RPP-x	28 28	S S			
25	FAGLO	CRCO-x	27	S			
26	FAGC	FAG-p	26	0			
27	FALI	FAGC-x	31	S			
28	CRCC- *SC*	FAG-up	30	S			
29	CCP- *RC* & RPP	CRCC-x	30	S			
30	CRCO	CCP-RC-x & RPP-x	34 34	S S			
31	FALO	CRCO-x	33	S			
32	FAGD	FAG-p FAHC-nl	32 37	S S			
33	FAGLI	FAG-d	37	S			
34	CRCC	FAG-up	37	S			
35	CCP- *PP*	CRCC-x	35	0			
36	TCSPU - *(RC & SC)*				CCP-PP-x	50	S
37	TCSPC- *SC* & TCSPOC	TCSPU -*(RC & SC)*-x	37	0			

Table 4.3.α (Continued)
Transition Conditions

#	Operation to Process	Internal Transition Conditions	↓ #	OS	External Transition Conditions	↓ #	O S
38	UCP	USPC-(RC & SC)-x LSPG-up	38 40	0 S	TCSPC-SC-x TCSPOC-x	42 42	S S
39	USPU	UCP-x	50	S	Radiation level low	40	S
40	USPO	USPU-x	40	0			
41	LSPGLO	USPO-x	50	S			
42	SPGC / SCLGC	LSPG-p2	42	0			
43	SPLI / SCLLI	LSPG-g	46	S			
44	TCSPO				LSPG-p1	44	S
45	SPLO / SCLLO				TCSPO-(RC & SC)-x	48	S
46	SPGD / SCLGD	LSPG-p3 LSPHC-nl	46 46	S S			
47	LSPGLI	LSPG-d	47	S			
48	TCSPC				LSPG-p1	49	0
49	LSPGLI	TCSPC-x	55	0			
50	USPC	LSPG-up	50	0			
51	USPL	USPC-x	51	0			
52	MFLI						
53	SDU				MF-up Radiation level nil	56 54	0 S
54	SDO	SDU-x	54	0			
55	TCU				SDO-x	56	0
56	TCR	TCU-x	56	0			

4.4 Transition validation

The means used to validate the transition conditions depend on their level of importance to safety. Most mechanical operations are monitored using the CCTV Subsystem. For the operations which are not important to safety but important with respect to the operation sequence (O), the administrative control, the viewing provided by the CCTV Subsystem and the indications provided by the mechanical equipment (motorization status, device position, ...) are sufficient to validate a transition. Concerning operations which are important to safety (S), this validation means is necessary but not sufficient. These transitions are validated using interlocks between the equipment. These interlocks are managed by the PLCs.

5.0 CONTROL AND MONITORING OF THE EQUIPMENT UNDER NORMAL OPERATING CONDITIONS

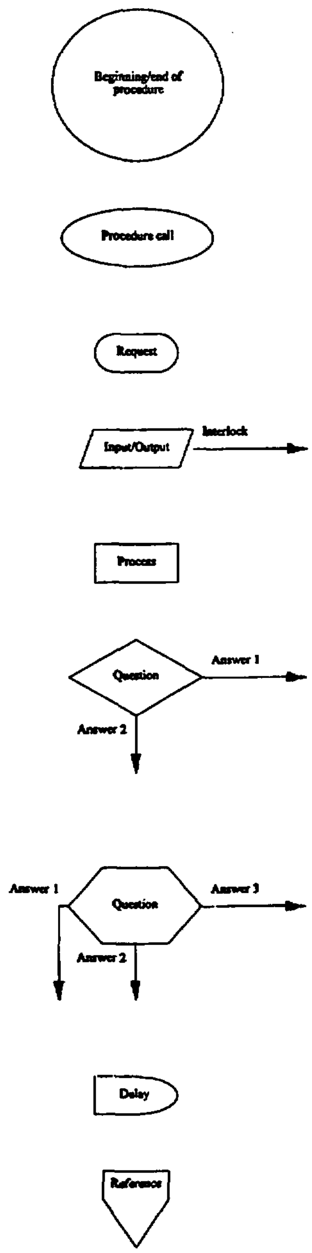
5.1 Introduction

The following flow charts describe the operating sequence, providing the high level procedures call sequence. The acronyms used for the procedure calls are listed in the flow chart table of contents. The flow charts describing the low level procedures (control of one single operation) are provided in each subsection.

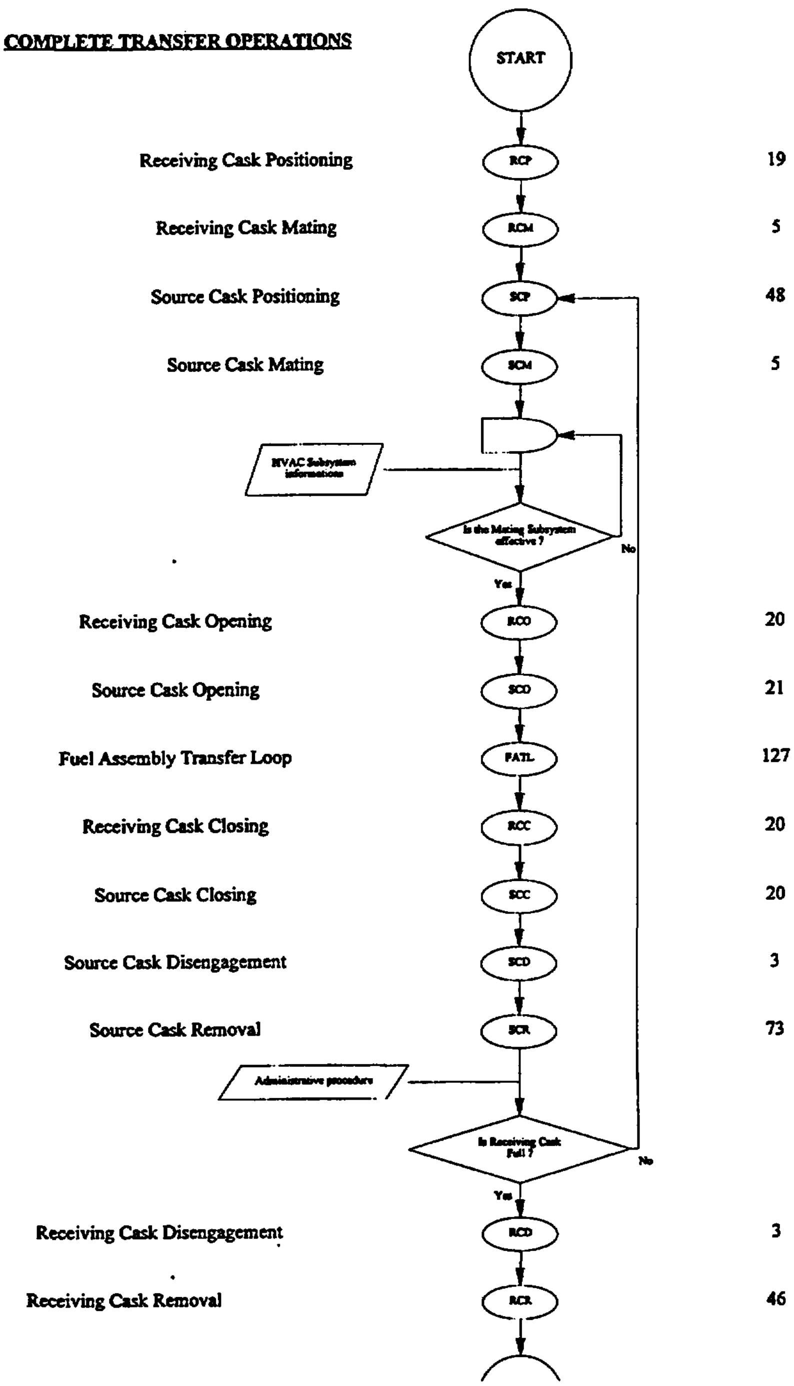
This section provides for all equipment:

- a brief description of the equipment
- a brief description of the operating principle
- the functional requirements for the control, monitoring and alarms
- the transition condition validation requirements including internal and external interlocking requirements, based on the previous analysis of the transitions
- the instrumentation requirements
- the flow charts for the control system

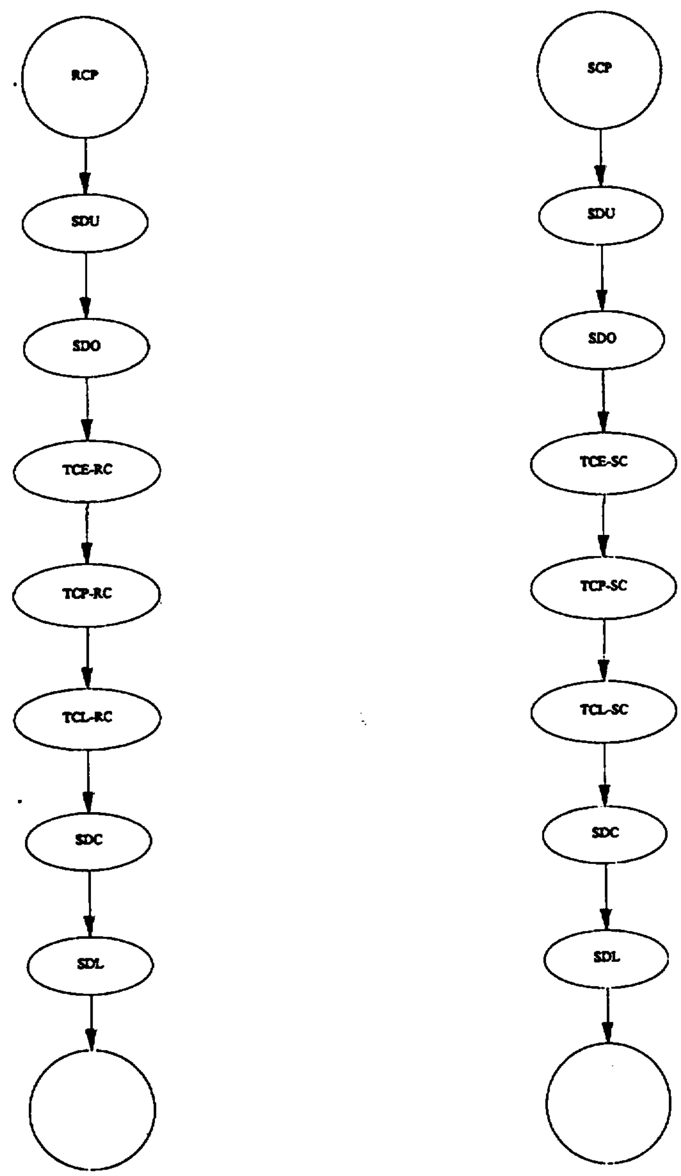
Flow Chart Legend



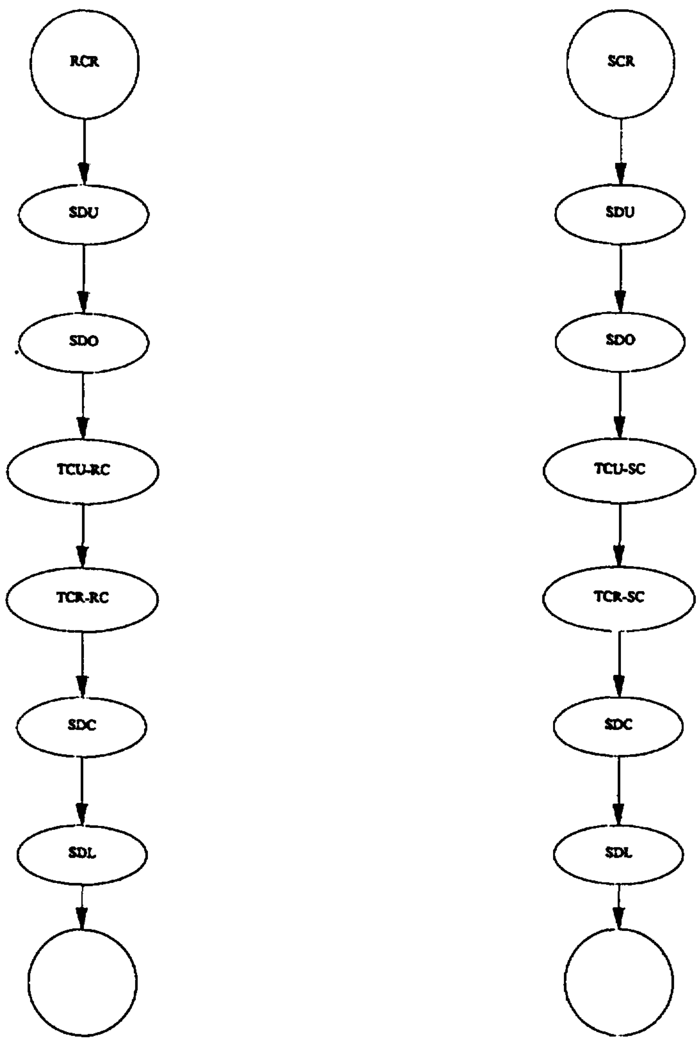
COMPLETE TRANSFER OPERATIONS



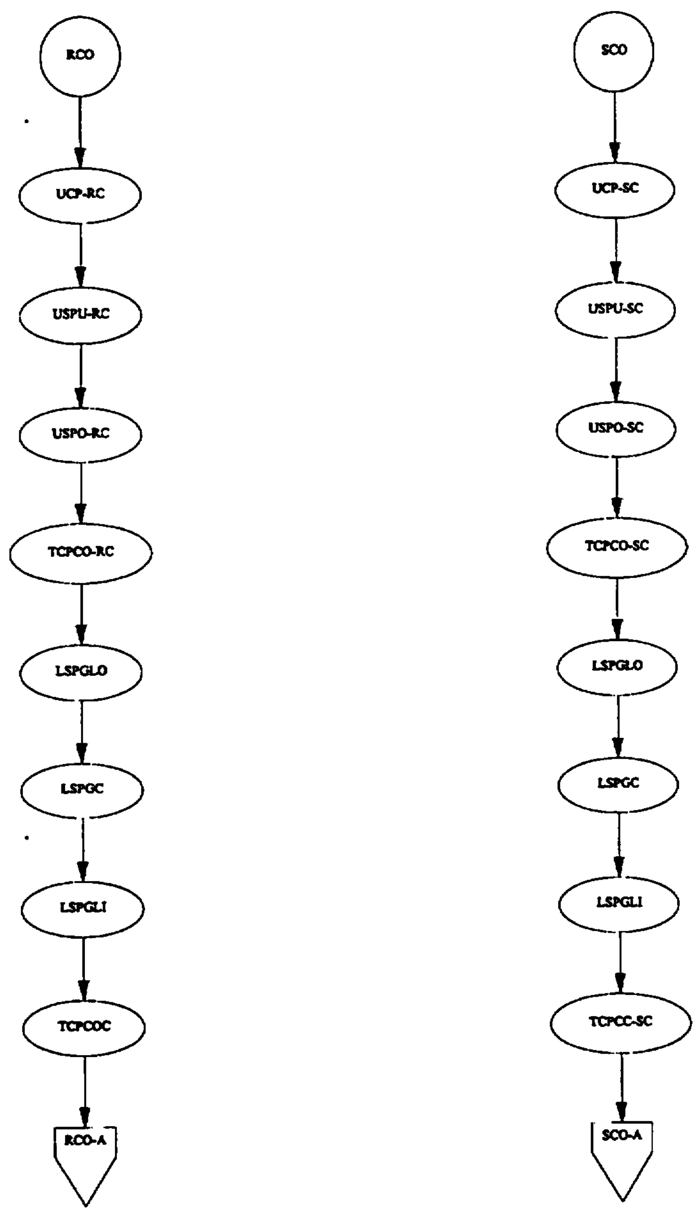
Source and Receiving Casks Positioning

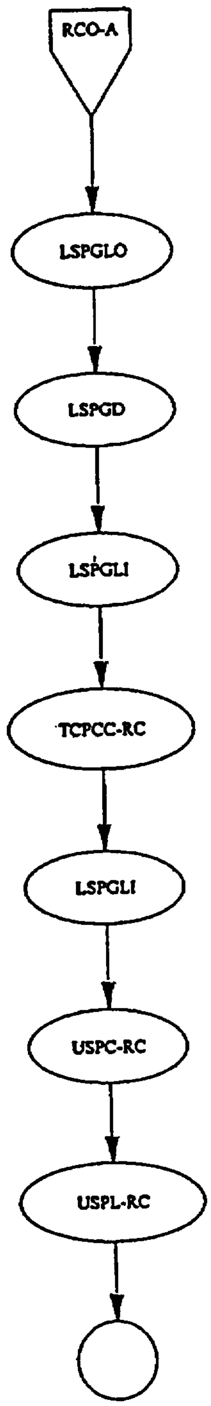


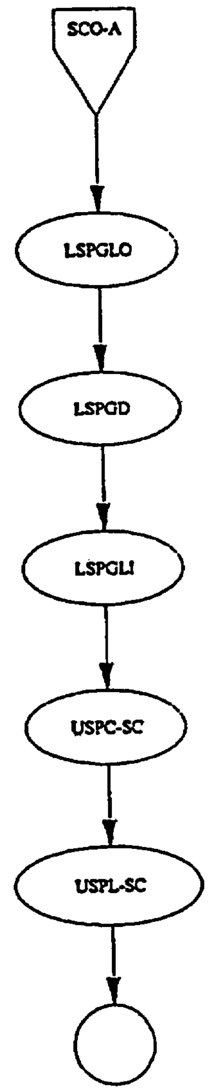
Source and Receiving Casks Removal



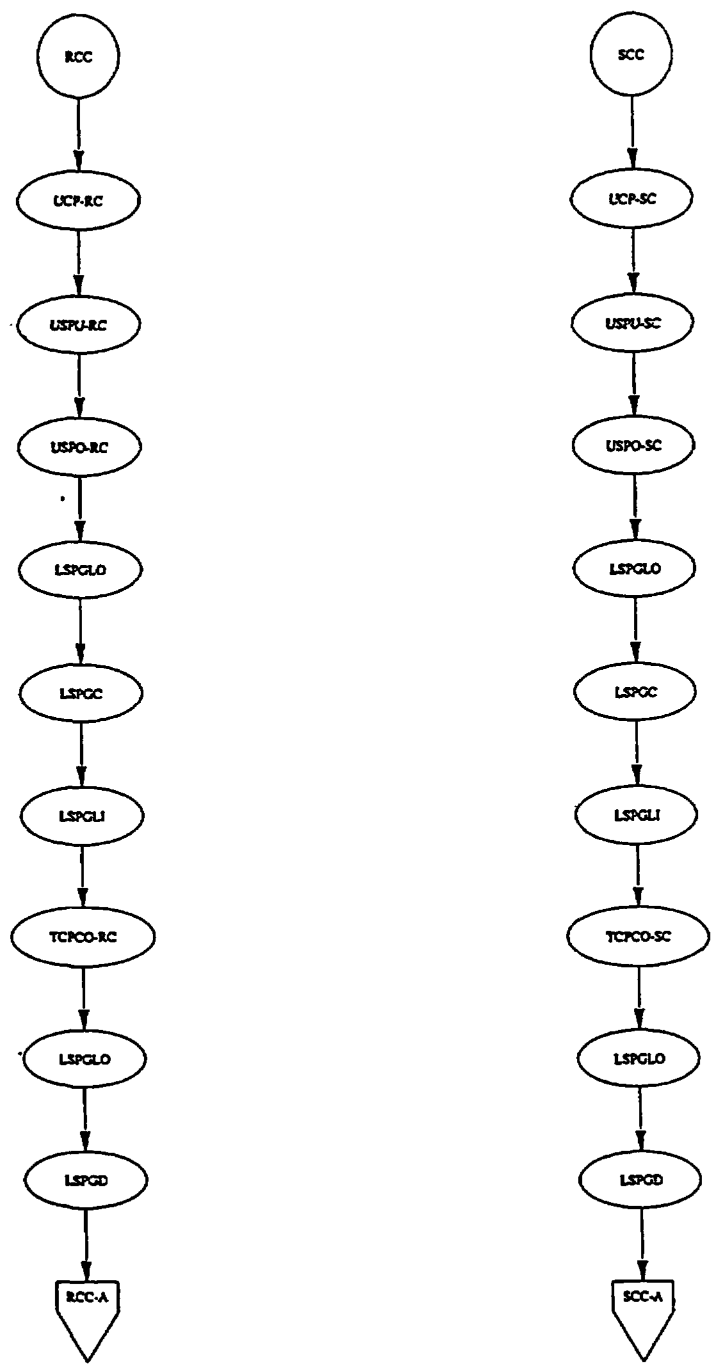
Source and Receiving Casks Opening

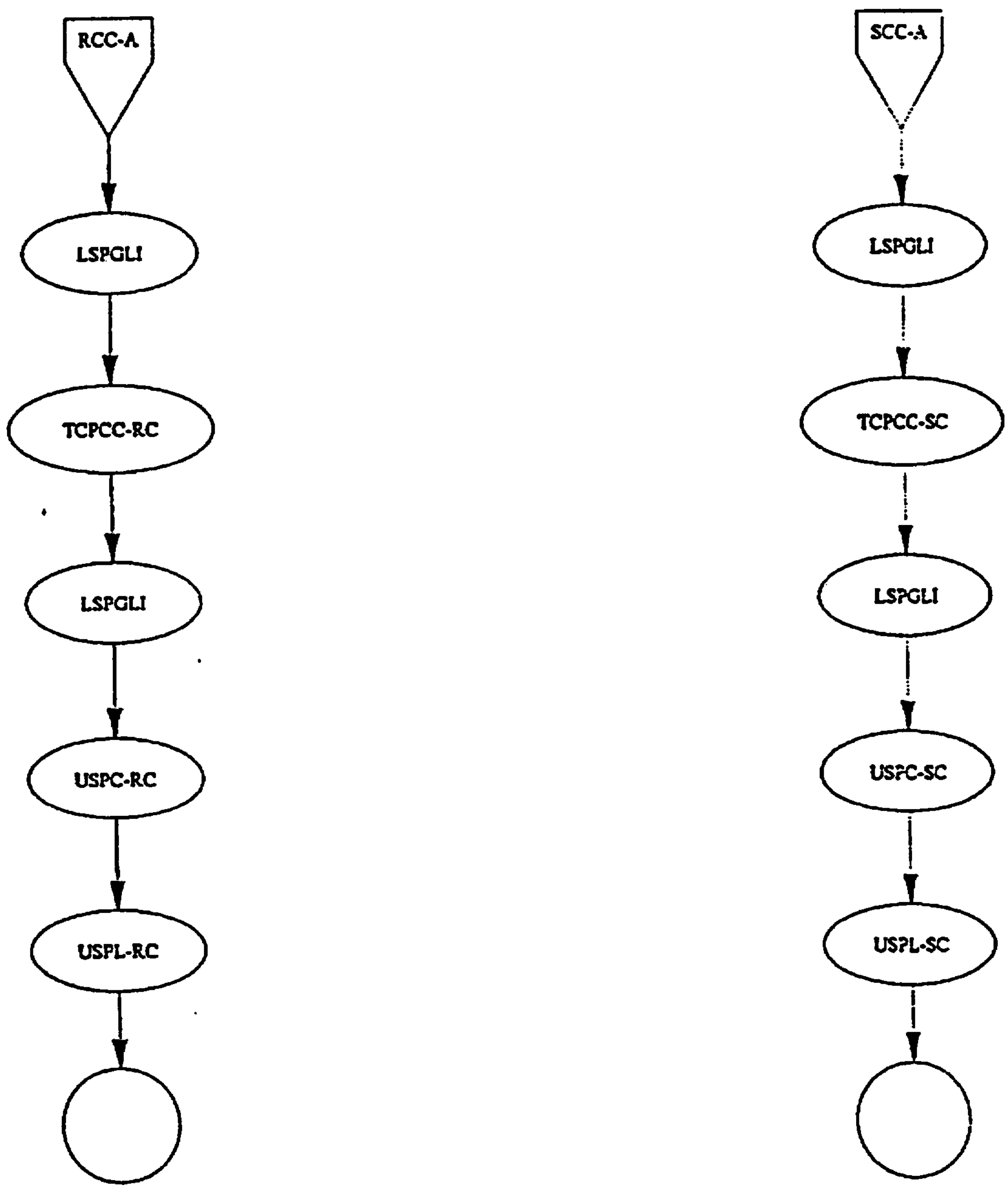



RCO-A
LSPGLO
LSPGD
LSPGLI
TCPCC-RC
LSPGLI
USPC-RC
USPL-RC

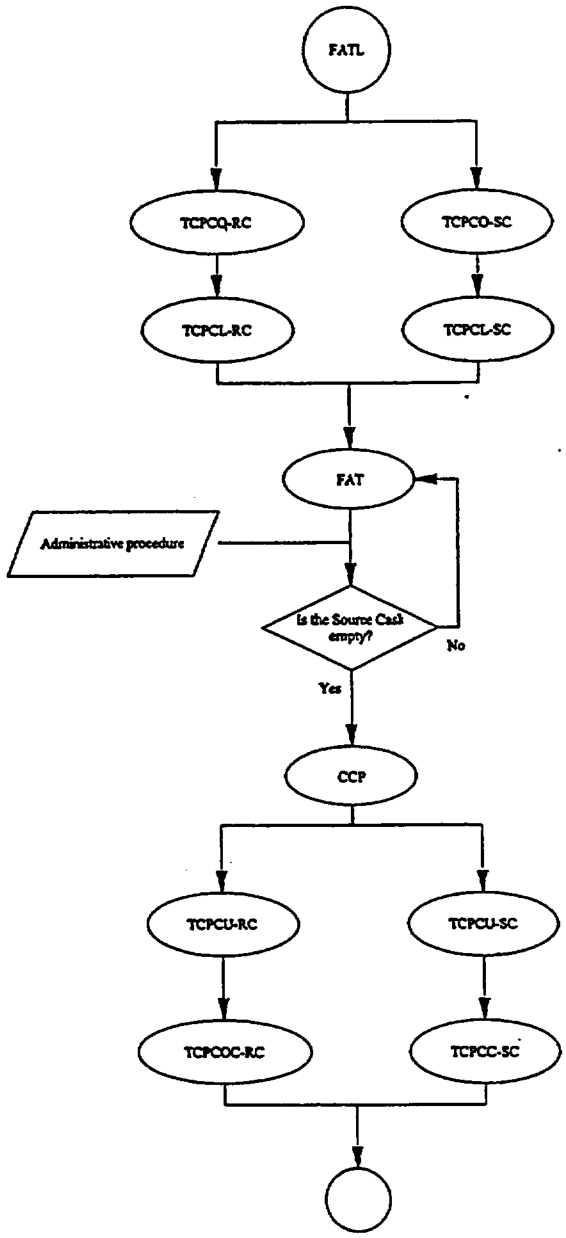

SCO-A
LSPGLO
LSPGD
LSPGLI
USPC-SC
USPL-SC

Source and Receiving Casks Closing

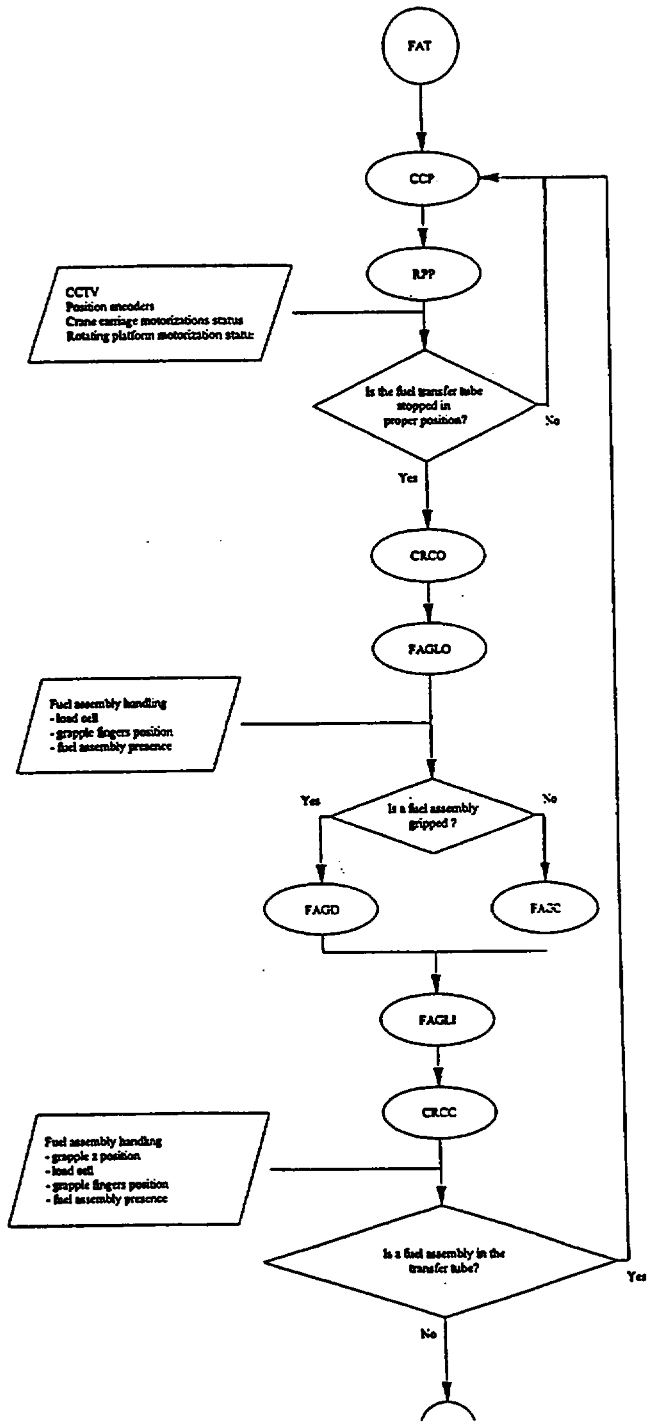



RCC-A
LSPGLI
TCPCC-RC
LSPGLI
USPC-RC
USPL-RC
SCC-A
LSPGLI
TCPCC-SC
LSPGLI
USPC-SC
USPL-SC

Fuel Assembly Transfer Loop



Fuel Assembly Transfer



5.2 Control and monitoring of the mechanical equipment

5.2.1 Control and monitoring of the Cask Transfer Subsystem

5.2.1.1 Description

The Cask Transfer Subsystem permits entry of the source and receiving casks into the Lower Access Area and supports and positions (x direction) them accurately beneath the Mating Subsystem. The equipment that supports the cask is composed of two motor driven trolleys on rails and locking devices (cf Referenced Document 1.2). The Source and Receiving Casks subparts of the Subsystem are identical in regard to the control and monitoring of the operations.

5.2.1.2 Operating principle

The two transfer trolleys are locally controlled by the operator using the Preparation Area or the Lower Access Area control panel. The operator controls the entry, positioning and removal operations by setting the direction and the speed of the trolleys' motorization. The trolleys stop when they reach a specific position in these areas. They are locally monitored by the operator.

5.2.1.3 Control and monitoring requirements

The Control Subsystem for each subpart of the Cask Transfer Subsystem shall :

- Locally control the motorization (run/direction/stop/2 speeds).
- Detect the proper positions of the trolley (stop motion).
- Detect an overrun (alarm + stop motion).
- Detect a collision with a bumper guard (alarm + stop motion).
- Detect a collision between the two trolleys (alarm + stop motion).
- Locally control the locking device (lock/unlock/stop).
- Monitor the position of the locking device (locked/unlocked/undefined).

Only indications on locking positions shall be indicated in the Control Center. The proper positions correspond to the preparation position in the Preparation Area and to the loading/unloading positions in the Lower Access Area. The preparation position is the same for the two trolleys while the other positions are trolley dependent.

5.2.1.4 Transition conditions validation requirements

Rationale:

The control of the motorization is local. Between the cask positioning and removal macro-operations of a source cask, no operator will be present in the Lower Access Area. The access to the Lower Access Areas is regulated by the Radiation Monitoring Subsystem (interlocked with the sliding door of the Structural Subsystem). The transfer trolleys shall only be unlocked locally, which guarantees that a cask will always be closed (lid/shield plug on) when its transfer trolley is unlocked. There is no interlock on this equipment.

Dependent equipment:

TC Cask Mating Subsystem - mating flanges

5.2.1.5 Instrumentation requirements

Redundant instrumentation is not necessary for the control of the trolleys since a recovery system is provided.

Table 5.2.1.α lists the necessary instrumentation for the Cask Transfer Subsystem.

5.2.1.6 Flow charts

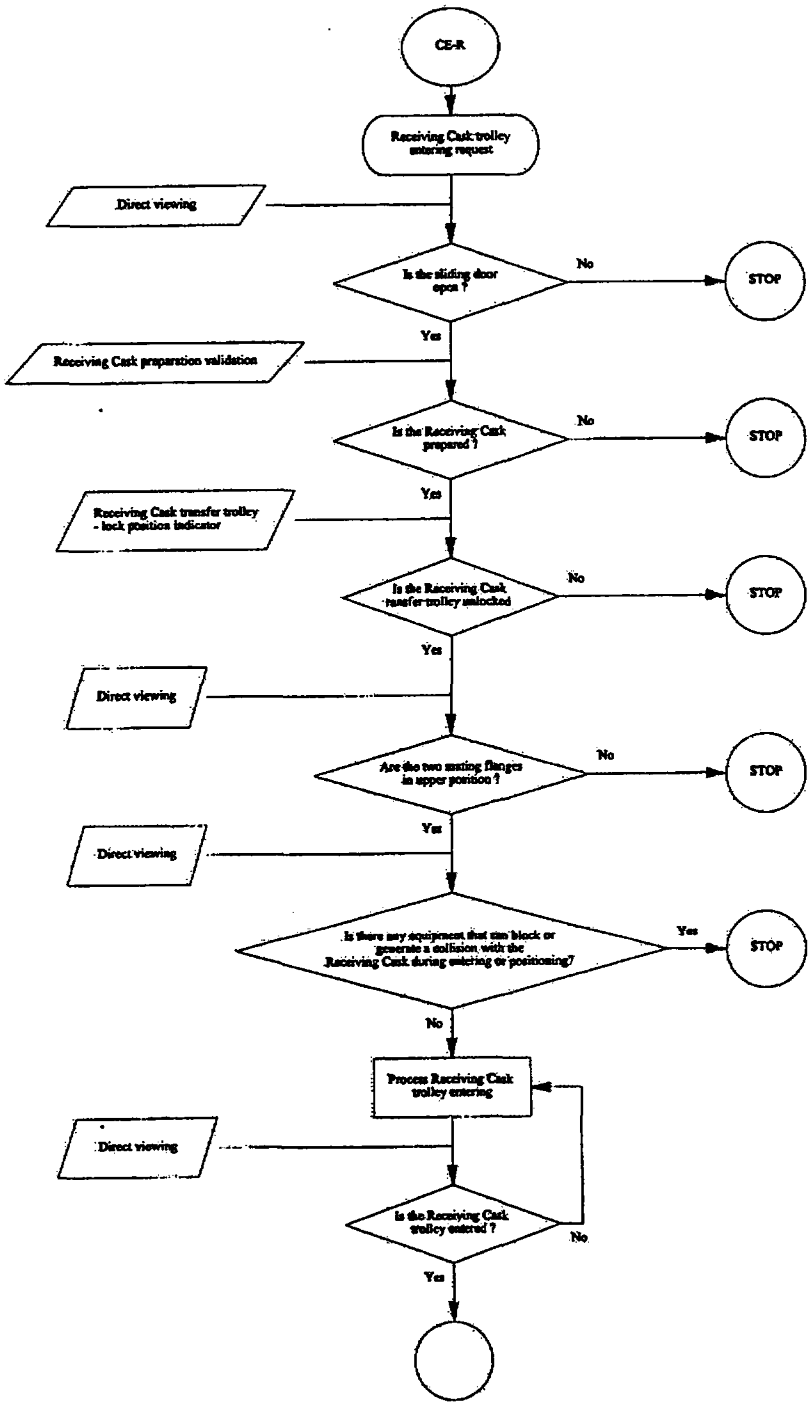
The flow charts describe the control for the following operations:

- Entry in the Lower Access Area of a cask on its transfer trolley (receiving and source casks)
- Positioning of a cask in its transfer position (receiving and source casks)
- Removal of a cask after transfer (receiving and source casks)
- Locking of a transfer trolley in the transfer position (receiving and source casks)
- Unlocking of a transfer trolley (receiving and source casks)

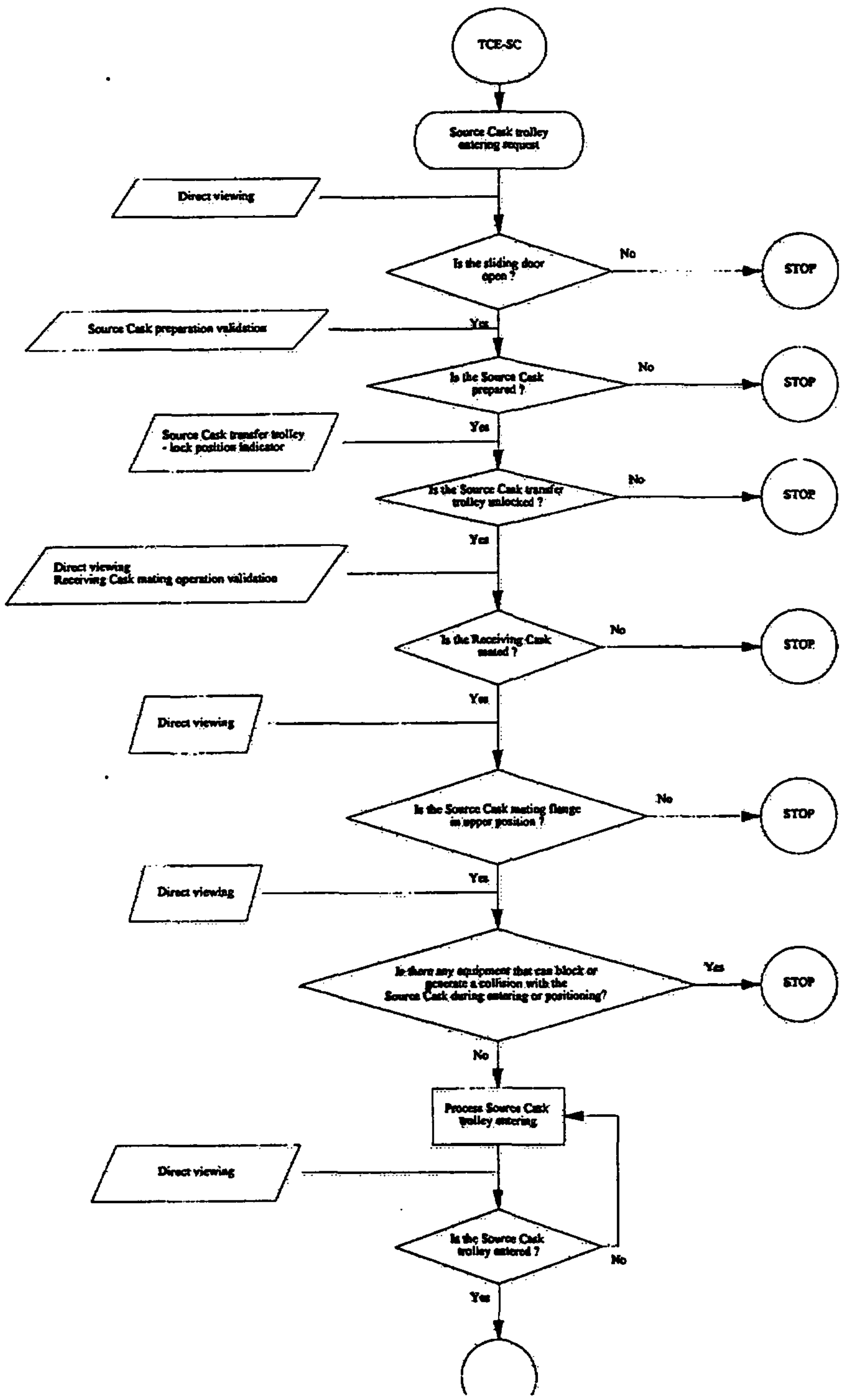
Table 5.2.1.α
Cask Transfer Subsystem Instrumentation

Equipment	Data	Sensor type	Action	Reference
Source cask trolley	Collision with bumper guard	Electrical switch	Stop motion	YAS 401A YAS 401B
Receiving cask trolley	Collision with bumper guard	Electrical switch	Stop motion	YAS 402A YAS 402C
	Collision with source cask trolley	Electrical switch	Stop motion	YAS 402B
Runway rails	Over travel	Electrical switch	Stop motion	ZASH 403D
	Preparation position	Electrical switch	Stop motion	ZS 403B
	Source cask loading position	Electrical switch	Stop motion	ZS 403C
	Receiving cask loading position	Electrical switch	Stop motion	ZS 403D
Ground	Locking at preparation position	Electrical contact	----	YL 404B YL 405B
	Locking at loading position / Source cask	Electrical contact	----	YL 404C
	Locking at loading position / Receiving cask	Electrical contact	----	YL 405C

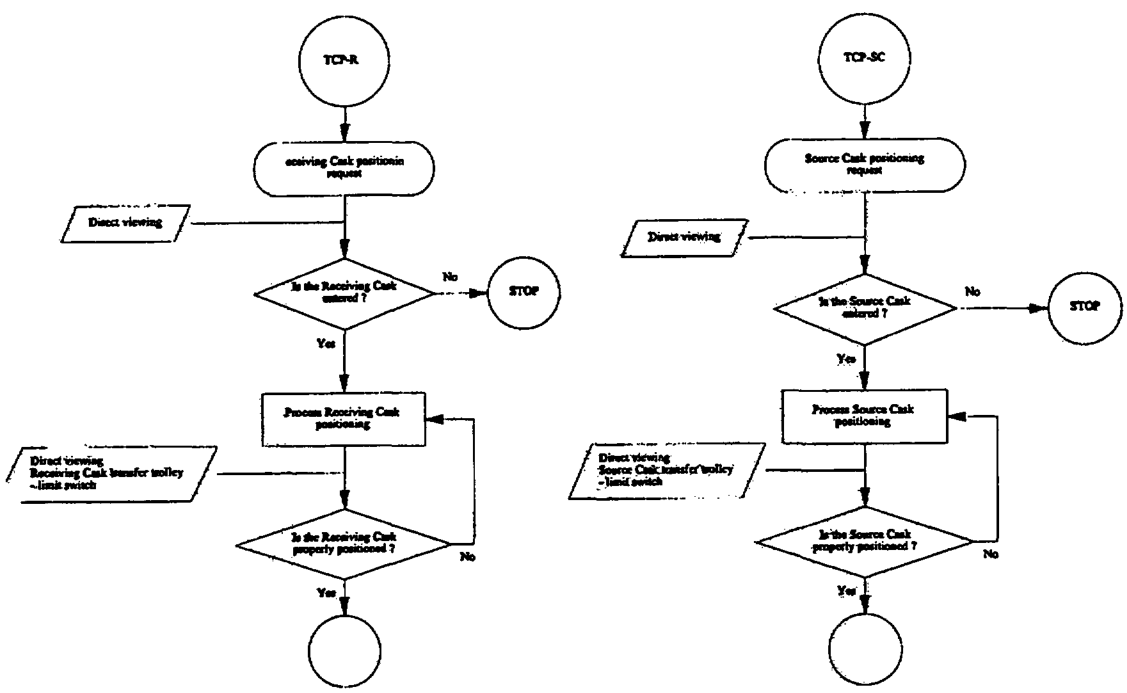
Transfer Cask Entering - Receiving Cask



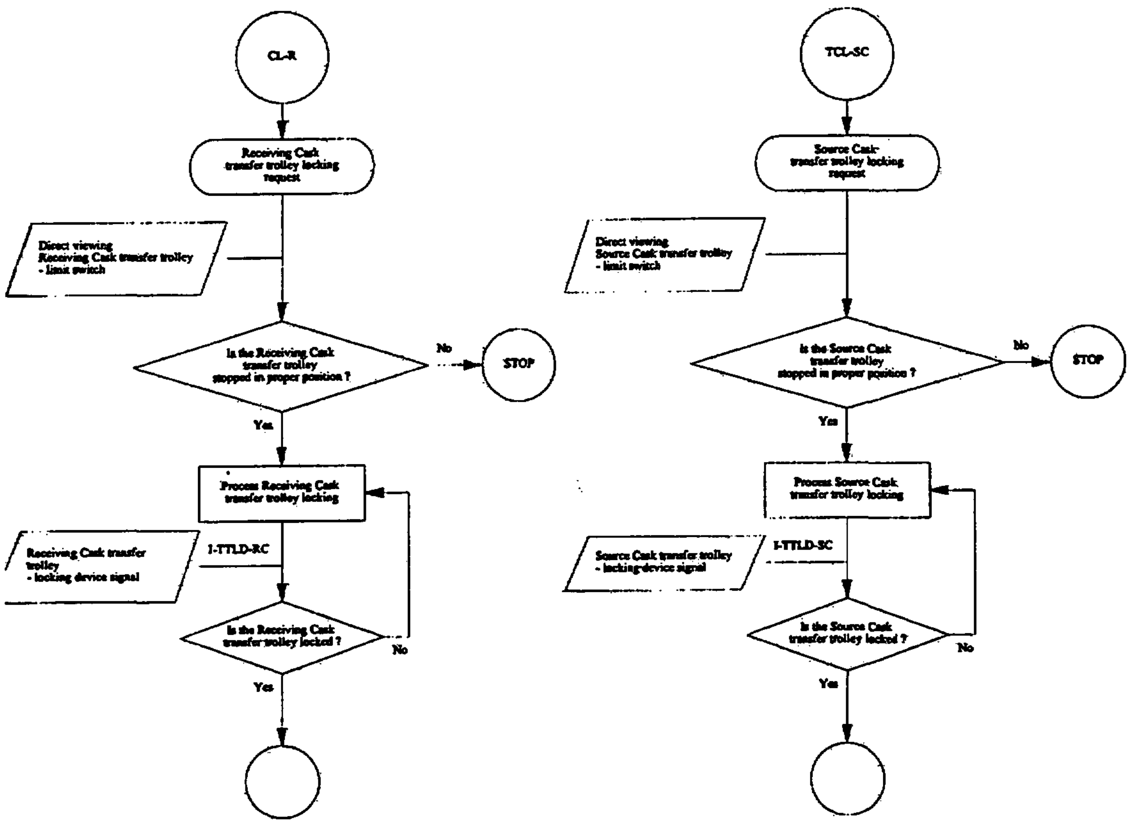
Transfer Cask Entering - Source Cask



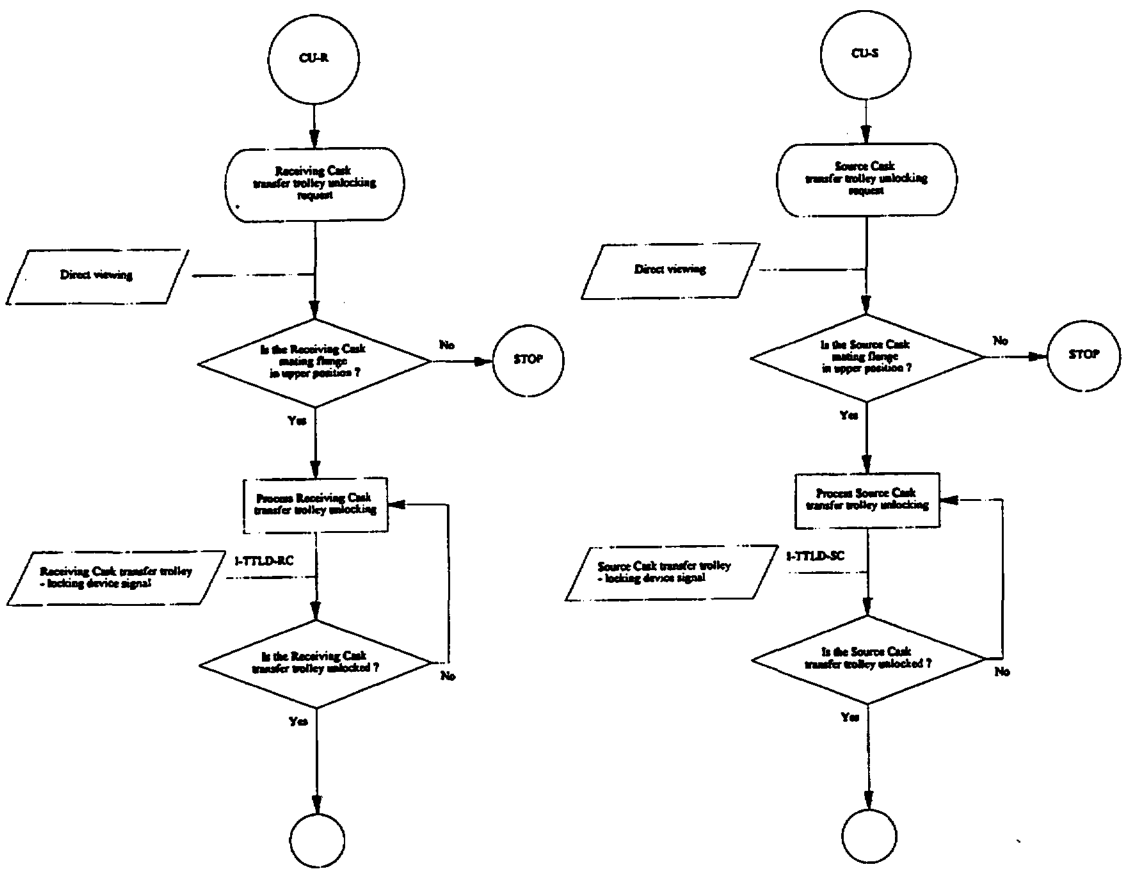
Transfer Cask Positioning - Receiving and Source Casks



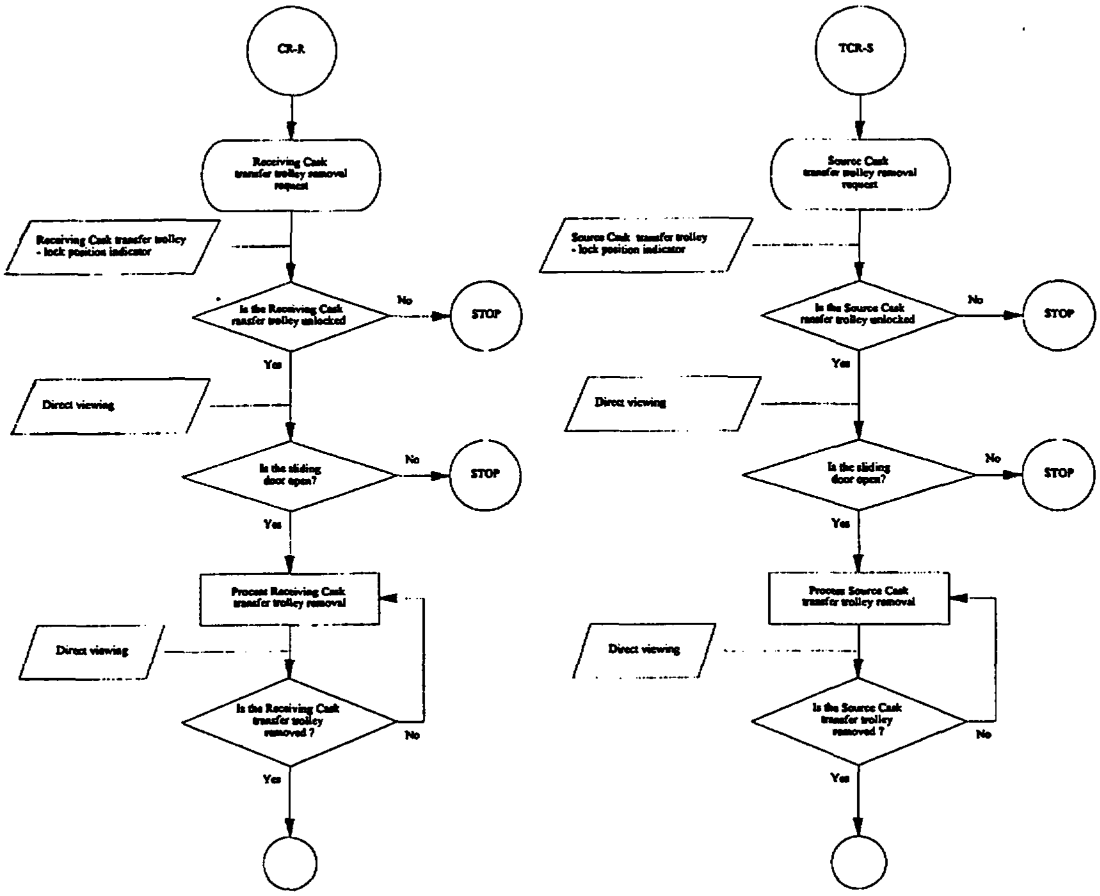
Transfer Cask Locking - Receiving and Source Casks



Transfer Cask Unlocking - Receiving and Source Casks



Transfer Cask Removal- Receiving and Source Casks



5.2.2 Control and monitoring of the Transfer Confinement Cask Mating Subsystem

5.2.2.1 Description

The Transfer Confinement (TC) Cask Mating Subsystem provides the mating and disengagement of the source and receiving casks with the floor of the TC Area (TCA). The Subsystem is divided into two functionnally identical parts, each one using three electric jacks attached to the mating flange, guiding its movement to make it fit around the cask. The mating flange provides a seal through the use of confinement bellows and static seals. Each subpart uses an overlid which permits the gripping and removal of the Source Cask lid/ Receiving Cask shield plug when activated by the lid/shield plug handling grapple (cf Referenced Document 1.3).

The two parts of the Subsystem are identical in regard to the control and monitoring of the operations.

5.2.2.2 Operating principle

The operation is remotely controlled. A camera provides viewing of the motion of the two mating flanges motion and z position. The operator controls the mating and disengagement operations. The electric jacks are operated simultaneously by the PLC.

Mating operations:

Once actuated, the jacks lower the platform until it makes contact with the top of the cask. Each of the three electric jacks individually and automatically stops when the contact load is reached. When the three jacks are stopped, the same procedure is repeated to ensure that the contact with the cask is perfect. The completion of the operation is displayed by the supervisor.

Disengagement operations:

The three jacks are actuated together. The operator has to stop motion when the platform reaches the mezzanine level.

5.2.2.3 Control and monitoring requirements

The Control Subsystem, for each part of the TC Cask Mating Subsystem, shall:

- Control the movement of the mating flange (lower/lift/stop).
- Monitor the mating status (mated/disengaged).
- Monitor the vertical position of each jack.

The proper positioning of the jacks is controlled by a PLC using the electric jack's pressure and vertical position information. The vertical position of each jack and the correct completion of the mating operation is displayed in the Control Center (in case of any load sensor failure).

The mating status is transmitted to the PLC managing the HVAC Subsystem. This information is required to enable the system to properly regulate the HVAC process (see Section 5.4).

5.2.2.4 Transition conditions validation requirements

Requirement:

Interlock the mating flange motion with the locking devices of the Cask Transfer Subsystem. It shall prevent any mating flange lowering if the corresponding Cask Transfer Subsystem trolley is not locked (interlock on one cask).

Rationale:

The interlock is justified by the importance of safely of locking the trolleys in place before starting any cask opening operation.

Dependent equipment:

The TC Cask Mating Subsystem status is never used for interlocks.

5.2.2.5 Instrumentation requirements

Redundant instrumentation is not necessary for the control of the mating flanges because the source and receiving casks are closed (lid / shield plug on) during the mating and disengagement operations, permitting removal and repair of the defective instrumentation.

Table 5.2.2.α lists the necessary instrumentation for the TC Casks Mating Subsystem.

5.2.2.6 Flow charts

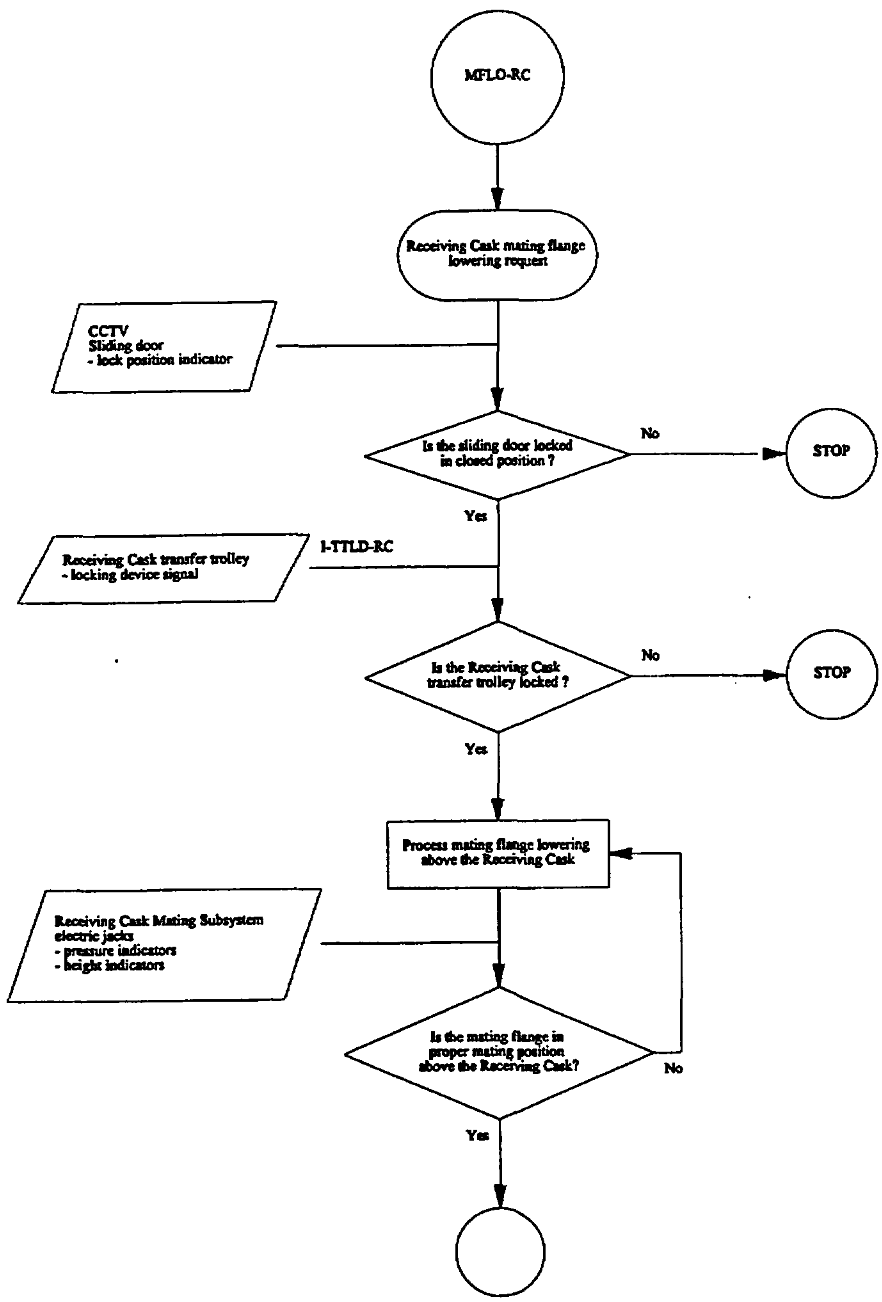
The flow charts describe the control of the following operations:

- Lowering of a mating flange (receiving and source casks)
- Lifting of a mating flange (receiving and source casks)

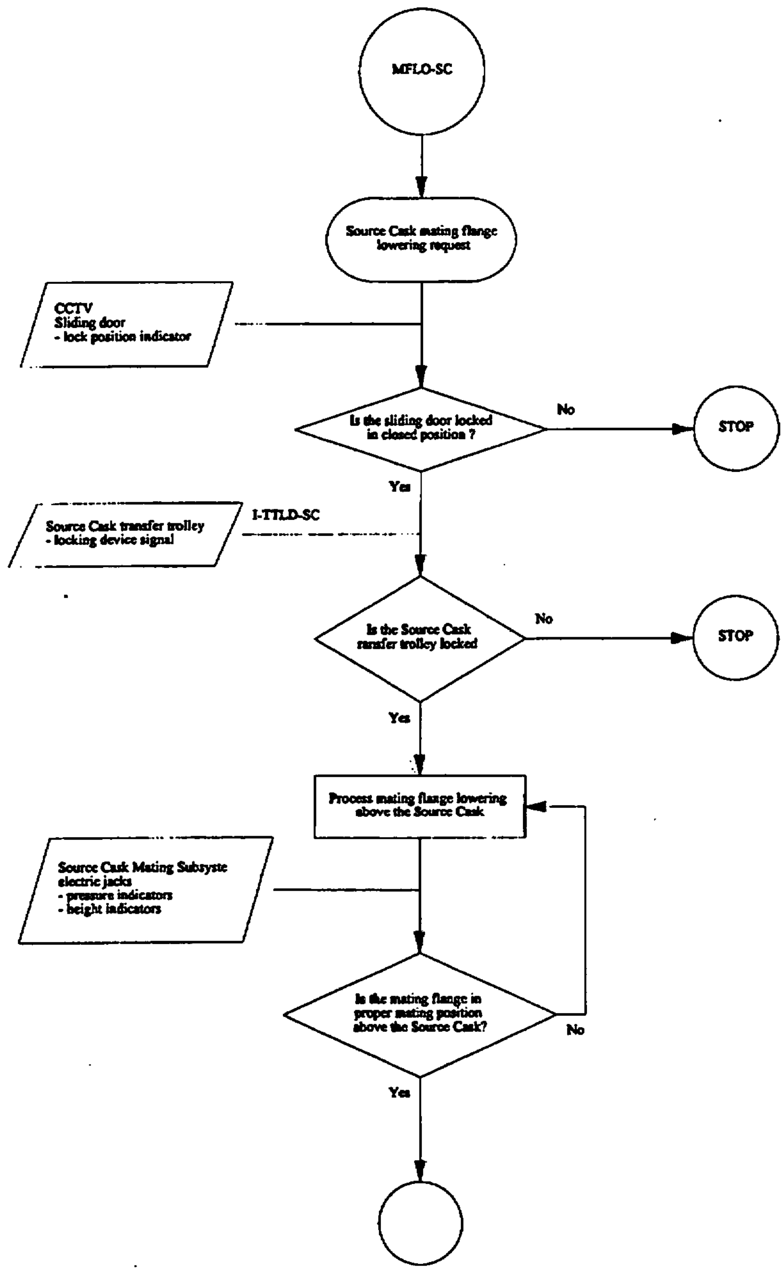
Table 5.2.2.α
TC Casks Mating Subsystem Instrumentation

Equipment	Data	Sensor type	Action	Reference
TC Source cask mating subsystem	Vertical position	Potentiometer	----	ZIT 208A ZIT 208B ZIT 208C
	Pressure operated by jack	Force (or load) sensor	Stop jack lowering	WSH 209A WSH 209B WSH 209C
TC Receiving cask mating subsystem	Vertical position	Potentiometer	----	ZIT 203A ZIT 203B ZIT 203C
	Pressure operated by jack	Force (or load) sensor	Stop jack lowering	WSH 204A WSH 204B WSH 204C

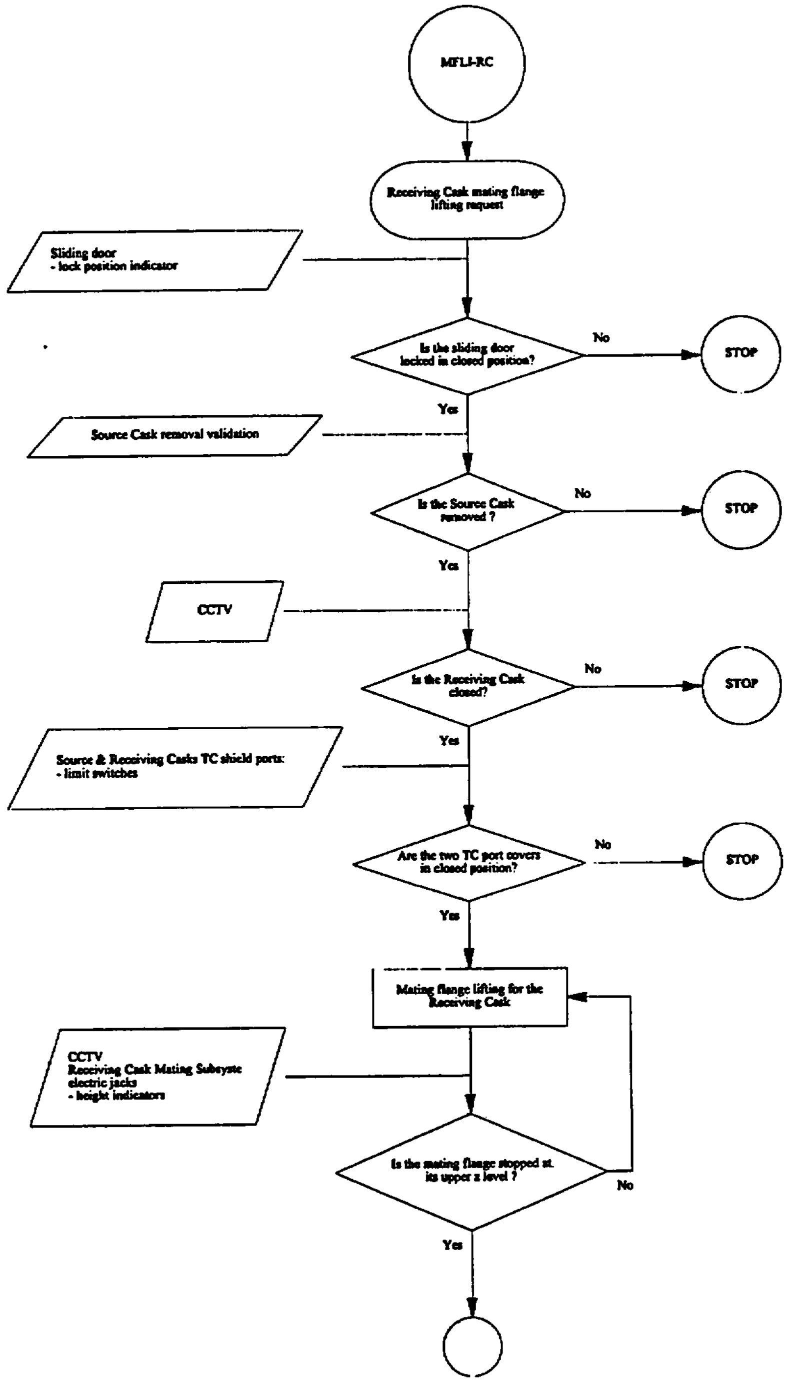
Receiving Cask Mating Flange Lowering



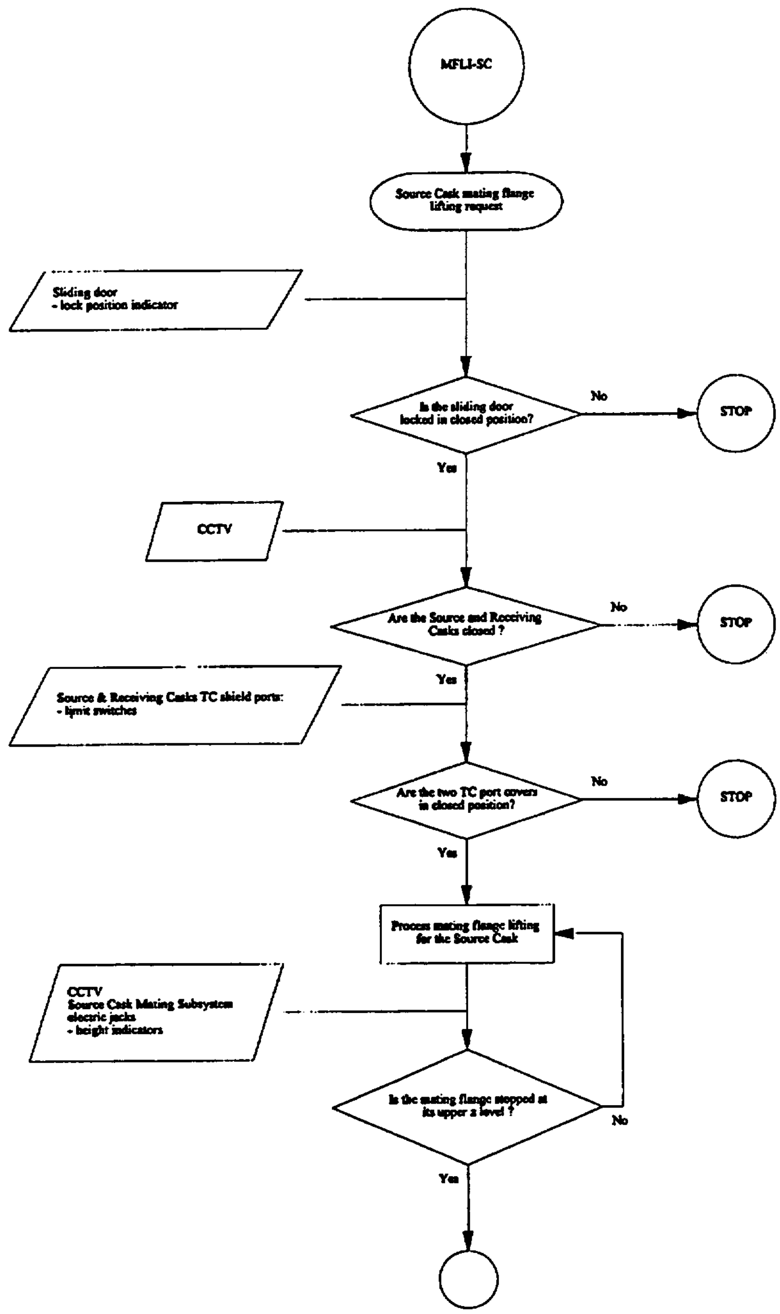
Source Cask Mating Flange Lowering



Receiving Cask Mating Flange Lifting



Source Cask Mating Flange Lifting



5.2.3 Control and monitoring of the Transfer Confinement Port/Shield Handling Subsystem

5.2.3.1 Description

The Transfer Confinement Port/Shield Handling Subsystem consists of two port covers that have a locking device (cf Referenced Document 1.4). They support the source cask lid and receiving cask shield plug when the casks are opened. The ports and the locking devices are actuated by electric jacks.

There are slight differences in the control and monitoring of the two port covers, because the receiving cask shield plug needs to be off centered on the TC port cover (one more specific position).

5.2.3.2 Operating principle

Cameras in the TCA provide viewing of the motion and position of the TC port covers . Both TC port covers and their locking devices are remotely controlled. The locking devices are only used in the open position, prior to transfer of any fuel assembly. Both TC port covers use a finite number of positions and need accurate positioning. The operator activates a TC port cover setting the position to be reached. The TC port cover is automatically stopped when the position is reached. The operator activates a locking device by setting the desired locking position. When the locking operation is completed, the information is transmitted to the supervisor which displays it.

5.2.3.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the movement of the motorized TC port covers (open/close/off center (receiving cask)/stop).
- Detect an overrun (alarm + stop motion).
- Detect the proper position of the TC port covers (stop motion).
- Monitor the TC port covers positions (open/closed/off centered (receiving cask)/undefined).
- Control the TC port covers locking devices (lock/unlock/stop).
- Monitor the lock positions (locked/unlocked/undefined).

All the TC port covers and locking devices' positions are displayed in the Control Center. The overrun detectors are on each side of the runway rails and automatically stop motion when activated.

5.2.3.4 Transition conditions validation requirements

Requirements:

The following interlocks shall be implemented:

- Interlock the TC port covers with the Source Cask Lid and Receiving Cask Shield Plug Handling Subsystem hoist. It shall prevent any TC port cover closing if the lid / shield plug grapple is not stopped above the TC port cover (with lid/shield plug on).

- Interlock the TC port covers with the upper shield ports. It shall prevent any TC port cover opening if the diagonal upper shield port is not closed.

- Interlock the TC port covers and their locking devices with the Fuel Assembly Handling Subsystem crane carriage. It shall prevent any TC port cover unlocking and closing or off-centering if the crane carriage of the Fuel Assembly Handling Subsystem is not stopped in the x and y directions or if fuel is being transferred.

- Interlock the TC port covers with the Structural Subsystem. It shall prevent opening of any TC port cover if the sliding door of the Structural Subsystem is not locked (in closed position).

- Interlock each TC port cover with its locking device. It shall prevent locking if the TC port cover is not in the opened position.

The PLC shall memorize the TC port covers' movements as well as those of the lid/shield plug grapple in order to know (logically) if the lid/shield plug is present on the port cover. This information shall be used to prevent any TC port cover opening when the relative upper shield port is opened if the lid/shield plug hoist is not handling the lid/shield plug and if the cask is not closed.

Rationale:

The interlocks on the TC port covers and their locking device prevent:

- any damage to the fuel assembly during a transfer due to an inadvertent TC port cover closure (seismic event or human error).
- high radiation levels at the upper plate level during the opening or closing of a cask due to a wrong synchronisation between the TC and upper shield ports and the lid/shield plug handling hoist system.
- high radiation levels at the sliding door level in case of a seismic event.
- compromise of recovery requirements (port cover stuck)

Dependent equipment:

Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem - upper shield ports, grapple

Fuel Assembly Handling Subsystem - crane carriage

5.2.3.5 Instrumentation requirements

Redundant instrumentation is not necessary for the control of the TC port covers and their locking devices, since manual backup equipment is provided for the locking devices and the port covers motorizations are outside the building. Two different instrumentations are necessary to detect the locked and unlocked positions of the TC port covers.

Table 5.2.3.α lists the necessary instrumentation for the TC Port Shield Subsystem.

5.2.3.6 Flow charts

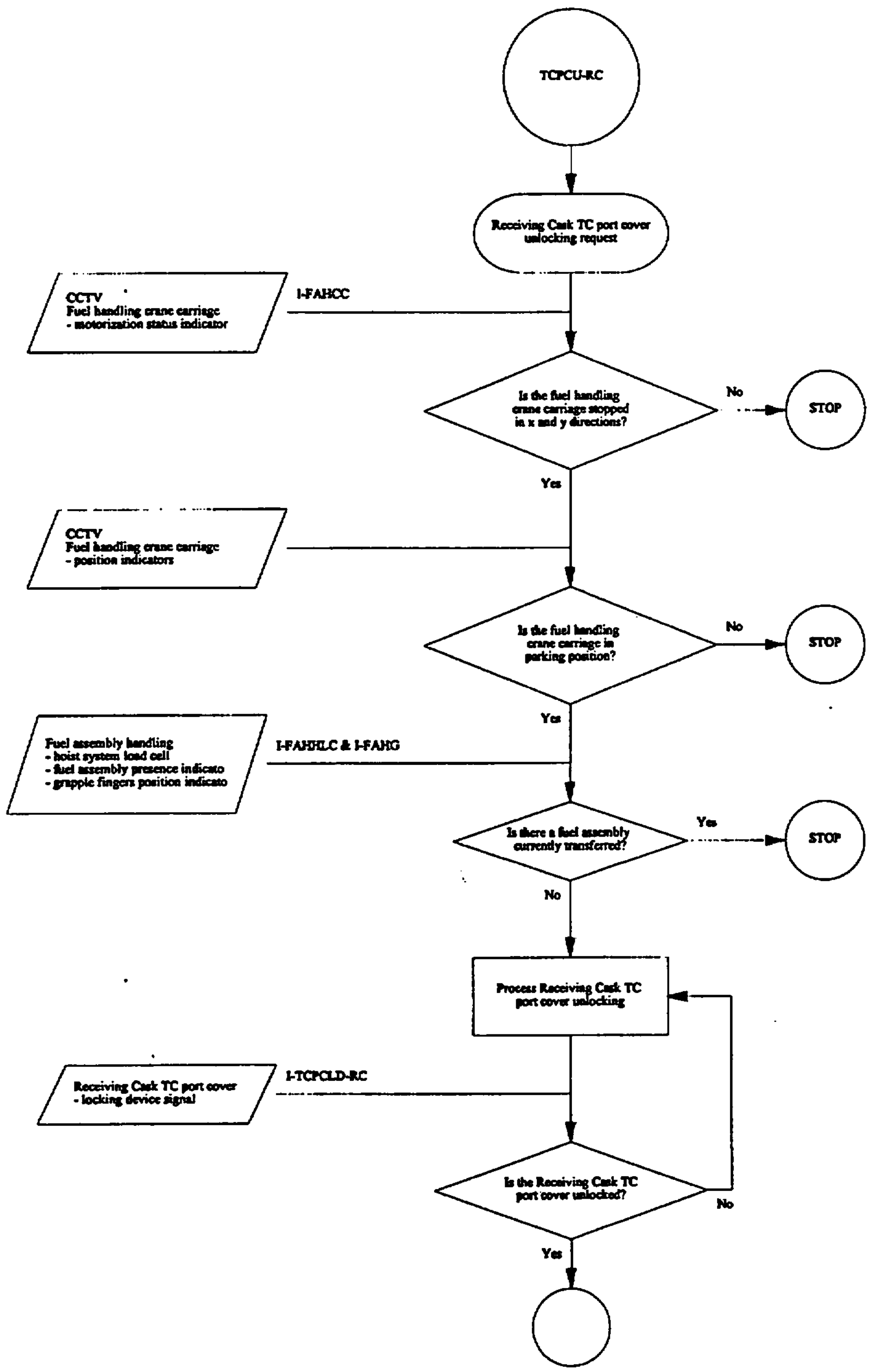
The flow charts describe the control of the following operations:

- TC port cover opening (receiving and source casks)
- TC port cover closing (receiving and source casks)
- TC port cover off centering (receiving cask)
- TC port cover locking (receiving and source casks)
- TC port cover unlocking (receiving and source casks)

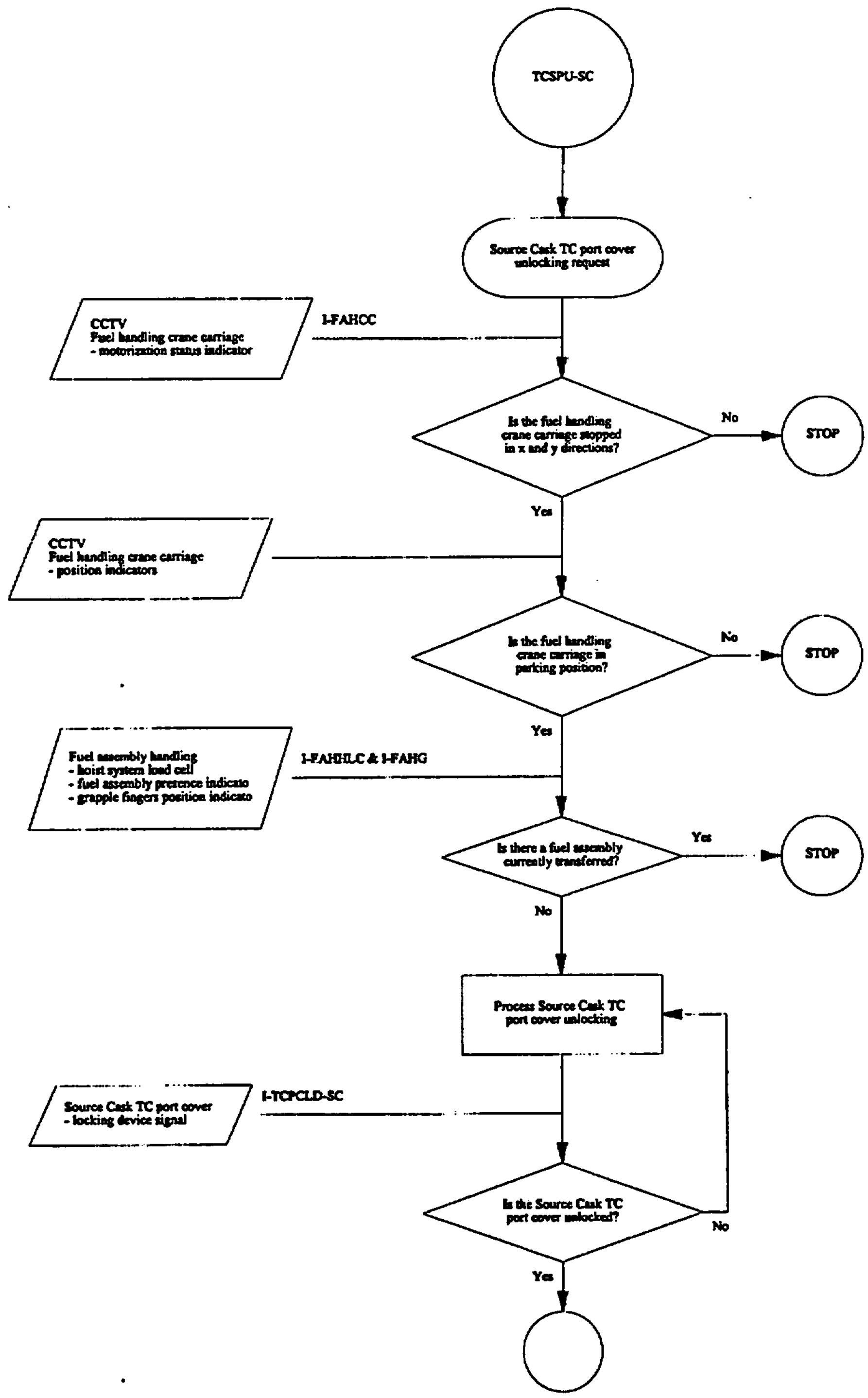
Table 5.2.3.α
TC Port Shield Subsystem Instrumentation

Equipment	Data	Sensor type	Action	Reference
Receiving cask TC port cover	Open position	Electrical switch	Stop motion	ZS 317A
	Closed position	Electrical switch	Stop motion	ZS 317B
	Off centered position	Electrical switch	Stop motion	ZS 317C
	Over travel	Electrical switch	Stop motion	ZASH 317A ZASH 317B
	Locked (in open position)	Electrical contact	----	YL 318A
	Unlocked (in open position)	Electrical contact	----	YL 318B
Source cask TC port cover	Open position	Electrical switch	Stop motion	ZS 315A
	Closed position	Electrical switch	Stop motion	ZS 315B
	Over travel	Electrical switch	Stop motion	ZASH 315A ZASH 315B
	Locked (in open position)	Electrical contact	----	YL 316A
	Unlocked	Electrical contact	----	YL 316B

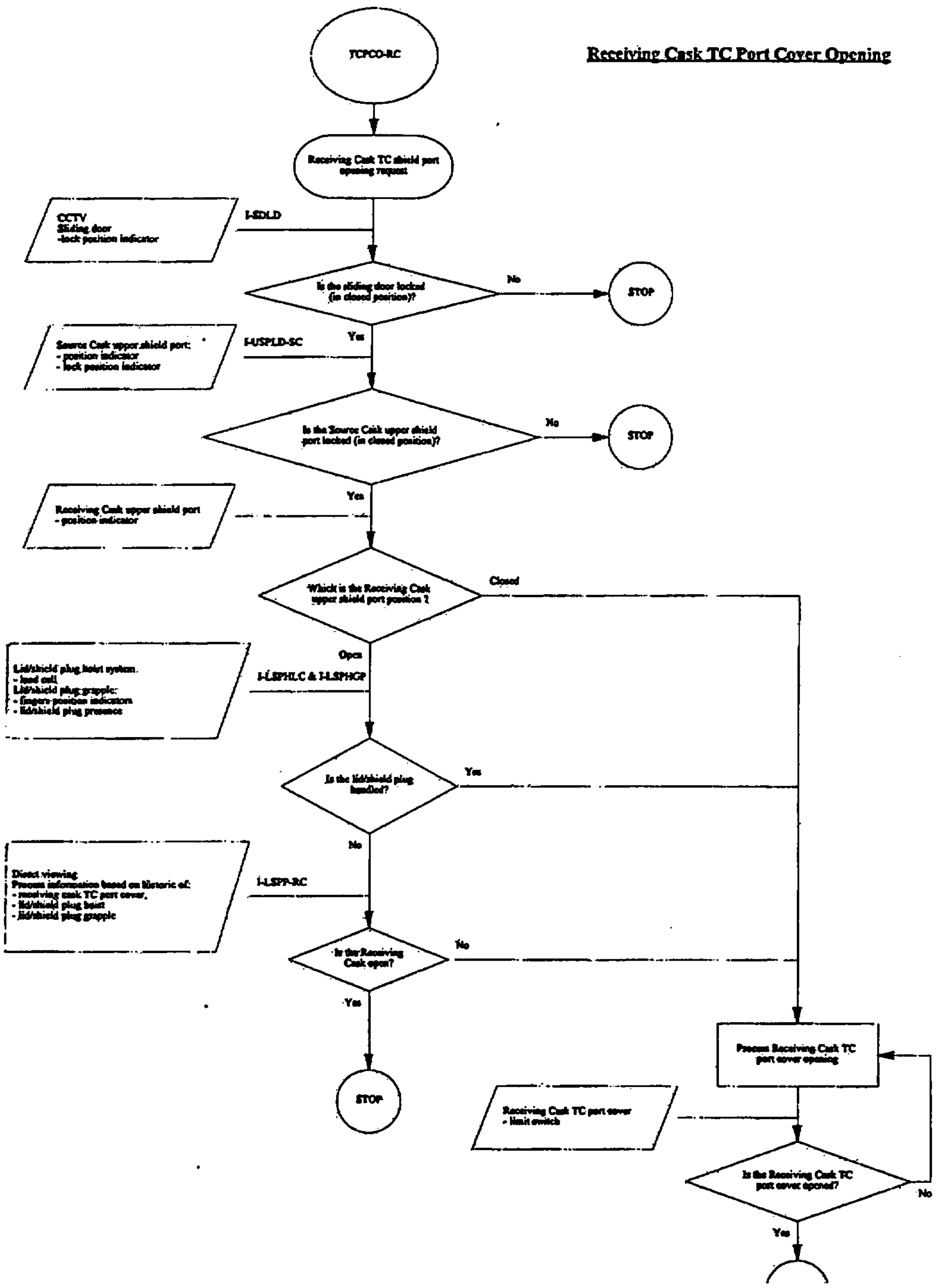
Receiving Cask TC Port Cover Unlocking



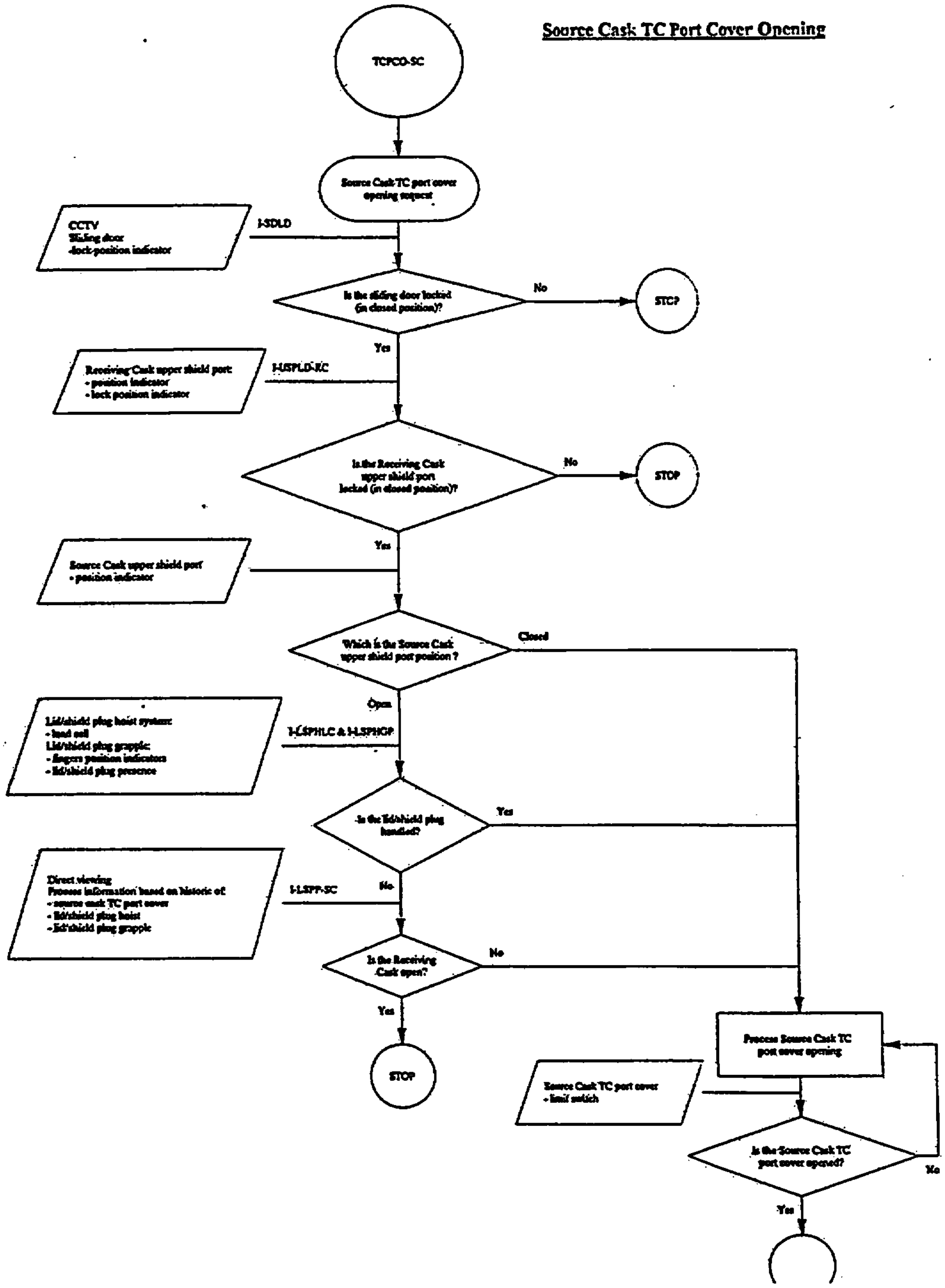
Source Cask TC Port Cover Unlocking



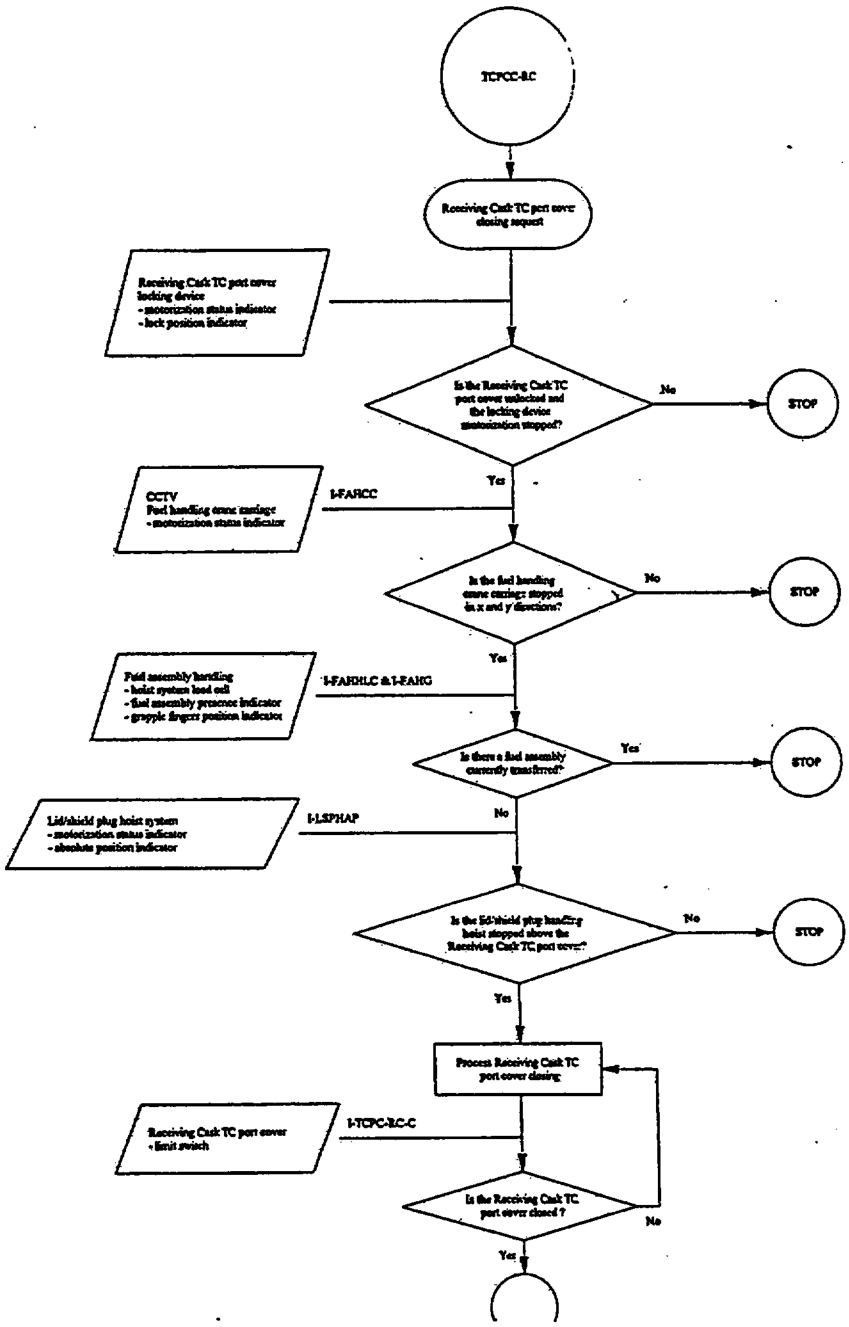
Receiving Cask TC Port Cover Opening



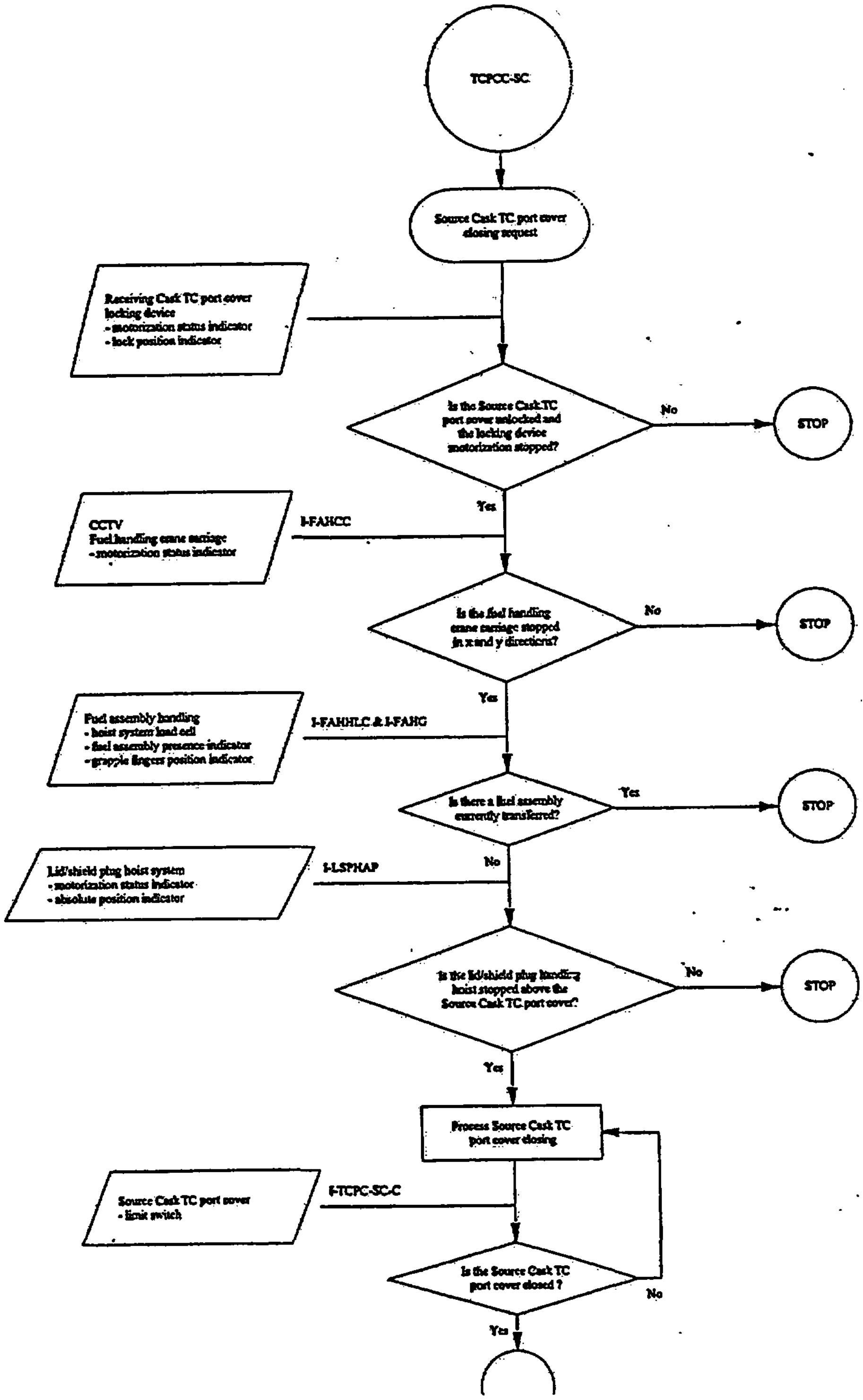
Source Cask TC Port Cover Opening



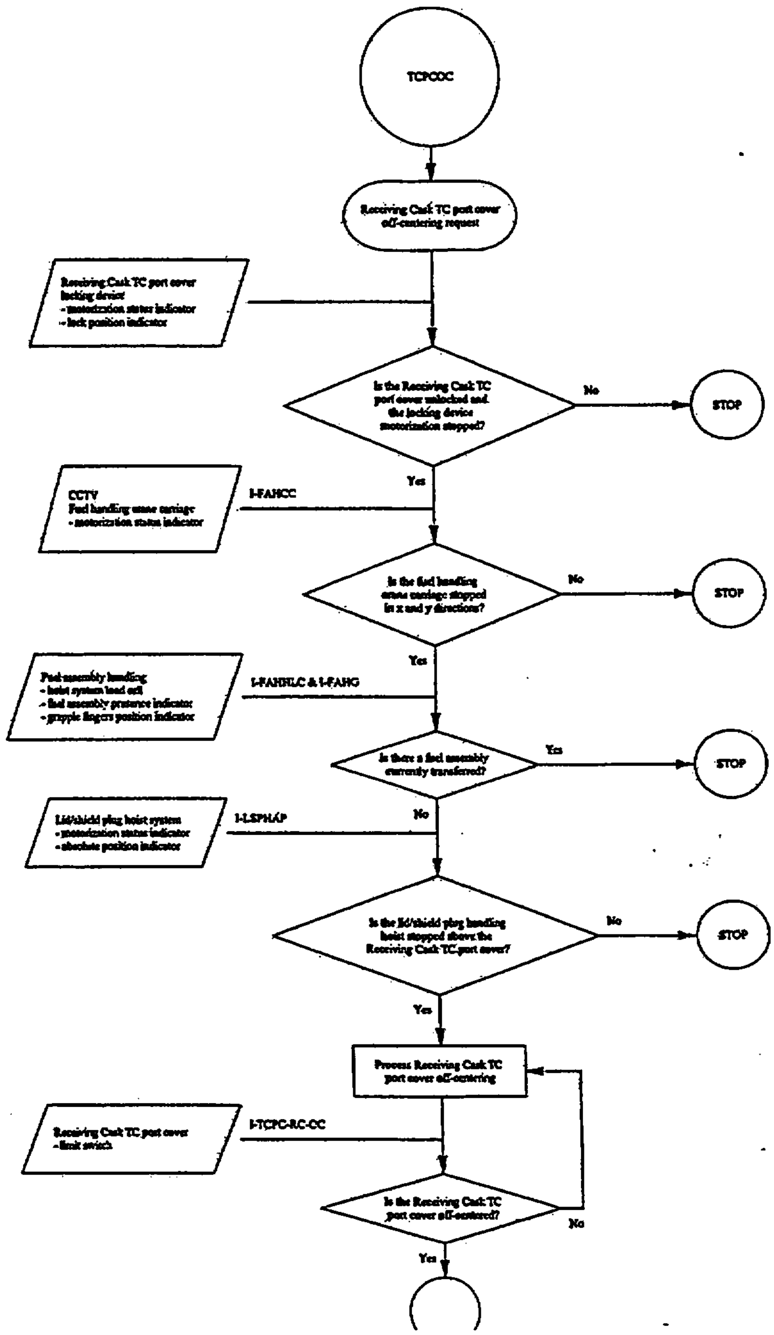
Receiving Cask TC Port Cover Closing



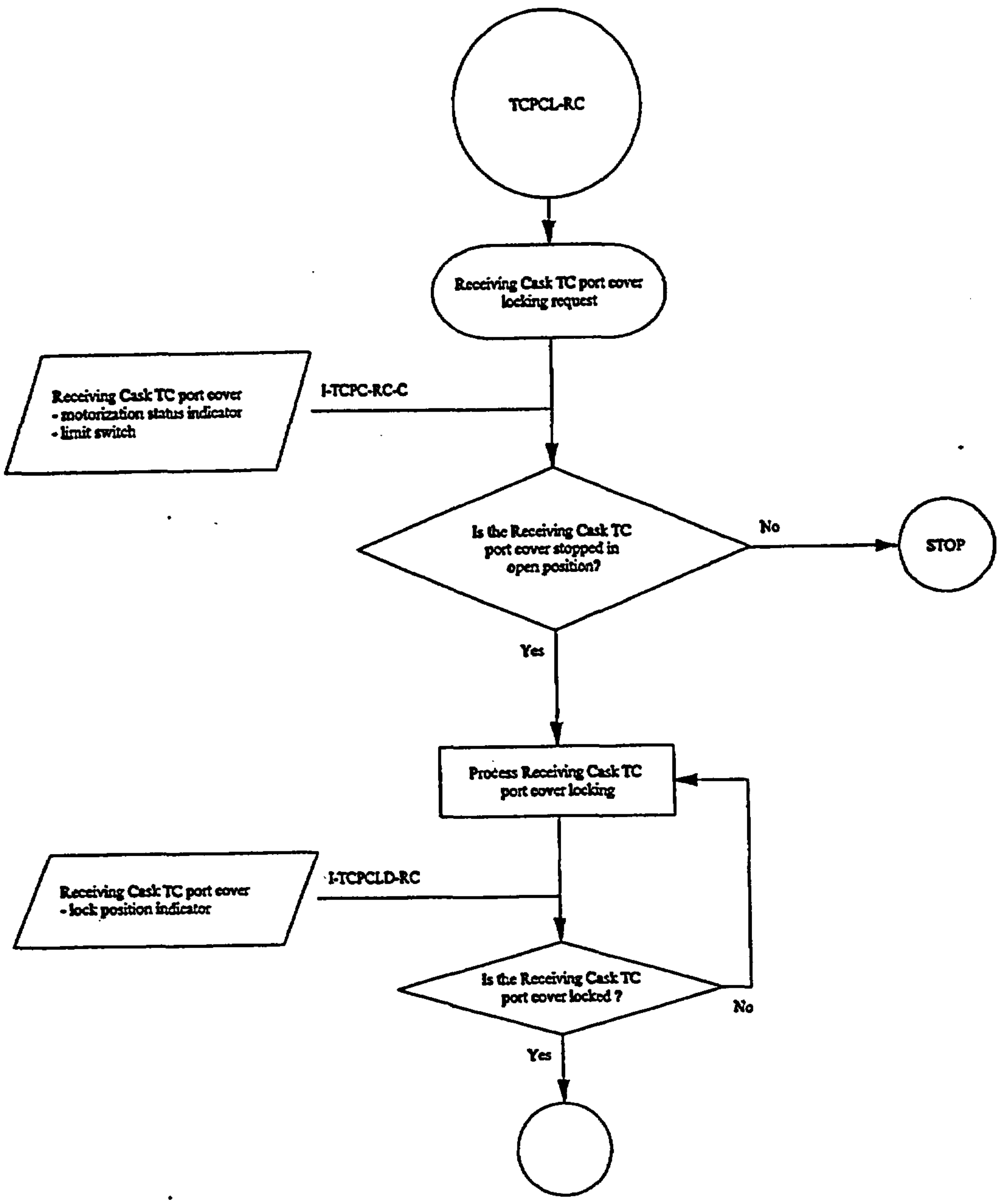
Source Cask TC Port Cover Closing



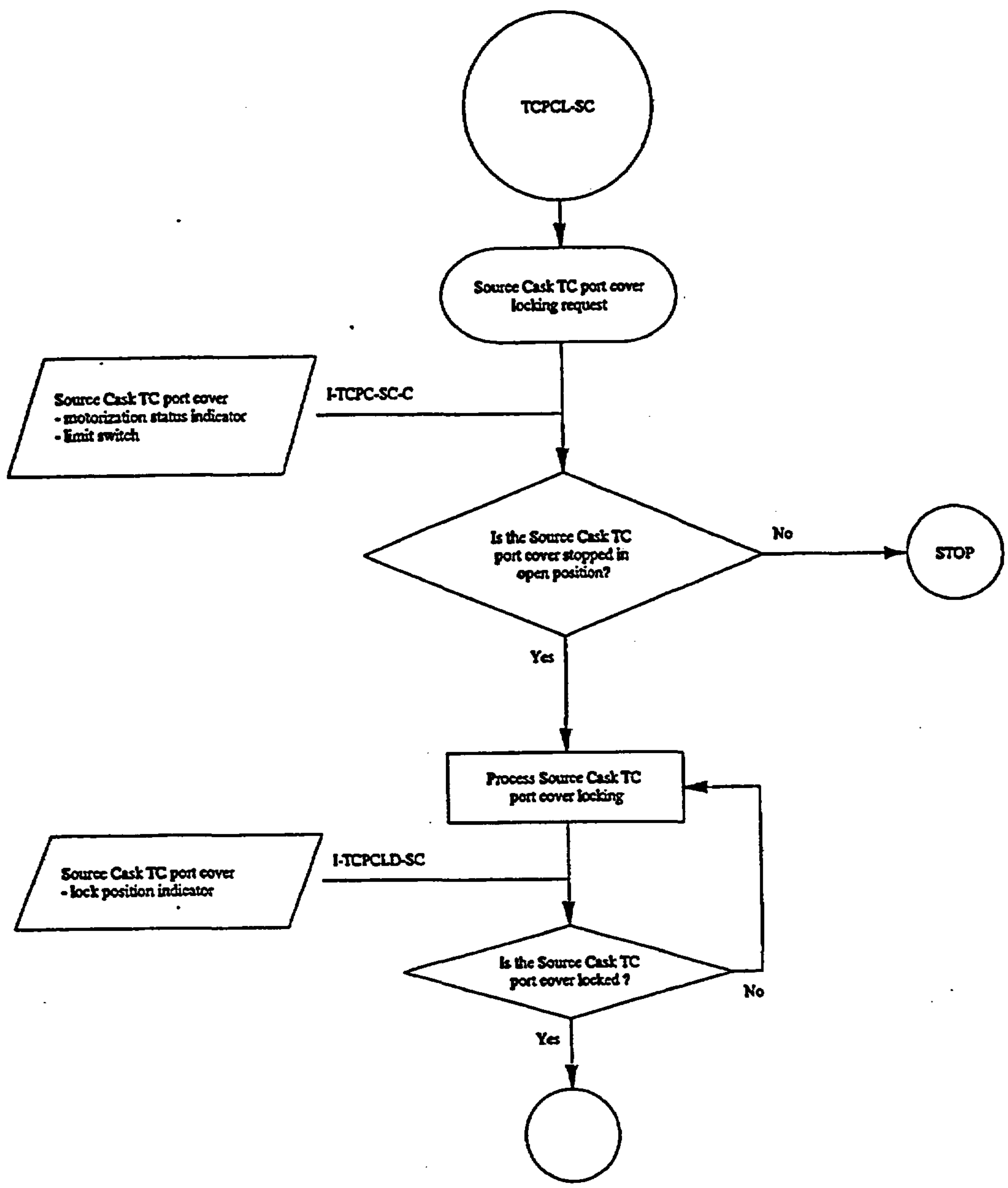
Receiving Cask TC Port Cover Off-centering



Receiving Cask TC Port Cover Locking



Source Cask TC Port Cover Locking



5.2.4 Control and monitoring of the Receiving Cask Shield Plug and Source Cask Lid Handling Subsystem

5.2.4.1 Description

The Receiving Cask Shield Plug and Source Cask Lid Handling Subsystem consists of a motor driven trolley which utilizes a motorized grapple attached to a hoist system and two shield ports actuated by electric jacks. The subsystem is housed on the roof of the Transfer Confinement Building and the shield ports provide access to the Transfer Confinement Area for the grapple. The motorized grapple is capable of grappling the overlid in order to grip the Receiving Cask shield plug or the source cask lid (cf Applicable Document 1.4).

5.2.4.2 General requirement

The function of the Control Subsystem is to allow:

- the upper crane to be properly positioned above the Source or Receiving Cask
- the upper shield ports to be opened, closed and locked in closed position
- the lid / shield plug grapple to be lowered and lifted
- the lid / shield plug grapple to grapple and disengage the overlids, and to activate the source cask lid or the receiving cask shield plug gripping and disengagement.

Cameras are only available to visually monitor the operations which occur in the Transfer Confinement Area. Monitoring and control are in the Control center.

5.2.4.3 Control and monitoring of the upper crane

5.2.4.3.1 Description

The upper crane is a motor driven trolley which positions the handling equipment over the source cask lid or receiving cask shield plug.

5.2.4.3.2 Operating principle

The operation consists of positioning of the upper crane in the source cask or receiving cask position. There is a finite number of positions therefore, accurate positioning over the source cask lid or the receiving cask shield plug is required. The operator activates the upper crane motion setting the position to be reached. The upper crane is automatically stopped when the position is reached. There is no CCTV monitoring of the upper crane motion or position.

5.2.4.3.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the upper crane motion (run/direction/stop).
- Detect an overrun (alarm + stop motion).
- Detect the proper positions of the trolley (stop motion).
- Monitor the position of the trolley (Receiving Cask/Source Cask/Undefined).

The overrun detectors are on each side of the runway rails and automatically stop motion when activated. The position of the trolley is displayed in the Control Center.

5.2.4.3.4 Transition conditions validation requirements

Requirement:
The following interlocks shall be implemented:

- Interlock the upper crane with the hoist system. It shall prevent any motion of the upper crane if the lid / shield plug handling grapple is not stopped in its upper z position.

- Interlock the upper crane with the upper shield ports. It shall prevent any motion of the upper crane if both upper shield ports are not stopped in the closed position.

Rationale:
The interlocks prevent any inadvertent motion of the trolley during handling, because that could cause:

- pendulum movement of the lid / shield plug (=> probable high dose rates)
- damage to the lid / shield plug
- damage to the confinement bellows

Dependent equipment:
Lid/shield plug handling - hoist system

5.2.4.3.5 Instrumentation requirements

Redundant instrumentation is not necessary for the control of the upper crane since the motorization is in a shielded area (roof enclosure) and since the crane includes a recovery system.

Table 5.2.4.3.α lists the necessary instrumentation for the Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem trolley.

5.2.4.3.6 Flow charts

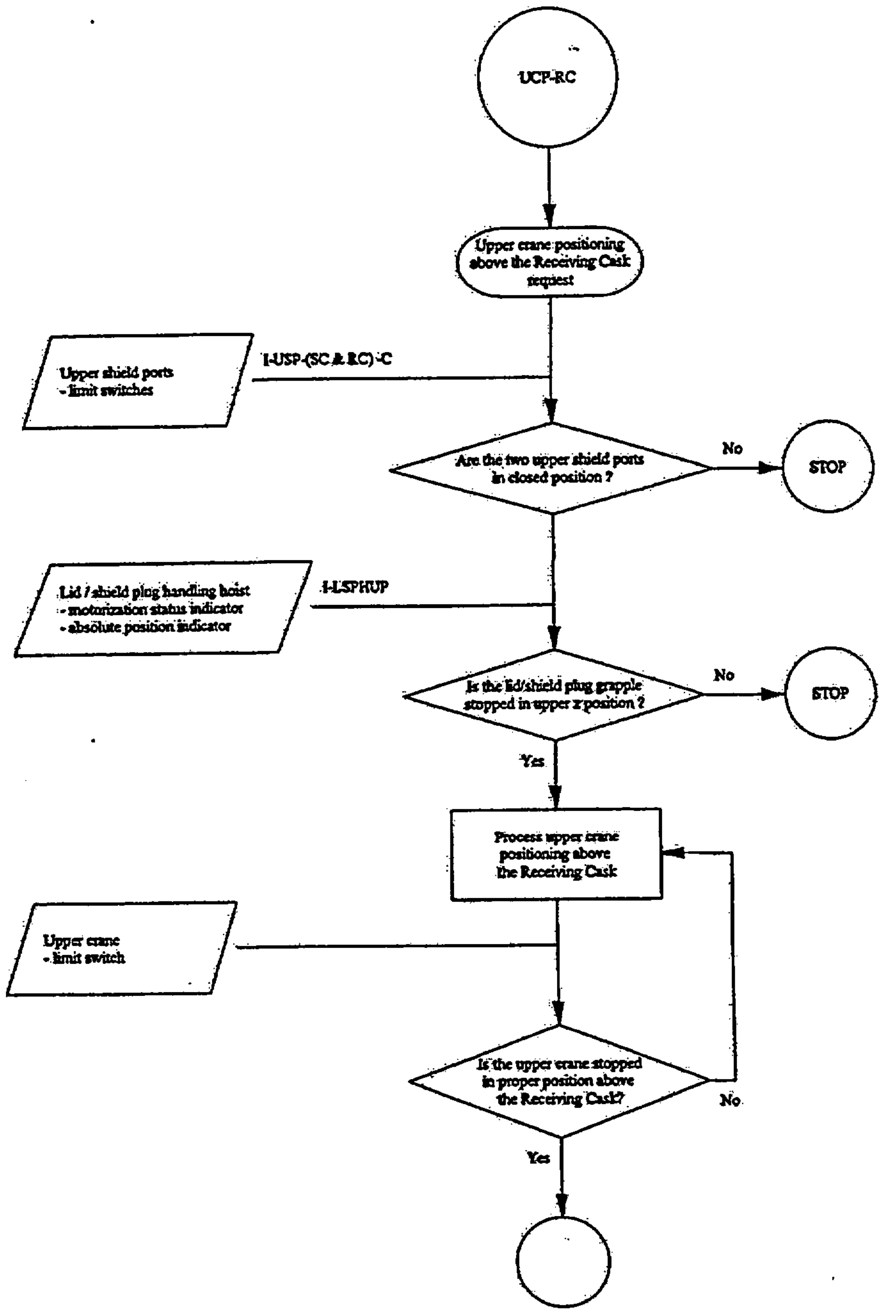
The flow charts describe the control of the following operations:

- Upper crane positioning above source cask
- Upper crane positioning above receiving cask

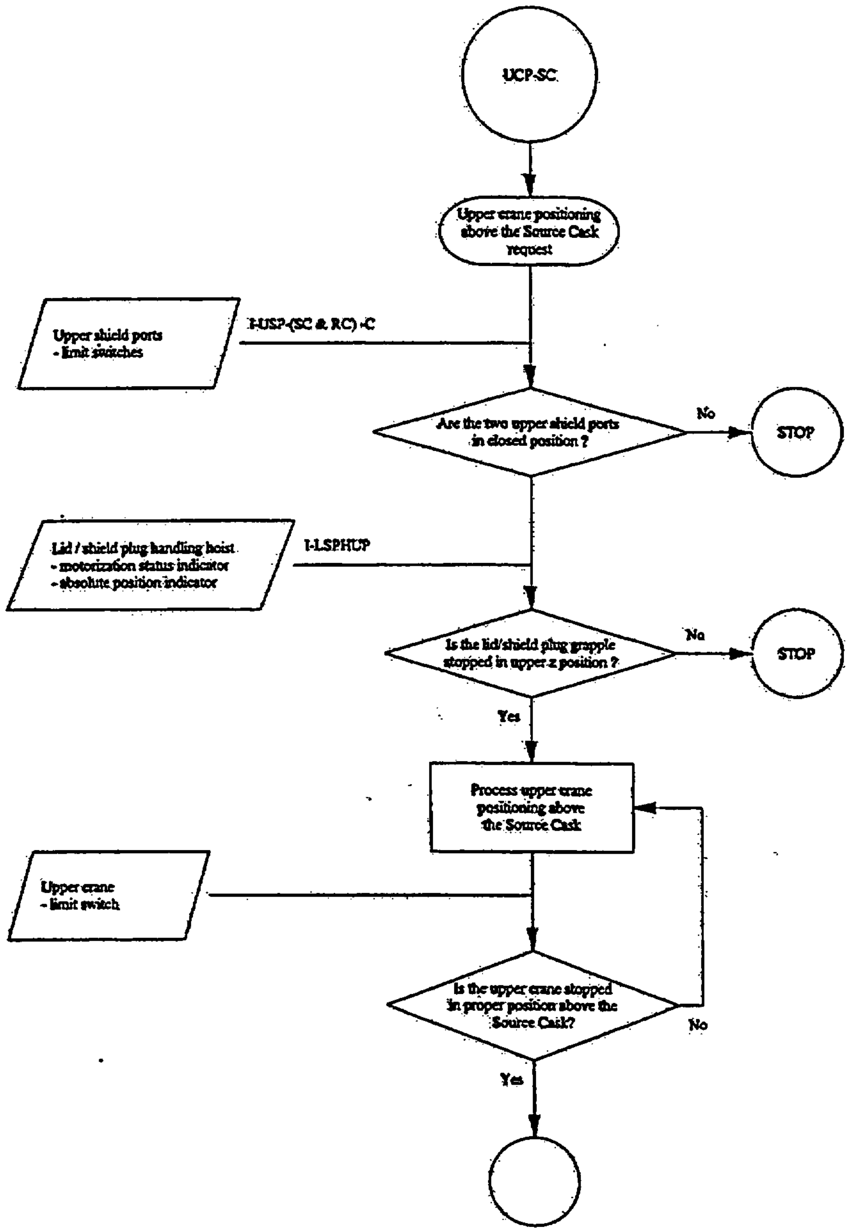
Table 5.2.4.3.α
Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem
Trolley Instrumentation

Equipment	Data	Sensor type	Action	Reference
Trolley (x)	Position above source cask	Electrical switch	Stop motion	ZS 303A
	Position above receiving cask	Electrical switch	Stop motion	ZS 303B
	Over travel	Electrical switch	Stop motion	ZASH 303A ZASH 303B

Upper Crane Positioning above the Receiving Cask



Upper Crane Positioning above the Source Cask



5.2.4.4 Control and monitoring of the upper shield ports

5.2.4.4.1 Description

The upper shield ports provide shielding between the TCA and the enclosure area. They permit lid / shield plug grapple access to the TCA allowing lid / shield plug removal and replacement on the casks. They consist of trolleys with a locking device. The equipment is actuated by electric jacks.

5.2.4.4.2 Operating principle

There is no viewing of the upper shield port motion or position. Both upper shield ports and their locking devices are remotely controlled. The locking devices are only used in the closed position. The operator activates an upper shield port or its locking device setting the position to be reached. The upper shield ports are automatically stopped when the position is reached. When the operation is completed, the information is transmitted to the supervisor which displays it.

5.2.4.4.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the movement of the upper shield ports (open/close/stop).
- Detect an overrun. (alarm + stop motion).
- Detect the upper shield ports proper positions (stop motion).
- Monitor the upper shield ports position (open/closed/undefined).
- Control the locking device (lock/unlock/stop).
- Monitor the locked positions (locked/unlocked/undefined).

The overrun detectors are on each side of the runway rails and automatically stop motion when activated. The position of the upper shield ports and of their locking device is displayed in the Control Center.

5.2.4.4.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the upper shield ports with the lid/shield plug handling hoist system. It shall prevent closing of the upper shield ports if the lid / shield plug grapple is not in the upper z position and if the hoist is loaded.

- Interlock the upper shield ports and the TC port covers. It shall prevent opening of any upper shield port if the opposite TC port cover is not closed (or off centered).

- Interlock the upper shield ports and their locking device with the fuel assembly handling hoist system. It shall prevent unlocking and opening of the upper shield ports if a fuel assembly is being transferred.

- Interlock the upper shield ports and their locking device with the radiation monitoring subsystem. It shall prevent unlocking and opening of an upper shield port if the radiation at the level of the roof enclosure is too high.

- Interlock the receiving and source casks upper shield ports. It shall prevent the opening of an upper shield port if the other is not closed.

- Interlock each upper shield port with its locking device. It shall prevent locking if the upper shield port is not in the closed position.

Rationale:
The interlocks prevent:

- any damage to the lid/shield plug and the fuel assembly transfer tube due to the closure of an upper shield port on the lid/shield plug handling cables.
- abnormal high radiation levels on the top of the building due to incorrect synchronisation of the upper shield ports with the TC port covers
- abnormal high radiation levels on the top of the building due to a seismic event during a fuel assembly transfer.

Dependent equipment:
Source Cask Lid/ Receiving Cask Shield Plug Handling Subsystem - upper crane
Fuel Assembly Handling Subsystem - crane carriage

5.2.4.4.5 Instrumentation requirements

Instrumentation which controls the motion of the upper shield ports and the locking devices is not redundant since in the event of malfunction, the shield port motorizations are outside the building (on the roof) and, for the locking devices, they are only used when the upper shield ports are in closed position. Two different instrumentations are necessary to detect the locked and unlocked position of the upper shield ports.

Table 5.2.4.4.α lists the necessary instrumentation for the Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem upper shield ports.

5.2.4.4.6 Flow charts

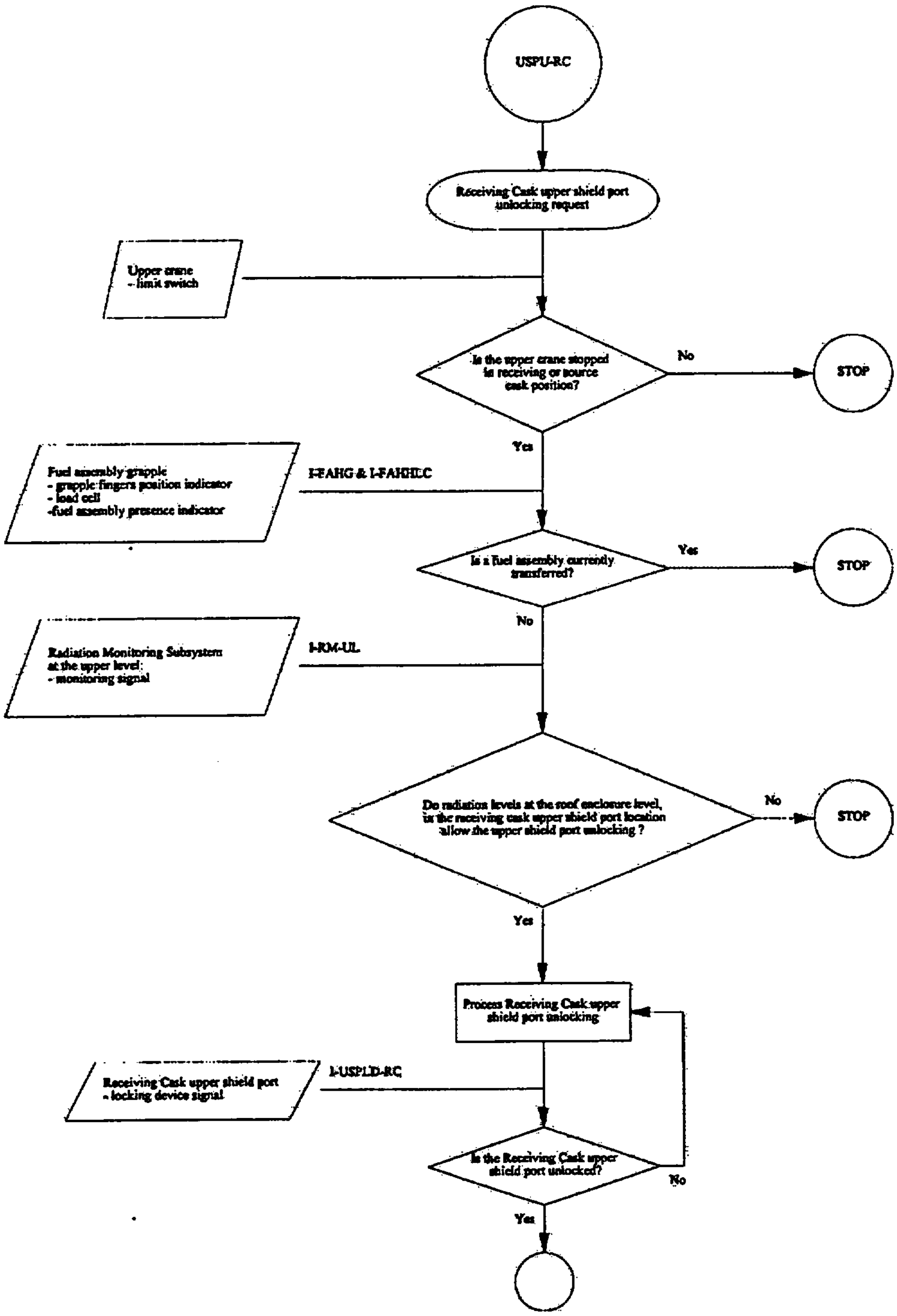
The flow charts describe the control of the following operations:

- Upper shield port opening (receiving and source cask)
- Upper shield port closing (receiving and source cask)
- Upper shield port locking (receiving and source cask)
- Upper shield port unlocking (receiving and source cask)

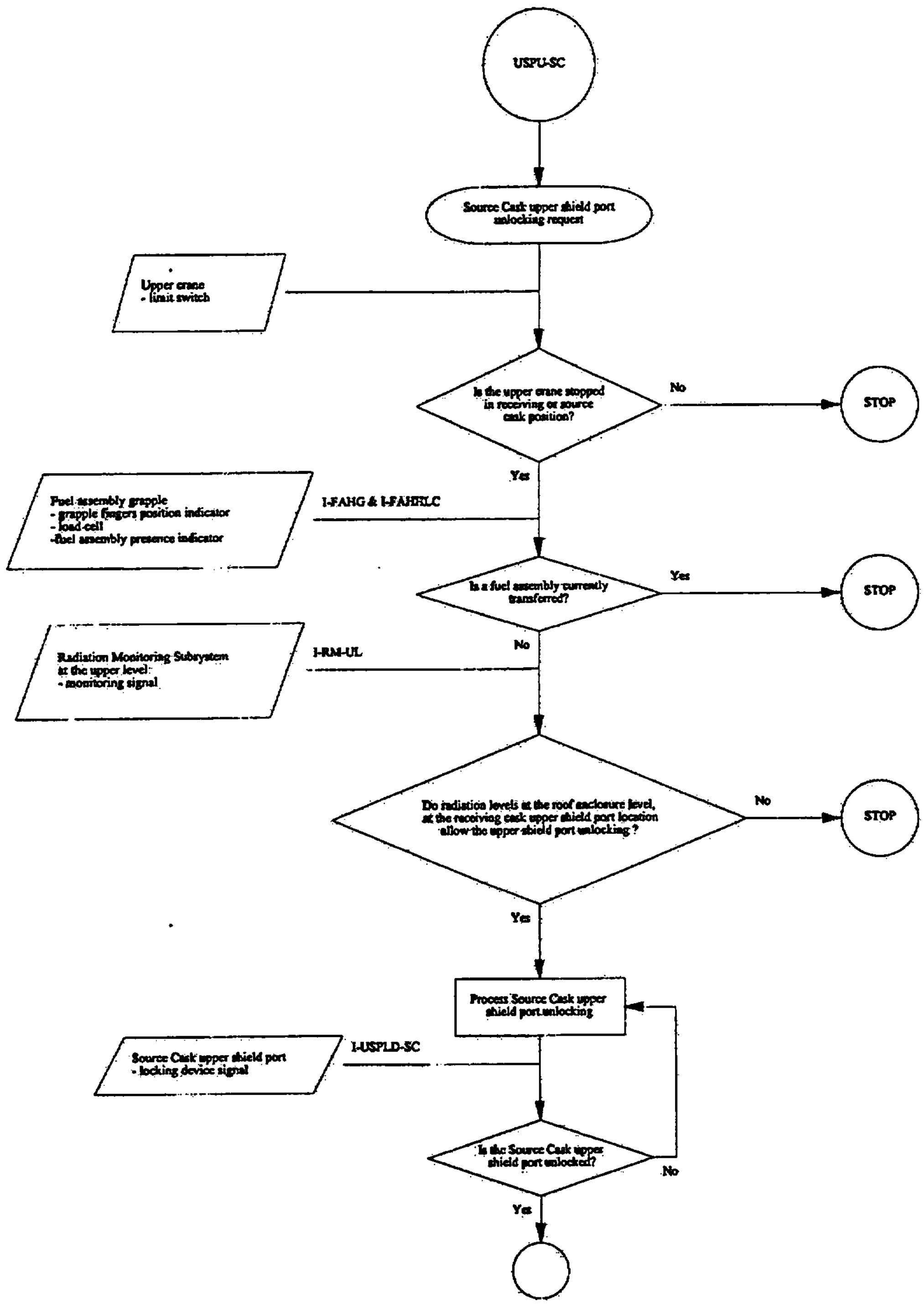
Table 5.2.4.4.α
Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem
upper shield ports instrumentation

Equipment	Data	Sensor type	Action	Reference
Upper shield ports (x2)	Open position	Electrical switch	Stop motion	ZS 301A ZS 302A
	Closed position	Electrical switch	Stop motion	ZS 301B ZS 302B
	Over travel	Electrical switch	Stop motion	ZASH 301A ZASH 301B ZASH 302A ZASH 302B
	Locked (in closed position)	Electrical contact	----	YL 312A YL 313A
	Unlocked	Electrical contact	----	YL 312B YL 313B

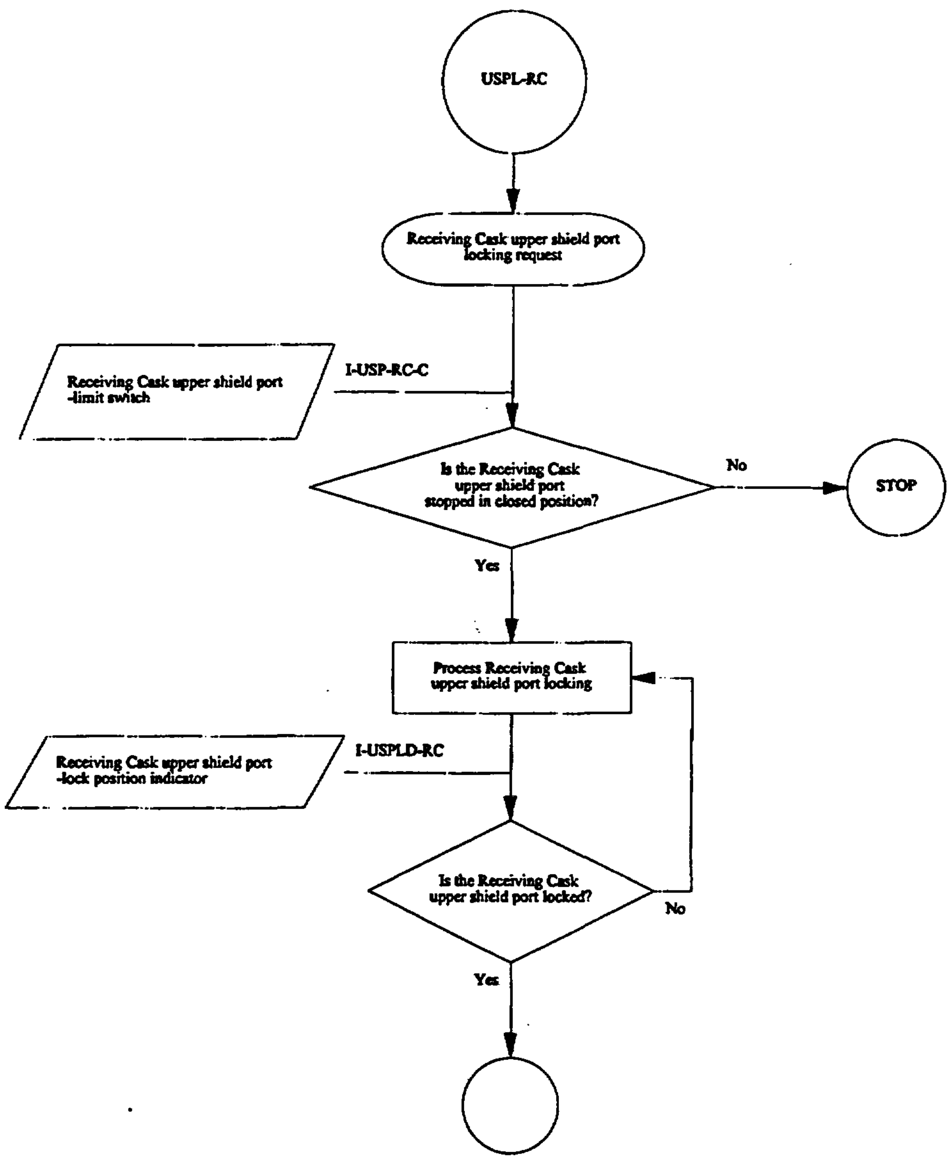
Receiving Cask Upper Shield Port Unlocking



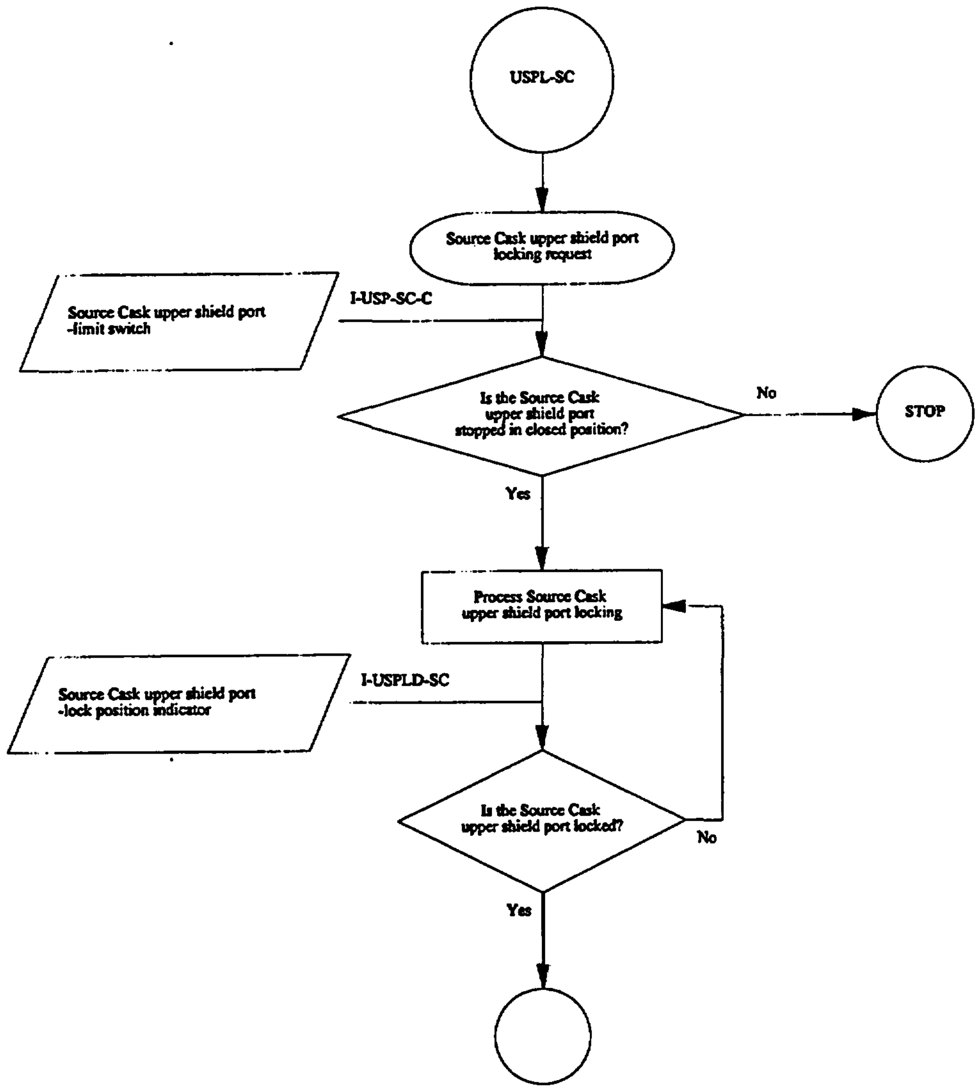
Source Cask Upper Shield Port Unlocking



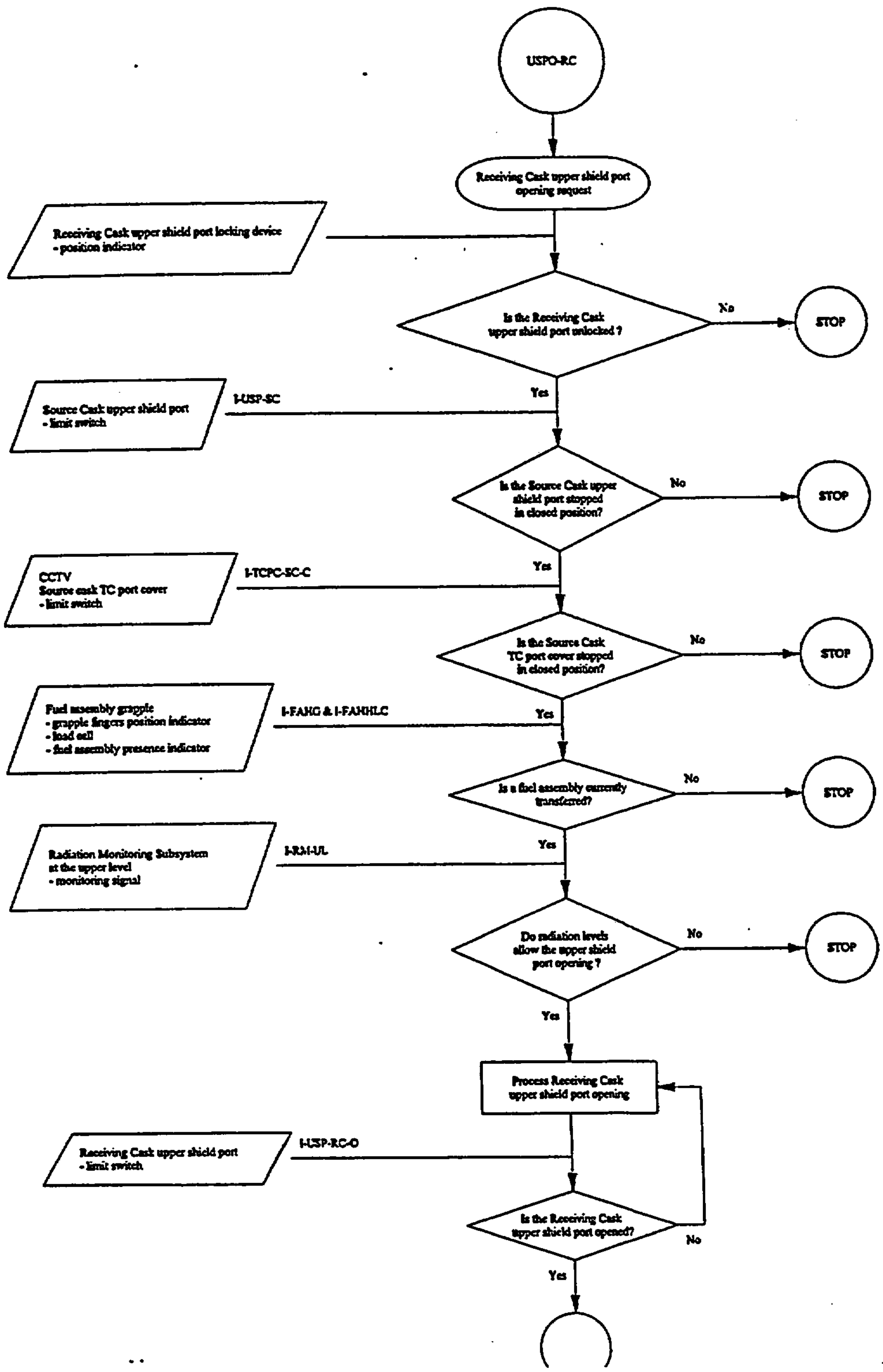
Receiving Cask Upper Shield Port Locking



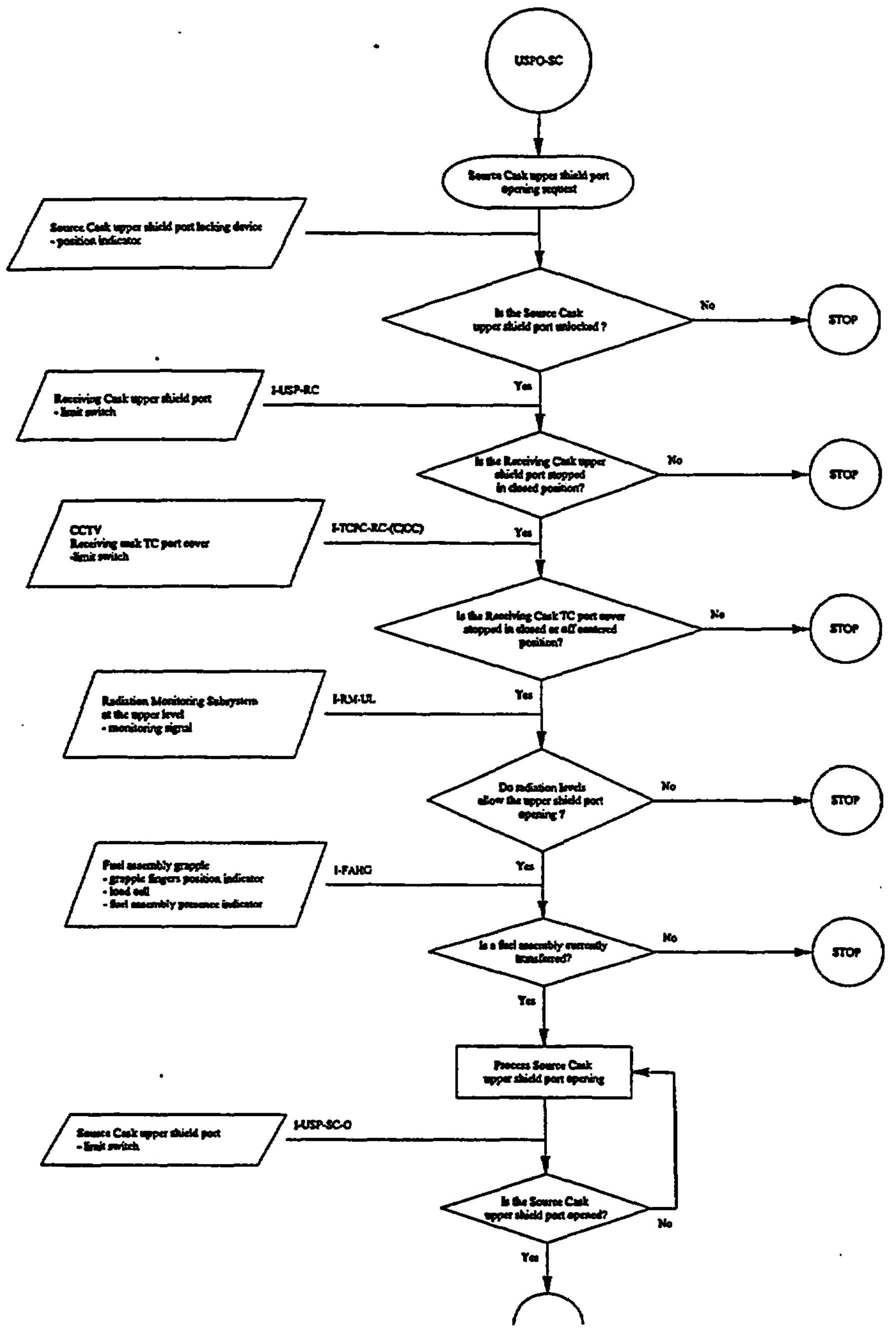
Source Cask Upper Shield Port Locking



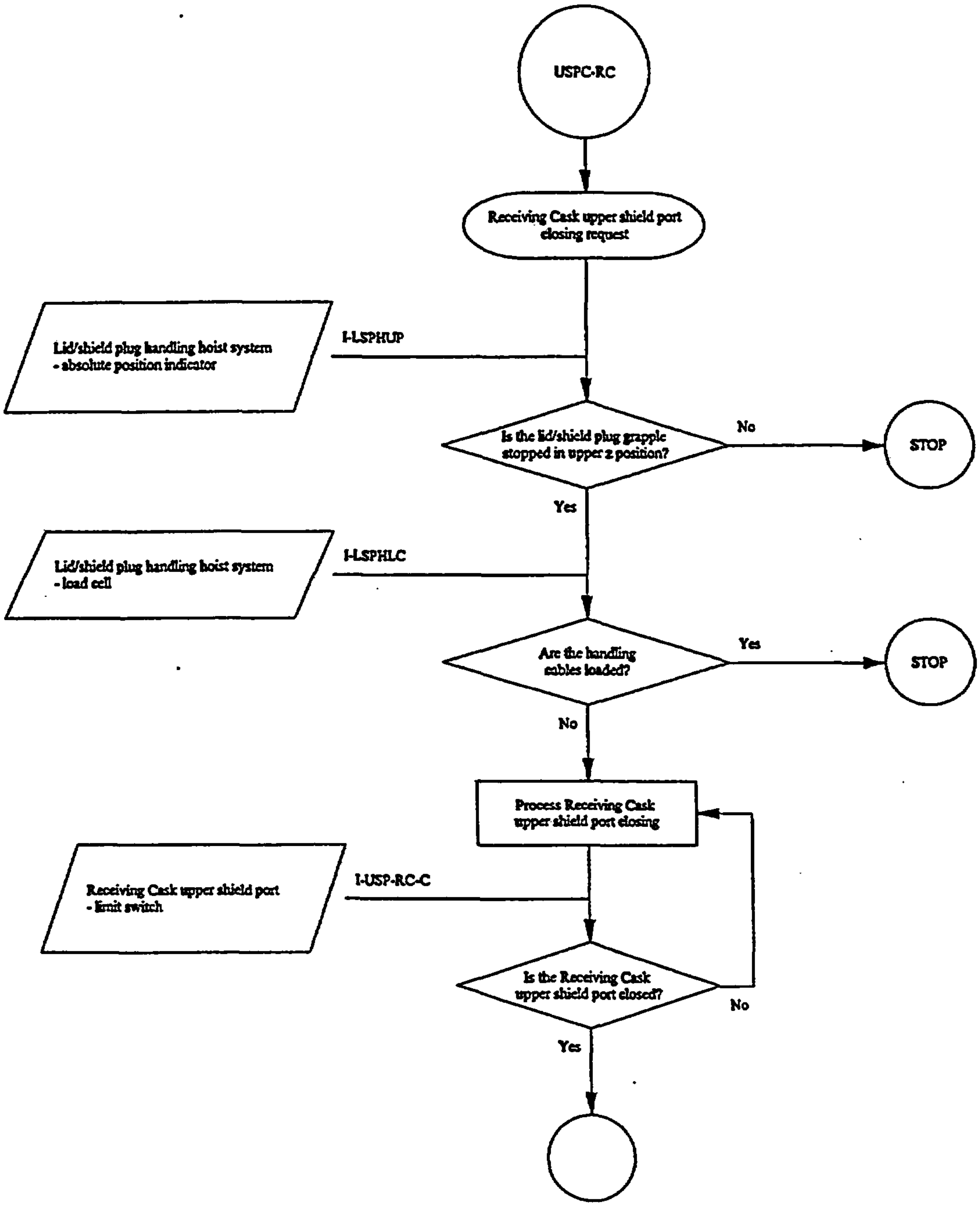
Receiving Cask Upper Shield Port Opening



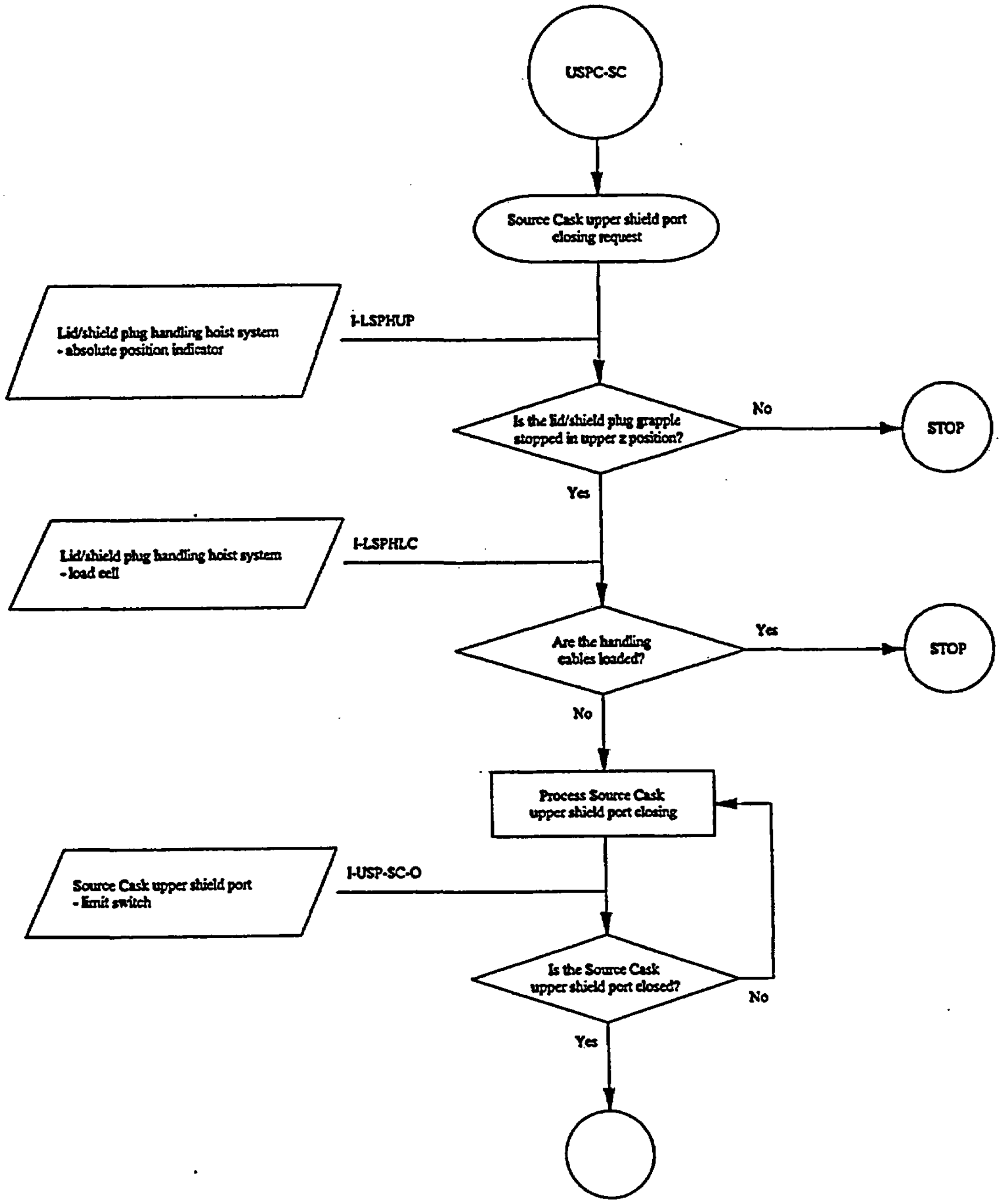
Source Cask Upper Shield Port Opening



Receiving Cask Upper Shield Port Closing



Source Cask Upper Shield Port Closing



5.2.4.5 Control and monitoring of the hoist system

5.2.4.5.1 Description

The motorized hoist system lowers and lifts the grapple by means of two cables. Cable breaking is detected by a compensator. Its motorization is located outside of the TCA.

5.2.4.5.2 Operating principle

The hoist system of the lid/shield plug handling system is remotely activated by the operator, setting the direction of the hoist motorization and using a variable speed. The viewing of the system is provided in the Transfer Confinemnt Area only.

Lowering:

The motion is automatically stopped when the cables are underloaded.

Lifting:

The motion is automatically stopped when the grapple reaches the upper position and the safety position above the TC port cover when the cables are loaded.

5.2.4.5.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the hoist (lower / lift / stop / variable speed).
- Monitor its status (lowering / lifting / stopped).
- Detect an overload (alarm + stop motion).
- Detect an overrun/underrun (alarm + stop motion).
- Detect breaking of a cable (alarm + stop motion).
- Detect an overspeed (alarm + stop motion).
- Detect an abnormal drum rope level wind (alarm + stop motion).
- Monitor the grapple z position.
- Detect an underload (stop motion).

The motion and the direction of the hoist system are indicated in the Control Center, as well as the grapple z position. The overload, underrun, overrun, overspeed, abnormal drum rope level wind and cable breaking are abnormal situations and their detection generates an alarm and automatically stops motion. The underload is a normal situation, its detection automatically stops motion. The overload limit is adapted to the weight to be handled and so, this limit depends on the upper crane position. The speed is variable but is automatically lowered to its minimum when a limit distance from the target is reached.

5.2.4.5.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the hoist with the cable load monitoring device and the grapple position monitoring device. It shall prevent the lifting of the grapple over the limit position if the cables are loaded.

- Interlock the hoist with the fuel assembly handling crane carriage. It shall prevent lowering and lifting if the crane is not stopped in parking position.

- Interlock the hoist with the lid/shield plug grapple. It shall prevent lifting if the grapple is not totally disengaged from the overlid or if both grapple and overlid are not totally engaged.

Rationale:
The mechanical resistance of the mezzanine between the TC area and the Lower Access Area is not designed to withstand the dropping of the lid/shield plug above a limit distance. In addition, the radiation levels at the upper level depend on the z position of the lid/shield plug.

The interlock with the lid/shield plug grapple ensures that the source cask lid or the receiving cask shield plug won't be dropped during lifting due to an incomplete engagement or disengagement of the grapple.

The interlock with the position of the crane carriage ensures that the lid/shield plug can't collide with the crane bridge which could damage it and compromise recovery requirements.

Dependent equipment:
TC port covers
Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem - upper crane, upper shield ports, grapple

5.2.4.5.5 Instrumentation requirements

The control of the winch motor is not redundant since it is located in an uncontaminated and shielded area.

Table 5.2.4.5.α lists the necessary instrumentation for the Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem hoist.

5.2.4.5.6 Flow charts

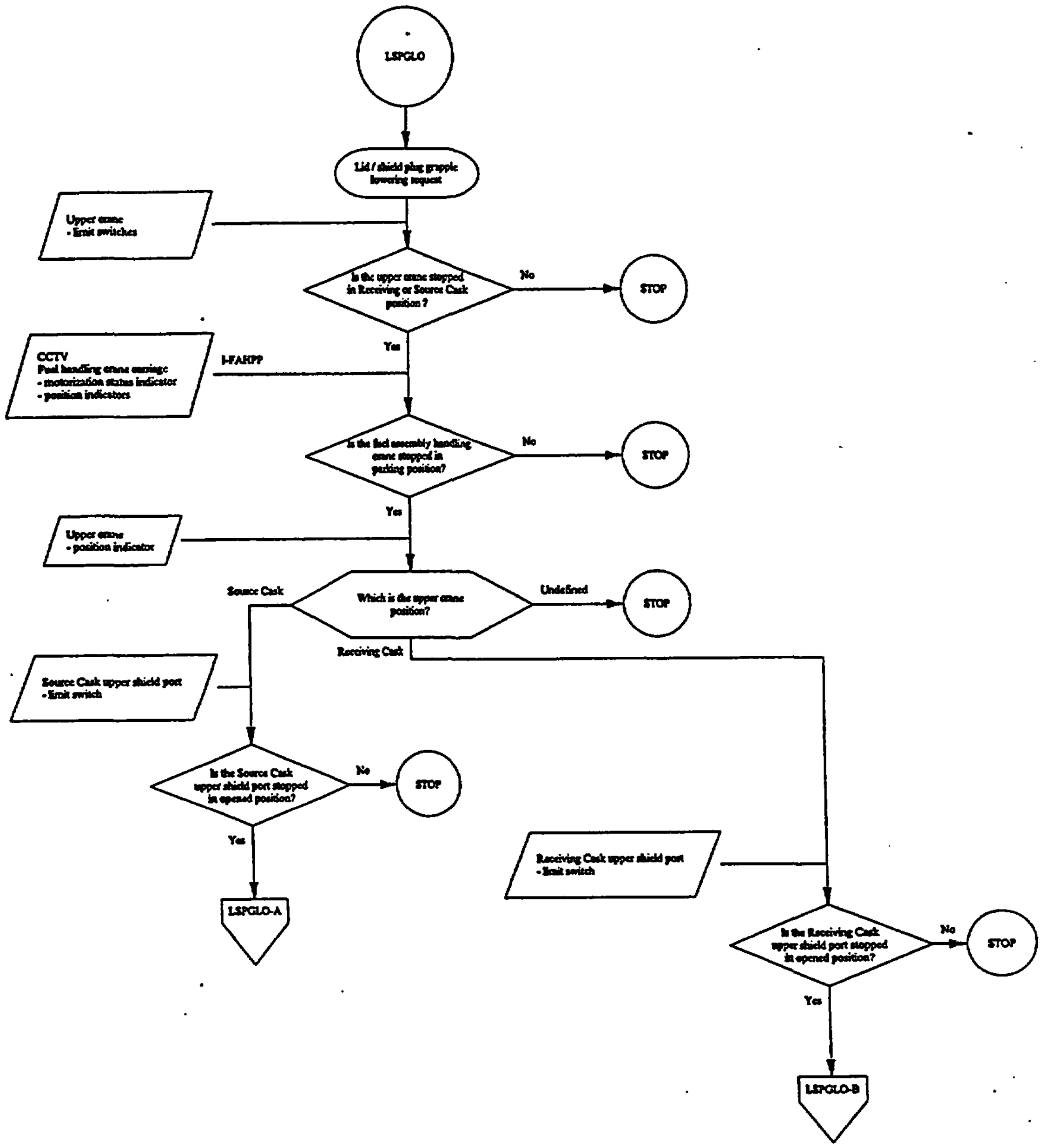
The flow charts describe the control of the following operations:

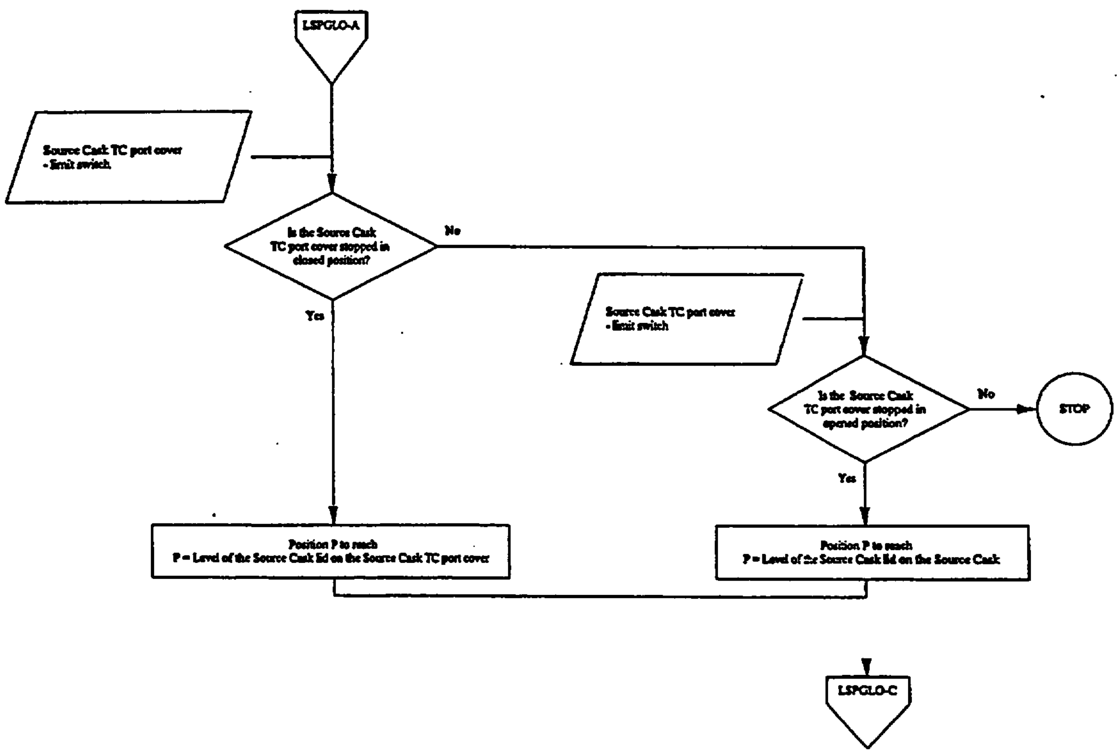
- Source Cask lid / Receiving Cask shield plug grapple lowering
- Source Cask lid / Receiving Cask shield plug grapple lifting

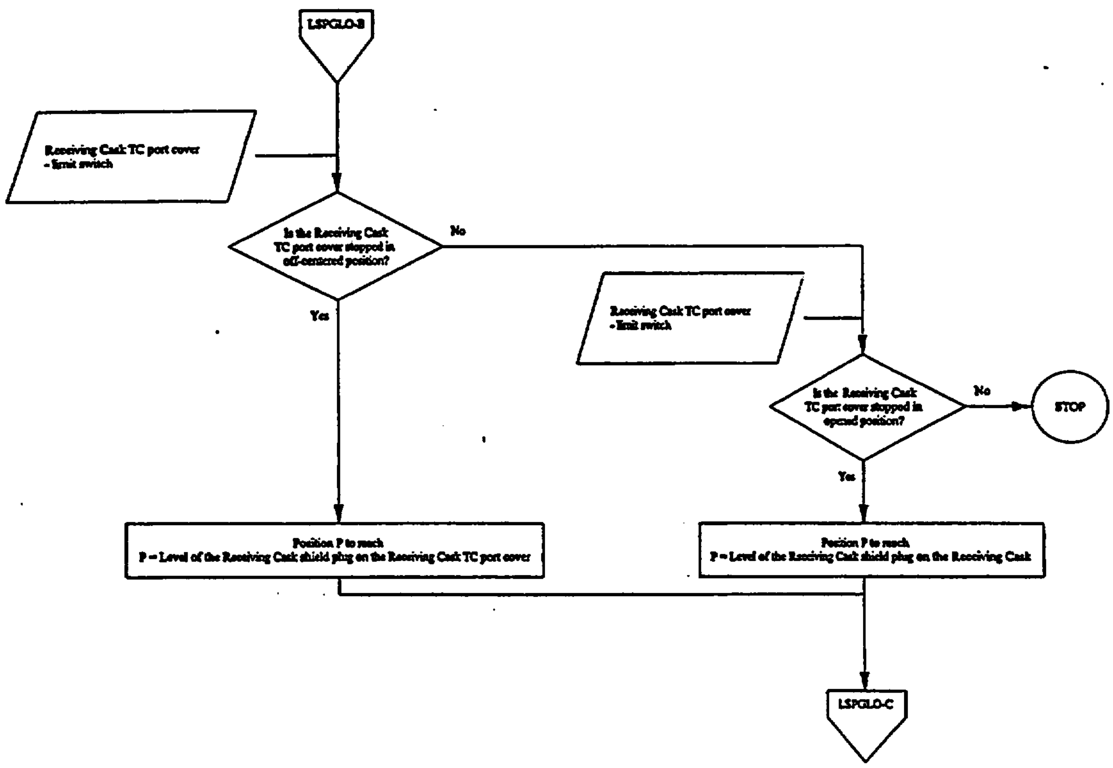
Table 5.2.4.5.α
Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem Hoist Instrumentation.

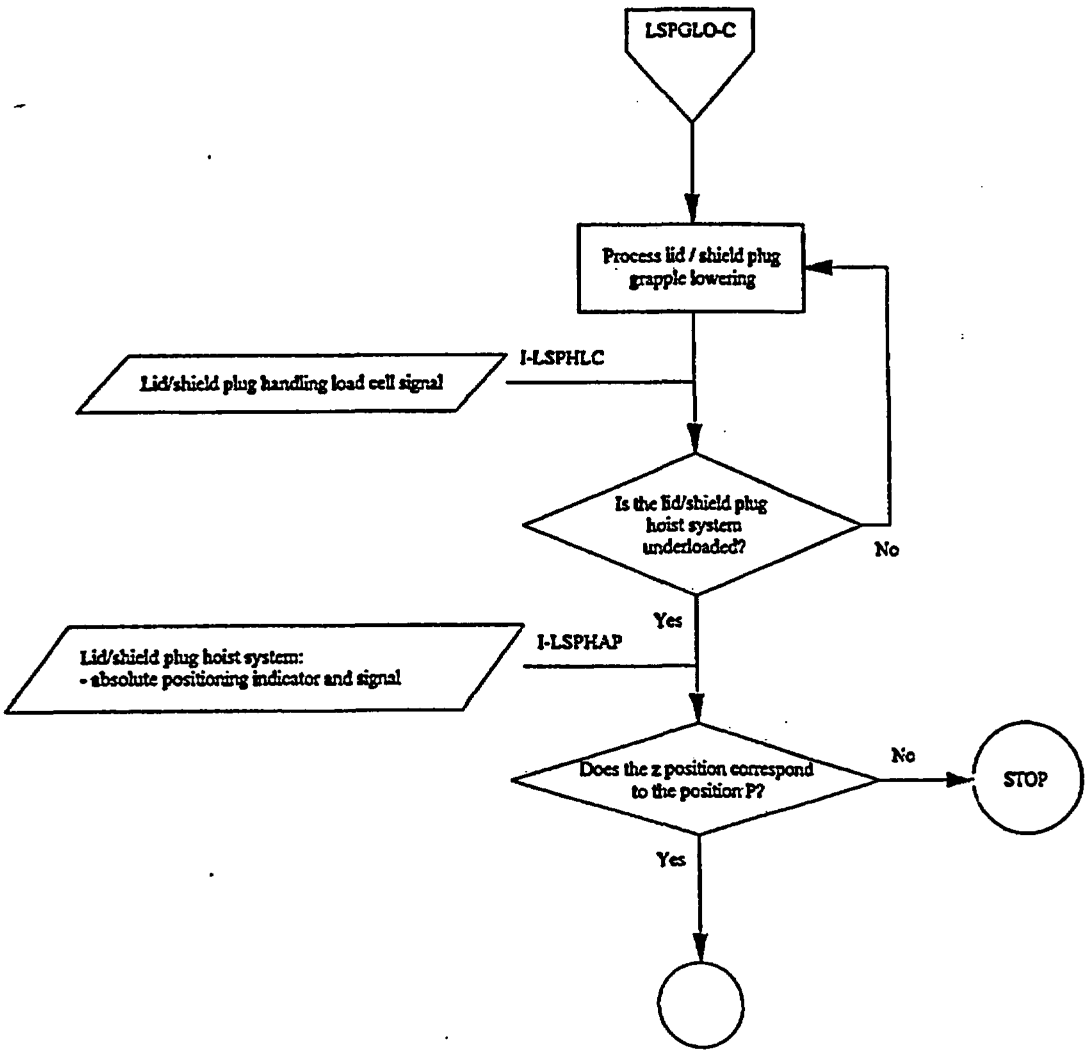
Equipment	Data	Sensor type	Action	Reference
Hoist motorization	Absolute lifting positioning	Wire potentiometer	----	ZIT 307
	First high limit	Form ZIT 307	----	ZLH 307
	Second high limit	Form ZIT 307	Stop motion	ZSHH 307
	Overtravel (final high limit)	Position selector	Stop motion	ZASH 314
	First low limit	Form ZIT 307	----	ZLL 307
	Overtravel (final low limit)	Position selector	Stop motion	ZASL 306
	Hoist overspeed limits	Electrical switch	Stop motion	SASH 305
	Hoist drum rope level winds limits	Electrical switch	Stop motion	ZS 308A ZS 308B
	Unbalanced load limits	Electrical switch	Stop motion	CS 304A CS 304B
	Weight of live load	Load cell	----	WIT 309
	Abnormal high weight of live load	From WIT 309	Stop motion	WASL 309 WASH 309

**Source Cask Lid / Receiving Cask Shield Plug
Grapple Lowering**

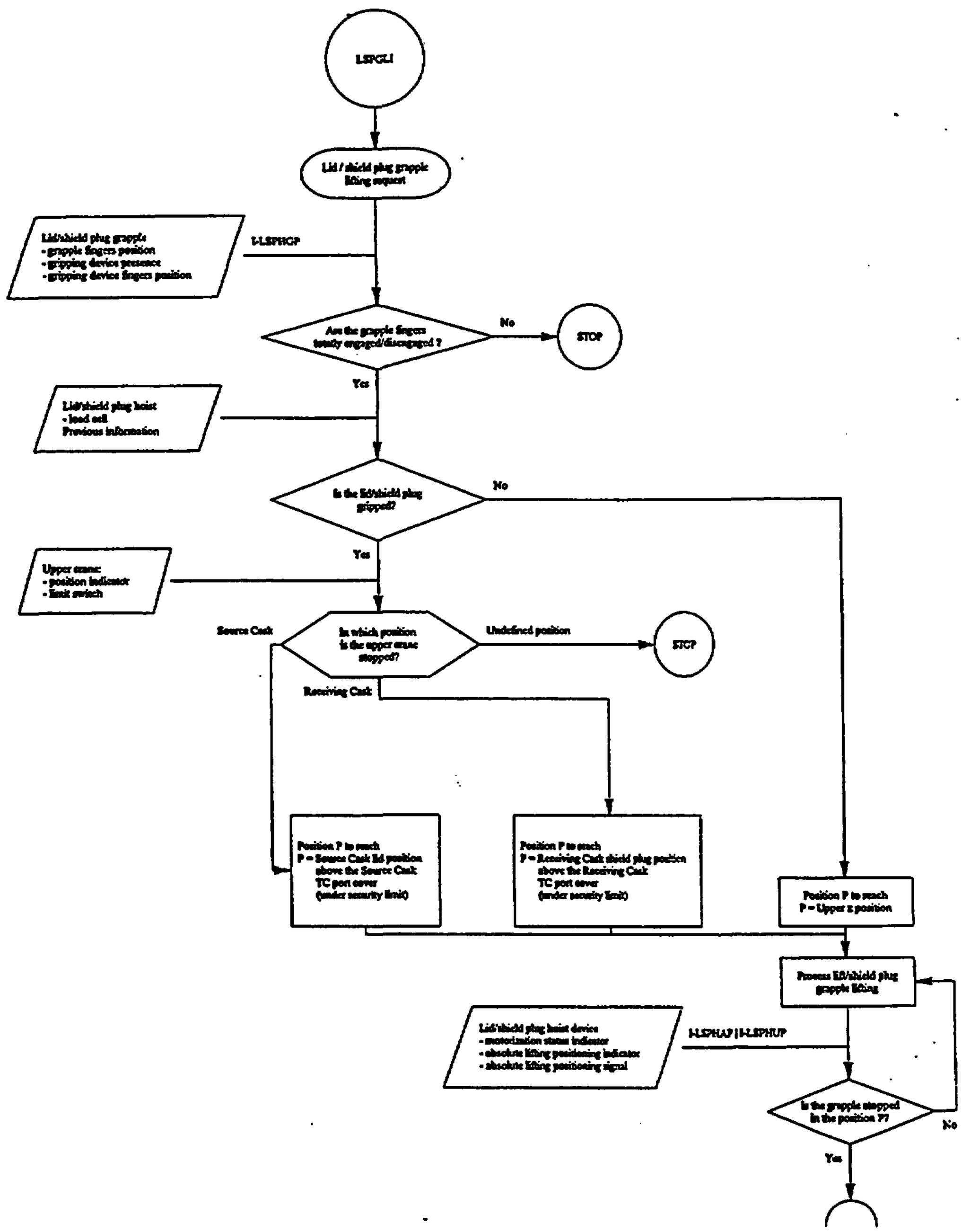



LSPGLO-A
Source Cask TC port cover
- limit switch
Is the Source Cask TC port cover stopped in closed position?
No
Yes
Source Cask TC port cover
- limit switch
Is the Source Cask TC port cover stopped in opened position?
No
STOP
Yes
Position P to reach
P = Level of the Source Cask lid on the Source Cask TC port cover
Position P to reach
P = Level of the Source Cask lid on the Source Cask
LSPGLO-C


LSPGLO-B
Receiving Cask TC port cover
- limit switch
Is the Receiving Cask TC port cover stopped in off-centered position?
No
Yes
Receiving Cask TC port cover
- limit switch
Is the Receiving Cask TC port cover stopped in opened position?
No
STOP
Yes
Position P to reach
P = Level of the Receiving Cask shield plug on the Receiving Cask TC port cover
Position P to reach
P = Level of the Receiving Cask shield plug on the Receiving Cask
LSPGLO-C


LSPGLO-C
Process lid / shield plug grapple lowering
I-LSPHLC
Lid/shield plug handling load cell signal
Is the lid/shield plug hoist system underloaded?
No
Yes
I-LSPHAP
Lid/shield plug hoist system:
- absolute positioning indicator and signal
Does the z position correspond to the position P?
No
STOP
Yes

Source Cask Lid / Receiving Cask Shield Plug Grapple Lifting



5.2.4.6 Control and monitoring of the lid / shield plug grapple

5.2.4.6.1 Description

The grapple is motorized and can grapple or disengage the source or receiving cask overlid that can grip or disengage the source cask lid or receiving cask shield plug.

5.2.4.6.2 Operating principle

The concerned operations are the connection and disconnection of the lid/shield plug grapple with the source cask lid or receiving cask shield plug. The operator activates the grappling operation by setting the desired status (connected/disconnected). The operation is automatically stopped when the desired status is reached, and this information is displayed by the supervisor. The remote viewing of the operation by CCTV is possible when it occurs above the mezzanine level.

5.2.4.6.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the motorized grapple (grapple/disengage/stop).
- Monitor the grapple fingers' position (open/closed/undefined).
- Monitor the presence of the overlid.
- Monitor the gripping device fingers' position (open/closed/unknown).
- Detect the gripping of overlid fingers (alarm + stop motion).

The system is independent of the object to grapple because of the overlids' design.

5.2.4.6.4 Transition conditions validation requirements

Interlock requirements:
The following interlock shall be implemented:

Interlock the grapple with the hoist system. It shall prevent the disengagement of the overlid if the cables are loaded and if the grapple is not in its proper z position.

Rationale:

The interlock prevents the dropping of the lid/shield plug and uses redundant information: load and z position.

Dependent equipment:

Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem - hoist system

5.2.4.6.5 Instrumentation requirements

No redundant device is necessary for the control of the grapple since a manual backup is provided to disengage it in case of a malfunction.

Table 5.2.4.6.α lists the necessary instrumentation for the Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem grapple.

5.2.4.6.6 Flow charts

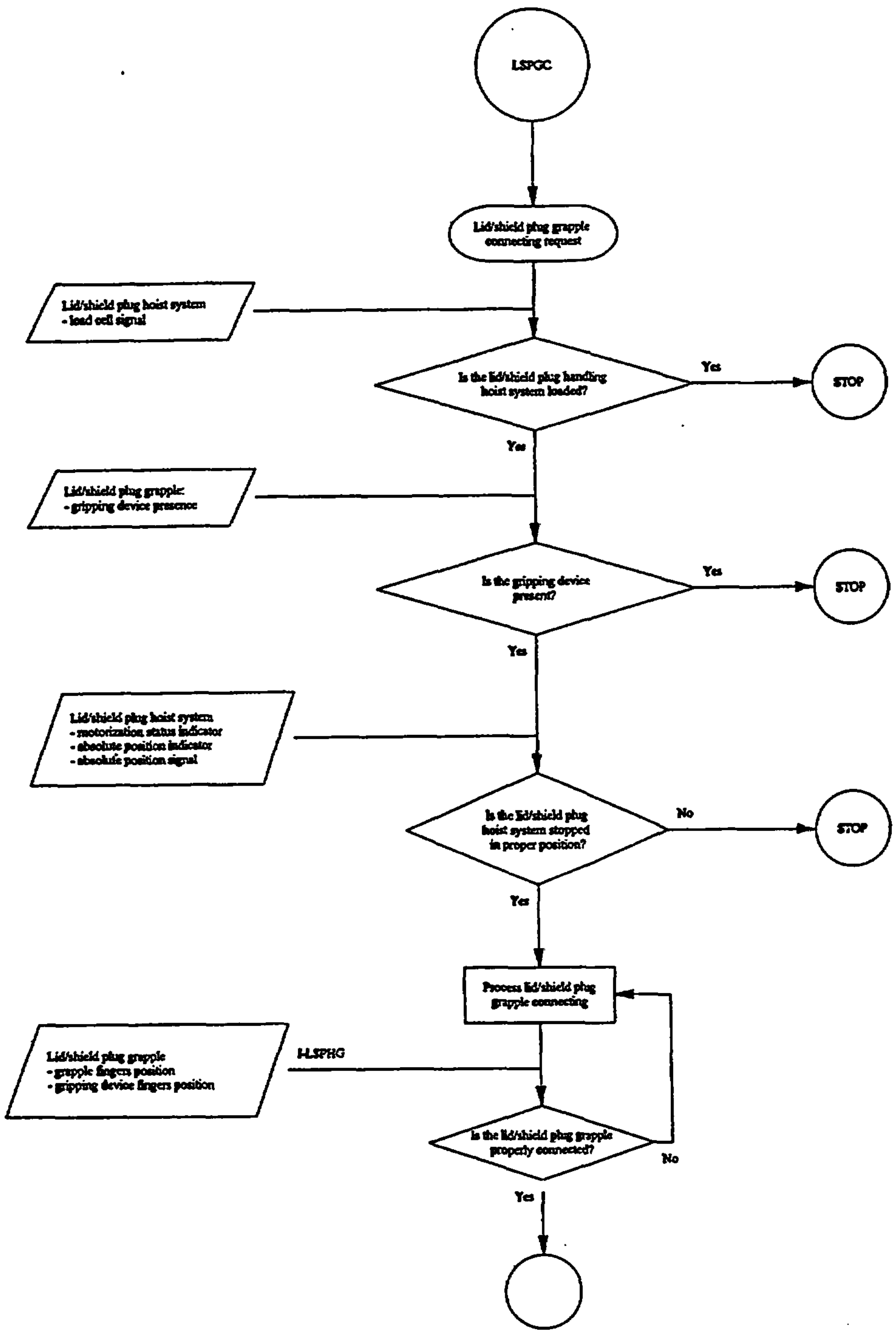
The flow charts describe the control of the following operations:

- Lid/shield plug grapple connection
- Lid/shield plug grapple disengagement

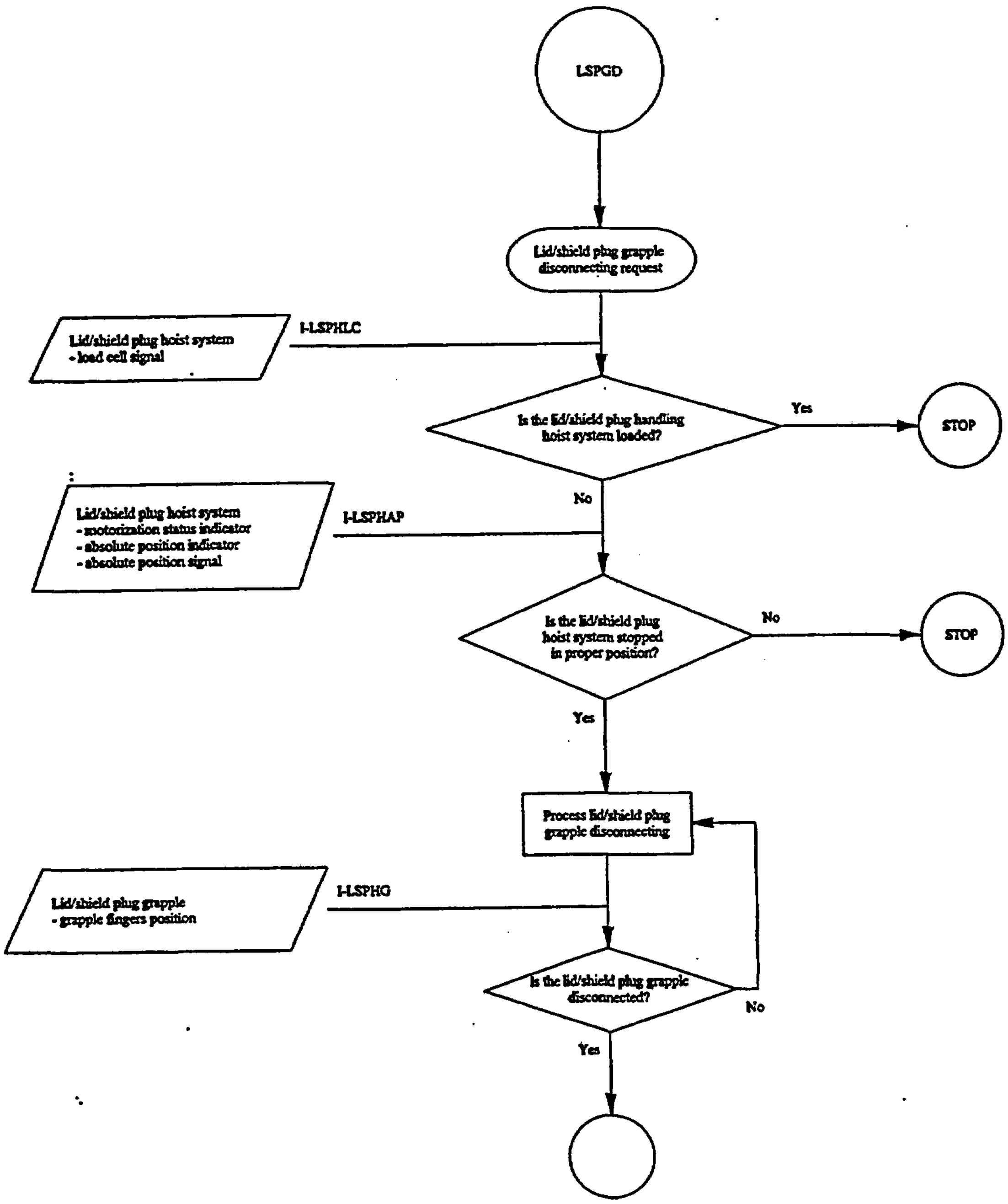
Table 5.2.4.6.α
Source Cask Lid/Receiving Cask Shield Plug Handling Subsystem
Grapple Instrumentation

Equipment	Data	Sensor type	Action	Reference
Lid/shield plug grapple	Grapple fingers open	Electrical contact	----	YL 311A
	Grapple fingers closed	Electrical contact	----	YL 311B
	Overlid presence	Electrical switch	Stop motion	YLS 310
	Overlid fingers open	Position detector	----	ZL 315A
	Overlid fingers closed	Position detector	----	ZL 315B
	Overlid fingers gripped	Position detector	----	ZL 315C

Lid/Shield Plug Grapple Connecting



Lid/Shield Plug Grapple Disconnecting



5.2.5 Control and monitoring of the Fuel Assembly Handling Subsystem

5.2.5.1 Description

The Fuel Assembly Handling Subsystem consists of a crane carriage which supports a rotating platform and a transfer tube fitted with a hoist system (including two motorized winches), a motorized grapple and a crud catcher (see Applicable Document 1.5).

5.2.5.2 General requirement

The Control Subsystem allows:
- positioning of the fuel transfer tube in the x, y and θ directions.
- the hoist system to lower / lift the grapple.
- the grapple to grip / remove the fuel assembly.
- the crud catcher to be opened / closed.

Monitoring and control are in the Control Center. Cameras are available to visually monitor the position and motion of the crane carriage, the rotating platform, and the crud catcher. Other cameras are available to visually monitor the positioning of the fuel transfer tube above a cell and the introduction of a fuel assembly in a cell.

5.2.5.3 Control and monitoring of the crane carriage

5.2.5.3.1 Description

The crane carriage consists of a motorized bridge (x direction) which supports a motorized trolley (y direction) which supports a motorized rotating platform. It can reach three types of positions :
- Over the source cask : over a fuel assembly centerline (or an empty cell in case of design event IV to replace a fuel in the source cask if necessary).
- Over the receiving cask : over an empty cell.
- In a "parking position" before opening or closing the source and receiving casks.

5.2.5.3.2 Operating principle

The motion is "strongly" computer assisted. To position the crane carriage of the Fuel Assembly Handling Subsystem, the operator sets the coordinates of the position (x,y) to be reached. After motion request, the bridge and the trolley are automatically positioned by the PLC using concurrent x and y movements (adapted speed, brakes...).

The position is rough and the operator has to finish the positioning of the transfer tube controlling x, y and θ motions. Fine tuning permits the operator to make the crane carriage reach the exact position over a fuel assembly (or empty cell) centerline.

5.2.5.3.3 Control and monitoring requirements

The Control Subsystem shall:

- Control crane carriage x direction motorization (mode / direction / run / stop / 2 speeds)
- Control crane carriage y direction motorization (mode / direction / run / stop / 2 speeds).
- Monitor the status (mode/running/stopped), and the current speed in the x direction.
- Monitor the status (mode/running/stopped), the current speed in the y direction.
- Detect an overrun in x and y directions (alarm + stop x and y motions).
- Monitor the x and y positions

Four overrun devices (one at each runway rail end of the two rails) which automatically stop motion (in both x and y directions) are provided. The PLC limits the use of the speeds to the slow one during the fine positioning.

5.2.5.3.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the crane carriage (bridge and trolley) with the hoist system. It shall prevent motion of the crane carriage if the fuel assembly grapple is not in its upper z position

- Interlock the crane carriage (bridge and trolley) with the crud catcher. It shall prevent motion of the crane carriage if the crud catcher is not closed.

- Interlock the crane carriage (bridge and trolley) with the upper shield ports. It shall prevent motion of the crane carriage if the two upper shield ports are not locked (in closed position).

- Interlock the crane carriage (bridge and trolley) with the TC port covers. It shall prevent motion of the crane carriage if the two TC port covers are not locked (in open position).

Rationale:
The interlocks prevent the crane carriage from moving during fuel assembly lifting/lowering operations. They guarantee that:

- if fuel is in the transfer tube, the crud catcher can minimize the spread of contamination and the fuel is fully retracted into the transfer tube during motion.

- if fuel is being lowered or lifted, the crane carriage won't move which could damage the fuel assembly and compromise recovery requirements.

- shielding to the roof of the DTS building during normal operating conditions or in case of a seismic event.

- the fuel transfer can't occur if the TC port covers are unlocked. If a seismic event occurs during a fuel transfer, the TC port covers will not collide with the fuel assembly.

- the safety of the source cask lid or receiving cask shield plug lifting won't be compromised by a collision with the fuel assembly handling crane

Dependent equipment:

TC port covers locking devices
Source Cask Lid/ Receiving Cask Shield Plug Handling Subsystem - hoist system
Fuel Assembly Handling Subsystem - crud catcher, hoist system

5.2.5.3.5 Instrumentation requirements

Redundant instrumentation is not necessary to control the crane carriage, since manual backup is provided.

Table 5.2.5.3.α lists the necessary instrumentation for the Fuel Assembly Handling Subsystem crane carriage.

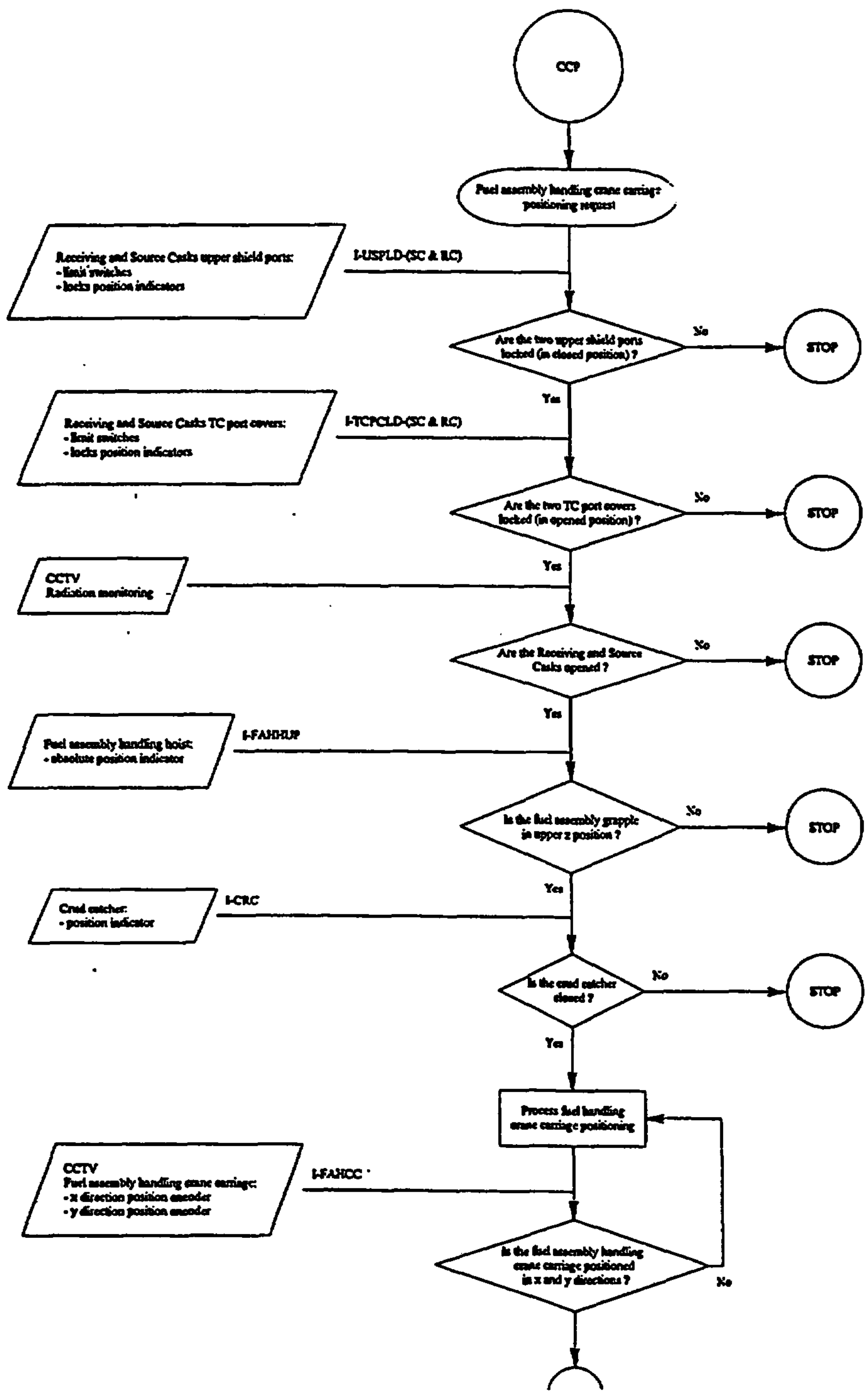
5.2.5.3.6 Flow charts

The flow chart describes the control of the crane carriage (bridge and trolley).

Table 5.2.5.3.α
Fuel Assembly Handling Subsystem
Crane Carriage Instrumentation

Equipment	Data	Sensor type	Action	Reference
Bridge (x)	Absolute traveling positioning	Synchroresolver	----	ZIT 101
	Over travel	Electrical switch	Stop motion	ZASH 102A ZASH 102B
Trolley (y)	Absolute traversing positioning	Synchroresolver	----	ZIT 104
	Over travel	Electrical switch	Stop motion	ZASH 105A ZASH 105B

Fuel Assembly Handling Crane Carriage Positioning



5.2.5.4 Control and monitoring of the rotating platform

5.2.5.4.1 Description

The rotating platform is motor driven, it supports the hoist motorization and can rotate ± 180 degrees around its centerline to allow the proper positioning of the fuel transfer tube above a fuel assembly centerline or an empty cell.

5.2.5.4.2 Operating principle

The operator remotely controls the θ motion of the rotating platform, chooses the direction (clockwise, counter clockwise) and the speed. The CCTV provides the viewing of the empty cell or of the fuel assembly centerline.

5.2.5.4.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the motorization of the rotating platform (run clockwise/counter-clockwise/stop/ 2 speed).
- Monitor the rotating platform orientation.

Monitoring, control and indications are in the Control center.

5.2.5.4.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the rotating platform with the hoist system. It shall prevent any rotation of the platform if the assembly grapple is not in upper z position.

- Interlock the rotating platform with the crud catcher. It shall prevent any rotation of the platform if the crud catcher is not closed.

Rationale:
The interlocks prevent the rotating platform from moving during a fuel assembly lifting or lowering operation which could damage the fuel assembly and compromise recovery requirements.

Dependent equipment:
Fuel Assembly Handling Subsystem - hoist system, crud catcher

5.2.5.4.5 Instrumentation requirements

No instrumentation has to be redundant for this scope.

Table 5.2.5.4.α lists the necessary instrumentation for the Fuel Handling Subsystem rotating platform.

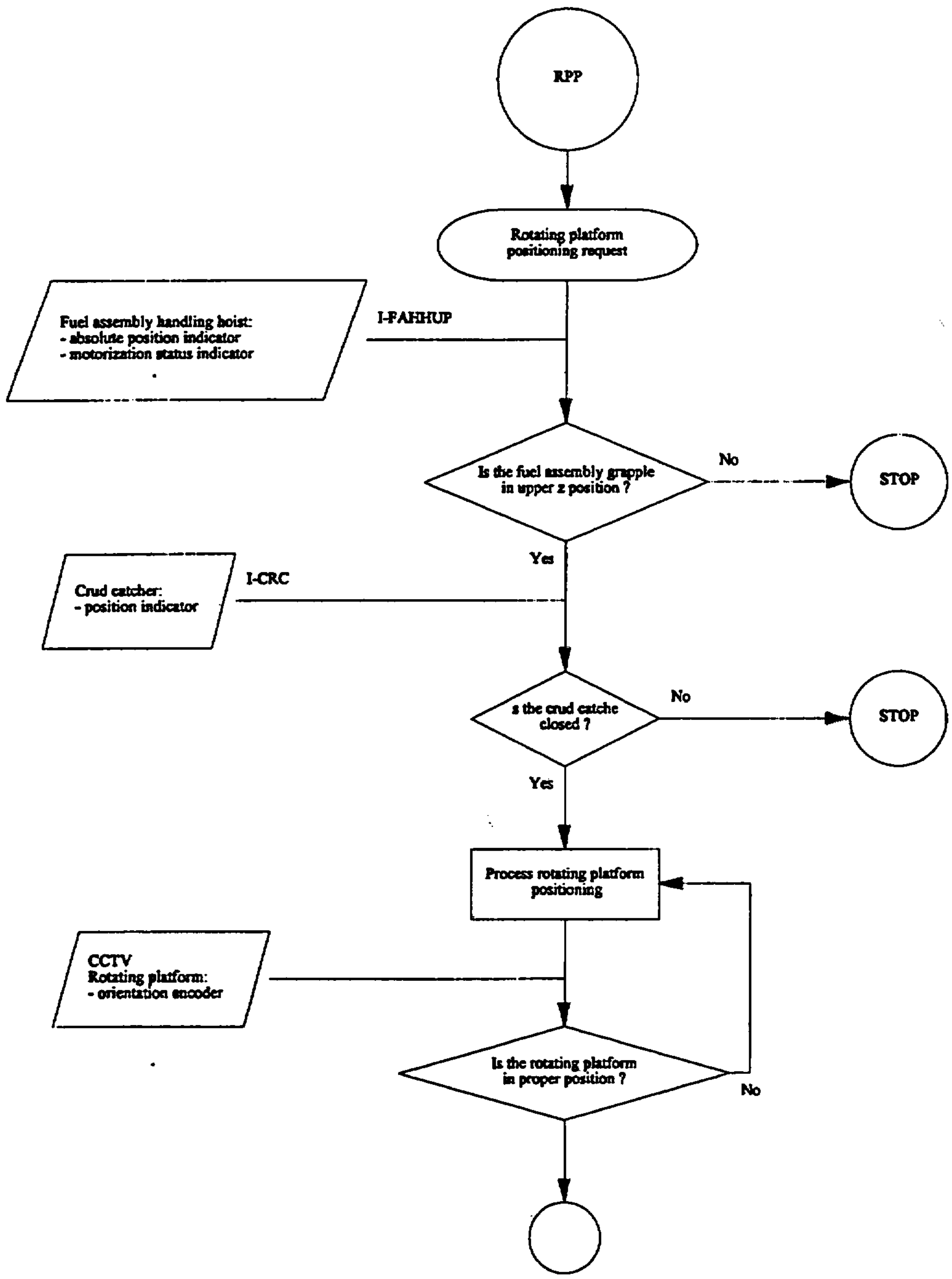
5.2.5.4.6 Flow charts

The flow chart describes the control of the rotating platform positioning.

Table 5.2.5.4.α
Fuel Handling Subsystem
Rotating Platform Instrumentation

Equipment	Data	Sensor type	Action	Reference
Rotating platform	Absoulte rotating positioning	Synchroresolver	----	ZIT 107

Rotating Platform Positioning



5.2.5.5 Control and monitoring of the crud catcher

5.2.5.5.1 Description

The crud catcher is a trapdoor actuated by an electric jack, which covers the bottom of the fuel assembly when it is fully retracted into the transfer tube. It minimizes the spread of radioactive particulate during the fuel transfer.

5.2.5.5.2 Operating principle

The crud catcher is remotely controlled. The operator sets the position he wants to reach (open/closed). When the electric jack is in the desired position, the completion of the operation is displayed by the supervisor. The CCTV Subsystem provides viewing of this equipment.

5.2.5.5.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the crud catcher motorization (open/close/stop).
- Monitor the device position (open/closed/undefined).

Monitoring and control are in the Control Center.

5.2.5.5.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the crud catcher with the crane carriage (bridge and trolley) motorizations. It shall prevent the crud catcher opening if the crane carriage is not stopped in x and y directions.

- Interlock the crud catcher with the rotating platform. It shall prevent the crud catcher opening if the rotating platform is in motion.

- Interlock the crud catcher with the fuel assembly handling hoist system. It shall prevent the crud catcher closure if the grapple is not in the upper z position.

Rationale:

The interlocks prevent crud catcher opening during fuel transfer tube positioning. They also ensure that if a fuel assembly is present in the transfer tube during positioning, it is fully retracted into it.

The interlock with the hoist system guarantees that the crud catcher can't damage the fuel assembly during closure.

Dependent equipment:
Fuel Assembly Handling Subsystem - crane carriage, rotating platform, hoist system

5.2.5.5.5 Instrumentation requirements

Table 5.2.5.5.α lists the necessary instrumentation for the Fuel Assembly Handling Subsystem crud catcher.

5.2.5.5.6 Flow charts

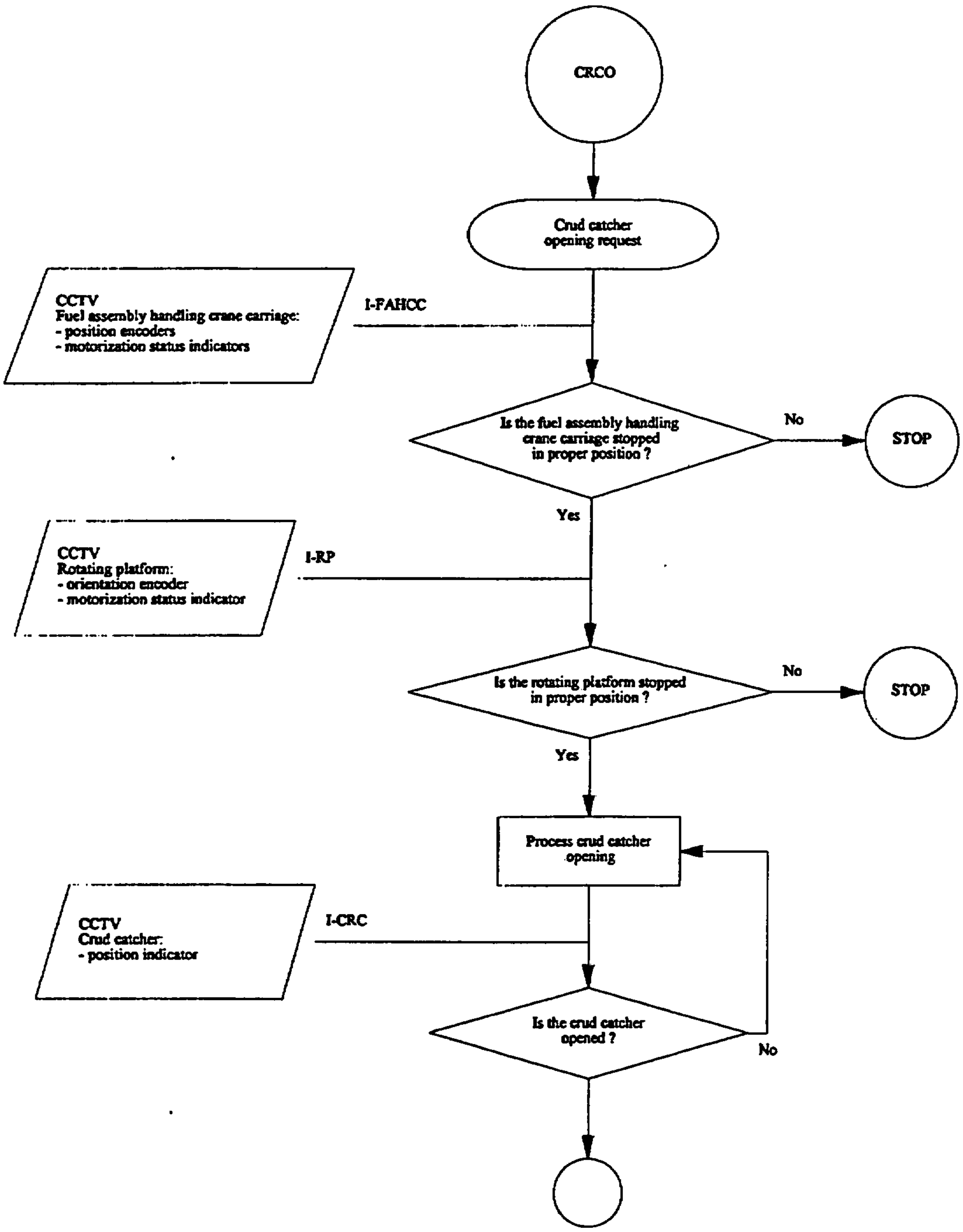
The flow charts describe the control of the following operations:

- Crud catcher opening
- Crud catcher closing

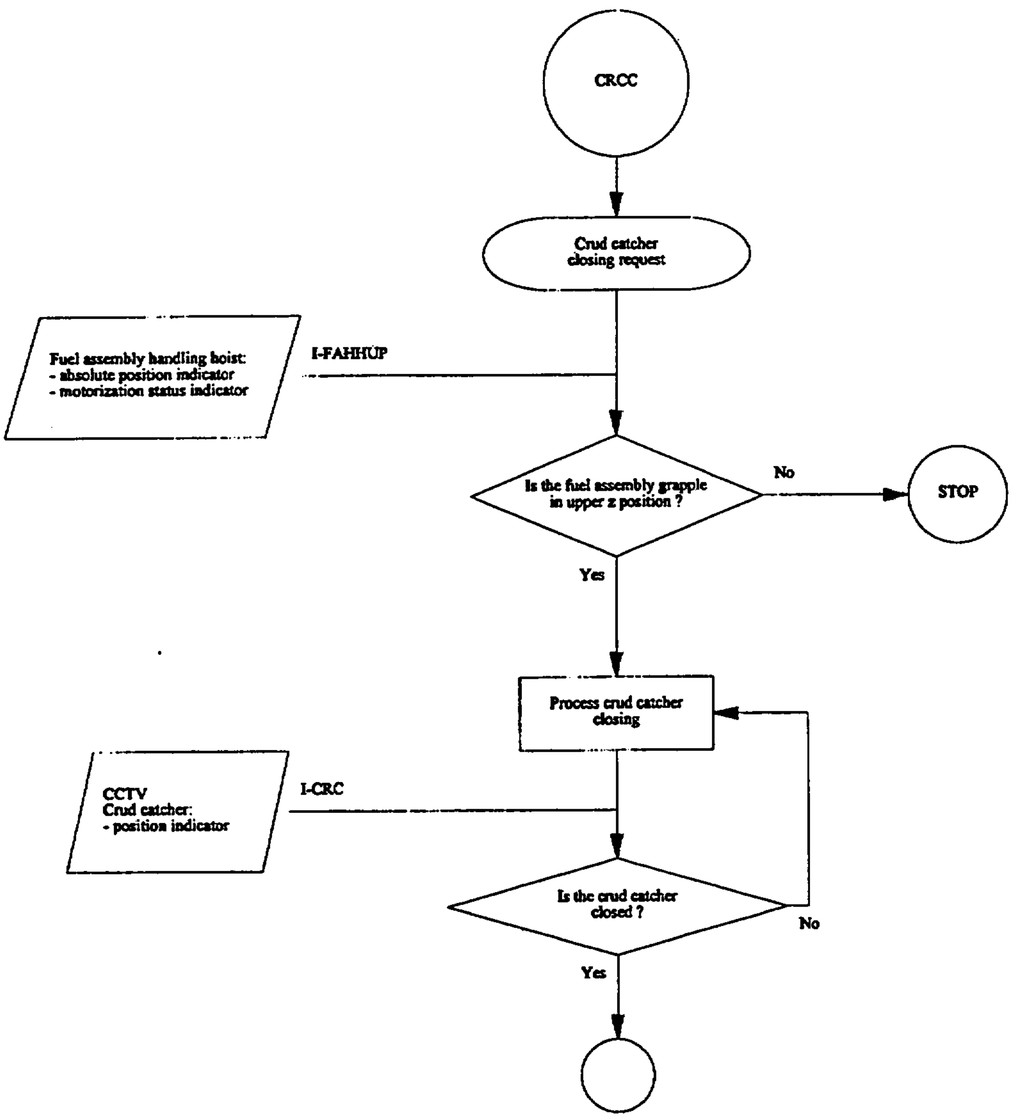
Table 5.2.5.5.α
Fuel Assembly Handling Subsystem
Crud Catcher Instrumentation

Equipment	Data	Sensor type	Action	Reference
Crud catcher	Open position	Electrical contact	----	YL 119A
	Closed position	Electrical contact	----	YL 119B

Crud Catcher Opening



Crud Catcher Closing



5.2.5.6 Control and monitoring of the hoist system

5.2.5.6.1 Description

The hoist system consists of a cable with two motorized winches.

5.2.5.6.2 Operating principle

Only one winch can be controlled at a time. The operator selects the current winch, and activates it for lowering and lifting operations.

Lowering:
The speed of each winch is variable. The lowering operation is automatically stopped when the cables are underloaded.

Lifting:
The operator uses the variable speed and the operation is automatically stopped when the grapple is in the upper position.

During operations, the operator can monitor the z position of the grapple. The CCTV Subsystem provides the viewing of the top of the fuel assembly in the cask or of the top of an empty cell. The operator can monitor the entry of the fuel assembly in an empty cell.

5.2.5.6.3 Control and monitoring requirements

The Control Subsystem shall:
- Allow the selection of the current winch
- Control the current motorized winch (lower / lift / stop / speed).
- Monitor the current motorization status (lowering / lifting / stopped), and the current speed.
- Detect an overrun (lowest grapple position)/underrun (highest grapple position) (alarm + stop motion).
- Detect an overload (alarm + stop motion).
- Detect an overspeed (alarm + stop motion).
- Detect an abnormal drum rope level wind (alarm + stop motion).
- Detect an underload (stop motion).
- Monitor the length of the unreeled cable.

The two motorized winches can not operate simultaneously and use the two different power supply channels. The speed is variable and is controlled by the operator. However the slow speed is automatically selected below a limit z position of the grapple.
The overrun/underrun, overload, overspeed and abnormal drum rope level winds situations are abnormal, their detection generates an alarm and automatically stops motion. The underload is

a normal situation.

5.2.5.6.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

- Interlock the hoist system with the crud catcher. It shall prevent lowering of the grapple if the crud catcher is closed.

- Interlock the hoist system with the fuel assembly grapple. It shall prevent lifting if the grapple is not totally engaged or disengaged.

- Interlock the hoist system with the crane carriage and the rotating platform. It shall prevent lowering if the crane carriage and the rotating platform are not stopped.

Rationale:
The interlocks prevent:
- the fuel assembly from getting stuck in the transfer tube
- dropping of a fuel assembly due to an improper gripping

Depending equipment:
Fuel Assembly Handling Subsystem - crud catcher, grapple, crane carriage, rotating platform

5.2.5.6.5 Instrumentation requirements

Redundant motorization, on two different power channels are provided.

Table 5.2.5.6.α lists the necessary instrumentation for the Fuel Assembly Handling Subsystem hoist.

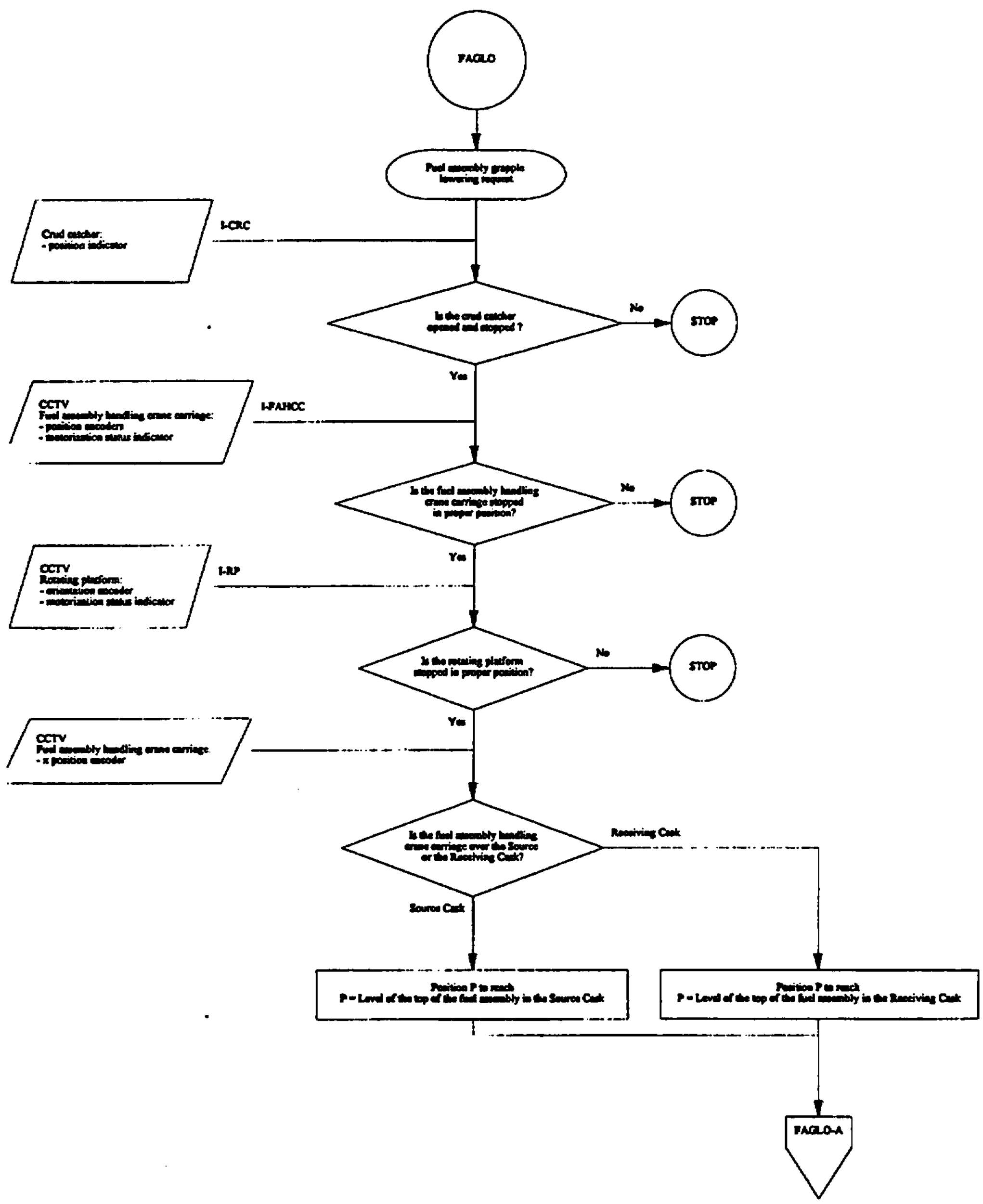
5.2.5.6.6 Flow charts

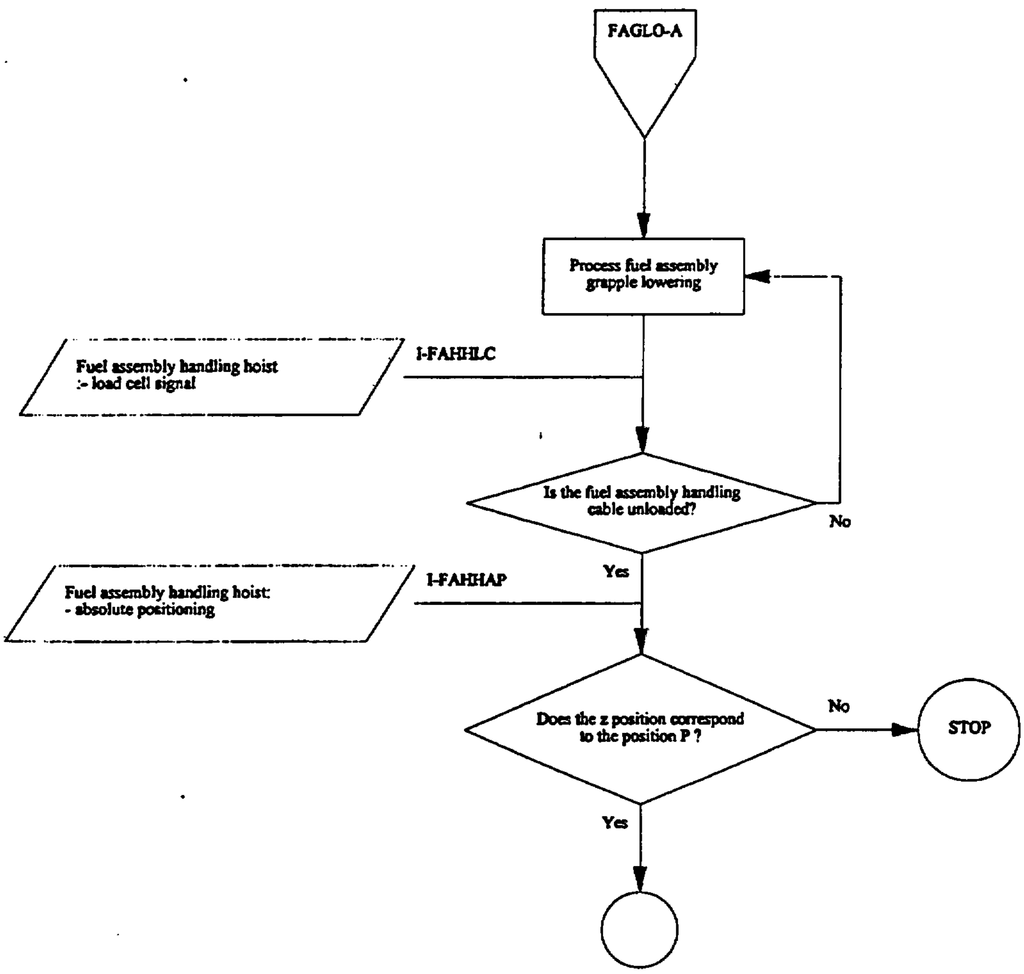
The flow charts describe the following operations:
- Fuel assembly grapple lowering
- Fuel assembly grapple lifting

Table 5.2.5.6.α
Fuel Assembly Handling Subsystem
Hoist System Instrumentation

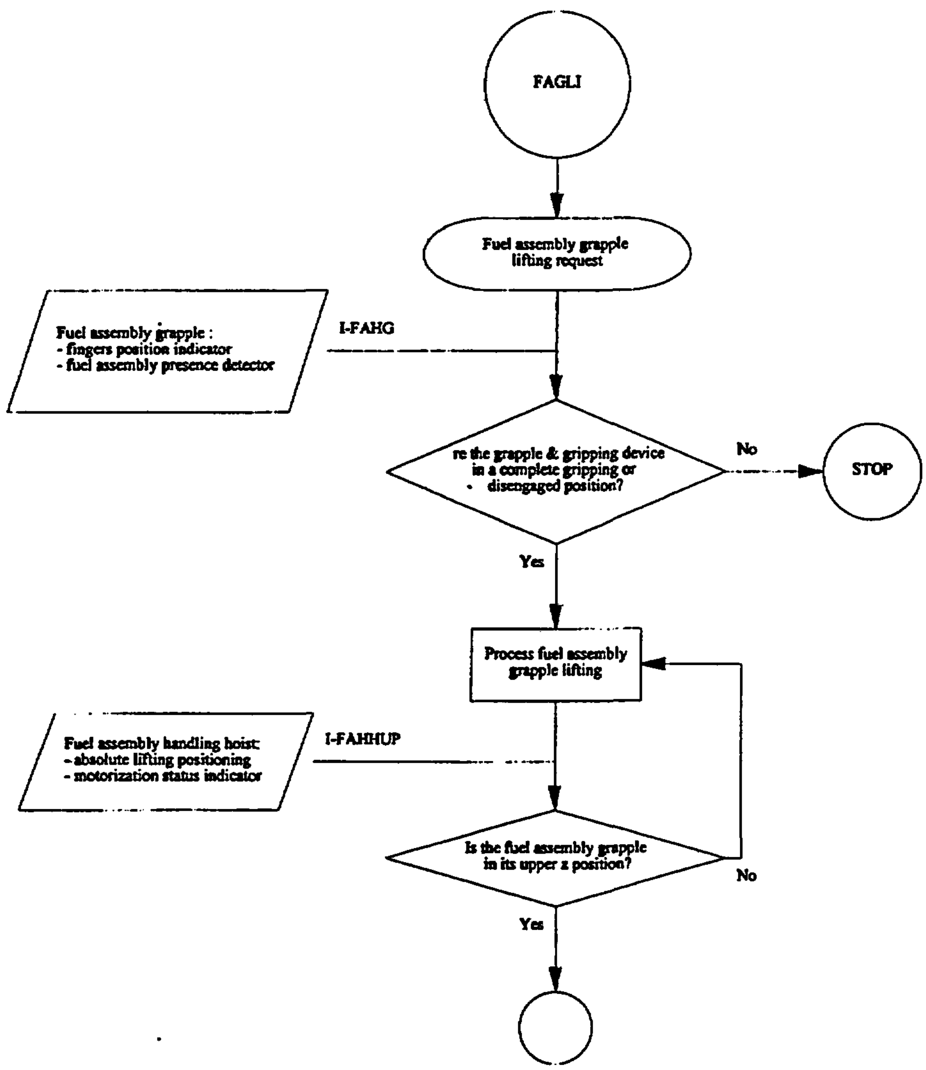
Equipment	Data	Sensor type	Action	Reference
Hoist motorization	Absolute lifting positioning	Wire potentiometer	----	ZIT 109
	First high limit	from ZIT 109	Stop motion	ZSH 109
	Final overtravel high limit	Electrical switch	Stop motion	ZASH 118
	First low limit	from ZIT 109	----	ZSLL 109
	Final overtravel low limit	Electrical switch	Stop motion	ZASL 110
	Hoist overspeed limits	Electrical switch	Stop motion	SASH 111 SASH 112
	Hoist drum rope level winds	Electrical switch	Stop motion	ZS 113 ZS 114
	Weight of live load	Load cell	----	WIT 115
	Limit weights	from WIT 115	Stop motion	WASH 115 WASL 115

Fuel Assembly Grapple Lowering




FAGLO-A
Process fuel assembly grapple lowering
Fuel assembly handling hoist :- load cell signal
I-FAHHLC
Is the fuel assembly handling cable unloaded?
No
Yes
Fuel assembly handling hoist: - absolute positioning
I-FAHHAP
Does the z position correspond to the position P ?
No
STOP
Yes

Fuel Assembly Grapple Lifting



5.2.5.7 Control and monitoring of the grapple

5.2.5.7.1 Description

The motorized grapple shall be able to grip and disengage the spent fuel assembly. There are three motors, one for normal operating conditions and the two others for backup.

5.2.5.7.2 Operating principle

The operator selects the normal or backup equipment using a switch on the main control panel, and activates it by setting the desired status (connected/disconnected). The operation is automatically stopped when the desired status is reached and this information is displayed by the supervisor. The CCTV Subsystem provides viewing of the operation.

5.2.5.7.3 Control and monitoring requirements

The Control Subsystem shall:

- Select the current grappling equipment (normal/backup).
- Control the motorized grapple (grapple/disengage/stop).
- Monitor the grapple status (grappling/disengaged/undefined).
- Monitor the grapple fingers position (open/closed/undefined).
- Detect the fuel assembly presence.

All the indications are displayed in the Control Center. The two backup motors shall be on the secondary power channel. The backup equipment shall only be used to disengage the grapple.

5.2.5.7.4 Transition conditions validation requirements

Requirements:
The following interlock shall be implemented:

Interlock the grapple with the hoist system. It shall prevent the disengagement of the fuel assembly if the cable is loaded and if the grapple is not stopped in a proper position.

Rationale:

The interlock with the hoist system guarantees that the spent fuel can't be dropped due to an operator error.

Dependent equipment:

Fuel Assembly Handling Subsystem - winches
TC port covers and locking devices
Source cask lid/receiving cask shield plug handling subsystem - upper shield ports and locking devices

5.2.5.7.5 Instrumentation requirements

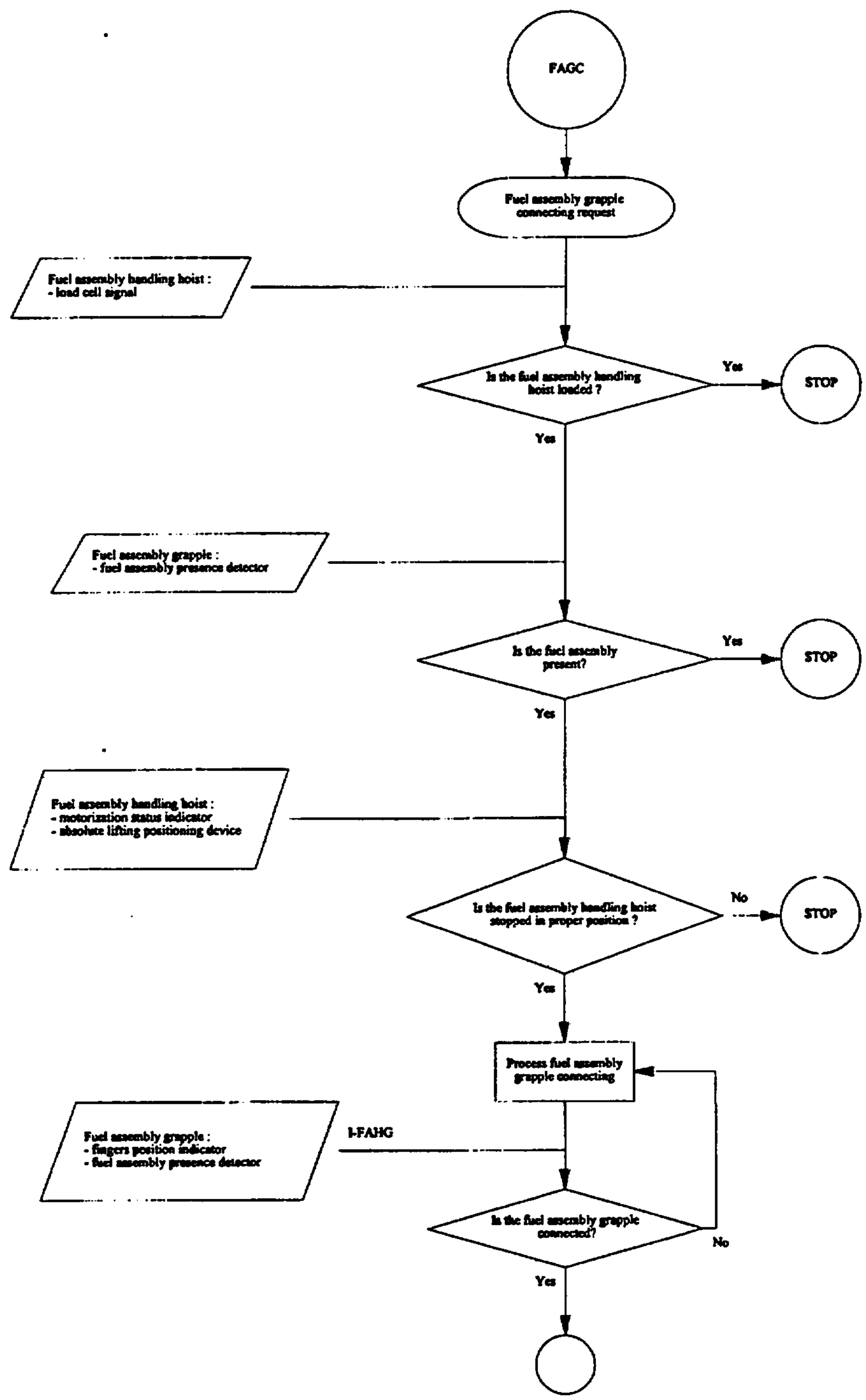
The grapple motorization is redundant.

Table 5.2.5.7.α lists the necessary instrumentation for the Fuel Assembly Handling grapple.

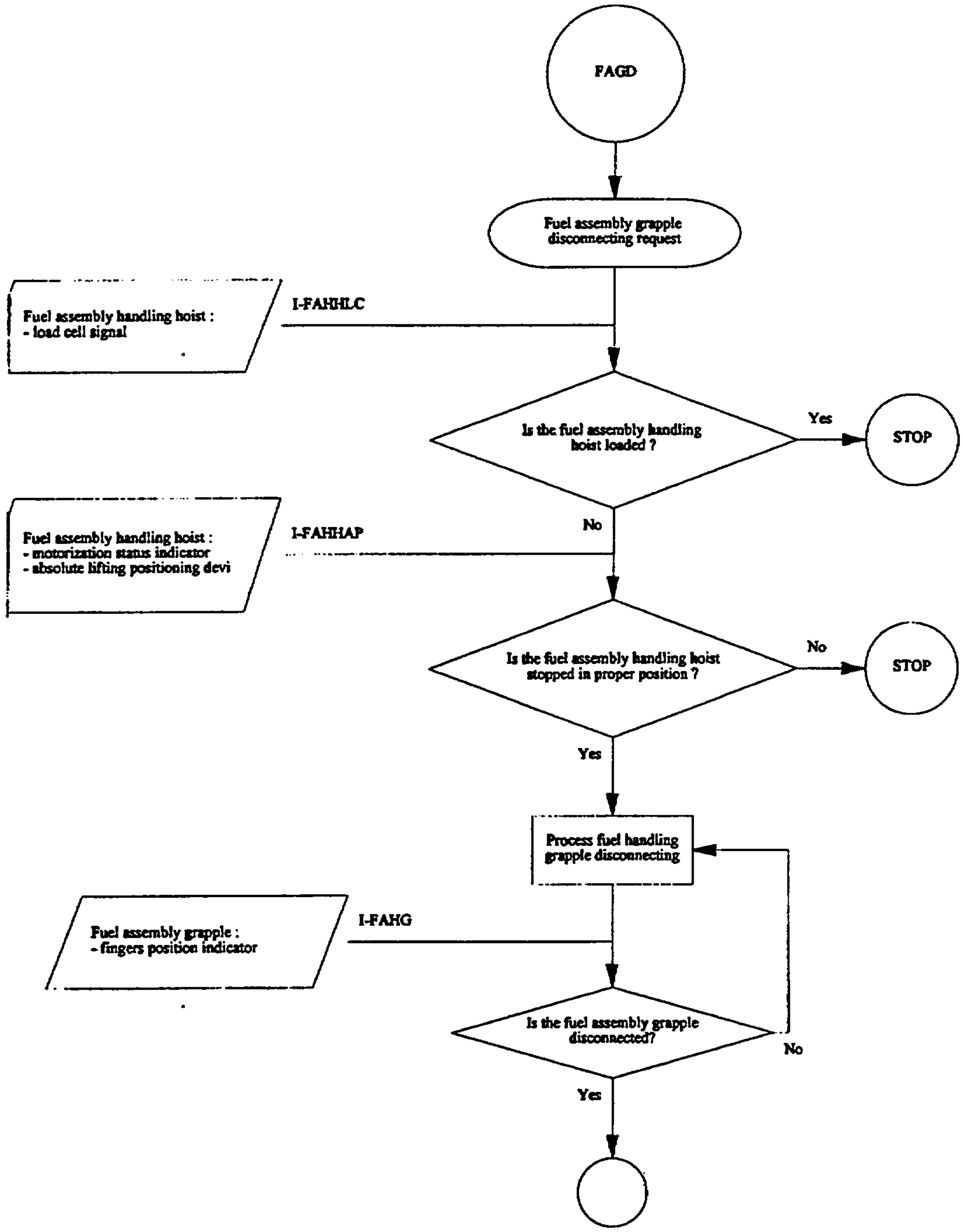
Table 5.2.5.7.α
Fuel Assembly Handling
Grapple Instrumentation

Equipment	Data	Sensor type	Action	Reference
Grapple	Grapple fingers closed	Electrical switch	----	YL 116B
	Grapple fingers open	Electrical switch	----	YL 116A
	fuel assembly presence	Electrical switch	Stop motion	YLS 117

Fuel Assembly Grapple Connecting



Fuel Assembly Grapple Disconnecting



5.3 Control and monitoring of the Structural Subsystem's doors

5.3.1 Description

The Structural Subsystem includes two motorized doors:

- a rollup door that permits entry and removal of the source and receiving casks in the Preparation Area.
- a sliding door that permits entry and removal of the source and receiving casks between the Preparation Area and the Lower Access Area.

The sliding door provides confinement of the Lower Access Area during operations (except casks transfer operations). Four locking devices guarantee that the sliding door remains closed in case of a seismic event. These locking devices are manually operated.

5.3.2 Operating principles

The sliding door is locally operated, and visually monitored, either from the Lower Access Area or from the Preparation Area.

The rolling door is locally operated, and visually monitored, either from outside the DTS or from the Preparation Area.

5.3.3 Control and monitoring requirements

The Control Subsystem shall:

- Control the sliding door motorization (open/close).
- Monitor the locked positions of the locking pins (locked/unlocked).
- Detect the closed position of the sliding door.
- Detect the closed position of the rollup door.

Control and monitoring of the sliding door shall be in the Preparation Area and in the Lower Access Area.

The detection of the doors' positions is used by the PLC for HVAC regulation (see Section 5.4).

5.3.4 Transition conditions validation requirements

Requirements:
The following interlocks shall be implemented:

Interlock the sliding door with the Radiation Monitoring Subsystem. It shall prevent opening of the sliding door if the radiation level is not acceptable.

Dependent equipment:

TC port covers

5.3.5 Instrumentation requirements

Table 5.3.α lists the necessary instrumentation for the Structural Subsystem sliding door.

5.3.6 Flow charts

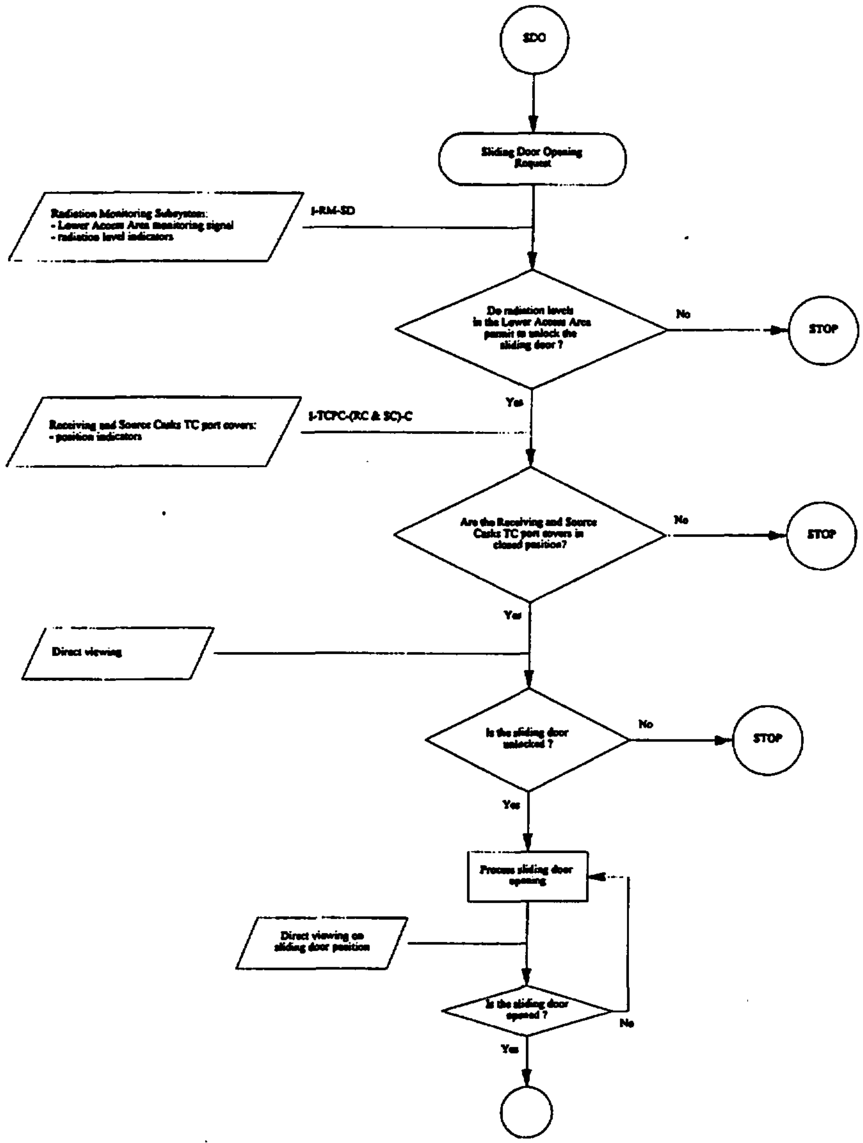
The flow charts describe the control of the following operations:

- Sliding door opening
- Sliding door closing

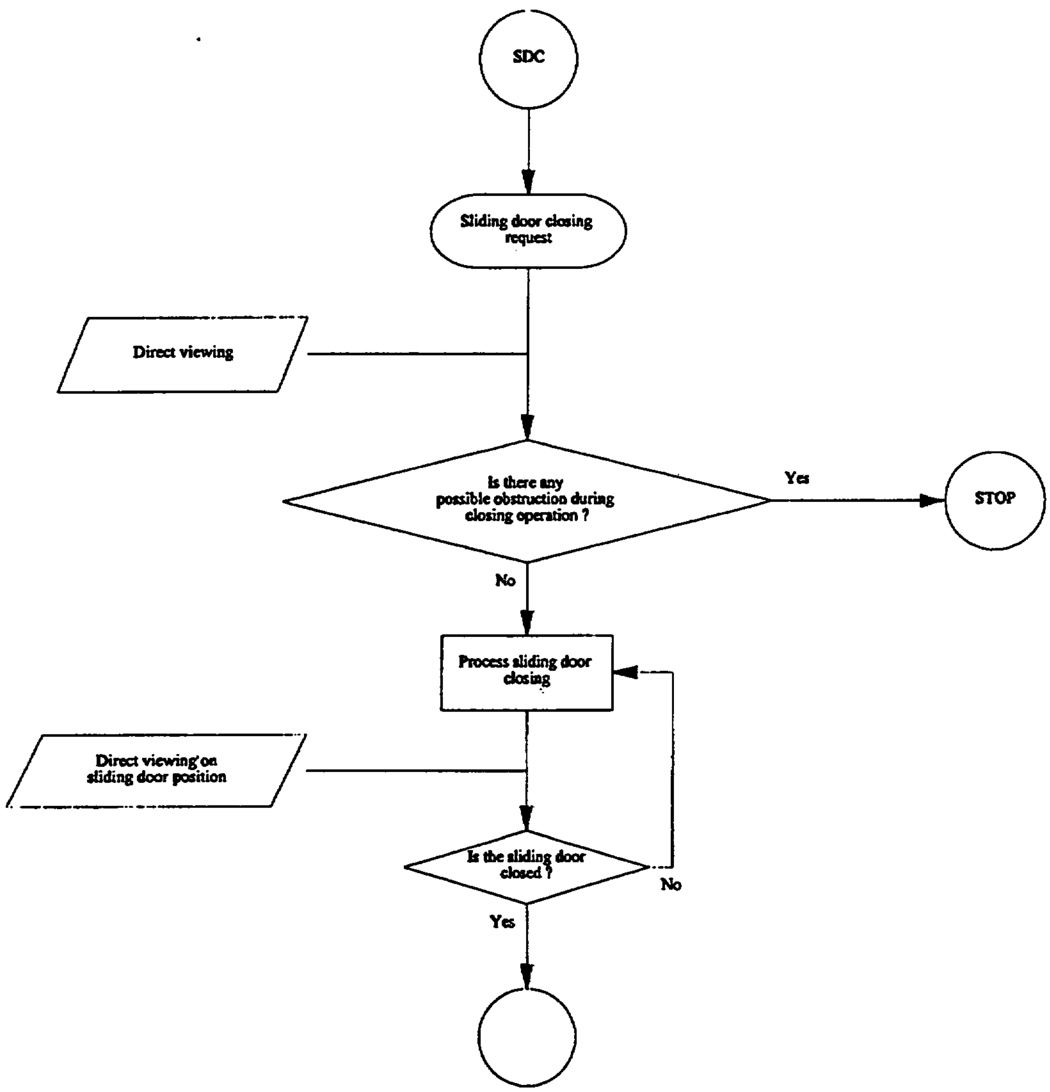
Table 5.3.α
Structural Subsystem
Sliding door Instrumentation

Equipment	Data	Sensor type	Action	Reference
Sliding door	Locking pin in position	Electrical contact	----	YL 801A YL 801B YL 801C YL 801D
	Closed position	Electrical switch	Stop motion	ZS 802
Rollup door	Closed position	Electrical switch	Stop motion	ZS 803

Sliding Door Opening



Sliding Door Closing



5.4 Interfaces with the HVAC Subsystem

5.4.1 Functional Description

The HVAC Subsystem is designed to provide an additional level of confinement of radioactive material associated with the transfer of spent fuel assemblies, to direct air flow from areas of low levels of potential contamination to areas of higher levels of potential contamination, and to control the temperatures of the spent fuel, fuel transfer equipment, the DTS structure and associated components. All three areas of the DTS, i.e., the Preparation Area, the Lower Access Area and the TCA are served by the HVAC Subsystem.

The HVAC Subsystem performs its confinement function by maintaining negative pressures in various areas relative to atmospheric pressure. By establishing pressure differentials, air flow direction is maintained from the ambient into the Preparation Area through the Lower Access Area to the TCA. The air is exhausted through HEPA filter banks up a stack. Redundant components such as exhaust fans and HEPA filters have been incorporated into the design to minimize the potential for failure of the confinement function during normal operating conditions. Motorized dampers can isolate a HEPA filter bank for replacement of the filter.

The temperature in each area of the DTS is maintained with a combination of air conditioning and heating units. The air in the Roof Enclosure Area is also maintained by a separate air conditioning/heat pump unit.

The control schematics of the HVAC Subsystem are provided in the Referenced Document 1.7.

5.4.2 Monitoring and alarms of the HVAC Subsystem

The equipment is controlled by the PLC which is specific to the HVAC Subsystem, the Radiation Monitoring Subsystem and the sliding door. The supervisor displays the HVAC Subsystem information such as:

- the temperature in each area
- the pressure in each area
- the equipment status

5.4.2.1 Pressure monitoring

The pressure information in each area is used to validate the proper functioning of the HVAC Subsystem, prior to initiating the cask opening process. The pressure in each area is based on pressure differentials between:

- the outside and the Preparation Area
- the Preparation Area and the Lower Access Area

- the Lower Access Area and the Transfer Confinement Area
- the Transfer Confinement Area and the outside

The failure of a pressure sensor is automatically detected by periodically verifying the consistency between all the pressure information. This generates an alarm which is activated by the PLC which uses the pressure differential information to regulate the system.

5.4.2.2 Temperature monitoring

Temperature information in each area is provided by sensors at each Air Handling Unit duct entrance. One temperature sensor in the ductwork before the exhaust fans, outside the DTS, provides the temperature of the exhausted air. The failure of a temperature sensor can result in an air overheating or overcooling. Alarms are generated when the signal from any sensor strays from within a given range. A failure of the Preparation Area cooling/heating system is detected by the Lower Access Area cooling/heating system. A failure of the Lower Access Area cooling/heating system is detected by the TCA cooling/heating system. A failure of the TCA cooling/heating system is detected by the temperature sensor outside the building. These failures generate alarms that the supervisor displays.

5.4.2.3 Equipment status monitoring

The status (on/off) of the two exhaust fans is displayed by the supervisor. The information is provided by the pressure differential switch in the exhaust fan. The speed of the operating exhaust fan is also monitored.

The dampers' position and motion, the cooling, heating or dehumidification systems' activities are not monitored.

5.4.2.4 HEPA filters alarms

Pressure differential sensors which measure the pressure differential accross each HEPA filter are linked to the PLC which generates alarms in the case of abnormally low (broken filter) or high (filter full) pressure differential.

5.4.3 Control of the HVAC Subsystem

5.4.3.1 Pressure control

Motorized dampers between the Preparation Area and the Lower Access Area and between the Lower Access Area and the TCA are controlled by the PLC as well as variable speed exhaust fans (lead and backup).

At system start-up, all dampers between areas are closed. The lead exhaust fan isolation control damper will open and the fan will ramp up via its variable frequency drive to a speed which will maintain the static pressure setpoint for the TCA as sensed by the TCA static pressure sensor. After an adjustable delay period, the damper between the Lower Access Area and the TCA will come under control of the Lower Access Area static pressure sensor and will modulate to maintain Lower Access Area static setpoint. After a second similar delay, the damper between the Preparation Area and the Lower Access Area will come under control of the Preparation Area static pressure sensor and will modulate to maintain the Preparation Area static setpoint. As each of these dampers comes on line, the exhaust fan speed will increase as required to maintain the TCA static setpoint. The static pressure control will only operate when the source and receiving casks are mated to the TCA, and the DTS sliding door and Preparation Area doors are closed. The system will react to changes in the infiltration of air into the DTS by speeding up or slowing down the fan and opening or closing dampers as necessary to maintain pressure differential setpoints. This is the typical operating mode during which the transfer of fuel will occur.

When the Preparation Area door (rollup door) is opened, the air curtain units will be energized via door mounted end switch to help prevent the influx of dust and insects. When the Preparation Area door is closed, these units will automatically be turned off.

In the event that the PLC senses a failure of the lead exhaust fan (absence of pressure differential), an alarm will be generated, the lead fan isolation damper will close, the standby fan isolation damper will open, and the startup sequence will continue as described above. In the event that a failure is sensed during normal operation (for example, a fan belt breaks) the lead fan isolation damper and the two transfer dampers will close, the standby fan isolation damper will open, and the startup sequence will continue as described above. The control dampers in the Lower Access Area and the TCA are designed to fail in the open position to allow the airflow through these areas to continue in the proper direction in the event of a loss of control of any damper. The control damper in the duct between the Preparation Area and the Lower Access Area is designed to fail in the closed position.

Four motorized dampers, on each side of the two sets of HEPA filters are used to isolate the HEPA filters in order to replace them. These dampers can be remotely opened or closed by the operator using bypasses. Two dampers (one on each side of the HEPA filters) are activated at the same time. When these dampers close, the absence of pressure differential accross the corresponding HEPA filters validates the closure of the dampers.

Normal operations of the DTS cycle have an influence on the control of the HVAC exhaust fan speed and dampers' control. When the source or receiving casks are being moved in or out of the DTS, the ventilation system air flow will be controlled to prevent high air flow rates within the TCA and increase the risk of the generating airborne contamination. Information that the Cask Mating Subsystem has been disengaged or the DTS sliding door has been opened, will be used by the PLC to override the fan/damper components from trying to re-establishing the pressure setpoints.

Once both casks are mated and the doors are closed, the PLC restarts the regulation process.

5.4.3.2 Temperature control

The cooling, heating and dehumidification devices are self-controlled. These devices only interface with the Control Subsystem providing temperature monitoring and alarms.

5.5 Interface with the Radiation Monitoring Subsystem

5.5.1 Monitoring requirements

Gamma area radiation monitors are located in the Preparation Area, in the Lower Access Area, in the Transfer Confinement Area and in the roof enclosure. Their values are interpreted by the PLC managing the HVAC Subsystem and the sliding door. All the values are transmitted to the PC to allow a remote monitoring of the radiation levels in the different areas and a periodical storage if necessary. Some values are used by the PLC for the interlocks with the sliding door. Some others are transmitted to the PLC for the mechanical equipment and for the interlocks with the upper shield ports.

5.5.2 Interlocking requirements

The Lower Access Area monitor is interlocked with the sliding door in order to prevent the opening of the sliding door in case of high radiation levels.

The roof enclosure monitor is interlocked with the upper shield ports to prevent their opening in case of high radiation levels.

5.6 Interfaces with the CCTV and Lighting Subsystems

5.6.1 Description

The CCTV Subsystem provides viewing of the mechanical equipment located in the Transfer Confinement Subsystem and in the Lower Access Area during operations. It is used as a validation means for most of the transition conditions. It is used for various functions too such as equipment inspection and fuel assembly identification. Each following subsection details the interface with the concerned mechanical equipment, operations and transition conditions.

5.6.2 Interfaces with the Transfer Confinement Cask Mating Subsystem

The CCTV Subsystem provides a side viewing of the two bellows and the mating platform during the mating and disengagement operations from the top of a cask to the mezzanine. The transition condition which is partially validated by the CCTV Subsystem is the disengagement of the mating flanges. The mating position can't be validated using the CCTV Subsystem because of the accuracy required for this operation. The transition validation means are described in Section 5.2.2.

5.6.3 Interfaces with the Transfer Confinement Port/Shield Subsystem

The CCTV Subsystem provides viewing of the two TC port covers during the closing, opening and off centering operations.

The different positions of the TC port covers are indicated by lines on the mezzanine. The position transitions are partially validated by the alignment of these lines with the TC port covers.

The locking operations can't be validated using the CCTV Subsystem as there is no visibility of the involved equipment. The transition validation means are described in Section 5.2.3.

5.6.4 Interfaces with the Source Cask Lid and Receiving Cask Shield Plug Handling Subsystem

The CCTV Subsystem provides viewing in the TCA only for this subsystem. The operations involving the upper shield ports and the upper crane can't be monitored with the CCTV Subsystem.

The motion of the grapple, its position above the mezzanine level and its connection with the source cask lid or receiving cask shield plug can be monitored but not validated with the CCTV Subsystem.

5.6.5 Interfaces with the Fuel Assembly Handling Subsystem

Cameras on the walls provide viewing of the following equipment:

- the crane carriage during positioning
- the rotating platform during positioning
- the crud catcher during opening and closing operations

The crud catcher position can be partially validated with this equipment.

Cameras on the bottom of the transfer tube provide viewing of the top of the baskets of the source and receiving casks. They permit the operator to:

- position the transfer tube above a fuel assembly centerline or an empty cell
- identify the fuel assemblies
- monitor the entrance of the fuel assembly in the basket
- monitor the position of the grapple around the basket level
- monitor the connection status between the grapple and the fuel assembly

The proper position of the transfer tube is validated using this equipment. The proper position of the grapple and its connection status can't be validated using the CCTV Subsystem.

5.7 Transition conditions validation synthesis

5.7.1 Viewing and instrumentation requirements for transition conditions validation

Based on Sections 5.2 and 5.6 information, this section provides a synthesis of the different instrumentation requirements necessary to validate the transition conditions.

Table 5.7.1.α lists these requirements for each transition condition validation.

Table 5.7.1.α
Viewing and means requirement for transition conditions validation

Legend

- N: Nothing
- D: Direct viewing
- C: CCTV
- S: Single means
- R: Redundant or two different means

Data	Transition Condition	Viewing N/D/C	Means N/S/R
Position of the sliding door	SDO-x	D	N
	SDC-x		
Lock position of the sliding door	SDL-x	D	S
	SDU-x		
Position of the casks transfer trolleys	TCE-x	D	S
	TCR-x		
	TCP-x		
Lock position of the tránsfer trolley	TCL-x	N	S
	TCU-x		
Position of the Mating flange	MF-up	C	S
	MF-mp	N	R

Table 5.7.1.α (Continued)
Viewing and means requirement for
transition conditions validation

Data	Transition Condition	Viewing N/D/C	Means N/S/R
Position of the TC port cover	TCSPO-x	C	S
	TCSPC-x		
	TCSPOC-x		
Lock position of the TC port cover	TCSPL-x	N	R
	TCSPU-x		
Position of the upper crane	UCP-x	N	S
Position of the upper shield port	USPO-x	N	S
	USPC-x		
Lock position of the upper shield port	USPL-x	N	R
	USPU-x		
z position of the lid / shield plug grapple	LSPG-up	N	S
	LSPG-p1		
	LSPG-p2		
	LSPG-p3		
Lid/shield plug grapple connection status	LSPG-c	N	R
	LSPG-d		
Lid / shield plug handling cable load	LSPHC-lz	N	S
Position of the crane carriage	CCP-x	C	S
Position of the rotating platform	RPP-x	C	S
Position of the crud catcher	CRCO-x	C	S
	CRCC-x		

Table 5.7.1.α (Continued)
Viewing and means requirement for
transition conditions validation

Data	Transition Condition	Viewing N/D/C	Means N/S/R
z position of the fuel assembly grapple	FAG-up	N	S
	FAG-p	N	
Fuel assembly grapple connection status	FAGD-x	N	R
	FAGC-x		
Fuel assembly handling cable load	FAHC-lz	N	S

5.7.2 Interlock synthesis

Based on Section 5.2, 5.3 and 5.4, table 5.7.2.α provides a synthesis of all the interlocks used to safely control the process. The table lists, for each interlock, the instrumentation which is the source of the information, the affected equipment and a brief description of the interlock. The interlock acronyms are those which are used in the flow charts.

Table 5.7.2.α
Interlock Synthesis

Interlock Acronym	Source equipment	Signal transmitters	Interlocked equipment	Prevention description
I-CRC	Crud catcher	YL 119A YL 119B	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the crud catcher is not in closed position
			Rotating platform	Any motion of the rotating platform if the crud catcher is not in closed position
			Fuel assembly handling hoist system	Lowering of the fuel assembly grapple if the crud catcher is not opened
I-FAHCC	Fuel assembly handling crane carriage (bridge and trolley)	No transmitter	Receiving and Source Casks TC port covers and locking devices	Unlocking and closing of any TC port cover if the fuel assembly handling crane carriage is in motion.
			Crud catcher	Opening of the crud catcher if the fuel assembly handling crane carriage is in motion.
			Fuel assembly handling hoist system	Lowering of the fuel assembly grapple if the fuel assembly handling crane carriage is in motion.
I-FAHG	Fuel assembly handling grapple	YL 116B YL 116A YLS 117	Fuel assembly handling hoist system	Lifting of the fuel assembly grapple if it is not totally connected or disconnected
			Receiving and Source Casks TC port covers and locking devices	Unlocking and closing of any TC port cover if the fuel assembly grapple is engaged
			Receiving and Source Cask upper shield ports and locking devices	Unlocking and opening of any upper shield port if the fuel assembly grapple is engaged
I-FAHHAP	Fuel assembly handling hoist system	ZIT 109	Fuel assembly handling grapple	Disconnecting the fuel assembly if the fuel assembly grapple is not in a proper position

Table 5.7.2.α (Continued)
Interlock Synthesis

Interlock Acronym	Source equipment	Signal transmitters	Interlocked equipment	Prevention description
I-FAHHLC	Fuel assembly handling hoist system	WIT 115	Fuel assembly handling grapple	Disconnecting the fuel assembly if the hoist is loaded
			Receiving and Source Casks upper shield ports and locking devices	Unlocking and opening of any upper shield port if the fuel assembly handling hoist is loaded
			Receiving and Source Casks TC port covers and locking devices	Unlocking and closing of any TC port cover if the fuel assembly handling hoist is loaded
I-FAHHUP	Fuel assembly handling hoist system	ZSH 109	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the fuel assembly grapple is not in its upper z position
			Rotating platform	Any motion of the rotating platform if the fuel assembly grapple is not in its upper z position
			Crud catcher	Closing of the crud catcher if the fuel assembly grapple is not in its upper z position
I-FAHPP	Fuel assembly handling crane carriage (bridge and trolley)	ZIT 101 ZIT 104	Lid/shield plug handling hoist system	Lowering and lifting of the lid/shield plug grapple if the crane carriage is not stopped in parking position
I-LSPHAP	Lid/shield plug handling hoist system	ZIT 307	Lid/shield plug grapple	Disconnecting of the lid/shield plug if the grapple is not in the proper position
			Receiving and Source Casks TC port covers	Closing of any TC port cover if the lid/shield plug handling hoist system is not above the position of the shield plug overlid on the TC port cover level
I-LSPHGP	Lid/shield plug handling grapple	YL 311A YL 311B YLS 310 ZL 315A ZL 315B	Lid/shield plug handling hoist system	Lifting of the lid/shield plug handling grapple if the grapple is not totally connected or disconnected (including overlid)

Table 5.7.2.α (Continued)
Interlock Synthesis

Interlock Acronym	Source equipment	Signal transmitters	Interlocked equipment	Prevention description
I-LSPHLC	Lid/shield plug handling load cell	WIT 309	Lid/shield plug handling grapple	Disconnecting the lid/shield plug if the cables are loaded
I-LSPHUP	Lid/shield plug handling hoist system	ZLL 307	Receiving and Source Casks upper shield ports	Closing of any upper shield port if the lid/shield plug grapple is not stopped in its upper z position
			Upper crane	Any motion of the upper crane if the lid/shield plug grapple is not stopped in its upper z position
I-RM-UL	Radiation monitoring at the upper level	RAH 905	Receiving and Source Casks upper shield ports and locking devices	Unlocking and opening of any upper shield port if the radiation level is too high
I-RM-SD	Radiation monitoring Lower Access Area	RAH 903	Sliding door	Opening of the sliding door in case of high radiation levels in the Lower Access Area
I-RP	Rotating platform	No transmitter	Fuel assembly handling hoist system	Lowering of the fuel assembly grapple if the rotating platform is not stopped
			Crud catcher	Opening of the crud catcher if the rotating platform is not stopped
I-SDLD	Sliding door locking device	YL 801A YL 801B YL 801C YL 801D	Receiving and Source Casks TC port covers	Opening of any TC port cover if the sliding door is not locked in closed position
I-TCPC-RC-C	Receiving Cask TC port cover	ZS 317B	Source Cask upper shield port	Opening of the Source Cask upper shield port if the Receiving Cask TC port cover is not in the closed or off centered position
I-TCPC-RC-O	Receiving Cask TC port cover	ZS 317A	Receiving Cask TC port cover locking device	Locking of the Receiving Cask TC port cover if the port cover is not in open position

Table 5.7.2.α (Continued)
Interlock Synthesis

Interlock Acronym	Source equipment	Signal transmitters	Interlocked equipment	Prevention description
I-TCPC-RC-OC	Receiving Cask TC port cover	ZS 317C	Source Cask upper shield port	Opening of the Source Cask upper shield port if the Receiving Cask TC port cover is not in closed or off centered position
I-TCPC-SC-C	Source Cask TC port cover	ZS 315B	Receiving Cask upper shield port	Opening of the Receiving Cask upper shield port if the Source Cask TC port cover is not in closed position
I-TCPC-SC-O	Source Cask TC port cover	ZS 315A	Source Cask TC port cover locking device	Locking oif the Source Cask TC port cover if the port cover is not in open position
I-TCPCLD-RC	Receiving Cask TC port cover locking device	YL 318A YL 318B	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the Receiving Cask TC port cover is not locked in opened position
I-TCPCLD-SC	Source Cask TC port cover locking device	YL 316A YL 316B	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the Source Cask TC port cover is not locked in opened position
I-TTLD-RC	Transfer trolley for the Receiving Cask locking device	YL 405C	Receiving Cask mating flange electric jacks	Lowering of the Receiving Cask mating flange if the Receiving Cask transfer trolley locking device is not in locked position
I-TTLD-SC	Transfer trolley for the Source Cask locking device	YL 404C	Source Cask mating flange electric jacks	Lowering of the Source Cask mating flange if the Source Cask transfer trolley locking device is not in locked position
I-USP-RC-C	Receiving Cask upper shield port	ZS 302B	Upper crane	Any motion of the upper crane if the Receiving Cask upper shield port is not in closed position
			Receiving Cask upper shield port locking device	Locking of the Receiving Cask upper shield port if it is not in closed position
			Source Cask upper shield port	Opening of the Source Cask upper shield port if the Receiving Cask upper shield port is not in closed position
I-USP-SC-C	Source Cask upper shield port	ZS 301B	Upper crane	Any motion of the upper crane if the Source Cask upper shield port is not in closed position
			Source Cask upper shield port locking device	Locking of the Source Cask upper shield port if it is not in closed position
			Receiving Cask upper shield port	Opening of the Receiving Cask upper shield port if the Source Cask upper shield port is not closed

Table 5.7.2.α (Continued)
Interlock Synthesis

Interlock Acronym	Source equipment	Signal transmitters	Interlocked equipment	Prevention description
I-USPLD-RC	Receiving Cask upper shield port locking device	YL 313A YL 313B	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the Receiving Cask upper shield port is not locked in closed position
			Source Cask TC port cover	Opening of the Source Cask TC port cover if the Receiving Cask upper shield port is not locked (in closed position)
I-USPLD-SC	Source Cask upper shield port locking device	YL 312A YL 312B	Fuel assembly handling crane carriage (bridge and trolley)	Any motion of the fuel assembly handling crane carriage if the Source Cask upper shield port is not locked in closed position
			Receiving Cask TC port cover	Opening of the Receiving Cask TC port cover if the Source Cask upper shield port is not locked (in closed position)

6.0 CONTROL AND MONITORING OF THE EQUIPMENT UNDER OFF NORMAL OPERATING CONDITIONS

6.1 Alarms, Warnings and Emergencies

6.1.1 Principles

Alarm panels including buzzers and lights are located in the Control Center and in each area of the building (and outside for radiation alarms). Each alarm is audible, at least, in the Control Center. The only automatic action that can have an alarm is to stop the failing equipment. Emergency pushbuttons are available in all the DTS areas and in the Control Center. They deenergize the equipment and activate the alarms. The main alarm sources which are the HVAC Subsystem, the mechanical equipment and the Radiation Monitoring Subsystem are easily distinguishable. Depending on their classification, different procedures are necessary to resume the process.

6.1.2 Classification

6.1.2.1 Radiation alarms and warnings

Warnings:

The warnings of the radiation monitoring system inform the operating staff that high radioactivity levels are detected. This information is used by the PLC controlling the mechanical equipment to interlock the sliding door and the upper shield ports. Each radiation monitor has two levels of warnings activated according to the radiation level detected. These warnings are displayed locally and remotely.

Alarms:

Alarms are generated when the self checking of a radiation monitor has detected a failure or when the batteries are low. These alarms are displayed by the monitoring system which indicates the involved monitor and the alarm cause. The alarm is released after operator identification to ensure that someone has been notified of the failure.

6.1.2.2 Mechanical equipment alarms

The alarms generated by the mechanical equipment can be broken down into two categories:
Defaults:

The defaults correspond to mechanical or electrical functioning defaults which can show the loss of redundancy (overtravel) or of safe functioning (overspeed). These defaults are important to the safety of the process. The concerned operation is always stopped under these circumstances. No operation can be initiated before alarm deactivation which requires password entry and so involves responsability levels.

The defaults are generated by the overtravel, overload, collision detectors, etc...

The PLC detects all the inconsistencies between information as for example: TC port cover in opened and closed position. These inconsistencies show the failure of an instrumentat and are considered as defaults. The release of the alarm may not always be sufficient to resume the operations, if the conditions which are not valid anymore are used for interlocks. In this case, the use of bypasses is necessary.

Incidents:

It corresponds to a non-compliance with the procedure or to an external factor. These alarms are detected by operation time-out managed by the PLC on all the mechanical equipment. Alarm release requires operator identification. The resumption of the operations shall not require any particular administrative procedure as the safety is not compromised. The monitoring system shall display a way to recover normal conditions.

For locally controlled operations, the operators are alarmed in the Preparation Area and in the Lower Access Area.

Alarms are always displayed by the monitoring system and the two failure levels are easily distinguishable.

6.1.2.3 HVAC alarms and warnings

Three alarm levels are considered for the HVAC Subsystem:

High level alarms:

It corresponds to the loss of the double confinement provided by this system or abnormal high temperature in any area. It is detected by the absence of pressure differential at the level of the two outside blowers. The alarms are audible and visible in the building and in the Control Center. The monitoring system provides sufficient means to understand the localisation of the failing equipment (temperature monitoring in each room displayed, blower activity and pressure differential displayed). The deactivation of alarms requires bypasses. The operations are not affected by this alarm, allowing a fast recovery to a safe condition.

Low level alarms:

The loss of redundancy on the blowers detected by the absence of pressure differential, the loss of any Fan Coil Unit (FCU) detected by the absence of pressure differential with a local temperature above the FCU initiation level, the malfunctioning of a damper (detected by the equipment) generate this alarm which is only audible and visible in the Control Center. If during the transfer operations, the HVAC is not able to maintain the pressure differential between the three areas, this alarm is generated. The activation of the detection automatically starts when the two casks are mated and automatically deactivated when the first operation after transfer is initiated (lifting of a mating flange). The deactivation of the alarms requires operator identification.

Warnings:

The need for HEPA filter maintenance detected by an abnormal low or high pressure differential accross the filter warns the operator.

6.2 Control and monitoring

The TC port covers and upper shield ports are actuated by electric jacks. The motorization is outside the DTS and can be replaced easily.

The fuel assembly handling winches are redundant. The fuel assembly grapple has three electric jacks, one for normal operating conditions and the two others, on the secondary power supply channel, for backup during off normal operating conditions.

The lid/shield plug handling hoist motorization is located in an uncontaminated and shielded area and so can be replaced easily. The lid/shield plug grapple can be disengaged manually from the overlid.

In the case of loss of the CCTV Subsystem (seismic event), penetrations in the DTS structure for manual backup can be used to introduce fiberscopes, borescopes... The lid/shield plug handling subsystem can be used to introduce viewing equipment in the TCA.

7.0 FAILURE MODE AND EFFECT ANALYSIS

7.1 Introduction

The DTS is designed such that a single failure of a component will not result in unacceptable high radiation levels outside the DTS, in any damage to a fuel assembly, in any damage to the lid or the shield plug and in compromising the recovery requirements.

This section presents the potential failures of the Control Subsystem, describing the failures types, effects, detection means and provisions used to compensate the failures. Only single failures are considered in this analysis.

The section is divided in three parts:

- evaluation of the general failures (PLC, network communication...)
- description and evaluation of instrumentation failure impact on operations
- description and evaluation of instrumentation failure impact on interlocks

7.2 Failure analysis

7.2.1 General Failures analysis

The general failures of the Control Subsystem are those which are not specific to an operating component, either because the responses to the failures are the same for all the equipment or because they can have influence on the general control and monitoring of the process.

A watch dog detects the failure of the PLC's CPU, based on internal clock checking, and automatically stops all the equipment in the activity by resetting all its outputs. A coupler's failure, a network disconnection of the PLC, a network failure between the PLC and the monitoring PC or between the main control panel and the PLC are detected and the equipment is automatically stopped. A failure of the link between the PLC and the electronic cabinets results in a deenergization of the controlled equipment which activates the emergency brakes. A loss of control (wire disconnection/breaking) between the electronic cabinets and the equipment has the same effect.

A loss of power directly stops the operating equipment. The PLCs and the PC are supplied by an independent backup and then keep their historic information (process, positions...), and update the equipment status (stopped).

7.2.2 Sensor failure analysis

The failure of sensors result in absence of detection or erroneous information. The PLC will then have an information which is not updated and which validity is either undetermined or erroneous. The information inconsistencies are not considered in the sensors failures analysis as they are detected by the PLC which generates an alarm, stops the equipment and requires operator identification to resume the operations.

Table 7.2.2.α lists all the sensor failures which can have an effect on safety. For each type of failure, the possible effect on the current operation involving the use of the failing sensor is described, the means provided to detect the failure and the compensating provisions.

7.2.3 Interlock failure analysis

The interlock failure analysis describes for each interlock, the instrumentation failures which can affect its function, its possible effect, the means provided to detect it and the compensating provisions. The erroneous information which generates a control request refusal can be bypassed to resume the operations.

Table 7.2.3.α lists all the interlocks and their failure analyses.

Table 7.2.2.α
Sensor failure analysis

Data provided by sensor	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Transfer trolley position limit switches	No position detection	Transfer trolley not stopped in position. Collision between casks	Visual	Overtravel limit switches and collision detectors stop motion
Transfer trolley lock position	Erroneous lock position information	Erroneous validation of a safety condition		Operation performed on contact
Electric jack vertical position	Erroneous value	Loss of mating operation validation means	CCTV	Electrical jack vertical position and load information used to operate and validate the mating operation, controlled by the PLC.
Electric jack load sensor	Higher than actual load reading	Jacks stopped before reaching proper mating position. Mating ineffective.	CCTV Vertical position indicators	
	Lower than actual load reaading	Final mating phase never happens as a jack never reaches its mating pressure. Jacks overloaded.	Alarm	Time out on mating operation generates alarm.
TC port covers position limit switches	No position detection	TC port cover motion not stopped in proper position.	CCTV Alarm	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed or off centered position information	Lid/shield plug can be left in an unsafe position on the port cover and this position not being predictible, closing operations may be compromised.	CCTV	Marks on the mezzanine show the proper positions of the TC port covers. Centering guides on port covers prevent improper positioning of the lid/shield plug on the port cover.
	Erroneous detected open position information	Locking operation can be processed in an improper position.	Alarm	Time out on locking operation generates alarm.
TC port covers lock position	Erroneous locked position information	Erroneous validation of a safety condition (see interlocks).	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC

Table 7.2.2.α (Continued)
Sensor failure analysis

Data provided by sensor	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Upper crane trolley position (X motion)	No position detection	Trolley motion not stopped	Alarm	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous position detection	Erroneous validation can make the gripping of the lid/shield plug impossible or can cause damage of the grapple on the upper plate.	Alarm	Underload detection stops motion. Range of time to process the operation controlled by the PLC, generates alarm.
Upper shield ports position (opened/closed)	No position detection	Upper shield port motion not stopped.	Alarm	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed position	Erroneous validation makes that locking operation can be processed in an improper position.	Alarm	Range of time to process the operation controlled by the PLC, generates alarm.
	Erroneous detected open position	Erroneous validation can cause damage to lid/shield plug grapple on upper shield port.	Alarm	Underload detection stops motion. Range of time to process operation controlled by the PLC, generates alarm.
Upper shield ports locking position	Erroneous locked position	Erroneous validation of a safety condition (see interlocks).	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation controlled by the PLC.
Lid/shield plug hoist z position	Erroneous z position	Damage to the lid/shield plug or to the cask due to excessive lowering. Unsafe lifting due to excessive lifting. Dropping due to collision with upper plate.	Alarm CCTV	Overtravel electrical switch stops motion and generates alarmn Overload stops motion and generates alarm.
Lid/shield plug grapple status	Erroneous closed fingers position	Unsafe lifting due to incorrect grappling.	Alarm	Range of time to process operation controlled by the PLC, generates alarm
	No position detection	Jack can be damaged and ungrappling compromised.	Alarm	Jack is stopped by hard stops and then shutdown after short time
	Erroneous overlid closed fingers position	Unsafe lifting due to incorrect gripping.	Alarm	Operation stopped by load.

Table 7.2.2.α (Continued)
Sensor failure analysis

Data provided by sensor	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Fuel assembly crane carriage x and y positions	Erroneous x,y position	Damage to the transfer tube, to the crud catcher and to the lid/shield plug due to excessive crane carriage movement. Can make the FA stuck in the transfer tube.	Alarm CCTV	Overtravel electrical switches stop motion in x and y directions and generate alarms.
Crud catcher position	Erroneous position detection	Crud catcher stopped in an undefined position	CCTV	
	No position detection	Operation never ends	Alarm	Time out on operation generates alarm
FA grapple z position	Erroneous z position	No detection of first high and low limits. Damage to the FA. Excessive lifting.	CCTV Alarm	Overtravels electrical switches stop motion and generate alarms. Underload stops motion
FA grapple status	No grapple fingers detection	Operation never ends. Damage to the jacks.	Alarm	Time out on operation generates alarm. Operation stopped by load.
	Erroneous closed fingers detection	Grapple fingers closed in an undefined position. Safe lifting of FA compromised.		Operation stopped by load.
	Erroneous FA presence detection	Grapple positioning not validated.		Grapple doesn't engage FA

Table 7.2.3.α
Interlock failure analysis

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
I-CRC	Erroneous crud catcher closed position information	FA crud spreading during motion. FA damaged or stuck due to motion or platform rotation if not fully retracted into transfer tube.	CCTV	Transfer tube positioning (x,y,θ) interlocked with the grapple upper z position.
	Erroneous crud catcher open position information	Lowering of the FA onto the crud catcher. Damage to the FA. Stuck FA in the transfer tube because of crud catcher stuck in closed position.	CCTV Unexpected loss of load	Loss of load stops motion. Crud catcher position validated visually before lowering FA.
I-FAHG	Erroneous FA gripping information	Unsafe lifting of FA. High radiation levels at upper level due to possible unlocking and opening of the upper shield ports	Alarm	Open and closed grapple fingers position sensors. Redundancy on proper gripping information Upper shield ports interlocked with load cell and radiation monitoring.
I-FAHHAP	Erroneous z position information of the FA hoist system	Damage to FA due to disconnection above the proper position.	CCTV Alarm due to inconsistency between load and position	Redundancy on FA disconnection based on underload situation. Mechanical design of grapple prevents its opening when loaded.
I-FAHHLC	Erroneous underload information	Damage to FA due to disconnection above the proper position High radiation levels at the upper level due to upper shield port opening FA stuck in the transfer tube because of damage to transfer tube due to collision with TC port cover.	CCTV Alarm due to inconsistency between position and load	FA disconnection interlocked with position encoder. Mechanical design of grapple prevents its opening when loaded. Upper shield port interlocked with gripping status and radiation monitoring device. TC port cover closing interlocked with gripping status.
I-FAHHUP	Erroneous upper position information	Damage to FA due to crane motion or platform rotation with FA not fully retracted into the transfer tube. Damage to FA and crud catcher due to crud catcher closure on FA.	CCTV	Crane carriage and rotating platform motion interlocked with crud catcher position. Visual verification prior to closing crud catcher.
I-FAHPP	Erroneous x,y position information	Damage to the lid/shield plug Dropping of the lid/shield plug, gripping of the grapple	CCTV	Visual verification prior to lift the lid/shield plug. Minimum speed imposed by PLC under the safety level

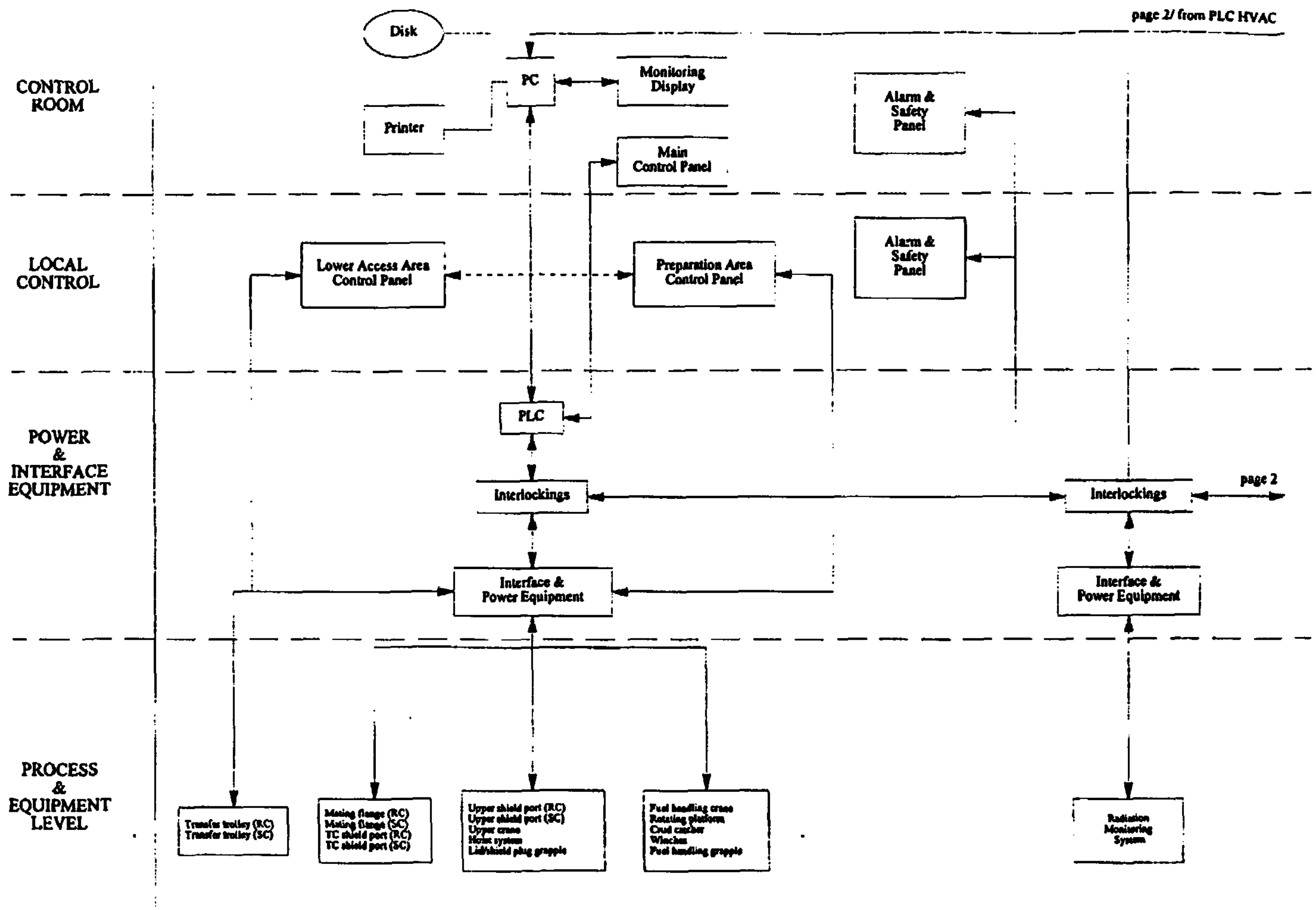
Table 7.2.3.α (Continued)
Interlock failure analysis

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
I-LSPHAP	Erroneous z position information of the lid/shield plug hoist system	Damage to the lid/shield plug due to disconnection of the lid/shield plug above the proper position	CCTV Alarm due to inconsistency between load and position	Lid/shield plug disconnection interlocked with load cell (underload situation)
		Lid/shield dropping or damage due to closure of TC port cover on the handling cables.	CCTV	The grapple position is visible and has to be validated before closing a TC port cover.
I-LSPHGP	Erroneous gripping status	Unsafe lifting and dropping of the lid/shield plug	Alarm due to inconsistency between gripping information	Open and closed grapple fingers position sensors Redundancy on proper overlid gripping Open and closed overlid fingers position Overlid fingers gripping detection
I-LSPHLC	Erroneous underload information	Damage to lid/shield plug due to dropping of the lid/shield plug above the proper position	CCTV Inconsistency between load and position	Redundancy on lid/shield plug disconnection based on z position.
I-LSPHUP	Erroneous upper position information	Dropping of the lid/shield plug due to closure of an upper shield port on the handling cables.	CCTV	Upper shield ports closure interlocked with gripping status.
		Unsafe handling of the lid/shield plug due to upper crane motion.		Upper crane motion interlocked with upper shield ports closed position.
I-RM-UL	Erroneous dose rate	High dose rate at the upper level due to upper shield port unlocking and opening during FA transfer or with cask and TC port cover open.	CCTV Radiation monitoring alarms Inconsistency between radiation monitoring devices	Radiation monitoring equipment alarms on failure. Upper shield port unlocking and opening interlocked with TC port covers positions, FA grapple and load cell status.
I-RM-SD	Erroneous dose rate	High dose rate at the sliding door level.	Inconsistency with Preparation Area radiation monitoring	Radiation monitoring equipment alarms on failure. Sliding door opening requires severe administrative procedure
I-SDLD	Erroneous sliding door locked position	High dose rates in case of a seismic event due to sliding door opening	Direct viewing	Operating procedure. Operation performed on contact.

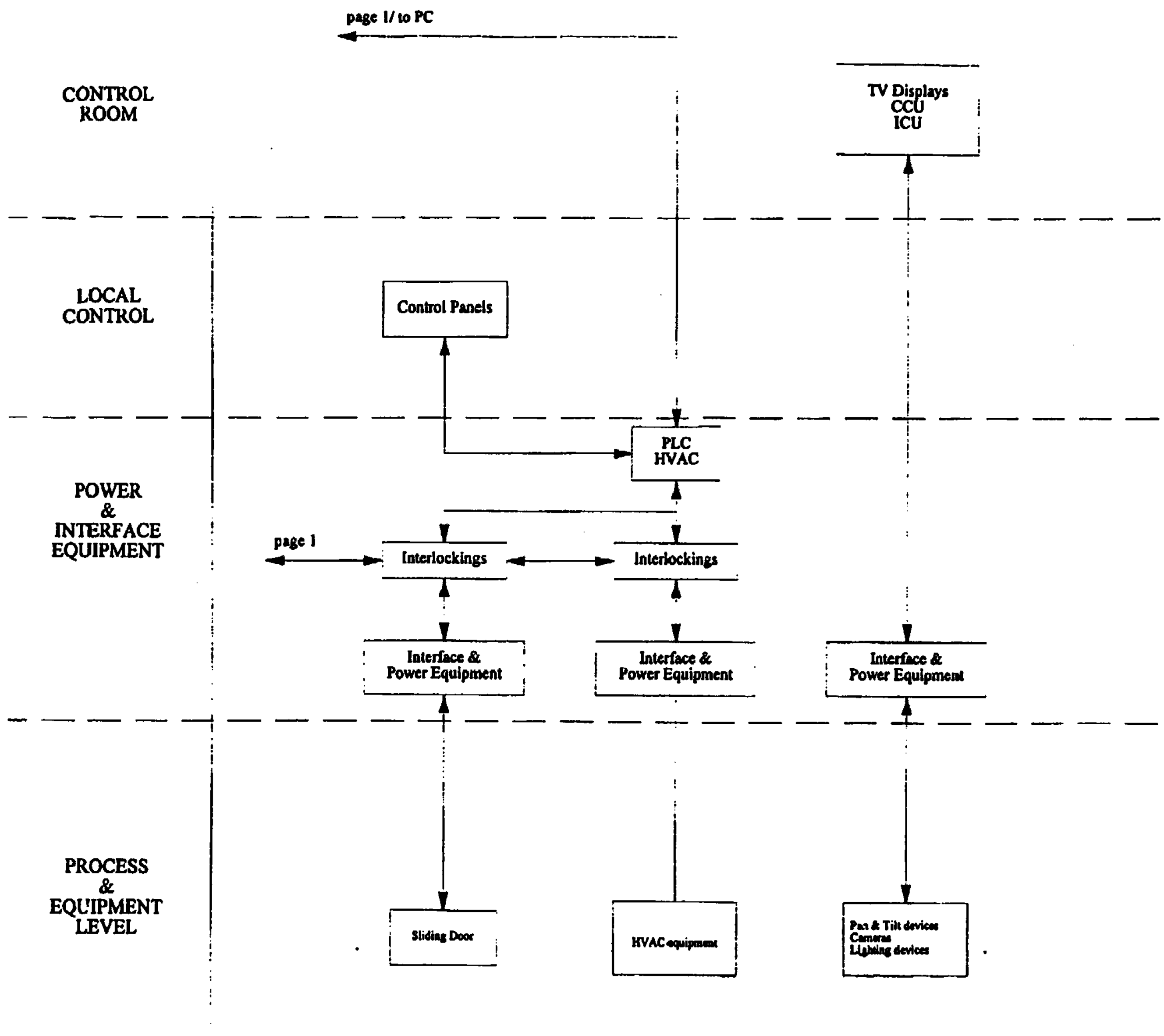
Table 7.2.3.α (Continued)
Interlock failure analysis

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
I-TCPC-RC-C I-TCPC-RC-OC I-TCPC-SC-C	Erroneous TC port cover closed position	High dose rates at the upper level due to upper source cask opening with TC port cover not closed or off-centered	CCTV	Upper shield port opening interlocked with radiation monitoring.
I-TCPCLD-RC I-TCPCLD-SC	Erroneous TC port cover lock position	Unsafe FA transfer with TC port.cover unlocked which could damage the FA in case of a seismic event Collision between source cask lid or receiving cask shield plug and FA crane carriage.	Alarm	Unlocked position information provided by jack. Locking operation validated with time information.
I-TTLD-RC I-TTLD-SC	Erroneous cask transfer trolley lock position	Transfer trolley can be projectile in case of a seismic event. Damage to FA in case of transfer.	Visual	Operating procedure. Operation performed on contact.
I-UC-SC I-UC-RC	Erroneous upper crane position	Cask opening or closing impossible Damage to the lid/shield plug grapple onto the upper plate.	Alarm Unexpected loss of load or unconsistency between load and position.	Time information is used to validate the upper crane positioning information.
I-USP-RC-C I-USP-SC-C	Erroneous upper shield port position	Dropping of the lid/shied plug or unsafe lifting due to upper crane motion. High dose rates at the upper level during opening/closing of the opposite cask.		Upper crane motion interlocked with upper z grapple position. Upper shield port opening interlocked with radiation monitoring
I-USPLD-RC I-USPLD-SC	Erroneous upper shield port lock position	High dose rates at the upper level during FA transfer in case of a seismic event.		Unlocked position information provided by jack. Locking operation validated with time information.

Appendix A
Instrumentation and Control Structural Diagram



Instrumentation & Control Structural Diagram page1/2



Instrumentation & Control Structural Diagram page2/2

CHAPTER 6

SITE GENERATED WASTE CONFINEMENT AND MANAGEMENT

6.1 Onsite Waste Sources

The concentration, radiological content, and amount of waste generated from the DTS during normal operations cannot be readily quantified. Waste generation is dependent upon site specific conditions, primarily the crud levels on the fuel assemblies.

The DTS will not accept damaged fuel and the source cask will be decontaminated at the spent fuel pool area. Therefore, liquid and solid waste generation is expected to be minimal and the radiological impact from such waste is also expected to be minimal. Table 6.1-1 shows the expected waste sources from DTS operations.

Table 6.1-1

Expected Waste Sources

Potential Source	Volume	Disposal
Local Decontamination - using spray & swab techniques	Undetermined - depending upon amount of spalled material during fuel transfer (Source cask will be decontaminated prior to entry at the DTS)	Waste receptacles at the DTS which will be incorporated in utility waste stream.
Area Decontamination - vacuum	Undetermined - depending upon the amount of spalled material during fuel transfer.	The vacuum system is a non destructive system that will minimize or avoid the generation of additional secondary waste. This system is independent of the DTS and has filtration capability. Waste will be collected and incorporated in utility waste stream.
Spalled material in Crud Catcher	Undetermined - depending upon the amount of spalled material during fuel transfer. Spalled material is expected to fall into the receiving cask during fuel assembly placement.	The crud catcher would be opened from the Control Center. The vacuum system described above would be used.
Pre-Filters and HEPA filters from the HVAC Subsystem	Undetermined - depending upon the amount of radioactive particulate generated during fuel transfer.	Standard bagging techniques on a standard maintenance schedule. These will be incorporated with other utility waste streams

Table 6.1-1 (Continued)

Expected Waste Sources

Potential Source	Volume	Disposal
Mechanical Equipment Lubricants	Undetermined - depending upon servicing during maintenance activities	Collected on absorbent cloths and incorporated in similar utility waste stream.
Rain, Snow, Ice melt outside of DTS Structure	Undetermined - site specific. The source is not considered radiologically contaminated	Part of site surface water drainage system.

6.2 Offgas Treatment and Ventilation

One level of confinement at the DTS is the HVAC Subsystem. The HVAC Subsystem utilizes negative pressures to direct air flow from areas of lower potential contamination to areas of higher potential contamination. This system has pre-filters and HEPA Filters to minimize the release of radioactive particulate to the environment. The waste generated from this system consists of solid material in the form of filters. Discussion of solid waste management is in Section 6.4.

6.3 Liquid Waste Treatment and Retention

Liquid wastes are also limited to small amounts of liquids produced from the localized decontamination of the source cask, receiving cask, and areas within the DTS. Local decontamination is conducted using standard swabbing techniques.

The DTS is not equipped with any water supply and has no drains for collection of such waste. Basically the casks will be decontaminated using moist swipes and any trash will be collected in 55 gallon drums. The waste will be removed using standard utility techniques. The wastes will be included in the radioactive waste stream at the utility. Site specific operations will be followed for the proper disposal of wastes arising from the DTS.

6.4 Solid Wastes

Solid wastes are limited to filters from the HVAC Subsystem which will be changed using standard methods. Other wastes will be from Health Physics and "good housekeeping" materials such as protective clothing, swipes, and vacuum bags.

6.5 Radiological Impact of Normal Operations - Summary

The concentration, radiological content, and amount of waste generated from the DTS during normal operations cannot be readily quantified. Waste generation is dependent upon site specific conditions, primarily the crud levels on the fuel assemblies. Liquid and solid waste generation is expected to be minimal and the radiological impact from such waste is also expected to be minimal.

CHAPTER 7

RADIATION PROTECTION

7.1 Ensuring That Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA)

7.1.1 Policy Considerations

A radiological protection program will be implemented at the Dry Transfer System in accordance with the requirements of 10 CFR 20. This program will be based upon the site specific policies of the facility utilizing the DTS.

Plant personnel are given training in the proper operations of the DTS. This training covers operation, inspection, repair and maintenance of the DTS. Proper training of the DTS operators aids in minimizing exposure to radiation such that the total individual and collective exposure to personnel in all phases of operations and maintenance are kept as low as reasonably achievable.

7.1.2 Design Considerations

The DTS design takes into account radiation protection considerations, and ensures that occupational radiation exposures are within 10 CFR 20 limits and are ALARA. The most significant radiation protection design feature is the heavy shielding used to reduce personnel exposures.

Regulatory Position 2, Facility and Equipment Design Features, of Regulatory Guide 8.8 (Reference 7.7-1) is incorporated into the design as described below and in Section 7.3.1.

- Access control of radiation areas (Position 2a) will be met by several barriers. A locked fence surrounds the DTS facility. Platforms are also present in the Preparation Area, the Lower Access Area and the Transfer Confinement Area to allow easier servicing and maintenance of components. There will be personnel monitoring equipment and controlled areas for removal of protective clothing.

- Radiation shields and geometry (Regulatory Position 2b) are present through the use of one physical barrier, the DTS structure. The walls of the structure are concrete and the roof and the sliding door is steel.

- Radiation shields and geometry (Regulatory Position 2b) minimizing radiation scatter and streaming are the use of "stepped" streaming paths in the ventilation system, in the wall penetrations, and in the roof plate.

- Process instrumentation and controls (Regulatory Position 2c) is met by designing the instrumentation for long service life and locating readouts in low dose rate locations.

- The control of airborne contaminants and gaseous radiation sources (Regulatory Position 2d) is met by designing an HVAC system using negative pressure differentials that directs air flow towards areas of increasing levels of contamination under standard operating conditions. HEPA filters, activated charcoal filters and prefilters are present in the HVAC exhaust. These HEPA filters also provide a barrier between the DTS and the environment.

- The control of airborne contaminants and gaseous radiation sources (Regulatory Position 2d) is also met by decontaminating the exterior of the source cask before leaving the spent fuel area for the DTS. The exteriors of the source and receiving casks will also be decontaminated before leaving the DTS, thereby reducing radiation exposure to personnel from surface contamination.

- Crud control (Regulatory Position 2e) is met by designing a fuel transfer tube that is completely enclosed with a hinged bottom designed to catch crud.

- Isolation and decontamination (Regulatory Position 2f) is met because the exteriors of the receiving and source casks are designed for decontamination. The building and its equipment are designed for decontamination.

- Radiation monitoring in the DTS (Regulatory Position 2g) is met by providing fixed locations for area radiation monitor and airborne radiation monitors throughout the DTS. Radiation monitoring equipment is located in the Transfer Confinement Area, the Lower Access Area, the Preparation Area, the Weather Protective Structure and the HVAC exhaust. It provides indications of radiation levels at times during cask preparation, fuel transfer and cask removal and closure.

- Resin treatment systems (Regulatory Position 2h) is not applicable to the DTS because there are no systems containing resins.
- Other features of the DTS (Regulatory Position 2i) concerning miscellaneous ALARA items is met as described below.

    - To minimize personnel operating times around the loaded casks, the source cask lid and the shield plug have threaded removable lifting pintles. The pintles are interchangeable to allow for easy connection and disconnection. Placement and removal of the pintles on the covers will take place in a low radiation area (Preparation Area).

- To minimize personnel operating times around potentially contaminated equipment, spacing of equipment in the DTS is designed with the considerations of operations and maintenance. Personnel will have accessibility and space to carry out operations (or maintenance activities) at a distance from higher contaminated equipment and therefore lowering the potential for contact.

Other ALARA considerations which are dependent on site specific systems and operating procedures will be addressed in the site specific license application.

7.1.3 Operational Considerations

General methods, plans and procedures for ensuring that occupational exposures to radiation are ALARA are discussed here. However, site specific methods will be addressed in the site specific license application.

- The DTS design considers the need for the removal and periodic maintenance of components which is reflected in component placement. The equipment is designed to be dismantled and transported to another utility.

- The DTS structure and operation will be similar from site to site. The DTS is operable by site personnel following appropriate training and qualification.

7.2 Radiation Sources

7.2.1 Characterization of Sources

The data presented within this report are from the most recent information on the US DOE MPC Program (Reference 7.7-2). The data in this report are generic in nature. The DTS design will require modification to incorporate site specific data when used by a commercial nuclear power utility.

For the shielding analysis, the DTS is designed to accommodate bare PWR spent fuel assemblies as specified in Section 3.1.1 design basis characteristics The design basis spent fuel assembly is a B&W 15x15, with 40,000 MWd/MTU burnup and an initial enrichment of 3.75%. The average fuel region gamma source is 7.8E+15 γ/s/assembly and the peak source is 9.9E+15 γ/s/assembly. The neutron source is 2.4E+08 n/s/assembly and the peak neutron source is 5.4E+08 n/s/assembly. The fuel assembly characteristics are provided in Table 3.1-1. The gamma source spectrum is provided in Table 3.1-2 and the neutron source spectrum is provided in Table 3.1-3.

For the fission gas and volatile nuclides inventory, calculations were made using the Westinghouse 17 x 17 assembly with a 3.85% wt enrichment. The fuel is irradiated with a typical specific power of 37.5 MW/MTU to total burnup of 40,000 MWD/MTU. Three cycles are used with a down time of 30 days between cycles. The ORIGEN2 computer code (Reference 7.7-3) was used to generate the fission gas and volatile nuclides inventory. Since the fuel mass is similar and the burnup is the same, the fission product inventory of the Westinghouse fuel analyzed should not differ significantly from the design basis B&W fuel.

Damaged fuel is assumed to be detected at the reactor facility and will not be accepted at the DTS facility. Damaged fuel is primarily considered as fuel that is not dimensionally or structurally sound and fuel that cannot be handled by normal means. Fuel assemblies that are damaged in transit will not be part of fuel transfer operations.

7.2.2 Airborne Radioactive Material Sources

The design of the DTS is such that during normal operations, a small amount of material may become airborne in the DTS. Material which may spall from the fuel assemblies during the fuel transfer process is expected to be caught by the crud catcher and dropped into the receiving cask. Small airborne amounts of material will be carried to the HEPA filtration unit.

The quantity of fission gas produced in a typical PWR assembly for the design irradiation condition is approximately 600 liters at STP (Reference 7.7-4). Of this quantity only a small fraction is radioactive with Kr-85 being the dominant nuclide. Most of the fission products generated are retained within the fuel pellet. A small fraction, nominally 30% for Kr-85 and 10% for noble gases, and 10% for tritium is released. Table 7.2-1 shows the inventory of fission gases and volatile nuclides contained in the 17 x 17 Westinghouse fuel assembly described in Section 7.2.1. These are the total curies in the fuel assembly, not just the plenums. No fission gas will be released during normal operations in the DTS facility.

Table 7.2-1

Estimated Fission Gas and Volatile Nuclides Inventory (Curies/Assembly)

Nuclide	Ci/assy
H-3	323
Kr-85	3,800
I-129	0.0172
Cs-134	17,000
Cs-137	51,500

7.3 Radiation Protection Design Features

7.3.1 Installation Design Features

7.3.1.1 Access Control of Radiation Areas

The first barrier is a fence with a locked gate that surrounds the DTS and prevents unauthorized access. Normal access to the DTS is through the gate in the fence. Access to the inside of the DTS structure is limited to two points of entry and egress. These points are a door to the Preparation Area and another door to the Roof Enclosure Area on the roof of the DTS. The door to the Preparation Area is for normal access to the DTS. Access to the Lower Access Area is only through the Preparation Area. Access to the Transfer Confinement Area is either through the Lower Access Area or through the upper shield ports from the Roof Enclosure Area.

A stairway is mounted to the outside of the DTS for access to the roof and the Roof Enclosure Area. This access is for maintenance and servicing activities only. This stairway is enclosed and locked.

Emergency egress provisions are provided on a site specific basis.

Occupational access to radiation areas will be in accordance with site specific programs and will be addressed in the site specific license applications. However, basic radiation zone designations are identified in Table 7.3-1.

Table 7.3-1

Radiation Zone Designations

Zone No	Zone Description	Dose Rate (mrem/hr)
I	Unrestricted Area	< 2.0
II	Radiation Area	> 2.0
III	High Radiation Area	> 100
IV	Very High Radiation Area	≥ 500

The expected zone designation of the various DTS areas during cask preparation, fuel transfers, and cask removal operations of the DTS are given in Table 7.3-2.

Table 7.3-2

Expected Zone Designations within the DTS During Normal Operations

Time During	DTS Location	Zone No
Receiving Cask Preparation Operations	Preparation Area	II
	Lower Access Area	II
	Transfer Confinement Area	II
	Roof Enclosure Area	II
	Control Center	I
Source Cask Preparation Operations	Preparation Area	II
	Lower Access Area	II
	Transfer Confinement Area	II
	Roof Enclosure Area	II
	Control Center	I
Fuel Transfer Operations	Preparation Area	III
	Lower Access Area	IV
	Transfer Confinement Area	IV
	Roof Enclosure Area	III
	Control Center	I
Source or Receiving Cask Removal Operations	Preparation Area	II
	Lower Access Area	II
	Transfer Confinement Area	II
	Roof Enclosure Area	II
	Control Center	I
Maintenance Operations	Preparation Area	II
	Lower Access Area	II
	Transfer Confinement Area	II
	Roof Enclosure Area	II
	Control Center	I

7.3.1.2 Radiation Shields and Geometry

The primary shield of the DTS is its physical structure. Its concrete walls are three feet thick (914 mm). The steel sliding door separating the Preparation Area from the Lower Access Area is seven inches (178 mm) thick scaling up to nine inches (229 mm) thick at the top. The steel roof on the DTS is seven inches (178 mm) thick.

7.3.1.3 Process Instrumentation and Controls

Process instrumentation and controls throughout the DTS allow the control and monitoring of the following:

- Mechanical equipment including the Cask Transfer Subsystem; the Cask Mating Subsystem; the TC Port Shield Subsystem; the MPC Shield Plug and Source Cask Lid Handling Subsystem; and the Fuel Assembly Handling Subsystem.

- The HVAC Subsystem equipment.

- The Radiation Monitoring Subsystem.

The control and monitoring of DTS mechanical equipment and HVAC Subsystem equipment is described in Section 5.2.6. The control and monitoring of the Radiation Monitoring Subsystem is described in this section and also in Section 5.2.6.

The Radiation Monitoring Subsystem includes permanently mounted area radiation detectors in the Preparation Area, in the Lower Access Area, in the Transfer Confinement Area, in the Roof Enclosure Area, and in the HVAC Subsystem.

The Radiation Monitoring Subsystem has displays at the detector location, the Preparation Area and the Control Center. Audible and visible alarms for high radiation levels, low radiation/low battery, and detector failure are also at the detector location, the Preparation Area and the Control Center.

The Radiation Monitoring Subsystem is interlocked with the sliding door. Once fuel transfer begins, the area radiation monitor within the Lower Access Area will be interlocked with the sliding door preventing the door from being opened until the radiation levels inside the Lower Access Area have fallen below a given setpoint. This is to prevent inadvertent access to the Lower Access Area during fuel transfer.

The roof enclosure radiation monitor is interlocked with the upper shield ports to prevent their opening in the presence of high radiation levels.

7.3.1.4 Confinement of Airborne Contaminants and Gaseous Radiation Sources

The confinement of airborne contaminants and particulate and aerosol radiation sources is performed by two systems, the DTS structure and the HVAC system. The DTS structure provides a physical barrier preventing the spread of contaminants. The HVAC system is designed to provide an additional level of confinement of radioactive material.

The HVAC system performs its confinement function by maintaining negative pressures in various areas relative to atmospheric pressure. By establishing pressure differentials, air flow is maintained from the ambient into the Preparation Area through the Lower Access Area to the TCA. The air is exhausted through the HEPA filter banks up a stack that extends approximately 10 feet above the DTS structure and air flow is from lower to higher levels of contamination. Redundant components are present in the DTS which minimizes the potential for failure. Further details on the operation of the HVAC system and its components are provided in Section 5.3.2.

The HVAC system is designed to maintain the following conditions:

- Concentrations of airborne radioactivity within the DTS less than the allowable concentrations of 10 CFR 20;
- Concentrations of airborne radioactivity in areas accessible to personnel not specifically involved in DTS operations less than the allowable concentrations in 10 CFR 20; and
- ALARA airborne concentrations.

Gaseous radiation is not a significant source in the DTS. Failed fuel is not acceptable at the DTS, and the source cask will be checked for fission gas prior to cask preparation.

In addition to the HVAC Subsystem, leakage paths are minimized by the presence of seals around openings in the DTS. The receiving and source casks will be confined to the floor of the Transfer Confinement Area through the use of bellows and seals. Also, once the sliding door is closed, a seal around the door will be maintained to aid in minimizing leakage.

7.3.1.5 Crud Control

A crud catcher at the bottom portion of the Fuel Handling Subsystem transfer tube covers the bottom of the fuel assembly when it is fully retracted into the transfer tube and minimizes the spread of radioactive material that may spall from the assembly during movement. The crud catcher is described in Section 5.2.5.6.

7.3.1.6 Radiation Monitoring

The DTS has installed radiation monitoring equipment which continuously monitors and displays the radiation dose rates. This avoids the need to have personnel routinely entering areas to obtain the data manually. As discussed in Section 3.3.4, this also allows the monitoring of radiation level changes throughout operations and permits prompt personnel action if alarm situations occur.

The following features are included in the system:

- Display at each detector location and remote display at the Preparation Area and the Control Center;
- Warning for Low Level Detection;
- Alarms for High Level Detection, Detector Failure, and Low Battery;
- Audible and visible alarms at each detector, the Preparation Area, and the Control Center;
- Battery backup of monitoring equipment;
- Remotely operated check source; and
- Associated electronic equipment and cabling.

The selected equipment has readout capability at the highest anticipated radiation levels and positive readout at lowest radiation levels. Since a criticality accident is not credible as described in Section 3.3.4, no criticality monitors are utilized.

7.3.2 Shielding

7.3.2.1 Shielding Evaluation

Shielding is designed to maintain dose rates around the DTS structure ALARA. Shielding considerations include minimizing the dose to personnel at the DTS and to other utility personnel.

The following scenarios have been evaluated for shielding effectiveness:

- A source cask containing four fuel assemblies;
- A receiving cask containing twenty one assemblies;
- One fuel assembly at the start of fuel transfer, fully removed from the source cask and in the position closest to the DTS sliding door; and
- One fuel assembly during fuel transfer, in the position closest to the DTS roof.

Conservative assumptions are used throughout the analysis:

- For purposes of the shielding evaluation, fuel assemblies are cooled for a minimum of 5 years and are at the peak source strength;
- Axial distributions for the source are taken as uniform, while in reality, the source will be relatively low near the top and bottom of the fuel region. This is because the power shape during operation is non-uniform.
- The mechanical equipment within the DTS which provides additional shielding is neglected;
- The steel and aluminum structure of the basket within the source and receiving cask is neglected;
- The Preparation Area steel Butler-type building is neglected; and
- The steel rebar in the concrete walls of the DTS is neglected.

During fuel transfer, the shielding for the single fuel assembly is the 0.8 inch (20mm) steel fuel transfer tube, the concrete walls, the steel sliding door and the steel roof of the DTS structure. Figure 7.3-1 illustrates a cross section view of the DTS structure (Figures 1.2-17 and 1.2-18 show the dimensions of the DTS structure.)

The design of the DTS does not include the design of the source and receiving casks. Evaluating the shielding capability of the source and receiving cask is not part of this analysis. Section 3.1 discusses the design basis source and receiving cask. The design basis source and receiving casks are conceptual designs. Figures 3.1-1, 3.1-2 and 3.1-3 illustrate the Design Basis Receiving Canister, the Design Basis Receiving Transportation Overpack, and the Design Basis Source Cask, respectively.

Shielding for fuel assemblies in the receiving and source cask is provided by the thick walled cask body. For the neutron shielding, a borated polyester resin compound surrounds the cask body. Additional shielding is provided by the steel shell surrounding the resin layer. When the receiving and source casks are open during fuel transfer, shielding in the vertical direction is provided by the DTS building structure. ANSI standard flux-to-dose rate factors included in the SCALE4.3 computer package (Reference 7.7-5) are used in the analysis .

<u>Primary Gamma</u>

The three dimensional point kernel computer code SCALE4.3 / QADS is used to calculate the primary gamma dose rate. For this evaluation, the exposure buildup factor for concrete is used.

Neutron

The neutron analysis is performed using the one dimensional SAS1 module of SCALE4.3 , with the 27n-18g coupled cross-section library. This uses the codes XSDRMPM and XSDOSE to calculate the surface flux and translate the flux into dose rates away from the cask surface. ANSI standard flux-to-dose factors within SCALE4.3 are used for the dose calculation at the selected points.

For the axial calculations, the DISK geometry is chosen and buckling corrections, using the cask diameters, are used to correct for a finite dimension rather than an infinite plane.

7.3.2.2 Dose Rates

The calculated dose rates around the bare spent fuel assembly are presented in Table 7.3-3 (gamma dose rates were calculated using QADS and neutron dose rates were calculated using SCALE4.3 / SAS1). The calculated dose rates around the source cask containing four design basis fuel assemblies are presented in Table 7.3-4. This table illustrates the axial dose rates both with and without the lid. Table 7.3-5 presents the calculated dose rates around the design basis receiving cask containing 21 design basis fuel assemblies. This table also presents the axial dose rates with the various shield plug and lid configurations. The results presented in Tables 7.3-4 and 7.3-5 were calculated using SCALE4.3 / SAS1.

Table 7.3-6 presents the calculated maximum dose rates in the radial direction from the bare spent fuel assembly. The gamma dose rates listed in this table were calculated using QADS and the neutron dose rates were calculated using SCALE4.

The design of the DTS does not include the design of the source and receiving casks. The contact dose rates are high (300 mrem/hr at the design basis source cask and 100 mrem/hr at the design basis receiving cask). The actual source and receiving casks are expected to result in lower dose rates.

Table 7.3-7 presents the calculated maximum dose rates around the DTS from an open filled source cask and from an open receiving cask. The gamma dose rate was calculated using QADS and the neutron dose was calculated using SCALE4.3. The cask itself provides radiation shielding of the source and therefore the dose rates through the walls from the open casks was found to be negligible.

Table 7.3-3

Summary of Maximum Dose Rates around Single Bare Fuel Assembly

	contact	3 feet (1 meter) from Surface
Dose on Top of Fuel Assembly (gamma and neutron)	3.6E+06 mrem/hr (3.6E+04 mSv/hr)	8.7E+04 mrem/hr (870 mSv/hr)
Doses on Sides of Fuel Assembly (gamma and neutron)	1.1E+08 mrem/hr (1.1E+06 mSv/hr)	3.7E+06 mrem/hr (3.7E+04 mSv/hr)

Table 7.3-4

Summary of Maximum Dose Rates around filled Source Cask

	contact	3 feet (1 meter) from Surface
Dose at Axial Midpoint at Top of Source Cask		
No Lid (Gamma and Neutron)	3.7E+06 mrem/hr (3.7E+04 mSv/hr)	6.9E+05 mrem/hr (6.9E+03 mSv/hr)
With Lid (Gamma and Neutron)	250 mrem/hr (2.5 mSv/hr)	95 mrem/hr (0.95 mSv/hr)
Doses at Radial Midpoint at Side of Source Cask		
(Gamma and Neutron)	300 mrem/hr (3.0 mSv/hr)	170 mrem/hr (1.7 mSv/hr)

Table 7.3-5

Summary of Maximum Dose Rates around filled Receiving Cask

	contact	3 feet (1 meter) from Surface
Dose at Axial Midpoint at Top of Receiving Cask		
No Lid (Gamma and Neutron)	1.2E+07 mrem/hr (1.2E+05 mSv/hr)	4.2E+06 mrem/hr (4.2E+04 mSv/hr)
Shield Plug in place (Gamma and Neutron)	230 mrem/hr (2.3 mSv/hr)	91 mrem/hr (0.91 mSv/hr)
Shield Plug and Inner Lid in place (Gamma and Neutron)	140 mrem/hr (1.4 mSv/hr)	50 mrem/hr (0.5 mSv/hr)
Shield Plug, Inner Lid and Outer Lid in place (Gamma and Neutron)	72 mrem/hr (0.72 mSv/hr)	26 mrem/hr (0.26 mSv/hr)
Shield Plug, Inner Lid, Outer Lid and Overpack Lid in place (Gamma and Neutron)	20 mrem/hr (0.20 mSv/hr)	7.2 mrem/hr (0.072 mSv/hr)
Doses at Radial Midpoint at Side of Receiving Cask		
(Gamma and Neutron)	91 mrem/hr (0.91 mSv/hr)	65 mrem/hr (0.65 mSv/hr)

Table 7.3-6

Summary of Maximum Dose Rates in Radial Direction from Bare Spent Fuel Assembly in Transfer Position

	contact
Radial Direction, Dose from Bare Spent Fuel Assembly (in transfer position closest to DTS concrete wall, Figure 7.3-3)	
Contact	3.2E+07 mrem/hr (3.2E+05 mSv/hr)
Inside DTS Wall	3.4E+06 mrem/hr (3.4E+04 mSv/hr)
Outside DTS Wall	9 mrem/hr (0.09 mSv/hr)
Radial Direction, Dose from Bare Spent Fuel Assembly (in transfer position closest to DTS sliding door, Figure 7.3-2)	
Outside DTS Concrete Wall	24 mrem/hr (0.24 mSv/hr)
Sliding Door - 3' (0.9 m) Elevation	0.024 mrem/hr (2.4E-04 mSv/hr)
Sliding Door - 10' (3.0 m) Elevation	21 mrem/hr (0.21 mSv/hr)
Sliding Door - 12' (3.7 m) Elevation	66 mrem/hr (0.66 mSv/hr)
Sliding Door - 13' (4.0 m) Elevation	113 mrem/hr (1.13 mSv/hr)
Sliding Door - 14' (4.3 m) Elevation	184 mrem/hr (1.84 mSv/hr)
Sliding Door - 16' (4.9 m) Elevation	49 mrem/hr (0.49 mSv/hr)
Sliding Door - 18' (5.5 m) Elevation	96 mrem/hr (0.96 mSv/hr)

Table 7.3-7

Summary of Maximum Dose Rates in Axial Direction

Axial Direction, Dose Above Open Source Cask filled with 4 Assemblies

Location	Directly Over Source Cask	Midpt between Source and Receiving Cask	Over Receiving Cask
Contact (top of fuel assemblies in source cask)	3.7E+06 mrem/hr (3.7E+04 mSv/hr)	not calculated	not calculated
Inside DTS Roof	4.6E+04 mrem/hr (4.6E+02 mSv/hr)	4.27E+04 mrem/hr (4.27E+02mSv/hr)	2.53E+03 mrem/hr (25.3 mSv/hr)
Above DTS Roof	50 mrem/hr (0.50 mSv/hr)	41.4 mrem/hr (0.414 mSv/hr)	1.63 mrem/hr (0.063 mSv/hr)
Above DTS Roof Enclosure	3.7 mrem/hr (0.037 mSv/hr)	3.21 mrem/hr (0.0321 mSv/hr)	0.31 mrem/hr (0.0031 mSv/hr)

Axial Direction, Dose Above Open Receiving Cask filled with 21 Assemblies

Location	Directly Over Receiving Cask	Midpt between Source and Receiving Cask	Over Source Cask
Contact	4.2E+06 mrem/hr (4.2E+04 mSv/hr)	not calculated	not calculated
Inside DTS Roof	2.2E+05 mrem/hr (2.2E+03 mSv/hr)	2.1E+05 mrem/hr (2.1E+03 mSv/hr)	1.4E+05 mrem/hr (1.4E+03 mSv/hr)
Above DTS Roof	230 mrem/hr (2.3 mSv/hr)	200 mrem/hr (2.0 mSv/hr)	110 mrem/hr (1.1 mSv/hr)
Above DTS Roof Enclosure	34 mrem/hr (0.34 mSv/hr)	31 mrem/hr (0.31 mSv/hr)	22 mrem/hr (0.22 mSv/hr)

Dose rates around the DTS during fuel transfer vary according to the position of the fuel assembly. Two scenarios combining the effects of the fuel assembly in the transfer position and a filled receiving cask are considered in this analysis:

- The first scenario assumes that the fuel assembly is being removed form the source cask and is suspended near the sliding door. The dose rates from this configuration are combined with the dose rates from the filled open receiving cask. Figure 7.3-2 illustrates the expected maximum dose rates from this scenario.

- The second scenario assumes that the fuel assembly is suspended (in the position closest to the roof) over the receiving cask. The dose rates from this configuration are combined with the dose rates from the filled open receiving cask. Figure 7.3-3 illustrates the expected maximum dose rates from this scenario.

7.3.3 Ventilation

The ventilation system is described in Section 4.3.1.

7.3.4 Radiation Monitoring Subsystem

The Radiation Monitoring Subsystem is for monitoring both personnel areas and environmental monitoring. Each radiation monitor will display and alarm in several locations. These locations are at the detector, at the Preparation Area and at the Control Area. Recording of radiation levels is dependent upon operations being conducted at the DTS.

In addition to monitors at fixed locations, portable monitors will also be used at the DTS. These portable monitors will be used as required by the site specific ALARA program. This will be described in the site specific license application. Set points for alarms will also be addressed in the site specific license application.

7.3.4.1 Area Radiation Monitors

Area gamma radiation monitors are mounted at several fixed locations within the DTS. The monitors are located in areas where personnel will be for periods of time during transfer operations and maintenance operations. Neutron measurements will be taken using portable instrumentation as necessary. Two detectors are mounted in the Preparation Area, one detector is mounted in the Lower Access Area, one is mounted in the Transfer Confinement Area, one is in the Roof Enclosure Area and one is on the exhaust stack off the DTS.

To support maintenance of the detector, each is mounted at a height of 5 feet (1.5 m) from the flooring. A list of the installed radiation monitors, their locations, and effective range is presented in Table 7.3-8.

The lower end range is such that the radiation levels below this point are not significant. The upper end range is above the anticipated radiation levels in the area.

Table 7.3-8

Locations of Area Gamma Radiation Monitors within the DTS

Detector Location	Range
Preparation Area, Monitor #1	0.1-10,000 mrem/hr (0.001-100 mSv)
Preparation Area, Monitor #2	0.1-10,000 mrem/hr (0.001-100 mSv)
Lower Access Area	0.1-10,000 mrem/hr (0.001-100 mSv)
Transfer Confinement Area	1-100,000 mrem/hr (0.01-1,000 mSv)
Roof Enclosure Area	0.1-10,000 mrem/hr (0.001-100 mSv)
Exhaust (HEPA Filters) Stack	1-100,000 mrem/hr (0.01-1,000 mSv)

7.3.4.2 Airborne Monitors

The exhaust stack is equipped with a continuous air monitor. This monitor is configured to allow the electronics to be mounted remotely from the sampling/detection system. The stack monitor collects and monitors airborne particulate, iodine and noble gases.

The sample stream will be drawn from the stack using an isokinetic probe. A pump/motor assembly is present to draw the sample and produce a flow through the monitor. A rotary vane pump with a 3/4 hp (0.56 kW) motor provides a flow rate of up to 4 CFM (1.90E-03 m^3/s). One inch inlet and outlet sample lines are used. A mass flow transducer with a controller integral to the monitor is used to regulate the flow.

Once the sample is drawn, particulate is collected on filter paper with a collection efficiency of 99% for particles 0.3 micron and larger. After passing through the filter paper, the sample stream is passed through the iodine and noble gas detectors.

After the sample has passed through the detectors, it is returned to the exhaust stack down stream of the sample inlet point.

The outputs are sent through a microprocessor to the Control Center and the Preparation Area. Audible and visible alarms will be present at both the Preparation Area and the Control Center.

Figure 7.3-1

Cross Section of DTS

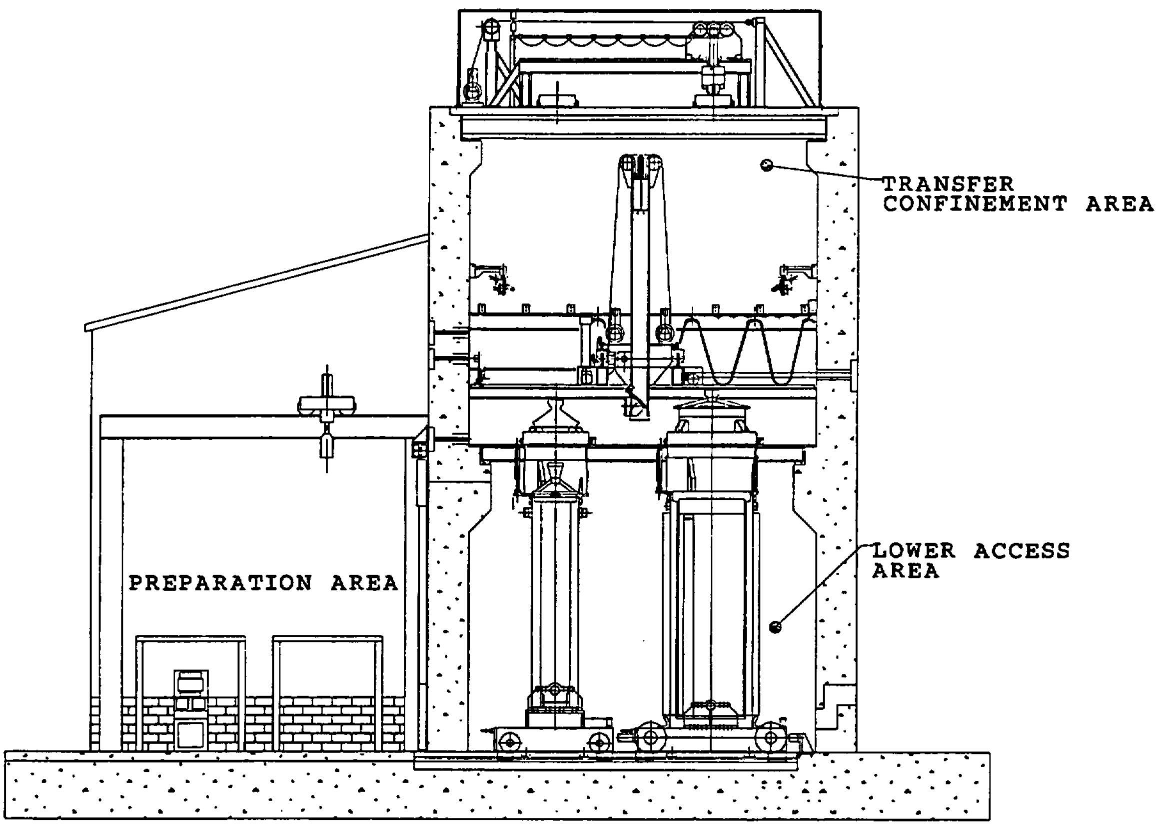


Figure 7.3-2

Dose Rates During Fuel Transfer
Scenario 1

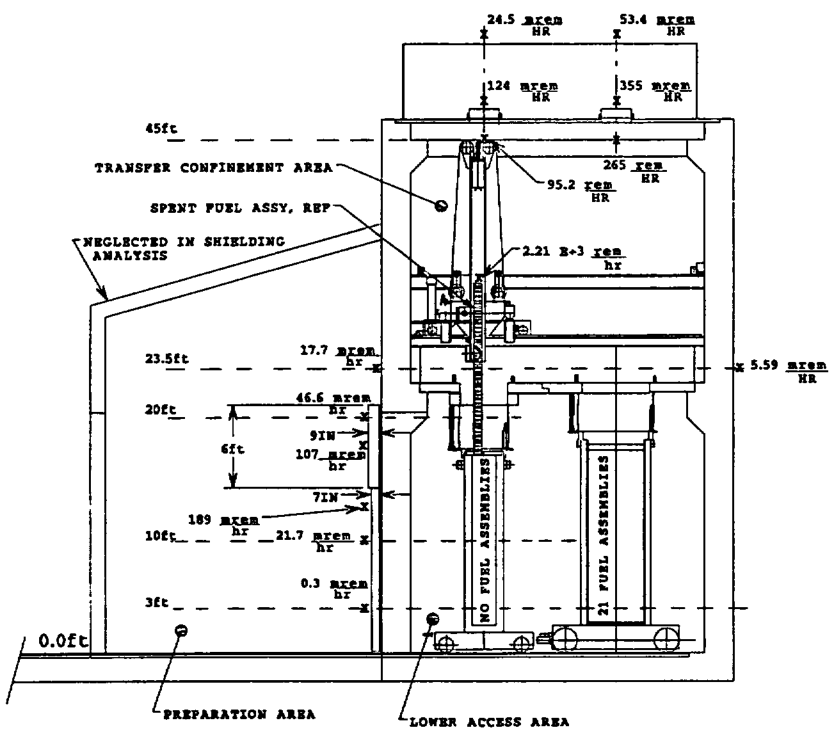
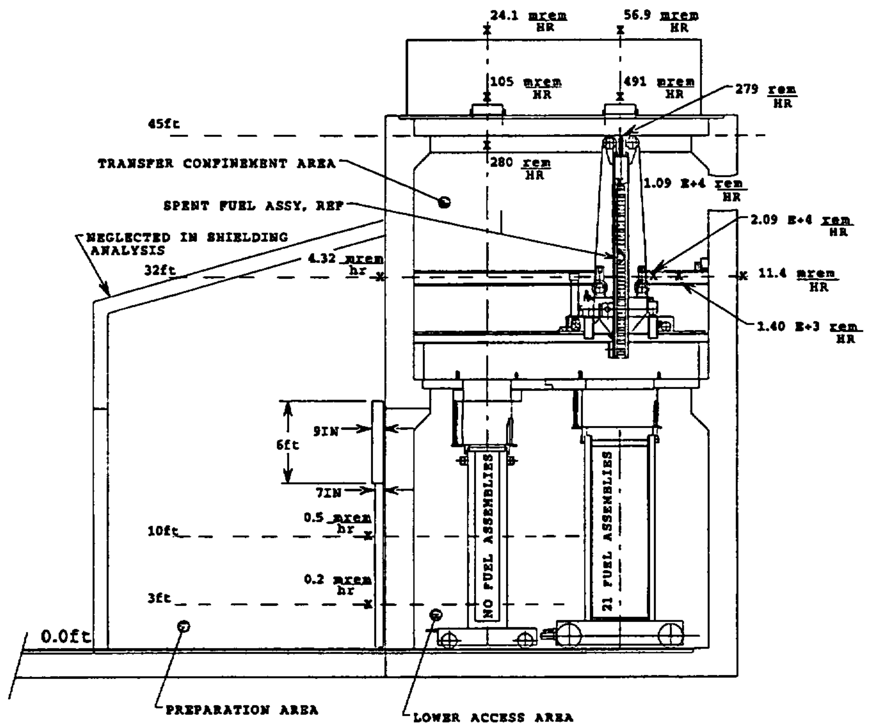


Figure 7.3-3

Dose Rates During Fuel Transfer
Scenario 2



7.4 Estimated Onsite Collective Dose Assessment

Table 7.4-1 shows the estimated design basis occupational exposures to the DTS personnel during the cask preparation, fuel transfer, and cask removal operations. Depending upon the nature of the cask operations, dose rates are taken at contact, at one meter and at three meters.

Table 7.4-1 provides the estimated time required for each task, the number of personnel required, the design basis dose rate and person-rem for each source or receiving cask during DTS operations. Dose rates from source cask operations are high. These doses are expected to lower once the actual design of the source cask is finalized. The design of the source cask is not part of the DTS design.

Contribution of the dose from the DTS with utility operations and to personnel will be addressed in the site specific license application.

Table 7.4-1

Design Basis Operations - Estimated Doses from DTS

Task		No. of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Total Dose (person-mrem)
Receiving Cask Preparation For DTS Entry						
1.	Load Receiving Cask on Cask Transfer System	2	45	---	---	---
2.	Move Receiving Cask into Preparation Area	2	10	---	---	---
3.	Remove Overpack and Receiving Cask Lids	2	60	---	---	---
4.	Position Shield Plug and Pintle	2	25	---	---	---
5.	Clean Surface of Receiving Cask, Overpack and Seals	2	15	---	---	---
6.	Open sliding door	2	5	---	---	---
7.	Move Receiving Cask into Lower Access Area	3	5	---	---	---
8.	Position Cask in Lower Access Area	2	5	---	---	---
9.	Cask Mating System engaged	2	15	---	---	---
10.	Sliding Door Closes	2	5	---	---	---

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Person Location	No of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Total Dose (person-mrem)
Source Cask Preparation for DTS Entry							
1	Setting Source Cask on Cask Transfer Subsystem	side	2	30	3 (9.8 ft)	13.1	13.1
2	Move Source Cask into Preparation Area	side	2	10	3 (9.8 ft)	13.1	4.37
3	Vent Source Cask	top	1	15	1 (3.3 ft)	14.2	3.55
		side	1	15	3 (9.8 ft)	13.1	3.28
4	Unbolt Source Cask Lid	top	2	25	1 (3.3 ft)	14.2	11.8
5	Position and Attach Pintle to Lid	top	2	20	1 (3.3 ft)	14.2	9.47
6	Clean Lid & Source Cask External Surfaces (removal of transport grit & grime)	top	1	15	1 (3.3 ft)	14.2	3.55
		side	1	15	1 (3.3 ft)	43.8	11.0
7	Open Sliding Door to Lower Access Area	side	2	5	3 (9.8 ft)	13.1	2.18
8	Move Cask Transfer Subsystem to Lower Access Area	side	2	15	3 (9.8 ft)	13.1	6.55
9	Fine Position Cask Transfer Subsystem in Lower Access Area	side	2	5	1 (3.3 ft)	43.8	7.30
10	Leave & Close Sliding Door to Lower Area	side	2	10	3 (9.8 ft)	13.1	4.37
					Subtotal (person-mrem):		80.5

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		No. of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Total Dose (person-mrem)
Fuel Transfer Operations (Remote Handling at Control Center)						
1.	Source Cask Lid Removed	---	36	---	---	---
2.	Receiving Cask Shield Plug Removed	---	33	---	---	---
3.	Positioning of Fuel Handling System over Source Cask	---	19	---	---	---
4.	Transfer of First Fuel Assembly from Source to Receiving Cask	---	24	---	---	---
5.	Placement of Fuel Assembly in Receiving Cask	---	7	---	---	---
6.	Positioning over Source Cask, Transfer of Second Assembly, Placement into Receiving Cask	---	50	---	---	---
7.	Positioning over Source Cask, Transfer of Third Assembly, Placement into Receiving Cask	---	50	---	---	---
8.	Positioning over Source Cask, Transfer of Fourth Assembly, Placement into Receiving Cask	---	50	---	---	---
9.	Receiving Cask Shield Plug Replaced	---	33	---	---	---
10.	Source Cask Lid Replaced	---	36	---	---	---

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		No. of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Total Dose (person-mrem)
Source Cask Removal from DTS						
1.	Source Cask Disengaged from Cask Mating System	3	15	3	---	---
2.	Sliding Door Unlocked & Opened	2	5	3	---	---
3.	Source Cask Removed from LAA	2	5	1	---	---
4.	Sliding Door Closes	2	5	3	---	---
5.	Source Cask Upper Surfaces Cleaned	3	60	1	---	---
6.	Pintle Removed	2	30	1	---	---
7.	Source Cask Lid Bolted	2	30	1	---	---
8.	Surfaces Dose Rates Checked	2	30	3	---	---
9.	Source Cask removed from Preparation Area	2	10	3	---	---

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Rate (mrem/hr)	Dose (person-mrem)
Receiving Cask Removal from DTS							
1	Receiving Cask disengaged from Cask Mating Subsystem						
2	Sliding Door Opens	side	2	5	3.04 (10 ft)	10.4	1.7
3	Unlocking of Receiving Cask	side	1	5	0	63.3	5.3
		side	1	5	1 (3.3 ft)	27.8	2.3
4	Removal of Receiving Cask from Lower Access Area and Locking in Preparation Area	side	2	5	3.04 (10 ft)	10.4	1.7
5	Sliding Door Closes	side	2	5	3.04 (10 ft)	10.4	1.7
6	Decontamination of Receiving Cask	top	1	30	1 (3.3 ft)	141	70.4
		side	1	30	1 (3.3 ft)	27.8	13.9
7	Check Surface Dose Rates	top	1	20	1 (3.3 ft)	141	46.9
		side	1	20	1 (3.3 ft)	27.8	9.3

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Rate (mrem/hr)	Dose (person-mrem)
8	Disengage Shield Plug Lifting Pintle	top	1	15	1 (3.3 ft)	141	35.2
9	Place Inner Lid on Receiving Cask	side	2	30	3.04 (10 ft)	10.4	10.4
10	Install Annulus Welding Protection* (Task Time - 12 min)		2	8	0.61 (2 ft)	80	21.3
11	Install Remote Welding Equipment * (Task Time - 45 min)		1	10	0.61 (2 ft)	80	13.3
			1	10	6.09 (20 ft)	0.5	0.1
12	Welding of Inner Lid*	---	---	1000	Remote	---	---
13	Perform NDE on Weld* (Task Time - 30 min)		1	5	0.61 (2 ft)	80	6.7
14	Removal of Welding Equipment* (Task Time - 20 min)		1	20	0.61 (2 ft)	80	26.7
			1	8	6.09 (2 ft)	0.5	0.1
15	Dry and Inert MPC* (Task Time - 90 min - TN estimate)		1	10	0.61 (2 ft)	80	13.3
			1	90	6.09 (20 fT)	11	16.5
16	Removal of Inerting Equipment* (Task Time - 12 min)		1	12	0.61 (2 ft)	220	44.0

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task	Relative Location	No of Person	Time (min)	Distance (m)	Rate (mrem/hr)	Dose (person-mrem)
17	Perform Leak Test on Seal Weld* (Task Time - 20 min)	1	20	0.61 (2 ft)	37	12.3
18	Weld Valve Cover Plates* (Task Time - 20 min)	1	10	0.61 (2 ft)	100	16.7
19	Place Receiving Cask Outer Lid*(Task Time - 18 min)	1	10	0.61 (2 ft)	100	16.7
		1	10	3.04 (10 ft)	11	1.8
		1	10	6.09 (20 ft)	0.5	0.1
20	Set Up Welding Equipment* (Task Time - 45 min)	1	30	0.61 (2 ft)	80	40.0
		1	10	3.04 (10 ft)	0.5	0.1
21	Weld Receiving Cask Outer Lid* (Task Time -1000 min)	---	1000	Remote	---	---
22	Perform NDT on Weld* (Task Time - 30 min)	1	5	0.61 (2 ft)	80	6.7
23	Removal of Weld Equipment* (Task Time - 20 min)	1	20	0.61 (2 ft)	80	26.7
24	Removal of Annulus Weld Protection* (Task Time - 12 min)	1	8	0.61 (2 ft)	80	10.7

Table 7.4-1 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Rate (mrem/hr)	Dose (person-mrem)
25	Place Receiving Cask Overpack Lid* (Task Time - 12 min)		1	12	0.61 (2 ft)	97	19.4
			1	12	3.04 (10 ft)	11	2.2
			1	12	6.09 (20 ft)	0.5	0.1
26	Perform HP Survey* (Task Time - 45 min)		2	20	0.61 (2 ft)	59	39.3
27	Bolt Overpack Lid	Top	2	30	0	9.3	9.3
28	Remove Receiving Cask from Preparation Area	Side	2	5	3.04 (10 ft)	10.4	1.7
					Subtotal (person - mrem)		545

* Number of personnel, dose rates, and times were provided by Department of Energy, based on the MPC program.

7.5 Health Physics Program

The Health Physics Program for the DTS is site specific and will be addressed in the site specific license application.

7.6 Estimated Offsite Collective Dose Assessment

The DTS is designed to prevent and minimize off-site doses from effluent streams. The primary contributors to offsite doses are direct and skyshine radiation.

The calculated dose versus distance from the DTS is provided in Table 7.6-1. The primary contributions to offsite doses are described below.

- Direct dose from the filled source cask arriving at the DTS;
- Direct dose from the fuel transfer operations;
- Direct dose from the filled receiving cask under cask removal operations;
- Scatter radiation from the open receiving cask; and
- Scatter radiation from the open source cask.

The direct dose from the filled source cask and the receiving cask are calculated using the SCALE4.3 / SAS1 code, a one-dimensional dose analysis method. The direct dose from fuel during transfer operations is calculated through the use of QADS, a three dimensional point kernel method. The scatter radiation is calculated using the SKYSHINE II computer code (Reference 7.7-6).

The dose rates presented in Table 7.6-1 show that between 100 to 200 meters (328 to 656 feet) from the DTS the controlled area boundary meet the annual dose limits as specified in 10 CFR 72.104. The calculation of these values is detailed in Appendix 7A.3.

Conservative assumptions are used throughout the analysis. The fuel being handled is five year cooled and at peak source strength. It is also assumed that an optimum operating schedule is followed for DTS operation. The optimum operating schedule assumes that each receiving cask is filled in ten days and ten receiving casks are filled prior to a scheduled 30 day maintenance period. In one year 30 receiving casks are filled or a total of 630 fuel assemblies are transferred in one year. It is likely that actual time use of the DTS will be less than the assumed time in use.

The offsite dose rate is also calculated assuming that the face of the DTS building with the highest dose rates (the side with the sliding door) is facing the boundary. Estimated offsite exposure levels taking into account the actual population locations will be addressed in the site specific license application.

Table 7.6-1

Calculated Maximum Offsite Exposures

Distance	Dose Rate (mrem/yr)
100 meters (328 feet)	43.5
200 meters (656 feet)	15.4
300 meters (984 feet)	5.97
400 meters (1,312 feet)	3.21
500 meters (1,640 feet)	2.05

7.7 References

7.7-1 U.S. Nuclear Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Exposures at Nuclear Power Stations will be As Low As Is Reasonably Achievable," Revision 3, June 1978.

7.7-2 "Multi-purpose Canister (MPC) Subsystem Design Procurement Specification," DBG6000000-01717-6300-00001, Revision 04, Prepared for the USDOE, Prepared by TRW Environmental Safety Systems, Inc., August 26, 1994."

7.7-3 ORIGEN 2, "Isotope Generation and Depletion Code - Matrix Exponential Method," CCC-371.

7.7-4 Transnuclear Inc., "Extended Fuel Burnup Demonstration Topical Report - Transport considerations for Transnuclear Casks," DOE/ET 34014-11 White Plains, New York, December 1983.

7.7-5 "SCALE4.3: A modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," ORNL/NUREG.CR-0200, US Nuclear Regulatory Commission, Revision 4, February 1990.

7.7-6 "SKYSHINE II: Calculation of the Effects of Structure Design on Neutron Primary Gamma-Ray Dose Rates in Air," CCC-289, Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 1979.

Appendix 7A Shielding Evaluation of the Dry Transfer System

This appendix details the shielding evaluation performed for the Dry Transfer System. The design is for the transfer of a single spent fuel assembly from the source cask to the receiving cask within a concrete and steel structure.

This appendix is separated into five sections, Section 7A.1 discusses the evaluation of the shielding performance of the DTS. Section 7A.2 discusses the worker dose evaluation. Section 7A.3 discusses the evaluation of the off site doses from the DTS. Section 7A.4 discusses the evaluation of the radiological consequences following off-normal conditions. Section 7A.5 presents the computer code inputs used for this appendix.

7A.1 Evaluation of the DTS Shielding Performance

An evaluation of the shielding performance of the DTS was performed using standard industry codes. The most significant shielding design features of the DTS are the 3 foot concrete walls, the steel sliding door, and the steel roof with a steel weather protective cover. To evaluate the shielding performance of the DTS four cases have been considered. These cases are:

- A source cask containing four fuel assemblies;
- A receiving cask containing twenty one assemblies;
- One fuel assembly at the start of fuel transfer, fully removed from the source cask and in the position closest to the DTS sliding door; and
- One fuel assembly during fuel transfer, in the position closest to the DTS roof.

Conservative assumptions are used through out the analysis:

- For purposes of the shielding evaluation, fuel assemblies are cooled for a minimum of 5 years and are at the peak source strength;
- Axial distributions for the source are taken as uniform, while in reality, the source will be relatively low near the top and bottom of the fuel region. This is because the power shape during operation is non-uniform.
- The mechanical equipment within the DTS which provides additional shielding is neglected;
- The steel and aluminum structure of the basket within the source and receiving cask is neglected;
- The Preparation Area steel butler building is neglected; and
- The steel rebar in the concrete walls of the DTS is neglected.

During fuel transfer, the shielding for the single fuel assembly is the 0.8 inch (20mm) steel fuel transfer tube, the concrete walls, the steel sliding door and the steel roof of the DTS structure. Figures 1.2-17 and 1.2-18 show the dimensions of the DTS structure.

The primary gamma dose rates are determined using the point kernel computer code QADS module of SCALE 4.3, which has the advantage of being able to model the source in three dimensions (Reference 7A-1). The source consists of two portions, the active fuel zone and the top fitting zone. Within each zone, the source is assumed to be uniform both radially and axially. ANSI standard gamma and neutron flux-to-dose rate conversion factors internal to SCALE 4.3 are used.

The gamma source term for the active fuel zone and the top fitting zone used for the DTS shielding evaluation in QADS are provided in Tables 7A-1 and 7A-2, respectively, below.

Table 7A-1

Active Fuel Zone - Gamma Source Terms Used in QADS

SCALE Group	SCALE Peak (γ/s/assembly)	SCALE Fraction
6	9.390E+10	1.59E-05
7	2.910E+12	4.91E-04
8	3.668E+12	6.21E-04
9	1.275E+14	2.15E-02
10	3.123E+14	5.27E-02
11	5.774E+14	9.75E-02
12	1.623E+15	2.74E-01
13	2.665E+15	4.50E-01
14	1.021E+14	1.72E-02
15	1.446E+14	2.45E-02
16	3.662E+14	6.13E-02
Total	5.92E+15	1.00E+00

For the top fitting, the Co-60 source term is 114 Ci. Converting to γ/s/assy:

Top Fitting Source = 114 Ci/assy * 3.7E10 dis/s-Ci * 2 γ/dis
Top Fitting Source = 8.436E12 γ/s/assy @ 1.25 MeV

Table 7A-2

Top Fitting Zone - Gamma Source Terms Used in QADS

Group	SCALE Peak (γ/s/assembly)	SCALE Fraction
10	8.436E+12	1.00E+00

7A.1.1 DTS Shielding Evaluation - Open Source Cask Containing Four Fuel Assemblies

The dose rates inside and around the DTS structure due to primary gamma from the source cask filled with four PWR spent fuel assemblies is calculated. The source is separated into two components: the active fuel zone and the top fitting zone. The source of the fuel zone is homogenized over the source cask cavity diameter and the appropriate axial length. The top fitting zone is homogenized over the source cask cavity diameter and the axial top fitting and plenum length.

In the QADS model, the basket of the source cask is neglected. The steel rebar in the concrete is also neglected. The buildup factor for concrete is utilized.

7A.1.1.1 Model Specification

The model utilized in the QADS calculation is shown in Figure 7A-1. Dimensions are taken from the DTS design drawings.

Figure 7A-1

QADS Model for the Open Source Cask Containing Four Fuel Assemblies

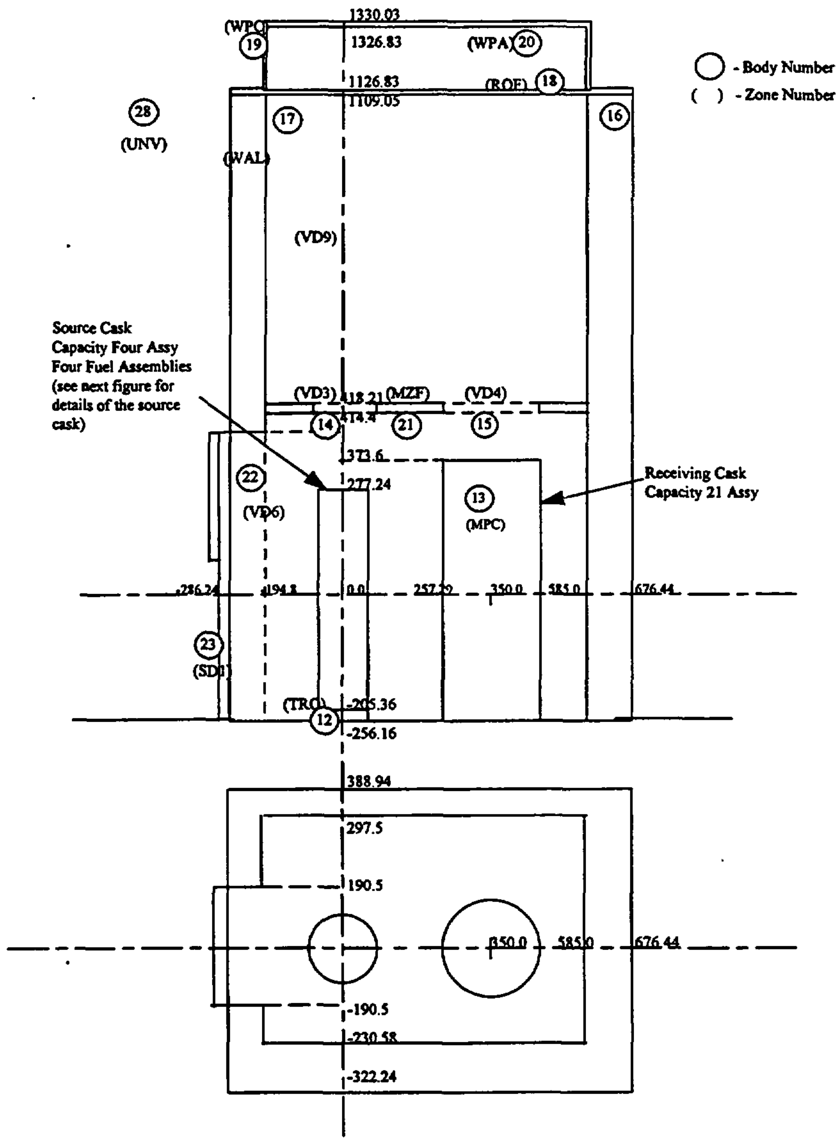
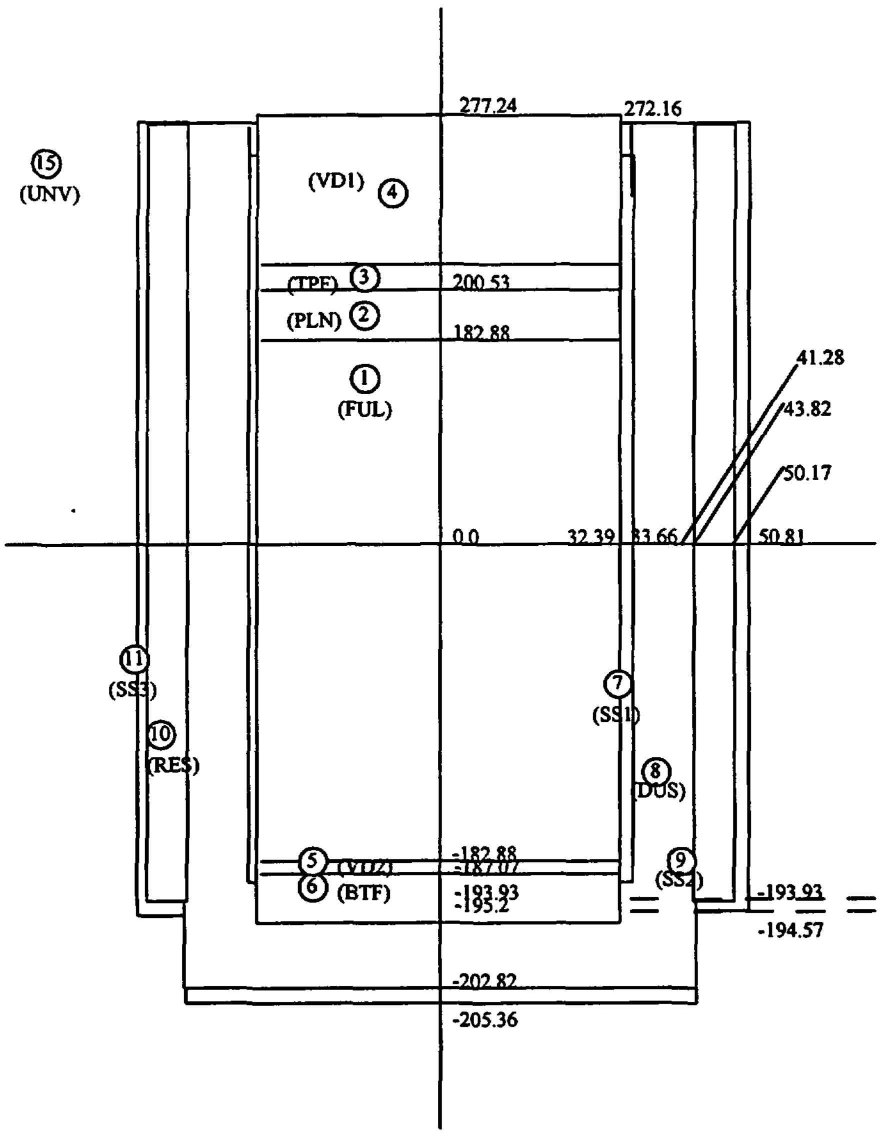


Figure 7A-1 (Continued)

QADS Model for the Open Source Cask Containing Four Fuel Assemblies



7A.1.1.2 Material Densities

The material densities used for this analysis are provided in Table 7A-3.

Table 7A-3

**Material Densities for QADS Model -
Open Source Cask Containing Four Fuel Assemblies**

Location	Material	Density (g/cc)
Fuel Zone[1]	U	1.531
	Zr	0.341
Plenum Zone[1]	Fe	0.147
	Zr	0.424
Top End Fitting Zone[1]	Fe	0.955
Bottom Fitting Zone[1]	Fe	1.008
Carbon Steel	Fe	7.82
Depleted Uranium	U(.27) metal[2]	19.05
Resin and Aluminum[3]	C	0.4802
	O	0.5704
	Al	0.556
Concrete - Regular	Reg-Concrete[2]	2.30

Notes:

1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected
2. This designation refers to the standard compositions built into the SCALE 4.3 code.
3. Resin density is 1.578 g/cc. Its major components are C (35 w%), O (42%), and Al (15%). The densities used are based on homogenizing the resin and the aluminum boxes that contain it, thus reducing the effective resin density, but raising the aluminum density.

7A.1.1.3 Gamma Source

The active fuel zone gamma source used for the QADS code is 5.92E+15 γ/s/assembly, or a total source of 2.37E+16 γ/s. The energy distribution is provided in Table 7A-1. The top fitting zone gamma source used for the QADS code is 8.436E+12 γ/s/assembly, or total source of 3.37E+13 γ/s/ The energy distribution is provided in Table 7A-2.

7A.1.1.4 Dose Locations

The selected dose points for the QADS runs are shown on Figure 7A-2. The QADS runs were calculated using the peak source strengths. It was assumed that the source cask is filled with four fuel assemblies at an average source strength. The results from the QADS runs were scaled down to determine average dose rates around the DTS from the cask. From reference 7.1-3, the ratio of average to peak gamma source strength is:

Peak gamma source = 9.9E+15
Average gamma source = 7.8E+15
Ratio of {Average/Peak} Gamma Source = 0.79

The average dose rates around the DTS are shown in the Table 7A-4. The QADS input file is provided in Section 7A.5.1.

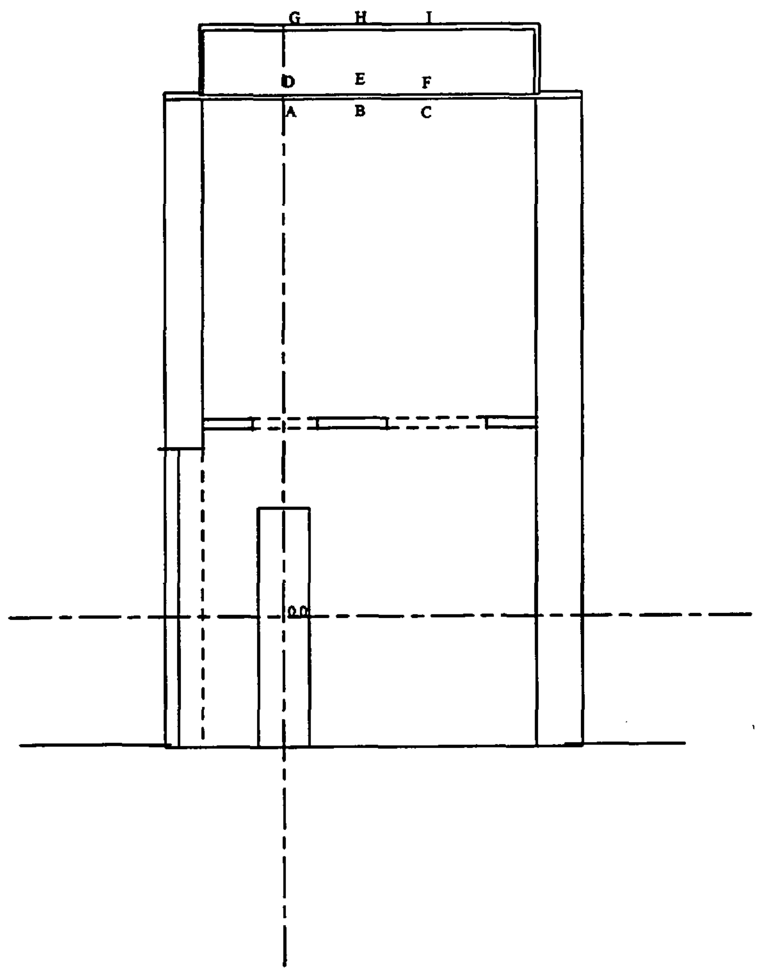
Table 7A-4

Dose Rate Analysis Results
Open Source Cask Containing Four Fuel Assemblies

Dose Point	Fuel Zone Dose Rate (mrem/hr)	Top Fitting Zone Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
A	34,500	5,090	39,600
B	22,600	3,810	26,400
C	2,040	964	3,000
D	41.8	24.0	65.8
E	24.4	16.0	40.4
F	1.49	1.82	3.31
G	8.53	5.00	13.5
H	5.66	3.64	9.32
I	1.26	1.19	2.45

Figure 7A-2

Dose Point Locations
Open Source Cask Containing Four Fuel Assemblies



7A.1.2 DTS Shielding Evaluation - Open Receiving Cask Containing Twenty One Fuel Assemblies

The dose rates inside and around the DTS structure due to primary gamma from the receiving cask filled with twenty one (21) PWR spent fuel assemblies is calculated. The source is separated into two components: the active fuel zone and the top fitting zone. The source of the fuel zone is homogenized over the receiving cask cavity diameter and the appropriate axial length. The top fitting zone is homogenized over the receiving cask cavity diameter and the axial top fitting and plenum length.

In the QADS model, the basket of the receiving cask is neglected. The steel rebar in the concrete is also neglected. The buildup factor for concrete is utilized.

7A.1.2.1 Model Specification

The model utilized in the QADS calculation is shown in Figure 7A-3. Dimensions are taken from the DTS design drawings.

Figure 7A-3

QADS Model for the Open Receiving Cask Containing Twenty One Fuel Assemblies

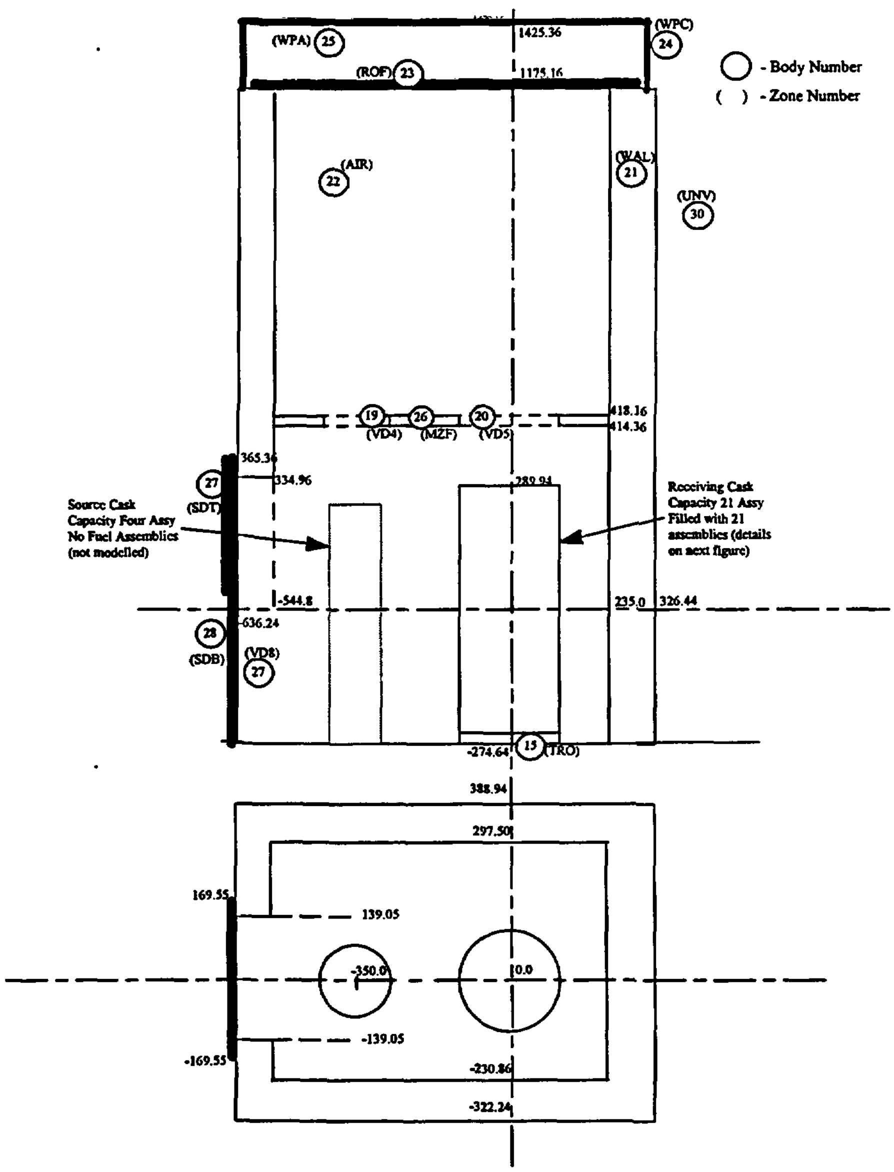
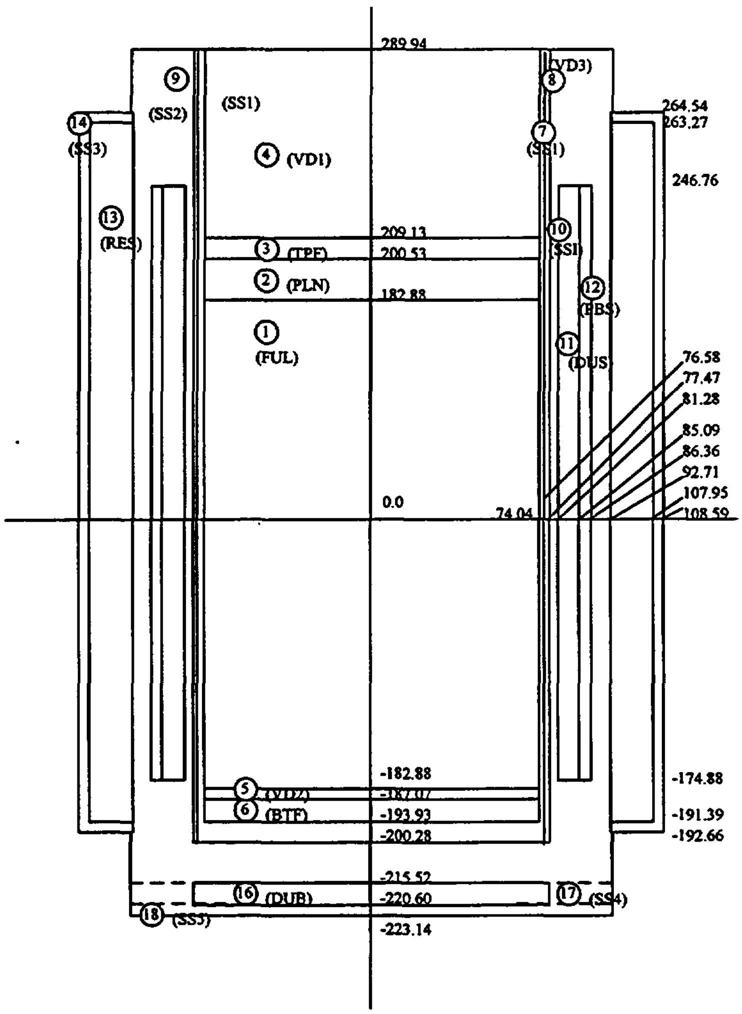


Figure 7A-3 (Continued)

QADS Model for the Open Receiving Cask Containing Twenty One Fuel Assemblies



7.A.1.2.2 Material Densities

The material densities used for this analysis are provided in Table 7A-5.

Table 7A-5

Material Densities
Open Receiving Cask Containing Twenty One Fuel Assemblies

Location	Material	Density (g/cc)
Fuel Zone[1]	U	1.538
	Zr	0.343
Plenum Zone[1]	Fe	0.131
	Zr	0.380
Top End Fitting[1]	Fe	0.960
Bottom Fitting Zone[1]	Fe	1.013
Carbon Steel	Fe	7.82
Depleted Uranium	U(.27) Metal[2]	19.05
Lead Shell	Pb	11.35
Resin and Aluminum [3]	C	0.501
	O	0.595
	Al	0.473
Concrete - Regular	Reg-Concrete[2]	2.30

Notes:
1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected.
2. Designation refers to the standard compositions built into the SCALE 4.3 code.
3. See note 3, Table 7A-3

7A.1.2.3 Gamma Source

The active fuel zone gamma source used for the QADS code is 5.92E+15 γ/s/assembly, or a total source of 1.23E+17 γ/s. The energy distribution is provided in Table 7A-1. The top fitting zone gamma source used for the QADS code is 8.436E+12 γ/s/assembly, or total source of 1.77E+14 γ/s. The energy distribution is provided in Table 7A-2.

7A.1.2.4 Dose Locations

The QADS runs were calculated using the peak source strengths. It was assumed that the source cask is filled with four fuel assemblies at an average source strength. The results from the QADS runs were scaled down to determine average dose rates around the DTS from the cask. From Section 7A.1.1.4, the ratio of average to peak gamma source strength is 0.79.

The selected dose points for the QADS runs are shown on Figure 7A-4. The average dose rates around the DTS from the receiving cask filled with twenty one assemblies are shown in Table 7A-6 below. The QADS input file is provided in Section 7A.5.2.

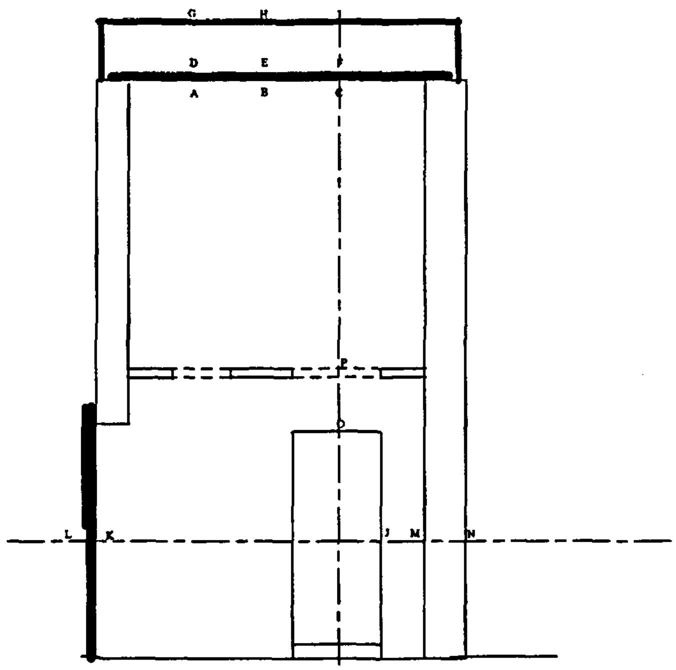
Table 7A-6

Dose Rate Analysis Results
Open Receiving Cask Containing Twenty One Fuel Assemblies

Dose Point	Active Fuel Zone Dose Rate (mrem/hr)	Top Fitting Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
A	64,300	13,400	77,700
B	137,000	21,600	158,000
C	160,000	24,000	183,000
D	50.2	37.4	87.74
E	148	90.1	238
F	190	112	303
G	12.2	8.30	20.5
H	24.3	14.9	39.2
I	29.4	17.5	46.9
J	132	---	132
K	17.5	0.171	17.6
L	0.0313	9.80E-05	1.32E-03
M	64.7	1.45E-03	64.7
N	1.90E-03	---	1.90E-03
O	8.22E+06	1.97E+06	1.02E+07
P	2.43E+06	436,000	2.86E+06

Figure 7A-4

Dose Point Locations
Open Receiving Cask Containing Twenty One Fuel Assemblies



7A.1.3 DTS Shielding Evaluation - One Fuel Assembly at Start of Fuel Transfer, Fully Removed From Source Cask and in Position Closest Sliding Door

The dose rates inside and around the DTS structure due to a single assembly being removed from the source cask (in a position close to the sliding door) are evaluated. The source consists of two portions, the active fuel zone and the top fitting zone. The fuel assembly is considered as a cylindrical source. The active fuel zone is homogenized over the equivalent diameter and axial length. Similarly, the top fitting zone is homogenized over the equivalent diameter and the plenum plus top fitting length.

The model neglects the basket and the steel rebar in the concrete. The calculation uses the buildup factor for concrete.

7A.1.3.1 Model Specification

The model utilized in the QADS calculation is shown in Figure 7A-5. The single fuel assembly is modeled not as a "box" but rather it is considered as a right circular cylinder. The conversion is shown below:

$$
\begin{aligned}
V_{\text{fuel assembly}} &= 8.8 \text{ inches} \times 8.8 \text{ inches} \times 144 \text{ inches} \\
&= 22.35 \text{ cm} \times 22.35 \text{ cm} \times 365.76 \text{ cm} \\
&= 182{,}705 \text{ cc}
\end{aligned}
$$

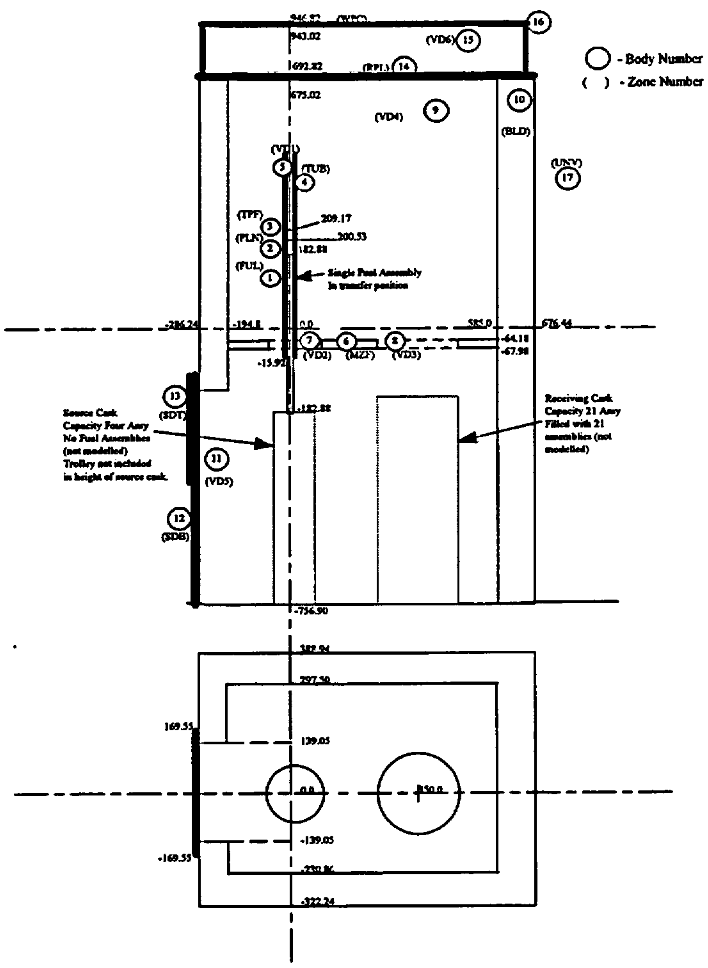
Converting to cylindrical:

$$V_{\text{cylindrical}} = \pi r^2 h \quad \therefore \; r = \sqrt{\{182{,}705/365.76\pi\}} = 12.61 \text{ cm}$$

Dimensions are taken from the DTS design drawings.

Figure 7A-5

QADS Model for the One Fuel Assembly at Start of Fuel Transfer Fully Removed From Source Cask and in Position Closest Sliding Door



7A.1.3.2 Material Densities

The material densities used for this analysis are provided in Table 7A-7.

Table 7A-7

Material Densities
One Fuel assembly at Start of Fuel Transfer
Fully Removed From Source Cask and in Position Closest Sliding Door

Location	Material	Density (g/cc)
Fuel Zone[1]	U	2.525
	Zr	0.563
Plenum Zone[1]	Fe	0.215
	Zr	0.624
Top End Fitting Zone[1]	Fe	1.576
Carbon Steel	Fe	7.82
Concrete - Regular	Reg-Concrete[2]	2.30

Notes:

1. "Density " of fuel assembly material homogenized over cavity volume, basket neglected
2. This designation refers to the standard compositions built into the SCALE 4.3 code.

7A.1.3.3 Gamma Source

The active fuel zone gamma source used for the QADS code is 5.92E+15 γ/s/assembly. The energy distribution is provided in Table 7A-1. The top fitting zone gamma source used for the QADS code is 8.436E+12 γ/s/assembly. The energy distribution is provided in Table 7A-2.

7A.1.3.4 Dose Locations

The QADS runs were calculated using the peak source strengths. The selected dose points for the QADS runs are shown on Figure 7A-6. The results from the QADS run are shown in Table 7A-8 below. The QADS input is provided in Section 7A.5.3.

Table 7A-8

Dose Rate Analysis Results - One Fuel assembly at Start of Fuel Transfer Removed From Source Cask, In Position Closest Sliding Door

Dose Point	Fuel Dose Rates (mrem/hr)	Top Fit Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
	Roof Area of DTS		
A	12,100	5,430	17,500
B	33,800	946	34,700
C	80,800	1,550	82,400
D	14.0	22.5	36.5
E	38.6	1.05	40.0
F	50.7	0.802	51.5
G	1.55	2.42	3.97
H	3.77	0.0417	3.81
I	6.36	0.112	6.47
	Radial Centerline of Fuel Assembly		
J	2.09E+07	---	2.09E+07
K	2.20E+06	6,040	2.21E+06
L	17.7	0.0178	17.7
M	339,000	1,950	341,000
N	5.56	0.0429	5.59

Table 7A-8 (Continued)

Dose Rate Analysis Results - One Fuel assembly at Start of Fuel Transfer Removed From Source Cask, In Position Closest Sliding Door

Dose Point	Fuel Dose Rates (mrem/hr)	Top Fit Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
	Sliding Door of DTS		
AA (20' elevation, contact)	46.6	---	46.6
BB (20' elevation, 30 cm)	38.8	---	38.8
CC (19' elevation, contact)	104	---	104
DD (19' elevation, 30 cm)	77.9	---	77.9
EE (18' elevation, contact)	107	---	107
FF (18' elevation, 30 cm)	89.7	---	89.7
GG (17' elevation, contact)	79.7	---	79.7
HH (17' elevation, 30 cm)	74.3	---	74.3
II (16' elevation, contact)	53.3	---	53.3
JJ (16' elevation, 30 cm)	53.2	---	53.2
KK (15' elevation, contact)	33.3	---	33.3
LL (15' elevation, 30 cm)	35.4	---	35.4
MM	33.3	---	33.3
NN	35.4	---	35.4
OO (14' elevation, contact)	189	---	189
PP (14' elevation, 30 cm)	200	---	200
QQ (13' elevation, contact)	115	---	115
RR (13' elevation, 30 cm)	135	---	135
SS (12' elevation, contact)	67.7	---	67.7
TT (12' elevation, 30 cm)	84.8	---	84.8
UU (10' elevation, contact)	21.7	---	21.7
VV (10' elevation, 30 cm)	31.0	---	31.0
WW (6' elevation, contact)	1.83	---	1.83
XX (6' elevation, 30 cm)	3.41	---	3.41
YY (3' elevation, contact)	0.264	---	0.264

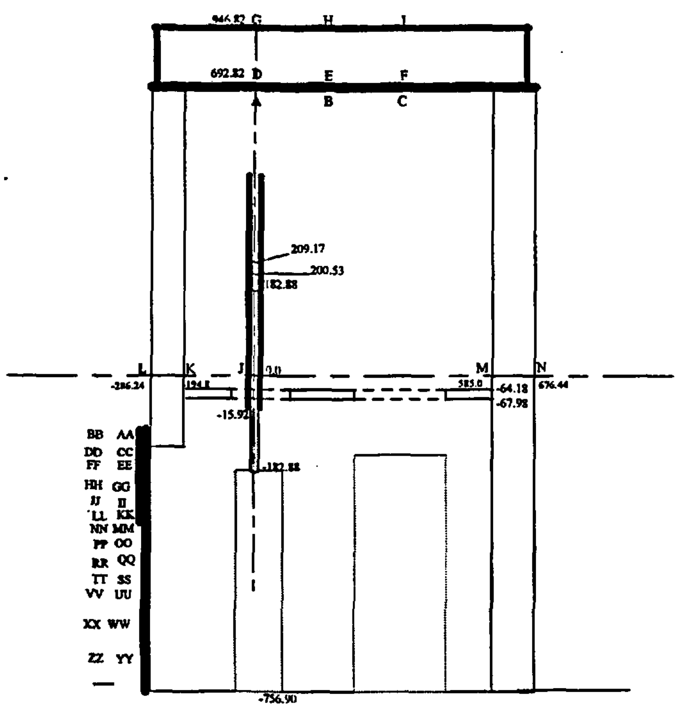
Table 7A-8 (Continued)

Dose Rate Analysis Results - One Fuel assembly at Start of Fuel Transfer Removed From Source Cask, In Position Closest Sliding Door

Dose Point	Fuel Dose Rates (mrem/hr)	Top Fit Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
ZZ (3' elevation, 30 cm)	0.594	---	0.594

Figure 7A-6

Dose Point Locations
One Fuel Assembly at Start of Fuel Transfer
Fully Removed From Source Cask and in Position Closest Sliding Door



7A.1.4 DTS Shielding Evaluation - One Fuel Assembly During Fuel Transfer in the Position Closest to the DTS Roof

The dose rates inside and around the DTS structure due to a single assembly during transfer where it is in a position closest to the roof and over the receiving cask is evaluated. The source consists of two portions, the active fuel zone and the top fitting zone. The fuel assembly is considered as a cylindrical source. The active fuel zone is homogenized over the equivalent diameter and axial length. Similarly, the top fitting zone is homogenized over the equivalent diameter and the plenum plus top fitting length.

The model neglects the basket and the steel rebar in the concrete. The calculation uses the buildup factor for concrete.

7A.1.4.1 Model Specification

The model utilized in the QADS calculation is shown in Figure 7A-7. The single fuel assembly is modeled not as a "box" but rather it is considered as a right circular cylinder. The conversion is shown below:

$$
\begin{aligned}
V_{\text{fuel assembly}} &= 8.8 \text{ inches} \times 8.8 \text{ inches} \times 144 \text{ inches} \\
&= 22.35 \text{ cm} \times 22.35 \text{ cm} \times 365.76 \text{ cm} \\
&= 182{,}705 \text{ cc}
\end{aligned}
$$

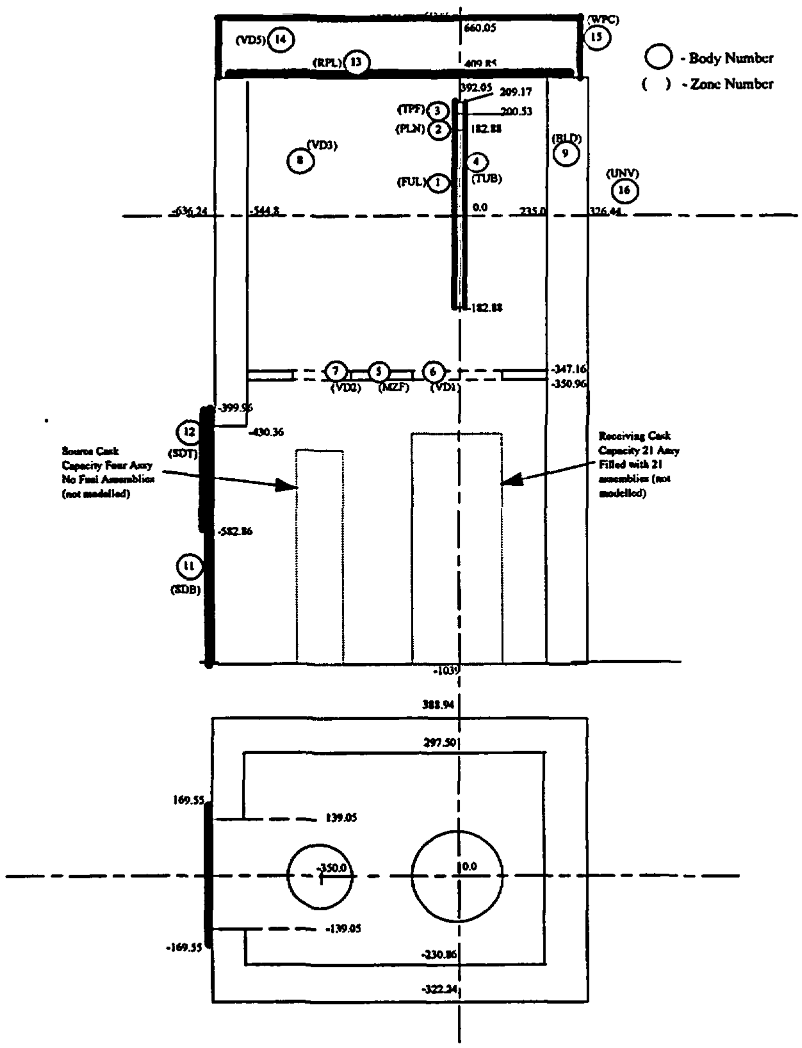
Converting to cylindrical:

$$V_{\text{cylindrical}} = \pi r^2 h \quad \therefore \; r = \sqrt{\{182{,}705/365.76\pi\}} = 12.61 \text{ cm}$$

Dimensions are taken from the DTS design drawings.

Figure 7A-7

QAD Model for the One Fuel Assembly During Fuel Transfer in Position Closest to the DTS Roof



7A.1.4.2 Material Densities

The material densities used for this analysis are provided in Table 7A-9.

Table 7A-9

Material Densities
One Fuel Assembly During Fuel Transfer in Position Closest to the DTS Roof

Location	Material	Density (g/cc)
Fuel Zone[1]	U	2.525
	Zr	0.563
Plenum Zone[1]	Fe	0.215
	Zr	0.624
Top End Fitting Zone[1]	Fe	1.576
Carbon Steel	Fe	7.82
Concrete - Regular	Reg-Concrete[2]	0.023

Notes:

1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected
2. This designation refers to the standard compositions built into the SCALE 4.3 code.

7A.1.4.3 Gamma Source

The active fuel zone gamma source used for the QADS code is 5.92E+15 γ/s/assembly. The energy distribution is provided in Table 7A-1. The top fitting zone gamma source used for the QADS code is 8.436E+12 γ/s/assembly. The energy distribution is provided in Table 7A-2.

7A.1.4.4 Dose Locations

The QADS runs were calculated using the peak source strengths. The selected dose points for the QADS runs are shown on Figure 7A-8. The results from the QAD run are shown in Table 7A-10 below. The QAD-CGGP input file is provided in Section 7A.5.4.

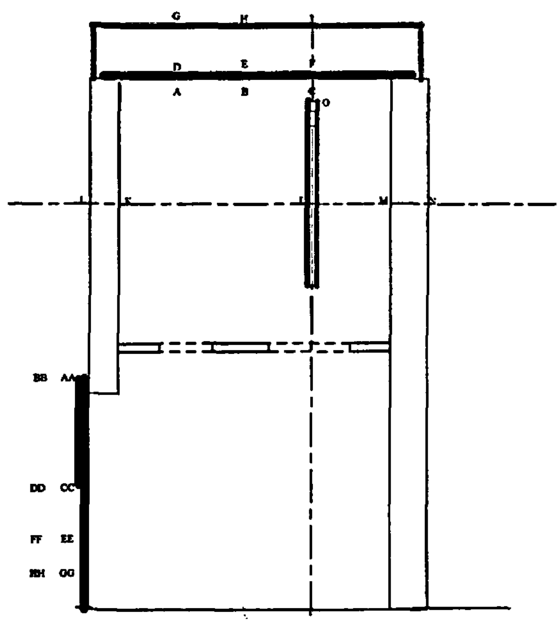
Table 7A-10

Dose Rate Analysis Results - One Fuel Assembly During Fuel Transfer In Position Closest to DTS Roof

Dose Point	Fuel Dose Rate (mrem/hr)	Top Fit Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
A	196,000	5,530	202,000
B	126,000	13,700	140,000
C	63,100	32,700	95,800
D	17.7	0.0349	17.7
E	42.5	6.80	49.3
F	66.1	122	188
G	3.21	0.355	3.57
H	2.02	2.63	4.65
I	3.77	6.26	10.0
J	2.09E+07	---	2.09E+07
K	320,000	2,190	322,000
L	4.32	0.0446	4.32
M	1.39E+06	5,740	1.40E+06
N	11.4	0.0272	11.4
O	2.18E+06	8.74E+06	1.09E+07
AA	0.331	4.52E-04	0.331
BB	0.570	6.13E-04	0.571
CC	0.147	1.34E-04	0.147
DD	0.155	2.15E-05	0.155
EE	0.544	5.68E-04	0.545
FF	0.617	8.36E-04	0.618
GG	0.205	1.33E-04	0.205
HH	0.248	2.14E-04	0.248

Figure 7A-8

**Dose Point Locations
One Fuel Assembly During Fuel Transfer
In Position Closest to the DTS Roof**



7A.1.5 Determination of Highest Dose Rates Around DTS Structure During Fuel Transfer Operations

The dose rates from various stages of fuel transfer are combined to estimate the dose rate during various stages of operations. Four scenarios have been evaluated for shielding effectiveness:

- A source cask containing four fuel assemblies (Section 7A.1.1).
- A receiving cask containing twenty one fuel assemblies (Section 7A.1.2).
- One fuel assembly at the start of fuel transfer, fully removed from the source cask and in the position closest to the DTS sliding door (Section 7A.1.3).
- One fuel assembly during fuel transfer in position closest to roof and over the receiving cask (Section 7A.1.4).

Dose rates around the DTS during fuel transfer vary according to the position of the fuel assembly. Two scenarios combining the effects of the fuel assembly in the transfer position and a filled receiving cask are considered in this analysis:

- The first scenario assumes that the fuel assembly is being removed form the source cask and is suspended near the sliding door. The dose rates from this configuration are combined with the dose rates from the filled open receiving cask. This case combines the results from Section 7A.1.1 and Section 7A.1.3. (See Table 7A-11 and Figure 7A-9.)

- The second scenario assumes that the fuel assembly is suspended (in the position closest to the roof) over the receiving cask. The dose rates from this configuration are combined with the dose rates from the filled open receiving cask. This case combines the results from Section 7A.1.1 and Section 7A.1.4. (See Table 7A-12 and Figure 7A-10.)

Table 7A-11

Dose Rate Analysis Results - Scenario 1
Open Receiving Cask Containing Twenty One Fuel Assemblies and One Fuel Assembly Suspended Near Sliding Door

Dose Point	Section 7A.1.1 (mrem/hr)	Section 7A.1.2 (mrem/hr)	TOTAL (mrem/hr)
Roof Dose Rates			
A	17,500	77,700	95,200
B	34,700	158,000	193,000
C	82,400	183,000	265,000
D	36.5	87.7	124
E	40.0	238	278
F	51.5	303	355
G	3.97	20.5	24.5
H	3.81	39.2	43.0
I	6.47	46.9	53.4
Radial Centerline of Fuel Assembly (nc- not calculated)			
J	2.09E+07	nc	2.09E+07
K	2.21E+06	nc	2.21E+06
L	17.7	nc	17.7
M	341,000	nc	341,000
N	5.59	nc	5.59
Sliding door of DTS (nc - not calculated)			
20 ft elevation, contact	46.6	nc	46.6
18 ft elevation, contact	107	nc	107
16 ft elevation, contact	53.3	nc	53.3
14 ft elevation, contact	189	nc	189
12 ft elevation, contact	67.7	nc	67.7

Table 7A-11

Dose Rate Analysis Results - Scenario 1
Open Receiving Cask Containing Twenty One Fuel Assemblies and
One Fuel Assembly Suspended Near Sliding Door

Dose Point	Section 7A.1.1 (mrem/hr)	Section 7A.1.2 (mrem/hr)	TOTAL (mrem/hr)
10 ft elevation, contact	21.7	1.32E-03	21.7
6 ft elevation, contact	1.83	nc	1.83
3 ft elevation, contact	0.264	nc	0.264

Table 7A-12

Dose Rate Analysis Results - Scenario 2
Open Receiving Cask Containing Twenty One Fuel Assemblies and
One Fuel Assembly Suspended over Receiving Cask

Dose Point	Section 7A.1.1 (mrem/hr)	Section 7A.1.4 (mrem/hr)	TOTAL (mrem/hr)
	Roof Dose Rates		
A	202,000	77,700	280,000
B	140,000	158,000	298,000
C	95,800	183,000	279,000
D	17.7	87.7	105
E	49.3	238	287
F	188	303	491
G	3.57	20.5	24.1
H	4.65	39.2	43.9
I	10.0	46.9	56.9
	Radial Centerline of Fuel Assembly (nc - not calculated)		
J	2.09E+07	nc	2.09E+07
K	322,000	nc	322,000
L	4.32	nc	4.32
M	1.40E+06	nc	1.40E+06
N	11.4	nc	11.4
O	1.09E+07	nc	1.09E+07
	Sliding Door (nc - not calculated)		
20 ft elevation, contact	0.331	nc	0.331
15 ft elevation, contact	0.147	nc	0.147
10 ft elevation, contact	0.545	1.32E-03	0.546
6 ft elevation, contact	0.205	nc	0.205

Figure 7A-9

Dose Point Locations - Scenario 1
Open Receiving Cask Containing Twenty One Fuel Assemblies and One Fuel Assembly Suspended Near Sliding Door

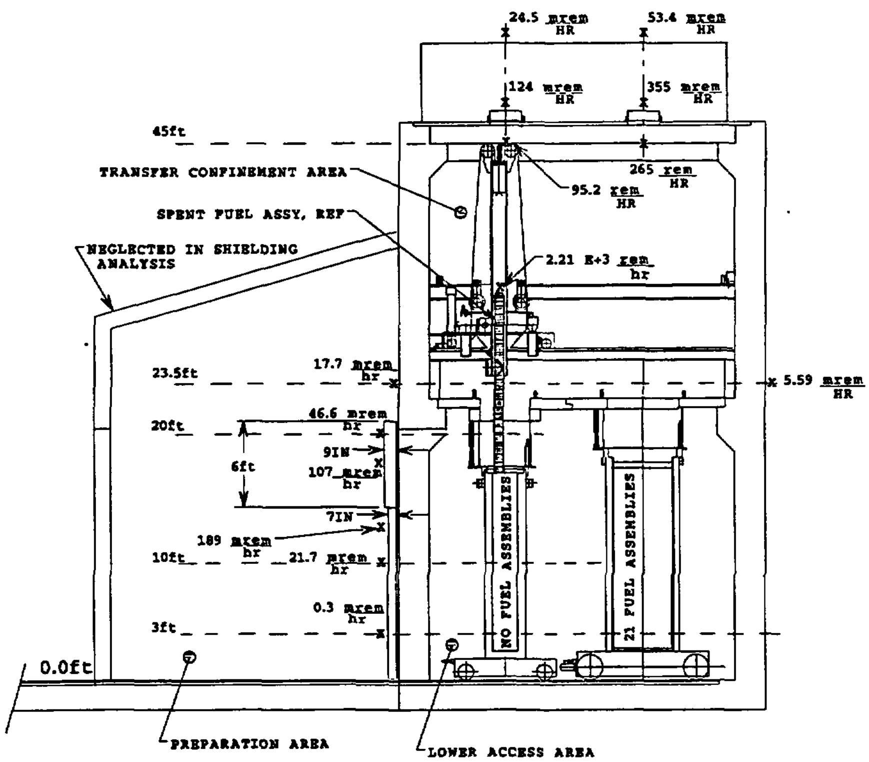
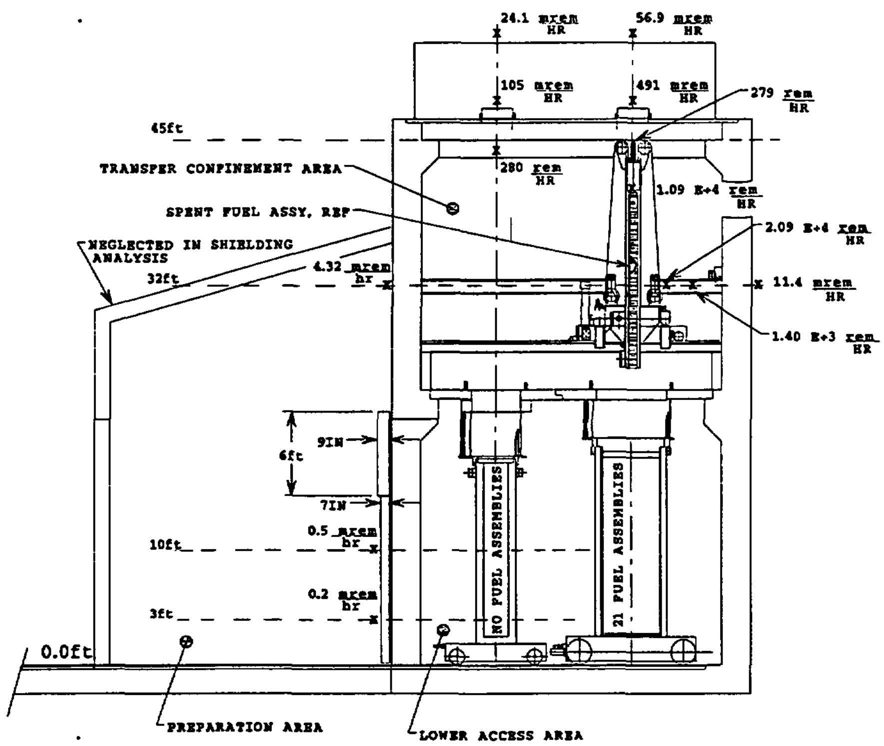


Figure 7A-10

Dose Point Locations - Scenario 2
Open Receiving Cask Containing Twenty One Fuel Assemblies and One Fuel Assembly Suspended over Receiving Cask



7A.1.6 References

7A.1-1 SCALE 4.3 Program Package.

7A.2 Evaluation of Worker Doses in the DTS

The doses from operations to workers are primarily from two components: worker handling of the filled source cask when it arrives at the DTS and worker handling of the filled receiving casks when it leaves the DTS. This section describes the evaluation of both these cases.

The design of the DTS does not include the design of the source and receiving casks. The contact dose rates are high (approximately 160 mrem/hr at the design basis source cask and 65 mrem/hr at the design basis receiving cask). The actual source and receiving casks are expected to result in lower dose rates.

For both cases the one dimensional SAS1 of the SCALE4.3 code was used (Reference 7A.2-1). The gamma and neutron source spectrum used for the source and receiving cask in this code is provided below.

Table 7A-13

Active Fuel Zone - Gamma Source Spectrum Used in SAS1

Group	SCALE Peak (γ/s/assembly)	SCALE Fraction
33	9.390E+10	1.59E-05
34	2.910E+12	4.91E-04
35	3.668E+12	6.21E-04
36	1.275E+14	2.15E-02
37	3.123E+14	5.27E-02
38	5.774E+14	9.75E-02
39	1.623E+15	2.74E-01
40	2.665E+15	4.50E-01
41	1.021E+14	1.72E-02
42	1.446E+14	2.45E-02
43	3.662E+14	6.13E-02
Total	5.92E+15	1.00E+00

Table 7A-14

Top Fitting Zone - Gamma Source Terms Used in SAS1

Group	SCALE Peak (γ/s/assembly)	SCALE Fraction
37	8.436E+12	1.00

Table 7A-15

Normalized Neutron Source Spectra for Fuel Region Spontaneous Fission and Alpha-N Reaction Sources

	Energy Group MeV	Fraction PWR 5 Years Decay
1	6.43E+00 - 2.00E+01	1.85E-02
2	3.00E+00 - 6.43E+00	2.10E-01
3	1.85E+00 - 3.00E+00	2.32E-01
4	1.40E+00 - 1.85E+00	1.31E-01
5	9.00E-01 - 1.40E+00	1.77E-01
6	4.00E-01 - 9.00E-01	1.93E-01
7	1.00E-01 - 4.00E-01	3.78E-02

7A.2.1 Source Cask Evaluation

7A.2.1.1 Source Cask Gamma Source

For the fuel region the gamma source peak value is approximately 5.92E+15 γ/s/assembly. For four fuel assemblies, the peak source peak strength is 2.37E+16 γ/s. The source spectrum is provided in Table 7A-13. The fuel zone gamma source term on a volumetric basis is:

Source Cask Fuel Zone Volume = $\pi r^2 h = \pi (32.39 \text{ cm})^2 (365.76 \text{ cm}) = 1.21E{+}06$ cc

Volumetric Fuel Zone Gamma Source = {2.37E+16 γ/s}/{1.21E+6 cc}
= 1.96E+10 γ/s/cc

For the top fitting region the peak gamma source strength is 8.436E+12 γ/s/assembly, or a total source of 3.37E+13 γ/s. The source spectrum is provided in Table 7A-14. The top fitting zone gamma source on volumetric basis is:

Source Cask Top Fitting Zone Volume = $\pi r^2 h = \pi$ (32.39 cm)^2 (26.25 cm)
= 8.65E+04 cc

Volumetric Top Fitting Gamma Source = {2.37E+16 γ/s}/{8.65E+04 cc}
= 3.90E+8 γ/s/cc

7A.2.1.2 Source Cask Neutron Source

The fuel region peak neutron source is 5.4E+08 n/s/assembly. The total peak neutron source for 4 assemblies is 2.16E+09 n/s. The neutron fractions are provided in Table 7A-15. The fuel zone neutron source on a volumetric basis is:

Source Cask Fuel Zone Volume = $\pi r^2 h = \pi$ (32.39 cm)^2 (365.76cm) = 1.21E+6 cc

Volumetric Fuel Zone Neutron Source = {2.16E+09 n/s}/{1.21E+6 cc} = 1785 n/s/cc

7A.2.1.3 Description of Radial and Axial Shielding Configurations

The gamma and neutron contributions to the dose rates were calculated using one dimensional models. The source strength characteristics of the active fuel zone and the top fitting zone were used in the models. The contribution from the bottom hardware was considered negligible.

The radial analysis model is shown in Figure 7A-11. This radial model considered only the active fuel zone. The gamma dose from the top fitting was considered to be negligible.

The axial analysis of the gamma and neutron dose rate uses a slab model with a source thickness of one half the active fuel length. The source beyond this does not contribute significantly to the dose rate. Figure 7A-12 illustrates the basic model configurations for these two analyses casks. The axial analysis considered the gamma dose from both the top fitting zone and the active fuel zone.

The source and shield material densities are described in the following section.

7A.2.1.4 Source and Shield Regional Densities

Material densities applicable for source and shield regions in both the radial and axial models are listed in Table 7A-16. The fuel source is homogenized over the cylindrical source volume of the internal cavity.

Table 7A-16

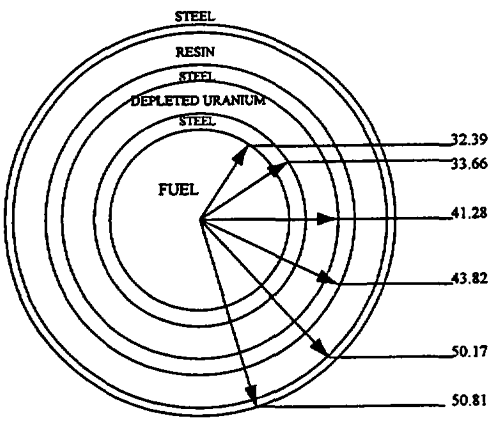
Source Cask Evaluation - Material Densities

Mixture No.	Element	Density (g/cc)
Fuel[1]	UO_2	1.737
	Zr	0.341
Plenum[1]	Fe	0.147
	Zr	0.424
Top Fitting [1]	Fe	0.955
Bottom Fitting[1]	Fe	1.008
Depleted Uranium	U(.27)Metal[2]	19.05
Resin / Aluminum[3]	H	0.071
	B	0.015
	C	0.497
	O	0.591
	Al	0.492
Steel	Fe	7.82

Notes:
1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected
2. This designation refers to the standard compositions built into the SCALE4.3 code.
3. See note 3, Table 7A.1-3

Figure 7A-11

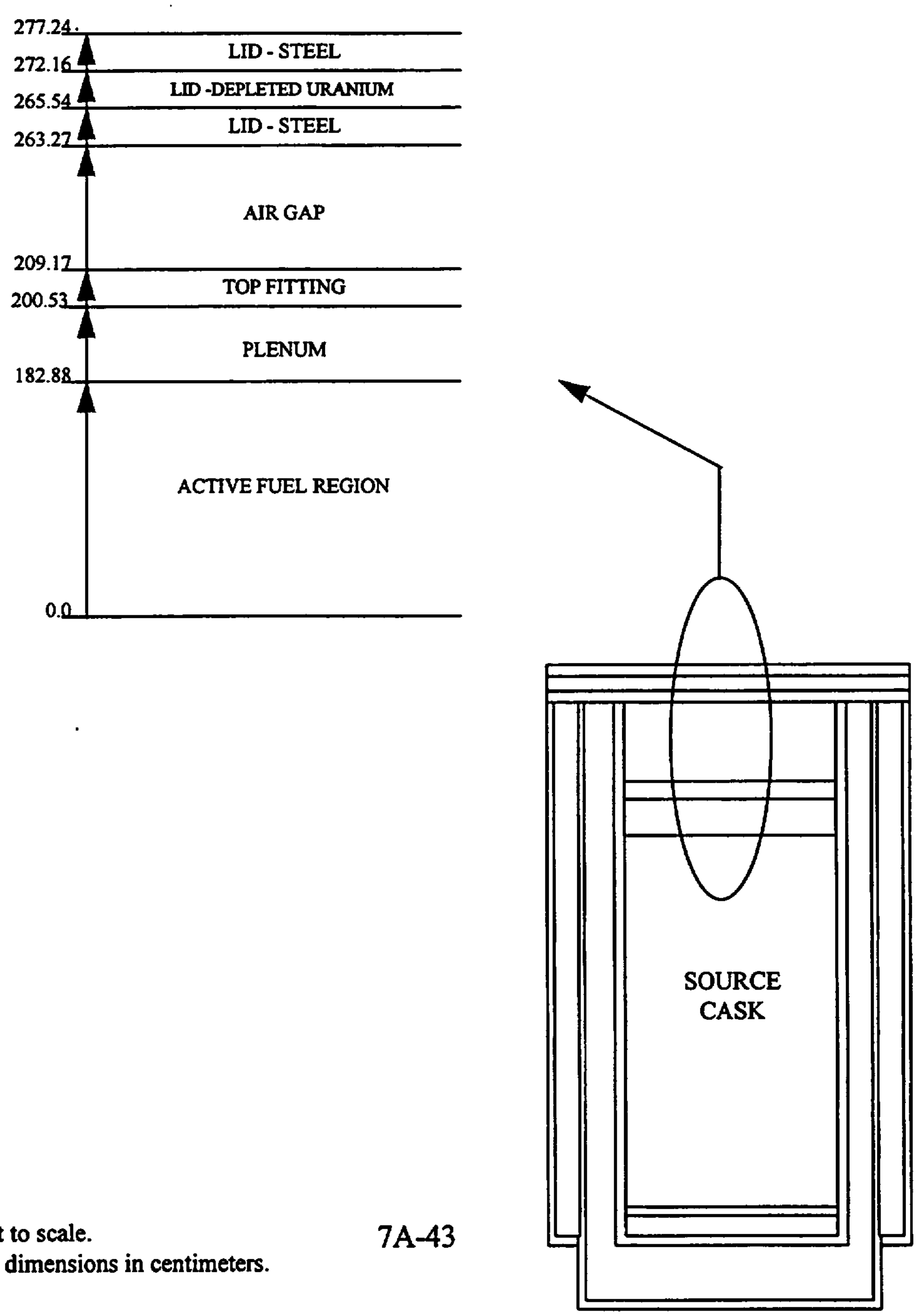
Source Cask Analysis - Radial Model



Notes:
1. Not to scale.
2. All dimensions in centimeters.

Figure 7A-12

Source Cask Analysis - Axial Model



Notes:
1. Not to scale.
2. All dimensions in centimeters.

7A.2.1.5 Source Cask Shielding Evaluation

The shielding analysis of the source cask is performed using industry standard codes and conservative modeling assumptions in order to approximate an upper bound of the expected dose rate.

The gamma and neutron analysis is performed using the one dimensional SAS1 module of SCALE-4.3, with the 27n-18g coupled cross-section library. This uses the codes XSDRNPM and XSDOSE to calculate the surface flux and translate the flux into dose rates away from the cask surface. ANSI standard flux-to-dose conversion factors, within SCALE-4.3, are used for the dose calculation at the selected points.

For the radial calculation, the length of the cylindrical surface source integrated by XSDOSE corresponds to the length of the fuel assembly active fuel region. For the axial calculations, the radius of the disc source corresponds to the radius of the fuel region and the cask in the radial model. Selected input for the SAS1 runs are included in Section 7A.5.5.

Radial Analysis

The SAS1 analysis is performed for the source cask using peak source strengths. It was assumed that the source cask is filled with four fuel assemblies at an average source strength. The results from the SAS1 runs were scaled down to determine the average dose rates around source cask. The ratio of average to peak gamma source strength is:

Peak gamma source = 9.9E+15
Average gamma source = 7.8E+15
Ratio of {Average/Peak} Source = 0.79

Similarly for the neutron source:

Peak neutron source = 5.4E+08
Average neutron source = 2.4E+08
Ration of {Average/Peak} Source = 0.44

Figure 7A-13 illustrates the location of the dose points. Table 7A-18 lists the calculated average dose rates. The dose points are taken at the centerline at the distances of contact, 1 meter, 2 meters, and 3.048 meter (10 feet).

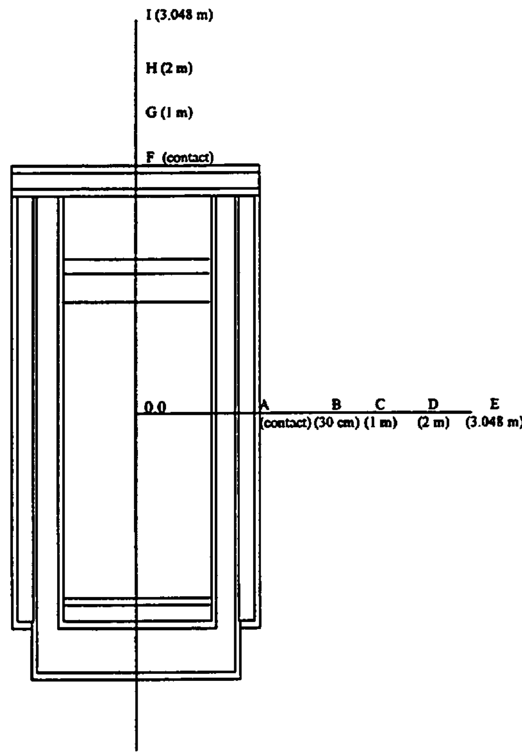
Table 7A-17

Dose Rate Analysis Results
Source Cask Radial Analysis

Radial Dose Point	n (mrem/hr)	γ (mrem/hr)	Total (mrem/hr)
A	103	55.2	158
B	55.9	32.6	88.5
C	27.1	16.7	43.8
D	13.6	9.01	22.6
E	7.66	5.47	13.1

Figure 7A-13

Dose Point Locations
Source Cask Radial Analysis



Notes:
1. Not to scale.

Axial Analysis

The locations of the dose points are illustrated in Figure 7A-13. Table 7A-18 lists the calculated average rates at these locations. The dose points are taken at the axial centerline at the distances of contact, 1 meter, 2 meters, and 3.048 meter (10 feet).

Table 7A-18

Dose Rate Analysis Results
Source Cask Axial Analysis

Axial Dose Point	Fuel Zone n (mrem/hr)	Fuel Zone γ (mrem/hr)	Top Fitting γ(mrem/hr)	Total (mrem/hr)
F	65.1	12.6	1.95	79.7
G	9.06	4.50	0.679	14.2
H	2.63	1.55	0.235	4.42
I	1.15	0.680	0.103	1.93

7A.2.1.6 Estimated Operational Doses

The operational doses around the source cask from preparation activities for DTS entry are calculated below in Table 7A-19. Times and distances are estimated from past TN activities. The operational doses calculated below are for a single cask filled with four assemblies.

Table 7A-19

Operational Doses around the Source Cask

	Activity	Position	No of Person	Dist (m)	Time (min)	Dose Rate (mrem/hr)	Dose (person -mrem)	Dose Point
1	Setting Source Cask on Cask Transfer Subsystem	side	2	3	30	13.1	13.1	E
2	Move Source Cask into Prep Area	side	2	3	10	13.1	4.37	E
3	Vent Source Cask	top	1	1	15	14.2	3.55	G
		side	1	3	15	13.1	3.28	E
4	Unbolt Source Cask Lid	top	2	1	25	14.2	11.8	G
5	Position & Attach Pintle to Lid	top	2	1	20	14.2	9.47	G
6	Clean Lid/Source Cask External Surfaces (removal of transport grit & grime)	top	1	1	15	14.2	3.55	G
		side	1	1	15	43.8	11.0	C
7	Open Sliding Door to LAA	side	2	3	5	13.1	2.10	E
8	Move Cask Xfer Subsystem to LAA	side	2	3	15	13.1	6.55	E
9	Fine Position Cask Xfer Subsystem in LAA	side	2	1	5	43.8	7.30	C
10	Leave & Close Sliding Door to LAA	side	2	3	10	13.1	4.37	E
						Subtotal	80.5 person-mrem	

7A.2.2 Receiving Cask Evaluation

7A.2.2.1 Receiving Cask Gamma Source

For the active fuel zone, the peak gamma source strength peak value is 5.92E+15 γ/s/assembly. For twenty one assemblies, the fuel zone gamma source is 1.24E+17 γ/s. The gamma source term on a volumetric basis is:

Rec'g Cask Active Fuel Volume = $\pi r^2h = \pi (74.04 \text{ cm})^2 (365.76 \text{ cm})$ = 6.30E+6 cc
Volumetric Gamma Source = {1.24E+17 γ/s}/{6.30E+6 cc} = 1.97E+10 γ/s/cc

The top fitting zone peak gamma source strength is 8.436E+12 γ/s/assembly. The gamma source for the top fitting zone on a volumetric basis is:

Rec'g Cask Active Fuel Volume = $\pi r^2h = \pi (74.04 \text{ cm})^2 (26.25 \text{ cm})$ = 4.52E+05 cc
Volumetric Gamma Source = {21 * 8.436E+12 γ/s}/{4.52E+05 cc} = 3.92E+08 γ/s/cc

7A.2.2.2 Receiving Cask Neutron Source

The fuel region peak neutron source is 5.4+08 (n/s/assembly). The total peak neutron source for 21 assemblies is 1.13E+10 n/s. The neutron fractions are provided below.

Rec'g Cask Active Fuel Volume = $\pi r^2h = \pi (74.04 \text{ cm})^2 (365.76 \text{ cm})$ = 6.30E+6 cc
Volumetric Neutron Source = {1.13E+10 n/s}/{6.30E+6 cc} = 1800 n/s/cc

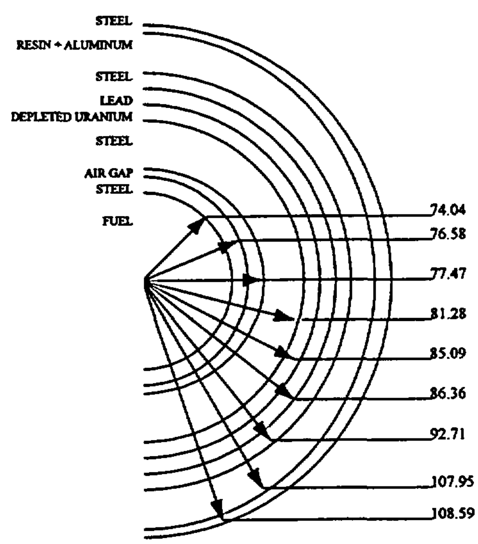
7A.2.2.3 Description of Radiation and Axial Shielding Configurations

The gamma and neutron contributions to the dose rates were calculated using one dimensional models. The source strength characteristics of the active fuel region were used in this model since the contribution from the top and bottom hardware was considered negligible. The radial analysis model is shown in Figure 7A-14.

The axial analysis of the gamma and neutron dose rate uses a slab model with a source thickness of one half the active fuel length. The source beyond this does not contribute significantly to the dose rate. Figure 7A-15 shows the model configurations for these two analyses casks. The source and shield material densities are described in the following section.

Figure 7A-14

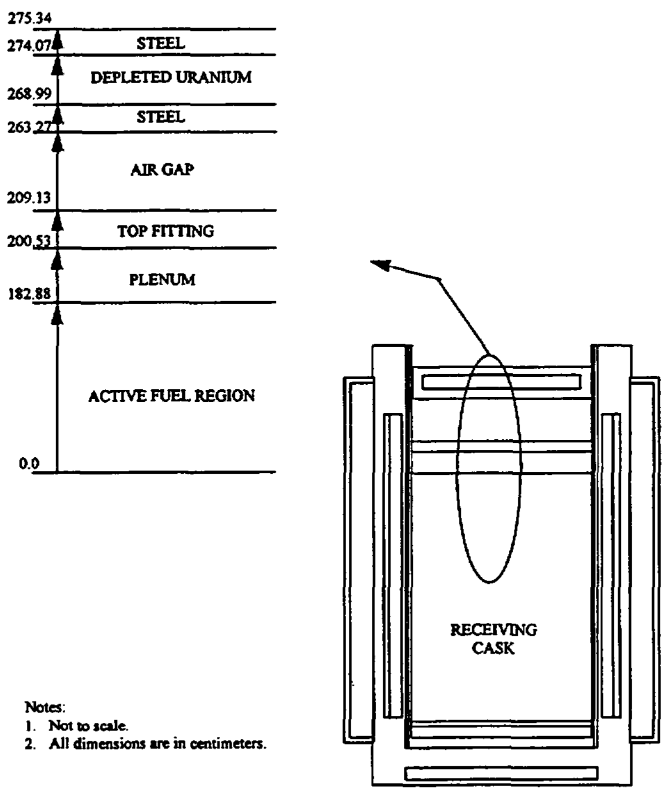
Receiving Cask Analysis - Radial Model



Notes:
1. Not to scale.
2. All dimensions in centimeters

Figure 7A-15

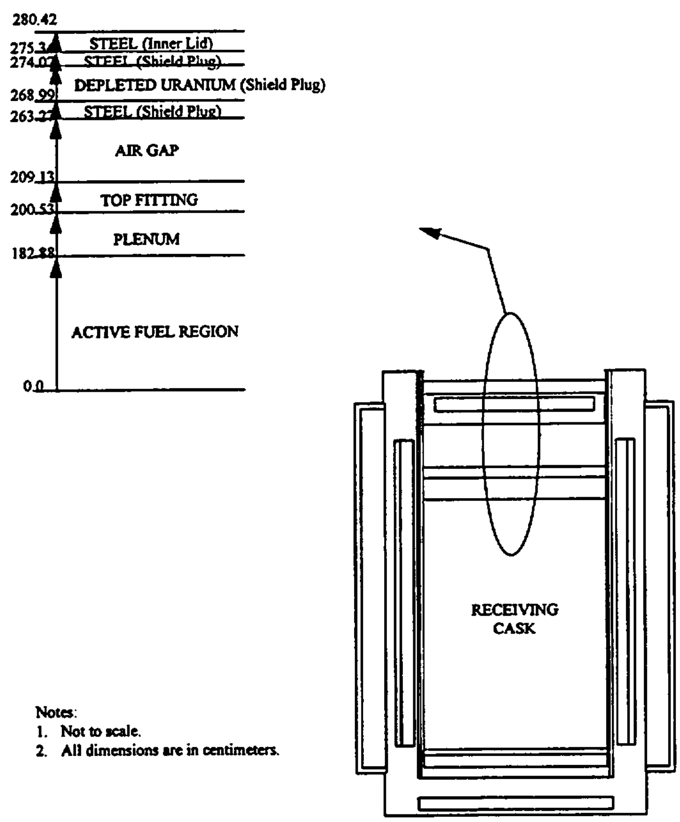
Receiving Cask Analysis - Axial Model



Notes:
1. Not to scale.
2. All dimensions are in centimeters.

Figure 7A-15 (Continued)

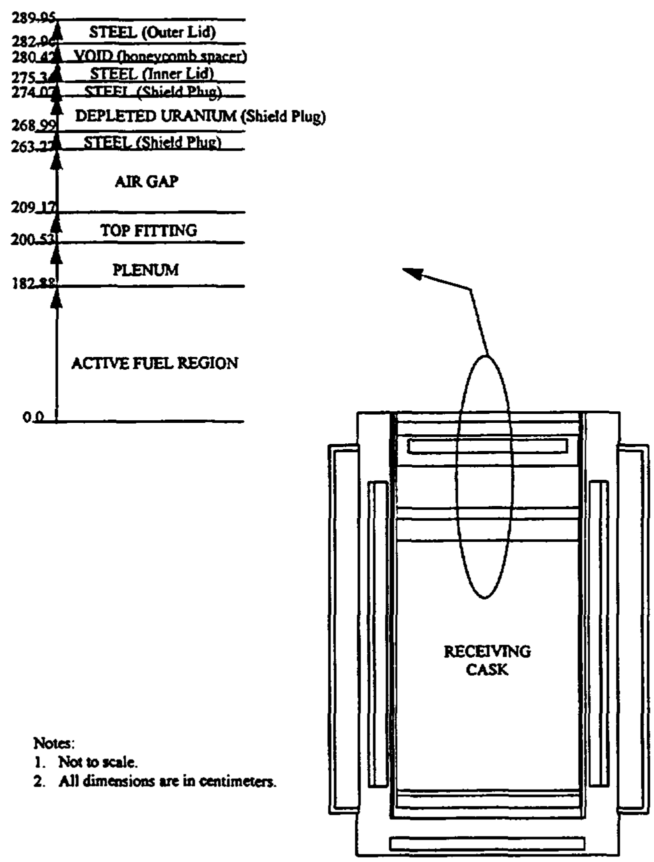
Receiving Cask Analysis - Axial Model



Notes:
1. Not to scale.
2. All dimensions are in centimeters.

Figure 7A-15 (Continued)

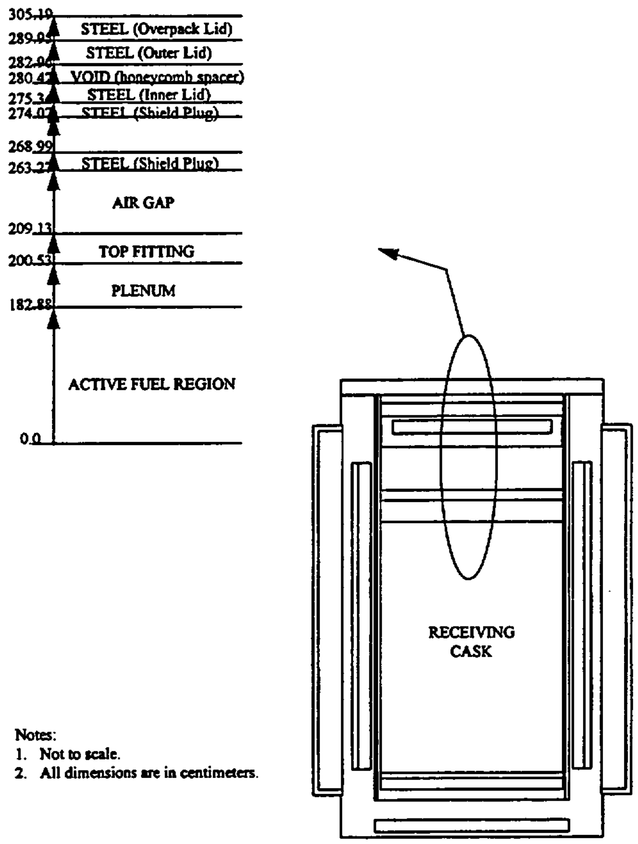
Receiving Cask Analysis - Axial Model



Notes:
1. Not to scale.
2. All dimensions are in centimeters.

Figure 7A-15 (Continued)

Receiving Cask Analysis - Axial Model



Notes:
1. Not to scale.
2. All dimensions are in centimeters.

7A.2.2.4 Source and Shield Regional Densities

Material densities applicable for all source and shield regions are listed in Table 7A-18.

Table 7A-20

Receiving Cask Material Densities

Mixture.	Element	Density (g/cc)
Fuel [1]	UO_2	1.745
	Zr	0.343
Plenum [1]	Fe	0.131
	Zr	0.380
Top Fitting [1]	Fe	0.960
Bottom Fitting [1]	Fe	1.013
Lead	Pb	11.35
Depleted Uranium	U(.27)Metal[2]	19.05
Resin / Aluminum[3]	H	0.071
	B	0.015
	C	0.497
	O	0.591
	Al	0.492
Steel	Fe	7.82

Notes:
1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected
2. This designation refers to the standard compositions built into the SCALE4.3 code.
3. See note 3, Table 7A.1-3

7A.2.2.5 Receiving Cask Shielding Evaluation

The shielding analysis of the receiving cask is performed using industry standard codes and conservative modeling assumptions in order to approximate an upper bound of the expected dose rate. The analysis performed is similar to that performed for the source cask.

Selected input for the SAS1 computer runs are included in Section 7A.5.6.

Radial Analysis

The analysis is performed for the receiving cask using the peak source terms. Similar to the source cask the values were scaled down to an average dose rate. Figure 7A-16 illustrates the location of the dose points. Table 7A-20 lists the calculated average dose rates. The dose points are taken at the centerline at the distances of contact, 1 meter, 2 meters, and 3.048 meter (10 feet).

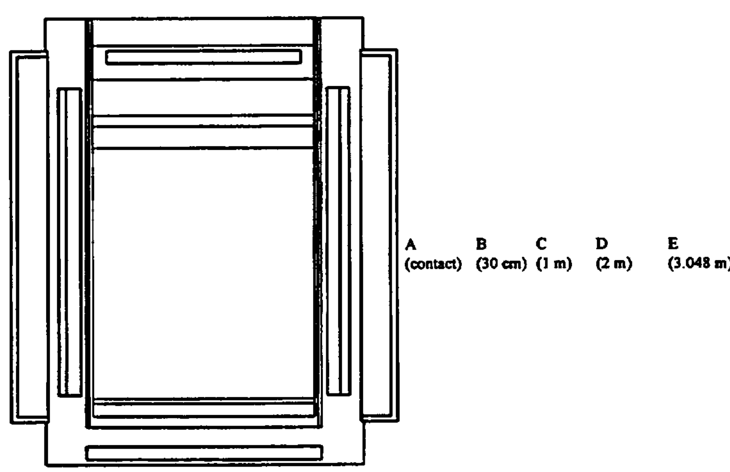
Table 7A-21

Dose Rate Analysis Results
Receiving Cask Radial Analysis

Radial Dose Point	n (mrem/hr)	γ (mrem/hr)	Total (mrem/hr)
A	10.6	52.7	63.3
B	7.13	38.2	45.3
C	4.18	23.6	27.8
D	2.33	14.4	16.5
E	1.40	9.01	10.4

Figure 7A-16

Dose Point Locations
Receiving Cask Radial Analysis



Notes:
1. Not to scale.

Axial Analysis

The locations of the dose points are illustrated in Figure 7A-17. Table 7A-21 lists the average dose rates calculated at these locations. The dose points are taken at the axial centerline at the distances of contact, 1 meter, 2 meters, and 3.048 meter (10 feet).

Table 7A-22

Dose Rate Analysis Results
Receiving Cask Axial Analysis

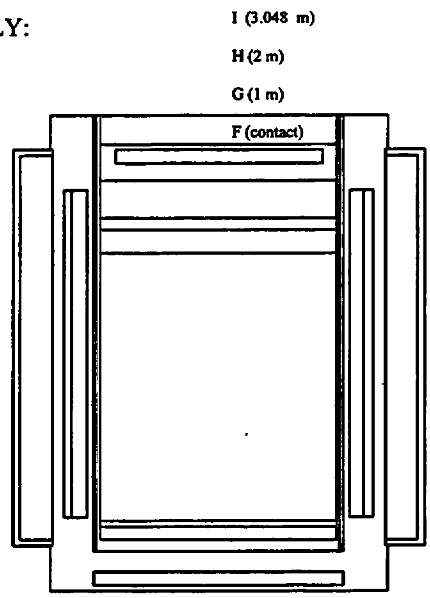
Shield Plug only

Axial Dose Point	Fuel Zone n (mrem/hr)	Fuel Zone γ (mrem/hr)	Top Fit Zone γ (mrem/hr)	Total (mrem/hr)
F	277	183	50.3	510
G	107	137	37.9	282
H	41.0	77.7	22.1	141
I	20.1	46.9	13.7	80.7
		Shield Plug and Inner Lid		
J	175	40.1	9.16	224
K	66.4	27.3	6.07	99.8
L	25.2	14.5	3.24	43.0
M	12.3	8.61	1.93	22.8
		Shield Plug, Inner Lid and Outerlid		
N	89.8	3.98	0.618	94.4
O	33.4	2.61	0.397	36.4
P	12.6	1.36	0.2052	14.2
Q	6.12	0.798	0.121	7.03
		Shield Plug, Inner Lid, Outerlid and Overpack Lid		
R	24.9	0.0956	0.0127	25.0
S	9.24	0.0421	0.000806	9.28
T	3.45	0.0178	0.000412	3.46
U	1.66	0.00932	0.000239	1.67

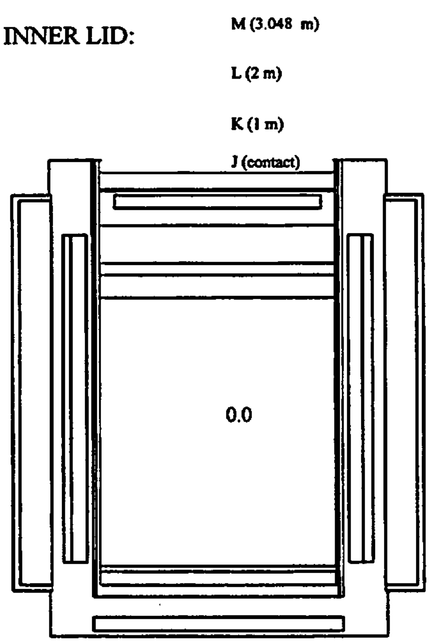
Figure 7A-17

Dose Point Locations
Receiving Cask Axial Analysis

SHIELD PLUG ONLY:



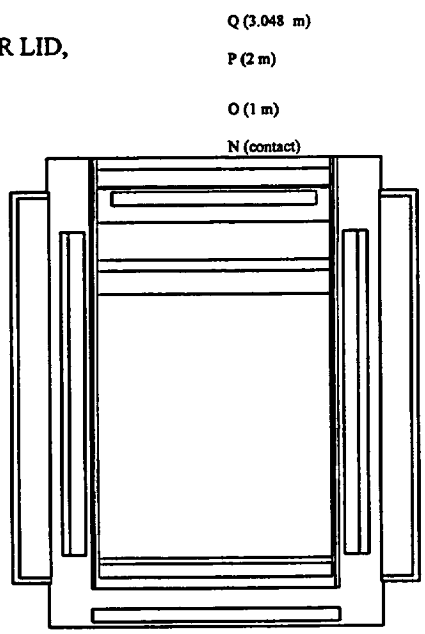
SHIELD PLUG & INNER LID:



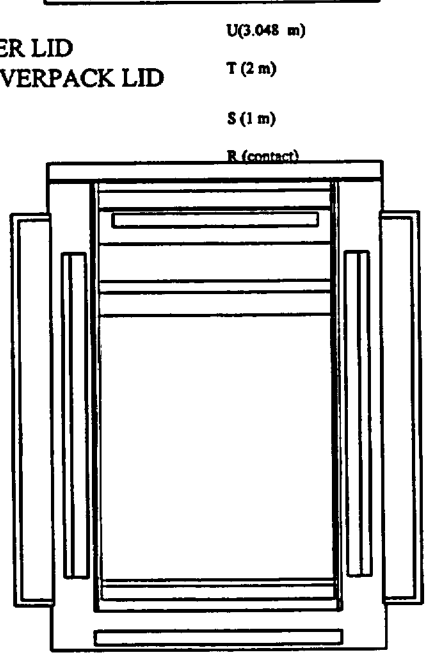
Notes:
1. Not to scale.

Figure 7A-17 (Continued)
Dose Point Location
Receiving Cask Axial Analysis

SHIELD PLUG, INNER LID,
AND OUTER LID



SHIELD PLUG, INNER LID
OUTER LID, AND OVERPACK LID



Notes:
1. Not to scale.

7A.2.2.6 Estimating Operational Doses from the Receiving Cask

The operational doses around the receiving cask from cask removal activities are calculated below. Times are estimated for Tasks 1-9 and Tasks 27-28 from past TN activities. The estimated doses in tasks 10-26 are from DOE references.

The operational doses below, Table 7A-22, are for a single receiving cask filled with 21 average assemblies.

Table 7A-23

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Dose (person-mrem)
Receiving Cask Removal from DTS							
1	Receiving Cask disengaged from Cask Mating Subsystem						
2	Sliding Door Opens	side	2	5	3.04 (10 ft)	10.4	1.7
3	Unlocking of Receiving Cask	side	1	5	0	63.3	5.3
		side	1	5	1 (3.3 ft)	27.8	2.3
4	Removal of Receiving Cask from Lower Access Area and Locking in Preparation Area	side	2	5	3.04 (10 ft)	10.4	1.7
5	Sliding Door Closes	side	2	5	3.04 (10 ft)	10.4	1.7
6	Decontamination of Receiving Cask	top	1	30	1 (3.3 ft)	14.1	70.4
		side	1	30	1 (3.3 ft)	27.8	13.9
7	Check Surface Dose Rates	top	1	20	1 (3.3 ft)	141	46.9
		side	1	20	1 (3.3 ft)	27.8	9.3
8	Disengage Shield Plug Lifting Pintle	top	1	15	1 (3.3 ft)	141	35.2
9	Place Inner Lid on Receiving Cask	side	2	30	3.04 (10 ft)	10.4	10.4

Table 7A-23 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Dose (person-mrem)
10	Install Annulus Welding Protection* (Task Time - 12 min)		2	8	0.61 (2 ft)	80	21.3
11	Install Remote Welding Equipment * (Task Time - 45 min)		1	10	0.61 (2 ft)	80	13.3
			1	10	6.09 (20 ft)	0.5	0.1
12	Welding of Inner Lid*	---	---	1000	Remote	---	---
13	Perform NDE on Weld* (Task Time - 30 min)		1	5	0.61 (2 ft)	80	6.7
14	Removal of Welding Equipment* (Task Time - 20 min)		1	20	0.61 (2 ft)	80	26.7
			1	8	6.09 (2 ft)	0.5	0.1
15	Dry and Inert MPC* (Task Time - 90 min - TN estimate)		1	10	0.61 (2 ft)	80	13.3
			1	90	6.09 (20 ft)	11	16.5
16	Removal of Inerting Equipment* (Task Time - 12 min)		1	12	0.61 (2 ft)	220	44.0
17	Perform Leak Test on Seal Weld* (Task Time - 20 min)		1	20	0.61 (2 ft)	37	12.3
18	Weld Valve Cover Plates* (Task Time - 20 min)		1	10	0.61 (2 ft)	100	16.7

Table 7A-23 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task	Relative Location	No of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Dose (person-mrem)
19	Place Receiving Cask Outer Lid*(Task Time - 18 min)	1	10	0.61 (2 ft)	100	16.7
		1	10	3.04 (10 ft)	11	1.8
		1	10	6.09 (20 ft)	0.5	0.1
20	Set Up Welding Equipment* (Task Time - 45 min)	1	30	0.61 (2 ft)	80	40.0
		1	10	3.04 (10 ft)	0.5	0.1
21	Weld Receiving Cask Outer Lid* (Task Time -1000 min)	---	1000	Remote	---	---
22	Perform NDT on Weld* (Task Time - 30 min)	1	5	0.61 (2 ft)	80	6.7
23	Removal of Weld Equipment* (Task Time - 20 min)	1	20	0.61 (2 ft)	80	26.7
24	Removal of Annulus Weld Protection* (Task Time - 12 min)	1	8	0.61 (2 ft)	80	10.7
25	Place Receiving Cask Overpack Lid* (Task Time - 12 min)	1	12	0.61 (2ft)	97	19.4
		1	12	3.04 (10 ft)	11	2.2
		1	12	6.09 (20 ft)	0.5	0.1

Table 7A-23 (Continued)

Design Basis Operations - Estimated Doses from DTS

Task		Relative Location	No of Person	Time (min)	Distance (m)	Dose Rate (mrem/hr)	Dose (person-mrem)
26	Perform HP Survey* (Task Time - 45 min)		2	20	0.61 (2 ft)	59	39.3
27	Bolt Overpack Lid	Top	2	30	0	9.3	9.3
28	Remove Receiving Cask from Preparation Area	Side	2	5	3.04 (10 ft)	10.4	1.7
						Subtotal (person -mrem)	545

* Number of personnel, dose rates, and times were provided by Department of Energy, based on the MPC program.

7A.2.3 References

7A.2-1 SCALE-4.3, "A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," CCC-545, ORNL.

7A.3 Evaluation of Off-Site Doses

The evaluation of off site doses is performed in four portions. The first portion evaluates the doses from the filled source cask and the filled receiving cask. The second portion evaluates the doses at long distances from fuel transfer operations. The third portion evaluates skyshine doses at long distances also from fuel transfer operations. The fourth portion combines the results from each individual contributor to evaluate the off-site doses from the placement of twenty-one fuel assemblies in the receiving cask.

7A.3.1 Doses at Long Distances from the Filled Source Cask

7A.3.1.1 Source Cask Gamma Source

The source cask gamma source is presented in Section 7A.2.1.1. The energy distribution is presented in Table 7A.2-1.

7A.3.1.2 Source Cask Neutron Source

The source cask neutron source is presented in Section 7A.2.1.2. The energy distribution is presented in Table 7A.2-2.

7A.3.1.3 Description of the Spherical Shielding Configuration

To evaluate the doses at long distances from the source cask, a spherical model is chosen. The inner radius of the sphere is calculated such that the volume of the sphere is equal to the volume of the cylindrical cavity containing either the source cask assemblies or the receiving cask assemblies. Layers of materials are represented by their actual thickness.

The source cask active fuel volume was converted from a cylindrical source to an equivalent spherical source. The calculation is shown below.

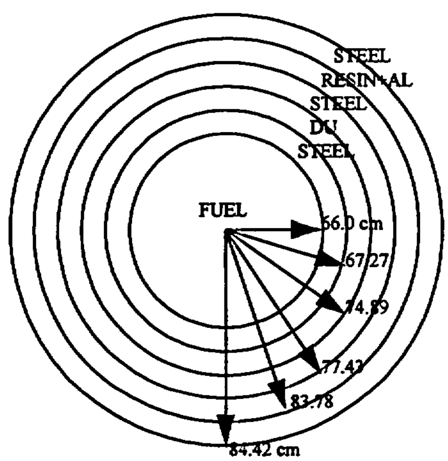
$$V_{cylindrical} = \pi r^2 h = (\pi \times 32.39^2 \times 365.76) = 1,205,502 \text{ cm}^3$$

$$V_{sphere} = 1.333\pi r_{sphere}^3 \text{ therefore } r_{sphere} = \{(1205502)/(4.188)\}^{1/3} = 66 \text{ cm}$$

Figure 7A-18 illustrates the spherical model used for the SAS1 analysis.

Figure 7A-18

Source Cask Spherical Model



7A.3.1.4 Source and Shield Regional Densities

Material densities used for the source and shields in the spherical model are presented in Table 7A-24 below.

Table 7A-24

Material Densities - Source Cask Spherical Model

Mixture No.	Composition	Density (g/cc)
Fuel[1]	UO_2	1.745
Plenum[1] Top Fitting[1] Bottom Fitting[1]	Zircaloy[2]	0.765
	SS304	2.11
Lead	Pb	11.35
Depleted Uranium	U(.27)Metal[2]	19.05
Resin/Aluminum[3]	H	0.071
	B	0.015
	C	0.497
	O	0.591
	Al	0.492
Steel	Carbonsteel[2]	7.82

Notes:

1. "Density" of fuel assembly materials homogenized over cavity volume, basket neglected
2. These material designations refer to the standard compositions built into the SCALE 4.3 code.
3. See note 3, Table 7A.1-3

7A.3.1.5 Source Cask Spherical Shielding Evaluation

The analysis for determining doses at long distances is performed with XSDRNPM and the SCALE 27n-18g coupled cross section library. XSDOSE is used with standard ANSI standard flux-to-dose factors to calculate the dose rate from the angular flux generated by

XSDRNPM.

The selected dose points for the SAS1 run were taken at 25 meters, 50 meters, 100 meters, and 150 meters from the source cask. Distances beyond 200 meters were extrapolated from the results at 150 meters assuming the sphere is a point source. For example:

$$\{150/200\}^2 * 0.00413 = 2.3E\text{-}03$$

This assumes ground scatter equals air attenuation. The results from the spherical model are presented in Table 7A-25. Selected input for the SAS1 runs are present in Section 7A.5.7.

Table 7A-25

Dose Rate Analysis Results
Source Cask Spherical Model

Distance from Source (m)	Neutron (mrem/hr)	Gamma (mrem/hr)	Total Dose (mrem/hr)
25	0.136	0.0328	0.1688
50	0.0339	0.00820	0.0421
100	0.00847	0.00205	0.01052
150	0.00377	0.000912	0.004682
200	2.1E-03	5.1E-04	2.6E-03
250	1.4E-03	3.3E-04	1.7E-03
300	9.4E-04	2.3E-04	1.2E-03
350	6.9E-04	1.7E-04	8.6E-04
400	5.3E-04	1.3E-04	6.6E-04
500	3.4E-04	8.2E-05	4.2E-04
600	2.4E-04	5.7E-05	2.9E-04
800	1.3E-04	3.2E-05	1.6E-04
1000	8.5E-05	2.1E-05	1.1E-04
1500	3.8E-05	9.1E-06	4.7E-05

7A.3.2 Doses at Long Distances from the Filled Receiving Cask

7A.3.2.1 Receiving Cask Gamma Source

The receiving cask gamma source is presented in Section 7A.2.2.1. The energy distribution is presented in Table 7A.2-1.

7A.3.2.2 Receiving Cask Neutron Source

The receiving cask neutron source is presented in Section 7A.2.2.2. The energy distribution is presented in Table 7A.2-2.

7A.3.2.3 Description of the Spherical Shielding Configuration

To evaluate the doses at long distances from the receiving cask, a spherical model is chosen. The inner radius of the sphere is calculated such that the volume of the sphere is equal to the volume of the cylindrical cavity containing the receiving cask assemblies. Layers of materials are represented by their actual thickness.

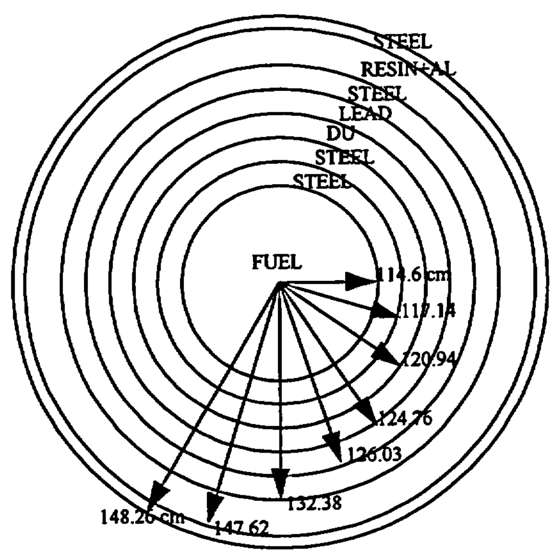
The receiving cask active fuel volume was converted from a cylindrical source to an equivalent spherical source. The calculation is shown below.

$V_{cylindrical} = \pi r^2 h = (\pi \times 74.04^2 \times 365.76) = 6.299E+06 \text{ cm}^3$
$V_{sphere} = 1.333 \pi r_{sphere}^3$ therefore $r_{sphere} = \{(6.299E+06)/(4.188)\}^{1/3} = 114.6$ cm

Figure 7A-19 illustrates the spherical model used for the SAS1 analysis.

Figure 7A-19

Receiving Cask - Spherical Model



7A.3.2.4 Source and Shield Regional Densities

Material densities used for the source and shields in the spherical model are presented in Table 7A-24

7A.3.2.5 Receiving Cask Spherical Shielding Evaluation

The doses at long distances analysis is performed with XSDRNPM and the SCALE 27n-18g coupled cross section library. XSDOSE is used with standard ANSI standard flux-to-dose factors to calculate the dose rate from the angular flux generated by XSDRNPM.

The selected dose points for the SAS1 run were taken at 25 meters, 50 meters, 100 meters, 150 meters, and 200 meters from the receiving cask. Distances beyond 200 meters were extrapolated from the results at 200 meters assuming the sphere is a point source. The results from the spherical model are presented in Table 7A-26. Selected computer input files are presented in Section 7A.5.7.

Table 7A-26

Dose Rate Analysis Results
Receiving Cask Spherical Model

Distance from Rec'g Cask (m)	Neutron (mrem/hr)	Gamma (mrem/hr)	Total Dose (mrem/hr)
25	0.0239	0.0831	0.107
50	0.00598	0.0208	0.0268
100	0.00150	0.00520	0.0067
150	6.65E-04	2.31E-03	2.98E-03
200	3.74E-04	1.30E-03	1.67E-03
250	2.4E-04	8.3E-04	1.1E-03
300	1.7E-04	5.8E-04	7.5E-04
350	1.2E-04	4.2E-04	5.4E-04
400	9.3E-05	3.2E-04	4.1E-04
500	6.0E-05	2.1E-04	2.7E-04
600	4.2E-05	1.5E-04	5.7E-04
800	2.3E-05	8.1E-05	1.0E-04
1000	1.5E-05	5.3E-05	6.8E-05
1500	6.7E-06	2.3E-05	3.0E-05

7A.3.3 Doses at Long Distances from Fuel Transfer Operations

The doses at long distances from fuel transfer operations was calculated using the same QADS models presented in Section 7A.1.3, One Fuel Assembly at Start of Fuel Transfer, and Section 7A.1.4, One Fuel Assembly During Fuel Transfer in Position Closest to the DTS Roof. The results from these models are provided in Table 7A-27 and Table 7A-28. The dose points are taken from the sliding door of the DTS since these are the most conservative values.

Table 7A-27

Doses at Long Distances from the One Fuel Assembly at Start of Fuel Transfer Fully Removed from Source Cask and in Position Closest to Sliding Door

Distance (m)	Dose Rate
10	4.30
25	1.06
50	0.272
100	0.0768
150	0.0299
200	0.0170
300	7.60E-03
400	4.22E-03
500	2.70E-03
800	1.07E-03
1000	6.82E-04
1500	3.11E-04

Table 7A-28

Doses at Long Distances from the One Fuel Assembly During Fuel Transfer in Position Closest to the DTS Roof

Dose Point(m)	Dose Rate(mrem/hr)
10	0.0905
25	0.128
50	0.0562
100	0.0176
150	8.47E-03
200	4.91E-03
300	2.24E-03
400	1.28E-03
500	8.25E-04
800	3.26E-04
1000	2.10E-04
1500	9.35E-05

7A.3.5 Skyshine Analysis from DTS Operations

The computer program SKYSHINE II is utilized to evaluate the skyshine dose contribution. The SKYSHINE code uses an equivalent point source for its calculation.

Two basic cases are considered the largest contributor to the skyshine dose. The first is a single assembly is in the transfer position near the roof of the DTS with the nearly filled receiving cask beneath it. The second case is the open filled receiving cask.

The SKYSHINE code, Reference 7A.3-1, is a code for determining the scatter radiation from a source or sources within a structure at points outside of that structure. However, the SKYSHINE code calculates the scatter radiation from a point source (or a series of point sources). For the skyshine analysis, the most conservative dose rate at the roof of the facility, due to the fuel transfer and an almost filled receiving cask or the filled receiving cask, is converted to an equivalent point source.

For the Skyshine code, a point source is utilized in the calculation. An equivalent point source, (γ), based on the most conservative results from Section 7A.1.5. Using the SCALE source term, from Table 7A.2-1, the following dose factors were calculated.

Table 7A-29

Skyshine Dose Factors

Group	SAS peak	SAS fraction	Dose Factor	SAS Fract * Dose Fact
33	9.390E+10	1.59E-05	3.960E-03	6.296E-08
34	2.910E+12	4.91E-04	3.469E-03	1.703E-06
35	3.668E+12	6.21E-04	3.019E-03	1.875E-06
36	1.275E+14	2.15E-02	2.628E-03	5.650E-05
37	3.123E+14	5.27E-02	2.205E-03	1.162E-04
38	5.774E+14	9.75E-02	1.833E-03	1.787E-04
39	1.623E+15	2.74E-01	1.523E-03	4.173E-04
40	2.665E+15	4.50E-01	1.172E-03	5.274E-04
41	1.021E+14	1.72E-02	8.759E-04	1.507E-05
42	1.446E+14	2.45E-02	6.306E-04	1.545E-05
43	3.662E+14	6.13E-02	3.834E-04	2.350E-05
	5.92E+15	1.00E+00		1.354E-03

Assuming no attenuation in air (air scatter = ground scatter), so the point source calculation becomes:

$$Dose\ Rate\ at\ R = \Sigma \frac{S_i\, D_i}{4\pi r^2} = \frac{S_o}{4\pi r} \Sigma\, f_i D_i$$

where:

$S = Source,\ \frac{\gamma}{s}$

$D = Distance\ source,\ cm$

$f = Dose\ Factor$

The most conservative dose rate on the weather protective cover is chosen to calculate the equivalent point source (See Section 7A.1.5). The most conservative dose rate on the weather protective cover was found to be 10 mrem/hr. The fuel assembly is located 663.85 centimeters below the weather protective cover. The equivalent point source is:

$$S_o \ at \ roof = \frac{(10)(4)(\pi)(663.85)^2}{1.354E\text{-}03}$$

$$S_o \ at \ roof = 4.09E11 \ \frac{\gamma}{\text{sec}}$$

This source is used as an equivalent point source for skyshine for the case where the single fuel assembly is in the transfer position above the almost filled receiving cask.

Similarly, the source term for the filled receiving cask is calculated as:

$$S_o \ at \ roof = \frac{(59\, mrem/hr)(4)(\pi)(1429.16 - 209.13)^2}{1.354E\text{-}03}$$

$$S_o \ at \ roof = 1.12E12 \ \frac{\gamma}{\text{sec}}$$

This source term is used as an equivalent point source for skyshine for the cask where the receiving cask is filled with twenty one assemblies. Selected computer input files are provided in Section 7A.5.8.

The selected dose points for the SKYSHINE II run were taken at 25 meters, 50 meters, 100 meters, 150 meters, 200 meters, 300 meters, 400 meters, 500 meters and 800 meters from the sources (receiving cask and source cask). The dose point is 1.8 meters (6 feet) from the ground surface and the source point was set at the height of the roof approximately 45 feet.

Skyshine II provides skyshine doses in terms of mrem/yr, since the DTS and the open cask will not be in this configuration continuously throughout the year, the dose are converted to mrem/hr. Table 7A-30 presents the results from the SKYSHINE analysis.

Results from the fuel assembly in the transfer position with an almost filled receiving cask beneath it:

Table 7A-30

Skyshine Dose Analysis Results
Fuel Assembly in Transfer Position Near Roof with Filled Receiving Cask

Distance from Source (m)	Dose Rate (mrem/yr)	Dose Rate (mrem/hr)
25	583	6.65E-02
50	331	3.78E-02
100	134	1.53E-02
150	62.6	7.15E-03
200	31.0	3.54E-03
300	8.37	9.55E-04
400	2.40	2.74E-04
500	0.73	8.30E-05
800	0.023	2.63E-06

7A.3.6 Off-Site Dose Assessment

The DTS is designed to prevent and minimize off-site doses from effluent streams. The primary contributors to offsite doses are direct and skyshine radiation.

The primary contributions to offsite doses are described below.

- Direct dose from the filled source cask arriving at the DTS;
- Direct dose from the fuel transfer operations;
- Direct dose from the filled receiving cask under cask removal operations;
- Scatter radiation from the open receiving cask; and
- Scatter radiation from the open source cask.

It is assumed that an optimum operating schedule is followed for DTS operation. The optimum operating schedule assumes that each receiving cask is filled in ten days and ten receiving casks are filled prior to a scheduled 30 day maintenance period. In one year 30 receiving casks are filled or a total of 630 fuel assemblies are transferred in one year.

7A.3.6.1 Direct Dose from the Filled Source Cask Arriving at the DTS

Table 7A-31 presents the total time the filled source cask will remain in the DTS and contribute to the off-site doses. Table 7A-32 presents the total dose from a single source cask at various distances.

Table 7A-31

Design Basis Operations - Estimated Source Cask Times

Task		Time (min)
Source Cask Preparation for DTS Entry		
1	Setting Source Cask on Cask Transfer Subsystem	30
2	Move Source Cask into Preparation Area	10
3	Vent Source Cask	15
4	Unbolt Source Cask Lid	25
5	Position and Attach Pintle to Lid	20
6	Clean Lid & Source Cask External Surfaces (removal of transport grit & grime)	30
7	Open Sliding Door to Lower Access Area	5
8	Move Cask Transfer Subsystem to Lower Access Area	15
9	Fine Position Cask Transfer Subsystem in Lower Access Area	5
10	Leave & Close Sliding Door to Lower Access Area	10
	Total Time (min)	165

Table 7A-32

Dose at Long Distances from Source Cask Receipt Operations

Distance (m)	Dose Rate (mrem/hr)	Time (min)	Dose per Source Cask (mrem)
100	1.05E-02	165	2.89E-02
200	2.60E-03	165	7.15E-03
300	1.20E-03	165	3.30E-03
400	6.60E-04	165	1.82E-03
500	4.20E-04	165	1.15E-03

7A.3.6.2 Direct and Scatter Dose from Fuel Transfer Operations

Table 7A-33 presents the total time fuel transfer operations with the source and receiving casks open (only the upper shield ports are providing shielding)

Table 7A-33

Design Basis Operations - Estimated Exposure Times

Task		Time (min)
1.	Source Cask TC Port Open	36
2.	Receiving Cask TC Port Open	33
3.	Positioning of Fuel Handling System over Source Cask	19
4.	Lowering Grapple and Gripping First Fuel Assembly	7
5.	Lifting and Transferring of First Fuel Assembly from Source to Receiving Cask	17
6.	Lowering and Releasing of Fuel Assembly in Receiving Cask	6
7.	Lifting of Grapple over Receiving Cask	1
8.	Positioning over Source Cask, Transfer of Second Assembly, Placement into Receiving Cask (Repeat Steps 3 - 7)	50
9.	Positioning over Source Cask, Transfer of Third Assembly, Placement into Receiving Cask (Repeat Steps 3-7)	50
10.	Positioning over Source Cask, Transfer of Fourth Assembly, Placement into Receiving Cask (Repeat Steps 3-7)	50
11.	Receiving Cask TC Port Closed	33
12.	Source Cask TC Port Closed	36

To evaluate the off site doses from direct and scatter radiation from fuel transfer, the following calculations were performed (the dose rates at 100 meters from the DTS are used in this example):

Steps 1-2 are multiplied by

1.72E-02 mrem/hr * (69 min/60 min/hr)	= 1.48E-02 mrem	

Steps 3-4 are multiplied by

1.72E-02 mrem/hr * (26 min/60 min/hr)	= 7.45E-03 mrem	

Step 5 is multiplied by

7.68E-02 mrem/hr * (17 min/60 min/hr)	= 2.18E-02 mrem	Direct
1.53E-02 mrem/hr * (17 min/60 min/hr)	= 4.34E-03mrem	Skyshine

Step 6 is multiplied by

1.76E-02 mrem/hr * (6 min/60 min/hr)	= 1.76E-03 mrem	Direct
1.53E-02 mrem/hr * (6 min/60 min/hr)	= 1.53E-03 mrem	Skyshine

Step 7 is multiplied by

1.72E-02 mrem/hr * (1 min/ 60 min/hr)	= 2.87E-04 mrem	Skyshine
Step 8 (total of Steps 3 - 7)	= 3.72E-02 mrem	
Step 9 (total of Steps 3 - 7)	= 3.72E-02 mrem	
Step 10 (total of Steps 3-7)	= 3.72E-02 mrem	

Steps 11-12 are multiplied by

1.72E-02 mrem/hr * (69 min/60 min/hr)	= 1.98E-02 mrem	
Total (for turnover of one source cask)	= 1.88E-01 mrem	

Table 7A-34 presents the off site doses from fuel transfer at various distances:

Table 7A-34

Off Site Doses from Fuel Transfer

Distance (m)	Dose from transfer of one source cask (mrem)
100	1.88E-01
200	7.58E-02
300	2.79E-02
400	1.50E-02
500	9.51E-03

7A.3.6.3 Direct Dose from the Filled Receiving Cask Under Cask Removal Operations

Table 7A-35 presents the total time the filled receiving cask will remain in the DTS and contribute to the off-site doses. Table 7A-36 presents the total dose from a single receiving cask at various distances.

Table 7A-35
Design Basis Operations - Estimated Exposure from DTS

Task		Time
	Receiving cask removal from DTS	
1	Receiving cask disengaged from cask mating subsystem	
2	Sliding door opens	5
3	Unlocking of receiving cask	10
4	Removal of receiving cask from lower access area and locking in preparation area	5
5	Sliding door closes	5
6	Decomtamination of receiving cask	30
		30
7	Check surface dose rates	20
8	Disengage shield plug lifting pintle	15
9	Place inner lid on receiving cask	30
10	Install annulus welding protection	8
11	Install remote welding equipment	45
12	Welding of inner lid	1000
13	Perform NDE on weld	5
14	Removal of welding equipment	20
15	Dry and inert MPD	90
16	Removal of inerting equipment	12
17	Perform leak test on seal weld	20
18	Weld valve cover plates	20
19	Place receiving cask outer lid	18
20	Set up welding equipment	45
21	Weld receiving cask outer lid	1000
22	Perform NDT of weld	30
23	Removal of weld equipment	20
24	Removal of annulus weld protection	12
25	Place receiving cask overpack lid	12
26	Perform HP survey	45
27	Bolt overpack lid	30
	Total Time (minutes)	2582

Table 7A-36

Dose at Long Distances from Receiving Cask Removal Operations

Distance (m)	Dose Rate (mrem/hr)	Time (min)	Dose per Receiving Cask (mrem)
100	6.70E-03	2582	2.87E-01
200	1.67E-03	2582	7.19E-02
300	7.50E-04	2582	3.23E-02
400	4.10E-04	2582	1.76E-02
500	2.70E-04	2582	1.16E-02

7A.3.6.4 Off-Site Dose Assessment

The values from these three components are then combined to determine the offsite doses from the filling of one receiving cask with twenty one fuel assemblies. The results of this calculation are presented in Table 7A-37 below and duplicated in Table 7.6.1.

Table 7A-37

Calculated Maximum Offsite Exposures

Distance (m)	Dose Rate (mrem/receiving Cask)	Dose Rate (mrem/yr)*
100	1.45	46.5
200	0.513	15.4
300	0.199	5.97
400	0.107	3.21
500	0.0684	2.05

*Assumes a turnaround of 30 receiving casks per year.

7A.3.7References

7A.3-1SKYSHINE II Program Package CCC-289, "Calculations of the Effects of Structure Design on Neutron Primary Gamma Ray Dose Rates in Air," NUREG/CR-0781.

7A.4 Computer Input Files

7A.4.1 SCALE4.3 / QADS Input Files - DTS Shielding Evaluation - Open Source Cask Containing Four Fuel Assemblies

```
=QADS
QADS - DTS FOUR FUEL ASSEMBLIES IN SOURCE CASK
27n-18couple infhommedium
uranium   1  den=1.531  end
zircalloy  1  den=0.341  end
fe          2  den=0.131  end
zircalloy  2  den=0.378  end
fe          3  den=0.955  end
fe          4  den=1.008  end
carbonsteel 5  1.0  end
u(.27)metal  6  1.0  end
c           7  den=0.4802  end
o           7  den=0.5704  end
al          7  den=0.556    end
reg-concrete 8  1.0    end
end comp
cylindrical 2.37E16 flats end
5z 1.59e-5 4.91e-4 6.21e-4 2.15e-2 5.27e-2  9.75e-2 2.74e-1
4.5e-1  1.72e-2 2.45e-2 6.13e-2 2z
end source
cylindrical shell cask
RCC 1  0.0    0.0    -182.88    0.0  0.0  365.76    32.39
RCC 2  0.0    0.0    182.88     0.0  0.0  17.65     32.39
RCC 3  0.0    0.0    200.53     0.0  0.0  8.64      32.39
RCC 4  0.0    0.0    209.17     0.0  0.0  68.07     32.39
rcc 5  0.0    0.0    -187.07    0.0  0.0  4.19      32.39
rcc 6  0.0    0.0    -193.93    0.0  0.0  6.86      32.39
rcc 7  0.0    0.0    -195.2     0.0  0.0  467.36    33.66
rcc 8  0.0    0.0    -202.82    0.0  0.0  474.98    41.28
rcc 9  0.0    0.0    -205.36    0.0  0.0  477.52    43.82
rcc 10  0.0   0.0    -193.93    0.0  0.0  466.09    50.17
rcc 11  0.0   0.0    -194.57    0.0  0.0  466.73    50.81
rcc 12  0.0   0.0    -256.16    0.0  0.0  50.8      43.82
rcc 13  350.0  0.0   -256.16    0.0  0.0  579.76    92.71
rcc 14  0.0   0.0    414.4      0.0  0.0  3.81      62.55
rcc 15  350.0  0.0   414.4      0.0  0.0  3.81      90.05
rpp 16  -286.24  676.44  -322.24  388.94  -256.16  1126.83
rpp 17  -194.80  585.00  -230.80  297.50  -256.16  1109.05
rpp 18  -240.52  630.22  -276.52  343.22  1109.05  1126.83
rpp 19  -228.84  571.34  -88.56   170.50  1126.83  1330.03
rpp 20  -225.64  568.14  -85.36   167.3   1126.83  1326.83
rpp 21  -194.8   585.0   -230.8   297.5   414.4    418.21
rpp 22  -273.54  -194.8  -190.5   190.5   -256.16  353.44
```

```
rpp 23  -286.24  -273.54  -190.5   190.5   -256.16  353.44
rpp 24  585.0    663.74   206.06   297.5   418.21   540.13
rpp 25  663.74   676.44   206.06   297.5   418.21   540.13
rpp 26  289.04   410.96   297.50   388.94  -256.16  -134.24
rpp 27  289.04   410.96   236.54   297.5   414.4    418.21
rpp 28  -1500.0  1500.0   -1500.0  1500.0  -800.0   2000.0
end body
FUL  7    1
PLN  6    2
TPF  5    3
VD1  4    4
VD2  4    5
BTF  3    6
SS1  5    7   -6    -5   -4   -3   -2   -1
DUS  5    8   -7
SS2  5    9   -8
RES  4    10  -9
SS3  4    11  -10   -9
TRO  4    12
MPC  2    13
VD3  2    14
VD4  2    15
VD5  2    27
MZF  5    21  -14   -15   -27
ROF  2    18
VD6  2    22
SD1  2    23
VD7  2    24
SD2  2    25
VD8  2    26
VD9  2    17  -21   -13   -11   -9   -12
WAL  3    16  -17   -22   -24   -18  -26   -23   -25
WPA  2    20
WPC  2    19  -20
UNV  2    28  -19   -16
end zone
  1   2   3 1000 1000   4   5   6   5   7   5   5   5 1000
1000 1000   5   5 1000   5 1000   5 1000 1000   8 1000   5 1000
end geom
conc exp
ndetec=9
 0.0     1108.0   0.0
 175.0   1108.0   0.0
 350.0   1108.0   0.0
 0.0     1127.0   0.0
 175.0   1127.0   0.0
 350.0   1127.0   0.0
 0.0     1331.0   0.0
 175.0   1331.0   0.0
```

```
 350.0    1331.0     0.0
end dose
end
```

7A.4.2 SCALE4.3 / QADS Input Files - DTS Shielding Evaluation - Open Receiving Cask Containing Twenty One Fuel Assemblies

```
=QADS
DTS - TWENTY ONE FUEL ASSEMBLIES IN MPC CASK - 7INCH ROOF PLATE
27n-18couple infhommedium
uranium      1    den=1.538    end
zircalloy    1    den=0.343    end
fe           2    den=0.131    end
zircalloy    2    den=0.380    end
fe           3    den=0.960    end
fe           4    den=1.013    end
carbonsteel  5    1.0          end
u(.27)metal  6    1.0          end
pb           7    1.0          end
c            8    den=0.501    end
o            8    den=0.595    end
al           8    den=0.473    end
reg-concrete 9    1.0          end
end comp
cylindrical  1.77E+14  flats  end
9z  1.00  8z  nzs=2
end source
cylindrical shell cask
rcc  1   0.0  0.0   -182.88  0.0  0.0  365.76   74.04
rcc  2   0.0  0.0    182.88  0.0  0.0  26.29    74.04
rcc  3   0.0  0.0    209.13  0.0  0.0  80.81    74.04
rcc  4   0.0  0.0   -187.07  0.0  0.0  4.19     74.04
rcc  5   0.0  0.0   -193.93  0.0  0.0  6.86     74.04
rcc  6   0.0  0.0   -200.28  0.0  0.0  490.22   76.58
rcc  7   0.0  0.0   -200.28  0.0  0.0  490.22   77.47
rcc  8   0.0  0.0   -215.52  0.0  0.0  505.46   92.71
rcc  9   0.0  0.0   -174.88  0.0  0.0  421.64   81.28
rcc 10   0.0  0.0   -174.88  0.0  0.0  421.64   85.09
rcc 11   0.0  0.0   -174.88  0.0  0.0  421.64   86.36
rcc 12   0.0  0.0   -191.39  0.0  0.0  454.66   107.95
rcc 13   0.0  0.0   -192.66  0.0  0.0  457.25   108.59
rcc 14   0.0  0.0   -274.64  0.0  0.0  51.5     92.71
rcc 15   0.0  0.0   -220.60  0.0  0.0  5.08     77.47
rcc 16   0.0  0.0   -220.60  0.0  0.0  5.08     92.71
rcc 17   0.0  0.0   -223.14  0.0  0.0  2.54     92.71
rcc 18  -350.0  0.0  414.36  0.0  0.0  3.8      62.6
rcc 19   0.0    0.0  414.36  0.0  0.0  3.8      90.0
rpp 20  -636.24  326.44  -322.24  388.94  -274.64  1157.36
rpp 21  -544.8   235.0   -230.8   297.5   -274.64  1157.36
rpp 22  -590.54  280.74  -276.52  343.22  1157.36  1175.16
rpp 23  -636.24  326.44  -322.24  388.94  1157.36  1429.16
rpp 24  -632.44  322.64  -318.44  385.14  1157.36  1425.36
rpp 25  -544.8   235.0   -230.8   297.5   414.36   418.16
```

```
rpp 26  -636.24  -544.8   -139.05  139.05  -274.64  334.96
rpp 27  -654.02  -636.24  -169.55  169.55  -274.64  182.46
rpp 28  -659.1   -636.24  -169.55  169.55  182.46   365.36
rpp 29  -1500.0  1500.0   -1500.0  1500.0  -800.0   2000.0
end body
ful  7     1
TPF  5     2
VD1  4     3
VD2  4     4
BTF  3     5
SS1  5     6    -5  -4 -3  -2  -1
VD3  5     7    -6
SSI  4     9   -7
DUS  4     10    -9
PBS  4     11    -10
SS2  4     8    -6  -7   -9  -10 -11
RES  4     12    -8
SS3  4     13    -12     -7
TRO  2     14
DUB  2     15
SS4  2     16    -15
SS5  2     17
VD4  2     18
VD5  2     19
MZF  5     25    -18    -19
ROF  2     22
VD8  2     26
SDT  2     27
SDB  2     28
AIR  4     21    -25  -8  -13  -14  -16  -17  -3
WAL  3     20     -21  -26  -23
WPA  2     24    -22
WPC  2     23    -24
UNV  3     29    -23  -20 -27  -28
end zone
  1    2 1000 1000    4    5 1000    5    6    7    5    8    5
  5    6    5    5 1000 1000    5    5 1000    5    5 1000    9 1000
  5 1000
end geom
CONC EXP
ndetec=16
 -350.0   1156.5   0.0
 -175.0   1156.5   0.0
 0.0      1156.5   0.0
 -350.0   1176.0   0.0
 -175.0   1176.0   0.0
 0.0      1176.0   0.0
 -350.0   1430.0   0.0
 -175.0   1430.0   0.0
```

```
 0.0     1430.0  0.0
 109.0    0.0    0.0
 -636.0   0.0    0.0
 -659.0   0.0    0.0
 234.0    0.0    0.0
 327.0    0.0    0.0
 0.0     290.0   0.0
 0.0     416.0   0.0
0.0      -223.14  0.0
end dose
end
```

7A.4.3 SCALE 4.3 / QADS Input File - DTS Shielding Evaluation - One Fuel Assembly at Start of Fuel Transfer Fully Removed from Source Cask and in Position Closest to Sliding Door

```
=QADS
DTS-ONE ASSY OVER SRCE CASK-NEAR LAA DOOR-7.0INCH/2.0IN-0.8 IN TUBE
27n-18couple infhommedium
uranium  1  den=2.525  end
zircalloy 1  den=0.563  end
fe       2  den=0.215  end
zircalloy 2  den=0.624  end
fe       3  den=1.576  end
carbonsteel  4  1.0   end
reg-concrete  5  1.0   end
end comp
cylindrical  5.92E15 flats  end
5z  1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2  9.75e-2  2.74e-1
4.5e-1  1.72e-2  2.45e-2  6.13e-2  2z
end source
cylindrical shell cask
RCC  1  0.0      0.0      -182.88   0.0      0.0      365.76   12.61
RCC  2  0.0      0.0      182.88    0.0      0.0      17.65    12.61
RCC  3  0.0      0.0      200.53    0.0      0.0      8.64     12.61
RCC  4  0.0      0.0      -15.92    0.0      0.0      392.0    14.64
RCC  5  0.0      0.0      209.17    0.0      0.0      166.96   12.61
RPP  6  -194.8   585.0    -230.8    297.5    -67.98   -64.18
RCC  7  0.0      0.0      -67.98    0.0      0.0      3.8      62.6
RCC  8  350.0    0.0      -67.98    0.0      0.0      3.8      90.0
RPP  9  -194.8   585.0    -230.8    297.5    -756.98  675.02
RPP 10  -286.24  676.44   -322.24   388.94   -756.98  675.02
RPP 11  -286.24  -194.8   -139.05   139.05   -756.98  -147.38
RPP 12  -304.04  -286.24  -169.55   169.55   -756.98  -299.88
RPP 13  -309.14  -286.24  -169.55   169.55   -299.88  -116.98
RPP 14  -240.54  630.74   -276.54   343.24   675.02   692.82
RPP 15  -282.44  672.64   -318.44   385.14   675.02   943.02
RPP 16  -286.24  676.44   -322.24   388.94   675.02   946.82
RPP 17  -200000. 200000.  -200000.  200000.  -2000.   200000.
```

```
end body
 FUL  8      1
 PLN  7      2
 TPF  6      3
 VD1  6      5
 TUB  6      4    -5    -1    -2    -3
 VD2  5      7    -1
 VD3  5      8
 MZF  5      6    -7    -8
 VD4  5      9    -6    -5    -1     -2     -3   -4
 VD5  6     11
 BLD  6     10    -9    -11
 SDT  6     12
 SDB  7     13
 RPL  4     14
 VD6  4     15    -14
 WPC  4     16    -15
 UNV  6     17    -16   -10   -12   -13
end zone
  1  2  3 1000  4 1000 1000 4 1000 1000  5
  4  4  4 1000  4 1000
end geom
CONC EXP
ndetec=40
 -310.0   -148.0   0.0
 -340.48  -148.0   0.0
 -310.0   -177.86  0.0
 -340.48  -177.86  0.0
 -310.0   -208.34  0.0
 -340.48  -208.34  0.0
 -310.0   -238.82  0.0
 -340.48  -238.82  0.0
 -310.0   -269.3   0.0
 -340.48  -269.3   0.0
 -310.0   -299.78  0.0
 -340.48  -299.78  0.0
 -310.0   -299.88  0.0
 -340.48  -299.88  0.0
 -310.0   -330.26  0.0
 -340.48  -330.26  0.0
 -310.0   -360.74  0.0
 -340.48  -360.74  0.0
 -310.0   -391.22  0.0
 -340.48  -391.22  0.0
 -310.0   -452.18  0.0
 -340.48  -452.18  0.0
 -310.0   -574.1   0.0
 -340.48  -574.1   0.0
 -310.0   -665.54  0.0
```

```
-340.48  -665.54  0.0
0.0      674.0    0.0
175.0    674.0    0.0
350.0    674.0    0.0
0.0      694.0    0.0
175.0    694.0    0.0
350.0    694.0    0.0
0.0      948.0    0.0
175.0    948.0    0.0
350.0    948.0    0.0
-15.0    0.0      0.0
-194.0   0.0      0.0
-287.0   0.0      0.0
584.0    0.0      0.0
677.0    0.0      0.0
end dose
end
```

7A.4.4 SCALE4.3 / QADS Input File - DTS Shielding Evaluation - One Fuel Assembly During Fuel Transfer in the Position Closest to the DTS Roof

```
=QADS
DTS - ONE ASSY OVER RECEIVING CASK - 7 IN ROOF - 1 IN XFER TUBE
 27n-18couple infhommedium
uranium     1   den=2.525   end
zircalloy   1   den=0.563   end
fe          2   den=0.215   end
zircalloy   2   den=0.624   end
fe          3   den=1.576   end
carbonsteel 4   1.0         end
reg-concrete 5  1.0         end
end comp
cylindrical  5.92E15 flats  end
5z  1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2  9.75e-2  2.74e-1
4.5e-1   1.72e-2  2.45e-2  6.13e-2  2z
end source
cylindrical shell cask
  RCC  1   0.0      0.0      -182.88  0.0      0.0      365.7    12.61
  RCC  2   0.0      0.0      182.88   0.0      0.0      17.65    12.61
  RCC  3   0.0      0.0      200.53   0.0      0.0      8.64     12.61
  RCC  4   0.0      0.0      -182.88  0.0      0.0      392.05   14.64
  RPP  5   -544.8   235.0    -230.8   297.5    -350.96  -347.16
  RCC  6   0.0      0.0      -350.96  0.0      0.0      3.8      90.0
  RCC  7   0.0      -350.0   -350.96  0.0      0.0      3.8      62.6
  RPP  8   -544.8   235.0    -230.8   297.5    -1039.96 392.05
  RPP  9   -636.24  326.44   -322.24  388.94   -1039.96 392.05
  RPP 10   -636.24  -544.8   -139.05  139.05   -1039.96 -430.36
  RPP 11   -654.02  -636.25  -169.55  169.55   -1039.96 -582.86
  RPP 12   -659.1   -636.25  -169.55  169.55   -582.86  -399.96
```

```
 RPP 13  -590.54  280.74   -276.54  343.24   392.05   409.85
 RPP 14  -632.44  322.64   -318.44  385.14   392.05   660.05
 RPP 15  -636.24  326.44   -322.24  388.94   392.05   663.85
 RPP 16  -200000. 200000.  -200000. 200000.  -2000.   200000.
end body
 FUL  8    1
 PLN  6    2
 TPF  4    3
 TUB  4    4  -1   -2   -3
 VD1  4    6
 VD2  4    7
 MZF  4    5  -6   -7
 VD3  5    8  -4   -5
 SDB  4   11
 SDT  4   12
 VD4  4   10
 BLD  4    9  -8   -10
 RPL  4   13
 VD5  4   14  -13
 WPC  4   15  -14
 UNV  4   16  -15   -9   -11   -12
end zone
 1  2  3  4 1000 1000  4 1000  4  4 1000  5  4 1000
 4 1000
end geom
CONC EXP
ndetec=35
-350.0   391.5   0.0
-175.0   391.5   0.0
0.0      391.5   0.0
-350.0   410.5   0.0
-175.0   410.5   0.0
0.0      410.5   0.0
-350.0   664.5   0.0
-175.0   664.5   0.0
0.0      664.5   0.0
-15.0    0.0     0.0
-544.0   0.0     0.0
-637.0   0.0     0.0
234.0    0.0     0.0
327.0    0.0     0.0
0.0      210.0   0.0
-660.0   -400.0  0.0
-690.48  -400.0  0.0
-660.0   -582.76 0.0
-690.48  -582.76 0.0
-660.0   -735.16 0.0
-690.48  -735.16 0.0
-660.0   -857.08 0.0
```

```
-690.48  -857.08  0.0
-1659.0  -857.08  0.0
-3159.0  -857.08  0.0
-5659.0  -857.08  0.0
-10659.0 -857.08  0.0
-15659.0 -857.08  0.0
-20659.0 -857.08  0.0
-30659.0 -857.08  0.0
-40659.0 -857.08  0.0
-50659.0 -857.08  0.0
-80659.0 -857.08  0.0
-100659.0 -857.08  0.0
-150659.0 -857.08  0.0
end dose
end
```

7A.4.5 SCALE-4.3 / SAS1 Input files - Source Cask Shielding Evaluation

7A.4.5.1 Radial Model

```
=SAS1
DRY TRANSFER SYSTEM, MPC W 4 FUEL ASSEMBLY, 5 YEAR, 40000 MTU FUEL
27N-18COUPLE INFHOMMEDIUM
' FUEL
UO2        1  DEN=1.737  1.0  293  92235  3.75  92238  96.25  END
ZIRCALLOY  1  DEN=0.341  END
'  PLENUM
ZIRCALLOY  2  DEN=0.424  END
SS304      2  DEN=0.147  END
'  TOP END FITTING
SS304      3  DEN=0.955  END
'BOTTOM FITTING
SS304      4  DEN=1.008  END
'DEPLETED URANIUM
U(.27)METAL 5  1.0      END
'RESIN SHELL
ARBMTNRES  1.58  5   1  0  0  5000  1.05  6012  35.13  8016  41.73  13027
  14.93  1001  5.05  6  0.896  END
AL         6  0.104      END
'CARBON STEEL
CARBONSTEEL 7  1.0      END
END COMP
END
LAST
DTS, SOURCE CASK RADIAL MODEL
CYLINDRICAL
1  32.39  35  -1  0  0  1785.0  1.96E10
7  33.66  2   0
```

```
5  41.28  8   0
7  43.82  2   0
6  50.17  7   0
7  50.81  1   0
END ZONE
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25Z
1.59E-5  4.91E-4  6.21E-4  2.15E-2  5.27E-2  9.75E-2  2.74E-1
4.5E-1  1.72E-2  2.45E-2  6.13E-2  2Z
NDETEC=5
READ XSDOSE
365.76
52.0 182.88  80.81 182.88  150.0 182.88  250.0 182.88  355.61 182.88
END
```

7A.4.5.2 Axial Model

```
=SAS1
DRY TRANSFER SYSTEM, MPC W 4 FUEL ASSEMBLY, 5 YEAR, 40000 MTU FUEL
27N-18COUPLE INFHOMMEDIUM
' FUEL
UO2        1  DEN=1.737  1.0  293  92235  3.75  92238  96.25  END
ZIRCALLOY  1  DEN=0.341  END
'  PLENUM
ZIRCALLOY  2  DEN=0.424  END
SS304      2  DEN=0.147  END
'  TOP END FITTING
SS304      3  DEN=0.955  END
'BOTTOM FITTING
SS304      4  DEN=1.008  END
'DEPLETED URANIUM
U(.27)METAL 5   1.0       END
'RESIN SHELL
ARBMTNRES  1.58  5   1  0  0  5000  1.05  6012  35.13  8016  41.73  13027
  14.93   1001  5.05  6  0.896  END
AL         6  0.104      END
'CARBON STEEL
CARBONSTEEL 7   1.0       END
END COMP
END
LAST
DTS, SOURCE CASK - Top model, lid in place
disc reflected
1    130.0   40  -1   0   0    1785.0   1.96e10
1    182.88  30  -1   0   0    1785.0   1.96e10
2    200.53  18   0
3    209.17   9   0
0    263.27  50   0
7    264.54   1   0
5    272.16   8   0
```

```
7   277.24   6   0
end zone
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25z
1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2   9.75e-2  2.74e-1
4.5e-1   1.72e-2  2.45e-2  6.13e-2  2z
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25z
1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2   9.75e-2  2.74e-1
4.5e-1   1.72e-2  2.45e-2·  6.13e-2  2z
ndetec=4    dy=87.64   dz=87.64
READ XSDOSE
43.82
0.0  0.5  0.0  100.0   0.0  200.0   0.0  304.8
end
```

7A.4.6 SCALE4.3 / SAS1 Input Files - Receiving Cask Shielding Evaluation

7A.4.6.1 Radial Model

```
=SAS1
DRY TRANSFER SYSTEM, MPC W 21 FUEL ASSEMBLY, 5 YEAR, 40000 MTU FUEL
27N-18COUPLE INFHOMMEDIUM
' FUEL
UO2        1  DEN=1.745  1.0  293  92235  3.75  92238  96.25  END
ZIRCALLOY  1  DEN=0.343  END
'  PLENUM
ZIRCALLOY  2  DEN=0.380  END
SS304      2  DEN=0.131  END
'  TOP END FITTING
SS304      3  DEN=0.960  END
'BOTTOM FITTING
SS304      4  DEN=1.013  END
'DEPLETED URANIUM
U(.27)METAL 5  1.0        END
' LEAD SHELL
PB         6  1.0        END
'RESIN SHELL
ARBMTNRES  1.58  5   1  0  0  5000  1.05  6012  35.13  8016  41.73  13027
  14.93  1001  5.05  7  0.896  END
AL         7  0.104       END
'CARBON STEEL
CARBONSTEEL 8  1.0        END
END COMP
END
LAST
DTS, RECEIVING CASK RADIAL MODEL
CYLINDRICAL
1  74.04  50  -1  0  0  1800.0  1.97E10
8  76.58  2   0
0  77.47  1   0
8  81.28  4   0
5  85.09  4   0
6  86.36  2   0
8  92.71  7   0
7  107.95 16  0
8  108.59 1   0
END ZONE
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25Z
1.59E-5  4.91E-4  6.21E-4  2.15E-2  5.27E-2  9.75E-2  2.74E-1
4.5E-1  1.72E-2  2.45E-2  6.13E-2  2Z
NDETEC=5
READ XSDOSE
365.76
109.1 182.88  138.6 182.88  208.6 182.88  308.6 182.88  413.4 182.88
```

```
END
```

7A.4.6.2 Axial Model

```
=sas1
dry transfer system receiving cask with 21 assemblies, 5 year, 40000 mtu fuel
27n-18couple infhommedium
'fuel
uo2    1  den=1.745   1.0  293  92235  3.75  92238   96.25  end
zircalloy 1 den=0.343    end
'plenum
zircalloy 2  den=0.38    end
ss304    2  den=0.131   end
'top fitting
ss304    3  den=0.96    end
'bottom fitting
ss304    4  den=1.013   end
'lead
pb       5  1.0         end
'depleted uranium
u(.27)metal  6   1.0    end
'resin shell
c        7   den=0.501  end
o        7   den=0.595  end
al       7   den=0.473  end
'carbon steel
carbonsteel  8   1.0   end
end comp
end
last
dts - receiving cask with 21 fuel assemlby - shield plug,inner lid, and outer lid
disc reflected
1    130.0   40  -1   0   0    1800.0   1.97e10
1    182.88  30  -1   0   0    1800.0   1.97e10
2    200.53  18   0
3    209.13   9   0
0    263.27  50   0
8    268.99   6   0
6    274.07   5   0
8    275.34   2   0
8    280.42   5   0
0    282.96   3   0
8    289.95   7   0
end zone
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25z
1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2   9.75e-2  2.74e-1
4.5e-1   1.72e-2  2.45e-2  6.13e-2  2z
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25z
1.59e-5  4.91e-4  6.21e-4  2.15e-2  5.27e-2   9.75e-2  2.74e-1
```

```
4.5e-1  1.72e-2  2.45e-2  6.13e-2  2z
ndetec=4   dy=148.08   dz=148.08
read xsdose
92.71
0.0  0.5 0.0  100.0   0.0 200.0  0.0  304.8
end
```

7A.4.7 SCALE4.3 / SAS1 Input Files - Spherical Shielding Evaluation

7A.4.7.1 Source Cask Spherical Model

```
=SAS1
DTS - RECEIVING AND SOURCE CASK, BOUNDARY DOSE - SHPERICAL MODEL
27N-18COUPLE INFHOMMEDIUM
UO2        1  DEN=1.745  1.0  293  92235  3.75  92238  96.25  END
ZIRCALLOY  1  DEN=0.765  END
SS304      1  DEN=2.11  END
PB         2  1.0   END
U(.27)METAL 3  1.0   END
ARBMTNRES 1.58  5  1  0  0  5000  1.05  6012  35.13  8016  41.73  13027
  14.93  1001  5.05  4  0.896  END
AL         4  0.104      END
CARBONSTEEL 5  1.0         END
END COMP
END
LAST
FOUR FUEL ASSEMBLIES IN SOURCE CASK, LONG DIST, NEUTRON AND GAMMA
SPHERICAL
1  66.0  50  -1  0.0  0.0  1791.0  1.97E10
5  67.27  2   0
3  74.89  8   0
5  77.43  3   0
4  83.78  7   0
5  84.42  1   0
END ZONE
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25Z
1.59-5  4.91-4  6.21-4  2.15-2  5.27-2  9.75-2  2.74-1
4.50-1  1.72-2  2.45-2  6.13-2  2Z
NDETEC=4
READ XSDOSE
2500.0  5000.0  10000.0  15000.0
END
```

7A.4.7.2 Receiving Cask Spherical Model

```
=SAS1
DTS - RECEIVING CASK, BOUNDARY DOSE - SHPERICAL MODEL
27N-18COUPLE INFHOMMEDIUM
```

```
UO2        1  DEN=1.745  1.0  293  92235  3.75  92238  96.25  END
ZIRCALLOY  1  DEN=0.765  END
SS304      1  DEN=2.11  END
PB         2  1.0   END
U(.27)METAL 3  1.0   END
ARBMTNRES  1.58  5   1  0  0  5000  1.05  6012  35.13  8016  41.73  13027
  14.93   1001  5.05  4  0.896  END
AL         4  0.104      END
CARBONSTEEL 5  1.0        END
END COMP
END
LAST
TWENTY-ONE FUEL ASSY IN RECEIVING CASK - LONG DISTANCES - NEUTRON AND GAMMA
SPHERICAL
1  84.6   30  -1  0.0  0.0  1800.0  1.97E10
1  114.6  30  -1  0.0  0.0  1800.0  1.97E10
5  117.14  3   0
5  120.95  4   0
3  124.76  4   0
2  126.03  2   0
5  132.38  7   0
4  147.62  16  0
5  148.26  1   0
END ZONE
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25Z
1.59-5  4.91-4  6.21-4  2.15-2  5.27-2  9.75-2  2.74-1
4.50-1  1.72-2  2.45-2  6.13-2  2Z
0.0185  0.210  0.232  0.131  0.177  0.193  0.0378  25Z
1.59-5  4.91-4  6.21-4  2.15-2  5.27-2  9.75-2  2.74-1
4.50-1  1.72-2  2.45-2  6.13-2  2Z
NDETEC=5
READ XSDOSE
 2500.0  5000.0  10000.0  15000.0  20000.0
END
```

7A.4.8 <u>SKYSHINE II Input Files</u>

7A.4.8.1 <u>Input File - Fuel Assembly in Transfer Position Near Roof with Filled Receiving Cask</u>

```
CALC 1051-19, SKYSHINE, GAMMA FROM DTS
 1.225E-3
      1
     3.0
      1
      1    45.4
      1    25.6
      1
      1    45.4
      1    25.6
```

```
       1
       1    45.4
       1    17.3
       1
       1    45.4
       1    17.3
       1
       1    25.6
       1    17.3
       1
       1    25.6
       1    17.3
       0
-9.7     7.6     -12.1    13.5    0.0    45.4
       0
SKYSHINE FROM SUSPENDED FUEL ASSY AND FILLED MPC
     100      10       0       0       1       0       0
       5
 92.62   0.0     6.0
 174.6   0.0     6.0
 338.7   0.0     6.0
 502.7   0.0     6.0
 666.8   0.0     6.0
      12       0
 0.100   0.200   0.30    0.40    0.60    0.80    1.00    1.33
 1.66    2.0     2.50    3.0
 0.0     0.0613  0.0858  0.103   0.553   0.827   0.9245
0.9772   0.9987  0.999321  0.999812  1.0
 2.27E11     0.0
     1
1.0      1.0     -1.0    0.0     1.5707963
 0.0     0.0     31.9
```

7A.4.8.2 <u>SKYSHINE Input File - Open Receiving Cask Containing Twenty One Fuel Assemblies</u>

```
CALC 1051-21, SKYSHINE, GAMMA FROM DTS, FROM FILLED MPC
 1.225E-3
       1
     3.0
       1
       1    45.4
       1    25.6
       1
       1    45.4
       1    25.6
       1
       1    45.4
       1    17.3
```

```
       1
       1     45.4
       1     17.3
       1
       1     25.6
       1     17.3
       1
       1     25.6
       1     17.3
       0
-9.7    7.6     -12.1    13.5     0.0      45.4
       0
SKYSHINE FROM FILLED MPC
      100       10       '0       0       1       0       0
       5
 92.62   0.0      6.0
 174.6   0.0      6.0
 338.7   0.0      6.0
 502.7   0.0      6.0
 666.8   0.0      6.0
      12        0
 0.100    0.200    0.30    0.40    0.60     0.80     1.00     1.33
 1.66     2.0      2.50    3.0
 0.0     0.0613   0.0858   0.103    0.553    0.827    0.9245
0.9772    0.9987    0.999321  0.999812  1.0
 6.18E11       0.0
      1
 1.0       1.0     -1.0      0.0      1.5707963
 0.0       0.0      15.9
```

CHAPTER 8

ACCIDENT ANALYSES

In previous chapters of this SAR, the features of the DTS system which are important to safety have been identified and discussed. The purpose of this chapter is to present the engineering analyses for normal and off-normal operation conditions, and to establish and qualify the system for a range of credible and hypothetical accidents.

In accordance with NRC Regulatory Guide 3.48 (Reference 8.1), the design events identified by ANSI/ANS 57.9 (Reference 8.2), form the basis for the analyses performed for the DTS system. Four categories of design events are defined. the calculations of design event Types I and II which cover the normal and off-normal conditions are addressed in Section 8.1. The calculations of design event Types III and IV covere a range of postulated accident conditions are addressed in Section 8.2. These events provide a means of establishing that the DTS design satisfies the applicable operational and safety acceptance criteria as specified in Chapter 3.

Since this is a Topical Report, the majority of analyses presented throughout this chapter are based on bounding conservative assumptions and methodologies, with the objective of establishing upper bound values for the design basis events. The operating equipment has been analyzed for the worst case loadings, which result from the seismic analysis and dead and live loads on the equipment. Effects on the operating equipment from other design basis events are discussed, but not analyzed. These evaluations will be provided in the site specific applications.

8.1 Off-Normal Events

This section evaluates Category I and II events as defined in ANSI/ANS 57.9-1992. Category I events are those events that are expected to occur regularly or frequently in the course of normal operations. Category I events shall not result in radioactive releases to the personnel, the public or the environment which exceed regulatory allowable limits. The evaluation of normal operating conditions is presented in Section 8.1.1.

Category II events are those which are expected to occur with moderate frequency on the order of once per calendar year. Category II events shall not result in radioactive releases to the personnel, the public or the environment which exceed regulatory allowable limits. In case of a category II event, the cause shall be determined and resolved. Operations can be immediately resumed after repairs are made. The following category II events are evaluated.

- Failure of any single active component to perform its intended function upon demand.
- Loss of external power supply for up to 24 hours.

- A single operator error followed by proper corrective action.
- Spurious operation of active components.
- Heavy snow storm.
- Failure of monitoring and control system.
- Failure of Cooling or Heating Portion of HVAC Subsystem.
- Lightning.

The DTS is designed such that a single failure of a component will not result in unacceptable high radiation levels outside the DTS, in any damage to a fuel assembly, in any damage to the lid or the shield plug or in the prevention of recovery of the fuel within the DTS.

Section 8.1.2 addresses each off normal design event independently. For each design event, the postulated cause of the event, detection of the event, analysis of effects and consequences and corrective actions are addressed.

8.1.1 Evaluation of Normal Conditions

8.1.1.1 Thermal Evaluation

The DTS is designed to reject the heat from the spent fuel being transferred and the equipment being operated while maintaining temperatures within specified limits.

Regardless of the condition outside the DTS, the HVAC Subsystem is designed to ensure relatively constant indoor conditions. In extreme cold conditions or extreme hot ambient conditions, the HVAC Subsystem also ensures that the temperature gradient across the concrete walls of the DTS does not exceed 70°F. This requirement ensures that the thermal stresses in the walls of the DTS do not exceed concrete design standards. If the temperature differential approaches 70°F, the inside temperature set point is adjusted.

The design basis for the heat dissipation during normal conditions is the following:

- A nominal full load of spent fuel assemblies in the receiving cask with a maximum heat load of 15.5 kW;

- Intact fuel; and

- Turnaround time of 10 days for the receiving cask and 1 day for the source cask.

The 15.5 kW decay heat load corresponds to twenty-one 10-year cooled fuel assemblies in the DTS. Originally, 5-year cooled fuel was to be accommodated by the DTS.

This cooling period corresponds to the requirement that the MPC system store 5-year cooled fuel. Initial HVAC design evaluations resulted in larger HVAC equipment which required a bigger DTS footprint to house the equipment. Recognizing that the receiving cask design basis is an MPC in a transportation overpack that will be designed for 10-year cooled fuel, it was reasonable to adopt a heat load equivalent to 10-year cooled fuel for the DTS. This approach considerably reduced fuel temperatures during the transfer process and thus minimized the rate of fuel cladding degradation when fuel is in an air environment. This approach allows mixing of less than 10-year cooled fuel with longer cooled fuel while maintaining a total heat load of 15.5 kW.

The DTS is provided with a dedicated HVAC system which is described in Section 3.5.1 and designed to maintain air temperatures in the DTS at or below 70°F (21°C) and remove the following heat loads:

TCA:

15.5 kw of decay heat load
1.5 kw of equipment heat load (continuous)

Roof Enclosure Area:

3.0 kw of equipment heat load for short durations

Lower Access Area:

15.5 kw of decay heat load
0.5 kw of equipment heat load (continuous)

Preparation Area:

15.5 kw of decay heat load
20 kw of equipment heat load (continuous)

Note that the total decay heat load is 15.5 kW which could potentially be dissipated in the TCA, the Lower Access Area or the Preparation Area. The high equipment heat load in the Preparation Area is mainly from the heat dissipated by the welding operation and welding equipment.

The above heat loads are in addition to the continuous heat loads generated by the HVAC equipment and heat addition from environmental conditions (ambient temperature, solar heat). The thermal inertia of the DTS structure (concrete and steel) and the equipment (including the casks) is very large (more than 325 tons of steel and 2,000 tons of concrete).

Heat loads from equipment used for short durations in the DTS will have an insignificant impact on the average 70°F (21°C) air temperature in the DTS.

Heat Removal During Fuel Transfer Operations

During fuel transfer operations, the source and receiving casks will be mated to the TCA through the Cask Mating Subsystem. All equipment to be operated is in the TCA or under the protective cover above the TCA. The sources for heat generation are described below. The sources for heat generation in the TCA, the Lower Access Area and the Roof Enclosure Area during fuel transfer and lid/shield plug handling are illustrated in Figures 8.1-1 through 8.1-3.

In the TCA:

- Spent fuel from the source and receiving casks dissipating heat upwards into the TCA. This is a fraction of the total decay heat load of 15.5 kW and estimated to be about 35%.
- Continuous heat load generated by the cameras and its associated lighting equipment (1.5 kw).
- Fuel transfer and lid/shield plug handling equipment which is used for short durations and does not exceed 3 kW.

The TCA HVAC equipment has the capacity to dissipate the heat load from decay heat, from mechanical equipment (including the HVAC Subsystem) and from environmental conditions. The air temperatures will easily be maintained at 70°F (21°C).

In the Roof Enclosure Area:

- Lid/shield plug handling equipment which is used for short durations and does not exceed 3 kW.

In the Lower Access Area:

- Spent fuel from the source and receiving casks dissipating heat radially into the Lower Access Area. This is a fraction of the total decay heat load of 15.5 kW and estimated to be about 65%.
- Continuous heat load generated by the cameras and its associated lighting equipment (0.5 kW).

The Lower Access Area HVAC equipment has the capacity to dissipate at least 16 kW. Air temperatures in this area will easily be maintained at 70°F (21°C).

In the Preparation Area:

Sources for heat generation dissipate negligible heat (no activity in this area during fuel transfer).

Fuel Temperature During Fuel Transfer

The thermal design of the source and receiving casks strongly influences the temperatures of the fuel in these casks. The following evaluation shows that the design basis source cask (four PWR assemblies) and receiving cask (21 assembly MPC with transportation overpack) will maintain fuel temperatures below the design limits.

Source Cask:

Typically, the source cask will be used to transfer fuel from the fuel pool to the DTS and would be designed to meet the requirements of 10CFR Part 72. With a design basis turnaround time of one day, the cask would be designed to transfer fuel in air while maintaining fuel cladding temperatures at or below the 240°C limit established for a two week period. This temperature limit would not be exceeded under the most severe ambient condition which typically is 115°F (46°C) ambient with insolation. When the cask is placed inside the DTS, the surrounding temperature is reduced to 70°F (21°C) and the solar heat is eliminated. Hence the fuel cladding temperature will remain below 240°C. When the cask lid is removed in the TCA, heat is also dissipated upwards through the lid opening further reducing fuel cladding temperatures. The removal of assemblies from the cask will rapidly decrease the heat load resulting in a further reduction in fuel cladding temperatures.

Receiving Cask:

To assess the potential fuel cladding temperatures of a receiving cask with its lid on or off in the DTS, a thermal study was performed using the TN-24P storage cask. This cask design is a forged thick shell with a welded bottom. The cask has a 24 assembly basket designed to accommodate W17x17 or W15x15 5-year cooled fuel. The maximum heat load permissible in the cask is 24 kw. The backfill medium is helium. The TN-24P TSAR thermal analysis predicts a maximum fuel clad temperature of 350°C under an ambient temperature of 47°C and a solar heat load of 7 kw for 10 hours a day (Reference 8-3).

Under a cooperative program sponsored by DOE, Virginia Power and EPRI, Idaho National Engineering Laboratory (INEL) performed thermal testing of this cask in the horizontal and vertical positions with three different internal storage environments (nitrogen, helium, and vacuum). The result of the tests have been discussed in detail in EPRI Report NP-5128 (Reference 8-4). The maximum fuel cladding temperatures (vertical orientation with helium and nitrogen back fill) measured were:

- With helium backfill 214°C
- With nitrogen backfill 232°C

The tests were conducted under the following conditions:

- Ambient temperature 20°C
- Decay heat load 20.6 kw

The EPRI report also presents the results of a three dimensional analysis using the COBRA-SFS computer code developed by Pacific Northwest Laboratory (PNL). For the same conditions, the following fuel clad temperatures were predicted:

- With helium backfill 220°C
- With nitrogen backfill 247°C

Recognizing that the thermal properties of nitrogen and air are nearly identical, the steady state fuel clad temperatures for this cask with the lid in place in the DTS would be less than 250°C with a heat load of 20.6 kw. With a 15.5 kw load, the maximum fuel cladding temperature would be less than 200°C.

In an effort to assess the thermal consequences resulting from storing a receiving cask in the DTS with the lid/shield plug removed, Transnuclear requested PNL to perform a scoping calculation using the existing computer model of TN-24P. A simple modification was made where the gas flowing down the downcomers at the lid region is set at 20°C. The results showed that there was a significant drop in fuel cladding temperature when an additional heat removal path is created when the lid is opened. It was estimated that about 35% of the decay heat would be rejected upwards. The maximum fuel cladding temperature would drop even further to an estimated 160°C. This estimated fuel cladding temperature limit would be below the 2 year handling limit of 175°C.

The DTS design basis calls for the receiving cask to be an MPC in a transportable overpack. Since a licensed design of this configuration is not available at the time of this study, an assessment of MPC thermal design was made using the concept presented in the MPC Conceptual Design Report (Reference 8-5). The MPC transport overpack is to be designed to maintain fuel cladding temperatures below 340°C and meet all the requirements of 10 CFR 71. The cask designer could use nitrogen or helium as the inert backfill gas depending on the design for the fuel basket (promoting gaseous conduction or convection).

The PNL report PNL-8451, "Spent Nuclear Fuel Storage - Performance Tests and Demonstrations" (Reference 8-6), concludes that in the vertical orientation, the fuel cladding temperatures would be within 10% if nitrogen or helium is used as the backfill gas. Since the thermal properties for air and nitrogen are similar, it would be logical to conclude that the steady state fuel cladding temperatures for the receiving cask with the lid/shield plug on will be approximately at or below the temperature limit of 340°C if stored indefinitely in the DTS. The two dimensional thermal analysis presented in the MPC Conceptual Design Report was reviewed and qualitatively evaluated as follows to represent the actual conditions that the MPC would be in the DTS:

- Heat load changed from 14.2 kw to 15.5 kw
- Ambient temperature changed from 38°C to 21°C
- 10 CFR 71 solar heat removed
- Helium environment replaced with air in cask/canister
- Orientation changed from horizontal to vertical
- Increased convection due to vertical orientation
- Increased surface area for heat dissipation from cask ends with no insulating impact limiters and cask on transfer trolley
- Increased heat dissipation from shield plug which is directly exposed to the DTS environment (no MPC lids or overpack lids)
- Convection from annulus between the MPC and the transportation overpack

The following qualitative estimates for fuel cladding temperatures in the MPC with the shield plug on and off are made based on the TN-24P performance studies above:

With shield plug on	
conservative estimate	270°C
optimistic estimate	230°C
With shield plug off	
conservative estimate	190°C
optimistic estimate	160°C

The loading of the 21 assembly receiving cask requires 6 loading cycles with a 4 assembly source cask. During each cycle the shield plug will be removed when fuel is transferred from the source cask to the receiving cask. Note that the empty fuel compartments serve as downcomers for natural convection, enhance the convection promoting lower temperatures. At the end of the fifth loading cycle, 95% of the total heat load could potentially be in the MPC. If at this point the receiving cask is allowed to reach thermal steady state, the maximum fuel cladding temperature will most probably be below the 240°C limit. Since adiabatic heatup of a 250,000 lb cask is about 1°C/hr, it would be more than 80 hours before this can occur. With a 1 day design basis turnaround for the source cask, the receiving cask would be reopened in the next 48 hours to load the last assembly and maintain fuel cladding temperatures below 240°C. The MPC will be inerted within 2 to 3 days following the transfer of the last assembly.

Based on the above assessment, it is concluded that fuel cladding temperatures for the design basis receiving cask are expected to remain below 240°C while in an air environment of the DTS. Confirmatory analysis or tests, if necessary, will be performed on the actual receiving cask design to demonstrate the performance of the receiving cask. The turnaround time for the receiving cask plays an important role in determining the allowable temperature for the fuel. If a cask with the TN-24P equivalent thermal performance is used as a receiving cask, the turnaround time can be relaxed considerably.

8.1.1.2 Building Structural Analysis

The structural calculations for normal operating conditions are briefly summarized here. They are included in more detail in Appendix 8A.1. Table 8.1-1 shows the normal operating loads for which the DTS structural components are designed. The table lists the individual components which are affected by each loading. The magnitude and characteristics of each load are described in this section.

Table 8.1-1

DTS Normal Operating Loads

Load Type	Affected Component				
	Reinforced Concrete Structure	Protective Cover	Roof Plate	Mezzanine Plate	Sliding Door
Dead Loads	X	X	X	X	X
Operational Handling Loads	X		X	X	
Live Loads	X	X	X	X	
Normal Thermal Loads	X	X	X	X	X
Internal Pressure	X	X	X	X	X
Design Basis Wind Pressure	X	X			

Dead Loads

Table 8.1-2 shows the weights of various components of the DTS. The dead weight of each component is determined based on nominal component dimensions.

Operational Handling Loads

The operational handling loads are included in the weight of the equipment presented in Table 8.1-2.

Live Loads

As discussed in Section 3.0, a live load of 250 lbs/ft^2 (11,970 Pa) is conservatively selected to envelope all postulated live loads acting on the DTS, including the effects of snow and ice.

Normal Thermal Loads

The DTS is subject to thermal expansion loads associated with normal operating conditions. The range of normal operating temperature used for the design of the DTS is

60°F to 100°F (16°C to 38°C) in the Preparation Area and 40°F to 130°F (4°C to 54°C) in other areas. In the event of extremely low external temperatures, the HVAC System will be set to establish a temperature of 50° F to ensure that the temperature gradient through the structural walls is less than 70° F.

Internal Pressure

The internal pressures (created by the HVAC system) during operation are as follows:

- TCA: 1 in (25.4 mm) H_20 less than ambient.
- Lower Access Area: 0.5 in (12.7 mm) H_20 less than ambient.
- Preparation Area: 0.25 in (6.4 mm) H_20 less than ambient.

Design Basis Wind Pressure

Design wind pressures for the structure have been determined at 25 ft (7.6 m), 50 ft (15.2 m) and 55 ft (16.8 m) above grade, and are summarized in Table 3.2-3.

8.1.1.2.1 Reinforced Concrete (Structure) Structural Analysis

The structure is designed to withstand a number of different loads and combinations of loads. The relevant normal operating loads are as follows (refer to Table 8.1-1):

- Dead loads
- Operational handling loads
- Live loads
- Normal thermal loads
- Internal pressure
- Design basis wind pressure

The DTS reinforced concrete wall thickness is primarily dictated by shielding requirements. For calculation of stresses, the design is dominated by the design basis tornado (DBT) and safe shutdown earthquake (SSE) loads. The stresses in the concrete wall due to normal operating conditions are negligible, with the exception of the thermal stresses. For example, the design basis wind pressure of 59 lb/ft^2 (2,825 Pa) is much less than the design basis tornado wind, which is 447 lb/ft^2 (21,400 Pa). In general, loads which are clearly not limiting are not evaluated; brief checks are included on less obviously unimportant loads.

The thermal analysis of the concrete building is also evaluated. Thermal loads within the structure due to the presence of the fuel assemblies and operating equipment induce two effects in the concrete walls.

- Bending due to temperature gradients across the walls
- Expansion due to rise in bulk temperature above base (setting) temperature

The results of the thermal analysis show that the maximum allowable temperature gradient across the wall is 70°F (21°C). The wall expansion due to bulk rise in temperature is considered largely underestimated and the stress is found to be negligible.

The HVAC subsystem ensures that the temperature gradient is not exceeded during all design events.

8.1.1.2.2 Protective Cover Structural Analysis

For normal operating conditions, a design load of 250 lbs/ft^2 (11,970 Pa) is conservatively used to calculate the stress as in the protective cover roof plate. The shell stress in the plate is evaluated using Roark (Reference 8.7), page 225, case 36, conservatively assuming the plate is simply supported with a uniform load over the entire surface. The analysis results show a maximum stress of 3,300 psi (22.8 MPa) which is less than the allowable stress of 21,600 psi (149 MPa).

Table 8.1-2

DTS Component Weights

Component Description		Calculated Weight
Reinforced Concrete Structure (including rebar and basemat)		4,395,600 lbs (1,993,840 kg)
Protective Cover		135,000 lbs (61,200 kg)
Roof Plate Level	Roof Plate	166,875 lbs (75,700 kg)
	Support Beam	56,741 lbs (25,700 kg)
	Equipment (including handling loads)	27,258 lbs (12,300 kg)
Fuel Handling Crane		22,000 lbs (10,000 kg)
Mezzanine Plate Level	Mezzanine Plate	25,230 lbs (11,400 kg)
	Support Beam	8,220 lbs (3,700 kg)
	Equipment (including handling loads)	49,500 lbs (22,400 kg)
Sliding Door		85,000 lbs (38,560 kg)

The protective cover is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

8.1.1.2.3 Roof Plate Structural Analysis

Normal operating loads on the roof plate and supporting beams are conservatively evaluated assuming all the weight (weight of roof plate, support beam and equipment loads) is supported by the five (5) W 14 x 550 beams only. An ANSYS (Reference 8.8) finite element model was developed using stiff 4 3D beam elements. The maximum calculated stress in the beams is 8,850 psi (61 MPa) which is much less than the allowable stress of 25,200 psi (174 MPa).

The plate stress due to the internal pressure is also evaluated and found to be negligible. These results are presented in Appendix 8A.1.

Both the roof plate and beams are bolted to the reinforced concrete. Oversized holes are provided at the plate and beam connection points to allow free thermal expansion.

8.1.1.2.4 Mezzanine Plate Structural Analysis

Normal operating condition loads on the mezzanine plate consist of the plate weight, the support beam dead weight, the Receiving and Source Cask Mating Subsystem dead weight, the Receiving and Source TC port cover weights, the receiving cask shield plug weight and the source cask lid weight. The analysis was performed conservatively assuming all the loads are supported by the beams only. A finite element (stif 4) model of the assembly is utilized to evaluate the beam stress. The analysis shows a maximum stress of 22,500 psi (155 MPa) in the beams which is less than the allowable stress of 27,600 psi (190 MPa). This analysis is described in Appendix 8A.1.

For thermal expansion, the required minimum clearance between the end of the plate and the inside surface of the concrete wall is approximately 0.125"(3 mm). Adequate clearance is provided between the plate and the concrete wall to permit free thermal expansion under the maximum differential temperatures expected during normal operation. The mezzanine plates are bolted to the support beams and the beams are bolted to the reinforced concrete. Oversized holes have been provided in the support beams and will permit free thermal expansion of the support beams and thus minimize thermal stress.

8.1.1.2.5 Sliding Door Structural Analysis

The design of the sliding door is based on shielding requirements. For the dead load analysis, the most limiting conditions are considered. By considering the sliding door to be supported at the rails, the weight of the sliding door is conservatively increased by a factor of

1.5. The maximum tensile stress at the door cross section is 106 psi (731,000 Pa) which is negligible. Other loads are much smaller; for example, the internal pressure is 2.59 lb/ft^2 (124 Pa), and is much less than the suction on the door due to the tornado wind, which is 419 lb/ft^2 (20,100 Pa). In general, loads which are clearly non-limiting are not considered explicitly; brief checks are included on less obviously unimportant loads. The stress calculations due to the DBT and SSE loads are described in Section 8.2.

The sliding door is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

8.1.1.3 Operating Equipment Structural Analysis

The operating equipment is designed to withstand all normal operating loads. In general, the equipment is sheltered from environmental loads by the DTS structure. One exception is the cask transfer subsystem, which during loading is located outside of the Preparation Area. All the equipment has been selected to function properly for the full range of operating temperatures and pressures. The Cask Transfer Subsystem is evaluated in Appendix 8A.2. The Cask Mating Subsystem is evaluated in Appendix 8A.3. The Source Cask Lid and Receiving Cask Shield Plug Handling Subsystem is evaluated in Appendix 8A.4. Appendix 8A.4 also includes the evaluation of the TC port covers and the upper shield port covers. The Fuel Handling Subsystem is evaluated in Appendix 8A.5.

Transportation package receipt, inspection, unloading, maintenance and loading are considered normal operations. The lifting equipment is sized in accordance with applicable industry standards to ensure that adequate safety factors are incorporated into the design. The lifting equipment within the DTS is designed in accordance with NOG-1, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder) with Single Failure-Proof Features (Type I Cranes).

Maintenance on equipment is performed on contact after removal of fuel and casks from the DTS and equipment decontamination. Remote systems are designed with backup measures to ensure that the DTS can be brought to a condition which would allow access for maintenance in the event of equipment failure. The system is designed to minimize the spread of contamination.

Equipment backup or remote access exists for all equipment involved in transferring fuel. The fuel handling crane is designed with single failure proof features.

Removal and installation of lids and shield plugs are normal operations. The source cask lid and receiving cask shield plug are installed and removed remotely by a single failure proof crane.

Removal and installation of the MPC lids and overpack lid are performed in the Preparation Area. This lifting equipment is not designated as Important to Safety, since in the event of a crane failure, the lids would fall onto or into the cask. The design of the casks prevents the lids from impacting the fuel assemblies. The cask cannot tipover due to a drop of a lid, and the fuel is shielded at all times. If a lid is dropped, the cask could be moved back into the Lower Access Area until a new lid could be brought into the DTS. Further, if there was damage to the cask sealing area, the cask could be brought back into the Lower Access Area, and the fuel could be transferred back into the source cask, and returned to its origin until a new receiving cask could be obtained.

8.1.1.4 Confinement

One of the primary design functions of the DTS structure is to provide a physical barrier for the purpose of preventing the release of radioactive particulate matter (to the environment) above the radiological protection limits described in Section 4.2. The achievement of ALARA in this regard is provided by the HVAC Subsystem to further control and confine potential contamination that may be released during transfer operations.

The source of the radioactive particulate under normal and most off-normal conditions is the crud on the external surfaces of the fuel rods and hardware. The primary confinement barrier for the escape of particulate from the fuel is the fuel cladding whether it is integral or contains pinholes or hairline cracks. Degradation of the cladding due to stress rupture and fuel oxidation (a time-at temperature phenomenon) will be minimized by maintaining low fuel cladding temperatures during the short duration of the fuel transfer process. The dedicated active cooling of the HVAC Subsystem will dissipate the decay heat from the fuel. Based on the study performed by Einziger (Effects of an Oxidizing Atmosphere in a Spent Fuel Packaging Facility, 1991), the following fuel cladding temperature limits have been adopted for the DTS:

- 464°F (240°C) for a two week period (before the receiving cask is inerted)
- 441°F (227°C) for a one month period
- 347°F (175°C) for a two year period

The design basis turnaround time for the source cask is 1 day and the receiving cask is 10 days. Considering that the receiving cask will be only partially filled during most of the actual transfer period, will be open during the transfer operations, has a large thermal mass, and is continuously maintained in a 70°F (21°C) ambient condition, it would be unlikely that fuel cladding temperatures would exceed the two week temperature limit of 464°F (240°C) during the 10 day design basis turnaround period. Confirmatory thermal analyses will be performed for the actual receiving cask and spent fuel to be used, and for the anticipated maximum turnaround period.

During fuel transfer, the confinement boundary for crud on the fuel assemblies is the physical enclosure formed by the DTS concrete walls including its sealed penetrations; the sliding door between the Preparation Area and the Lower Access Area; the weather protective cover, and the HEPA filters of the HVAC Subsystem. An additional level of confinement is provided by the HVAC Subsystem maintaining the TCA at negative atmospheric pressure so that air infiltration is into this area, and air flow from this potentially contaminated area is exhausted through a HEPA filtration system to the environment.

8.1.2 Evaluation of Off-Normal Conditions

8.1.2.1 Failure of a Single Active Component

A failure of any single active component to perform its intended function upon demand is considered a Category II event. For each component failure, the postulated cause of the failure, the method for detecting the failure, the effects and consequences, and the corrective action are provided.

8.1.2.1.1 Failures of the Cask Transfer Subsystem

The following failures of the Cask Transfer Subsystem have been postulated:

- Trolley will not move
- Trolley is incorrectly positioned
- Trolley moves without activation
- Trolley will not lock
- Trolley will not unlock
- Cask not secured on trolley
- Cask will not fit on trolley
- Cask will not come off trolley
- Limit switch fails to stop trolley motion

If the trolley will not move, it may be the result of a motor failure, a failure of the brakes to disengage, a lock which is still engaged or the jamming of the trolley. First, the operator would check the status of the locks. The rails would also be checked to ensure that there are no obstructions. If all is in order, the brakes would be checked. The service and emergency brake can both be manually disengaged. If the trolley still does not move, it is recommended that the trolley be moved into the Preparation Area for maintenance. The trolley can be pulled out of the Lower Access Area by attaching a prime mover. The cask should be closed and sealed prior to maintenance. Maintenance on the trolleys are performed on contact. The motor, brakes, guiding rollers and anti-taking off devices can be removed and replaced or repaired if necessary.

If the trolley is incorrectly positioned in the Lower Access Area or in the Preparation Area, it is probably due to a failed sensor, incorrectly positioned sensor, or a failure of the Control Subsystem. The incorrect positioning would be detected by the inability to lock the trolleys in place. The positioning of the trolley can be performed by manual jogging of the trolley until maintenance can be performed. The limit switches can be repositioned or replaced as necessary. Repairs would be performed on contact.

If the trolley were to move without operator activation, it would most probably be due to an operating mistake, a malfunction of the Control Subsystem, or an earthquake. This event could result in damage to the trolleys or damage to the casks. The worst likely result of an untimely activation is a collision of the two trolleys or a collision with the wall of the Lower Access Area or the sliding door. Failure would be detected visually. During engagement and Preparation Area operations, the trolley is always locked in place. Therefore, the operating mistake or the malfunction of the Control Subsystem should not result in movement of the trolley. The locking pin is also designed to withstand the seismic load. Brakes are also engaged when the trolley is not being moved.

If the trolley is in the loading/unloading area outside the DTS, the casks are either closed or empty. The casks are designed to withstand potential collisions in the area.

Bumper guards minimize damage to the trolley in the event of a collision. Limit switches mounted on each trolley in the front and back stop motion in the event of a collision. Limit switches at the end of the runway rails stop motion if the trolley overtravels.

If the trolleys will not lock, the trolley is either out of position or there is a problem with the jack. Positioning can be verified visually on contact. The locking jacks can be repaired on contact.

Cask fitup and securing are manual operations. The guides are adjustable and can be repositioned as necessary. As these operations are performed prior to opening the cask, there is no radiological consequence due to this event other than the increased worker radiation doses due to the extended period near the cask.

If the trolleys will not unlock, the locking jacks can be repaired on contact.

If a limit switch fails to stop the movement of the trolley, it is the operator's responsibility to stop moving the trolley. Overtravel limit switches and bumpers minimize damage to the trolley or cask. All operations are controlled locally.

There are no radiological effects of events regarding the operation of the Cask Transfer Subsystem. There would be additional radiation exposure to workers performing the repair, but the fuel is shielded by the casks.

8.1.2.1.2 Failures of the Cask Mating Subsystem

The following failures of the Cask Mating Subsystem have been postulated:

- The annular platform will not lower
- The annular platform only partially lowers
- The annular platform lowers without activation
- The annular platform is positioned incorrectly
- The seals are damaged
- The annular platform cannot be lifted
- The annular platform only partially lifts
- The annular platform lifts without activation
- The bellows tear or are punctured.
- The electric jack vertical positioning is erroneously reported to the PLC.
- The load sensor on an electrical jack reads higher than actual.
- The load sensor on an electrical jack reads lower than actual.

The annular platform will not lower if the load sensors or the electrical jacks are not working properly. This can be detected using the CCTV Subsystem or the jack vertical positioning sensor. Maintenance would be performed on contact after surveying the Lower Access Area and ensuring that both casks are closed.

The annular platform will only partially lower if there is an electrical jack failure, a failure of the load sensors, or a problem with the Control Subsystem. This problem would be detected by at least one of the following: the CCTV camera, a timing device in the PLC which would indicate that the operation is taking too long to perform, or the load sensors. Maintenance would be performed on contact after surveying the Lower Access Area and ensuring that both casks are closed.

If the annular platform lowered without activation, maintenance on the sensors or the Control Subsystem would be required. Damage to the Mating Subsystem could occur if a cask was moved into the Lower Access Area when the platform was in the wrong position. This error would be detected visually.

If the annular platform is positioned incorrectly, or if it lifts without activation, the error may be detected using the CCTV cameras, the load sensors on the electrical jacks, or by the vertical position indicators of the electrical jacks. Potential effects of this error are that particulate could enter the Lower Access Area during fuel transfer. This potential is unlikely since the HVAC Subsystem maintains a pressure differential which ensures that air flows into the TCA from the Lower Access Area. If contamination is spread to the Lower Access Area, the LAA would be decontaminated by conventional means.

The seals are inspected prior to each fuel transfer campaign, and are unlikely to be damaged. However, if the seals are damaged, particulate is confined by the HVAC Subsystem.

If the annular platform cannot be lifted or only partially lifts, it is probably the result of failure of the jacks. This failure will prevent movement of the cask. This error could be detected visually, by the jack load sensors or the jack position sensors. The casks would be closed and repair would be performed on contact.

If the bellows tear or are punctured, this condition would be detected visually. The HVAC Subsystem would provide particulate confinement.

If the position of the electrical jack is erroneously reported in the Control Center, it is easily checked by the operator using the CCTV camera.

If the electric jack load sensor reads higher than actual, the jacks will stop before reaching the proper mating position, rendering mating impossible. This error would be detected by the PLC timing device, which would generate a low level alarm if mating is not successful in a specified period of time.

If the electrical jack load sensor reads lower than actual, the jacks could become overloaded. Mating would not occur since the jack would never reach its mating pressure. This would also be detected by the timing device.

If there is an indication that the Cask Mating Subsystem has been damaged or is malfunctioning, the casks would be closed after completing the fuel transfer. If possible, the casks would be moved into the Preparation Area prior to maintenance and repair operations on the Cask Mating Subsystem.

There are no radiological effects of events regarding the Cask Mating Subsystem, since the HVAC Subsystem can maintain sufficient negative pressure within the Transfer Confinement Area to avoid particulate release to the Lower Access Area even assuming excess leakage of the Cask Mating Subsystem. There would be no particulate release to the environment, since the sliding door and concrete structure provide a barrier to the Preparation Area and the outside. There would be additional radiation exposure to workers performing the repair, but the fuel is shielded by the casks any time that the Cask Mating Subsystem would require repairs.

8.1.2.1.3 Failures of the TC Port Covers and Related Instrumentation

The potential failures of the TC port covers and related instrumentation are presented in Table 8.1-3. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-3. The radiological effects of events regarding the TC port covers are insignificant. They provide only minimal shielding, and during operation, all personnel are out of the Lower Access Area.

If the TC port covers can not be closed by normal means, they can be activated manually from outside of the DTS through penetrations in the concrete wall. Maintenance and repair operator dose assessments will be performed on a site specific basis.

8.1.2.1.4 Failures of the Upper Shield Port Covers and Related Instrumentation

The potential failures of the upper shield port covers and related instrumentation are presented in Table 8.1-4. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-4. There are no radiological effects of events regarding the upper shield port covers. If the upper shield port covers are not working properly, the shield plug would be returned to the receiving cask, the source cask lid would be installed, and the TC port covers closed. Then, personnel can enter the Roof Enclosure Area and perform maintenance on the Upper Shield Port Covers. Maintenance and repair operator dose assessments will be performed on a site specific basis.

Table 8.1-3

TC Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
TC port cover Opening	No Opening	Failure of Electrical Jack; Derailing	Subsequent operations cannot be performed.	Visual Position Sensors Inability to engage lock	Motors are placed outside the TCA and the port covers can be actuated manually
	Partial Opening	Failure of Electrical Jack		Visual Position Sensors; Inability to engage lock	
	Untimely Opening·	Spurious signal; error in processor	Potential contamination of Lower Access Area	Visual Position Sensors	Interlock prevents opening during fuel assembly lowering or lifting;
TC Port Cover Closing	No closing	Failure of electrical jack; derailing	Subsequent operations cannot be performed.	Visual Position Sensor Inability to proceed to next operation	Motors are placed outside the TCA and the port covers can be actuated manually.
	Partial closing	Failure of electrical jack	Subsequent operations cannot be performed.	Visual Position sensor Inability to proceed to next operation	
	Untimely closing	Spurious signal; error in processor ; operator error	Fuel assembly could be lowered onto the TC port cover. Collision with fuel assembly	Visual Position Sensors	Interlock prevents port cover closing if fuel grapple is not in "upper position"

Table 8.1-3 (Continued)

TC Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
TC Port Cover Locking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not engage	Mechanical or electrical failure of lock	TC Port Covers can collide with fuel assembly during a seismic event	Subsequent operations cannot be performed. Alarm	Shield Plug and Source Cask lid will be returned to casks, casks will be removed, and maintenance will be performed on lock after casks have been removed from the DTS.
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	Since lock is in the open position, fuel transfer can be completed. Access to the lock drive mechanism can be made through a penetration in the DTS wall to manually release the lock.
TC Port Cover Limit Switch failure	No position detection	Sensor Failure	Port Cover not stopped in proper position	Alarm CCTV	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed or off centered position		Lid/shield plug could be left in an unsafe position on the port cover and this position may not be predictable. Closing operations may be compromised.	CCTV	Marks on the mezzanine floor show the proper positions of the covers. Centering guides on the port covers prevent improper positioning of the lid/shield plug on the TC port cover.
	Erroneous detected open position		Locking operating can be processed in an improper position.	Alarm	Time out on locking operation generates an alarm.

Table 8.1-4

Upper Shield Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
upper shield port cover opening	No Opening	Failure of Electrical Jack; Derailing	Subsequent operations cannot be performed.	Position Sensors	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. Fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Partial Opening	Failure of Electrical Jack			
	Untimely Opening	Spurious signal; error in processor	Potential loss of shielding on the roof	Position Sensors Radiation Monitoring Alarm	Interlock prevents opening during fuel assembly lowering or lifting; Upper Shield port covers are locked during fuel transfer.
upper shield port cover closing	No closing	Failure of electrical jack; derailing	Subsequent operations cannot be performed.	Position Sensor Inability to proceed to next operation	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. Fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Partial closing	Failure of electrical jack	Subsequent operations cannot be performed.	Position sensor Inability to proceed to next operation	
	Untimely closing	Spurious signal; processor error; operator error	Collision with upper crane grapple or cables	Alarm Position Sensors	Interlock prevents port cover from closing if upper crane hoist is not in upper position.

Table 8.1-4 (Continued)

Upper Shield Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
Upper shield port cover Locking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not engage	Failure of lock	potential loss of shielding due to a seismic event	Subsequent operations cannot be performed. Alarm	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	
upper shield port cover limit switch failure	No position detection	Sensor Failure	Port Cover not stopped in proper position	Alarm overtravel indicator	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed or off centered position		Locking could be processed in an improper position. Improper shielding of port covers during fuel transfer	Alarm Radiation Monitoring Alarm	Range of time to process the operation controlled by the PLC generates an alarm. Upper shield port cover locks are interlocked with fuel transfer hoist.
	Erroneous detected open position		Locking operating can be processed in an improper position.	Alarm	Time out on locking operation generates an alarm.

8.1.2.1.5 Failurés of the Upper Crane and Related Instrumentation

The potential failures of the upper crane and related instrumentation are presented in Table 8.1-5. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-5. There are no radiological effects of events regarding the upper crane since the crane is housed in a shielded area. If the crane will not function, and the casks are not open, personnel can enter the Roof Enclosure Area and repair the crane. If the crane is not functioning properly, and the casks are open, personnel can enter the Roof Enclosure Area for short periods of time to perform repairs. Maintenance and repair operator dose assessments will be performed on a site specific basis.

8.1.2.1.6 Failures of the Fuel Handling Equipment

The potential failures of the fuel handling equipment and related instrumentation are presented in Table 8.1-6. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-6. The radiological effects of events regarding the fuel handling equipment are minimal since backup equipment, remote access or manual activation is provided which precludes the need to enter the DTS for repair until the fuel is loaded safely in either the source or receiving cask and the casks are closed. Maintenance and repair operator dose assessments will be performed on a site specific basis.

Manual operation of the trolley and rotating platform is performed as follows:

- The rotating platform is first positioned into the proper location using a long rod through a penetration in the side wall of the DTS. The rotating platform can only be positioned manually when the trolley is in a set location. Therefore, this operation is performed first.

- The trolley is then positioned using a long rod through a penetration in the side wall of the DTS. The trolley is operated manually by using a long rod through the wall of the DTS. The trolley can only be positioned manually when the trolley is one location. Therefore, this operation must be performed before the bridge is positioned.

- The bridge is then positioned using a long rod through a penetration in the side wall of the DTS. The bridge drive is fixed in position, and can be accessed manually regardless of the location of the bridge.

Table 8.1-5

Upper Crane Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Release of service brakes	No release	Brake failure	subsequent operation cannot be performed. Motor damage	Interlock alarm Crane trolley cannot move Sensor	Electrical interlock prevents motor actuation if brake is not released. Crane trolley is only moved when upper shield port covers are closed. Therefore, manual repairs can be made since the Roof Enclosure Area is shielded.
	Untimely release	Operating Error	Damage to Lid or Shield Plug	Sensor	Interlock prevents Z movement if X brakes are released.
Trolley movement	No movement	Motor failure; jammed trolley; derailing	Subsequent operation not possible	Sensors Timing device alarm	Range of time to process operation is controlled by PLC and will indicate that a failure has occurred. Manual repairs can be made in the Roof Enclosure Area.
	Incorrect positioning	Sensor failure	Grapple lowering cannot be performed.	Timing device alarm	
	Untimely movement	Operator error	Damage to lid or shield plug	alarm	Interlocks prevent trolley movement unless the grapple is in the full up position. Brakes immobilize trolley.
	Excessive movement	Sensor failure	Damage to trolley	overtravel limit switches	Limit switches stop motion. Motor overload detection stops motion
Trolley braking	No braking	Brake failure. Operator mistake	Possible movement of trolley due to seismic event.	Sensors indicate if trolley is out of position	Interlock prevents hoist movement if trolley brakes are released.
	Untimely braking		Subsequent operations can not proceed.	Trolley will not move	Brakes can be deactivated manually in the Roof Enclosure Area.

Table 8.1-5 (Continued)

Upper Crane Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Grapple lowering	No lowering	Motor failure	Plug/lid grapple can not be engaged. Lids cannot be put back on cask.	Visual Position indicator of hoist	Movement can be activated manually.
	Partial lowering	Failure of cable position indexing	Plug/lid grapple cannot be engaged. Lids cannot be put back on cask.	Visual Position indicator	
	Untimely lowering	Operator error; hoist failure	Collision of grapple or lid/shield plug with a port cover.	Visual	Interlocks Failure proof hoist Operating steps shown on control monitor
	Erroneous z position	Program error; operator error	Collision of grapple or lid/shield plug with a port cover	Visual	Testing prior to operation; Operating steps shown on control monitor.
Grapple lifting	No lifting	Motor failure	Subsequent operations can not proceed	Visual Position Sensors	Movement can be activated manually
	Partial lifting	Motor or position indicator failure			
	Excessive lifting	Position indicator failure	Damage to equipment Collision with trolley	Overtravel alarm	Overtravel stop
	Untimely lifting	Operator mistake	Drop of plug/lid during lifting resulting in damage which could prevent plug from being used.	Visual Interlocks	Overtravel stop
Shield plug/lid removal	No opening of grapple	Grapple failure jamming of fingers	Subsequent operations cannot proceed	Grapple engagement sensors	Grapple can be manually disengaged through a penetration in the TCA wall or from the Roof Enclosure Area after the TC port covers are closed.
	Partial opening of grapple	Grapple failure Jamming of fingers	Drop of plug/lid during lifting	Grapple engagement sensors interlocks	
	Untimely opening of grapple	Operator error.	Drop of plug/lid during lifting	Grapple engagement sensors; interlocks	Interlocks prevent opening of grapple under load or in incorrect position.

Table 8.1-6

Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Indexing	No indexing	operator error, interlocks not disengaged programming error	Transfer tube positioning not possible;	Visual Position Indicator	Timing device in PLC.
	Incorrect indexing	Programming error, operator error	Fuel assembly lowered onto cask basket	CCTV cameras on Transfer tube;	Fuel assembly is not lowered until it is aligned with the basket fuel compartment. Underload sensor and alarm
Release of service brakes	Untimely release	Operator error	Slight movement of fuel handling crane	Visual	Failure of service brake triggers activation of emergency brake
	No release	Brake failure	Subsequent operations cannot be performed; Motor overloaded	Overload detectors on motor; Inability to go to next operation; inability to move crane	Motor overload detector automatically stops operations; Manual deactivation of brakes through penetration in DTS wall

Table 8.1-6 (Continued)

Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Crud catcher opening	No opening	Operator error Failure of actuator jammed device	Fuel Assembly cannot be lowered into cask; jamming of fuel assembly in transfer tube	Visual Loss of load on crane cable and position signal of the cable are inconsistent Limit switch is not activated	Visual validation of the position of the device by operator before next sequence. Interlocks with fuel assembly hoist. Actuator can be activated manually through penetration in DTS wall
	Partial opening	Actuator failure		Limit switch is not activated	
	untimely opening	Operator error spurious signal	Dispersion of radioactive particulate on floor of TCA	Visual Limit switch	Interlock with fuel assembly hoist
Grapple lowering	No lowering	Motor failure;	Inability to lift or lower fuel assembly	Visual; Position indicator; timing device alarm	Complete backup hoisting system
	Partial Lowering	Motor failure; failure of positioning device or PLC	Inability to lift or lower fuel assembly; grapple cannot be disengaged safely	Visual; position indicator; timing device to perform operations triggers an alarm	Complete backup hoisting system.
	Untimely lowering	Operating error; failure of cable brakes; break of the cable	Damage to fuel assembly	Visual; interlock prevents grapple lowering if crane is not locked and crud catcher is not open; overspeed switch activates emergency brake	Cable designed with safety factors which prevents breaking; interlocks prevent grapple lowering unless a series of conditions have been met; Emergency brakes
Fuel Assembly Gripping	No gripping	Failure of actuators Jamming of fingers	Grappling operation can not be performed	Sensors on grapple fingers;	Casks would be closed, and repair work would be performed after decontamination of TCA.

Table 8.1-6 (Continued)

Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Fuel assembly gripping	Partial Gripping	Jamming of fingers Failure of actuators	Drop of Fuel Assembly during lifting	Sensors on grapple	Backup actuators and power supply. Fingers designed and tested so that jamming will not occur.
Fuel assembly lifting	No lifting	Motor failure Hoist brakes will not release	FA unloading cannot be completed	Visual Position indicator on Cable Motor overload detector	Backup hoist can be used to lift grapple until safe condition is met for repair on contact.
	Partial Lifting	Motor failure Failure of control system logic; Failure of cable position sensor	Fuel assembly is left hanging partially in cask and partially in transfer tube	Position indicator on Cable Motor overload detector Visual	
	Excessive Lifting	Cable positioning logic or sensor failure	Fuel assembly grapple could collide with trolley	overtravel limit switch; visual; motor overload	Overtravel limit switch stops motion; Overload detector stops motor
	Untimely lifting	Operator error	Drop of Fuel Assembly	Visual	Interlock prevents lifting of grapple if grapple is positioned on the fuel assembly but is not fully engaged
Crud catcher closing	No closing	Operator error; failure of actuator; jammed device	Crud or radioactive particulate will be dispersed in the TCA. Minor damage to fuel assembly	Visual; Position signal on crud catcher actuator;	Manual activation of the crud catcher is possible from a given position using a special tool through a penetration in the TCA wall

Table 8.1-6 (Continued)

Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
	Untimely closing	Operator error			
	Partial closing	Actuator failure Jammed device FA is not completely lifted into the transfer tube			
Trolley movement	No movement	failure of motor jammed trolley derailing	Fuel assembly stuck in the transfer tube	visual	trolley can be manually positioned using special equipment through a penetration in the TCA walls
	incorrect positioning	indexing failure; failure of position monitoring system	Loss of positioning information	visual	positioning can be made in manual mode using the CCTV. Positioning system can be re-zeroed by going back to the reference points on the cask.
	untimely movement	operator error spurious signal	Damage to fuel assembly	visual	Interlock prevents trolley movement if fuel assembly is not completely retracted into the transfer tube and if the crud catcher is not closed. The trolley is equipped with service and emergency brakes to prevent untimely motion
	Excessive movement	Failure of positioning system	Damage to fuel assembly	overtravel limit switch motor overload detection	Motor overload detection stops motion; Overtravel limit switches stop motion
Bridge Movement	No movement	failure of motor jammed bridge derailing	Fuel assembly stuck in the transfer tube	visual	bridge can be manually positioned using special equipment through a penetration in the TCA walls
	wrong positioning	indexing failure failure of position monitoring system	Loss of positioning information	visual	Positioning can be made in manual mode using the CCTV. Positioning system can be re-zeroed by going back to the reference points on the cask.

Table 8.1-6(Continued)

Fuel Handling Subsystem Postulated Failures,Effects and Compensating Provisions

Function	Failure Modes	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
	untimely movement	operator error spurious signal	Damage to fuel assembly	visual	Interlock prevents bridge movement if fuel assembly is not completely retracted into the transfer tube and if the crud catcher is not closed. The trolley is equipped with service and emergency brakes to prevent untimely motion
	Excessive movement	Failure of positioning system	Damage to fuel assembly	overtravel limit switch motor overload detection	Motor overload detection stops motion; Overtravel limit switches stop motion
Rotating Platform Movement	No movement	Motor failure Jammed equipment	Fuel assembly stuck in the transfer tube	Visual Position information	Motor can be manually activated by special tools which can force the rotating platform to rotate. Manual operation allows the transfer cycle to be completed, and access to the TCA is possible after removal of both casks with the fuel.
	Incorrect Positioning	Indexing failure. Logic error	Lowering of fuel assembly in wrong position	visual; final positioning performed in manual mode with CCTV feedback	Positioning must be validated by operator visually. Loss of load stops motion
	Untimely Movement	Operating mistake	Damage to fuel assembly	visual	Interlocks prevent movement of bridge, trolley or rotating platform from moving if the fuel assembly lifting operation is not complete or if the crud catcher is not closed. Brakes hold the position of the fuel assembly handling subsystem
Fuel Assembly Lowering	No lowering	Motor failure Crud catcher not open	Fuel assembly stuck in the transfer tube	Visual timing device in PLC; positioning of the cable	the system has two completely redundant drive mechanisms for the hoist with separate independent power supplies.

Table 8.1-6 (Continued)

Fuel Handling Subsystem Postulated Failures,Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Fuel Assembly Lowering	Partial Lowering	Motor failure Incorrect positioning of bridge, trolley or rotating platform; failure of cable positioning measurement or processing	Fuel assembly stuck partially inserted in cask and transfer tube	Visual; positioning of the cable	The system has two completely redundant drive mechanisms for the hoist with separate power lines. Loss of load on grapple stops motion.
	Excessive Lowering	failure of cable positioning measurement or processing	Damage to fuel assembly	Unexpected loss of load Overspeed detection Positioning of the cable	Limit switch stops motion. Overload signal stops motor. Overspeed signal activates emergency brakes.
	Untimely Lowering	Operator error	Damage to fuel assembly	visual; position indicator of cable	Interlock prevents lowering of the fuel assembly if crud catcher is not open and if trolley or bridge are moving.
Grapple Opening	No opening	Failure of actuators Jamming of fingers	Fuel assembly can not be disengaged	Visual; Limit contact "open" not activated	Two independent motors for the gripping device.
	Partial opening	Jamming of fingers	fuel assembly cannot be disengaged	visual limit contact "open" not activated	Two independent motors for the gripping device.
	Untimely opening	operating error failure of fingers	drop of a fuel assembly	visual Loss of load on cable limit contact "closed" not activated	Interlock prevents opening if cable is loaded and if FA lowering has not been validated. Mechanical design of grapple prevents it from opening under load.

8.1.2.1.7 Failure of the HVAC Subsystem Components

The potential failures of the HVAC Subsystem component failures are presented in Table 8.1-7. The failure, probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed. The radiological effects of events regarding the HVAC component failures are minimized since backup equipment will be used in case of primary equipment failure.

8.1.2.1.8 Failure of the Control Subsystem Components

Failures of sensors are included in the sections regarding the specific equipment which is being controlled or monitored. Sensor failures result in absence of detection or erroneous information. The PLC will then have information which is either undetermined or erroneous. Inconsistent information is not considered in the sensor failures analysis as this is detected by the PLC which generates an alarm, stops the equipment and requires operator identification to resume the operations. Failure of the Control Subsystem Components are described in more detail in Appendix 5A.

Some potential failures of the Control Subsystem are not specific to the equipment, either because the responses to the failures are the same for all equipment or because the failure can influence the general control and monitoring of the process. These general types of failures are discussed below.

A "watch dog" detects the failure of the PLC's CPU (Central Processing Unit), based on an internal operations timer, and automatically stops the equipment in operation by resetting its outputs. A coupler failure, a network disconnection of the PLC, a network failure between the PLC and the monitoring PC or between the main control panel and the PLC are detected and the equipment is automatically stopped. A failure of the link between the PLC and the electronic cabinets results in a de-energizing of the controlled equipment which activates the emergency brakes. A loss of control (wire disconnection/breaking) between the electronic cabinets and the equipment has the same effect.

A loss of power directly stops the operating equipment. All equipment returns to a safe condition in the event of a power failure, for example, all grapples engage. The PLCs and the PC are supplied by an independent (battery) backup which maintains historical information (process, positions...) and updates the equipment status (stopped) upon loss of power.

Interlock failures are described in Table 8.1-8. Interlocks can be bypassed by authorized personnel provided that they provide proper identification.

There are no radiological consequences of a failure of the control subsystem.

Table 8.1-7

HVAC Subsystem Postulated Failures, Effects and Compensating Provisions

Component	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Exhaust fan	Fan does not operate	Motor failure	No air flow	No pressure differential across blower unit	Standby fan will startup.
HEPA filter module	Blowout	Filter failure	Unfiltered air flow	No pressure differential across module	Redundant filtration system. Filter bank with defective module will be isolated.
Pressure sensor	Incorrect pressure data	Sensor failure	Air flow rate incorrect	Redundancy in pressure sensors	Override fan speed control.
Air Conditioning Subsystem in Lower Access Area	Temperature setpoint not maintained	Sensor/ fan/ cooling condenser/ heater failure	Lower/ higher temperatures in area	Temp. monitor	Shutdown air conditioning in area if necessary. Air conditioning system in TCA will compensate. Additional cooling/heating available by resetting setpoints in Preparation Area. Air flow rate may also be increased.
Air Condition-ing Subsystem in TCA	Temperature setpoint not maintained	Sensor/ fan/ cooling condenser/ heater failure	Lower/ higher temperatures in area	Temp. monitor	Shutdown air conditioning in area if necessary. Additional cooling/heating available by resetting setpoint in Lower Access Area. Air flow rate may also be increased.

Table 8.1-8

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Crud Catcher (Closed Indicator)	Erroneous crud catcher closed position information	FA crud spreading during motion. FA damaged or stuck due to motion or platform rotation if not fully retracted into transfer tube.	CCTV	Transfer tube positioning (x,y,θ) interlocked with the grapple upper z position.
	Erroneous crud catcher open position information	Lowering of the FA onto the crud catcher. Damage to the FA. Stuck FA in the transfer tube because of crud catcher stuck in closed position.	CCTV Unexpected loss of load	Loss of load stops motion. Crud catcher position validated visually before lowering FA.
Fuel Assembly Handling Crane Carriage	Erroneous movement detected	Interlocks prevent subsequent operations; Potential for collision if TC port covers are activated	CCTV	Bypass interlock.
	Movement not detected	Able to lower fuel assembly when carriage is in motion; Able to open crud catcher when crane carriage is in motion		Interlock with crud catcher closed position.
Fuel Assembly Handling Grapple	Erroneous FA gripping information	Unsafe lifting of FA. High radiation levels at upper level due to possible unlocking and opening of the upper shield ports	Alarm due to inconsistency between grapple fingers position and FA presence	Open and closed grapple fingers position sensors. Redundancy on proper gripping information with fuel assembly presence sensor. Upper shield ports interlocked with load cell and radiation monitoring.
Fuel Assembly Handling Hoist (Absolute Position Indicator)	Erroneous z position information of the FA hoist system	Damage to FA due to disconnection above the proper position.	CCTV Alarm due to inconsistency between load and position	Redundancy on FA disconnection based on underload situation. Mechanical design of grapple prevents its opening when loaded.

Table 8.1-8 (Continued)

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Fuel Assembly Handling Hoist (Load Cell)	Erroneous underload information	Damage to FA due to disconnection above the proper position High radiation levels at the upper level due to upper shield port opening FA stuck in the transfer tube because of damage to transfer tube due to collision with TC port cover.	CCTV Alarm due to inconsistency between position and load	FA disconnection interlocked with position encoder. Mechanical design of grapple prevents its opening when loaded. Upper shield port interlocked with gripping status and radiation monitoring device. TC port cover closing interlocked with gripping status.
Fuel Assembly Handling Hoist (Upper Position Indicator)	Erroneous upper position information	Damage to FA due to crane motion or platform rotation with FA not fully retracted into the transfer tube. Damage to FA and crud catcher due to crud catcher closure on FA.	CCTV	Crane carriage and rotating platform motion interlocked with crud catcher position. Visual verification prior to closing crud catcher.
Fuel Assembly Handling (Absolute Position Indicator)	Erroneous x,y position information	Damage to the lid/shield plug Dropping of the lid/shield plug, gripping of the grapple	CCTV	Visual verification prior to lift the lid/shield plug. Minimum speed imposed by PLC under the safety level
Lid/Shield Plug Hoist (Absolute Position Indicator)	Erroneous z position information of the lid/shield plug hoist system	Damage to the lid/shield plug due to disconnection of the lid/shield plug above the proper position	CCTV Alarm due to inconsistency between load and position	Lid/shield plug disconnection interlocked with load cell (underload situation)
		Lid/shield dropping or damage due to closure of TC port cover on the handling cables.	CCTV	The grapple position is visible and has to be validated before closing a TC port cover.

Table 8.1-8 (Continued)

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Lid/Shield Plug Hoist (Grapple Position)	Erroneous gripping status	Unsafe lifting and dropping of the lid/shield plug	Alarm due to inconsistency between gripping information	Open and closed grapple fingers position sensors Redundancy on proper overlid gripping Open and closed overlid fingers position Overlid fingers gripping detection
Lid/Shield Plug Hoist (Load Cell)	Erroneous underload information	Damage to lid/shield plug due to dropping of the lid/shield plug above the proper position	CCTV Inconsistency between load and position	Redundancy on lid/shield plug disconnection based on z position.
Lid/Shield Plug Hoist (Upper Position)	Erroneous upper position information	Dropping of the lid/shield plug due to closure of an upper shield port on the handling cables.	CCTV	Upper shield ports closure interlocked with gripping status.
		Unsafe handling of the lid/shield plug due to upper crane motion.		Upper crane motion interlocked with upper shield ports closed position.
Radiation Monitor - Upper Level	Erroneous dose rate	High dose rate at the upper level due to upper shield port unlocking and opening during FA transfer or with cask and TC port cover open.	CCTV Radiation monitoring alarms Inconsistency between radiation monitoring devices	Radiation monitoring equipment alarms on failure. Upper shield port unlocking and opening interlocked with TC port covers positions, FA grapple and load cell status.
Radiation Monitor - Sliding Door	Erroneous dose rate	High dose rate at the sliding door level.	Inconsistency with Preparation Area radiation monitoring	Radiation monitoring equipment alarms on failure. Sliding door opening requires severe administrative procedure

Table 8.1-8 (Continued)

Failure of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Sliding Door Locking Device	Erroneous sliding door locked position	High dose rates in case of a seismic event due to sliding door opening	Direct viewing	Operating procedure. Operation performed on contact.
Receiving Cask TC Port Cover - Closed Indicator Receiving Cask TC Port Cover - Off-Center Indicator Source Cask TC Port Cover - Closed Indicator	Erroneous TC port cover closed (or off-center) position	High dose rates at the upper level due to upper source cask opening with TC port cover not closed or off-centered	CCTV	Upper shield port opening interlocked with radiation monitoring.
Receiving Cask TC Port Cover - Open Indicator Source Cask TC Port Cover - Open Indicator	Erroneous TC port cover open position	Prevents subsequent operations; Potential collision with fuel assembly grapple	CCTV	Bypass Fuel assembly Z-motion has underload sensor which stops motion.
Receiving Cask TC Port Cover Locking Device Source Cask TC Port Cover Locking Device	Erroneous TC port cover lock position	Unsafe FA transfer with TC port cover unlocked which could damage the FA in case of a seismic event Collision between source cask lid or receiving cask shield plug and FA crane carriage.	Alarm	Unlocked position information provided by jack. Locking operation validated with time information.
Receiving Cask Transfer Trolley Locking Device Source Cask Transfer Trolley Locking Device	Erroneous cask transfer trolley lock position	Transfer trolley can be projectile in case of a seismic event. Damage to FA in case of transfer.	Visual	Operating procedure. Operation performed on contact.

Table 8.1-8 (Continued)

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Upper Crane - Source Cask Upper Crane -Receiving Cask	Erroneous upper crane position	Cask opening or closing impossible Damage to the lid/shield plug grapple onto the upper plate.	Alarm Unexpected loss of load or inconsistency between load and position.	Time information is used to validate the upper crane positioning information.
Receiving Cask Upper Shield Port - Closed Indicator Source Cask Upper Shield Port - Closed Indicator	Erroneous upper shield port position	Dropping of the lid/shied plug or unsafe lifting due to upper crane motion. High dose rates at the upper level during opening/closing of the opposite cask.		Upper crane motion interlocked with upper z grapple position. Upper shield port opening interlocked with radiation monitoring
Receiving Cask Upper Shield Port Locking Device Source Cask Upper Shield Port Locking Device	Erroneous upper shield port lock position	High dose rates at the upper level during FA transfer in case of a seismic event.		Unlocked position information provided by jack. Locking operation validated with time information.

8.1.2.1.9 Failure of the Radiation Monitoring Equipment

The Radiation Monitoring Subsystem is designed to have two monitors in the Preparation Area, one monitor in the Lower Access Area, one monitor in the Transfer Confinement Area, one monitor in the Roof Enclosure Area, and one monitor in the HVAC Subsystem. Each monitor is equipped with a battery backup for loss of power and with audible and visible alarms indicating detector failure.

Redundancy does exist in the Radiation Monitoring Subsystem should one detector fail. Two monitors are located in the Preparation Area. If one of the three radiation monitors within the DTS structure (the Lower Access Area, the Transfer Confinement Area, and the Roof Enclosure Area) should fail then the remaining two are adequate for reading dose rates within the DTS until fuel handling is completed.

There are no radiological consequences of a failure of the Radiation Monitoring Equipment.

8.1.2.1.10 Failure of Equipment in the Preparation Area

Repair and maintenance of equipment in the Preparation Area will be by "hands-on" means, once the casks have been removed from the area. There are no radiological effects due to failure of equipment in the Preparation Area.

8.1.2.2 Loss of External Power Supply for up to 24 hours

In the event of a power supply failure for a limited period of time, operations would normally cease until power is restored. Since fuel is shielded and confined at all times, there are no radiological effects of a short term loss of power.

The Radiation Monitoring Subsystem components have battery backup and the Control Subsystem has a battery backup which is used to save critical information such as sensor status, positioning information, etc.

The HVAC Subsystem exhaust fans and motorized dampers will be manually switched at the Control Center to the secondary power source.

Backup power to the fuel handling subsystem and the HVAC Subsystem is available.

There are no radiological effects due to a loss of power for a short period of time.

8.1.2.3 Heavy Snow Storm

Heavy snow storms result in loadings on the roof, weather protective cover and butler building. These have been designed for loads considerably greater than those expected from a heavy snow storm.

The stacks will be designed to ensure that snow and water do not drain into the DTS.

There are no radiological effects due to a heavy snow storm.

8.1.2.4 Lightning

Lightning is expected to occur regularly in the course of normal operation. Lightning arresters will be installed on the roof and/or the stack of the DTS to ensure that if the DTS is struck, minimal damage will result. No damage to the DTS structure will result. Lightning may result in a loss of power for a short period of time which is addressed in Section 8.1.2.2.

8.1.3 Radiological Impact from Off-Normal Operations

The radiological impact from Off-Normal Operations is expected to be minimal, since the DTS has been designed so that backup equipment is available for all operations which are performed remotely. All sensors which provide information on safety operations are also provided with backup sensors to verify that the operations are being performed in a safe manner.

Estimated doses due to off-normal operations will be provided on a site specific basis.

Figure 8.1-1

**Transfer Confinement Area
Equipment Heat Loads**

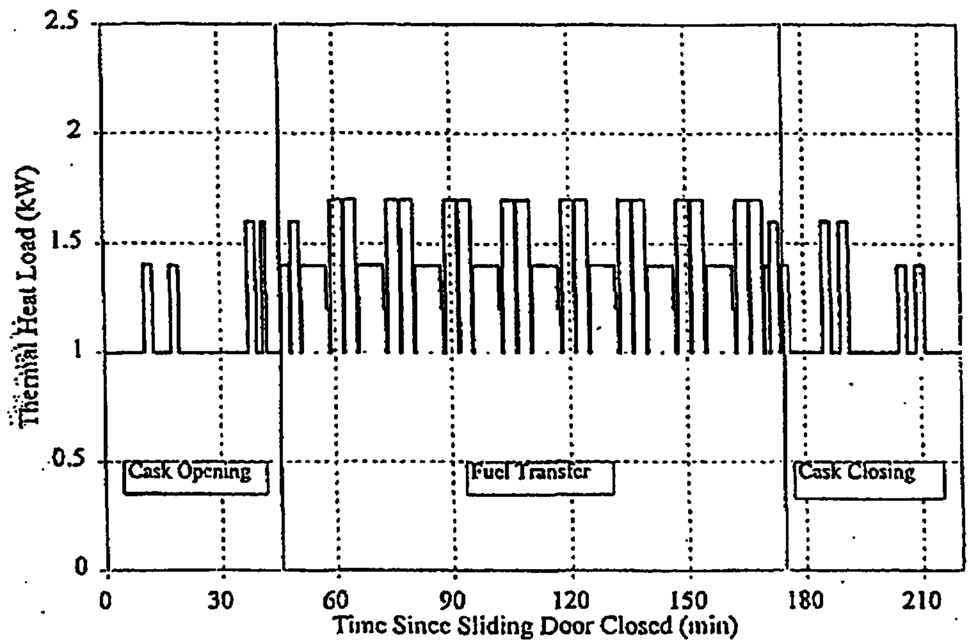


Figure 8.1-2

**Roof Enclosure Area
Equipment Heat Loads**

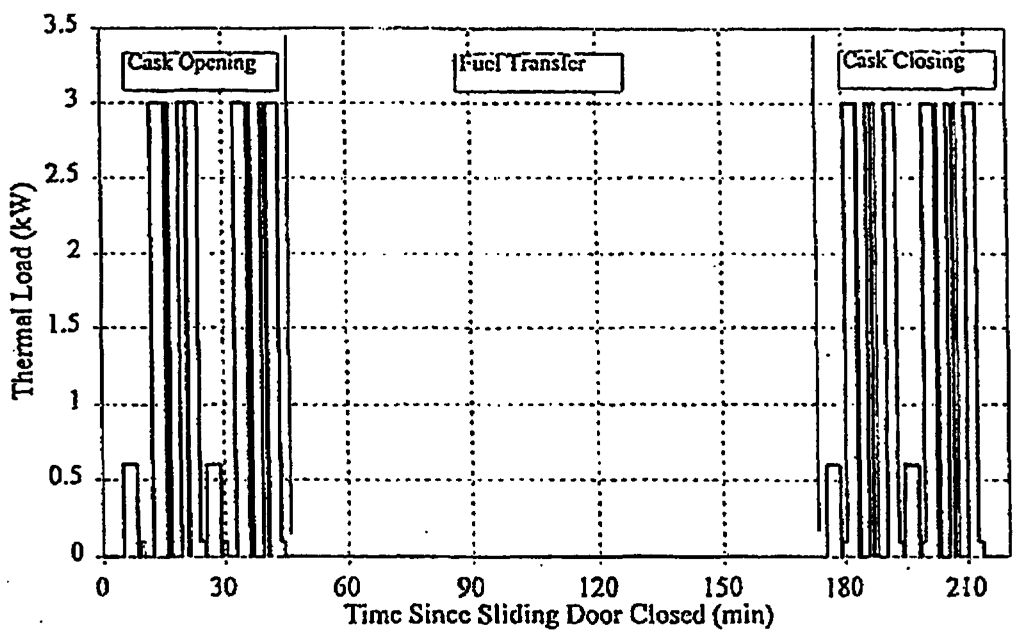
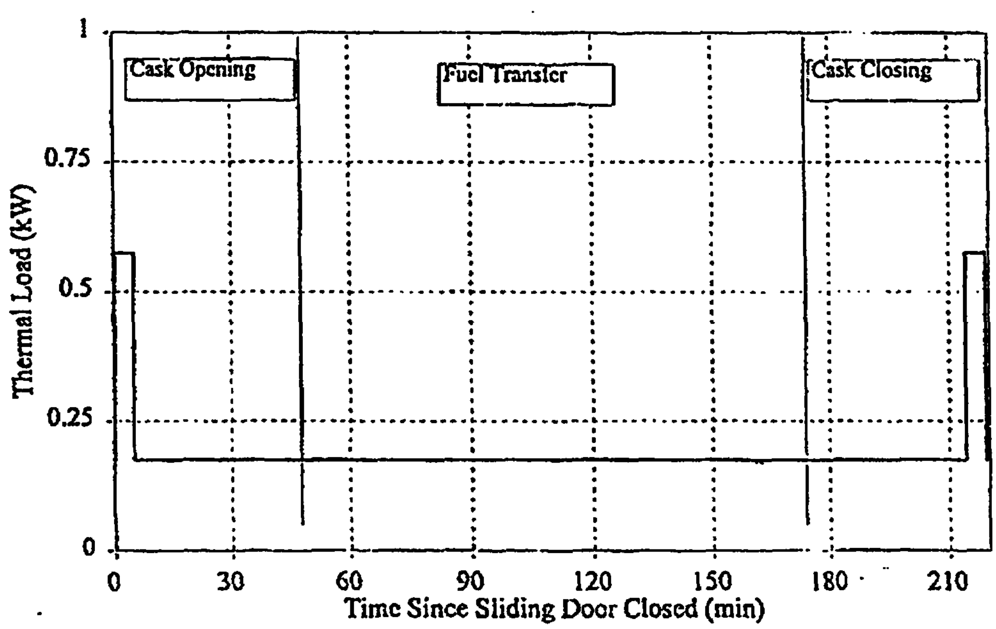


Figure 8.1-3

**Lower Access Area
Equipment Heat Loads**



8.2 Accidents

Category III events are infrequent events that are postulated to occur once in the life of the DTS. Category III events shall not result in radioactive releases to the personnel, the public or the environment which exceed limits for radiological effects in accidental conditions. A category III event may result in a long interruption in operations. The following category III events are evaluated.

- A loss of external power supply for an extended interval.
- Stuck fuel assembly or inability to insert a fuel assembly into a cask.
- Failure of the fuel grapple to disengage.

Category IV events are those events that are unlikely to occur, but are postulated because their consequences may result in the maximum potential impact on the immediate environs. These events are anticipated to occur less than once during the lifetime of the DTS. Category IV events shall not result in radioactive releases to the personnel, the public or the environment which exceed limits for radiological effects in accidental conditions. The following category IV events are evaluated.

- Seismic Event.
- Tornado missiles, hurricanes and high winds.
- Fire.
- Major mechanical malfunction involving the spent fuel handling system during operation resulting in dropping of a fuel assembly.
- Complete loss of HEPA filters and loss of pressure differential
- Loss of a shield plug or source cask lid (either by damage or inability to be placed on the cask)

8.2.1 Loss of External Power for an Extended Interval

In the event of loss of the primary electrical power for an extended interval, the DTS would be shut down in the safest configuration. The secondary power source would be manually switched on-line to provide power to the following equipment:

- HVAC subsystem exhaust fans and motorized dampers;
- DTS operating equipment (excluding the receiving cask trolley, which requires 15 kW of power. The HVAC subsystem could be shut down for a short period of time to operate the receiving cask trolley);
- Control Subsystem equipment; and
- CCTV and Lighting Subsystem equipment.

The CPU (Central Processing Unit) of the Control Subsystem would automatically switch to a battery back up to prevent any loss of information until secondary power is provided. The radiation monitors and the emergency lighting will automatically switch to battery backup as well.

If fuel was being transferred, the fuel assembly would be lowered into the nearest cask by the secondary hoist system which is operated on the secondary power supply. The grapple would be disengaged using the secondary grapple electrical drive system. The source cask lid and the receiving cask shield plugs would be replaced on the casks. The casks would then remain in the Lower Access Area until power could be restored. The HVAC exhaust fans and motorized dampers are run to ensure that the fuel pin cladding temperature remains below acceptable limits.

If the power outage extends beyond several weeks, the sliding door would be connected to the emergency power supply and opened. The cask would be brought into the Preparation Area and inerted. Portable equipment (e.g. a generator) can be brought to the DTS to perform cask inerting operations. If primary power is restored in a shorter period of time, these operations are not necessary.

There are no radiological implications of this event since the fuel can be brought to a safe, well shielded condition.

8.2.2 Stuck fuel assembly or inability to insert a fuel assembly into a cask

A stuck fuel assembly or the inability to insert a fuel assembly into a cask would increase the site boundary dose due to increased time of operations with the fuel assembly in the TCA.

There are several measures which have been taken in the design of the system to make this potential accident extremely unlikely, such as load sensors on the hoisting device which automatically stop motion if the load is greater than or less than the expected load, sufficient clearance and lead-ins for the transfer tube, interlocks which prevent movement of the fuel handling equipment in the X, Y or θ directions if the fuel assembly is not in the full up position and acceptance of only structurally intact fuel.

If, despite the preventative measures taken, the fuel assembly still becomes stuck, special recovery procedures would be followed to free the assembly. These would include carefully monitoring the lifting or lowering load, jogging the fuel hoist in both directions to free the assembly, using special equipment through the penetrations in the TCA wall to free foreign material, etc. The CCTV cameras on the fuel handling subsystem and on the walls of the TCA allow full viewing of recovery operations.

Since the fuel assembly may be in the TCA for an extended period of time, the dose at the site boundary could increase.

If a fuel assembly is stuck part way out, the bridge, trolley and rotating platform are unable to move since the fuel grapple is not in the full upright position. The fuel assembly would be lowered back into the cask. This scenario could either result from a foreign object being jammed between the fuel assembly and the fuel cell, or if there are protrusions on the inside of the cask which could result in the fuel assembly getting caught. The fuel assembly load cell would automatically stop movement if abnormal loads are encountered while lifting the fuel assembly. Using bypasses, the fuel would be slowly lowered back into the cask. If the fuel will move neither up or down, through administrative control and the use of bypasses, the load cell limit could be increased to allow additional force to lift the assembly. It may be necessary to jog the fuel assembly from side to side. This is recommended as a last resort only.

There is no time limit in which to free the assembly, since the fuel is shielded and provided that the HVAC System is working, fuel cladding temperatures will remain well below the temperature at which fuel cladding failure would occur.

If a fuel assembly has become so bowed or distorted that it cannot be inserted into either the source or receiving cask, but is free from both casks, a special "recovery" cask would need to be provided to contain the damaged fuel. This could be a source cask with an oversized basket. The fuel assembly would be moved laterally, as far away from the sliding door as possible. A fully shielded tent would be built in the Preparation Area, enclosing the sliding door and providing enough room to completely enclose the source cask and its trolley. The Preparation Area and all surrounding areas would be evacuated.

The lid would be placed on the source cask. The source cask may have fuel assemblies in it. The source cask would be disengaged from the cask mating subsystem and the trolley would be unlocked. These operations would be done remotely, without entering the Lower Access Area. Using bypasses, the sliding door would be opened. Radiation levels outside and inside of the shielding tent would be carefully monitored. The source cask and the trolley would be moved into the shielding tent, and the sliding door would be closed. These operations would also be performed remotely.

Using the standard operating procedures, the source cask would be bolted, tested, inspected and removed from the DTS. After the source cask is unloaded from the trolley, the recovery cask would be placed onto the source cask trolley and secured. The recovery cask and trolley would be moved into the shielding tent. While carefully monitoring radiation levels in and around the shielding tent, the sliding door would be opened. The recovery cask would be moved into the Lower Access Area and positioned below the source cask mating subsystem. These operations would be performed remotely. The lid of the recovery cask would be removed, and the damaged fuel assembly would then be loaded into the recovery cask.

If a fuel assembly is stuck in the upright position, the maximum expected dose rates around the DTS structure would be the same as calculated in Section 7.3.2 and illustrated in Figures 7.3-2 and 7.3-3.

Assuming the assembly remains stuck for two weeks (336 hours), the off site maximum dose rates at various distances from the DTS are provided in Table 8.2-1.

Table 8.2-1

Radiological Consequences from a Stuck Fuel Assembly

Distance from DTS	Direct Dose Rate[1]	Skyshine[2]	Total Dose Rate	Total Dose
100 m (328 ft)	0.12 mrem/hr (0.0012 mSv/hr)	1.6E-02 mrem/hr (1.6E-04 mSv/hr)	1.4E-01 mrem/hr (1.4E-03 mSv/hr)	47 mrem (0.47 mSv)
200 m (646 ft)	2.8E-02 mrem/hr (2.8E-04 mSv/hr)	3.6E-03 mrem/hr (3.6E-05 mSv/hr)	3.2E-02 mrem/hr (3.2E-04 mSv/hr)	11 mrem (0.11 mSv)
500 m (1640 ft)	4.7E-03 mrem/hr (4.7E-05 mSv/hr)	2.8E-04 mrem/hr (2.8E-06 mSv/hr)	5.0E-03 mrem/hr (5.0E-05 mSv/hr)	1.7 mrem (0.017 mSv)

1 Assuming the face of the DTS building with the highest dose rates (the side with the sliding door) is facing the boundary.

2 Assuming the assembly is stuck while the Receiving Cask filled with 21 assemblies.

The results of this analysis shows that the total dose at the site boundary (at least 100 meters from the DTS) is 47 mrem (0.47 mSv) which is less than the design basis accident dose allowable of 5 Rem (50 mSv). This analysis is based on freeing the stuck fuel assembly within 2 weeks.

8.2.3 Failure of the fuel grapple to disengage

Two independent grapple activation mechanisms with independent power lines are provided to prevent the fuel grapple from becoming stuck in the engaged position. In addition, extensive testing prior to and after installation of the grapple is required to ensure that the likelihood of this event is extremely low. If the grapple were to fail, fiberscopes or other special viewing devices would be lowered into the DTS through penetrations in the roof plate. Special procedures and special tools would be required to deactivate the grapple.

There is no significant increase in the site boundary doses since the fuel assembly would be in the shielded cask.

The dose rates to workers would be evaluated prior to recovery operations.

After recovery, no fuel transfer would occur until a complete check out and repair of the fuel grapple was performed.

8.2.4 Seismic Event

The concrete structure of the DTS is designed to safely withstand the seismic event, but depending on the severity of the event, the DTS may not return to normal operations. The DTS concrete structure is designed to withstand the seismic event without collapsing. In addition, the structure has been analyzed to ensure that the seismic loadings on specific operating equipment will not cause the equipment to become projectiles. The fuel handling crane and the upper crane are designed so that they will not drop their load due to the seismic event. The following subsections address the seismic event as related to the specific structure, the HVAC Subsystem, the Major Operating Subsystems and the Control Subsystem.

8.2.4.1 Seismic Effects on Structure

DTS Concrete Structure

Seismic loads have been evaluated for the reinforced concrete structure including the base mat, the weather protective cover, the roof plate, the mezzanine plate and the sliding door. The structure is designed to withstand seismic loads due to the SSE without collapse. The seismic analysis of the structure is fully described in Appendix 8A.1. The analysis is summarized below.

The seismic analysis of the DTS assumes that the structure is founded on competent rock. In this circumstance, the phenomenon of Soil Structure Interaction (SSI) in which there is dynamic interaction between the structure and supporting soil medium need not be considered. Furthermore the structure can be analyzed as fully fixed at the base of the shear walls at the top of the basement.

The DTS structure is a relatively stiff shear wall structure of reinforced concrete supporting equipment on two flexible internal structural steel floors. In common with normal practice, equipment and internal structural steel floors are assumed not to contribute to the stiffness of the supporting reinforced concrete structure.

The structure has been modeled for seismic analysis purposes using the computer code ANSYS. Rigid equipment is generally represented as lumped translational masses. Internal floors (including the roof plate and mezzanine plate) which support major equipment are flexible in the vertical direction and have been represented as structural beam elements supporting vertical mass elements representing equipment, self weight, and floor imposed loading.

All reinforced concrete walls have been represented by four-node shell elements with elastic material properties based on gross uncracked concrete sections. Walls have been modelled at center line locations throughout the model.

A fixed base modal analysis technique was used to predict the structure response (in terms of acceleration) to the design earthquake input motion. A damping level of 7% was used which reflects the overall damping in a reinforced concrete structure stressed to levels approaching yield at the SSE.

A separate modal analysis has been carried out for each earthquake direction. The results from the 3 runs were combined using the square root sum of the squares method (SRSS). Results for individual earthquake direction analysis have been combined using the Complete Quadratic Combination technique (CQC).

Results from the modal analysis are as follows:

- Mode shapes, frequencies and mass participation factors for all structure modes of vibration up to approximately 50 Hertz.

- Zero period accelerations (rigid body accelerations) at selected locations throughout the structure. These represent the maximum acceleration response at the locations in 2 horizontal and the vertical translational directions on the structure.

Zero period accelerations are subsequently adjusted manually by adding base input accelerations by SRSS to correct for:

- Dynamic mass missing from the modes considered and
- Base input motion constant acceleration profile.

These corrected zero period accelerations are used for structure design purposes and as a starting point for estimating secondary response spectra for equipment design.

The detailed calculations and results of the structural design are described in Appendix 8A.1, and the stresses are within allowables.

An analysis is also performed to establish the worst case factor of safety against overturning of the DTS building. The overturning moment is 62,755 kNm (555,434 in-kip) and the stabilizing moment is 144,205 kNm (1,276,333 in-kips). The result of this analysis indicates that the DTS building will not overturn during a seismic event. The margin of safety against overturning is 2.3.

Summaries of the calculated results are provided in Tables 8.2-2, 8.2-3, and 8.2-4.

Stresses in the concrete are less than the tensile limit, ignoring the additional tensile strength contributed by the rebar. Minor concrete cracking may result at particularly highly stressed locations, but the reinforcement would still be only lightly loaded and will prevent collapse. Stresses in the steelwork are considerably less than the allowable stresses.

The SSE causes no damage to the building structure which might lead to release of radioactivity.

Table 8.2-2

DTS Reinforced Concrete Wall Enveloping Load Combination Results

Load	Calculated Stress			Allowable Stress		
	Compression (Concrete)	Tension (Rebar)	Bending (Rebar)	Compression (Concrete)	Tension (Rebar)	Bending (Rebar)
$D+L+E_{ss}$	291 psi (2.01 MPa)			1,785 psi (12.3 MPa)		
		30,287 psi (209 Mpa)			54,000 psi (372 MPa)	
$D+L+W_t$	259 psi (1.79 MPa)			1,785 psi (12.3 MPa)		
		22,774 psi (157 MPa)			54,000 psi (372 MPa)	
$D+L+T_o+E_{ss}$			51,726 psi (357 MPa)			54,000 psi (372 MPa)
$D+L+T_o+W_t$			37,515 psi (259 MPa)			54,000 psi (372 MPa)

Where:
D = Dead Loads
L = Live Loads and Handling Loads
E_{ss} = Seismic Loads
W_t = Tornado Wind/Missile Loads
T_o = Thermal Loads

Source: Appendix 8A.1

Table 8.2-3

DTS Reinforced Concrete Structure - Building Shear Stress

Component	Governing Load	Calculated Concrete Shear Stress	Allowable Concrete Shear Stress
Wall at Roof 540" Level	E_{ss}	55 psi (0.038 MPa)	93 psi (0.64 MPa)
Wall above Mezzanine Floor at 271" Level	E_{ss}	85 psi (0.59 MPa)	93 psi (0.64 MPa)
Walls Between Base and mezzanine Floor Front Wall	W_t	104 psi* (0.72 MPa)	93 psi (0.64 MPa)
Back Wall	W_t	93 psi (0.64 MPa)	93 psi (0.64 MPa)

* Shear Stress on the front concrete wall just over the allowable. Shear reinforcements are calculated per ACI-349, Section 11.5.6.
Required Rebar Area = 0.06 in^2/ft
Provide Rebar Area = 1.58 in^2/ft

Source: Appendix 8A.1

Table 8.2-4

DTS Reinforced Concrete Structure - Building Stability

Loading	Overturning moment	Stabilizing Moment	Factor of Safety
E_{ss}	62,755 kNm (555,434 in-kips)	144,205 kNm (1,276,333 in-kips)	2.3
W_t	70,340 kNm (622,567 in-kips)	138,225 kNm (1,223,409 in-kips)	1.97

Source: Appendix 8A.1

Roof Plate

The maximum calculated seismic accelerations for the roof plate are 0.77g horizontally and 0.4g vertically. An analysis using these seismic loads shows that the roof plate will not lift off of the support beam. The resulting stresses in the support beam due to the vertical seismic loads are also determined and included in the appropriate load combinations. The results show the maximum combined stress of 12,390 psi (85.4 MPa) which is much less than the allowable stress of 40,300 psi (278 MPa). For the load evaluation of the roof plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.77g is assumed to be resisted by the one hundred and ten (110) - 5/8"(16 mm) bolts. The maximum shear stress in the bolt is 6,010 psi (41.4 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa). This analysis is presented in Appendix 8A.1.

Protective Cover.

The protective cover is analyzed in Appendix 8A.1. The seismic loadings do not result in stresses which would result in a loss of confinement.

Mezzanine Plate

The maximum calculated seismic accelerations for the mezzanine plate are 0.5g horizontally and 0.7g vertically. With the mezzanine plate bolted to the support beam, the beam stresses due to the resulting 0.7g vertical acceleration are calculated by factoring the normal operating condition load analysis results reported in Section 8.1.1.5. The maximum combined beam stress obtained from this analysis is 38,250 psi (263.7 MPa) which is less than the allowable stress of 44,160 psi (304.4 MPa). For the load evaluation of the mezzanine plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.5g is assumed to be resisted by the sixty three (63) - 5/8" (16 mm) bolts, the shear stress in the bolt is 2,630 psi (18 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa). This analysis is presented in Appendix 8A.1.

Sliding Door

The maximum calculated seismic accelerations for the sliding door are 0.7 g vertically, 0.37 g longitudinally, and 0.5 g laterally. With the sliding door hanging on the support rails, the door stresses due to the resulting 0.7 g vertical acceleration are calculated by factoring the dead load analysis results reported in Section 8.1.1.6. The maximum combined door shell stress obtained from this analysis is 180 psi (1.24 MPa). For the stress evaluation of the sliding door due to seismic acceleration in the lateral direction, the resulting equivalent static acceleration of 0.5 g is assumed to be resisted by four (4) - 2"(508 mm) dia. pin. The local bearing stresses of the sliding door at the support pin locations are calculated to be 483 psi

(3.33 MPa). For the stress evaluation of the sliding door due to seismic acceleration in the longitudinal direction, axial retainers are included in the design of the sliding door support system to prevent pulling off the door in the axial direction during a postulated seismic event. For a longitudinal load, the stresses induced in the sliding door due to the restraining action of these support rails are evaluated and found to be negligible.

Preparation Area

The Preparation Area structure is not designed to withstand the seismic event. However, since it does not provide shielding or confinement, there are no radiological consequences of losing the Preparation Area structure. Heavy load drops initiated by seismic events or crane failures (e.g. lid drops) will be evaluated to show no fuel failure or significant particulate releases occur on a site specific basis (specific cask designs will be evaluated for the postulated drops).

There are no immediate radiological consequences of losing the Preparation Area structure. The trolleys are designed to prevent tipover of the casks and the trolleys due to the design basis SSE. The Preparation Area can be rebuilt by conventional means if the DTS is to return to normal operation. The concrete base mat is designed to withstand the seismic event.

8.2.4.2 Seismic Effects on HVAC Subsystem

Loss of any of the ventilation components (not the cooling system components) of the HVAC Subsystem results in a loss of the additional level of confinement provided by the system. The physical boundary consisting of the DTS concrete structure, the sliding door, weather protective cover and the HEPA filtration units will continue to provide confinement of radioactive particulate. The duct work associated with the HEPA filtration units will be seismically restrained. It is extremely unlikely that the duct work, filtration system or both exhaust fans will be rendered inoperable during a seismic event.

Failure of both ventilation and cooling system would cause the active cooling process to be disrupted and results in the DTS attempting to re-establish its thermal equilibrium based on passive cooling only. Because of the large thermal mass and inertia of the DTS system: i.e. equipment (76,800 lbs, 34,700 kg); sliding door (85,000 lbs, 38,600 kg); mezzanine floor and its support beams (33,500 lbs, 15,100 kg); roof plate and its support beams (223,600 lbs, 101,400 kg); source cask (60,000 lbs, 27,200 kg); and receiving cask (250,000 lbs, 113,100 kg); the temperature response is very slow. The adiabatic temperature rise in the DTS with the design heat load of 15.5 kW is about 0.68°F (0.38°C) per hr or 47°F (26°C) over a 72 hr period. The actual temperature rise will be considerably less due to heat dissipation through the sliding door, the steel roof plate and the concrete structure.

The exhaust fans are easily accessible for replacement. These are located outside the DTS structure. The exhaust fans and duct work are standard commercial items. With the requirement that spare parts for the exhaust fans are to be stored off-site but easily retrievable, repair of an exhaust fan, if necessary, should occur within a 72 hour recovery period. Once the ventilation system is operable, the air flow, alone, through the DTS will maintain temperature within the DTS and of the spent fuel.

8.2.4.3 Seismic Effects on the Major Operating Equipment

The major operating equipment is designed so that it does not become a projectile due to seismic loads. Also, the upper shield ports are locked in the closed position, to ensure that shielding is not removed during the seismic event. The cranes are also designed so that there is no loss of load. The equipment may or may not be operable by normal means. The operating equipment, with the exception of the Z motion of the fuel handling equipment and the fuel handling grapple can be activated manually or repaired from outside of the TCA or from inside the Roof Enclosure Area.

If the operating equipment cannot be operated by normal means or by the backup means after the seismic event, special equipment can be lowered into the TCA from the Roof Enclosure Area for viewing and special recovery operations. Attachments to the TCA and the penetrations will be installed in the DTS. Recovery equipment will be designed as required.

Cask Transfer Subsystem

The cask trolleys are designed so that they do not allow the cask to tip over due to seismic loading. The trolleys are also designed with special devices which prevent derailing due to the seismic event. When not being moved, the trolleys are normally locked in the Preparation Area and the Lower Access Area which prevents movement of the trolleys due to seismic loading.

The cask trolleys are evaluated for seismic loading in Appendix 8A.2. The locking pins, transmission cradles, anti-derailing devices, guidance rollers and wheels are evaluated for seismic loading.

The stresses on the components which provide a safety related function are summarized in Tables 8.2-5 and 8.2-6.

Cask Mating Subsystem

The components of the Cask Mating Subsystem which perform a lifting function are evaluated in Appendix 8A.3 for normal loading and seismic loading. The components which form part of the load path are designed with a safety factor of 6 to yield strength and 10 to ultimate strength for normal loads. The stresses are summarized in Table 8.2-7.

Shield Plug and Source Cask Lid Handling Subsystem

The components of the Shield Plug and Source Cask Lid Handling Subsystem, including the TC Port Covers and the Upper Shield Port Covers are analyzed in Appendix 8A.4 for normal loading and seismic loading. The resulting stresses are summarized in Table 8.2-8. The upper crane meets the criteria of a Class I crane in accordance with NOG-1 (Reference 8-9).

Table 8.2-5

Summary Source Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 MPa	96 MPa	6 bolts M30 (1.2 in dia.)	3
Plate of anti-taking off device	Seismic	186 MPa	11 MPa	30 mm thick (1.2 in)	17
Bolts of anti-taking off Device	Seismic	287 MPa	19 MPa	4 bolts M16 (0.6 in)	15
Diameter of the locking pin	Seismic	103 MPa	33 MPa	D = 80 mm (3.2 in)	3.1
Wheel diameter	Static	39,449 lbf	24,811 lbf	D = 450 mm (17.7 in)	1.5
Rail width minimum	Static	39,449 lbf	24,811 lbf	b = 40 mm (1.6 in)	1.5
Guidance roller	Static	9,863 lbf	2,481 lbf	D = 150 mm (5.9 in)	3.9
Rail height minimum	Static	9,863 lbf	2,481 lbf	b = 30 mm (1.2 in)	3.9

Table 8.2-6

Summary Receiving Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 MPa	172 MPa	6 bolts M30 (1.2 in dia.)	1.6
Plate of anti-taking off device	Seismic	186 MPa	138 MPa	40 mm thick (1.6 in)	1.3
Bolts of anti-taking off Device	Seismic	287 MPa	153 MPa	4 bolts M24 (1 in)	1.8
Diameter of the locking pin	Seismic	103 MPa	47 MPa	D = 120 mm (4.8 in)	2.2
Wheel diameter	Static	151,141 lbf	79,946 lbf	D = 700 mm (27.6 in)	1.9
Rail width minimum	Static	151,141 lbf	79,946 lbf	b = 100 mm (3.9 in)	1.9
Guidance roller	Static	19,490 lbf	7,995 lbf	D = 180 mm (7.1 in)	2.4
Rail height minimum	Static	19,490 lbf	7,995 lbf	b = 50 mm (1.97 in)	2.4

Table 8.2-7

Summary - Stresses in the Cask Mating Device Lifting Components

Part	Load	Allowable Value (ksi)	Calculated Value(ksi)	Calculated Size
Axis for finger of the overlid diameter	Static	36 (yield) 58 (tensile)	12.6 (shear) 21.0 (shear)	25 mm (1.0 in)
Overlid finger thickness	Static	36 (yield) 58 (tensile)	25.3(bending) 42.2(bending)	50 mm (2 in.)
Plug Pintle thickness	Static	36 (yield) 58 (tensile)	22.3(bending) 37.2(bending)	50 mm (2 in.)
Overlid Pintle Thickness	Static	36 (yield) 58 (tensile)	22.2(bending) 37.0(bending)	40 mm (1.6 in.)

Table 8.2-8

Summary of Results
Shield Plug and Source Cask Lid Handling Subsystem

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Cable Diameter	Static	88,042 N	70,000 N	12 mm (0.48 in.)	1.25
Trolley Wheel Diameter	Static	11,109 lbf	5,540 lbf	139 mm (5.5 in.)	2
Rail Width	Static	11,109 lbf	5,540 lbf	37 mm (1.45 in)	2
Guidance Roller Diameter	Static	994 lbf	496 lbf	36 mm (1.4 in)	2
Anti-Taking Off Device Bolt	Seismic	287 MPa	19 MPa	16 mm dia. (0.63 in)	15
Anti-Taking Off Device Plate Thickness	Seismic	186 MPa	27 MPa	20 mm (0.8 in)	6.8
Anti-Seismic Bumper Bolt Diameter	Seismic	287 MPa	215 MPa	16 mm dia. (0.63 in)	1.3
Finger of grapple axis diameter	Static	200 MPa	15.6 MPa	30 mm (1.2 in)	12.8

Table 8.2-8 (Continued)

Summary of Results
Shield Plug and Source Cask Lid Handling Subsystem

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Grapple finger thickness	Static	399 MPa	36.7 MPa	60 mm (2.4 in)	10.9
Compensator axis diameter	Cable Breaking	93 MPa	42 MPa	40 mm (1.6 in.)	2.2
Trolley locking pin diameter	Seismic	103 MPa	47 MPa	30 mm (1.2 in)	2.2
Upper Shield Port locking pin diameter	Seismic	103 MPa	49 MPa	24 mm (1 in)	2.1
Receiving Cask TC port cover locking pin diameter	Seismic	103 MPa	48 MPa	40 mm (1.6 in.)	2.1
Source Cask TC port cover locking pin diameter	Seismic	103 MPa	47 MPa	50 mm (2 in)	2.2

Fuel Handling Subsystem

The fuel handling subsystem is evaluated in Appendix 8A.5 for lifting and seismic loads. The results of the analysis are summarized in Table 8.2-9. The fuel handling subsystem meets the criteria of a class I crane in accordance with NOG-1.

Table 8.2-9

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Cable Diameter	Static	21,420 N	15,000 N	12 mm (0.48 in.)	1.4
Bridge wheel diameter	Static	12,321 lbf	6,070 lbf	153 mm (6.1 in.)	2
Bridge Rail Width	Static	12,321 lbf	6,070 lbf	37 mm (1.45 in)	2
Trolley Wheel Diameter	Static	7,878 lbf	3,906 lbf	99 mm (3.9 in)	2
Trolley rail width	Static	7,878 lbf	3,906 lbf	37 mm (1.45 in.)	2
Guidance roller diameter	Static	781 lbf	379 lbf	28 mm (1.1 in)	2
Bolt of Bridge anti-taking off device	Seismic	287 MPa	177 MPa	16 mm (0.63 in)	1.6
Plate of Bridge anti-taking off Device	Seismic	186 MPa	114 MPa	t = 30 mm (1.2 in.)	1.6

Table 8.2-9 (Continued)

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Bolt of Trolley anti-taking off Device	Seismic	287 MPa	233 MPa	16 mm (0.63 in.)	1.2
Plate of Trolley anti-Taking Off Device	Seismic	186 MPa	150 MPa	t= 30 mm (1.2 in)	1.2
Bolts of Rotating Platform anti-taking Off Device	Seismic	287 MPa	1321 MPa	16 mm (0.63 in.)	2.1
Plate of Rotating Device Anti-Taking Off Device	Seismic	186 MPa	64 MPa	t = 25 mm (1 in)	2.9
W 6 x 20 Beam of the Platform Anti-taking Off Device	Seismic	186 MPa	68 MPa	W 6 x 20	2.7
Bolts of Bridge anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia. (0.63 in)	1.2

Table 8.2-9 (Continued)

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Bolts of Trolley anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia (0.63 in.)	1.2
PWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	6.7 ksi (shear) 11.2 ksi (shear)	18 mm dia. (0.7 in.)	>6 to yield >10 to ultimate
BWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	5.7 ksi (shear) 9.4 ksi (shear)	18 mm dia. (0.7 in)	>6 to yield >10 to ultimate
Grapple Finger (PWR and BWR)	Static	36 ksi yield 58 ksi tensile	30.5 ksi (bending) 50.9 ksi (bending)	t = 20 mm (0.8 in)	>6 to yield >10 to ultimate

8.2.4.4 Seismic Effects on the Control Subsystem

In case of a seismic event, the Control Center can be damaged. The operator can lose the human/machine interface to monitor and control the DTS process. The PLC's, housed in control cabinets in the Preparation Area, can be damaged by shock or vibration or equipment which has become projectiles in this area. The Control Subsystem can be completely lost in a seismic event. The only requirement for recovery is that the electrical wires of the fuel assembly handling hoist and grapple remain accessible from the Preparation Area, since it is the only equipment without manual backup or accessible motorization.

8.2.4.5 Seismic Effects on CCTV Subsystem

The Control Center, the cameras, lights and rotating devices may get damaged in a seismic event. The attachment of the cameras and lights prevent them from becoming projectiles.

For recovery, fiberscopes can be introduced in the DTS using the different penetrations for the manual backup equipment or using the upper shield port openings.

8.2.4.6 Conclusions

If a seismic event were to occur, the DTS would remain intact, providing shielding and confinement. The DTS might no longer be operable. If required, special equipment could be used to return the fuel to the casks for removal. The HVAC Subsystem can fail due to the seismic event, but can be easily replaced or repaired so that temperatures within the DTS can be maintained. The accident site boundary dose rates would not be significantly larger than those evaluated for normal operations.

8.2.5 Tornado Missiles, Hurricanes and High Winds

The DTS structure is designed to withstand loadings due to tornado missiles, hurricanes or high winds. In the event of a tornado warning or watch, the DTS will be shut down.

Any unsealed or partially sealed casks in the Preparation Area will be moved into the Lower Access Area. The sliding door will be closed. Any fuel in the transfer process will be lowered into the closest (either source or receiving) cask. The TC port covers and upper shield port covers will be closed. The fuel handling grapple will be moved to its highest position. The control center trailer, if deemed appropriate by the utility, may be disconnected and moved to a sheltered area.

The Radiation Monitoring Subsystem and the HVAC Subsystem will continue to operate. Personnel will be evacuated from the site. The site will be locked to prevent unauthorized entry.

Operations will not be restarted until the tornado watch has passed.

8.2.5.1 Tornado and tornado missiles effects on structure

The tornado poses two types of threats to the structures: wind loads (caused by the static pressure drop and the dynamic wind pressure), and missiles lifted by the wind and accelerated into the structures. These two types of threats are considered separately. Detailed calculations are presented in Appendix 8A.1.

Tornado Wind Load

The overturning moment due to the tornado wind pressure is 70,340 kNm (622,567 in-kips) and the building stabilizing moment is 138,225 kNm (1,223,409 in-kips). Since the overturning moment is smaller than the stabilizing moment, the DTS building will not overturn. The resulting factor of safety against overturning effects for DBT wind loads is 1.97. Tornado wind loads will not cause structural damage to the DTS.

Tornado Missiles

The side walls of the reinforced concrete are 36 inches thick (914 mm). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Section 3.0. Nevertheless, in order to demonstrate the adequacy of the DTS design for tornado missiles, detail analysis of the concrete wall has been performed and presented in Section 3.2.1.4. The items evaluated include the resistance to penetration, spalling, scabbing and perforation for a postulated missile impact.

Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the structure cause only superficial damage. The structure thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the structure will not compromise their confinement capability. Local repair to the structure will be performed if required after a missile impact.

Protective Cover

The protective cover is analyzed to verify its adequacy for local barrier impingement of a DBT missile. Detail analysis of the protective cover has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, there is a adequate protection against local design basis tornado missile impact damage. Local bending and distortion to protective cover is acceptable, since the DTS will not be operated during a tornado watch or warning. The effect of the tornado wind load is analyzed in Section 8A.1.6.2.

Sliding Door

The sliding door is evaluated for both tornado wind loads and tornado missiles.

Tornado Wind Load

The sliding door design is evaluated for the effects of tornado wind loads in accordance with the design criteria indicated in Section 3.0. The maximum stresses induced in the sliding door by DBT wind pressure loads are very conservatively calculated using the correlation presented in Roark, page 228, Case 48 (Reference 8.8). The wind pressure load, 419 lbs/ft^2, (0.02 MPa) is applied as a uniform load over the entire surface. Substituting the sliding door physical dimensions and an equivalent uniform distributed load of 419 lbs/ft^2 (0.02 MPa) into the correlation, the maximum calculated shell stress is 564 psi (3.9 MPa). Since the resulting sliding door stress is a small fraction of the code allowable, DBT wind loads are not considered further.

Tornado Missiles

The thickness of the sliding door is 7" (bottom) and 9" (top) (178 mm and 229 mm, respectively). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Section 3.0. Detailed analysis of the sliding door has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the sliding door cause only superficial damage. The sliding door thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the sliding door will not compromise their confinement capability.

The maximum stress induced in the sliding door by the automobile impact load is calculated using the correlation presented in Roark, page 226, Case 38 (Reference 8.7). The impact pressure, 196 psi (1.35 MPa) is applied as a uniform load over the impact area, 4029.4 in^2 (2.6 m^2). Substituting the sliding door physical dimensions and the pressure load into the correction, the maximum calculated stress is 8,704 psi (60 MPa) which is less than the allowable stress of 21,600 psi (148.9 MPa).

Preparation Area

The Preparation Area structure is not designed to withstand tornados. The Preparation Area structure may collapse or be completely removed by the tornado. There are no radiological consequences of losing the Preparation Area.

8.2.5.2 Effect of Tornado on HVAC Subsystem

It is possible that a missile from the tornado event could damage a HVAC component that is located outside the DTS. This includes the exhaust fans and their ductwork, and the three condensing coil units for the air conditioning systems in the DTS.

Damage to the ducting of the exhaust fans is possible and could render the ventilation system inoperable. In this scenario, the cooling system will continue to operate maintaining temperatures in the DTS, assuming that the cooling units have not also been rendered inoperable by the tornado.

The filters are housed within the DTS structure and protected from the tornado missiles.

Loss of the cooling system has an insignificant impact when the ventilation system is operable. The air flow through the DTS will continue to dissipated the spent fuel decay heat.

The damage of the HVAC Subsystem due to the tornado has no radiological consequences since, during tornado conditions, the receiving and source casks will be closed (shield plug and source cask lid installed) and the DTS will not operate if the HVAC Subsystem is destroyed by a tornado. The casks would be removed from the Lower Access Area and inerted after the tornado has passed.

The effect of losing both the cooling system and the ventilation system is discussed in Section 8.2.4.2.

8.2.5.3 Effect of Tornado on Major Operating Subsystem

In the event of a tornado warning or watch, the DTS will be shut down. The fuel assembly in transfer (if any) will be lowered into the nearest cask (source or receiving), the receiving cask shield plug and the source cask lid will be lowered onto the casks. It will take less than 2 hours to get the casks in this "safest" condition, provided that either the primary or backup electrical system is functional.

If the casks are being worked on in the Preparation Area, they will be moved into the Lower Access Area. The sliding door will be closed. In this way, the casks will not tipover due to impact of a tornado missile onto a cask.

All the DTS operating equipment is protected from damage due to tornado missiles, hurricanes and high winds by the DTS structure, with the exception of the motors and jacks used to manipulate the TC Port Covers. These jacks can be removed and replaced in the event of tornado impact. Since the fuel is brought back into the source or receiving casks prior to a tornado, these jacks can be damaged with no effect on fuel recovery, shielding or confinement. The jacks would be repaired prior to resumption of normal operations.

The major operating equipment are all protected by the DTS structure during a tornado event. If the structure is hit by a tornado missile, some of the impact force may by transmitted to the equipment. It is anticipated that these forces will be well below the forces resulting from the seismic event. Transmitted forces to the equipment due to tornado missile impact on the building structure will be evaluated on a site specific basis.

If the TC port cover motors or jacks are hit by a tornado missile, they can be removed and replaced without entering the DTS.

8.2.5.4 Effect of Tornado on Control Subsystem

In the event of a tornado, the fuel is replaced in the casks, the casks are closed and are in a tornado resistant area. There is no need to control or monitor the operations during these events and there is no recovery requirement concerning the Control Subsystem since manual backup can be used to pull the casks outside the Lower Access Area and opening of the sliding door can be locally controlled. The Control Trailer can be disconnected and moved to a tornado resistant area. The PLCs, which are housed in the Preparation Area, can be lost but damage will not result in any unsafe condition for the equipment as the disconnection from the Control Center places the equipment in safety conditions (emergency brakes activated, dampers open...).

8.2.5.5 Closed Circuit Television Subsystem

In the event of a tornado, the CCTV Subsystem is used before the event to place the system in its safety condition. The Preparation Area houses the interface between the cameras, lights, pan and tilt devices and the Control Center. This interface equipment can be lost. Operations which are required to replace the CCTV equipment can be performed on contact.

8.2.5.6 Conclusions

Tornado winds, tornado missiles or hurricanes will not result in a significant radiological release. To aid in recovery operations, the DTS will be shut down in the event of a tornado watch or warning.

8.2.6 Fire

The DTS is designed so that fires within the DTS structure are avoided through choice of materials and proper cooling techniques. To prevent spread of a postulated fire in the DTS such as a small electrical fire, a Fire Suppression Subsystem will be installed in the DTS.

The DTS will be located such that fire or explosion near the DTS is also very unlikely.

8.2.6.1 Fire Effects on Structure

Fire-fighting equipment will be supplied for the building and personal access-way on a site specific basis. Local fire extinguishers will be provided as dictated by site specific conditions.

The DTS is constructed from steel and concrete and there is no scope for major fire. Minor local fires or hydro-carbon fires, will be dealt with by local extinguishers or CO_2 injectors built into electrical control cabinets. There are no foreseeable situations where a minor fire can compromise the containment boundary or the integrity of the structure.

8.2.6.2 Fire Effects on HVAC Subsystem

In the event of a fire, some of the filters could be burned. This accident is bounded by the analysis of the case where the filters have been destroyed presented in Section 8.2.8.

8.2.6.3 Fire Effects on the Major Operating Equipment

All major operating equipment is either accessible or is backed up by manual means, with the exception of the fuel assembly hoist and grapple. There are two independent drive mechanisms for this equipment. The cables are separated to ensure that if there is a fire, the two separate drives will not both be affected and that the fire will not travel along the cable. The CO_2 Fire Suppression Subsystem will be installed above the motors to put out electrical fires.

8.2.6.4 Fire Effects on the Control Subsystem

In the event of a fire in the Control Center, the monitoring system can be lost. A failure of the Control Panel can result in the submittal of an erroneous order to the PLC's which are located in the Preparation Area, but the PLC's software is designed to refuse unsafe orders. Therefore some equipment could be controlled by the PLC without any specific operator order. This would not result in an unsafe operation. The PLCs interlocks are based on sensor information which come directly from the equipment but not from the Control Center. In case of a network failure due to the fire, the PLC's detect the failure and place the equipment in its safety conditions.

In the event of a fire in the Preparation Area, the PLC's are housed in control cabinets which include a temperature monitoring sensor directly linked to the PLCs. In case of abnormal high temperature, the PLC places the equipment in its safe condition disconnecting the link between the Control Subsystem and the mechanical or HVAC equipment at the level of the motorization.

The HVAC Subsystem operations can be resumed immediately in manual mode, not using the dedicated PLC.

The mechanical equipment operations can be resumed after PLC replacement if necessary.

8.2.6.5 Closed Circuit Television Subsystem

In case of fire in the Control Center or in the Preparation Area, the complete remote viewing can be lost. The equipment to be replaced is accessible.

8.2.6.6 Conclusions

A small electrical fire is the only credible fire event in the DTS. This fire results in no significant effect on the DTS structure or equipment. Backup equipment or manual means can be used to completely recover from a fire. The DTS would need to be inspected and repaired prior to return to normal operations. The effect of a fire on the off-site doses is less severe than the hypothetical accident of losing all the HEPA filters which is addressed in Section 8.2.8. The effect of a fire on operator doses will depend on the type of fire, location of the fire, and longevity of the fire. Operator doses due to repairs required to the DTS to bring it back to full operation will be evaluated on a site specific basis.

8.2.7 Fuel Assembly Drop

The fuel assembly grapple and hoist are designed so that a fuel assembly drop is not credible. The fuel assembly grapple and hoist have a safety factor of 6 to yield strength and 10 to ultimate strength. However, for the purpose of determining the maximum potential impact on the immediate environs, this event has been analyzed.

Recovery of a fuel drop will be through extraordinary means and evaluated at the time of the event.

There will be an increase in occupational doses from recovery operations. Direct radiation doses around the DTS will be similar to the expected doses during fuel transfer which are presented in Section 7.3.2.

The potential off site radiological consequences from the single fuel assembly drop are bounded by the loss of confinement barrier analysis presented in Section 8.2.8 and the stuck fuel assembly analysis presented in Section 8.2.2.

8.2.8 Complete loss of HEPA filters and loss of pressure differential

The following postulated accident scenario is not considered to be credible. It is hypothesized solely to demonstrate the inherent safety of the DTS by subjecting it to a set of simultaneous multiple failures, any of which is far beyond the capability of natural phenomena or man-made hazards to produce. A simultaneous failure of protective layers of confinement is postulated to occur by unspecified means.

This is equivalent to loss of HVAC system, loss of HEPA filtration capability, failing the cladding in the loaded fuel assemblies (gap activity release), and finally failing the fuel pellets themselves such that the remaining Kr-85, I-129, and H-3 is released from the fuel matrix. Detailed analysis of this design event is provided in Appendix 8A.6.

Table 7.2-1 lists the nuclides present in a receiving cask containing 21 fuel assemblies. The only nuclide listed in this table which naturally occur in the gaseous state, which could escape from the DTS following a postulated breach of the DTS confinement barrier and which would be significant to dose contributors, are Kr-85, I-129, and H-3. All of the Kr-85, I-129 and H-3 gas is assumed to be released over a period of at least 20 minutes from the DTS.

Most of the fission products are retained within the fuel pellet. It is assumed a fraction, nominally 30% for Kr-85, and 10% for other noble gases is released into the fuel rod plenum and is available for release in the event of a fuel clad failure. Therefore, about

6.78E+08 μCi of H-3, 3.61E+04 μCi of I-129 and 2.39E+10 μCi of Kr-85 could be released from the DTS.

The release is assumed to occur over a period time greater than 20 minutes. The relative concentrations (χ/Q) at 100 meters and 500 meters are determined by the method of Regulatory Guide 1.145 (Reference 8.15). Section 1.1.1, assuming stable (Pasquill F) atmospheric conditions and a slow wind speed of 1 m/s. These conditions provide a high estimate of relative concentration. At 100 meters, χ/Q = 8.65E-03 s/m^3 and at 500 meters, 4.74E-04 s/m^3.

Dose components are calculated following the method of Regulatory Guide 1.109 (Reference 8.16) and utilizing dose conversion factors from EPA Federal Guidance Reports Numbers 11 and 12 (References 8.14 and 8.15):

- Whole body gamma dose from a semi-infinite cloud of Kr-85.
- Whole body dose to an adult due to inhalation of H-3 and thyroid dose due to I-129.

The external dose due to tritium and iodine is negligible compared to the inhalation dose and Kr-85 is not considered for the inhalation dose because it is a noble gas.

Following Regulatory Guide 1.109, the dose for inhalation is calculated by:

$$Dose_{isotope} = R * \chi * DCF_{inhalation\text{-}isotope}$$
$$Dose_{H\text{-}3} = R * \chi/Q * Q * DCF_{inhalation\text{-}H\text{-}3}$$

$$Dose_{H\text{-}3} = (8000\ m^3/yr)*(8.65E\text{-}03\ sec/m^3)*(6.78E{+}08\ \mu Ci)*(0.0641\ mrem/\mu Ci)*(3.1706E\text{-}08\ yr/sec)$$
$$Dose_{H\text{-}3} = 95.2\ mrem$$

Similarly, for air immersion:

$$Dose_{air\ imm} = \chi * DCF_{air\ immersion} = Q * \chi/Q * DCF_{air\ immersion}$$
$$Dose_{Kr\text{-}85} = (6.57E\text{-}06\ \mu Ci)*(8.65E\text{-}03\ sec/m^3)*\{2.57E{+}07\ (mrem/yr)/(\mu Ci/cm^3)\}*(3.1706E\text{-}08\ yr/sec)*(1E\text{-}06\ m^3/cm^3)$$

$$Dose_{Kr\text{-}85} = 169\ mrem$$

These calculations were performed for H-3, Kr-85 and I-129. The results are shown in Table 8.2-10. It can be seen that the dose is well below the 5 Rem limit of 10CFR72.106 at the minimum controlled boundary.

Table 8.2-10

Confinement Failure Dose

Isotope	Inhalation Dose (mrem)	Immersion Dose (mrem)
Complete Failure	at 100 meters	
H-3	95.2	7E-03
Kr-85	---	169
I-129	457	8E-04
Total	552	169
Complete Failure	at 500 meters	
H-3	5.22	4E-04
Kr-85	---	9.25
I-129	25.1	4E-05
Total	30	9.3

8.2.9 Loss of a Shield Plug or Source Cask Lid

The shield plug and source cask lid handling subsystem is designed as single failure proof. The upper crane and the load path items of the cask mating subsystem are designed with a safety factor of 6 to yield and 10 to ultimate strength. In addition, interlocks are provided which prevent opening of the grapple if the grapple is under load or if the grapple is positioned incorrectly for release of the load. Therefore, a loss of a shield plug or a source cask lid during operations is not considered credible. However, for completeness, recovery methods for this hypothetical accident is addressed below.

If a source cask lid is damaged and cannot be replaced on the cask, the fuel must be completely transferred to the receiving cask. The shield plug will be installed on the receiving cask, and the source cask will be removed from the Lower Access Area without the lid on. The receiving cask would then be removed from the Lower Access Area. The source cask lid would be retrieved from the TCA after appropriate decontamination measures, by entering the TCA through the Lower Access Area.

If a receiving cask shield plug is damaged or cannot be replaced on the cask, it is a much more significant event. All of the fuel must be transferred to source casks to be removed from the DTS. Procedures to be followed would be similar to the event of a stuck fuel assembly described in Section 8.2.2.

There is no time limit in which to recover the fuel, since the fuel is shielded and provided that the HVAC System is working, fuel cladding temperatures will remain well below the temperature at which fuel cladding failure would occur.

A fully shielded tent would be built in the Preparation Area, enclosing the sliding door and providing enough room to completely enclose the source cask and its trolley. The Preparation Area and all surrounding areas would be evacuated.

The source cask would be loaded with fuel emptied from the receiving cask. The lid would be placed on the source cask. The source cask would be disengaged from the cask mating subsystem and the trolley would be unlocked. These operations would be done remotely, without entering the Lower Access Area. Using bypasses, the sliding door would be opened. Radiation levels outside and inside of the shielding tent would be carefully monitored. The source cask and the trolley would be moved into the shielding tent, and the sliding door would be closed. These operations would also be performed remotely.

Using the standard operating procedures, the source cask would be bolted, tested, inspected and removed from the DTS. After the source cask is unloaded from the trolley, another source cask would be placed onto the source cask trolley and secured. The source cask and trolley would be moved into the shielding tent. While carefully monitoring radiation levels in and around the shielding tent, the sliding door would be opened. The recovery cask would be moved into the Lower Access Area and positioned below the source cask mating subsystem. The sliding door would be closed. These operations would be performed remotely. Source casks would be loaded and removed from the DTS using this approach until the receiving cask has been completely emptied.

After all of the fuel has been removed from the DTS, and the TCA and Lower Access Area have been decontaminated, the shield plug would be repaired or removed as necessary allowing personnel access into the TCA.

8.3 Site Characteristics Affecting Safety Analysis

A site has not been selected for the Dry Transfer System at this time. The bounding site characteristics are discussed in Chapter 3, Principal Design Criteria.

8.4 References

8.1 Nuclear Regulatory Commission, Regulatory Guide 3.48, Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)

8.2 American Nuclear Society, ANSI/ANS 57.9-1992, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type).

8.3 "Topical Report for the TN-24 Storage Cask", Transnuclear, June 1989.

8.4 EPRI Report NP-5128.

8.5 Multipurpose Canister Implementation Program Conceptual Design Phase Report, Final Draft, USDOE A200000000-00811-5705, September 30, 1993.

8.6 PNL Report 8451.

8.7 Roark, Formulas for Stress and Strain, Fourth Edition.

8.8 ANSYS Engineering Analysis Systems User's Manual, Volume 1 and 2, Revision 4.4A.

8.9 American Society of Mechanical Engineers, Nuclear Power Plant Air Cleaning Units and Components, ASME N509.

8.10 American Society of Mechanical Engineers, Code on Nuclear Air and Gas Treatment, ASME AG-1.

8.11 J.R. McDonald, K.C. Mehta, and J.E. Minor, "Design Guidelines for Wind Resistant Structures, " Institute for Disaster Research and Department of Civil Engineering, Texas Tech University, Lubbock, Texas, June 1975.

8.12 Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1, 1983.

8.13 Nuclear Regulatory Commission, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I" Revision 1, October 1977

8-14 Environmental Protection Agency Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion," EPA-520/1-88-020, September, 1988.

8-15 Environmental Protection Agency Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil" EPA-402-R-93-081, September, 1993.