B2.4.1.4 Fault Tree Model

The top event is "Spurious Movement of the CTT during Cask Loading in the Cask Preparation Room" (Figure B2.4-3). This can occur if the control system initiates a spurious signal and both of the pin limit switches fail, or the operator initiates a command to move the CTT and both of the pin limit switches fail. A third failure mode is the mechanical failure of the main supply valve in conjunction with a spurious signal from the control system to initiate movement or failures of the control valves or the valve to the air bags.

A conservative mission time for this operation has been set at one hour.

B2.4.1.5 Basic Event Data

Table B2.4-1 contains a list of basic events used in the fault trees (Figure B2.4-3 and B2.4-4) for spurious movement of the CTT in the preparation area during cask loading.

Table B2.4-1. Basic Event Probabilities for Spurious Movement of the CTT during Cask Loading

Name	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CTT-SV401-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT--CT001---CT--SPO	3	2.270E-005	0.000E+000	2.270E-005	1.000E+000
200-CTT--HC001---HC--SPO	3	5.230E-007	0.000E+000	5.230E-007	1.000E+000
200-CTT-SV301-SV-SPO	3	4.090E-007	0.000E+000	4.090E-007	1.000E+000
200-CTT--ZS301---ZS--FOD	1	2.930E-004	2.930E-004	0.000E+000	0.000E+000
200-CTT--ZS302---ZS--FOD	1	2.930E-004	2.930E-004	0.000E+000	0.000E+000
200-CTT-FWDREVM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-FWDREVM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-OPSPURMOVE01-HFI-NOD	1	1.000E-004	1.000E-004	0.000E+000	0.000E+000
200-CTT-ZS301-SW-CCF	C	1.377E-005	---	---	---

NOTE: [a]For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time. See Table 6.3-1 for definitions of calculation types.
Calc. = calculation; Fail. = failure; Miss. = mission; Prob. = probability.

Source: Original

B2.4.1.5.1 Human Failure Events

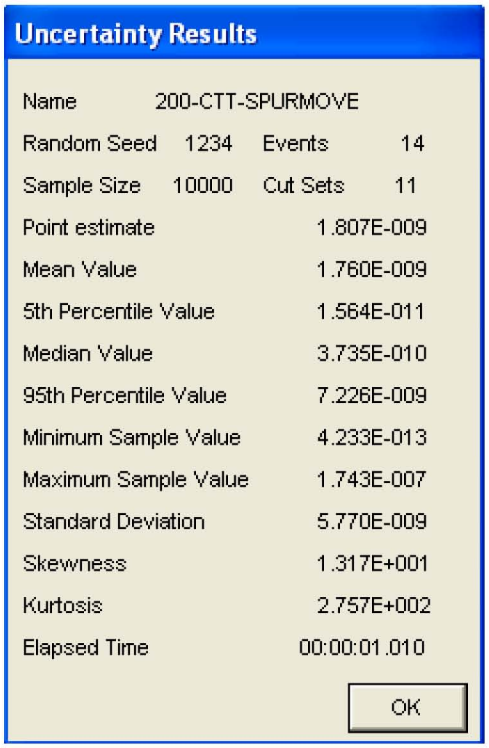
One operator error involves initiation of spurious movement. The operator error is 200-OPSPURMOVE01-HFI-NOD.

B2.4.1.5.2 Common-Cause Failures

One CCF was added to the fault tree to account for the failure of both restraint pin limit switches. An alpha factor of 0.047 was used to determine the common-cause value using two of two as the failure criteria (Table C3-1, CCCG = 2). The CCF is 200-CTT-ZS301-SW-CCF.

B2.4.1.6 Uncertainty and Cut Set Generation Results

Figure B2.4-1 contains the uncertainty results obtained from running the fault tree for the "Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading" fault tree. Figure B2.4-2 provides the cut set generation results for the "Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading" fault tree, calculated using a 1E-15 cutoff.



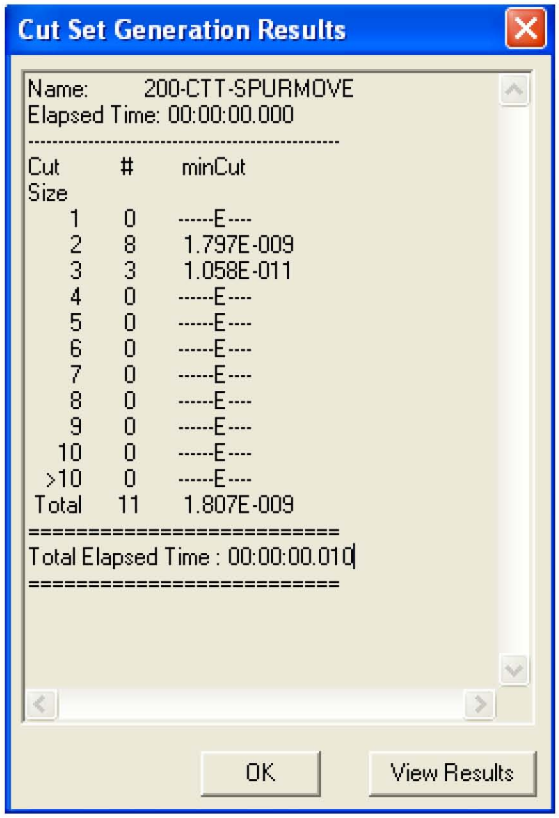
Uncertainty Results

Name	200-CTT-SPURMOVE		
Random Seed	1234	Events	14
Sample Size	10000	Cut Sets	11
Point estimate			1.807E-009
Mean Value			1.760E-009
5th Percentile Value			1.564E-011
Median Value			3.735E-010
95th Percentile Value			7.226E-009
Minimum Sample Value			4.233E-013
Maximum Sample Value			1.743E-007
Standard Deviation			5.770E-009
Skewness			1.317E+001
Kurtosis			2.757E+002
Elapsed Time			00:00:01.010

OK

Source: Original

Figure B2.4-1. Uncertainty Results of the Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading Fault Tree



Source: Original

Figure B2.4-2. Cut Set Generation Results for the Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading Fault Tree

B2.4.1.7 Cut Sets

Table B2.4-2 contains the cut sets for the "Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading" fault tree. The total probability per cask loading is 1.81E-009.

Table B2.4-2. Cut Sets for Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading

Fault Tree	% Cut Set	Prob./ Frequency	Basic Event	Description	Event Prob.
200-CTT-SPURMOVE	76.21	1.377E-09	200-CTT-ZS301-SW-CCF	Common-cause failure of limit switches	1.377E-05
	17.30	3.133E-10	200-OPSPURMOVE01-HFI-NOD	Operator initiates spurious movement	1.000E-04
			200-CTT--CT001---CT--SPO	On-board controller initiates spurious signal	2.270E-05
			200-CTT-ZS301-SW-CCF	Common-cause failure of limit switches	1.377E-05

Table B2.4-2. Cut Sets for Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading (Continued)

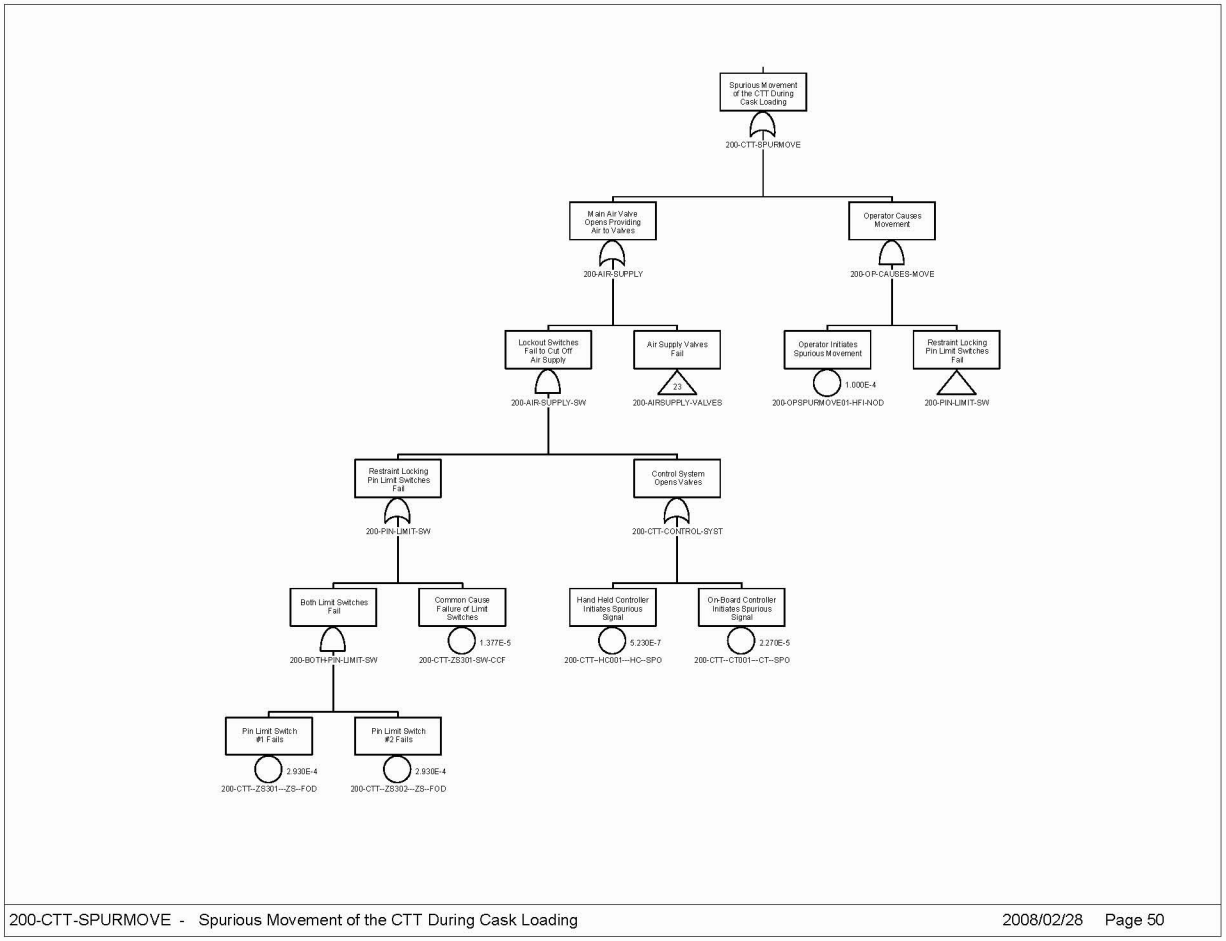
Fault Tree	% Cut Set	Prob./ Frequency	Basic Event	Description	Event Prob.
	1.10	1.992E-11	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-07
			200-CTT-SVROTM1-SV-FOH	Failure of solenoid valve providing rotation to motor 1	4.870E-05
	1.10	1.992E-11	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-07
			200-CTT-SV401-SV-FOH	Failure of air supply solenoid valve for air bags	4.870E-05
	1.10	1.992E-11	200-CTT-FWDREVM2-SV-FOH	Failure of solenoid valve providing fwd/rev to motor 2	4.870E-05
			200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-07
	1.10	1.992E-11	200-CTT-FWDREVM1-SV-FOH	Failure of solenoid valve providing fwd/rev to motor 1	4.870E-05
			200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-07
	1.10	1.992E-11	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-07
			200-CTT-SVROTM2-SV-FOH	Failure of solenoid valve providing rotation to motor 2	4.870E-05
200-CTT-SPURMOVE (continued)	0.47	8.585E-12	200-CTT--ZS301---ZS--FOD	Pin limit switch #1 fails	2.930E-04
			200-CTT--ZS302---ZS--FOD	Pin limit switch #2 fails	2.930E-04
			200-OPSPURMOVE01-HFI-NOD	Operator initiates spurious movement	1.000E-04
	0.40	7.202E-12	200-CTT--HC001---HC--SPO	Hand held controller initiates spurious signal	5.230E-07
			200-CTT-ZS301-SW-CCF	Common-cause failure of limit switches	1.377E-05
	0.11	1.949E-12	200-CTT--CT001---CT--SPO	On-board controller initiates spurious signal	2.270E-05
			200-CTT--ZS301---ZS--FOD	Pin limit switch #1 fails	2.930E-04
			200-CTT--ZS302---ZS--FOD	Pin limit switch #2 fails	2.930E-04
	0.00	4.490E-14	200-CTT--HC001---HC--SPO	Hand held controller initiates spurious signal	5.230E-07
			200-CTT--ZS301---ZS--FOD	Pin limit switch #1 fails	2.930E-04
			200-CTT--ZS302---ZS--FOD	Pin limit switch #2 fails	2.930E-04
Total	1.811E-009				

NOTE: Prob. = probability

Source: Original

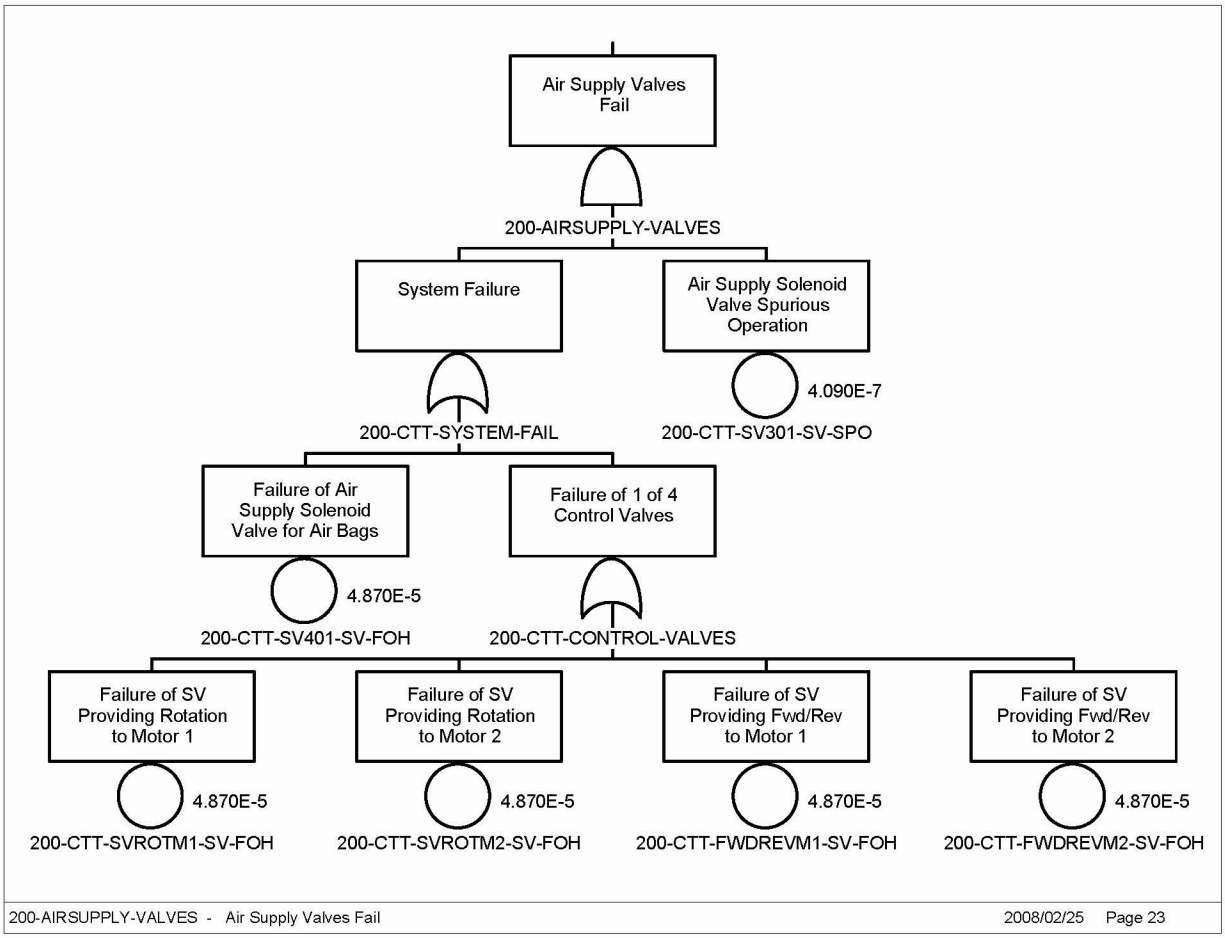
B2.4.1.8 Fault Trees

The fault trees for spurious movement of the CTT during cask loading are shown in Figures B2.4-3 and B2.4-4.



Source: Original

Figure B2.4-3. Fault Tree for Spurious Movement of the CTT in the Cask Preparation Room during Cask Loading



Source: Original

Figure B2.4-4. Fault Tree for Air Supply Valves Fail

B2.4.2 Spurious Movement of the CTT in the Preparation Area during Cask Preparation

B2.4.2.1 Description

This fault tree describes spurious movement of the CTT during cask preparation to satisfy ESD-03 pivotal event, "Side Impact to Transportation Cask." The top event is "Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation" which is defined as unplanned movement of the CTT while the cask is being prepared for movement to the Cask Unloading Room by unbolting the lid and installing the lid adapter. This fault tree is shown in Figure B2.4-7.

During this operation, the locking pins have been installed and the limit switches are closed. Spurious movement can be caused by multiple equipment failures or by operator error. For equipment failures to cause spurious movement the main air supply valve must open to supply air to the air bags to levitate the CTT. This can occur through failure of the main air supply valve coupled with spurious commands from the control system or failure of the control valves.

Alternatively, the operator can initiate spurious movement since at this stage of the operation there are no preventive interlocks.

B2.4.2.2 Success Criteria

The success criterion is that the CTT remain motionless during cask preparation. Movement of the CTT during this operation could cause impact to occur resulting in damage to the transportation cask.

B2.4.2.3 Design Requirements and Features

There are no design requirements or features for this operation.

B2.4.2.4 Fault Tree Model

The top event in this fault tree is "Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation" (Figure B2.4-7). This can occur through spurious signals from the control system, spurious operation of the main air supply valve, failure of the control valves, or operator error initiating CTT movement.

B2.4.2.5 Basic Event Data

Table B2.4-3 contains a list of basic events used in the fault tree (Figure B2.4-7) for the "Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation."

Table B2.4-3. Basic Event Probabilities for Spurious movement of the CTT in the Cask Preparation Room during Cask Preparation

Name	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CTT--CT001---CT--SPO	3	2.270E-005	0.000E+000	2.270E-005	1.000E+000
200-CTT--HC001---HC--SPO	3	5.230E-007	0.000E+000	5.230E-007	1.000E+000
200-OPSPURMOVE01-HFI-NOD	1	1.000E-004	1.000E-004	0.000E+000	0.000E+000
200-CTT-SV401-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SV301-SV-SPO	3	4.090E-007	0.000E+000	4.090E-007	1.000E+000
200-CTT-FWDREVM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-FWDREVM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000

NOTE: [a] For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time.
Calc. = calculation; Fail. = failure; Miss. = mission; Prob. = probability.

Source: Original

B2.4.2.5.1 Human Failure Events

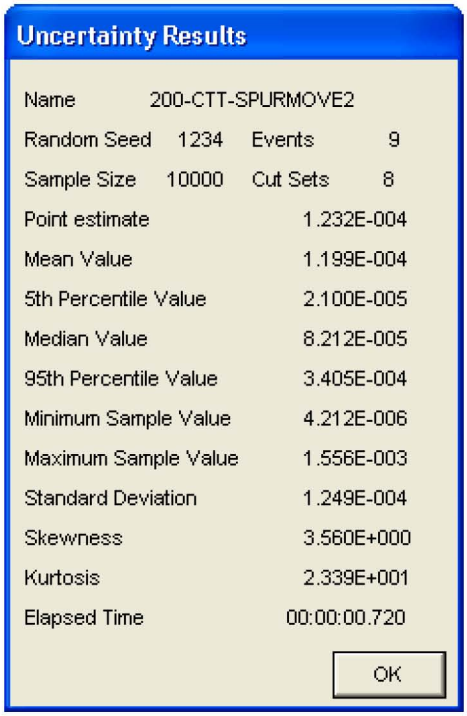
One operator error (200-OPSPURMOVE01-HFI-NOD) involves initiation of spurious movement.

B2.4.2.5.2 Common-Cause Failures

There are no CCFs associated with this fault tree.

B2.4.2.6 Uncertainty and Cut Set Generation Results

Figure B2.4-5 contains the uncertainty results obtained from running the fault tree for spurious movement of the CTT in "Spurious movement of the CTT in the Cask Preparation Room during Cask Preparation." Figure B2.4-6 provides the cut set generation results for "Spurious movement of the CTT in the Cask Preparation Room during Cask Preparation" fault tree, calculated using a 1E-15 cutoff.



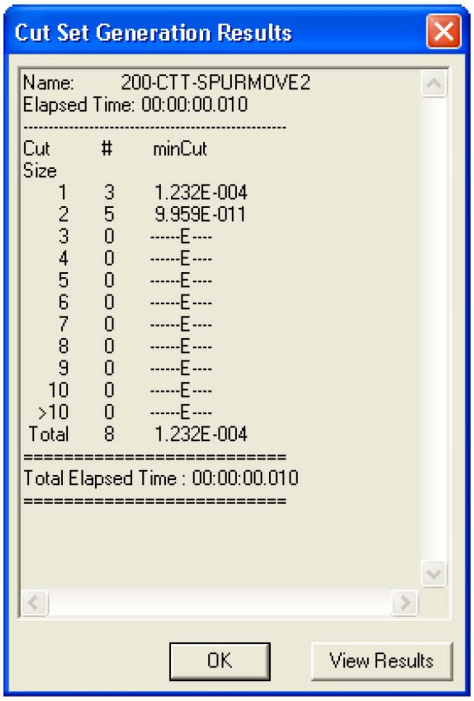
Uncertainty Results

Name	200-CTT-SPURMOVE2		
Random Seed	1234	Events	9
Sample Size	10000	Cut Sets	8
Point estimate			1.232E-004
Mean Value			1.199E-004
5th Percentile Value			2.100E-005
Median Value			8.212E-005
95th Percentile Value			3.405E-004
Minimum Sample Value			4.212E-006
Maximum Sample Value			1.556E-003
Standard Deviation			1.249E-004
Skewness			3.560E+000
Kurtosis			2.339E+001
Elapsed Time			00:00:00.720

OK

Source: Original

Figure B2.4-5. Uncertainty Results of the Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation



Source: Original

Figure B2.4-6. Cut Set Generation Results for Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation

B2.4.2.7 Cut Sets

Table B2.4-4 contains the cut sets for the "Spurious movement of the CTT in the Cask Preparation Room during Cask Preparation" fault tree. The total probability per cask is 1.23E-004 with operator initiation of spurious movement the dominant cause of movement during cask preparation.

Table B2.4-4. Cut Sets for Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-CTT-SPURMOVE2	81.16	1.000E-004	200-OPSPURMOVE01-HFI-NOD	Operator initiates spurious movement	1.000E-004
	18.42	2.270E-005	200-CTT--CT001---CT--SPO	On-board controller initiates spurious signal	2.270E-005
	0.42	5.230E-007	200-CTT--HC001---HC--SPO	Hand held controller initiates spurious signal	5.230E-007
	0.00	1.992E-011	200-CTT-FWDREVM2-SV-FOH	Failure of solenoid valve providing fwd/rev to motor 2	4.870E-005
			200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-007

Table B2.4-4. Cut Sets for Spurious Movement of the CTT in the Cask Preparation Room during Cask Preparation (Continued)

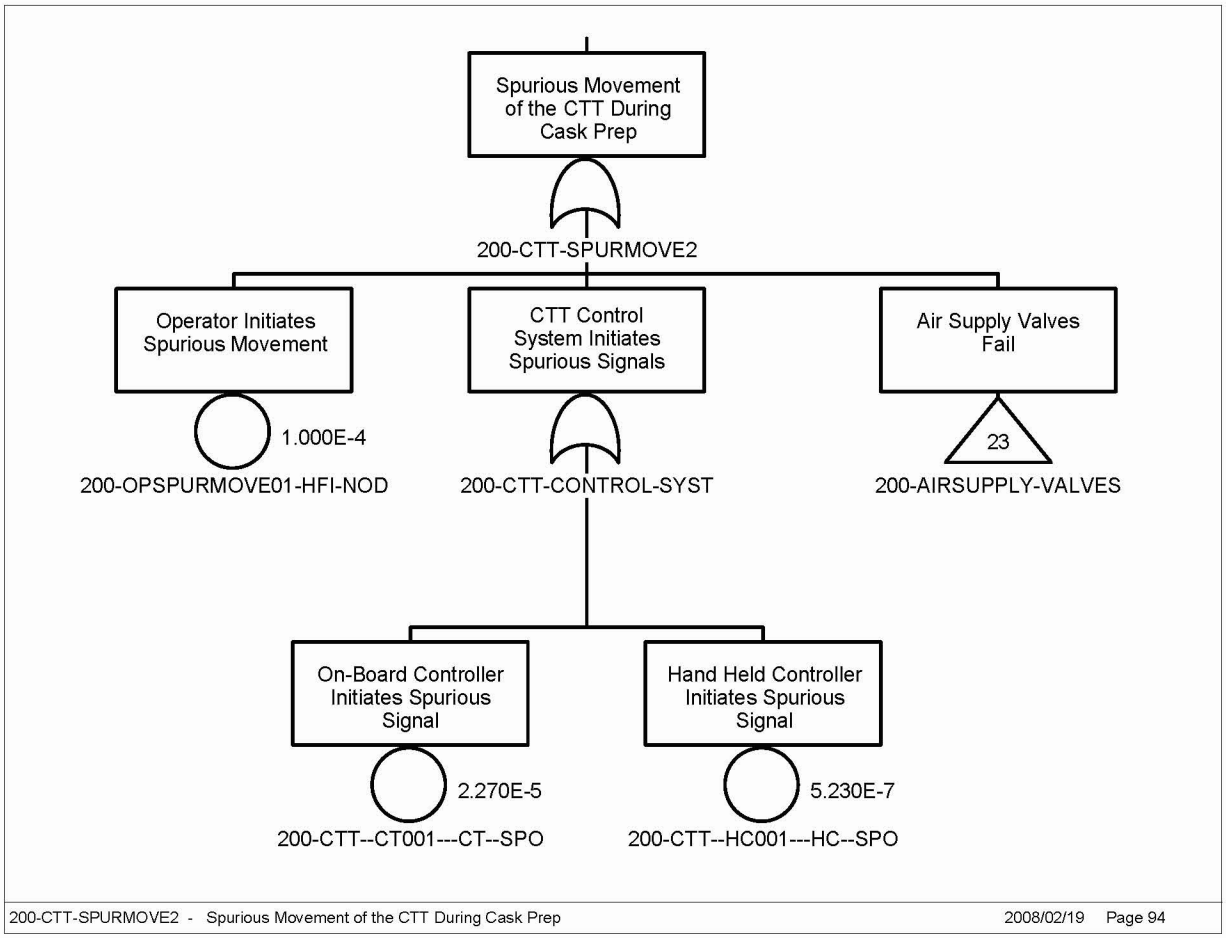
Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-CTT-SPURMOVE2 (continued)	0.00	1.992E-011	200-CTT-FWDREVM1-SV-FOH	Failure of solenoid valve providing fwd/rev to motor 1	4.870E-005
			200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-007
	0.00	1.992E-011	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-007
			200-CTT-SV401-SV-FOH	Failure of air supply solenoid valve for air bags	4.870E-005
	0.00	1.992E-011	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-007
			200-CTT-SVROTM1-SV-FOH	Failure of solenoid valve providing rotation to motor 1	4.870E-005
	0.00	1.992E-011	200-CTT-SV301-SV-SPO	Air supply solenoid valve spurious operation	4.090E-007
			200-CTT-SVROTM2-SV-FOH	Failure of solenoid valve providing rotation to motor 2	4.870E-005
Total	1.232E-004				

NOTE: Prob. = probability

Source: Original

B2.4.2.8 Fault Trees

The fault trees for "Spurious Movement of the CTT in the Cask Preparation Area during Cask Preparation" are shown in Figures B2.4-7. Note that the transfer gate 23 in Figure B2.4-7 refers to the fault tree in Figure B2.4-4.



Source: Original

Figure B2.4-7. Fault Tree for Spurious Movement of the CTT during Cask Preparation

B2.4.3 Collision of CTT during Cask Transfer

B2.4.3.1 Description

This fault tree considers the potential for the CTT to collide into a structure or object while moving a cask from the preparation area to the transfer area to satisfy ESD-04, pivotal event "CTT collision with Another Vehicle, Facility Structure, or Equipment." The top event is "CTT Collision into Structure." This fault tree is shown in Figures B2.4-10 and B2.4-11.

Two primary causes of a collision are operator initiated (possibly through inattention) or failure of the CTT to stop. Movement in the wrong direction as a contributing factor is negated by the use of guide rails forcing the CTT to only move forward and backward. A runaway condition is prevented by the control system, designed to give a proportional signal to the air valve that produces a speed range of only 0 to 10 ft/min, and an in-line factory set mechanical throttle valve that limits the speed to 10 ft/min in the event the control system fails. In the event both of these devices fail, the stop functions must also fail. Since all three functions must fail for a runaway condition, the primary events leading to a collision are operator error or failure to stop.

Failure to stop the CTT requires that failure of the normal stop function, deadman switches, and the air supply valve all fail to close on demand. The emergency stop buttons, one on the pendant and one on the CTT, must also fail; however, because these are recovery actions to be taken by the operator, the emergency stop functions are not credited in the fault tree.

B2.4.3.2 Success Criteria

The success criterion for this event is that the CTT does not experience a collision with any object, including the shield door, during transfer of a cask from the Cask Preparation Room to the Cask Unloading Room. A collision of the CTT could cause damage to the transportation cask.

B2.4.3.3 Design Requirements and Features

The design feature is the deadman switches on the pendant control that must be pressed for air to be supplied to the CTT to provide motive power. There are no requirements for this operation.

B2.4.3.4 Fault Tree Model

The top event of the fault tree is a collision of the CTT into an object or structure during transfer of a cask from the Cask Preparation Room to the Cask Unloading Room (Figures B2.4-10 and B2.4-11). This may occur through operator error or equipment failure of the normal or emergency stop functions. A conservative mission time for this operation has been set at one hour.

B2.4.3.5 Basic Event Data

Table B2.4-5 contains a list of basic events used in the "Collision of CTT during Cask Transfer" fault tree (Figures B2.4-10 and B2.4-11).

Table B2.4-5. Basic Event Probability for Collision of CTT during Cask Transfer

Name	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CTT--DSW000--ESC-CCF	C	1.175E-005	—	—	—
200-CTT--DSW001--ESC-FOD	1	2.500E-004	2.500E-004	0.000E+000	0.000E+000
200-CTT--DSW002--ESC-FOD	1	2.500E-004	2.500E-004	0.000E+000	0.000E+000
200-CTT--HC021---HC--FOD	1	1.740E-003	1.740E-003	0.000E+000	0.000E+000
200-CTT--SV601---SV--FOD	1	6.280E-004	6.280E-004	0.000E+000	0.000E+000
200-CTT--SV602---SV--FOD	1	6.280E-004	6.280E-004	0.000E+000	0.000E+000
200-OPCTTCOLLID2-HFI-NOD	1	1.000E-003	1.000E-003	0.000E+000	0.000E+000

NOTE: [a] For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time. See Table 6.3-1 for definitions of calculation types.
Calc. = calculation; Fail. = failure; Miss. = mission; Prob. = probability.

Source: Original

B2.4.3.5.1 Human Failure Events

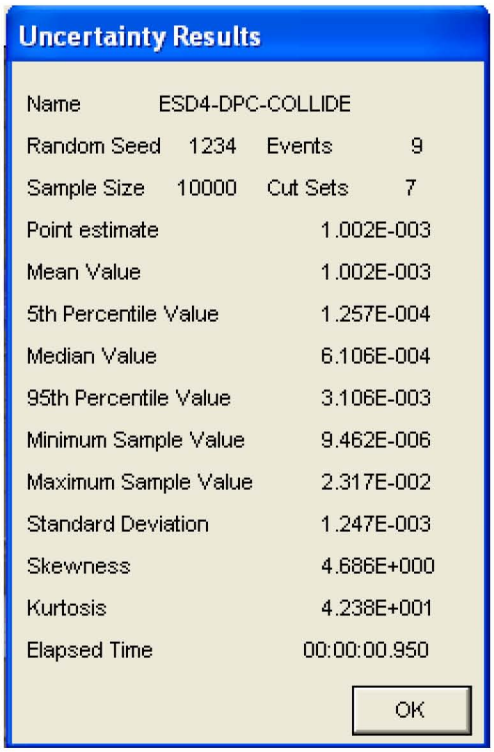
A collision may be caused by an operator error (200-OPCTTCOLLID2-HFI-NOD) failing to stop the CTT.

B2.4.3.5.2 Common-Cause Failures

One CCF (200-CTT--DSW000--ESC-CCF) involves the failure of both deadman switches, both of which must be pressed for the main air supply valve to open. An alpha factor of 0.047 was used to determine the CCF value using two of two as the failure criteria (Table C3-1, CCCG = 2).

B2.4.3.6 Uncertainty and Cut Set Generation Results

Figure B2.4-8 contains the uncertainty results obtaining from running the fault trees for the "Collision of CTT during Cask Transfer" fault tree. Figure B2.4-9 provides the cut set generation results for "Collision of CTT during Cask Transfer" fault tree, calculated using a 1E-15 cutoff.



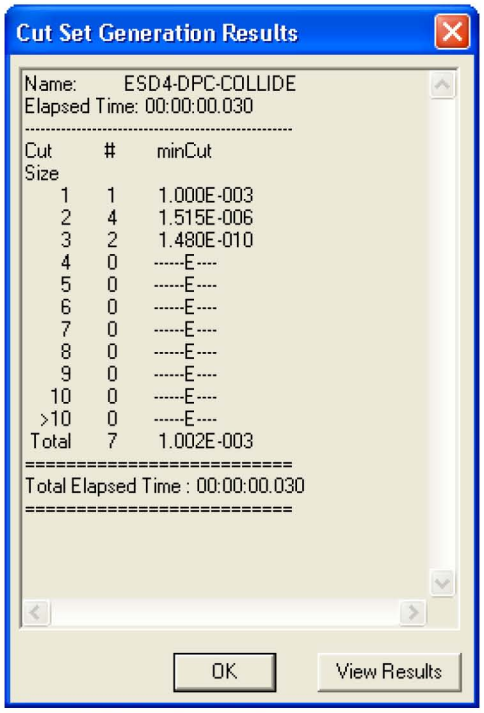
Uncertainty Results

Name	ESD4-DPC-COLLIDE		
Random Seed	1234	Events	9
Sample Size	10000	Cut Sets	7
Point estimate			1.002E-003
Mean Value			1.002E-003
5th Percentile Value			1.257E-004
Median Value			6.106E-004
95th Percentile Value			3.106E-003
Minimum Sample Value			9.462E-006
Maximum Sample Value			2.317E-002
Standard Deviation			1.247E-003
Skewness			4.686E+000
Kurtosis			4.238E+001
Elapsed Time			00:00:00.950

OK

Source: Original

Figure B2.4-8. Uncertainty Results for the Collision of CTT during Cask Transfer Fault Tree



Source: Original

Figure B2.4-9. Cut Set Generation Results for the Collision of CTT during Cask Transfer Fault Tree

B2.4.3.7 Cut Sets

Table B2.4-6 contains the cut sets for collision of the "Collision of CTT during Cask Transfer" from the Cask Preparation Room to the Cask Unloading Room fault trees. The total frequency per cask is 1.00E-003 with operator error the dominant cause of collision.

Table B2.4-6. Cut Sets for Collision of the Collision of CTT during Cask Transfer

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
ESD4-DPC-COLLIDE	99.85	1.000E-003	200-OPCTCOLLIDE2-HFI-NOD	Operator causes CTT collision	1.000E-003
	0.11	1.093E-006	200-HTC--HC021---HC--FOD	Remote stop control transmits wrong instruction	1.740E-003
			200-HTC--SV601---SV--FOD	Main air supply valve fails on demand	6.280E-004
	0.04	3.944E-007	200-HTC--SV601---SV--FOD	Main air supply valve fails on demand	6.280E-004
			200-HTC--SV602---SV--FOD	Solenoid valve fails to close	6.280E-004

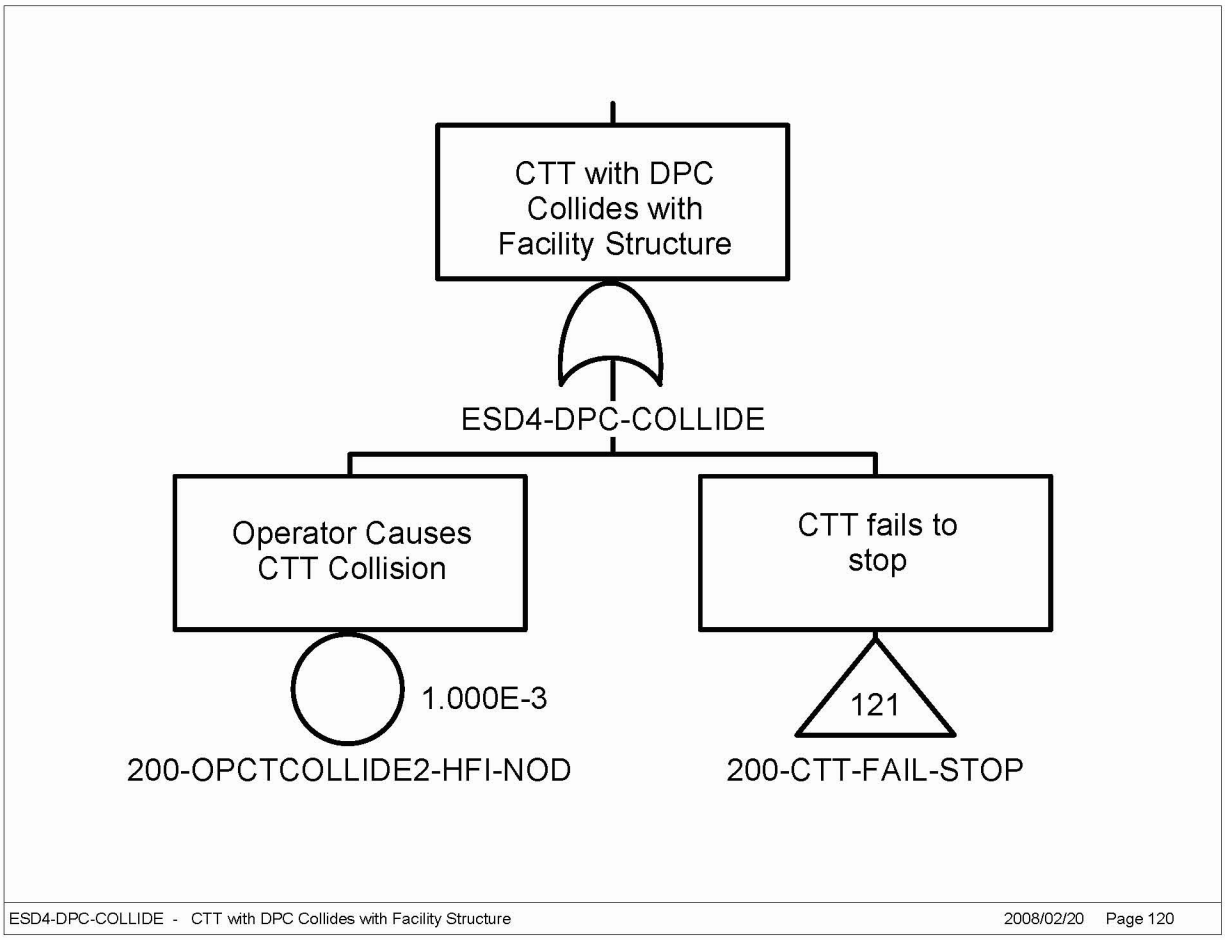
Table B2.4-6. Cut Sets for the Collision of CTT during Cask Transfer (Continued)

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
ESD4-DPC-COLLIDE (continued)	0.00	2.045E-008	200-CTT--DSW000--ESC-CCF	Common-cause failure of deadman switches	1.175E-005
			200-HTC--HC021---HC--FOD	Remote stop control transmits wrong instruction	1.740E-003
	0.00	7.379E-009	200-CTT--DSW000--ESC-CCF	Common-cause failure of deadman switches	1.175E-005
			200-HTC--SV602---SV--FOD	Solenoid valve fails to close	6.280E-004
	0.00	1.088E-010	200-CTT--DSW001--ESC-FOD	Deadman switch #1 fails closed	2.500E-004
			200-CTT--DSW002--ESC-FOD	Deadman switch #2 fails closed	2.500E-004
			200-HTC--HC021---HC--FOD	Remote stop control transmits wrong instruction	1.740E-003
	0.00	3.925E-011	200-CTT--DSW001--ESC-FOD	Deadman switch #1 fails closed	2.500E-004
			200-CTT--DSW002--ESC-FOD	Deadman switch #2 fails closed	2.500E-004
			200-HTC--SV602---SV--FOD	Solenoid valve fails to close	6.280E-004
Total	1.002E-003				

NOTE: CTT = cask transfer trolley; Prob. = probability

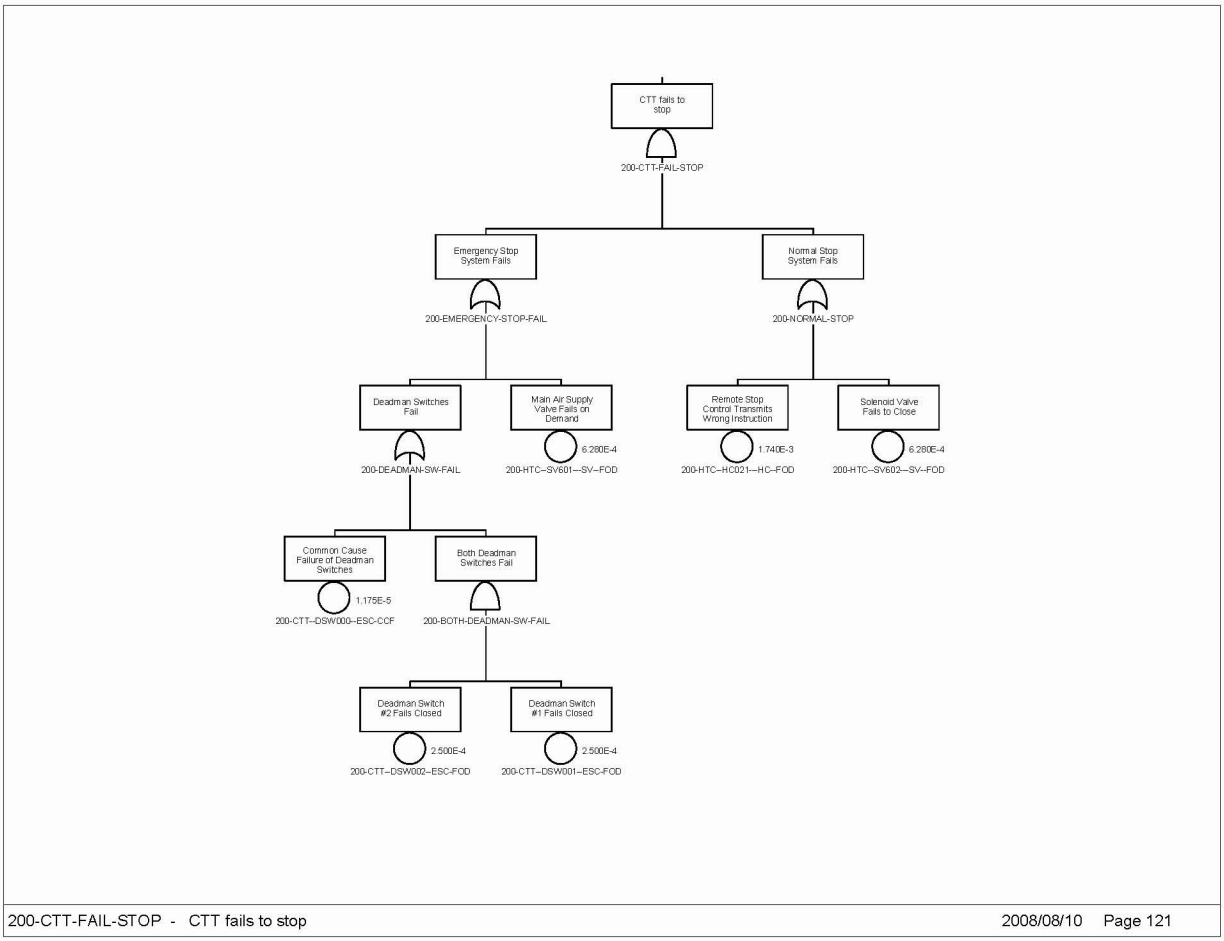
Source: Original

B2.4.3.8 Fault Trees



Source: Original

Figure B2.4-10. Fault Tree for Collision of the Collision of CTT during Cask Transfer Sheet 1



Source: Original

Figure B2.4-11. Fault Tree for Collision of the Collision of CTT during Cask Transfer Sheet 2

B2.4.4 Spurious Movement of the CTT in the Cask Unloading Room

B2.4.4.1 Description

This fault tree describes spurious movement of the CTT during extraction, or unloading, of the canister from the transportation cask on the CTT to satisfy ESD-06, "Canister Impact Due to Movement of CTT during Lift." The top event is "Spurious Movement during Canister Transfer" which is defined as unplanned movement of the CTT while the canister is being removed from the transportation cask. This fault tree is shown in Figures B2.4-14.

Spurious movement is prevented in the Cask Unloading Room by disconnecting the air supply hose from the CTT. The shield door interlock (external to the CTT) must be closed to allow the port slide gate to open and canister extraction to begin. Thus, if the shield door is not closed the slide gate cannot open and extraction of the canister cannot begin. With the air supply located outside the transfer room, the operator must disconnect the air supply hose to the CTT for the shield door to be closed, or the shield door cuts through the hose upon closing. If the operator fails to disconnect the hose, movement may be initiated by failure of the door interlocks and the

control system causing the main air supply valve to open, or the main air supply valve to "fail open" in conjunction with failure of the controls or the control valves. During this transfer process the operator is not in the transfer room and cannot access the controls to initiate spurious movement.

B2.4.4.2 Success Criteria

Success criterion is that the CTT remain motionless during canister extraction from the transportation cask. Movement of the CTT during this operation could cause impact and/or shear and damage to the canister.

B2.4.4.3 Design Requirements and Features

The design feature is the shield door interlocks that prevent the extraction operation until the shield door is closed. Requirements include locating the air supply outside the canister transfer room, and for the operator to disconnect the air supply to the CTT prior to unloading.

B2.4.4.4 Fault Tree Model

The top event is the "Spurious Movement of the CTT in the Cask Unloading Room" during extraction of the canister from the transportation cask on the CTT. This may occur through failure to disconnect the air supply resulting in operation of the main air supply valve. The air supply valve may fail through spurious operation of the valve or spurious signals generated by the control system. Compressed air may be available to the CTT through failure of the operator to disconnect the air hose, or failure of the shield door interlocks. A conservative mission time for this operation has been set at one hour.

B2.4.4.5 Basic Event Data

Table B2.4-7 contains a list of basic events used in the fault tree (Figure B2.4-14) for "Spurious Movement of the CTT in the Cask Unloading Room."

Table B2.4-7. Basic Event Probability for Spurious Movement of the CTT in the Cask Unloading Room

Name	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CR---IEL001--IEL-FOD	1	2.750E-005	2.750E-005	0.000E+000	0.000E+000
200-CR---IEL002--IEL-FOD	1	2.750E-005	2.750E-005	0.000E+000	0.000E+000
200-CR---IELCCF--IEL-CCF	C	1.293E-006	---	----	---
200-CTT--CT001---CT--SPO	3	2.270E-005	0.000E+000	2.270E-005	1.000E+000
200-CTT--HC001---HC--SPO	3	5.230E-007	0.000E+000	5.230E-007	1.000E+000
200-OPNODISCOAIR-HFI-NOD	1	1.000E-003	1.000E-003	0.000E+000	0.000E+000
200-CTT-SV301-SV-SPO	3	4.090E-007	0.000E+000	4.090E-007	1.000E+000
200-CTT-SV401-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-FWDREVM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-FWDREVM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM1-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000
200-CTT-SVROTM2-SV-FOH	3	4.870E-005	0.000E+000	4.870E-005	1.000E+000

NOTE: [a] For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time. See Table 6.3-1 for definitions of calculation types.
Calc. = calculation; Fail. = failure; Miss. = mission; Prob. = probability.

Source: Original

B2.4.4.5.1 Human Failure Events

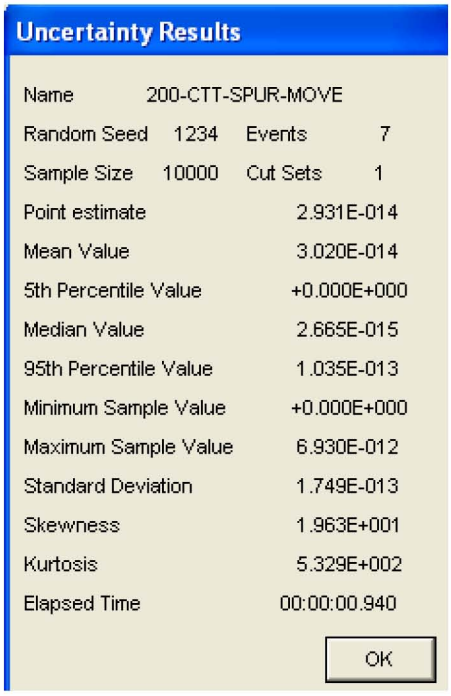
One operator error involves failure to disconnect the air supply (200-OPNODISCOAIR-HFI-NOD).

B2.4.4.5.2 Common-Cause Failures

One CCF (200-CR---IELCCF--IEL-CCF) involves failure of both shield door interlocks allowing the shield door to close and the slide port gate to open. An alpha factor of 0.047 was used to determine the CCF value using two of two as the failure criteria (Table C3-1, CCCG = 2).

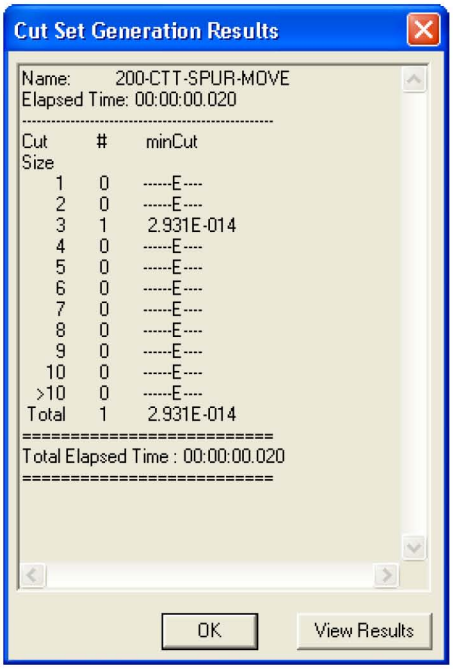
B2.4.4.6 Uncertainty and Cut Set Generation Results

Figure B2.4-12 contains the uncertainty results obtained from running the fault trees for "Spurious Movement of the CTT in the Cask Unloading Room" while extracting the canister from the transportation cask in the unloading area. Figure B2.4-13 provides the cut set generation results for the "Spurious Movement of the CTT in the Cask Unloading Room" fault tree, calculated using a 1E-15 cutoff.



Source: Original

Figure B2.4-12. Uncertainty Results for the Spurious Movement of the CTT in the Cask Unloading Room Fault Tree



Source: Original

Figure B2.4-13. Cut Set Generation Results for the Spurious Movement of the CTT in the Cask Unloading Room Fault Tree

B2.4.4.7 Cut Sets

Table B2.4-8 contains the cut sets for the "Spurious Movement of the CTT in the Cask Unloading Room" fault tree. The total frequency per cask is 2.93E-014.

Table B2.4-8. Cut Sets for Spurious Movement of the CTT in the Cask Unloading Room

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-CTT-SPUR-MOVE	99.91	2.931E-014	200-CR---IELCCF--IEL-CCF	Common-cause failure of interlocks from slide gate	1.293E-006
			200-CTT--CT001---CT--SPO	On-board controller initiates spurious signal	2.270E-005
			200-OPNODISCOAIR-HFI-NOD	Operator fails to disconnect air supply to CTT	1.000E-003
Total	2.931E-014				

NOTE: CTT = cask transfer trolley; Prob. = probability.

Source: Original

B2.4.4.8 Fault Trees

The fault tree for "Spurious Movement of the CTT in the Canister Transfer Room" is shown in Figure B2.4-14. Note that the transfer gate 23 in Figure B2.4-14 refers to the fault tree in Figure B2.4-4.

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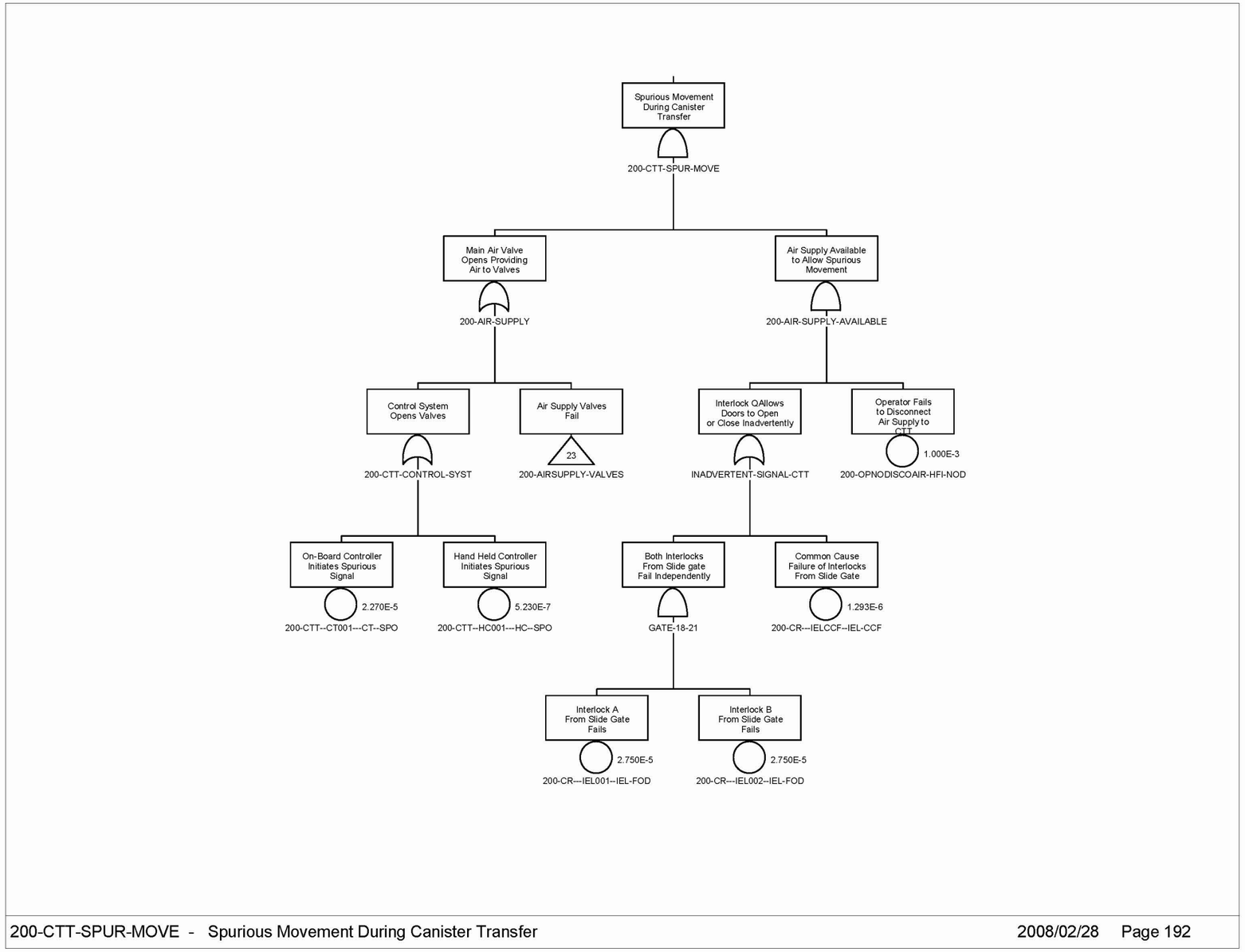

Source: Original

Figure B2.4-14. Fault Tree for Spurious Movement of the CTT in the Cask Unloading Room

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B3 LOADING/UNLOADING ROOM SHIELD DOOR AND SLIDE GATE FAULT TREE ANALYSIS

B3.1 REFERENCES

Design Inputs

The PCSA is based on a snapshot of the design. The reference design documents are appropriately documented as design inputs in this section. Since the safety analysis is based on a snapshot of the design, referencing subsequent revisions to the design documents (as described in EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1, Section 3.2.2.F)) that implement PCSA requirements flowing from the safety analysis would not be appropriate for the purpose of the PCSA.

B3.1.1 BSC (Bechtel SAIC Company) 2007. *Nuclear Facilities Equipment Shield Door Process and Instrumentation Diagram*. 000-M60-H000-00101-000 REV 00D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071220.0024.

B3.1.2 BSC 2008. *Nuclear Facilities Slide Gate Process and Instrumentation Diagram*. 000-M60-H000-00201-000 REV 00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080123.0025.

B3.1.3 BSC 2007. *Receipt Facility General Arrangement Ground Floor Plan*. 200-P10-RF00-00102-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071212.0011.

B3.1.4 BSC 2007. *Receipt Facility General Arrangement Second Floor Plan*. 200-P10-RF00-00103-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071212.0012.

B3.2 SLIDE GATE AND SHIELD DOOR SYSTEM DESCRIPTION

B3.2.1 Overview

The shield doors and slide gates provide shielding during canister unloading and loading. They are considered important to safety (ITS) as they protect workers from radioactive material that is exposed while being handled in the Cask Unloading Room and Loading Room. There are two slide gates in the RF. One shields the unloading port between the Cask Unloading Room and the Canister Transfer Room and the other shields the loading port between the Loading Room and the Canister Transfer Room. Shield doors provide equipment access to the Loading Room and Cask Unloading Room. The Cask Unloading Room shield door provides access for the CTT to move from the Cask Preparation Room into the Cask Unloading Room. The Loading Room shield door provides a site transporter access to the Loading Room from the Lid Bolting Room ((Ref. B3.1.3) and (Ref. B3.1.4)).

B3.2.2 Operations Description

The Cask Unloading Room shield door is opened to allow the CTT to enter the room. Once equipment is positioned properly in the Cask Unloading Room, shield doors are shut in preparation for removing canisters from the cask. Once the shield doors are shut, the slide gate may be opened to allow the canister transfer machine (CTM) to perform cask unloading operations. Loading of the aging overpack is analogous to cask unloading operations. The slide gate may be opened to allow aging overpack loading access if the shield doors are closed. Once loading is complete and the slide gate is closed, the shield doors are opened to allow aging overpack removal.

B3.2.3 Physical Description

The shield doors consist of pairs of large heavy doors that are operated by individual motors with over-torque sensors to prevent crushing of an object. Each door has two position sensors to indicate either a closed or open door and an obstruction sensor prevents the doors from closing on an object. The obstruction sensor is also alarmed to provide operators indication when an object is between the shield doors. The shield doors and slide gates are interlocked to prevent one another from opening if the other is open. The shield doors are opened and closed via a hand lever that must be enabled by an enable/disable switch. An emergency open switch exists enabling the doors to be opened in case of an emergency situation.

Similar to the shield doors, the slide gates consist of two gates that close together between the Loading/Cask Unloading Rooms and the Canister Transfer Room. The gates are operated by individual motors that also have over-torque sensors. Each gate has limit switches to indicate open or closed gates. A CTM skirt-in-place switch is interlocked to the slide gate to prevent the gates from opening without the CTM in place. Slide gate operation is controlled by a hand switch coupled with an enable/disable switch and shield door interlocks prevent the slide gate from opening when the shield door is open. Open/closed and CTM in-place indicators exist to assist operators in their activities.

B3.2.4 Schematics

Schematics for the shield door and slide gate are available separately for review ((Ref. B3.1.1) and (Ref. B3.1.2)).

Additional shield door details are available in *Nuclear Facilities Slide Gate Process and Instrumentation Diagram* (Ref. B3.1.2), including slide gate instrumentation.

B3.2.5 Dependencies and Interactions

Dependencies are broken down into five categories with respect to their interactions with structures, systems, and components. The five areas considered are addressed in Table B3.3-1 with the following dependencies:

1. Functional dependence
2. Environmental dependence
3. Spatial dependence

4. Human dependence
5. Failures based on external events.

Table B3.3-1. Dependencies and Interactions Analysis

Systems, Structures, Components	Dependencies and Interactions				
	Functional	Environmental	Spatial	Human	External Events
Door/gate motors	—	—	—	Inadvertent operation	—
Door/gate position limit switches	CTM	—	—	—	—
CTM	Gate position switches, obstruction sensor	—	—	—	—
Obstruction sensor	CTM	—	—	—	—

NOTE: CTM = canister transfer machine

Source: Original

B3.3 SLIDE GATE AND SHIELD DOOR FAILURE SCENARIOS

The slide gate and shield door system has three credible failure scenarios as follows:

1. Inadvertent opening of the shield door
2. Inadvertent opening of the slide gate
3. Shield door closes on conveyance.

B3.3.1 Inadvertent Opening of the Shield Door

B3.3.1.1 Description

Inadvertent opening of the shield door while a canister is being unloaded from a cask or loaded into an aging overpack can cause an exposure. For this situation to occur, the slide gate must be open for the CTM to be unloading/loading a canister. Interlocks between the slide gate and shield door prevent an operator from being able to open the shield door during canister unloading or loading. However, this situation can occur if the interlocks fail and an operator attempts to open the door, or a spurious open signal is received.

B3.3.1.2 Success Criteria

The success criteria for this failure scenario require that the interlocks between the slide gate and shield door prevent the shield door from opening when the slide gate is open.

B3.3.1.3 Design Requirements and Features

Redundant hardwired interlocks prevent the shield door from opening while the slide gate is open and vice versa. The shield door system does not have any test, maintenance, or other modes/settings that allows bypass of interlocks.

B3.3.1.4 Fault Tree Model

The top event in this fault tree is "Shield Door Inadvertently Opened While Unloading Cask." This is defined as an opening of the shield door during unloading operations while the cask is in a position that would result in a direct exposure to personnel outside of the unloading room. Faults considered in the evaluation of this top event include: failure of components in the control circuitry of the slide door and a human event that contribute to the inadvertent door opening. The fault tree is shown in Figure B3.4-3.

B3.3.1.5 Basic Event Data

Six basic events, as shown in Table B3.4-1, are used to model this failure scenario, including one human failure event (HFE), one common-cause failure, and one situational event.

The basic event, "Canister is Exposed During Mid-Unloading" represents the probability that the canister is removed from the cask, but has not reached the CTM skirt yet. The screening value of 1.0 is used for this event.

Table B3.4-1. Basic Event Probabilities for Inadvertent Opening of Shield Door

Basic Event	Description	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CR---IELCCF--IEL-CCF	Common-cause failure of interlocks from slide gate	C	1.293E-06	---	---	---
200-CR--IEL001--IEL-FOD	Interlock A from slide gate fails	1	2.750E-05	2.750E-05	0.000E+00	0.000E+00
200-CR--IEL002--IEL-FOD	Interlock B from slide gate fails	1	2.750E-05	2.750E-05	0.000E+00	0.000E+00
200-CR--PLC001--PLC-SPO	Inadvertent signal sent due to PLC failure	3	3.650E-07	0.000E+00	3.650E-07	1.000E+00
200-CR-CASK-UNLOADING	Canister is exposed during mid-unloading	1	1.000E+00	1.000E+00	0.000E+00	0.000E+00
200-OPDIREXPOSE1-HFI-NOD	Operator mistakenly opens door	1	1.000E-01	1.000E-01	0.000E+00	0.000E+00

NOTE: [a]For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time. See Table 6.3-1 for definitions of calculation types.
Calc. = calculation; Fail. = failure; Miss. = mission; PLC = programmable logic controller; Prob. = probability.

Source: Original

B3.3.1.5.1 Human Failure Events

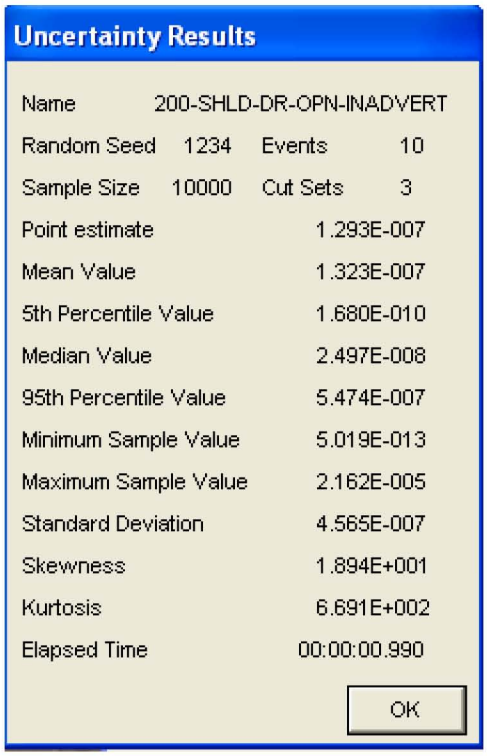
One HFE is modeled in the fault tree as an operator attempting to open the shield doors during a CTM loading or unloading operation. However, for the operator to open the shield door while the slide gate is open the interlock must fail. The screening value used for this HFE has a probability of 1.0E-01 (Table 6.4-1).

B3.3.1.5.2 Common-Cause Failures

One CCF scenario is modeled in the fault tree. The redundant interlocks that prevent the shield door from opening while the slide gate is open can both fail due to a common cause. The common-cause failure alpha factor for two of two successes is 0.047 (Attachment C).

B3.3.2 Uncertainty and Cut Set Generation Results

Figure B3.4-1 contains the uncertainty results obtained from running the fault trees for "Inadvertent Opening of the Shield Door" while unloading cask fault tree. Figure B3.4-2 provides the cut set generation results for the "Inadvertent Opening of the Shield Door" while unloading cask fault tree, calculated using a 1E-15 cutoff.



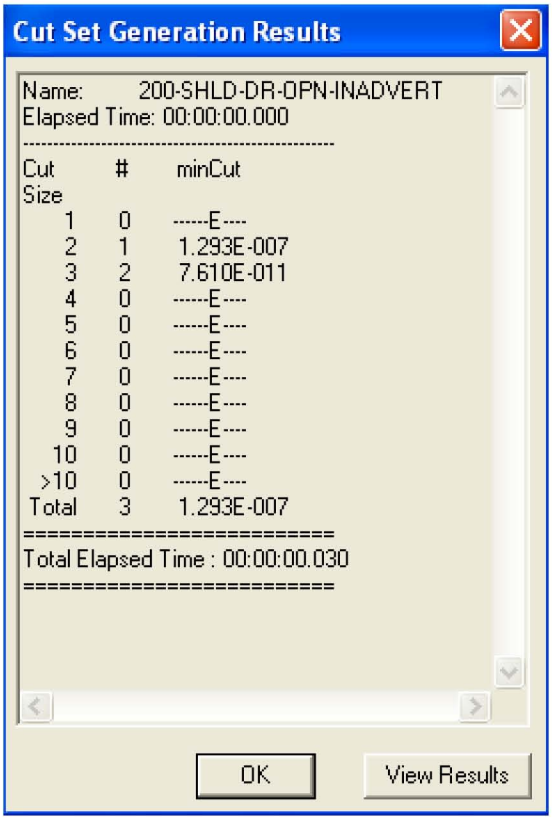
Uncertainty Results

Name	200-SHLD-DR-OPN-INADVERT		
Random Seed	1234	Events	10
Sample Size	10000	Cut Sets	3
Point estimate			1.293E-007
Mean Value			1.323E-007
5th Percentile Value			1.680E-010
Median Value			2.497E-008
95th Percentile Value			5.474E-007
Minimum Sample Value			5.019E-013
Maximum Sample Value			2.162E-005
Standard Deviation			4.565E-007
Skewness			1.894E+001
Kurtosis			6.691E+002
Elapsed Time			00:00:00.990

OK

Source: Original

Figure B3.4-1. Uncertainty Results for the Shield Door Inadvertently Opened While Unloading Cask Fault Tree



Source: Original

Figure B3.4-2. Cut Set Generation Results for the Shield Door Inadvertently Opened While Unloading Cask Fault Tree

B3.3.2.1 Cut Sets

Cut sets for "Inadvertent Opening of Shield Door" are displayed in Table B3.4-2.

Table B3.4-2. Cut Sets for Inadvertent Opening of Shield Door

Fault Tree	% Cut Set	Prob./Freq.	Basic Event	Description	Event Prob.
200-SHLD-DR-OPN-INADVERT	99.94	1.292E-007	200-CR--IELCCF-IEL-CCF	Common-cause failure of interlocks from slide gate	1.292E-006
			200-OPDIREXPOSE1-HFI-NOD	Operator mistakenly opens door	1.000E-001
	0.06	7.562E-011	200-CR--IEL001--IEL-FOD	Interlock A from slide gate fails	2.750E-005
			200-CR--IEL002--IEL-FOD	Interlock B from slide gate fails	2.750E-005
			200-OPDIREXPOSE1-HFI-NOD	Operator mistakenly opens door	1.000E-001
	0.00	4.718E-013	200-CR--IELCCF-IEL-CCF	Common-cause failure of interlocks from slide gate	1.292E-006
			200-CR—PLC001—PLC-SPO	Inadvertent signal sent due to PLC failure	3.650E-007
			200-CR-CASK-UNLOADING	Canister is exposed during mid-unloading	1.000E+000

NOTE: Freq. = frequency; PLC = programmable logic controller; Prob. = probability.

Source: Original

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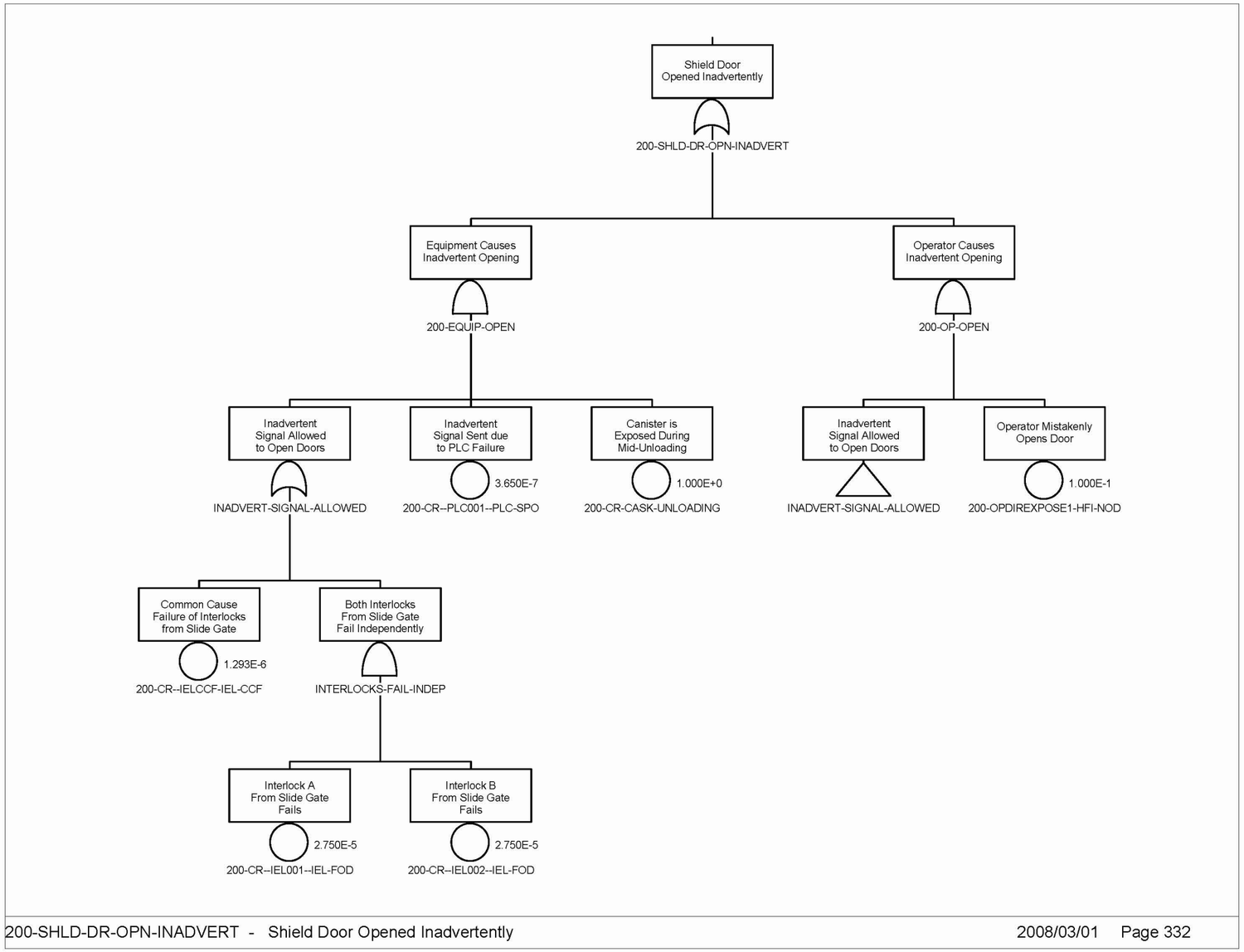
B3.3.2.2 Fault Trees



Source: Original

Figure B3.4-3. Fault Trees for Inadvertent Opening of the Shield Door

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B3.3.3 Inadvertent Opening of Slide Gate Causing Direct Exposure

B3.3.3.1 Description

Inadvertent opening of a slide gate can result in an exposure if personnel are present in the Canister Transfer Room and a radiation source is exposed in the Loading or Cask Unloading Room. There are two ways that a slide gate may be inadvertently opened: (1) an operator mistakenly opens the slide gate or, (2) the control electronics spuriously opens the slide gate. Additionally, an interlock that prevents the slide gate from opening unless the CTM skirt is in place must also fail or be disabled. In this situation, the shield door may be closed; therefore the interlocks that prevent the slide gate from opening while the shield door is open do not prevent the slide gate from opening.

B3.3.3.2 Success Criteria

The success criteria for this failure scenario require that the shield bell slide gate not open during canister transfer operations unless the shield skirt is lowered.

B3.3.3.3 Design Requirements and Features

A single interlock is used to prevent the slide gate from opening when the CTM skirt is not in place.

B3.3.3.4 Fault Tree Model

The top event in this fault tree is "Inadvertent Opening of the Slide Gate Causing Direct Exposure." This is defined as an opening of the slide gate during unloading operations while the cask is in a position that would result in a direct exposure to personnel in the Canister Transfer Room. Faults considered in the evaluation of this top event include: failure of components in the control circuitry of the slide gate and a human event that contribute to the inadvertent gate opening. The fault tree is shown in Figure B3.4-6.

B3.3.3.5 Basic Event Data

Three basic events, as shown in Table B3.4-3, are used to model this failure scenario, including one human failure event and two hardware events.

Table B3.4-3. Basic Event Probabilities for Inadvertent Opening of Slide Gate Causing Direct Exposure

Name	Description	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-CR---IEL001-IEL-FOD	Skirt interlock failed	1	2.750E-05	2.750E-05	0.000E+00	0.000E+00
200-CR-PLC001-PLC-SPO	Inadvertent signal sent due to PLC failure	3	3.650E-07	0.000E+00	3.650E-07	1.000E+00
200-OPFAILRSTINT-HFI-NOM	Skirt interlock disabled	1	1.000E-02	1.000E-02	0.000E+00	0.000E+00

Table B3.4-3. Basic Event Probabilities for Inadvertent Opening of Slide Gate Causing Direct Exposure (Continued)

NOTE: [a]For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time.
Calc. = calculation; Fail. = failure; Miss. = mission; PLC = programmable logic controller; Prob. = probability.

Source: Original

B3.3.3.5.1 Human Failure Events

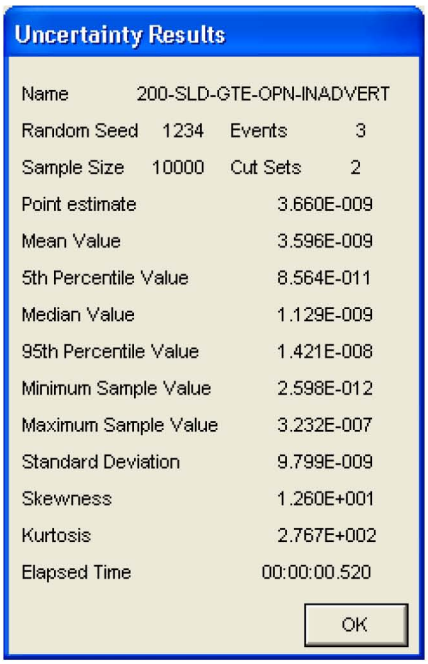
One HFE is modeled in the fault tree. This HFE is a combination of operator actions and interlock failures that can result in the slide gate being opened when the shield skirt is raised. The development of this event is presented in detail as part of the human reliability analysis in Section 6.4 (Table 6.4-1) and Attachment E.

B3.3.3.5.2 Common-Cause Failures

No CCFs are identified for this fault tree.

B3.3.3.6 Uncertainty and Cut Set Generation Results

Figure B3.4-4 contains the uncertainty results obtaining from running the fault tree for "Inadvertently Opening of the Slide Gate Causing Direct Exposure." Figure B3.4-5 provides the cut set generation results for the "Inadvertently Opening of the Slide Gate Causing Direct Exposure" fault tree, calculated using a 1E-15 cutoff.



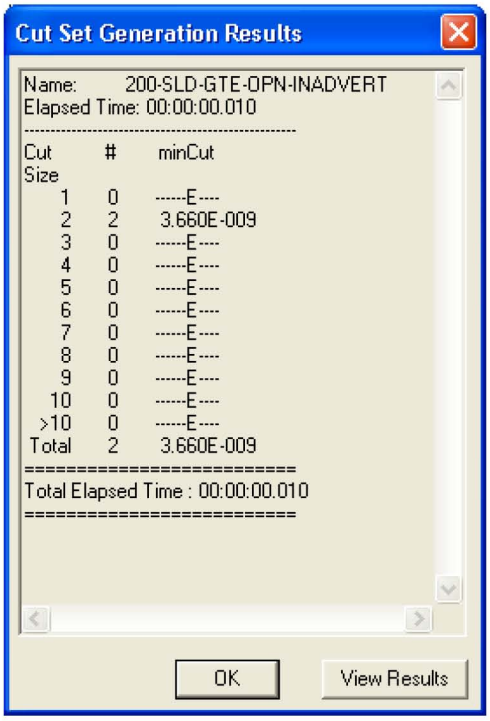
Uncertainty Results

Name	200-SLD-GTE-OPN-INADVERT		
Random Seed	1234	Events	3
Sample Size	10000	Cut Sets	2
Point estimate			3.660E-009
Mean Value			3.596E-009
5th Percentile Value			8.564E-011
Median Value			1.129E-009
95th Percentile Value			1.421E-008
Minimum Sample Value			2.598E-012
Maximum Sample Value			3.232E-007
Standard Deviation			9.799E-009
Skewness			1.260E+001
Kurtosis			2.767E+002
Elapsed Time			00:00:00.520

OK

Source: Original

Figure B3.4-4. Uncertainty Results for the Inadvertent Opening of the Slide Gate Causing Direct Exposure Fault Tree



Source: Original

Figure B3.4-5. Cut Set Generation Results for the Inadvertent Opening of the Slide Gate Causing Direct Exposure Fault Tree

B3.3.3.7 Cut Sets

Table B3.4-4 contains the cut sets for the "Inadvertent Opening of the Slide Gate Causing Direct Exposure" fault tree.

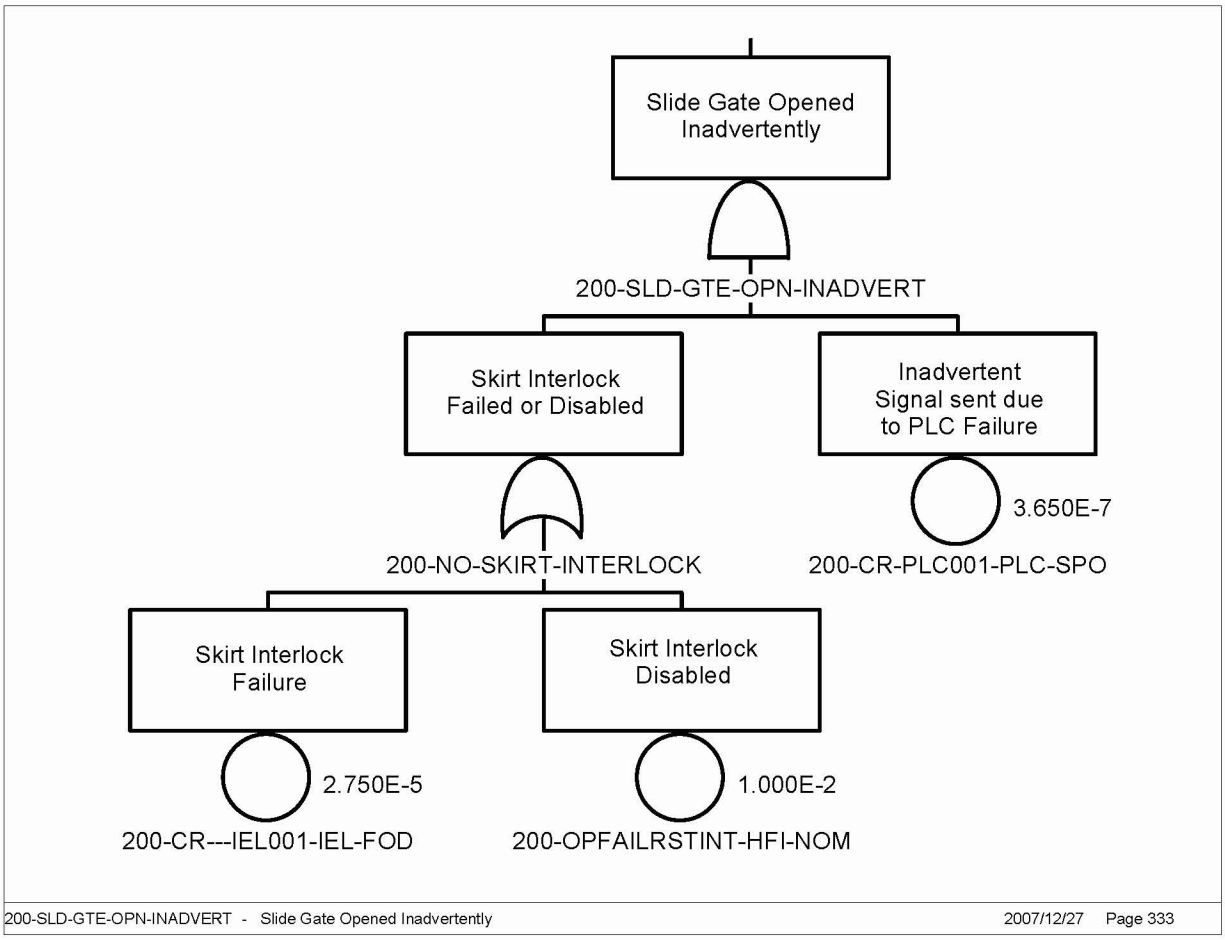
Table B3.4-4. Cut Sets for Inadvertent Opening of the Slide Gate Causing Direct Exposure

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-SLD-GTE-OPN-INADVERT	99.73	3.650E-009	200-CR-PLC001-PLC-SPO	Inadvertent signal sent due to PLC failure	3.650E-007
			200-OPFAILRSTINT-HFI-NOM	Skirt interlock disabled	1.000E-002
	0.27	1.004E-011	200-CR---IEL001-IEL-FOD	Skirt interlock failure	2.750E-005
			200-CR-PLC001-PLC-SPO	Inadvertent signal sent due to PLC failure	3.650E-007
		3.660E-009	= Total		

NOTE: PLC = programmable logic controller; Prob. = probability.

Source: Original

B3.3.3.8 Fault Trees



Source: Original

Figure B3.4-6. Fault Trees for Inadvertent Opening of the Slide Gate

B3.3.4 Shield Door Closes on Conveyance

B3.3.4.1 Description

If the shield doors to the Loading/Cask Unloading Rooms are closed as casks or aging overpacks are transferred to/from the Loading/Cask Unloading Rooms, a release may occur as a result. Measures are in place to ensure this situation does not occur, including the presence of an obstruction sensor and motor over-torque sensors.

B3.3.4.2 Success Criteria

The success criterion for this scenario is defined as the shield doors not causing a release due to closure on the conveyance. Specifically, success criteria are defined as follows:

- Obstruction sensor prohibits the initiation of shield door closure.
- In the event that the obstruction sensor fails and the shield doors do close on a conveyance, the motor over-torque sensors prevent excessive closure force, ensuring no release.

B3.3.4.3 Design Requirements and Features

Objects or obstructions are detected between the shield doors to prevent door closure initiation. Motor over-torque sensors prevent the shield doors from causing damage to casks or waste packages in the event of closure on a conveyance.

B3.3.4.4 Fault Tree Model

The top event in this fault tree is "Collision of Shield Door into Conveyance." This is defined as an inadvertent closure of the shield doors due to either operator action or component failure while the conveyance is in position to be hit by the doors. Faults considered in the evaluation of this top event include: failure of components in the control circuitry of the shield doors and human events that contribute to the inadvertent shield door closing. The fault tree is shown in Figure B3.4-9.

B3.3.4.5 Basic Event Data

Six basic events listed in Table B3.4-5 are used to model this failure scenario, including one HFE and one CCF.

Table B3.4-5. Basic Event Probabilities for Shield Door Closes on Conveyance

Name	Description	Calc. Type[a]	Calc. Prob.	Fail. Prob.	Lambda	Miss. Time[a]
200-OPSDCLOSE001-HFI-NOD	Operator collides shield door with CTT	1	1.000E+00	1.000E+00	0.000E+00	0.000E+00
200-SD---PLC001--PLC-SPO	Spurious signal from PLC closes door	3	3.650E-07	0.000E+00	3.650E-07	1.000E+00
200-SD---SRU001--SRU-FOH	Ultrasonic obstruction sensor fails	7	2.161E-03	0.000E+00	9.62E-05	45
200-SD---TL000---TL--CCF	Common-cause failure of over-torque sensors	C	6.681E-04	---	---	---
200-SD---TL001---TL--FOH	Motor #1 over-torque sensor fails	7	2.843E-02	0.000E+00	8.050E-05	720
200-SD---TL002---TL--FOH	Motor #2 over-torque sensor fails	7	2.843E-02	0.000E+00	8.050E-05	720

Table B3.4-5. Basic Event Probabilities for Shield Door Closes on Conveyance (Continued)

NOTE: [a]For Calc. Type 3 with a mission time of 0, SAPHIRE performs the quantification using the system mission time. See Table 6.3-1 for definitions of calculation types.
For Type 7 calculations, the mission time column contains the testing interval.
CTT = cask transfer trolley; PLC = programmable logic controller; Prob. = probability; ST = site transporter.

Source: Original

B3.3.4.5.1 Human Failure Events

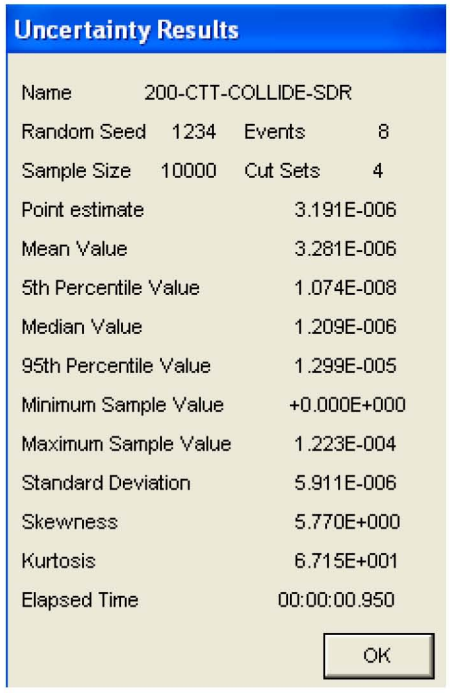
One HFE is modeled in the fault tree as an operator attempting to close the shield doors while a conveyance is between the doors. The screening value used for this HFE has a probability of 1.

B3.3.4.5.2 Common-Cause Failures

One CCF considered is the failure of the shield door over-torque sensors. This CCF allows the shield doors to continue to attempt to close once an obstruction, in this case the conveyance, is encountered.

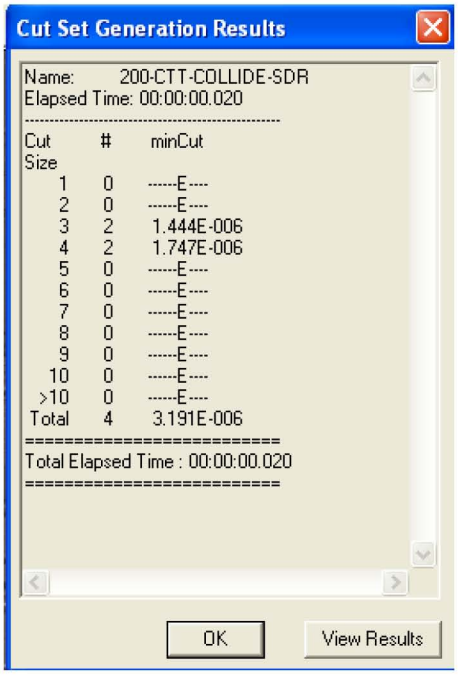
B3.4.3.6 Uncertainty and Cut set Generation Results

Figure B3.4-7 contains the uncertainty results obtaining from running the fault tree of "Shield Door Closes on Conveyance". Figure B3.4-8 provides the cut set generation results for the "Shield Door Closes on Conveyance" fault tree, calculated using a 1E-15 cutoff. The fault tree and results for shield door closing on the CTT are identical with the fault tree and results for the shield door closing on the site transporter.



Source: Original

Figure B3.4-7. Uncertainty Results for the Shield Door Closes on Conveyance Fault Tree



Source: Original

Figure B3.4-8. Cut Set Generation Results for the Shield Door Closes on Conveyance Fault Tree

B3.3.4.6 Cut Sets

Table B3.4-6 contains the cut sets for spurious door closing on a conveyance.

Table B3.4-6. Cut Sets for Shield Door Closes on Conveyance

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-CTT-COLLIDE-SDR	54.75	1.747E-006	200-OPSDCLOSE001-HFI-NOD	Operator collides shield door with CTT	1.000E+000
			200-SD---SRU001--SRU-FOH	Ultrasonic obstruction sensor fails	2.161E-003
			200-SD---TL001---TL--FOH	Motor #1 over-torque sensor fails	2.843E-002
			200-SD---TL002---TL--FOH	Motor #1 over-torque sensor fails	2.843E-002
	45.25	1.444E-006	200-OPSDCLOSE001-HFI-NOD	Operator collides shield door with CTT	1.000E+000
			200-SD---SRU001--SRU-FOH	Ultrasonic obstruction sensor fails	2.161E-003
			200-SD---TL000---TL--CCF	Common-cause failure of over-torque sensors	6.681E-004

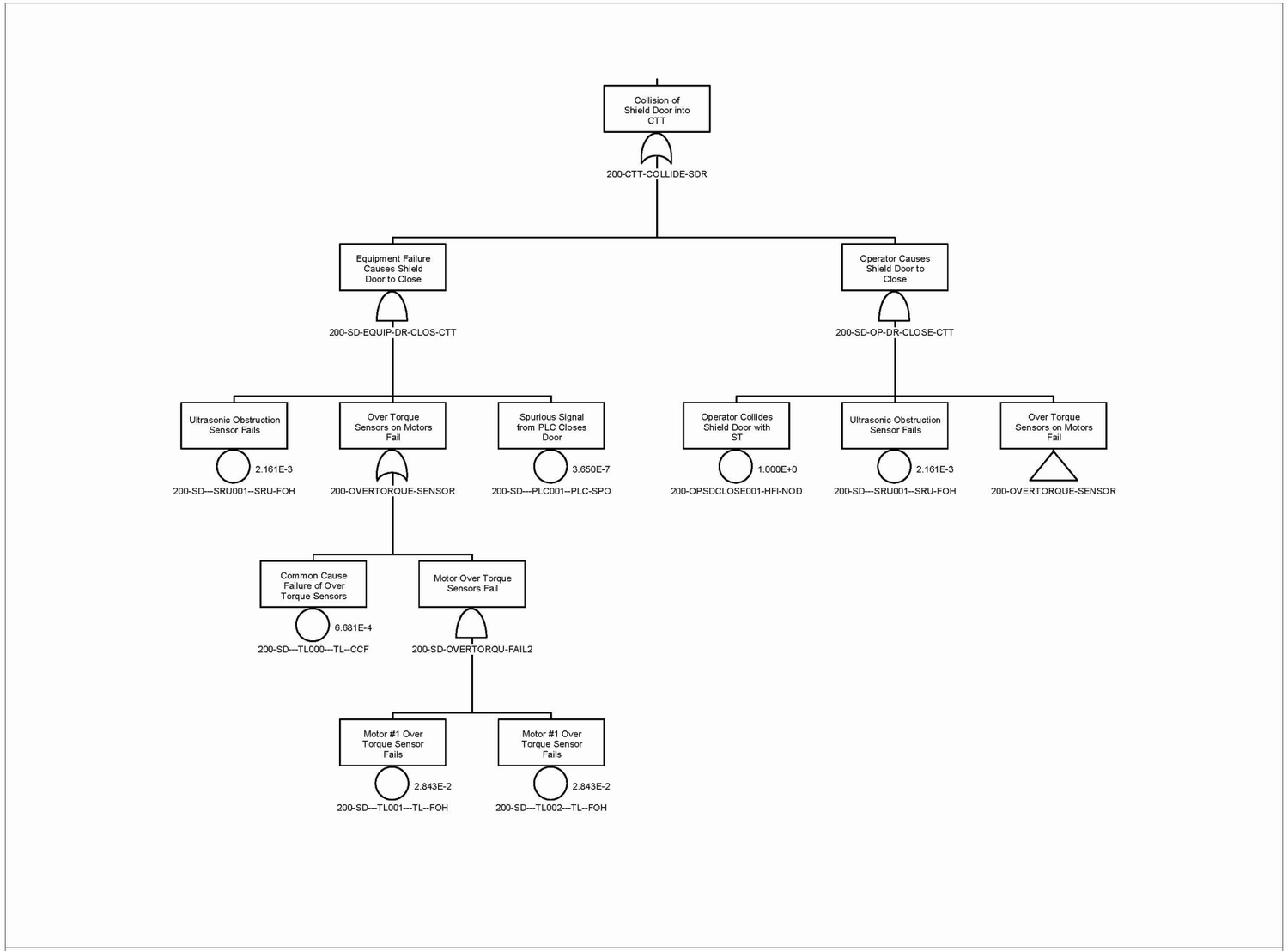
Table B3.4-6. Cut Sets for Shield Door Closes on Conveyance (Continued)

Fault Tree	% Cut Set	Prob./Frequency	Basic Event	Description	Event Prob.
200-CTT-COLLIDE-SDR (continued)	0.00	6.376E-013	200-SD---PLC001--PLC-SPO	Spurious signal from PLC closes door	3.650E-007
			200-SD---SRU001--SRU-FOH	Ultrasonic obstruction sensor fails	2.161E-003
			200-SD---TL001---TL--FOH	Motor #1 over-torque sensor fails	2.843E-002
			200-SD---TL002---TL--FOH	Motor #1 over-torque sensor fails	2.843E-002
	0.00	5.270E-013	200-SD---PLC001--PLC-SPO	Spurious signal from PLC closes door	3.650E-007
			200-SD---SRU001--SRU-FOH	Ultrasonic obstruction sensor fails	2.161E-003
			200-SD---TL000---TL--CCF	Common-cause failure of over-torque sensors	6.681E-004

NOTE: CTT = cask transfer trolley; Fail. = failure; PLC = programmable logic controller; Prob. = probability.

Source: Original

B3.3.4.7 Fault Trees



Source: Original

Figure B3.4-9. Fault Trees for Shield Door Closes on Conveyance

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B4 CANISTER TRANSFER MACHINE FAULT TREE ANALYSIS

B4.1 REFERENCES

Design Inputs

The PCSA is based on a snapshot of the design. The reference design documents are appropriately documented as design inputs in this section. Since the safety analysis is based on a snapshot of the design, referencing subsequent revisions to the design documents (as described in EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1, Section 3.2.2.F)) that implement PCSA requirements flowing from the safety analysis would not be appropriate for the purpose of this document. There are no superseded or cancelled documents associated with the modifications that led to the issuance of this revision. Cancelled or superseded documents associated with the portions of this document for which the snapshot has not yet been updated are designated herein with a dagger (†).

B4.1.1 ASME NOG-1-2004. 2005. *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)*. New York, New York: American Society of Mechanical Engineers. ISBN: 0-7918-2923-1. TIC: 257672.

B4.1.2 BSC (Bechtel SAIC Company) 2007. *CRCF, RF, WHF, and IHF Canister Transfer Machine Process and Instrumentation Diagram Sheet 1 of 4*. 000-M60-HTC0-00101-000 REV 00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071218.0028.

B4.1.3 BSC 2007. *CRCF, RF, WHF and IHF Canister Transfer Machine Process and Instrumentation Diagram Sheet 2*. 000-M60-HTC0-00102-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071030.0022.

B4.1.4 BSC 2007. *CRCF, RF, WHF, and IHF CTM Canister Grapple Process and Instrumentation Diagram*. 000-M60-HTC0-00201-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071011.0008.

B4.1.5 BSC 2007. *Nuclear Facilities Shield Door Process and Instrumentation Diagram*. 000-M60-H000-00101-000 REV 00D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071220.0024.

B4.1.6 BSC 2008. *CRCF, RF, WHF and IHF Canister Transfer Machine Process and Instrumentation Diagram Sheet 3*. 000-M60-HTC0-00103-000 REV 00D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080103.0011. (DIRS 184613)

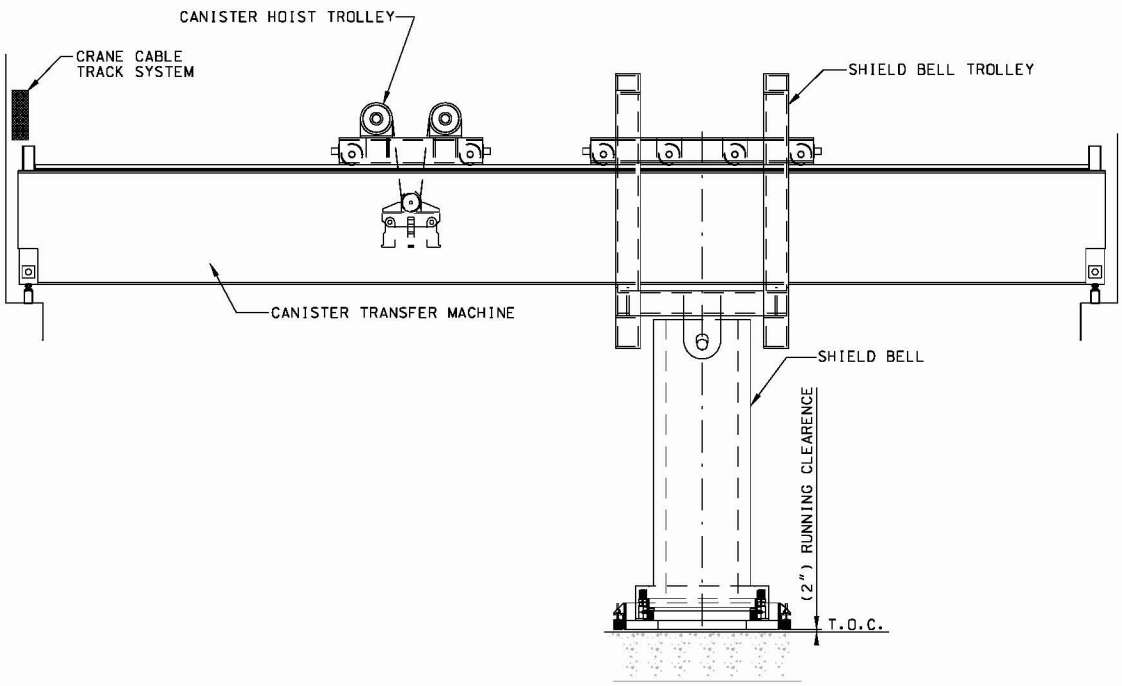
B4.1.7 BSC 2008. *Nuclear Facilities Slide Gate Process and Instrumentation Diagram*. 000-M60-H000-00201-000 REV 00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080123.0025. (DIRS 184865)

B4.1.8 †BSC 2008. *Mechanical Handling Design Report - Canister Transfer Machine*. 000-30R-WHS0-01900-000 REV 002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080109.0022.

B4.2 CANISTER TRANSFER MACHINE DESCRIPTION

The CTM operates in the Canister Transfer Room of the RF. Its function is to transfer waste canisters from a cask on a CTT to an aging overpack on a site transporter in the Loading Room. The ports in the floor of the Canister Transfer Room provide access to the Cask Unloading Room and Loading Room.

The CTM is an overhead bridge crane with two trolleys as shown in Figure B4.2-1. The first is a canister hoist trolley with a grapple attachment and hoisting capacity of 70 tons. The second is a shield bell trolley that supports the shield bell. The shield bell is approximately 25 feet tall with an inside diameter of about 6 feet. The bottom end of the shield bell is attached to a larger chamber to accommodate cask lids with a diameter of up to 84 in. The CTM bottom plate assembly supports a 12-in. thick motorized slide gate. The slide gate, when closed, provides bottom shielding of the canister once the canister is inside the shield bell.



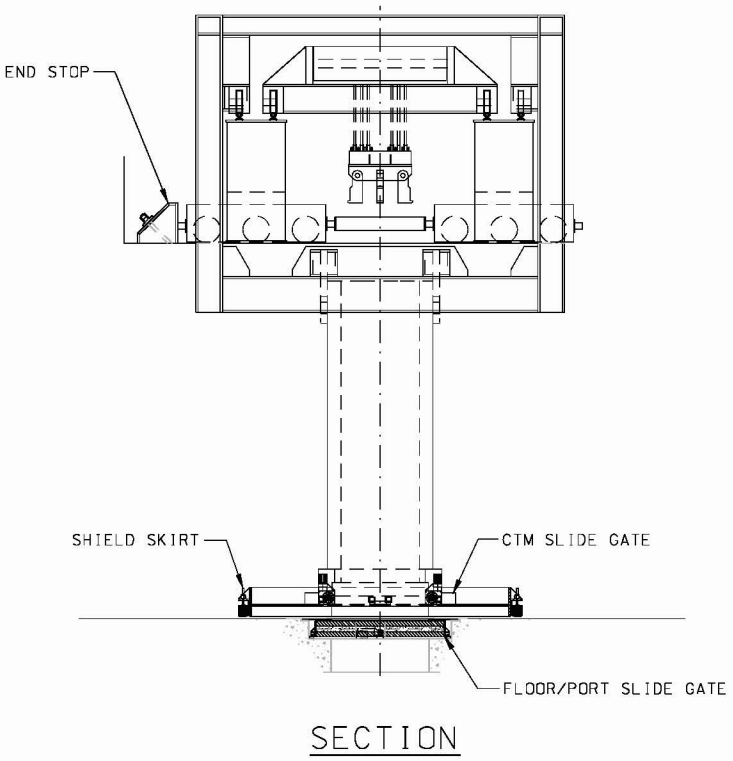
Source: Modified from Ref. B4.1.8

Figure B4.2-1. Canister Transfer Machine Elevation

Around the perimeter of the bottom plate, a 9-in. thick shield skirt is provided which can be raised and lowered. The shield skirt is used to close any gap between the CTM bottom plate and floor surface to prevent lateral radiation shine during a canister transfer operation. The shield skirt in its lowered position is the only part of the CTM that touches the floor.

The CTM bridge is very similar to a typical crane bridge, with end trucks riding rails supported by wall corbels. Each bridge girder supports two sets of trolley rails; the two inner rails are for the canister hoist trolley and the two outer rails are for the shield bell trolley.

The CTM design allows for the two trolleys to move independently when required for maintenance but they are normally mechanically locked together and operate as a unit when performing a canister transfer operation. The hoist trolley with grapple is positioned over the shield bell and grapple center is aligned with the shield bell center as depicted in Figure B4.2-2.



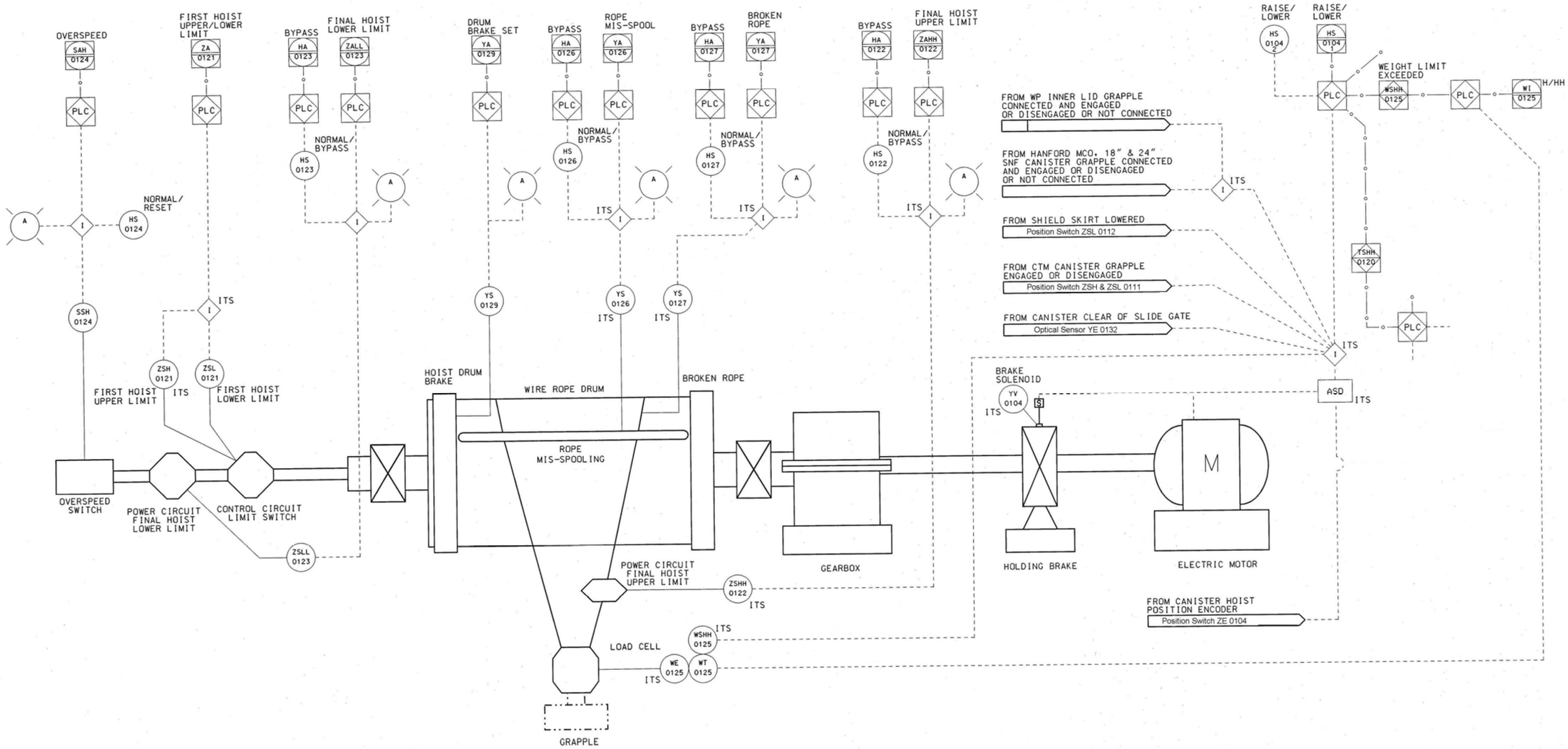
Source: Modified from Ref. B4.1.8

Figure B4.2-2. Canister Transfer Machine Cross Section

Figures B4.2-3 through B4.2-6 show the ITS related instrumentation and controls incorporated into the CTM ((Ref. B4.1.2), (Ref. B4.1.3), and (Ref. B4.1.6)). Additional interlocks between the CTM and other systems (e.g., shield doors) are shown and described in *CRCF, RF, WHF, and IHF CTM Canister Grapple Process and Instrumentation Diagram* (Ref. B4.1.4), *Nuclear Facilities Shield Door Process and Instrumentation Diagram* (Ref. B4.1.5), and *Nuclear Facilities Slide Gate Process and Instrumentation Diagram* (Ref. B4.1.7). Hard-wired interlocks are provided to limit the possibility of operator error resulting in a CTM drop (of either a canister or any other object) or collision. While much of the operational controls are provided by programmable logic controllers (PLCs), the operation of these non-ITS devices are not credited in the system analysis. However, spurious operation of the PLCs are considered when such operation may contribute to a drop or collision event. Hard-wired interlocks are provided to:

- Prevent bridge and trolley movement when the shield bell skirt is lowered.
- Prevent raising the shield bell skirt when the slide gate is open.
- Prevent hoist movement unless the grapple is fully engaged or disengaged.
- Stop the hoist and erase the lift command when a canister clears the shield bell slide gate.
- Stop a lift before upper lift heights are reached (two interlocks are provided for this function).
- Prevent opening of the port slide gate unless the shield bell skirt is lowered and in position.
- Prevent hoist movement unless the shield bell skirt is lowered.
- Prevent lifting of a load beyond the operational load limit of the CTM (load cells).

Some of these interlocks can be bypassed during maintenance. The most significant of these is the interlock between the shield skirt position and the position of the slide gate (shield skirt cannot be raised unless the slide gate is closed or the bypass is engaged). The design of the grapple interlock ensures that this interlock cannot be bypassed when the CTM is being used during operation.



Source: Modified from Ref. B4.1.6

Figure B4.2-3. Canister Hoist Instrumentation

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