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Identification of Process Hazards and Accident Scenarios for Site 300 B-Division Firing Areas

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DISCLAIMER

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1.0 Introduction

This report describes a hazard and accident analysis conducted for Site 300 operations to support update of the *Site 300 B-Division Firing Areas Safety Analysis Report* (SAR) [LLNL 1997]. A significant change since the previous SAR is the construction and the new Contained Firing Facility (CFF). Therefore, this hazard and accident analysis focused on the hazards associated with bunker operations to ensure that the hazards at CFF are properly characterized in the updated SAR. Hazard tables were created to cover both the CFF and the existing bunkers with "open air" firing tables.

The analysis was based upon information gathered from the following key sources.

- The existing SAR [LLNL 1997],
- The Facility Safety Procedure (FSP) [LLNL 2000a],
- Operational Safety Procedures (OSPs) [LLNL 200b, LLNL 2000c, LLNL 2000d, LLNL 2000e, LLNL 2001],
- Walk-through of the CFF,
- The Safety Question Review for CFF qualification testing [Ingram 2000],
- A description of the Contained Firing Facility [Visoria 2001],
- Ongoing discussions with subject matter experts including:
    - Jim Lyle, B Division/CFF Laboratory Associate/PSAR Author,
    - Jack Lowry, West Area Supervisor,
    - Kent Haslam, B Division Site 300 Facilities Manager,
    - Carl Ingram, Assistant B Div. Leader for ES&H,
- Witnessing of a shot at Building 851 which included informal briefings by bunker staff,
- A meeting with bunker staff after the witnessed shot to discuss residual questions.

1.1 Acronyms Used in this Report

CFF Contained Firing Facility, Building 801

LLNL Lawrence Livermore National Laboratory

H&S ManualThe LLNL Health and Safety Manual UCRL-M-133867 [LLNL current]

SAR Safety Analysis Report

2.0 Hazard Identification

Hazard identification was based upon Table 2 of the LLNL H&S Manual, Supplement 6.06. Each of the hazard sources in this table was considered to identify hazards that are beyond those associated with activities commonly performed by the public. Table 1 Lists the specific hazards identified.

The different areas and operations that represented substantially different hazard conditions were identified based upon a consideration of facility layouts and operations. Table 2 lists the locations identified, Table 3 lists the operations identified.

For each location the list of specific hazards was reviewed to identify the operations during which a specific hazard would be present. The result was table 4.

Table 1 Non-routine hazards of bunker operations

Hazard Sources	Specific Hazards
Flammable Materials	Mobilelift or Forklift: Batteries, Hydraulic fluid
	Electrical equipment
	Solvents
	Fire in or around service building
Toxic Materials	Toxic explosion by products
	Beryllium
	Highly Toxic Materials
Reactive Materials	HE accumulation in systems
Oxygen Deficiency	Explosion creates oxygen diffident atmosphere
	Inert or toxic gas systems
Carcinogens	N/A
Intense Light	Flash Devices
Lasers	Diagnostic lasers
	Experimental lasers
Ultraviolet	N/A
X-rays	X-ray machines & linear accelerators
Infrared	N/A
Electron Beams	N/A
Magnetic Fields	N/A
RF Fields	Portable Radios
Nuclear Criticality	N/A
High Energy Particles	N/A
Capacitors	FXR
	Flash Device Power Supplies
Transformers	N/A
Exposed Conductors	N/A
ESD	Tools
Lightning	Lightning

Hazard Sources	Specific Hazards
Rotating equipment	Cameras
Shears, sharp edges	N/A
Pinch Points	N/A
Vehicles	Mobilelift or Forklift: Mechanical Impact
Mass in motion	Shrapnel from shot
	Shrapnel from tire blowout
	Blast effects and shrapnel from shot
	Test launcher or gun
	Liquid abrasive cutters
	Shrapnel from camera failure
Falling	Equipment Falling on HE
Falling Objects	Diagnostic or setup equipment falling on HE
Lifting	Dropped HE
Tripping, Slipping	N/A
Earthquakes	Seismic Event
Steam	N/A
Fire	Equipment
Solar	N/A
Chemical Reactions	Chemical reaction with assembly materials
Spontaneous combustion	N/A
Cryogenics	N/A
Ice, snow, wind, rain	N/A
Heaters	Preconditioning heaters
Confined gases	N/A
Explosives	Unreacted HE after test
Noise	N/A
Pathogens	N/A
Allergens	N/A

Table 2 Bunker areas containing significantly different hazards

Firing Table, CFF Firing Chamber
CFF Grey Area
CFF Diagnostic Equipment Room
CFF Diagnostics room penetration area
Bunker / CFF Control Room
Camera Room
CFF vent duct areas

Table 3 Bunker operations posing significantly different hazards

HE Transport	HE present in area but not secured to test stand. Vehicles may be present on firing table or in firing chamber
Shot setup	HE present but not being moved, prior to muster
Shot	Period during which personnel are mustered under cover
Post shot	Period from the point when personnel leave cover until firing table is declared secure
Camera operations	Period when high speed streak cameras are running
Continuous	All operations

Table 4 Summary of hazard exposure

Specific Hazards	Firing Table, CFF Firing Chamber	CFF Grey Area	Diagnostic Equipment Room	Diagnostics room penetration area	Bunker / CFF control room	Camera Room	CFF vent duct areas
Mobilelift or Forklift: Batteries, Hydraulic fluid	HE transport	HE transport					
Electrical equipment	Shot setup						
Solvents	Shot setup						
Fire in or around firing table or CFF service building	HE transport Shot setup	HE transport					
Toxic explosion by products	Post shot	Post shot	Post shot	Post shot		Post shot	Post test
Beryllium						Camera operation	
Highly toxic material contained in experiments	Shot setup						
HE accumulation in systems	Shot setup Post shot						
Explosion creates oxygen diffident atmosphere	Post shot	Post shot	Post shot	Post shot		Post shot	Post test
Inert or toxic gas systems				Continuous			
Flash Devices	Shot setup						
Diagnostic lasers	Shot setup						
X-ray machines, linear accelerators					Shot		
Portable Radios	Shot setup						
FXR							
Flash Device Power Supplies	Shot setup						
Tools	Shot setup						
Lightning	HE transport	HE transport					
Cameras							
Mobilelift or Forklift: Mechanical Impact	HE transport	HE transport					
Blast effects and shrapnel from shot		Shot	Shot	Shot	Shot	Shot	
Shrapnel from tire blowout	HE transport	HE transport					
Test launcher or gun	Shot setup						
Shrapnel from camera failure						Camera operation	
Liquid abrasive cutters	Shot setup						
Equipment Falling on HE	HE transport	HE transport					
Diagnostic or setup equipment falling on HE	Shot setup						
Dropped HE	HE transport	HE transport					
Seismic Event	HE transport	HE transport					
Equipment	HE transport	HE transport					
Chemical reaction with assembly materials	Shot setup						
Preconditioning heaters	Shot setup						
Unreacted HE after test	Post shot						
HE with attached detonators	Shot setup						

3.0 Hazard Analysis

For each combination of location and operation, each relevant specific hazard was considered. One or more deviations were identified which would cause each specific hazard to be realized as a hazardous event and the possible causes for these deviations were described. The deviations, together with the cause describe an event scenario. The worst-case consequences were identified for each event scenario together with the possible methods of detecting, preventing, and mitigating the event. The results of this analysis are given in Appendix A.

A simplified summary of this analysis was incorporated into the SAR update by grouping the analysis according to common hazard scenarios and providing more general descriptions of the causes, methods of detection, preventative features, consequences, and mitigative features. The last column of the Appendix A tables identifies the associated summary hazard scenario given in the Table 4-2 of the updated SAR.

4.0 Risk Assessment

Simple event trees were constructed for each hazard scenario in the updated SAR to help in the qualitative assessment of event occurrence probabilities. Appendix B contains these event trees. Each event in an event tree was classified into one of the probability categories shown in Table 5.

Table 5 Probability rating levels

Category	Description	Estimated occurrence rate per year
Incredible	Probability of occurrence is so small that a reasonable scenario is not conceivable	$< 10^{-6}$
Extremely low	Probability of occurrence is extremely unlikely or event is not expected to occur during the life of the facility or operation	10^{-6} to 10^{-4}
Low	Probability of occurrence is unlikely, or event is not expected to occur; but may occur during the life of the facility or operation.	10^{-4} to 10^{-2}
Medium	Event may occur during the facility or operation lifetime	10^{-2} to 10^{-1}
High	Event is likely to occur several times during the facility or operation lifetime.	$> 10^{-1}$

The probability of each event tree branch was estimated by examining pairs of events and estimating the probability of event pairs as shown in Table 6 Where more than two events make up an event tree branch the branch probability was estimated by examining pairs of events, treating a pair as a single event and re-entering Table 6

Table 6 Probability estimates for combined events

	Incredible	Extremely Low	Low	Medium	High
Incredible	Incredible	Incredible	Incredible	Incredible	Incredible
Extremely low	Incredible	Incredible	Incredible	Extremely Low	Extremely Low
Low	Incredible	Incredible	Extremely Low	Low	Low
Medium	Incredible	Extremely Low	Low	Low	Medium
High	Incredible	Extremely Low	Low	Medium	High

The probability of a hazard scenario was taken as the probability of the most likely branch in the associated event tree. No attempt was made to sum probabilities over all branches as the trees contain relatively few branches. Summing over branches in a quantitative probability estimation scheme would affect the probability estimates by a factor of 3 to 5. Such changes are below the resolution of the qualitative scheme adopted here.

The probability estimates of this analysis are used in the updated SAR summary hazard tables and together with the estimated consequences form the basis for deciding risk acceptability.

5.0 References

Ingram 2000 "Safety Question Review for Building 801,Proof Testing of Contained Firing Facility," SQR No.: BdivS300-CY00-CFF-01, C. Ingram, Livermore National Laboratory, Livermore, CA (November 13, 2000)

LLNL 1997 *Site 300 B-Division Firing Areas Safety Analysis Report,* UCRL-AR-122036, Rev. 1, Lawrence Livermore National Laboratory, Livermore, CA (September 1997)

LLNL Current *Environmental Safety and Health Manual,* UCRL-MA-133867, Lawrence Livermore National Laboratory, Livermore, CA (November 2000)

LLNL 2000a *Facility Safety Plan, B Division Site 300,* S300.1, Change 2, Revision 1, Lawrence Livermore National Laboratory, Livermore, CA (October 1, 2000)

LLNL 2000b "Operation ofThree-Inch Gas Gun," Operational Safety Procedure No. 300.64, Lawrence Livermore National Laboratory, Livermore, CA (March, 2000)

LLNL 2000c "Potential Scattering of Explosives by Shape Charges," Operational Safety Plan No. 300.66, Lawrence Livermore National Laboratory, Livermore, CA (July 1, 2000)

LLNL 2000d "Use Of Propane Burning to Remove Unexpended Explosives Contaminant Residue from B Division Firing Tables," Operational Safety Plan No. 300.71, Lawrence Livermore National Laboratory, Livermore, CA (December 1, 2000)

LLNL,2000e "Use of a 1550 nm cw Laser at B-Division Site 300 Firing Facilities, "Operational Safety Plan No. 851.12, Lawrence Livermore National Laboratory, Livermore, CA (August 1, 2000)

LLNL 2001 "Explosives Experiments at Elevated Temperatures; Post Test Handling," Operational Safety Plan No. 300.68, Lawrence Livermore National Laboratory, Livermore, CA (January 24, 2001)

Visoria 2001 "Description Contained Firing Facility," R. Visoria, A. Lee, L. Simmons, C. Ingram, Lawrence Livermore National Laboratory (January 5, 2001)

Appendix A

Detailed Hazard Tables

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	Mobilelift or Forklift: Batteries, Hydraulic fluid	Fire on nearby vehicle creates sufficient heat to detonate HE when personnel present	Hydraulic fluid leak with ignition source, Hydrogen leak with ignition source	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Inspection of vehicle hydraulic and electrical systems before first use on a given day Periodic inspection of vehicle batteries Approved explosives handling equipment Control of ignition sources Separation distance between combustible materials and explosives	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamber, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		B

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Hand held fire suppression Evacuation to approved cover if fire threatens HE Separated exits from CFF firing chamber TV cameras and atmosphere monitoring systems to support fire response Time delay before entering area with unreacted HE Limited time of HE exposure to hazards				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
2	Seismic Event	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Inadequate support	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Nearby equipment separated from HE and supported to prevent falling Design of test stands Transport container or other cushioning material protects from shock and friction during transport Limited time of HE exposure to hazards	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)	Assume HE is secured on firing table during this condition. Other condition is covered under setup condition.	A

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
3	Lightning	Electrical input sufficient to fire detonators or to directly initiate HE when personnel present	Procedure violation, Failure of lightning warning	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Detonators disconnected and shorted until final arming High energy Initiators used except as approved under specific OSP Evacuation to approved cover on lightning warning Detonator leads / initiation circuit grounded until personnel under cover	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only), Evacuation of explosives area as soon as practical after lightning alert	This event is most likely not applicable to CFF, but credit is not taken for firing chamber structure as an electrical shield	C

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Separated exits from CFF firing chamber Limited exposure time				
4	Mobilelift, Forklift or other lifting equipment: Mechanical Impact	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Human Error, Failure of vehicle controls	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Approved explosives handling equipment Inspection of crane and forklift tires, steering, suspension and lift mechanisms prior to first use in a given day. Transportation containers or other cushioning material	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		A

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Specific OSP required for handling of large explosive charges Plans and procedures for movement of explosives Training and qualification of explosives handlers				
5	HE dropped or slid	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Human Error	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Training and qualification of explosives handlers Two person lift of large explosive charges	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		A

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Use of approved work procedures Specific OSP required for handling of large explosive charges				
6	Shrapnel from tire blowout	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Equipment failure	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Inspection of crane and forklift tires, steering, suspension and lift mechanisms prior to first use in a given day. Limited time of HE exposure to hazards	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		A

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
7	Equipment Falling on HE	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Human Error, Inadequate support, Failure of vehicle controls	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Transport container or other cushioning material protects from shock and friction during transport Nearby equipment separated from HE and supported to prevent falling Limited exposure time	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		A

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
8	Fire in or around firing table or CFF service building	Fire creates sufficient heat to detonate HE	Brush/grass fire (N/A CFF)	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Minimize amount of combustible materials. Control of ignition sources Hand held fire suppression Evacuation to approved cover if fire threatens HE Time delay before entering area with unreacted HE Limited exposure time	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamber, Q-D siting / Maximum explosives weight, Sites Remote location		B

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	HE transport							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
9	Inert or toxic gas systems	Inert or toxic gas leak into confined space	Equipment failure	Atmosphere Monitoring System, Observed by Personnel	Design of gas systems to contain toxic or inert gas Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting		P

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
1	Mobilelift or Forklift: Batteries, Hydraulic fluid	Fire on nearby vehicle creates sufficient heat to detonate HE when personnel present	Hydraulic fluid leak with ignition source, Hydrogen leak with ignition source	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Inspection of vehicle hydraulic and electrical systems before first use on a given day Periodic inspection of vehicle batteries Control of ignition sources	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamber, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		B

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Separation distance between combustible materials and explosives Hand held fire suppression Evacuation to approved cover if fire threatens HE Separated exits from CFF firing chamber TV cameras and atmosphere monitoring systems to support fire response Time delay before entering area with unreacted HE Limited time of HE exposure to hazards				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
2	Seismic Event	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Inadequate support	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Design of test stands Nearby equipment separated from HE and supported to prevent falling Limited time of HE exposure to hazards	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)	Assume HE secured on firing table during this condition. Other condition is covered under transport condition.	A

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
3	Lightning	Electrical input sufficient to fire detonators or to directly initiate HE when personnel present	Procedure violation, Failure of lightning warning	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Detonators disconnected and shorted until final arming	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only), Evacuation of explosives area as soon as practical after lightning alert	This event is most likely not applicable to CFF, but credit is not taken for firing chamber structure as an electrical shield	C

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					High energy Initiators used except as approved under specific OSP Detonator leads / initiation circuit grounded until personnel under cover Evacuation to approved cover on lightning warning Separated exits from CFF firing chamber Limited time of HE exposure to hazards				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
4	Electrical equipment	Fire on nearby electrical equipment creates sufficient heat to detonate HE	Equipment failure	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Periodic inspection of electrical equipment located near HE. Hand held fire suppression Use of approved work procedures	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamber, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		B

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Prior review and approval of portable electrical equipment Installed equipment rated for use in areas of explosives hazard Separation distance between combustible materials and explosives Separated exits from CFF firing chamber TV cameras and atmosphere monitoring systems to support fire response Time delay before entering area with unreacted HE				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Limited time of HE exposure to hazards				
5	Solvents	Chemical fire creates sufficient heat to detonate HE	Human Error, Equipment failure	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Control of ignition sources Minimize amount of combustible materials.	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamber, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		B

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Separation distance between combustible materials and explosives Use of approved work procedures Hand held fire suppression Evacuation to approved cover if fire threatens HE Separated exits from CFF firing chamber TV cameras and atmosphere monitoring systems to support fire response Time delay before entering area with unreacted HE				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Limited time of HE exposure to hazards				
6	Portable Radios	RF output sufficient to trigger detonator	Procedure violation	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Radio transmitters controlled in area	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		C

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Detonator leads / initiation circuit grounded until personnel under cover High energy Initiators used except as approved under specific OSP Detonators disconnected and shorted until final arming Limited time of HE exposure to hazards				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
7	Flash Devices, Diagnostic lasers	Personnel exposure to laser beam or intense light sufficient to cause injury	Inadequate muster, Equipment failure, Inadequate maintenance of beam filters, Beam scattering or reflection, Wiring error	Observed by Personnel	Compliance with ANSI Standard Z136.1 Interlocked laser room shutter for pulsed laser Control of dark flap key Capacitor bank interlocks Enclosed optical paths for high intensity lasers Leak testing of high intensity laser paths before connection to high intensity laser source	Personnel injury (eye damage and physical burns).	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Laser safety glasses		L

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Optical fiber end caps when fibers for high intensity lasers are not connected Muster before generation of intense laser light Light filters Training and qualification of personnel Paging announcements before firing Visual observation of firing area Use of approved work procedures Signs and alarms				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
8	Flash Device Power Supplies	Electrical input sufficient to fire detonators or to directly initiate HE when personnel present	Equipment failure	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Detonator leads / initiation circuit grounded until personnel under cover Detonator cables separated from other energized cables	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		C

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Detonators disconnected and shorted until final arming Test stand electrically isolated from floor by rubber mat Limited time of HE exposure to hazards Use of approved work procedures Electronic photographic flashes evaluated for intrinsic safety before use and separation distance from explosives maintained				

	Project: Site 300 SAR Location: Firing Table, CFF Firing Chamber, CFF Gray Area Condition: Shot setup								
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
9	Exposed Conductors	Electrical input sufficient to fire detonators or to directly initiate HE when personnel present	Fire with hot-short	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Detonator cables separated from other energized cables Test stand electrically isolated from floor by rubber mat Hand held fire suppression	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		C

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Limited time of HE exposure to hazards Noninitiating systems disconnected or connected through intrinsic safe boxes when personnel present				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
10	ESD	Electrical input sufficient to fire detonators or to directly initiate HE when personnel present	Electrostatic discharge triggers detonator	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Detonator leads / initiation circuit grounded until personnel under cover High energy Initiators used except as approved under specific OSP	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		C

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Detonators disconnected and shorted until final arming Test stand electrically isolated from floor by rubber mat Tasks involving tools and other spark sources completed before explosives arrive. Limited time of HE exposure to hazards Personnel handling ESD sensitive explosives / components wear clothing that does not generate static electricity.				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
11	Chemical reactor with assembly materials	Chemical reaction on HE creates sufficient heat input to: cause detonation, sensitize HE such that detonation caused by normal acceptable energy source, or release toxic gas.	Unanticipated chemical reaction, Procedure violation	Observed by Personnel, Heat detectors (CFF only)	Materials placed in contact with HE evaluated for compatibility Training and qualification of explosives handlers Use of approved work procedures	HE detonation (personnel death or injury), or Toxic gas release	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		D

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
12	Preconditioning heaters, Diagnostic lasers	Sufficient heat input to cause detonation or to catalyze detonation caused by other energy sources	Equipment failure	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only), HE temperature monitoring	Redundant temperature control systems maintain temperature below critical temperature when chamber is manned, except as allowed by specific OSP. Use of approved heating equipment	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Separated emergency exits in firing chamberQ-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		E

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Grounding of high energy heater leads when personnel present Use of approved work procedures Limits on allowed laser intensity when personnel present Temperature monitoring Muster before generation of intense laser light Interlocked laser room shutter for pulsed laser Control of dark flap key				

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
13	Test launcher or gun	Premature firing of launcher or gun	Wiring error, Equipment failure, Exposure of launcher to hazards similar to those analyzed for HE., Inadequate muster, Use of incorrect test equipment	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Protection from unplanned initiation inputs similar HE detonation hazards.	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		F

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
14	HE with attached detonators	Planned source of electrical or laser input causes detonators to fire while personnel in chamber	Equipment failure, Use of incorrect test equipment, Wiring error, Inadequate muster	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Key interlocked firing and charging circuits High energy Initiators used except as approved under specific OSP Use of approved test equipment for initiating circuits.	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		G

	Project: Location: Condition:	Site 300 SAR Firing Table, CFF Firing Chamber, CFF Gray Area Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Detonators disconnected and shorted until final arming Run / safe boxes Interlocks Beam blocks on laser fibers connected to detonators when personnel are present Use of approved work procedures Training and qualification of explosives handlers Paging announcements before firing Muster before firing				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Detonator leads / initiation circuit grounded until personnel under cover Installed equipment rated for use in areas of explosives hazard Visual observation of firing area				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
15	Test launcher or gun	Premature firing of launcher or gun	Equipment failure, Use of incorrect test equipment, Wiring error, Inadequate muster, Exposure of launcher to hazards similar to those analyzed for HE.	Observed by Personnel, Heat detectors (CFF only), Sprinkler Activation (CFF gray area only)	Control of gun cart key Launcher not loaded until just before firing Detonator leads / initiation circuit grounded until personnel under cover	Personnel death or injury from impact	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight, Sites Remote location, Confinement system (CFF Only)		J

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					High energy Initiators used except as approved under specific OSP Run / safe boxes Key interlocked firing and charging circuits Use of approved work procedures Training and qualification of explosives handlers Muster before firing Paging announcements before firing Shielding and sandbags Visual observation of firing area				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Use of approved test equipment for initiating circuits.				
16	X-ray machines & linear accelerators	Personnel radiation exposure exceeds allowable occupational dose	Failure of X-ray machine / linear accelerator control and interlock systems, Inadequate muster	Observed by Personnel, Dosimetry	Interlocks Paging announcements before firing Muster before firing Run / safe boxes Use of approved work procedures Visual observation of firing area Training and qualification of personnel	Personnel injury or death (radiation exposure)	Operational access controls limit number of exposed personnel, Facility Emergency Response Procedures		K

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
17	Inert or toxic gas systems	Inert or toxic gas leak into confined space	Equipment failure	Atmosphere Monitoring System, Observed by Personnel	Design of gas systems to contain toxic or inert gas Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting		P

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
18	HE accumulation in systems	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Procedure violation, Equipment failure	Observed by Personnel	Redundant filters or traps in vacuum lines that provide a path between bare HE and evacuated volumes Washdown system designed to safely pump fluids containing HE Wash down collected and disposed of separately if unreacted material is detected Sampling of washdown system filters	Personnel injury or illness	Facility Emergency Response Procedures		R

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Washdown system filters disposed of as HE if HE concentration exceeds pre-determined limit Periodic inspection of potential HE collection points in ventilation, vacuum, and washdown systems.				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
19	Liquid abrasive cutters	Mechanical impact or friction sufficient to detonate or react HE when personnel present	Equipment failure, Wiring error, Inadequate muster	Observed by Personnel	Control of safety / grounding panel key Training and qualification of explosives handlers Use of approved work procedures Limited exposure time Visual observation of firing area	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Confinement system (CFF Only), Q-D siting / Maximum explosives weight, Sites Remote location		S

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber, CFF Gray Area							
	Condition:	Shot setup							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Muster before firing				
20	Highly toxic materials contained in experiments	Inert or toxic gas leak	Container struck or dropped, Corrosion of container materials, Container opened to atmosphere due to human error	Observed by Personnel, Monitoring equipment when odor threshold is below exposure limits	Container design Compatibility review of container materials Leak testing of container prior to filling Onsite transportation procedures for highly toxic materials	Personnel injury or death (poisoning, suffocation, lung damage)., Personnel injury (eye damage and physical burns).	Sites Remote location, Operational access controls limit number of exposed personnel, Facility Emergency Response Procedures	Not applicable to CFF	U

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
1	Toxic explosion by products, Explosion creates oxygen diffident atmosphere(CFF Only)	Firing chamber is not adequately purged before personnel entry	Vent and purge system airflow less than design	Atmosphere Monitoring System, Observed by Personnel, Chamber pressure monitoring, Hand held atmosphere monitoring	Atmosphere monitoring Firing chamber pressure monitoring Firing chamber purge and ventilation Confined space entry procedures Use of appropriate personnel protective equipment Use of approved work procedures	Personnel injury or death (poisoning, suffocation, lung damage).	Operational access controls limit number of exposed personnel, Facility Emergency Response Procedures, Portable gas monitoring used on entry		N

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
2	Unreacted HE after test	HE, sensitized by test detonates as a result of normal handling	Failure to recognize explosive hazard posed by test residue, Inadequate cleanup procedure	Observed by Personnel, Heat detectors (CFF only)	Post-shot assessment of firing chamber using CCTV or robot-mounted TV Recovery of unexpended explosives under control of OSP or explosives expert Detonation in place of unexpended explosives considered unsafe to handle	HE detonation (personnel death or injury)	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Debris shield on burner vehicles (not CFF), Sites Remote location, Confinement system (CFF Only)		H

	Project: Site 300 SAR Location: Firing Table, CFF Firing Chamber Condition: Post shot								
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
					Training and qualification of explosives handlers Time delay before entering area with unreacted HE Explosives qualified vacuum cleaner Burn-off of residual HE that is not amenable to hand collection (not CFF) Use of static free clothing and bags Use of soft soled shoes Washdown of residue (CFF only)				

	Project:	Site 300 SAR							
	Location:	Firing Table, CFF Firing Chamber							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Mitigative Features	Comments	SAR Hazard Scenario
3	Fire in or around firing table or CFF service building	Brush/grass fire (N/A CFF)	Detonation of explosives on firing table ignites grass	Observed by Personnel	Clear zone around bunker firing table Controlled burns Restricted shot time (not firing on high wind days) Fire breaks Fragment analysis Fire department	Personnel injury or death (radiation exposure), Damage to facilities beyond Site 300	Fire hydrants and extinguishers, Fire breaks, Fire department, Evacuation	Not applicable to CFF	M

	Project:	Site 300 SAR							
	Location:	Vent duct areas, CFF Gray Area							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	Toxic explosion by products, Explosion creates oxygen diffident atmosphere	Facility areas in which firing chamber purge and vent ducts are routed contain toxic or oxygen diffident atmosphere	Firing chamber not isolated during shot, Leakage past firing chamber doors	Hand-held atmosphere monitoring, Observed by Personnel	Structural design of isolation valves and penetrations Firing chamber vent ducts not routed through areas inhabited during shot Isolation valve position indication Firing chamber pressure monitoring	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Portable gas monitoring used on entry, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting, Operational access controls limit number of exposed personnel		N

	Project:	Site 300 SAR							
	Location:	Vent duct areas, CFF Gray Area							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Control over quantity of explosives in tests Muster before firing Structural design of bunkers and CFF firing chamber Use of approved work procedures				

	Project:	Site 300 SAR							
	Location:	CFF Diagnostic Equipment Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	Toxic explosion by products, Explosion creates oxygen diffident atmosphere	Wall penetrations fail to provide adequate seal	Equipment failure	Atmosphere Monitoring System, Observed by Personnel	Penetration design Periodic inspection of penetrations Double barrier between firing chamber and occupied areas,	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Portable gas monitoring used on entry, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting, Operational access controls limit number of exposed personnel	Would require massive failures of two sets of penetrations	N

	Project:	Site 300 SAR							
	Location:	CFF Diagnostic Equipment Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
2	Blast effects and shrapnel from shot	Personnel exposed to blast effects or shrapnel as a result of planned firing	Failure to properly secure penetrations or doors, Structural failure of bunker or CFF firing chamber, Failure of CFF door closing and pinning mechanisms, Error in size of explosive, Error in locating explosives	Observed by Personnel	Structural design of bunkers and CFF firing chamber	Personnel injury	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight		T
					Double structural barriers between CFF firing chamber and diagnostic area				
					Layout of CFF support area shields occupied areas from blast effects in the event of door failure				

	Project:	Site 300 SAR							
	Location:	CFF Diagnostic Equipment Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					CFF firing chamber equipment door and door pin indication Training and qualification of explosives handlers Use of approved work procedures Control over quantity of explosives in tests Localized shielding Experiment design review Pre-designated test positions Accidental detonation hazard zone				

	Project:	Site 300 SAR							
	Location:	CFF Diagnostics Room Penetration Area, Camera Room							
	Condition:	Continuous							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	Inert or toxic gas systems	Inert or toxic gas leak into confined space	Equipment failure	Atmosphere Monitoring System, Observed by Personnel	Design of gas systems to contain toxic or inert gas	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting		P
					Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting				
					Use of appropriate personnel protective equipment				
					Confined space entry procedures				

	Project:	Site 300 SAR							
	Location:	CFF Diagnostics Room Penetration Area, Camera Room							
	Condition:	Continuous							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Atmosphere monitoring				

	Project:	Site 300 SAR							
	Location:	Bunker / CFF control room							
	Condition:	Shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	X-ray machines & linear accelerators	Personnel radiation exposure exceeds allowable occupational dose	Shot	Observed by Personnel, Radiation monitors, Dosimetry	Shielding Radiation monitors Use of approved work procedures Training and qualification of personnel	Personnel injury or death (radiation exposure)	Operational access controls limit number of exposed personnel, Facility Emergency Response Procedures, Radiation monitors		K

	Project:	Site 300 SAR							
	Location:	Bunker / CFF control room							
	Condition:	Shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
2	Blast effects and shrapnel from shot	Personnel exposed to blast effects or shrapnel as a result of planned firing	Failure to properly secure penetrations or doors, Structural failure of bunker or CFF firing chamber, Failure of CFF door closing and pinning mechanisms, Error in size of explosive, Error in locating explosives	Observed by Personnel	Structural design of bunkers and CFF firing chamber Separation distance between CFF firing chamber and control room Training and qualification of explosives handlers	Personnel injury	Facility Emergency Response Procedures, Operational access controls limit number of exposed personnel, Q-D siting / Maximum explosives weight		T

	Project:	Site 300 SAR							
	Location:	Bunker / CFF control room							
	Condition:	Shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of detecting event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Use of approved work procedures Control over quantity of explosives in tests Localized shielding Experiment design review Pre-designated test positions Accidental detonation hazard zone				

	Project:	Site 300 SAR							
	Location:	Camera Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
1	Toxic explosion by products, Explosion creates oxygen diffident atmosphere	Personnel exposed to toxic gas in area due to camera or cable penetrations failure.	Failure of or leakage past penetrations	Atmosphere Monitoring System, Observed by Personnel, Chamber pressure monitoring	Penetration design Muster before firing Periodic inspection of penetrations Atmosphere monitoring Venting of camera room on overpressure Double lenses in camera penetrations	Personnel injury or death (poisoning, suffocation, lung damage).	Facility Emergency Response Procedures, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting, Camera exhaust systems		N

	Project:	Site 300 SAR							
	Location:	Camera Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Double barrier between firing chamber and occupied areas. Confined space entry procedures				
2	Beryllium	Beryllium scattered or vaporized by camera failure	Equipment failure	Observed by Personnel, Monitoring equipment when odor threshold is below exposure limitsAudio monitoring (B851 only)	Camera rotors designed for operational stresses	Personnel injury or illness	Facility Emergency Response Procedures, Ventilation systems in areas containing toxic gas, inert gas, or firing chamber ventilation ducting, Camera exhaust systems		Q
					Beryllium contained by camera case Muster before firing				

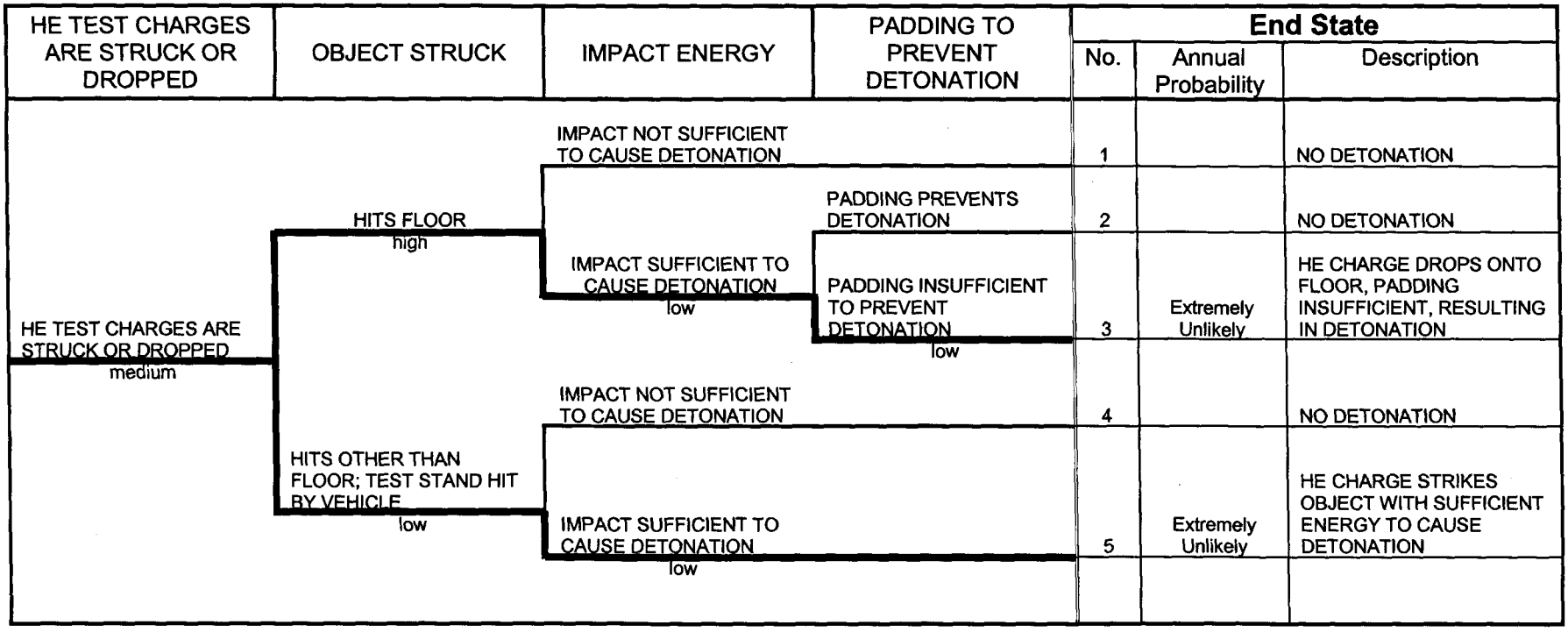
	Project:	Site 300 SAR							
	Location:	Camera Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
3	Blast effects and shrapnel from shot	Personnel exposed to blast effects or shrapnel as a result of planned firing	Error in locating explosives, Error in size of explosive, Failure to properly secure penetrations or doors, Inadequate muster	Observed by Personnel	Run / safe boxes Interlocks Control of safety / grounding panel key Double lenses in camera penetrations	Personnel injury or illness	Facility Emergency Response Procedures, Facility shape shields camera penetrations from fragments and reduces overpressure, Inhabited areas protected from camera room by walls and, in CFF, by distance, Camera room venting, confinement, and design for overpressure (CFF only)		O

	Project:	Site 300 SAR							
	Location:	Camera Room							
	Condition:	Post shot							
Scenario No.	Hazard	Deviation	Possible Causes	Methods of Detecting Event	Preventative Features	Possible Consequences	Migitative Features	Comments	SAR Hazard Scenario
					Structural design of isolation valves and penetrations Training and qualification of explosives handlers Paging announcements before firing Muster before firing Control over quantity of explosives in tests Experiment design review Pre-designated test positions				

Appendix B

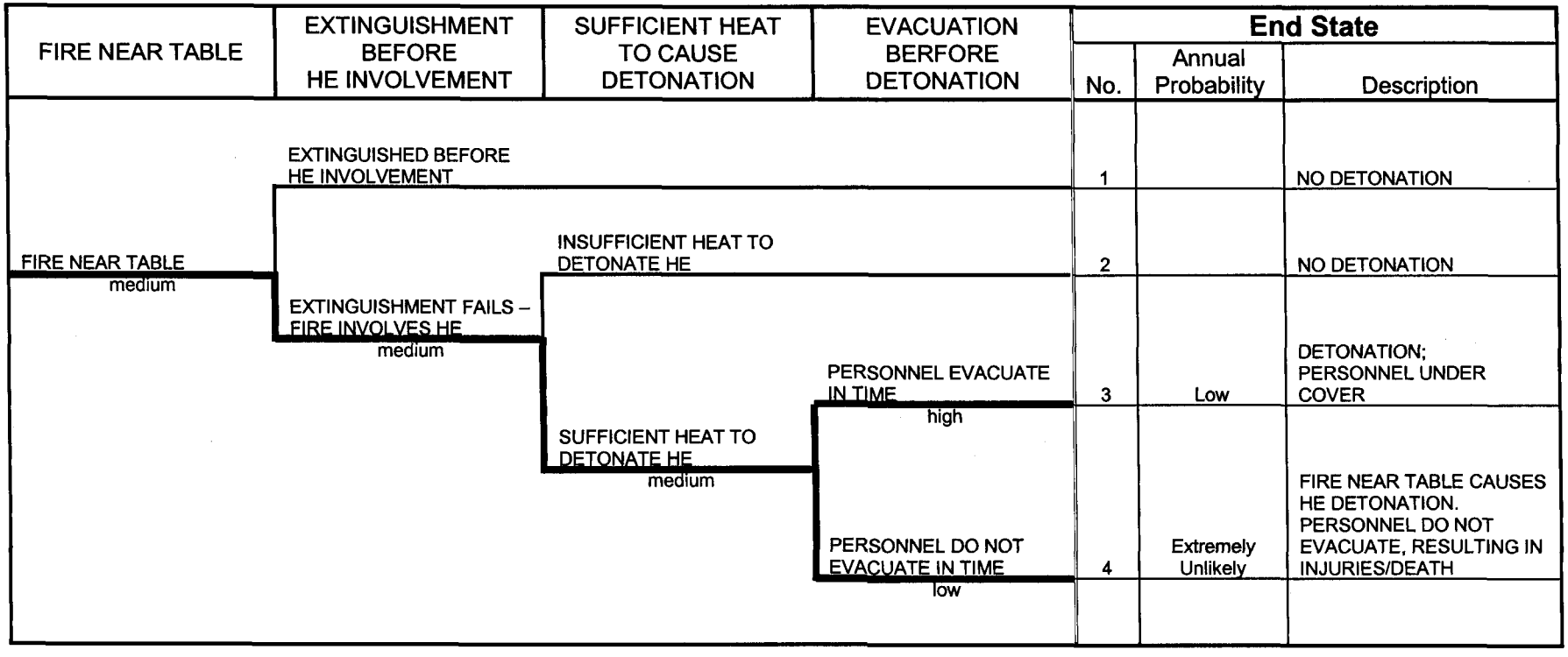
Summary Event Trees

Fig B.1 – SAR Scenario A -- Unplanned detonation on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present: Test charges are struck or dropped, causing detonation.



HE TEST CHARGES ARE STRUCK OR DROPPED	OBJECT STRUCK	IMPACT ENERGY	PADDING TO PREVENT DETONATION	End State		
				No.	Annual Probability	Description
		IMPACT NOT SUFFICIENT TO CAUSE DETONATION		1		NO DETONATION
	HITS FLOOR high		PADDING PREVENTS DETONATION	2		NO DETONATION
		IMPACT SUFFICIENT TO CAUSE DETONATION low	PADDING INSUFFICIENT TO PREVENT DETONATION low	3	Extremely Unlikely	HE CHARGE DROPS ONTO FLOOR, PADDING INSUFFICIENT, RESULTING IN DETONATION
HE TEST CHARGES ARE STRUCK OR DROPPED medium		IMPACT NOT SUFFICIENT TO CAUSE DETONATION		4		NO DETONATION
	HITS OTHER THAN FLOOR; TEST STAND HIT BY VEHICLE low	IMPACT SUFFICIENT TO CAUSE DETONATION low		5	Extremely Unlikely	HE CHARGE STRIKES OBJECT WITH SUFFICIENT ENERGY TO CAUSE DETONATION

Fig B.2 – SAR Scenario B. Unplanned detonation caused by Fire on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present.



FIRE NEAR TABLE	EXTINGUISHMENT BEFORE HE INVOLVEMENT	SUFFICIENT HEAT TO CAUSE DETONATION	EVACUATION BERFORE DETONATION	End State		
				No.	Annual Probability	Description
	EXTINGUISHED BEFORE HE INVOLVEMENT			1		NO DETONATION
FIRE NEAR TABLE medium		INSUFFICIENT HEAT TO DETONATE HE		2		NO DETONATION
	EXTINGUISHMENT FAILS – FIRE INVOLVES HE medium		PERSONNEL EVACUATE IN TIME high	3	Low	DETONATION; PERSONNEL UNDER COVER
		SUFFICIENT HEAT TO DETONATE HE medium				
			PERSONNEL DO NOT EVACUATE IN TIME low	4	Extremely Unlikely	FIRE NEAR TABLE CAUSES HE DETONATION. PERSONNEL DO NOT EVACUATE, RESULTING IN INJURIES/DEATH

Fig B.3 – SAR Scenario C1. Unplanned detonation on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present: Electrical input from unplanned source. Detonator sensitive to ESD.

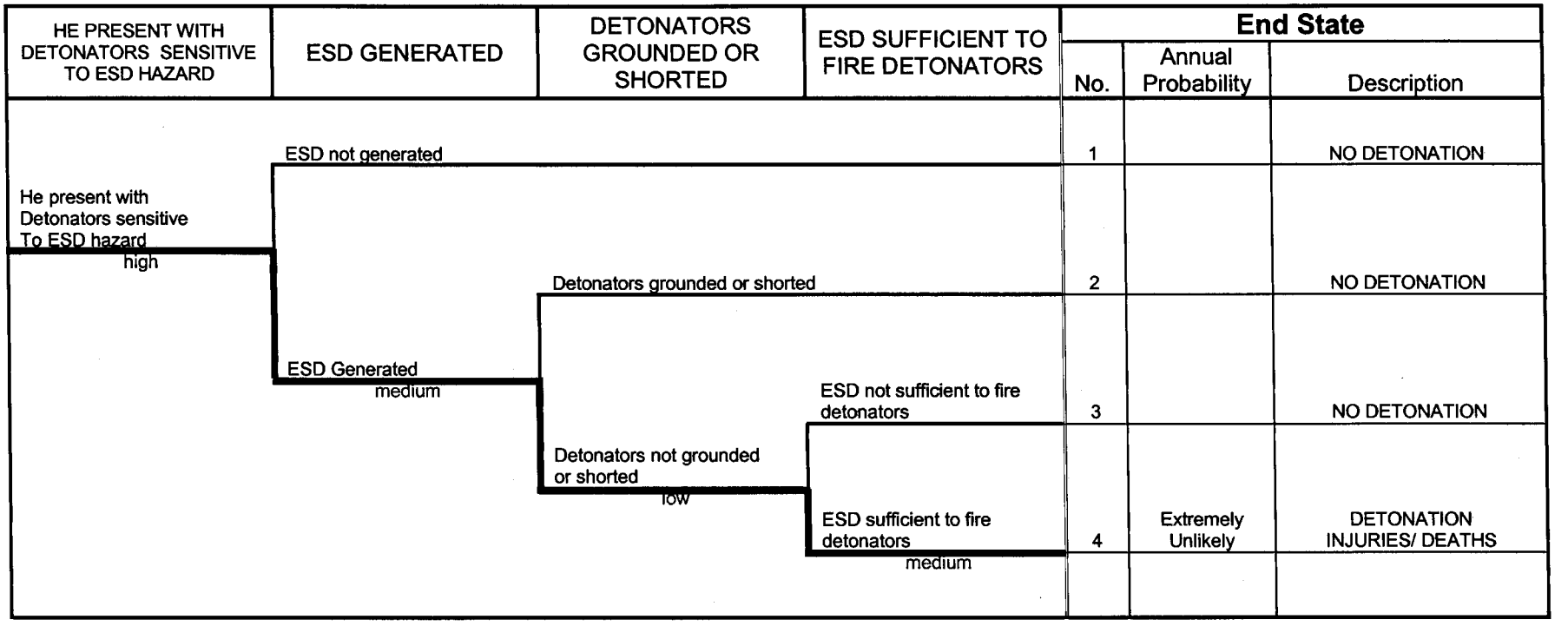


Fig B.4 – SAR Scenario C2. Unplanned detonation on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present: Electrical input from unplanned source. Detonation caused by fire Induced short in energized cables co located with detonator cables

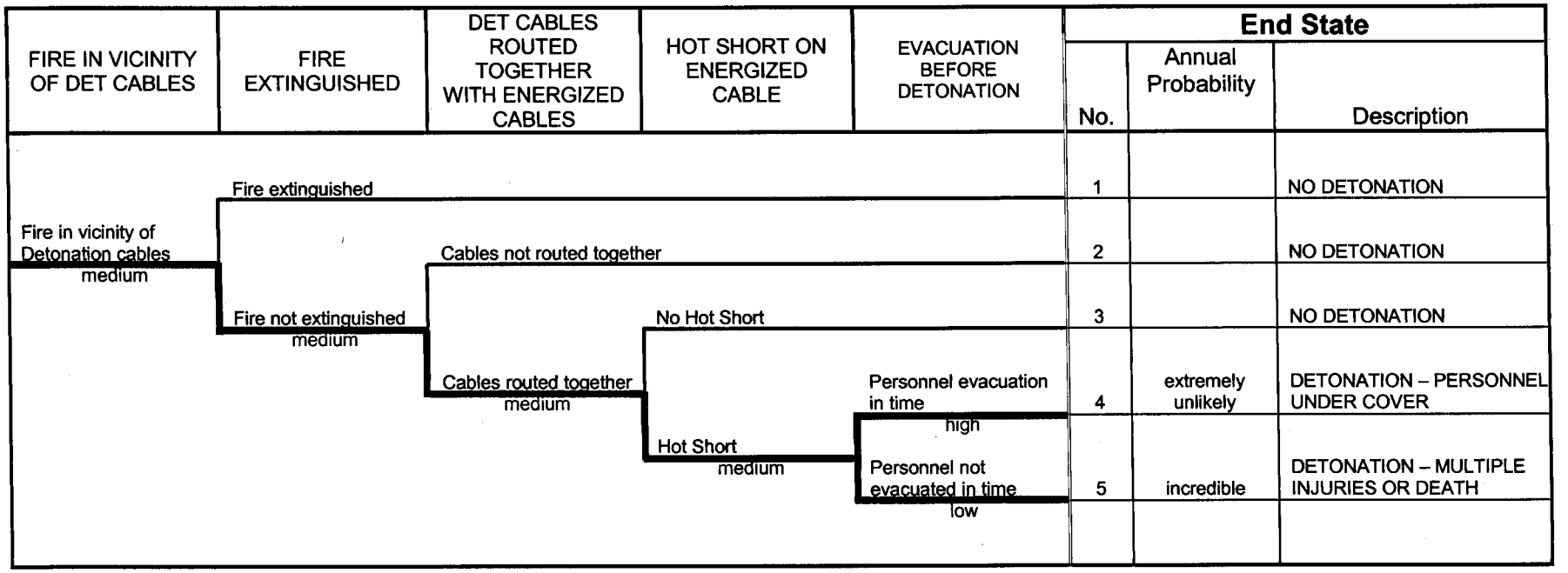


Fig B.5 – SAR Scenario C3. Unplanned detonation on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present: Electrical input from unplanned source. Lightning imparts sufficient energy to fire detonators or to directly initiate HE.

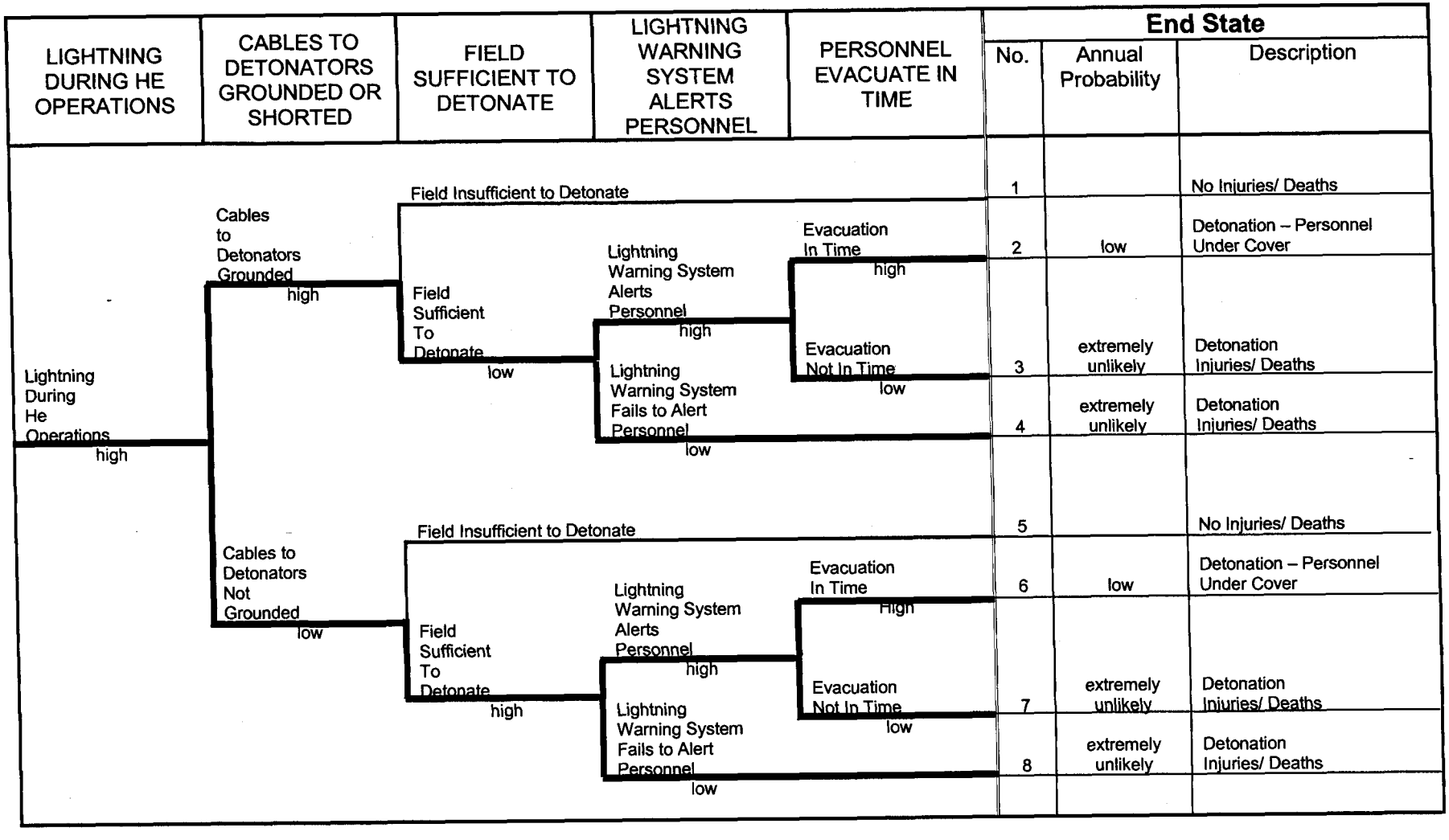


Fig B.6 – SAR Scenario D. Unplanned detonation on bunker firing table, or in CFF firing table chamber with personnel present: Chemical reaction with assembly materials either detonates or sensitizes such that normal operation detonates HE.

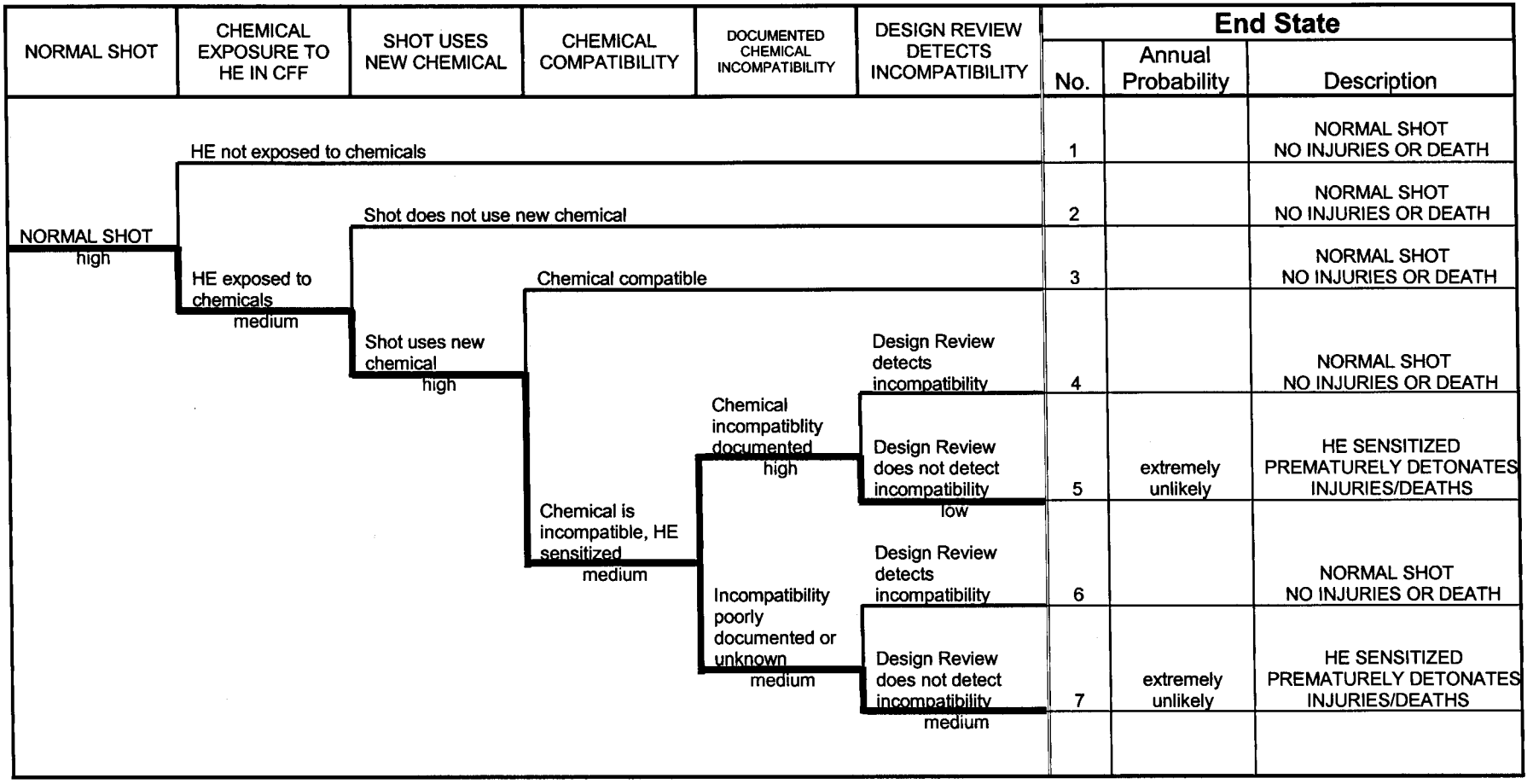
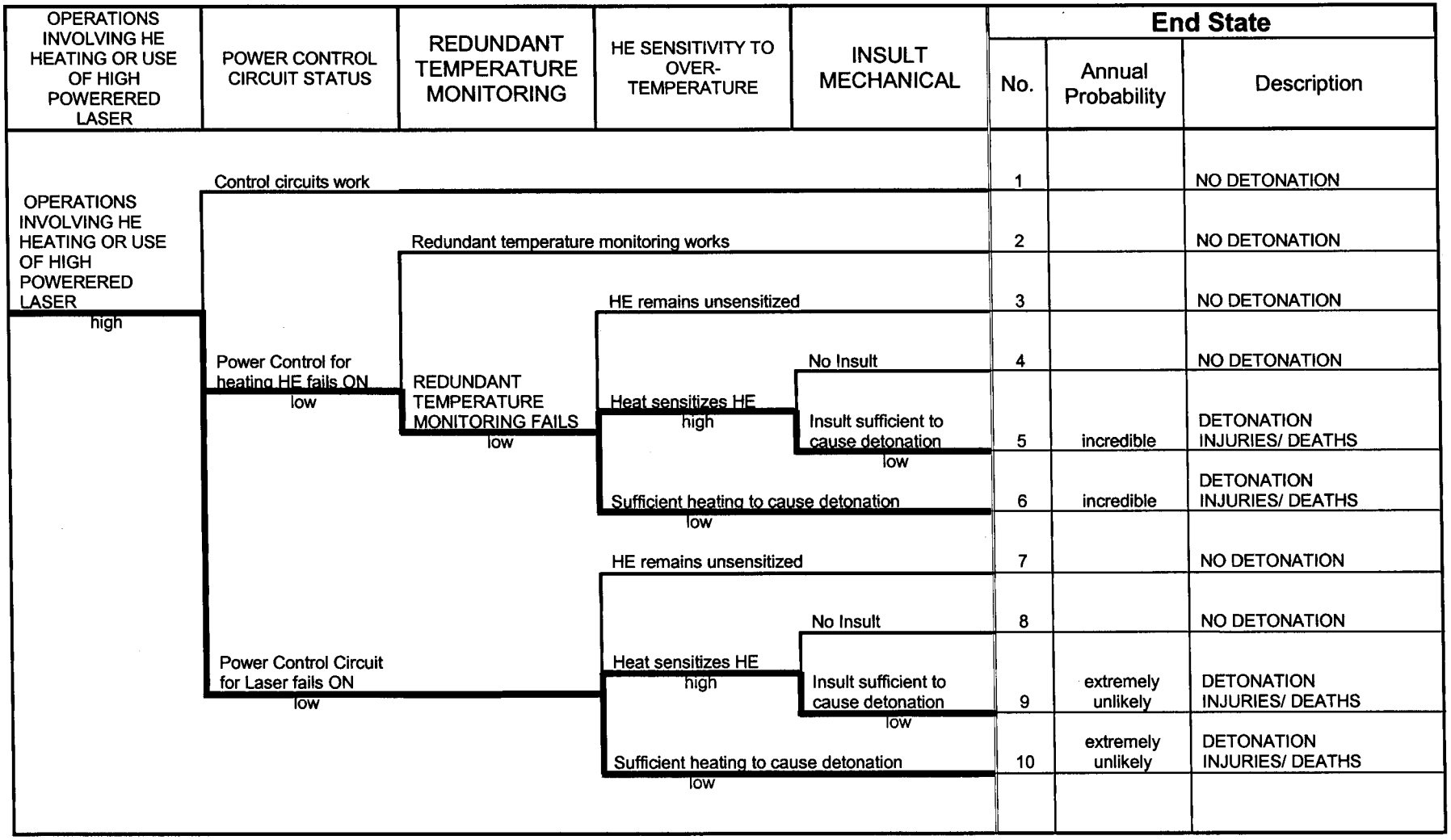


Fig B.7 – SAR Scenario E. Unplanned detonation on bunker firing table, in CFF firing chamber, or in CFF gray area with personnel present: Preconditioning heater or laser detonates or sensitizes such that normal operation detonates HE.



OPERATIONS INVOLVING HE HEATING OR USE OF HIGH POWERERED LASER	POWER CONTROL CIRCUIT STATUS	REDUNDANT TEMPERATURE MONITORING	HE SENSITIVITY TO OVER-TEMPERATURE	INSULT MECHANICAL	End State		
					No.	Annual Probability	Description
OPERATIONS INVOLVING HE HEATING OR USE OF HIGH POWERERED LASER high	Control circuits work				1		NO DETONATION
	Power Control for heating HE fails ON low	Redundant temperature monitoring works			2		NO DETONATION
		REDUNDANT TEMPERATURE MONITORING FAILS low	HE remains unsensitized		3		NO DETONATION
			Heat sensitizes HE high	No Insult	4		NO DETONATION
				Insult sufficient to cause detonation low	5	incredible	DETONATION INJURIES/ DEATHS
			Sufficient heating to cause detonation low		6	incredible	DETONATION INJURIES/ DEATHS
	Power Control Circuit for Laser fails ON low		HE remains unsensitized		7		NO DETONATION
			Heat sensitizes HE high	No Insult	8		NO DETONATION
				Insult sufficient to cause detonation low	9	extremely unlikely	DETONATION INJURIES/ DEATHS
			Sufficient heating to cause detonation low		10	extremely unlikely	DETONATION INJURIES/ DEATHS

Fig B.8 – SAR Scenario G1. Detonation on bunker firing table, in CFF firing table chamber with personnel present: Electrical or laser light input from plannned source – Authorized personnel fail to muster before shot.

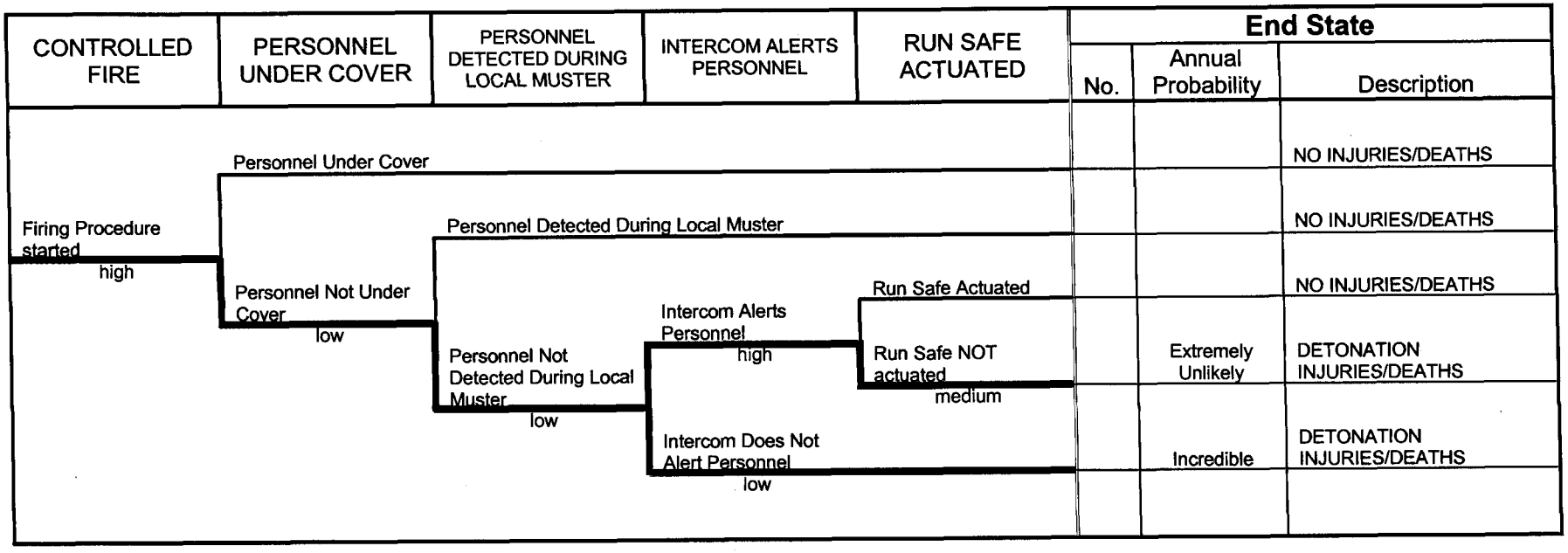


Fig B.9 – SAR Scenario G2. Detonation on bunker firing table, in CFF firing table chamber with personnel present: Electrical or laser light input from plannned source – Detonators inadvertently fired before muster.

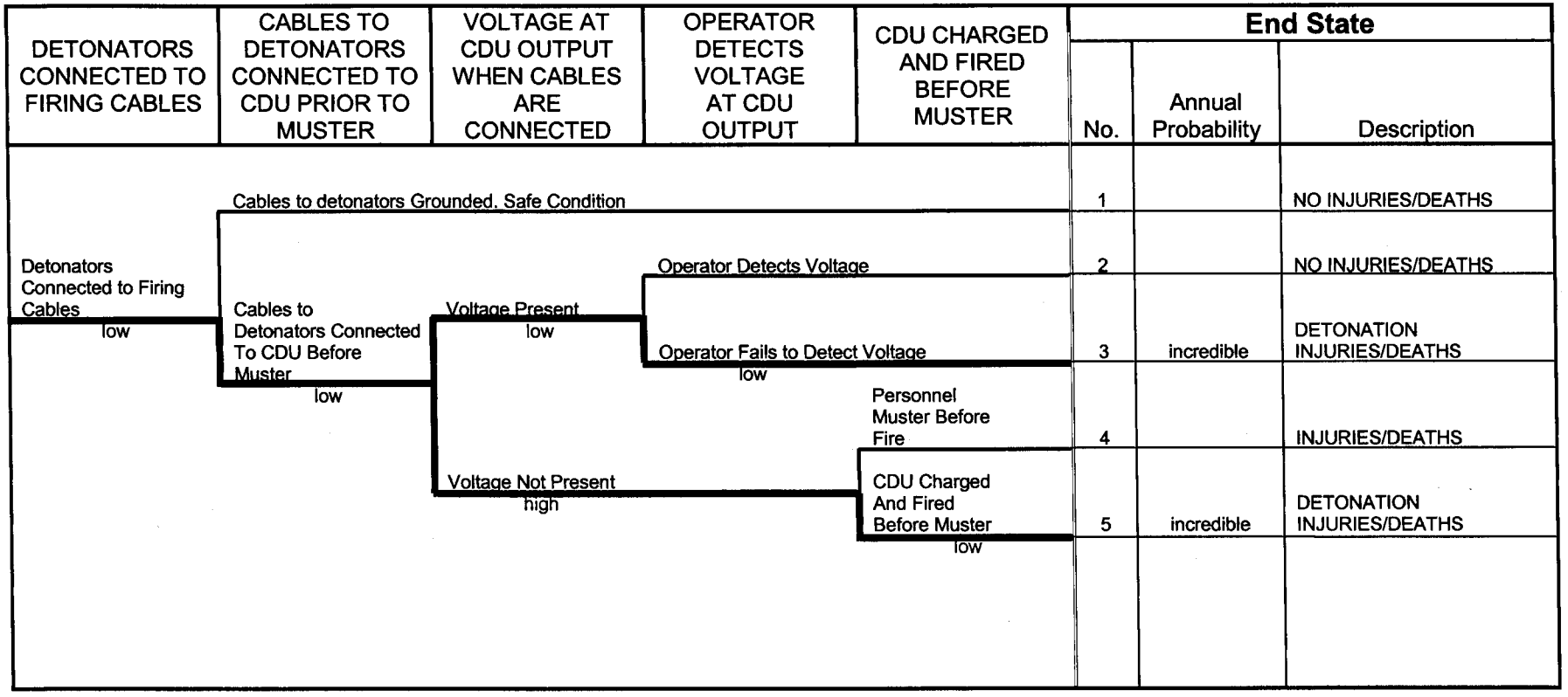


Fig B.10 – SAR Scenario G.2A Detonation on bunker firing table, in CFF firing chamber with personnel present: Electrical or laser light input from planned source -- unauthorized personnel in mustering area

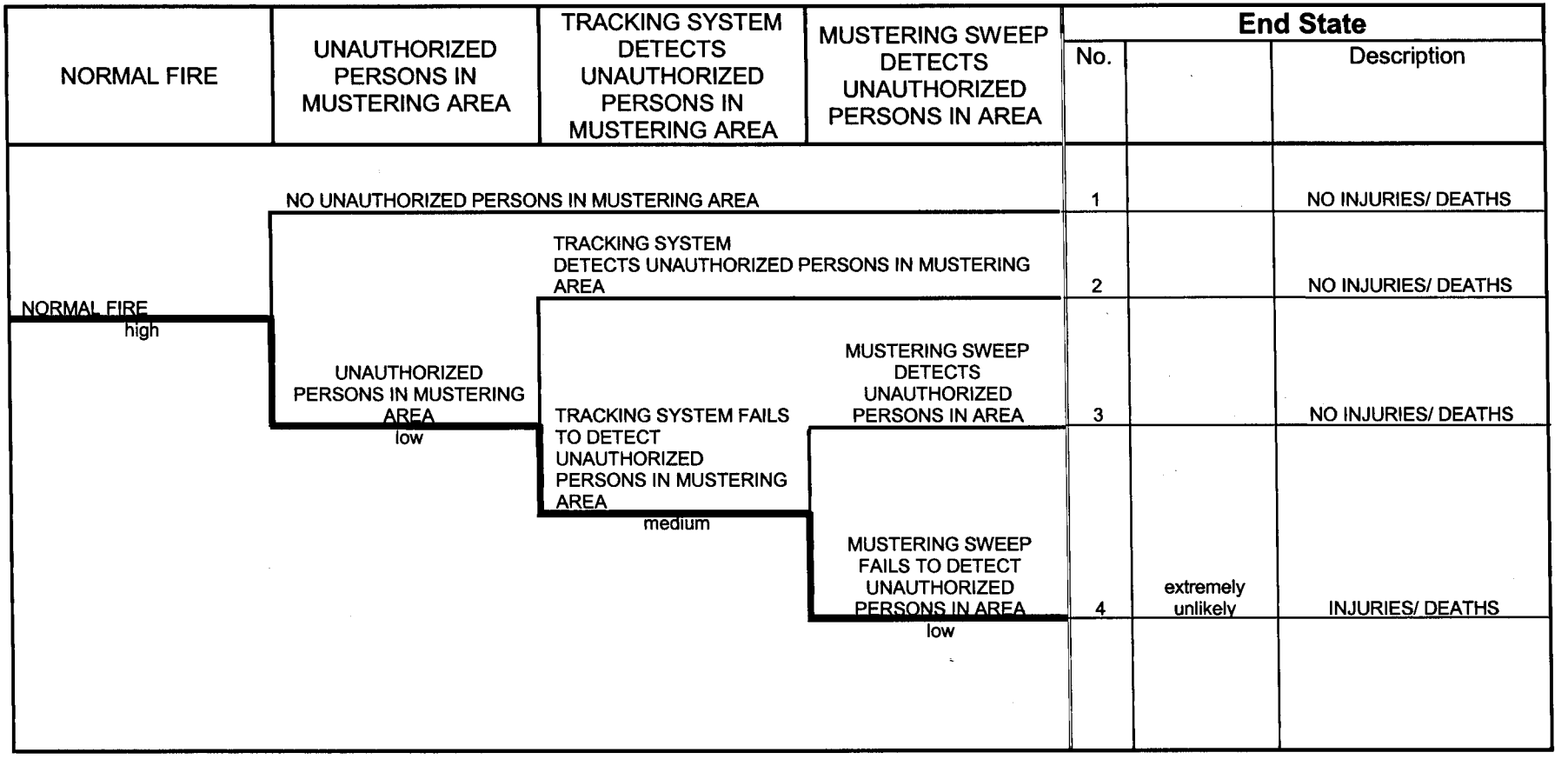


Fig B.11– SAR Scenario H. Unplanned detonation on bunker firing table, or in CFF firing chamber with personnel present: Detonation of unreacted HE after shot.

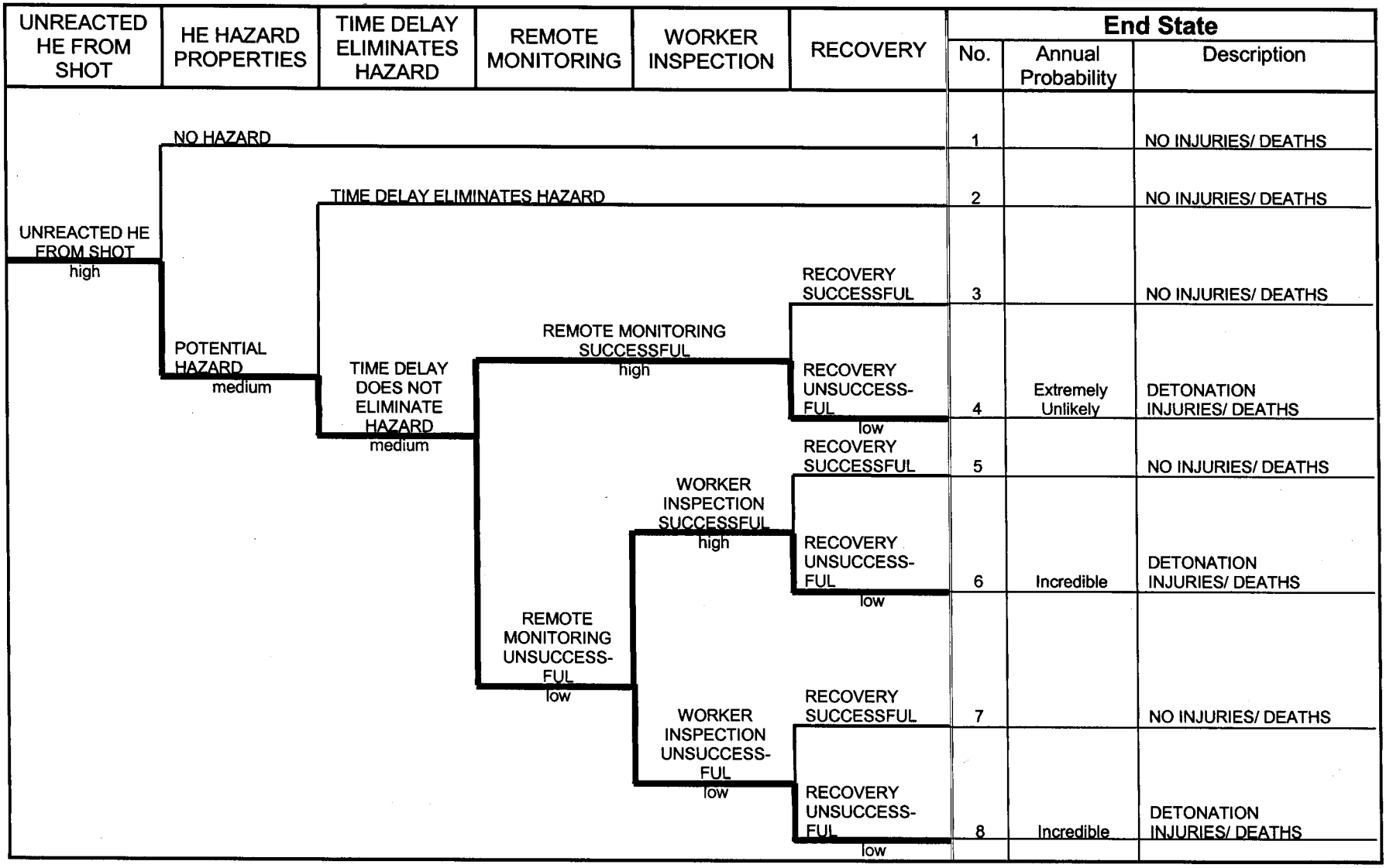


Fig B.12 – SAR Scenario N. Personnel exposed to toxic material above exposure limits or oxygen deficient atmosphere in facility after test (CFF only).

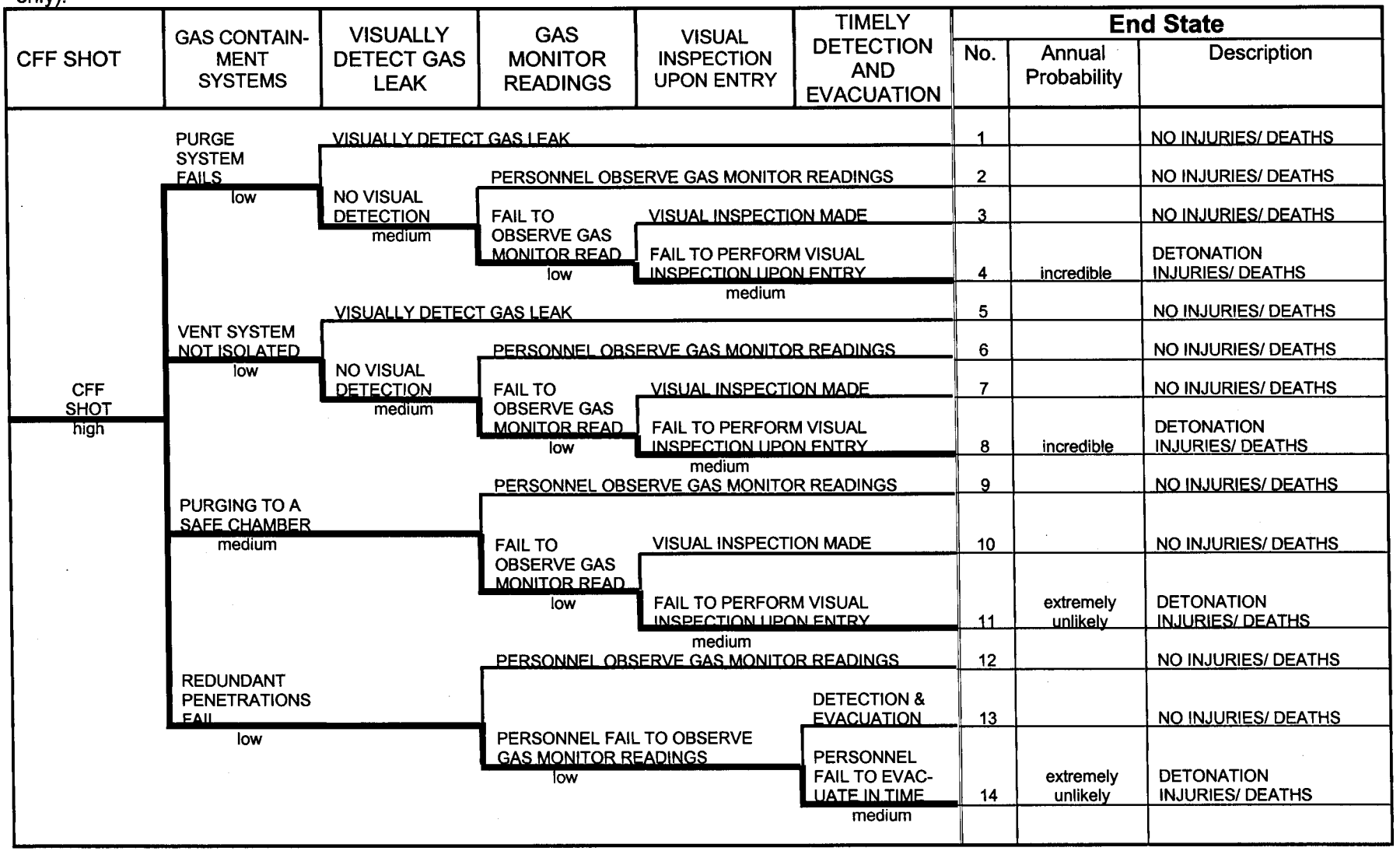


Fig B.13 – SAR Scenario O. Camera room port breaches, exposing personnel inside of facility to blast effects.

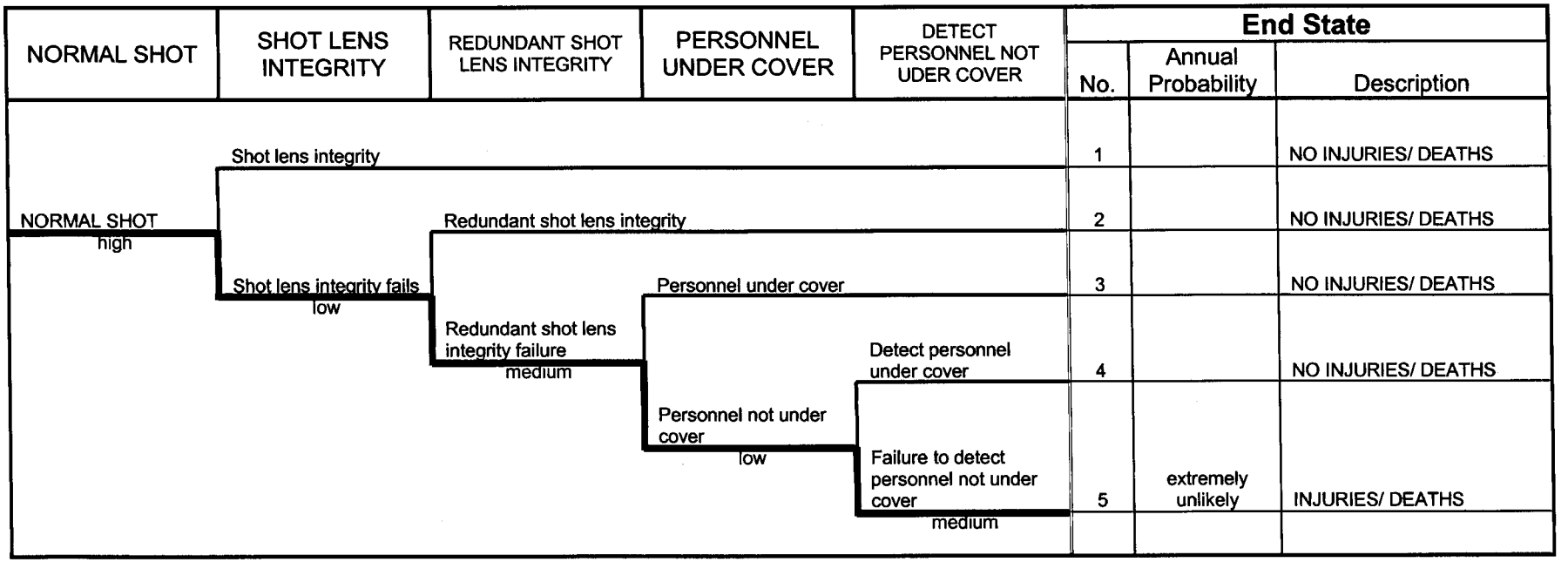


Fig B.14 – SAR Scenario P. Personnel exposed to toxic gas or oxygen deficient atmosphere in firing chamber, camera room or diagnostic equipment penetration room
(CFF only).

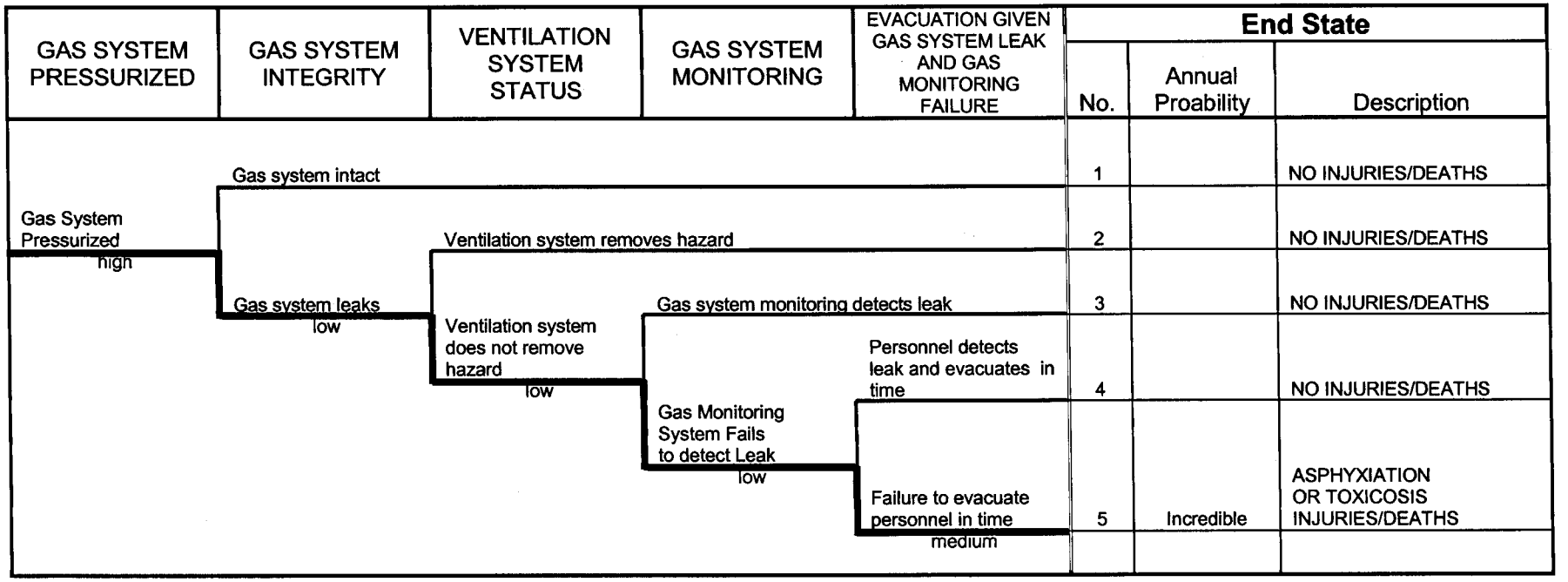


Fig B.15 – SAR Scenario Q. Personnel exposed to beryllium shrapnel or contamination in camera room.

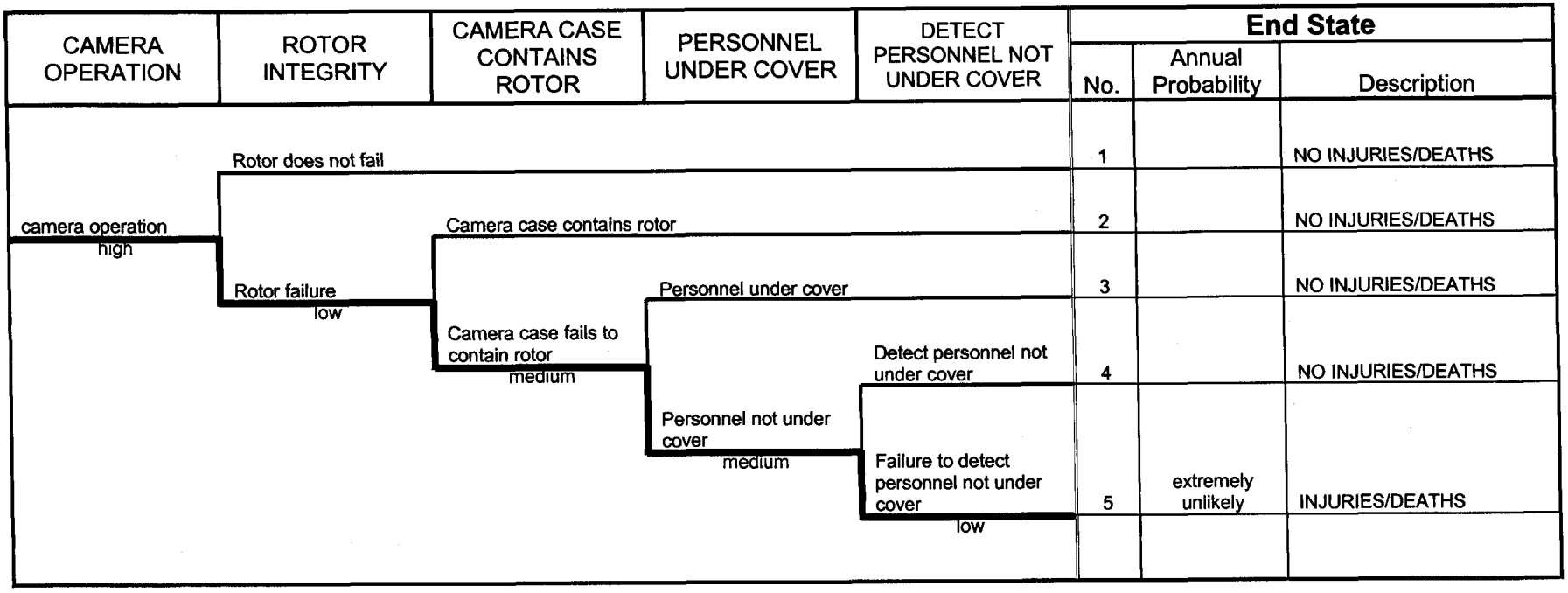


Fig B.16 – SAR Scenario T. Personnel under cover during CFF test exposed to blast effects.

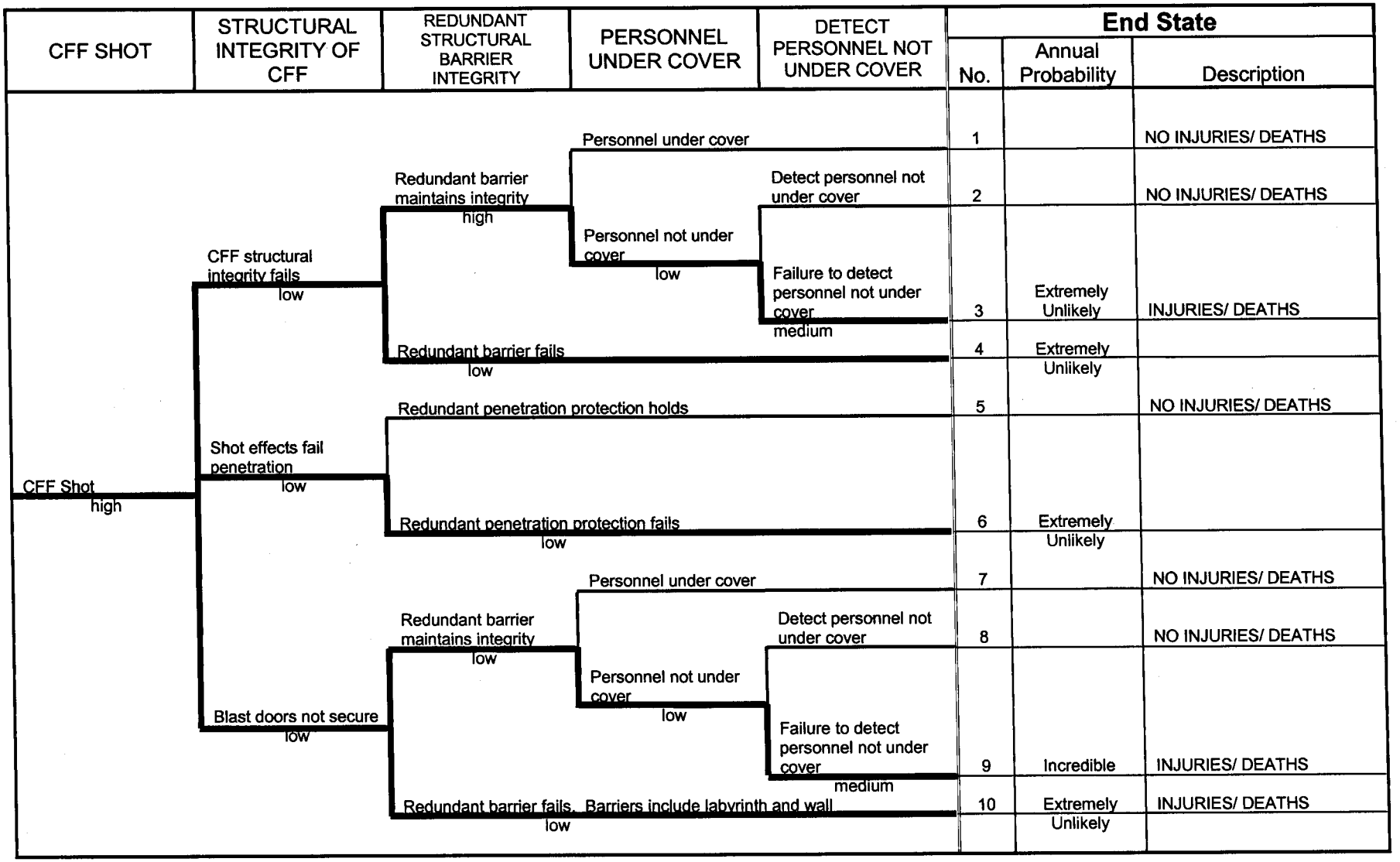
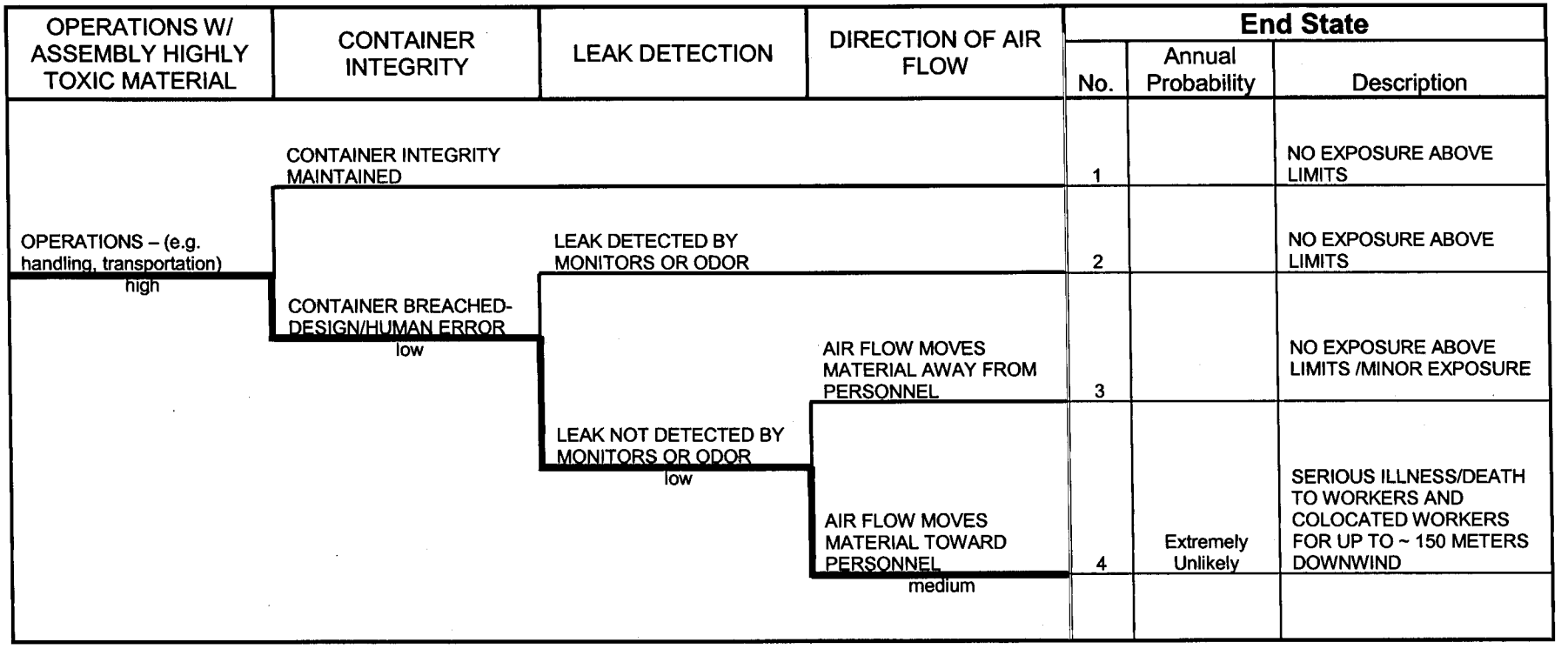


Fig B.17 – SAR Scenario U. Exposure of personnel on firing table, in magazine or other structure to highly toxic material in experiment: Container leaks due to design or human error in assembly or filling process



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