OAK RIDGE National Laboratory

August 10th, 2026 – Oak Ridge, TN

Accelerator Safety

Tristan Grover

ORNL Accelerator Safety

U.S. DEPARTMENT of ENERGY

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Outline

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- ORNL Accelerator Safety Program
- Hazard Evaluation Approach - Integrating Safety with the STS Design
- STS Policy for Selection of Safety Related Credited Controls
- HAR Hazard Evaluation Table
- HAR Structure & Credited Controls Summary Documentation
- HAR Breakdown
- Moderator Reflector Assembly: Example HAR Events & Controls
- Target Systems: Example HAR Events and Controls
- Path Forward

Regulatory Requirements

Develops safety documents required by DOE Orders (e.g., Order 413.3B Project Management, Order 420.1C Facility Safety, and Order 420.2D Accelerator Safety)

- **Preliminary Hazards Analysis Report (PHAR).** Issued in conjunction with **CD-1** approval. Initial project documentation of hazards, hazard event sequences, and safety risk mitigation.
- **Hazards Analysis Report (HAR).** Issued prior to **CD-2/3**. Updates the PHAR with greater detail (as needed) and designates required Credited Controls. This is an integral part of the Safety Basis for the facility.
- **Safety Assessment Document (SAD).** To be issued prior to **CD-4**. Incorporates the primary results of the HAR and the project solutions to address these hazards. The SAD provides a basis from which the ASE is developed.
- **Accelerator Safety Envelope (ASE).** The ASE documents the major requirements and operational limits needed to ensure that the STS operates within the approved Safety Basis for the facility. DOE approval is required.
- **Operational Envelope (OE).** Developed by Operations to implement the ASE. The OE establishes an internal set of operational limits to guide and control operations so that the facility operations do not violate the ASE limits.

ORNL Accelerator Safety Program

Standards-Based Management System (SBMS)

Your one-stop solution for lab-wide procedures

SBMS Home | Revisions | Variances | Requirements Sources | Subscriptions | My Favorites | Help

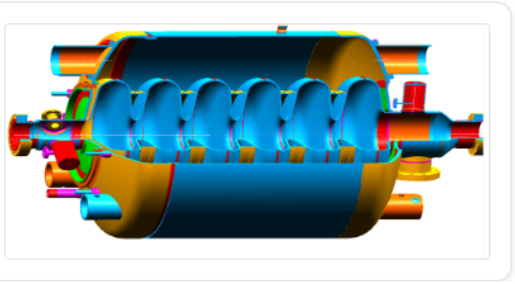
SBMS Home Page ▸ SBMS Structure ▸ Management Systems ▸ Accelerator Safety ▸ Accelerator Safety

Procedures

- Overview
- Determine Applicable Accelerator Safety Requirements
- Comply with Requirements for Accelerators that Operate Above 10 MeV
  - Develop and Maintain Safety Assessment Document
  - Develop and Maintain Accelerator Safety Envelope
  - Develop Unreviewed Safety Issue Process
  - Develop Accelerator Readiness Review Process
- Comply with Requirements for Accelerators that Operate at or Below 10 MeV
- Decommission Accelerators

Questions/Comments? | View/Print All | Highlight Changes

Accelerator Safety



Management System Owner: Michael Whittenbarger

Subject Matter Expert: Jacob Platfoot / Harry Perdomo

Last Revision: Jun 1, 2026

Major Revision: Feb 26, 2025

The **Determine Applicable Accelerator Safety Requirements** procedure provides instructions for determining if a device is an accelerator, helps characterize the accelerator as either operating above 10 MeV or operating at or below 10 MeV and defines allowed exemptions and equivalencies to the requirements in DOE Order 420.2D.

The **Comply with Requirements for Accelerators that Operate Above 10 MeV** procedure provides instructions for developing and maintaining the following program elements:

1. Safety assessment document (SAD)
2. DOE-approved accelerator safety envelope (ASE)
3. Unreviewed safety issue (USI) process
4. Accelerator readiness review (ARR) process
5. Clearly defined roles and responsibilities for accelerator activities, including those for training and procedures

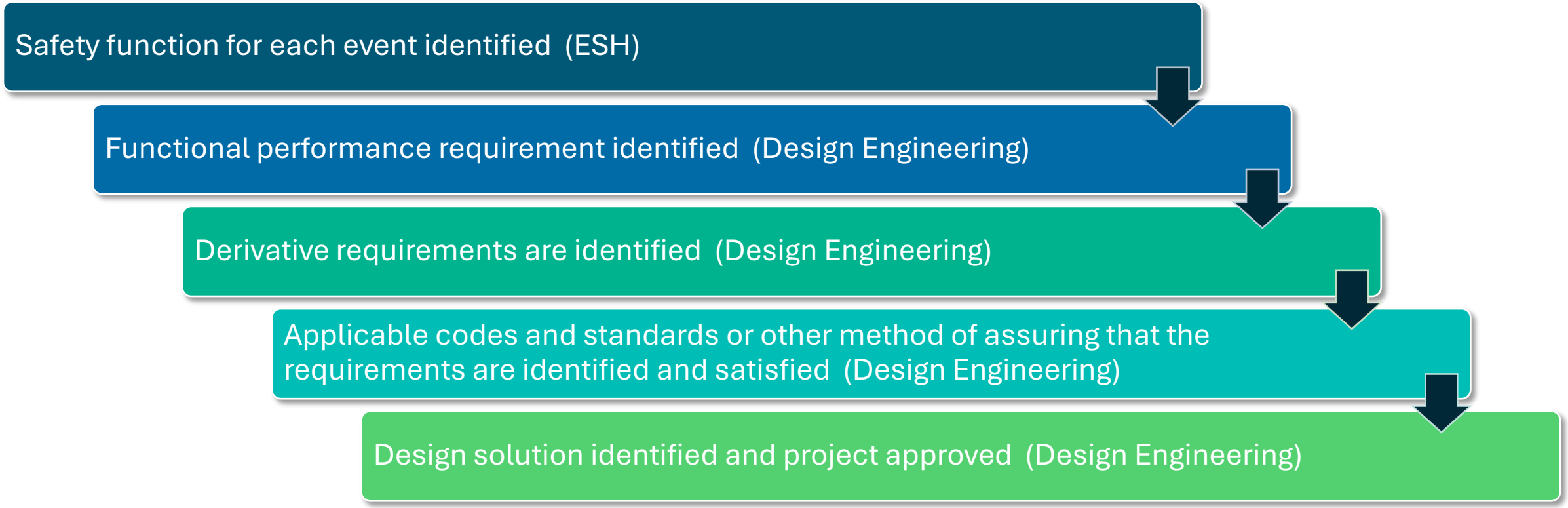
Hazard Evaluation Approach - Integrating Safety with the STS Design

Hazard evaluation approach consistent with the process used for the SNS:

- ESH SME facilitating the system-by-system evaluations with the full participation of the affected design engineering team leads.
- All affected technical areas are involved in developing the hazard analysis, identifying potential mitigative and preventive features planned for the facility and finally selecting any required Credited Safety Controls.
- Credited Safety Controls are based on satisfying the identified safety function and functional performance criteria.
- Design engineering identifies the codes, standards, and derivative controls required to satisfy the function and functional performance criteria.

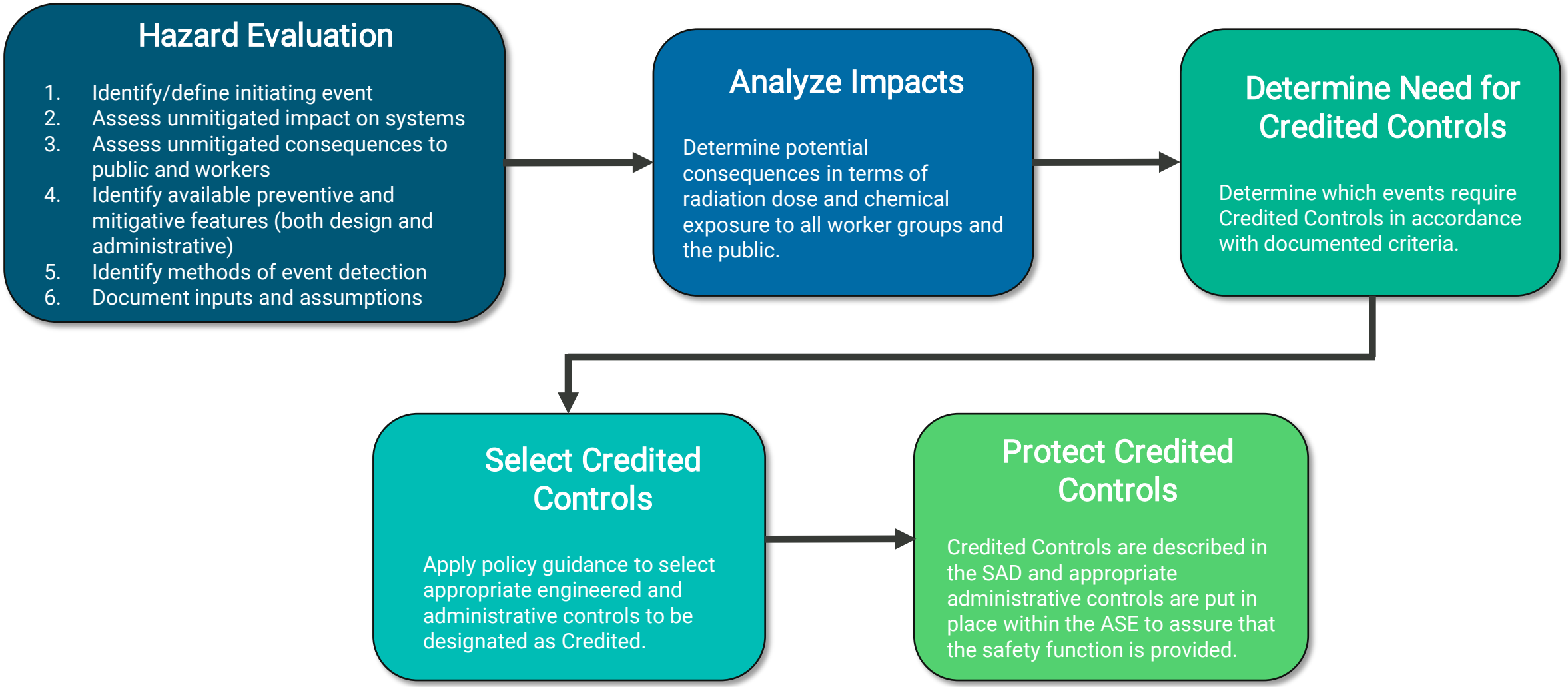
Hazard Evaluation Approach - Integrating Safety with the STS Design Continued.

By reviewing each of the postulated hazard events (and the event specific safety function) for which the control has been credited, the functional performance criteria can be identified for that SSC.



STS Policy for Selection of Safety Related Credited Controls

S01030100-ES0001, R00



HAR Hazard Evaluation Table

Event Number Designator Event Category-Event Number			
Event Description:			
Assumptions and Initial Conditions: 1. Assumptions made in the evaluation (IC) 2. Initial condition for the event. (IC)	**Causes:** 1. All possible causes for the event		**Initiating Event Frequency A, U, EU, or BEU**
Unmitigated Impact on Systems: Damage to other systems or operations	**Unmitigated Consequences**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Clear statement of high level safety function without identifying a specific control.			
Method of Detection:			
List every possible means of detecting the event			
Preventive Features – Attributes:			**Credited:**
Engineered Controls that "prevent" the initiating event (EC)			X
Design Features that "prevent" the initiating event (DF)			
Administrative Controls that "prevent" the initiating event (AC)			
Mitigative Features – Attributes:			**Credited:**
List of all ECs, DFs, and ACs that mitigate the event scenario			
Planned analysis, assumption validations, and Risk/Opportunities: This is the "actions" section.	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: Any general note that supports the event evaluation or would help in future evaluations.			**Mitigated Frequency** A, U, EC, BEU, Prevented

HAR Structure & Credited Controls Summary Documentation

Section 1 - Introduction/Background

Section 2 – Project Description

Section 3 – Summary of Hazards

Section 4 – Hazard Events and Controls

Credited Control Summary Tables:

- Credited Engineered Controls (ECs) (Table 4.5)
- Credited Design Features (DFs) (Table 4.6)
- Credited Administrative Controls (ACs) (Table 4.7)
- Critical Assumptions and Initial Conditions (Table 4.8)

Appendices – Event Specific Hazard Evaluation Tables (A-S)

HAR Breakdown

Appendix	Designator	System	HAR Events
A	AIC	Accelerator Interface Components	12
B	AS	Accelerator Systems	25
C	BG	Building General	25
D	CMS/MRA	Cryogenic Moderator System/Moderator Reflector Assembly	29
E	CW	Cooling Water	19
F	GW	Gas Waste Processing	17
G	HB	High Bay	8
H	HPV	Hot Process Vaults	17
I	HV	Secondary and Primary Confinement Systems	10
J	IS	Instrument Systems and Bunker	20
K	LCS	Leak Collection Systems	7
L	PW	Process Waste	4
M	RH	Remote Handling	36
N	RW	Contact and Remote Handling and Decontamination Area	24
O	SP	Storage Pad	0
P	SS/SSP	Service Cell & Pie Cell	25
Q	TB	Truck Bay	7
R	TS	Target, Drive, and Support Systems/Buildings	21
S	VS	Vessel Systems	8

*Total: 314

Moderator Reflector Assembly: Example HAR Events & Controls

Credited Design Features:	Associated HAR Events
Hydrogen transfer lines shall be designed and constructed in accordance with the applicable portions of ASME B31.12 and shall remain capable of performing their intended safety function following a design basis seismic event.	CMS7-5
Moderator and Hydrogen transfer lines designed to meet design basis seismic loads.	BG7-12
Design Features Critical to Event Evaluation:	
A vacuum layer surrounds the hydrogen vessel and serves as insulation between the cold hydrogen (20 degrees K) and the pre-moderator/reflector (Loop 2) water.	CMS3-5; CW3-10
Vacuum vessel is designed to contain a moderator vessel failure and hydrogen release.	CMS3-6
Hydrogen vessels are buried in the reflector with two layers of aluminum and the beryllium reflector preventing any contact.	CMS4-2

Target Systems: Example HAR Events and Controls

Target Protection System (TPS)	Associated HAR Events
TPS beam trip for abnormal Loop 1 return flow.	BG3-2; BG7-11; BG7-12; CW3-1a; CW3-7a; TS3-4
TPS beam trip for abnormal Loop 1 return temperature.	BG7-9a; TS3-5; TS3-15
TPS beam trip if target rotation stops or slows beyond limits.	TS3-2; TS3-3; TS3-7a; TS3-16
TPS beam trip if target rotation increases beyond limits.	TS3-14
TPS beam trip for differential Loop 1 bulk flow across the target out of range.	TS3-7b; TS3-12; TS3-13; TS3-15; TS3-16; CW3-1a; CW3-7a
TPS beam trip for Loop 1 cooling water heat exchanger outlet temperature out of range.	CW3-2a
Credited Design Features:	
Target cooling system quick disconnects to all target segment cooling lines include an integral valve on each side of the connector that closes when it is disengaged, and a device that provides a visual indication that shows when the connector is properly engaged.	TS4-4
Target design interface with the target support system requires the target segment to be fully inserted and in the right position for the operator to insert the locking screw to attach the target.	TS4-3; TS4-4; TS3-12
Inlet screen in Loop 1 header to target segment.	TS3-6; TS3-12
Credited Administrative Controls:	
RSO performs independent visual verification that all target segments are installed and that all quick disconnects are properly made up prior to operation.	TS4-3; TS4-4

Path Forward

- **Continue ESH & Design Engineering interactions to maintain alignment of the HAR with the design:**
  - HAR development via iterative face-to-face meetings between ESH and Design Engineering
  - Revise the HAR as necessary

- **Future Safety Documentation Development:**
  - Safety Assessment Document (SAD)
  - Accelerator Safety Envelope (ASE)

Questions and Discussion

Backup Slides

HAR Bounding Accident Events

Used to establish bounding conditions and identify key regulatory drivers for the facility design and operations:

- Loss of Cooling Accident without Beam Trip
    - “Unmitigated events with inadequate cooling and continued proton beam operation can result in very high target temperatures in short time periods, with associated releases of target material by vaporization.” [1]
- Seismic Accident with Detonations
    - “A beyond-design-basis seismic event can result in a hydrogen release from the moderator systems into the core vessel. The seismic event could also cause the core vessel boundary to fail allowing air to enter the vessel so that the potential for either a hydrogen deflagration or detonation exists. Detonation in the free volumes adjacent to the rotating target is assumed to cause a release of a fraction of the target mass.”[1]

[1]S01030100-ESH10002, “SECOND TARGET STATION (STS) PROJECT STS Bounding Accident Dose Estimates” & S01030100-ESH10003, “Effect of New Radionuclide Inventories on Worst Case Accident Doses”

Bounding Accident Events

Seismic Accident with Detonations[1]

Table 1			
Seismic Accident w. Detonations			
Off-site Dose, 2024		0.4	rem
Off-site Dose, 2019		0.62	rem
100-m Dose, 2024		8.1	rem
100-m Dose, 2019		12.6	rem
Ratio=0.65			
Top 10 Nuclides	2024 Inventory	2019 Inventory	2024 Doses /2019 Doses
	(Ci)	(Ci)	Ratio, no units
I 125	3.05E+02	4.22E+02	7.23E-01
Ta182	5.37E+04	3.75E+05	1.43E-01
Gd148	2.13E+02	1.19E+02	1.79E+00
I 124	1.67E+00	5.13E+01	3.26E-02
H 3	2.28E+04	1.60E+04	1.42E+00
I 126	3.10E-01	1.29E+01	2.40E-02
P32	4.75E+00	1.04E+02	4.57E-02
I 123	3.30E+02	3.51E+02	9.41E-01
I 120	2.34E+02	2.09E+02	1.12E+00
P33	5.28E+00	3.90E+01	1.35E-01

Loss of Cooling Accident without Beam Trip[1]

Table 2			
Loss of Cooling Accident			
Off-site Dose, 2024		0.52	rem
Off-site Dose, 2019		0.87	rem
100-m Dose, 2024		10.6	rem
100-m Dose, 2019		17.8	rem
Ratio=0.60			
Top 10 Nuclides	2024 Inventory	2019 Inventory	2024 Doses/ 2019 Doses
	(Ci)	(Ci)	Ratio, no units
W-187	2.16E+05	3.86E+05	5.60E-01
W-185	1.16E+05	1.78E+05	6.51E-01
Ta-182	5.37E+04	3.75E+05	1.43E-01
I-125	3.05E+02	4.22E+02	7.23E-01
Gd-148	2.13E+02	1.19E+02	1.79E+00
W-181	3.74E+04	4.44E+04	8.43E-01
I-124	1.67E+00	5.13E+01	3.26E-02
H-3	2.28E+04	1.60E+04	1.42E+00
I-126	3.10E-01	1.29E+01	2.40E-02
P-32	4.75E+00	1.04E+02	4.57E-02

[1]S01030100-ESH10002, "SECOND TARGET STATION (STS) PROJECT STS Bounding Accident Dose Estimates" & S01030100-ESH10003, "Effect of New Radionuclide Inventories on Worst Case Accident Doses"

Event Type Designations

- E-1 Fire
- E-2 Explosion
- E-3 Loss of Confinement/Containment
- E-4 Direct Radiation or Chemical Exposure
- E-5 Cryogenic or ODH Events
- E-6 External Events
- E-7 Natural Phenomena Events

Event Frequency Ranges

Event frequency level	Estimated annual likelihood of occurrence	Description
Anticipated (A)	$10^{-1} > p > 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)
Unlikely (U)	$10^{-2} > p > 10^{-4}$	Events that are not anticipated to occur during the lifetime of the facility.
Extremely Unlikely (EU)	$10^{-4} > p > 10^{-6}$	Events that will probably not occur during the life cycle of the facility.
Beyond Extremely Unlikely (BEU)	$10^{-6} > p$	All other events

Radiological Consequences by receptor: High, Moderate, Low, Negligible

Consequence level	Off-site receptor	On-site receptor
High (H)	≥25 rem	≥100 rem
Moderate (M)	$5 \leq C < 25$ rem	$25 \leq C < 100$ rem
Low (L)	$0.5 \leq C < 5$ rem	$5 \leq C \leq 25$ rem
Negligible (N)	<0.5 rem	<5 rem

HAR Credited Controls Summary Documentation

Credited Engineered Controls (ECs) (Table 4.5)

- Target Protection System (TPS), Personnel Protection System (PPS) (for RTST, Target, and Instruments), etc.

Credited Design Features (DFs) (Table 4.6)

- Shielding, ASME NOG-1 Crane, etc.

Credited Administrative Controls (ACs) (Table 4.7)

- Procedures, Radiation Safety Program, etc.

Critical Assumptions and Initial Conditions (Table 4.8)

- Includes ACs, DFs, ICs, ECs that are important to design and operations to guide and/or bound evaluation of the specific event.

NOTE: A control may be listed in multiple events. In some cases, the control may only provide defense in depth and is not counted on as the primary item(s) needed to provide the identified safety function for that event.

These summary tables are provided to guide designers and other project personnel to the critical information in the appendices.

Documentation Evolution Process

- April 2019 - PHAR Rev 0 issued to support CD-1 approval
- January 2021- Policy for Selection of Safety Related Credited Controls issued to support PHAR development
- July 2021- PHAR Rev 1 issued to provide a basis with which to work with the design team and to support them in designing safety into the facility
- January 2023 - PHAR Rev 2 issued to continue the process of working with the design team and to support them in designing safety into the facility
- September 2025 - PHAR Rev 3 Draft submitted for signature
- March 2026 – Draft HAR developed for Director's Review
- June 2026 – HAR issued prior to DOE CD-2/3 IPR

Documentation Development Timeline