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Engineering Qualification Plan

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1.0 INTRODUCTION

A Large Bore Powder Gun (LBPG) is being designed to enable experimentalists to characterize material behavior outside the capabilities of the NNSS JASPER and LANL TA-55 PF-4 guns. The combination of these three guns will create a capability to conduct impact experiments over a wide range of pressures and shock profiles. The Large Bore Powder Gun will be fielded at the Nevada National Security Site (NNSS) U1a Complex. The Complex is nearly 1000 ft below ground with dedicated drifts for testing, instrumentation, and post-shot entombment.

To ensure the reliability, safety, and performance of the LBPG, a qualification plan has been established and documented here. Requirements for the LBPG have been established and documented in WE-14-TR-0065 U A, *Large Bore Powder Gun Customer Requirements*. The document includes the requirements for the physics experiments, the gun and confinement systems, and operations at NNSS. A detailed description of the requirements is established in that document and is referred to and quoted throughout this document.

Two Gun and Confinement Systems will be fielded. The Prototype Gun will be used primarily to characterize the gun and confinement performance and be the primary platform for qualification actions. This gun will also be used to investigate and qualify target and diagnostic modifications through the life of the program (U1a.104 Drift). An identical gun, the Physics Gun, will be fielded for confirmatory and Pu experiments (U1a.102D Drift). Both guns will be qualified for operation. The Gun and Confinement System design will be qualified through analysis, inspection, and testing using the Prototype Gun for the majority of process. The Physics Gun will be qualified through inspection and a limited number of qualification tests to ensure performance and behavior equivalent to the Prototype gun. Figure 1.1 shows the partial configuration of U1a and the locations of the Prototype and Physics Gun/Confinement Systems.

To establish consistent nomenclature for the two systems, the following terms have been established:

- Prototype Gun: Gun to characterize gun and confinement performance and the primary system for qualification actions. (Upper left in Fig. 1.1)
- Development Alcove: Area within U1a where the Prototype Gun is located.
- Physics Gun: Gun to characterize EOS for confirmatory and Pu experiments. (Lower center in Fig. 1.1)
- Experiment Room: Area within U1a where the Physics Gun is located.

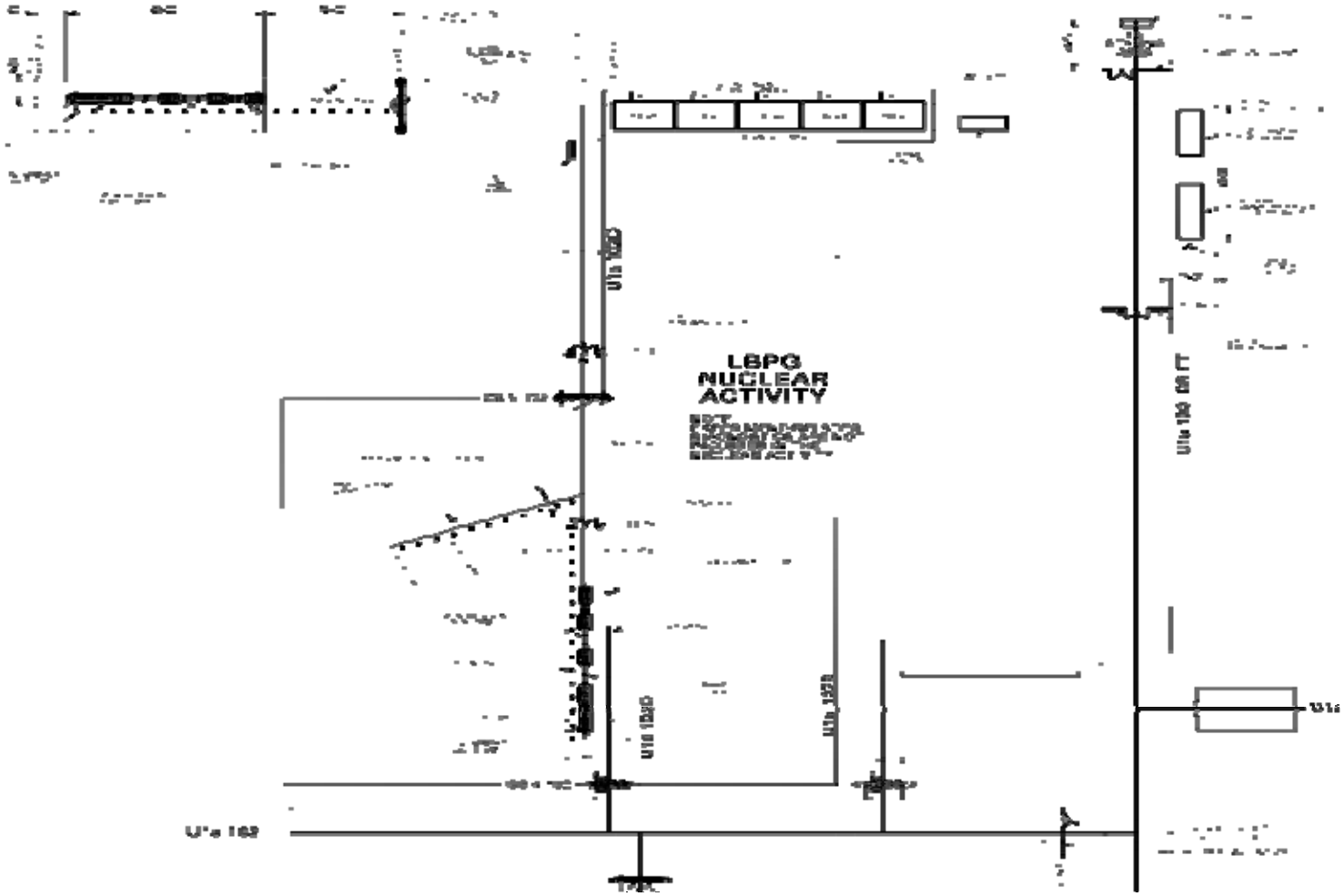


Figure 1.1 U1a LBPG Configuration.

Objectives from the requirements documents are enumerated below:

Procedures

1.2.1 Establish procedures that encompass engineering processes, safety categorization, quality designation, and quality assurance.

Gun System

1.2.2 Design the gun bore diameter to allow for multiple samples or large monolithic samples to enable prescribed pressure profiles and shock duration.

1.2.3 Launch a range of projectiles (with a maximum mass of 2 kg) to velocities up to a maximum velocity of 2 km/s.

Confinement System

1.2.4 Stop and confine the projectile and target materials in a catch tank without structural failure.

Diagnostics

1.2.5 Field reliable high fidelity diagnostics and instrumentation to record material behavior during impact, and monitor the performance of the Gun and Confinement Systems.

Structural Integrity

1.2.6 Ensure structural integrity of the Gun System for a maximum of 60 shots.

1.2.7 Ensure structural integrity of the Gun System and Confinement System to withstand a seismic event.

Entombment

1.2.8 Entomb the contaminated components of the experiment.

Qualification

1.2.9 Establish a qualification methodology that ensures the safety, performance, and reliability of the Gun and Confinement Systems.

Nevada National Security Site U1a Complex

1.2.10 Design systems that are compatible with the physical and operational constraints of the NNSS U1a complex.

Off-Normal Events

1.2.11 Design the Gun and Confinement Systems to withstand off-normal events without endangering personnel. Off-normal events include blast over pressure, projectile break-up, and closure valve failure.

This document is organized around the eleven objectives listed above. In addition it includes:

- The Large Bore Powder Gun description
- The qualification strategy
- The plan for fulfilling each of the objectives

- The qualification actions for component and system testing
- And the component-by-component required qualification actions

The qualification methodology includes two overlapping approaches:

- Section 4.0 addresses the Gun and Confinement Systems and its operation.
- Section 5.0 addresses the component and system testing required.
- Section 6.0 addresses each component or subassembly of the system and qualification actions to meet each requirement.

1.1 Change Authority

This document will be revised and updated as applicable. Changes to this document require the appropriate subject matter expert review and management approval.

1.2 References

1. W-SE-0027U, Rev A, *Engineering Process for Confinement and Containment Systems used in the Execution of Dynamic Experiments*.
2. WE-14-TR-0065 U A, *Large Bore Powder Gun Customer Requirements*.
3. C2-DPE-2009-0008, *Large Bore Powder Gun Project and Large Bore Powder Gun Experiments Project Functional Requirements July 30, 2009*.
4. P330-2, *Control and Calibration of Measuring and Test Equipment*.
5. P341-1, *Engineering Process Manual*.
6. DOE Standard 1189, Appendix A, *Integration of Safety into the Design Process*.
7. DOE Guide 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosives Safety Guide for use with DOE O 420.1, Facility Safety*.
8. W-EP-Q-0001, *Weapons Systems Engineering (W) Quality Assurance Plan for Experimental Program.*
9. LANL Engineering Standards Manual PD342, Appendix A – 10 CFR 851, Appendix A, *Part 4 Pressure Safety.*
10. WE-SE-0001U, Issue B, *Requirements Management Plan, Weapon Systems Engineering Division (U).*

1.3 Acronyms and Abbreviations

ASME	American Society of Mechanical Engineers
EOS	Equation of State
FEM	Finite Element Method
LANL	Los Alamos National Laboratory
LBPG	Large Bore Powder Gun
LBPG/CS	Large Bore Powder Gun and Confinement Systems
ML-2	Management Level -2
NDE	Nondestructive Examination
NSTec	National Security Technologies, LLC
NNSS	Nevada National Security Site
PDV	Photon Doppler Velocimetry
REOP	Real Estate/Operations Permit
SNM	Special Nuclear Material
VISAR	Velocity Interferometry System for Any Reflector

2.0 LARGE BORE POWDER GUN AND CONFINEMENT SYSTEM DESCRIPTION

The Large Bore Powder Gun and Confinement System consists of two major systems, the Gun System, and the Confinement System (Figs. 2.1 and 2.2). Other subsystems associated with the operation of the gun and confinement are referenced and described in Table 2.1. The slip joint allows isolation of recoil from the Confinement System. Isolating these major systems enables post-shot removal of the confinement for entombment. Key assembly drawings are shown in Appendix A. Major components have the following dimensions:

- Total length of the LBPG: 733.15 in. (61.09 ft.)
  Dwg. 34Y1757761
- Total length of gun system: 551.9 in. (45.99 ft.)
  Dwg. 34Y1741975
- Confinement system, slip tube and stand: 183.6 in. (15.30 ft.)
  Dwg. 34Y1759560
- Gun tube diameter 3.535-3.540 in.
  Dwg. 34Y1741977

The gun system is a Multicomponent system. Its major components include:

- The Gun Stand
- The Breech and Powder Chamber assembly (~33 in. long with a 16 in. OD and 6.48 in. ID) Dwg. 34Y1741988 Rev. B
- Two gun tubes connected by a tube coupling (each ~240 in. long with 3.5 in. ID and 7 in. OD) Dwg. 34Y1741976 Rev. A
- The Recoil Rail subsystem and multiple tube supports
- Shock Absorber subsystem to control gun recoil.

A slip joint interface joins the Gun System and the Confinement System and is used to isolate each system (Dwg. 34Y1757744 B). The Confinement System is a multicomponent system used to isolate and confine materials and gases from the Experiment Room or Development Alcove and the Gun System.

The Confinement System consists of the following:

- A fast closure that closes as the projectile passes downstream to seal combustion products, projectile, and target materials into the Confinement System. (Dwg.TBD)
- The spool assembly which enables the projectile to travel toward the Target Chamber leaving the fast closure system sufficient time to close before target materials reach the seal after target impact. (Dwg. 34Y1757771)
- The Target Chamber used for holding the target in place and housing diagnostics. (Dwg. 34Y1759548)

- The Catch Tank assembly used to stop the projectile and target materials (Dwg. 34Y1759569)
- Crush materials and backstop to stop the Catch Tank assembly as it translates downstream due to projectile impact. (Dwg. 34Y1759567)

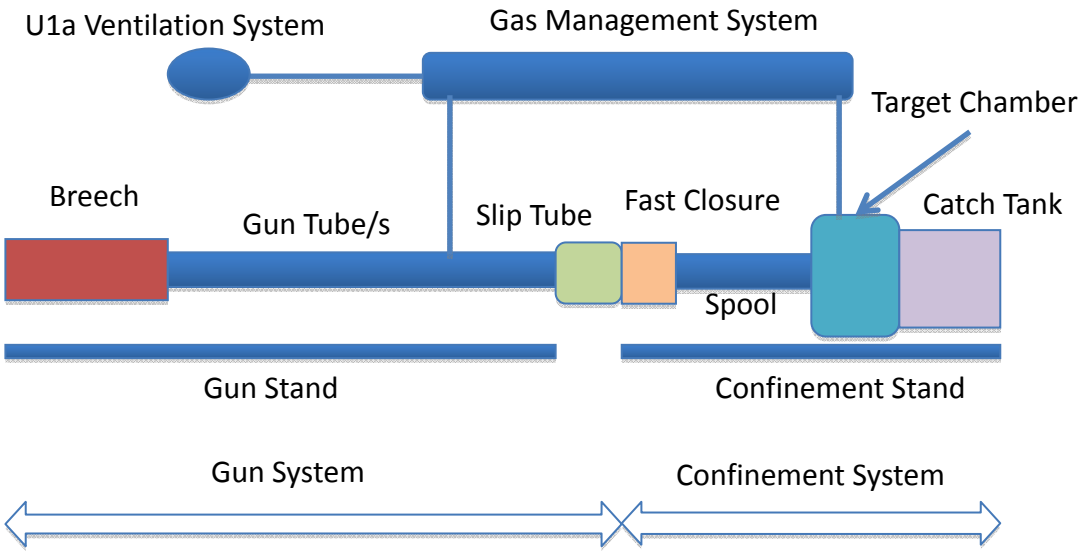


Fig. 2.1 LBPG Systems and Components.

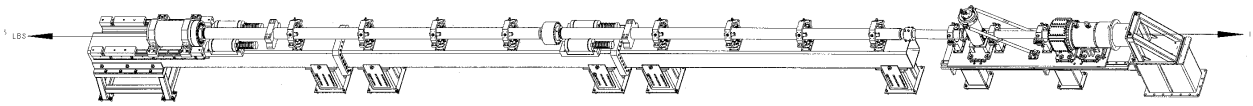


Figure 2.2 LBPG Schematic.

Table 2.1 System and Subsystem Definitions

Project	System	Subsystem	Definitions
Large Bore Powder Gun (LBPG)	Gun System	Breech	Breech, breech closure, and ignition
		Gun Tube/s	Gun tube/s and gun tube coupling/s
		Slip Joint	Component for isolation of the Gun and Confinement Systems
		Gun stand	Structure to hold up Gun System and control recoil.
	Confinement System	Fast-acting closure valve	Fast closing valve to seal the Confinement System and isolate the Gun System from the Confinement System
		Spool	The spool (or drift tube) is used to allow the fast-acting valve time to close after the projectile passes
		Target Chamber	The chamber where the target is mounted and its associated diagnostics
		Catch Tank	Tank to stop the projectile, target materials, and propellant gas
		Confinement Stand	The confinement stand holds up the Confinement System and dissipates energy associated with confinement momentum. The stand is not entombed.
	Gas Management System		Fluid handling system for pre-shot and post-shot conditioning. Establishes pre-shot vacuum and evacuates post-shot effluent.

A general description of the operational sequence of the LBPG is described in the list below for a 2-kg projectile with a muzzle velocity of 2.0 km/s. For the purpose of illustration these are calculated numbers. In actual shots timing varies with propellant initiation.

Pre shot: Gun and confinement are prepared for test.

- The target is secured in the Target Chamber
- Diagnostics and pre-test checks are completed
- A 2-kg projectile is loaded into the gun and approximately 9.5 lb. of M14 propellant loaded into the powder chamber.
- Leak checks are performed
- The gun tube and Target Chamber are evacuated to 1.0E-2 Torr and leak checked.
- Cameras and instrumentation are checked
- Non-essential personnel are removed to safe areas for the loading of the priming system and connection of the fire set systems

- The priming system and fire set is put in place
- Safety checks are completed in preparation of firing.

t=0.0ms. The primer is ignited, propellant begins to burn, pressure builds in the powder chamber and on the base and obturator of the 2 kg projectile.

t=3.6ms Pressure builds in the chamber as powder burns, the projectile has moved down stream and pressurized the gun tube in back of the projectile.

- Projectile travel: 1 in.
- Projectile velocity: 0.04 km/s
- Breech/Powder Chamber Pressure: 4 ksi

t=8.0ms Peak breech pressure

- Projectile travel: 54 in.
- Projectile velocity: 0.68 km/s
- Breech/Powder Chamber Pressure: 27 ksi

t=15.0ms Projectile enters the slip interface.

- Projectile travel: 472 in.
- Projectile velocity: 2.0 km/s
- Breech/Powder Chamber Pressure: 7 ksi

t=15.5 ms The projectile passes through the fast closure, and the explosive is detonated beginning the closure process. Propellant gases place lateral loads (25 ksi peak over a short duration) on the fast closure during operation.

- Projectile travel: 511 in.
- Projectile velocity: ~2.0 km/s

t=16.1 ms The 2 kg projectile impacts the target, diagnostics are triggered and data collected, projectile and target break up occur, debris begins to move down stream and upstream.

- Projectile travel: 567 in.

t=16.3 ms Debris and contaminated gases impact the shut closure device. Projectile and target material have moved down range into the Catch Tank and impacted the first of five steel/Dyneema shear plate pairs. High velocity propellant gas has filled the Catch Tank. The energy trap begins to respond to Catch Tank translation.

- Projectile travel: 580 in.
- Projectile velocity: <2.0 km/s

t=17+ ms Projectile and debris stop in Catch Tank

- Projectile travel: <597 in.
- Projectile velocity: 0 km/s

Combustible gases vented from the breech and barrel (i.e., gases behind the projectile) are appropriately managed (e.g. purge, dilution, vent, etc.) using the Gas Management System and are eventually exhausted through the U1a Ventilation System. Additionally, gases from the isolated Confinement System are managed using the Gas Management System and are eventually exhausted through the U1a Ventilation System. The Confinement System includes HEPA equivalent filters in the connection to the Gas Management System. The Gas Management System vents the filtered gases into the Experiment Room ventilation exhaust duct. The exhaust from the Experiment Room passes through a HEPA equivalent filter before it joins the U1a Complex ventilation system. The Confinement System is disconnected from the Gun System and entombed.

3.0 QUALIFICATION METHODOLOGY

The qualification methodology chosen for LBPG system is verification of the requirements developed for that system. Requirements verification is the proof process for showing that a particular design satisfies the corresponding requirements. Verification follows the design activities in the normal flow of events during the development process. There are seven methods of verification as defined by WE-SE-0001U, Issue B, *Requirements Management Plan, Weapon Systems Engineering Division (U).* Those methods are:

a. Inspection
b. Test
c. Analysis
d. Demonstration
e. Certification
f. Similitude
g. Verification by sub-requirements

A qualification methodology for the LBPG using several distinct methods to qualify components and Gun and Confinement Systems has been established. These include the following:

I. Coupon testing for material validation of critical components (Test)
II. Structural simulations, analytical methods, and fracture control plans (Analysis)
III. Gun and confinement instrumented component testing (Test)
IV. Instrumented systems testing (Test)
V. Nondestructive examination (Inspection)
VI. Component leak testing (Test)
VII. Diagnostic and instrumentation validation (Certification)
VIII. Gas management evaluations and verification (Testing and Certification)

This combination of activities has implications to the integration of qualification actions. In some instances numerical simulations will be used to develop loads that will be validated by the qualification tests. These loads will then be used in the finite element simulations to develop stress and strain levels within the gun system. Material coupon testing will be used to determine and validate the material properties used in the finite element simulations to underwrite the maximum stress and strains in any material that the gun may experience. Finally using the above information and making a comparison against design criteria, a statement can be made that the gun can reliably function without failure of the system or component that would lead to gross venting.

In Section 5 and 6 of this plan, the simulations, testing, and NDE requirements are outlined for each component. Simulations will be validated against experiments and then used to simulate a broader set of environments to qualify the entire performance spectrum of the Gun and Confinement Systems. Post-test NDE will be used to ensure the structural integrity of critical gun components.

4.0 SYSTEM QUALIFICATION ACTIONS

Qualification actions have been established to ensure that the Gun and Confinement Systems meet requirements as established in WE-14-TR-0065 U A, Large Bore Powder Gun Customer Requirement. Section 5 describes Component Testing. Section 6 outlines component-by-component qualification actions.

4.1 Safety and Quality Processes for LBPG

REQUIREMENT 2.1.1: *W-SE-0027U, Rev A, Engineering Process for Confinement and Containment Systems used in the Execution of Dynamic Experiments, shall be followed for the construction (i.e., material selection, design, analysis, fabrication, inspection & examination, testing, and documentation) of the Gun System and Confinement System.*

Table 4.1.1 Evidence: REQUIREMENT 2.1.1

Action	Verification Evidence	Evidence Pool
FollowW-SE-0027U	Demonstrated adherence to methodology for material selection, design, analysis, fabrication, inspection & examination, testing, and documentation.	Eng. Processes Report

REQUIREMENT 2.1.2: *The Gun System and Confinement System safety categorization shall meet the requirements of nuclear safety 10CFR830.*

Table 4.1.2 Evidence: REQUIREMENT 2.1.2

Action	Verification Evidence	Evidence Pool
Follow 10CFR830	Matrix of component safety categorization, matrix of verification evidence listing verification for each component/system that meets its requirements.	Eng. Processes Report

REQUIREMENT 2.1.3: *The Gun System and Confinement System management level designation shall be per LANL procedures.*

REQUIREMENT 2.1.4: *The engineering process used for the construction of the Gun System and Confinement System shall conform to LANL Weapons Experimental Programs Quality Plan W-EP-Q-0001 "Weapons Systems Engineering (W) Quality Assurance Plan for Experimental Programs".*

Table 4.1.3 Evidence: REQUIREMENT 2.1.3 and 2.1.4

Action	Verification Evidence	Evidence Pool
Follow LANL P341-1	Matrix of component quality level designations	Eng. Processes Report

4.2 Gun System

REQUIREMENT 2.2.1: *The gun system shall withstand the impulsive load and confine the resulting gases from the M14 powder burn for a 2kg projectile launched to 2km/s.*

RATIONALE: The velocity range and projectile mass is established to achieve the pressure regimes outside of the JASPER and PF-4 gun performance envelopes. In this context "withstand" implies that the Gun System confines the gas from launching the projectile and any other debris generated during the dynamic experiment, without gross venting.

VERIFICATION: Gun System performance verification will be accomplished through a combination of numerical simulations, material coupon testing, NDE, and component and system testing. Initial gun performance curves will be established numerically over the 0.2–2.0 km/s velocity range with projectile masses ranging from 1.0–2.0kg. Simulations will include pressure time histories for the breech and projectile and projectile maximum velocity. Breech and gun/s instrumentation for verification of performance will include indirect measures of breech internal pressure and direct measurement of projectile velocity. Action and verification evidence is outlined in Table 4.2.1.

Table 4.2.1 Evidence: REQUIREMENT 2.2.1

Action	Verification Evidence	Evidence Pool
Numerical Simulations	Gun system simulations will be completed to establish the performance envelope for 0.2–2.0 km/s for projectiles 1.0-2.0 kg. Results will include pressure time history for breech, gun tube, and projectile base and for projectile velocity. Interior ballistic code predictions shall match observed peak breech pressure within 20% for the fifteen qualification experiments to validate the broader simulation-based gun performance curves.	Performance Envelope Report

Action	Verification Evidence	Evidence Pool
Component Testing	Gun system component testing will be accomplished to establish performance envelope and enable numerical simulation benchmarking.	Component Testing Report
Material Coupon Testing	Breech and gun material coupon testing will be used to establish material properties including yield, ultimate, and fracture toughness.	Coupon Testing Results
Instrumented Gun System test	Fifteen qualification experiments are required to characterize gun performance through the range of projectile masses and stated velocity range.	Performance Envelope Report
NDE	Nondestructive examinations will be established based on the fracture control plan.	Structural Analysis Report
Finite Element Simulations (FEM) and comparisons to experiment	Experimentally recorded strain readings coupled with finite element simulations to establish breech pressure and direct measures of projectile velocity from five experiments spread over the velocity regime will be used as simulation benchmarks. From this a fracture control plan will be established for the breech and gun tube	Analysis Benchmark Report Structural Analysis Report

REQUIREMENT 2.2.2: *The bore diameter shall be nominally 3.5-in.*
Commentary: *The Gun System bore will be large enough to allow for a variety of loading conditions that may include complex loading profiles (shock-ramp, ramp, shock-release-re-shock, etc.). The large format will also provide longer time durations than those from the PF-4 and JASPER Gun Systems.*

RATIONALE: The 3.5 inch diameter has been established to ensure a variety of shock profiles.
VERIFICATION: Verification of key gun interior dimensions is required for initial assembly operations. Verification evidence for this requirement is based on dimensional inspection records of the components listed. Table 4.2.2 outlines these inspections.

Table 4.2.2 Evidence: REQUIREMENT 2.2.2

Part	Dimension (in.)	Drawing	Evidence Pool
Powder chamber throat	3.498–3.502	34Y1741983	Inspection record for every assembly process
Gun tube bore interior diameter	3.535–3.540	34Y1741978	
Slip tube interior diameter	3.535–3.540	34Y1757737	
Closure Device	3.535–3.540	TBD	
Drift tube interior diameter	3.535–3.540	34Y1757771	
Projectile diameter	3.520–3.530	TBD	

REQUIREMENT 2.2.3: *The Gun System shall be capable of launching a maximum mass projectile of 2 kg to a maximum velocity of 2.0 km/s. Lower mass projectiles shall not exceed the 2.0 km/s maximum velocity.*

RATIONALE: The velocity range and projectile mass is established to achieve the pressure regimes outside of the JASPER and PF-4 gun performance envelopes.
VERIFICATION: Gun performance verification will be accomplished through a combination of numerical simulations and testing. Initial gun performance curves will be established numerically over the 0.2–2.0 km/s velocity range with projectile masses ranging from 1.0–2.0 kg. Simulations will include pressure time histories for the breech and projectile and projectile maximum velocity. Gun instrumentation for verification of gun performance will include indirect measures of breech internal pressure and direct measurement of projectile velocity. Action and verification evidence is outlined in Table 4.2.3.

Table 4.2.3 Evidence: REQUIREMENT 2.2.3

Action	Verification Evidence	Evidence Pool
Numerical Simulations	Gun Simulations will be completed to establish the performance envelope for 0.2–2.0 km/s for projectiles 1.0–2.0 kg. Results will include pressure time history for breech and projectile base and for projectile velocity. Interior ballistic code predictions shall match observed projectile velocity within 7% for the fifteen qualification experiments to validate the broader simulation based gun performance curves.	Performance Envelope Report
Instrumented Gun System test	Fifteen qualification experiments are required to characterize gun performance through the range of projectile masses and stated velocity range.	Performance Envelope Report
Component Testing	Gun System component testing will be accomplished to establish performance envelope and enable numerical simulation benchmarking.	Component Testing Report
Finite Element Simulations (FEM) and comparisons to experiment	Experimentally recorded gun strain readings coupled with finite element simulations to establish breech pressure and direct measures of projectile velocity from five experiments spread over the velocity regime will be used as simulation benchmarks.	Analysis Benchmark Report

REQUIREMENT 2.2.4: *The Gun System shall maintain an internal vacuum of 1.0e-2 Torr from bore evacuation through propellant initiation.*

VERIFICATION: Vacuum at 1.0E-2 Torr will be demonstrated through instrumentation. Table 4.2.2 describes the actions and evidence for this requirement. (Table 4.2.4)

Table 4.2.4 Evidence: REQUIREMENT 2.2.4

Action	Verification Evidence	Evidence Pool
Evacuate the gun and confinement system to 1.0E-2 Torr for each shot.	Leak testing of the system in qualification tests	Test Report

REQUIREMENT 2.2.5: *Pressure-retaining components shall be capable of passing helium leak checks with leakage less than 1.3e-5 std.* cm^3/s *of helium gas throughout the lifetime of the gun. Helium leak checks shall not exceed 5 psi.*

RATIONALE: The LBPG Gas Management System functions to control the release of combustion products. The Gas Management System will utilize isolation valves between the high pressure portions of the LBPG and the Gas Management System. The Gas Management System will not experience the gas dynamic loading that the launcher and Confinement System undergo. The isolation valves will be the barrier components that isolate the Gas Management System from any gas dynamic input.
VERIFICATION: The performance of the Gas Management System will be measured by operating the system with test gasses, and by operating the system after actual gun firings to handle actual system effluent. See Table 4.2.5.

Table 4.2.5 Evidence: REQUIREMENT 2.2.5

Action	Verification Evidence	Evidence Pool
The Gas Management System will filter particulates smaller than 1 micron out of the effluent stream and include parallel filtration.	System Isolation Valves: The performance of the isolation valves will be measured by the same means as is the balance of the pressure boundary components.	Test Report

REQUIREMENT 2.2.6: *The Gun System and Confinement System interface shall isolate recoil of the gun to allow independent motion between the two systems.*

VERIFICATION: Demonstration of independent motion between the Gun System and Confinement System will be verified with high-speed video for each Gun system on three qualification shots. (Table 4.2.6)

Table 4.2.6 Evidence: REQUIREMENT 2.2.6

Action	Verification Evidence	Evidence Pool
Install high-speed video and record the shot event for three shots on each gun.	Video with no evidence or leakage at critical locations.	Test Report
Inspect LBPG supports, including connections to embed plates in the invert	Inspection	Test Report

4.3 Confinement System

REQUIREMENT 2.3.1: *The fast-acting closure valve shall confine the resulting propellant gases and withstand the impulsive load associated with the gases.*

RATIONALE: As the projectile clears the fast-acting closure valve, propellant gases following the projectile at velocities up to 2km/s impact the closed valve. These gases represent a significant impulse. The fast-acting closure valve must maintain structural and seal integrity during the event to trap the propellant gases on the gun side of the closure.
VERIFICATION: A combination of numerical simulations, component tests, and system tests will be performed to establish the response of the fast-acting closure to the impulsive load.

Table 4.3.1 Evidence: REQUIREMENT 2.3.1

Action	Verification Evidence	Evidence Pool
Numerical Simulations	Hydrocode simulations will be performed to model the gas formation, determine the gas velocity distribution and the pressure loading associated with the impacting gas. FEM simulations will use the hydrocode generated pressure histories to determine the structural response of the valve	Structural Analysis Report
Component Tests	Component test will be performed to establish the response of the valve to ambient conditions, static tail pressure, and the dynamic pressure.	Component Test Report
System Tests	Qualification tests will be performed to ascertain the valve performance in sealing the gun propellant gas from the confinement and the confinement gas and target materials from the gun components.	Test Report

REQUIREMENT 2.3.2: *The fast-acting closure valve shall isolate and seal the radiological material and gases in the Confinement System from the Gun System.*

RATIONALE: The fast-acting closure valve needs to seal gases and target materials to the confinement side of the system and keep the seal from when the fast-acting closure closes until gas venting before entombment.

VERIFICATION: A combination of numerical simulations, component tests, and system tests will be performed to establish the ability of the fast-acting closure to create a seal. (Table 4.3.2)

Table 4.3.2 Evidence: REQUIREMENT 2.3.2

Action	Verification Evidence	Evidence Pool
Numerical Simulations	Hydrocode simulations will be performed to ascertain the pressure time history associated with propellant gas following the projectile and target material and projectile splash from target impact. FEM simulations will use the hydrocode generated pressure histories to determine the structural response of the valve.	Structural Analysis Report
Component Tests	Component test will be performed to establish the response of the valve to ambient conditions, static tail pressure, and the dynamic pressure.	Component Test Report
System Tests	Qualification tests will be performed to ascertain the valve performance in sealing the confinement gas and target materials from the gun components.	Test Report

REQUIREMENT 2.3.3: *The spool (drift tube) bore diameter shall be nominally 3.5-in.*

Table 4.3.3 Evidence: REQUIREMENT 2.3.3

Action	Verification Evidence	Evidence Pool
Inspection	Inspection data for bore diameter of the spool for each assembly operation	Inspection Report

REQUIREMENT 2.3.4: *The Target Chamber shall withstand the impulsive load resulting from gas flow trailing the projectile and projectile impact in the Catch Tank.*

RATIONALE: After the fast-acting closure seals, projectile gas immediately following the projectile impact the target followed by impact with the plates within the Catch Tank. The most severe condition is a 2kg projectile moving at 2km/s. This combination of projectile mass and velocity creates the most severe loading due to pressure and impact pressure. In this context "withstand" implies that the gun system confines the gas from launching the projectile and any other debris generated during the dynamic experiment, without gross venting.
VERIFICATION: A combination of numerical simulations and system test will be performed to determine the structural integrity of the Catch Tank due to gas pressure.

Table 4.3.4 Evidence: REQUIREMENT 2.3.4

Action	Verification Evidence	Evidence Pool
Demonstrate a factor of safety of 2.0 utilizing Method 2 (see 4.5) for fracture on the Catch Tank and rear closure.	Stress analysis and a fracture analysis for the Catch Tank system Numerical simulation of propellant gas impact	Structural Analysis Report
Directly measure structural performance due to gas pressure	Strain gage readings to establish structural performance to gas pressure.	Test Report

REQUIREMENT 2.3.5: *The Catch Tank shall stop the projectile and target materials and their fragments without causing structural failure or breaching confinement.*
Commentary: *Plastic material response and deformation in the Catch Tank is acceptable.*

RATIONALE: The Catch Tank is a single-use item. Plasticity is acceptable but confinement must be maintained in the system.
VERIFICATION: Confinement will be validated through a combination of numerical simulations and experiments. A minimum of ten experiments will be performed to establish structural performance of the confinement (Section 5) as well as benchmarks for simulation. Structural performance combined with leak checks shall establish compliance. The test series will start with lighter projectiles and low velocities to determine levels of penetration as benchmarks for numerical simulations while increasing the kinetic energy in the system from test to test. (Table 4.3.5)

Table 4.3.5 Evidence: REQUIREMENT 2.3.5

Action	Verification Evidence	Evidence Pool
Demonstrate a factor of safety of 2.0 utilizing Method 2 (see 4.5) for fracture on the Catch Tank and rear closure.	Numerical Simulations and a fracture control plan for the Catch Tank assembly Numerical simulation of projection penetration	Structural Analysis Report
Experiments to assess depth of penetration. Perforating the fifth plate of the armor stack will constitute unacceptable penetration for the Confinement System.	Establish depth of penetration. Perforating the fifth plate of the armor stack will constitute unacceptable penetration for the Confinement System.	Test Report

REQUIREMENT 2.3.6: *The Confinement System shall confine the materials and gases resulting from the gas flow, the projectile, and the target materials.*

VERIFICATION: Absence of external venting will be verified in the qualification post-shot leak tests as less than 1.3×10^{-5} std cm^3/ of helium.

Table 4.3.6 Evidence: REQUIREMENT 2.3.6

Action	Verification Evidence	Evidence Pool
Leak checking for shots will be done on the Confinement System to check the sealing performance of the closure valves and integrity of the external pressure boundary. The Confinement System will be pressurized with 1.0 psig minimum helium gas not to exceed 15 psi, and external leak sensing performed to check for any leakage in excess of 1.3E-5 std cm^3/s of helium gas.	Results for venting test	Test Report

4.4 Diagnostics

Diagnostics on the gun, confinement, and target systems are divided into multiple categories. These include physics diagnostics, confinement diagnostics, gun diagnostics, and timing and firing diagnostics. Each is addressed separately.

REQUIREMENT 2.4.1: *Pressure-retaining feed-throughs or penetrations shall allow the diagnostic signals to enter/exit the Target Chamber as required and withstand the impulsive load associated with firing while maintaining confinement.*
Commentary: *Diagnostics will include optical fiber, electrical cable, and an optical window.*

RATIONALE: Feedthroughs and penetrations are sources of potential leakage.
VERIFICATION: To determine the integrity of the feedthroughs and penetrations, leak checks will be performed associated with pre- and post-shot helium leak checking. (Table 4.4.1)

Table 4.4.1 Evidence: REQUIREMENT 2.4.1

Action	Verification Evidence	Evidence Pool
High-speed video at feedthroughs and penetrations recording the shot event for five shots on each gun.	High-speed video of the system being fired to image areas of dynamic leakage	Test Report
Leak down tests will be completed from 1.0E-2 Torr for each qualification shot to characterize integrity of vacuum.	Pre-leak testing of the system in qualification tests	Test Report
Helium gas will be introduced into the whole interior volume of the system at a pressure of 1 psig minimum and not to exceed 15psig. A helium leak sniffer type mass spectrometer instrument will be used to detect for helium leakage through the joints and manifested as a gas plume on the outside of the system.	Post-shot leak testing of the system in qualification tests	Test Report
Inspections	Feedthrough inspection after qualification tests to look for damaged/charred areas.	Test Report

REQUIREMENT 2.4.2*: Tests shall include reliable physics diagnostics with high-fidelity instrumentation to record target material behavior during impact. Detailed target diagnostic requirements will be established in a separate document.*
Commentary: *Standard target (or physics) diagnostics include: (1) VISAR, (2) PDV, (3) Piezoelectric impact pins, (4) Pyrometry or radiance, (5) Surface Reflectometry and (6) Cross Timing. "C2-DPE-2009-0008, Large Bore Powder Gun Project and Large Bore Powder Gun Experiments Project Functional Requirements July 30, 2009" outlines typical parameters for the listed diagnostics. These are representative but not necessarily a complete list of target diagnostics that will be fielded. The maximum cable run from the target to either the control room or a diagnostic alcove for select diagnostics shall be less than or equal to 100m.*

VERIFICATION: A separate document will be written detailing the qualification actions associated with target diagnostic qualification.

REQUIREMENT 2.4.3*: Confinement diagnostics will be designed and fielded to ensure confinement of the plutonium and other hazardous materials.*
Commentary: *The confinement diagnostics are pressure-retaining diagnostics and are likely to include pressure gauges (within the gun, within the underground ventilation system, and within the experiment room), radiation monitors and swipes, carbon monoxide gauges, strain gauges, and accelerometers. Note that some diagnostics might serve as both system and confinement diagnostics.*

VERIFICATION: Instrumentation will be utilized to verify the structural integrity of the Catch Tank and Confinement System and to quantify the factor of safety against structural failure.

Table 4.4.2 Evidence: REQUIREMENT 2.4.3

Action	Verification Evidence	Evidence Pool
High-speed video at feedthroughs and penetrations recording the shot event for five shots on each gun.	High-speed video of the system being fired to image areas of dynamic leakage.	Test Report
Leak down tests will be completed from 1.0E-2 Torr for each shot to characterize integrity of vacuum. Helium gas will be introduced into the whole interior volume of the system at a pressure of 1 psig minimum. A helium leak sniffer type mass spectrometer instrument will be used to detect for helium leakage through the joints and manifested as a gas plume on the outside of the system.	Results of leak down test.	Test Report
Post test inspection	Feedthrough inspection after development and qualification tests to look for damaged/charred areas.	Test Report

Strains gages on the catch take closure will be installed and monitored as well as hoop gages on the Catch Tank assembly.	Strain gage data will be analyzed to determine structural integrity of the Catch Tank and closure.	Test Report

REQUIREMENT 2.4.4*: Gun diagnostics will be designed and fielded to monitor gun performance.*

VERIFICATION: The following gun diagnostics will be fielded to provide data on gun performance.

Table: 4.4.3 Gun Diagnostic Instrumentation

Diagnostic	**Use**	**Placement**	**Precision**	**Data Rate**
High-speed camera	Monitor seal performance for gun, closure, and Catch Tank	gun, closure device, and Catch Tank		>400fps
High-speed camera	Monitor seal performance for gun, closure, and Catch Tank	gun, closure device, and Catch Tank		>4500fps
Strain gages, 2X redundant	Correlation of breech pressure, code validation, and projectile exit velocity	breech	an uncertainty that does not exceed ± 2% of the measurement	500 kHz
Strain gages, 2X redundant	Measure performance and detector operation	fast closure device	an uncertainty that does not exceed ±2% of the measurement	500 kHz
Dynamic pressure gages	Determine dynamic pressure due to impact and gas expansion	Target Chamber and Catch Tank	nonlinearity aspect that does not exceed 2% of the full scale	500 kHz
Quasi-Static pressure gages	Determine the internal pressure of the Gas Management System	the confinement and Gun Systems and the Gas Management System	uncertainty that does not exceed ± 2% of the full scale reading	0.016 Hz
Thermocouples	Monitor temperature to establish temperature prior to gas venting	launcher barrel and the confinement system outer wall surfaces	uncertainty that does not exceed ±3.0°C	0.016 Hz
Accelerometers	Measure acceleration and deceleration profiles	Confinement System	amplitude nonlinearity no greater than 0.04%	500 kHz
PDV	Measure projectile velocity time history	Target Assembly		

Commentary: *A calibrated diagnostic is one that has undergone a calibration process that satisfies the LANL procedure P330-2, "Control and Calibration of Measuring and Test Equipment".*

Table 4.4.4 Evidence: REQUIREMENT 2.4.4

Action	Verification Evidence	Evidence Pool
Catalog instrumentation certification	Catalog of instrumentation certification	Instrumentation certification file
Inspect installation and run data checks	Visual inspection and instrumentation check data	Test Report
Review data results from each qualification shot to determine reliability of instrumentation	Data from instrumentation and review for viability	Test Report

REQUIREMENT 2.4.5: *Timing and Firing diagnostics shall provide signals to activate the timing and firing subsystem used for actuating gun and confinement components.*

VERIFICATION: Pre-shot tests will be performed to establish signal reliability. During the qualification series, testing will be performed to verify performance of timing and firing diagnostics.

Table 4.4.5 Evidence: REQUIREMENT 2.4.5

Action	Verification Evidence	Evidence Pool
Redundant diagnostics will be utilized during a subset of qualification tests to verify signals are reliable and produce reliable data.	Timing and Firing data from fifteen qualification tests	Test Report

4.5 Gun Life Span

Qualification actions to establish structural integrity for the systems and/or subsystems will utilize a design philosophy to meet one of three following structural criteria. These criteria meet the intent listed within W-SE-0027U, Rev A, "Engineering Process for Confinement and Containment Systems used in the Execution of Dynamic Experiments" as well as the intent described in LANL Engineering Standards Manual PD342 Appendix A – 10CFR851, Appendix A, Part 4 Pressure Safety.

Method 1: Peak vonMises stress will have factors of safety of:

2.0 for σ_{yield}

3.0 for $\sigma_{ultimate}$

Method 2: For $\sigma_{vonMises}$ near yield for a particular component, a fracture control plan will be established for the components with analysis and NDE requirements. The load cycles established by the fracture control plan will be reduced by a factor of 2.0.

Method 3: Satisfy ASME Boiler and Pressure Vessel Code requirements

REQUIREMENT 2.5.1: *The Gun System shall be designed to perform 60 experimental shots with of factor of safety of 2.0 on the number of shots.*

VERIFICATION: This series of simulations will characterize the dynamic stress environment associated with launch and satisfy one of the three qualification methodologies stated in the requirement. (Table 4.5.1)

Table 4.5.1 Evidence: REQUIREMENT 2.5.1

Action	Verification Evidence	Evidence Pool
A series of high-fidelity simulations or calculations shall be performed on the gun system for the most severe structural conditions. Results from the simulations will be used to locate areas of high stress associated with Method 2. These areas will be analyzed as fracture critical. With those locations established simulations and calculations will be performed to establish the shot life of those fracture critical components with an established fracture control plan with a shot life factor of safety of two.	Resultant strains and/or accelerations shall agree within 25% over ten experiments to enable code results to be categorized as predictive. With this benchmark established simulation and/or calculations will be used to fulfill one of the three structural methods outlined in the requirement to establish qualification. Results from that plan shall include: • Fracture critical components • Shot life for each component • Required material properties for fracture critical components including yield, ultimate, and fracture toughness • Coupon samples results will meet required material properties for fracture critical parts • Component retirement and replacement requirements • NDE requirements	Structural Analysis Report Analysis Benchmark Report
Material Coupon Testing	Material coupon testing will be used to establish material properties including yield, ultimate, and fracture toughness	Coupon Testing Results
NDE	nondestructive examinations will be established based on the fracture control plan	Structural Analysis Report

4.6 Seismic

REQUIREMENT 2.6.1: *Each system and/or subsystem shall be designed to meet requirements associated with the seismic environment defined for the Nevada National Security Site U1a complex. The Gun System and Confinement System are subject to DOE Standard 1189 Appendix A criteria, which includes acceptable performance so that failure of the component does not present a life safety hazard as well as sliding or tipping.*

VERIFICATION: Simulations and/or calculations will be completed to demonstrate compliance with the DOE Standard 1189 Appendix A seismic criteria as stated in the requirement. The Nevada National Security Site seismic environment will be used in the simulations and/or calculations. The focus of the study will be based on life safety hazard as well as sliding or tipping. See Table 4.6.1

Table 4.6.1 Evidence: REQUIREMENT 2.6.1

Action	Verification Evidence	Evidence Pool
Seismic Analysis of the gun and Confinement System	Results of seismic analysis and determination if the Gun and Confinement System is vulnerable to tipping or overturning	Seismic Analysis Report

4.7 Entombment

REQUIREMENT 2.7.1: *The entombed portion of the Confinement System shall be modular in design and fit within a 95.5 in. x 41.375 in. x 29.5 in. physical envelope.*

RATIONALE: The design has to be modular to enable personnel to remove the contaminated components place them in an entombment box, transport them to the entombment drift and grout them in place within the box. See Table 4.7.1.

Table 4.7.1 Evidence: REQUIREMENT 2.7.1

Action	Verification Evidence	Evidence Pool
Entombment qualification will be accomplished through a series of entombment rehearsals associated with the prototype gun qualification tests 11 and 12 as well as the physics gun qualification shots 1–5 as outlined in 6.12 “Entombment Assembly” of this document.	Results of the entombment rehearsals	Test Report CAD Study

REQUIREMENT 2.7.2: *The Gun System and Confinement System shall be vented (i.e., depressurized) entombment. The vented gas will pass through filters per the NNSS and LANL interface document.*

RATIONALE: Combustible gases vented from the breech and barrel (i.e., gases behind the projectile) are appropriately managed (e.g. purge, dilution, vent, etc.) using the Gas Management System and are eventually exhausted through the U1a Ventilation System. Additionally, gases from the isolated Confinement System are managed using the Gas Management System and are eventually exhausted through the U1a Ventilation System.

VERIFICATION: The filters and dilution system will be tested to verify that they operate to depressurize the gun system. One aspect to include in the entombment rehearsal is the disconnection of the Gas Management System downstream of the filters, and the inclusion of this hardware in the Confinement System preparation and movement segments of the operation. See Table 4.7.2.

Table 4.7.2 Evidence: REQUIREMENT 2.7.2

Action	Verification Evidence	Evidence Pool
Establish Filtration: The Gas Management System will filter particulates smaller than 1 micron out of the effluent stream.	System Filters: The performance of the filters will be measured by handling the effluent from actual gun firings. The capability of the filters to load with fine particulates and maintain a usable flow rate will be determined.	Test Report
Establish Filtration Pressure Drop: Each filter installation will include a means for measuring the pressure drop across the filter.	System Filter Pressure Drop Measurement: The performance of the filter pressure drop measurement will be checked by handling the effluent from actual gun firings. The pressure drop change across the filters as they load with fine particulates will be determined.	Test Report
A means for diluting the effluent with a clean gas stream will be provided. Dilution will only be used if the detected downstream constituent concentrations are close to release limits.	Effluent Dilution: The performance of the dilution means will be measured by handling the effluent from actual gun firings. The range of dilution possible will be checked by sampling the undiluted and diluted effluent.	Test Report
Entombment qualification will be accomplished through a series of entombment rehearsals associated with the prototype gun qualification tests 11 and 12 as well as the physics gun qualification shots 1-5 as outlined in 6.12 “Entombment Assembly” of this document.	Results of the venting exercises associated with each of entombment rehearsals.	Test Report

4.8 Nevada National Security Site U1a Complex Requirements and Constraints

Requirements associated with the Nevada National Security Site U1a include constraints on size, weight, and available power. In addition there are contingency plans for unplanned events, gas analyses for gun byproducts, and evaluation of a worst-case "over pressure" event.

REQUIREMENT 2.8.1: *Individual components of the Gun System and Confinement System shall weigh less than or equal to 12,000-lb.*
Commentary: *The Gun System and Confinement System component weights are constrained as follows:*

a. *Rated payload, cage, people, and supplies – 12,000 lb. without counterweight*
b. *Maximum load, cage material – 20,000 lb., with 8,000 counterweight attached to skip*
c. *Maximum under slung load, cage, material – 6,000 lb.*
d. *The 102D drift is not configured with a crane. A monorail and chain hoist are planned to be installed in the 102D Drift for handling and entombment activities.*
e. *Components that require lifting should include pick points and weights for design of the monorail/chain hoist system*

Table 4.8.1 Evidence: REQUIREMENT 2.8.1

Action	Verification Evidence	Evidence Pool
Establish a component by component matrix and establish through CAD drawings that each component meets the weight constraints associated with U1a	Matrix indicating part weight as contrasted to requirement	CAD dimensional assessment and Facility Walk-throughs

REQUIREMENT 2.8.2: *No single component of the LBPG System shall exceed 25-ft in length to ensure insertion into the U1a Complex and the LBPG Experiment Room.*
Commentary: *LBPG System components will be inserted into the U1a Complex using the U1h Cage. The maximum length of a load that can be hung under the U1h Cage is 25-ft. The U1h Cage inside dimensions are 10.5-ft deep x 6.25-ft wide x 12.0-ft high.*

Table 4.8.2 Evidence: REQUIREMENT 2.8.2

Action	Verification Evidence	Evidence Pool
Establish a component-by-component matrix and establish through CAD drawings that each component meets the size constraints associated with U1a	Matrix indicating part size as contrasted to constraint	CAD dimensional assessment and Facility Walk-throughs

REQUIREMENT 2.8.3: *The LBPG System shall be less than 70.5-ft long when assembled.*

Table 4.9.3 Evidence: REQUIREMENT 2.9.3

Action	Verification Evidence	Evidence Pool
Determine total length of assemblies through CAD drawings.	Result of CAD study	CAD dimensional assessment

REQUIREMENT 2.8.4*: The maximum length of the LBPG System components, assuming minimal diameter (gun barrel section) shall be less than or equal to 35.0 ft.*

Commentary: *Limiting (smallest) dimensions of the .01 drift between U1h station and the intersection with the .100 drift – 7.33 ft high by 8.33 ft wide (near the U1g shaft). The maximum length of a component that can turn the corner from the .01 drift into the .100 drift is 35.0 ft.*

Table 4.8.4 Evidence: REQUIREMENT 2.8.4

Action	Verification Evidence	Evidence Pool
Establish a component-by-component matrix and establish through CAD drawings that each component meets the size constraints associated with U1a.	Matrix indicating part size as contrasted to constraint.	CAD dimensional assessment

REQUIREMENT 2.8.5: *Gun System and Confinement System components shall be designed such that they can be assembled and disassembled within a 14.5-ft. height constraint.*

Commentary: *The maximum lift height in the Experiment Room for assembly and disassembly of the gun is 10-ft.*

Table 4.8.5 Evidence: REQUIREMENT 2.8.5

Action	Verification Evidence	Evidence Pool
Establish a component-by-component matrix and establish through CAD drawings that each component meets the size constraints associated with U1a.	Matrix indicating part size as contrasted to constraint.	CAD dimensional assessment

REQUIREMENT 2.8.6: *Gun and Confinement electrically powered systems within the Experiment Room, Development Alcove, and outside those rooms shall not exceed 480V. All electrical systems that support Gun/Confinement Systems and operations shall total less than 400 amps total capacity in each area.*

Commentary:

a. Available power in the LBPG Experiment Room is 208/120V, 100 amp box.

b. Available power outside the experiment room (at both ends of the room) is 480V and 208/120V.

c. GFCI are not in the current configuration of the alcove that will house the LBPG; GFCI breakers can be installed if required.

d. UPS power will be required in the diagnostic alcoves and experiment room.

e. Capacity can be added as needed.

Table 4.9.6 Evidence: REQUIREMENT 2.9.6

Action	Verification Evidence	Evidence Pool
Establish power requirements for all instrumentation and diagnostics and determine total load on system	Matrix of individual power requirements and composite of total use.	Power and Load Study

4.9 Off-Normal Events

The Gun System and Confinement System will be designed to withstand off-normal events without endangering personnel.

REQUIREMENT 2.9.1 *The Gun System and Confinement System shall be designed for off-normal events without compromising facility safety.*

EVENT 1: *Gun and Confinement System performance to an uncontrolled pressure release and subsequent blast overpressure in the drift.*

EVENT 2: *Gun and Confinement System performance to projectile breakup during launch.*

EVENT 3: *Gun and Confinement System performance to determine system response to closure valve failure during launch. This includes:*

(1) Closure valve fails to close;

(2) Closure valve closes too early (i.e., before projectile reaches closure valve);

(3) Closure valve closes during projectile passage.

Table 4.9.1 Evidence: REQUIREMENT 2.9.1

Action	Verification Evidence	Evidence Pool
Numerical Simulations of blast over pressure, projectile breakup and closure valve failure.	Results from Analysis	Structural Analysis Report

5.0 COMPONENT AND SYSTEM TESTING

To qualify individual components and the entire system a series of numerical simulations, inspections, and component and system testing has been outlined to ensure the gun and confinement meet the requirements outlined. Component testing is directed at individual components to establish the response to system environment or the partial environment while the system testing is associated with the integrated testing of all components. Some of the system testing may concentrate on a particular component while others are designed to determine the response of the entire system and to establish the ability of each component to work in conjunction with the other components in the subsystems.

5.1 Component Testing

Component tests are limited primarily to the closure valve subsystem and the gun system. Other components such as the Gun System, Gun Stand, Target Subsystem, Catch Tank and Confinement System will be tested as part of the system tests. The closure valve will be tested separately to demonstrate performance over a series isolated tests. Table 5.1 outlines those tests.

Table 5.1 Closure Component Test Series

Test #	Verification Evidence	Configuration	Instrumentation
Closure Valve Test 1	Establish relationship between charge and piston velocity Demonstrate structural integrity of system	Closure Valve by itself	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Closure Valve Test 2	Establish relationship between charge and piston velocity Demonstrate structural integrity of closure system	Closure Valve by itself	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Closure Valve Test 3	Demonstrate integrity of the seal without static or dynamic tube pressure. Demonstrate structural integrity of system	Closure Valve configured with static pressure tube with zero pressure	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Closure Valve Test 4	Demonstrate integrity of the seal without static or dynamic tube pressure. Determine response to piston driving into static pressure associated with pressurized tube	Closure Valve configured with static pressure tube with projectile tail pressure	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.

Test #	Verification Evidence	Configuration	Instrumentation
Closure Valve Test 5	Determine response to piston driving into static pressure associated with pressurized tube to determine seal integrity under static pressure	Closure Valve configured with static pressure tube with projectile tail pressure	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.

Gun component testing will be completed to establish the performance envelope for the gun and enable numerical simulation benchmarking. (Table 5.2)

Table 5.2 Gun System Component Test Series

Test #	Verification Evidence	Configuration	Instrumentation
Test 1 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	1.5 kg projectile at 1.0 km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Test 2 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	1.5 kg projectile at 1.6 km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Test 3 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	1.5kg projectile at 2.0 km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Test 4 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	2.0kg projectile at 1.0 km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Test 5 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	2.0kg projectile at 1.6km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.
Test 6 Gun System	Establish relationship between charge and gun velocity Demonstrate structural integrity of system	2.0kg projectile at 2.0km/s	PDV or equivalent to determine projectile velocity. Strain gages to establish structural response.

5.2 System Testing

The qualification test series will be used to qualify both the Prototype and Physics guns for operations. Table 5.3 outlines the minimum set of tests associated with the qualification series.

Table 5.3 System Qualification Test Series

Gun/Test#	Proj. Mass (kg)	Proj. Velocity (km/s)	Fast-closure	Target Material	Target Diagnostics	Analysis Benchmark	Gun Performance Benchmark	Abnormal Environments Test	Comments
Prototype 1	1.0	0.2		Generic			x		
Prototype 2	1.0	1.0	x	Generic			x		
Prototype 3	1.0	1.5		Generic			x		
Prototype 4	1.0	2.0	x	Generic	x		x		
Prototype 5	1.5	1.0		Confirmatory	x		x		NDE
Prototype 6	1.5	1.5	x	Confirmatory	x		x		
Prototype 7	1.5	2.0	x	Confirmatory	x	x	x		
Prototype 8	2.0	0.2	x	Confirmatory	x		x		
Prototype 9	2.0	1.0	x	Confirmatory	x		x		
Prototype 10	2.0	1.5	x	Confirmatory	x		x		NDE
Prototype 11	2.0	2.0		Generic	x	x	x		Worst case Catch Tank
Prototype 12	2.0	2.0	x	Confirmatory	x	x	x		Entombment rehearsal
Prototype 13	2.0	2.0	x	Confirmatory	x		x		Entombment rehearsal
Prototype 14	2.0	2.0	x	Confirmatory	x		x	x	
Prototype 15	2.0	2.0	x	Confirmatory	x		x	x	NDE
Physics 1	1.0	1.0		Generic			x		Entombment rehearsal
Physics 2	1.5	1.5		Confirmatory	x		x		Entombment rehearsal
Physics 3	2.0	2.0		Confirmatory	x		x		Entombment rehearsal
Physics 4	2.0	2.0		Confirmatory	x		x		Entombment rehearsal
Physics 5	2.0	2.0		Confirmatory	x		x		NDE /Entombment rehearsal

6.0 COMPONENT-BY-COMPONENT QUALIFICATION ACTIONS

Component-by-component qualification actions mirror the global system qualification actions outlined above in 4.1-4.9. This section outlines specific qualification actions that need to occur to qualify specific parts and assemblies. Table 6.0.1 outlines those parts and assemblies. Qualification actions required for each component or assembly are described below.

Table 6.0.1 Component Definitions

#	**Component**	**Dwg.**
6.1	Gun Stand	TBD
6.2	Breech Assembly	34Y1741988
6.3	Projectile	TBD
6.4	Gun Tube Assembly	34Y1741977, 34Y1741978 C, 34Y1741976 A
6.5	Slip Tube Assembly	34Y1757744 B
6.6	Closure Valve Assembly	TBD
6.7	Spool Assembly	34Y1759552 D, 34Y1757771 C
6.8	Target Chamber Assembly	34Y1759548 C, 34Y1759619 A
6.9	Catch Tank Assembly	34Y1759569 B, 34Y1742158, 34Y1759572
6.10	Momentum Trap Assembly	TBD
6.11	Projectile Catch System Stand	TBD
6.12	Entombment Assembly	34Y1759561, 34Y1759579 A
6.13	Gas Management System	TBD

6.1 Gun Stand

The gun stand shall survive 60 shots and withstand a seismic event.

Table 6.1 Gun Stand Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	High-speed video to demonstrate independent movement of the gun and confinement	Test Report
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*		
2.4.4	*Gun Diagnostics*	Strain gages results at key stand locations	Test Report
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	• FEM simulations of stand performance demonstrating Factor of Safety of 2.0 on yield and 3.0 on ultimate. • Instrumentation during qualification shots to benchmark FEM simulations. • NDE of fracture critical parts after Qual shots 11 and 15. • Stand to invert interface inspections and test stand inspections after each qualification shot.	Structural Analysis Report
2.6.1	*Seismic*	FEM and calculations to demonstrate compliance with seismic criteria DOE 1189 Appendix A at NNSS	Seismic Analysis Report
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	CAD drawings and actual hardware to demonstrate compliance with U1a weight constraints	CAD study

Req	Keywords	Verification Evidence	Evidence Pool
2.8.2	*U1a Size*	CAD drawings and actual hardware to demonstrate NNSS size constraints	CAD study
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	CAD drawings and actual hardware to demonstrate NNSS size constraints	CAD study
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	FEM simulation of blast overpressure for 2kg shot at 2km/s compromising facility safety	Structural Analysis Report

6. 2 Breech Assembly

The breech shall demonstrate structural integrity through 60 shots for a 3.5-in.-diameter 2 kg projectile with velocities up through 2.0 km/s. NDE requirements and breech life shall be demonstrated. (Table 6.2)

Table 6.2 Breech Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	• FEM to determine areas of high stress. • Utilizing Method 2 in 4.5, establish a breech assembly fracture control plan with a factor of safety on shot life of 2.0. (60×2=120 shots) • Experimental benchmarking of FEM simulations for shots 5, 10, and 15. • NDE to demonstrate fidelity of fracture control plan after shots, 5, 10, and 15 or equivalent utilizing NDE. • Material Coupon Testing	• Structural Analysis Report • Analysis Benchmark Report
2.2.2	*Bore Diameter*	Part inspection as outlined in 4.2 for the powder chamber throat.	Test Report
2.2.3	*2kg @ 2km/s*	Gun performance curves simulations and benchmarks as described in 4.2.	Performance Envelope Report
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	Post test leak checks on qualification shots demonstrating <1.3e-5 std cm^3/s of helium gas	Test Report
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	Strain gages results at key locations	Test Report
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	See breech above in this table Req. 2.2.1	

Req	Keywords	Verification Evidence	Evidence Pool
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	n/a	

6.3 Projectile

Projectile designs shall be established for 1.0, 1.5, and 2.0 kgs. Standards will be established for other mass projectiles as developed through the life of the gun system. Analysis and design will address the most vulnerable projectiles to enable flexibility in the design for a variety of configurations (Table 6.3). Projectile dynamics will be characterized through analysis and instrumentation.

Table 6. 3 Projectile Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	• FEM simulations of projectile in bore utilizing gun performance curves. Projectile shall have a FS of 3.0 on failure during launch and before impact. • PDV instrumentation as indication of projectile survival prior to target impact.	• Performance Envelope Report • Test Report • Structural Analysis Report
2.2.2	*Bore Diameter*	Part inspection as outlined in 4.2 for the projectile. Tolerance study to establish planarity range. FEM simulations to ascertain balloting behavior and potential planarity range.	• Inspection Report • Structural Analysis Report
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feed-throughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	

Req	Keywords	Verification Evidence	Evidence Pool
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	n/a	

6.4 Gun Tube Assembly

The gun tube assembly shall demonstrate structural integrity through 60 shots for a 3.5 in., 2 kg projectile with velocities up through 2.0 km/s. NDE requirements and barrel life shall be demonstrated. (Table 6.4)

Table 6.4 Gun Tube Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	Part inspection as outlined in 4.2 for the gun bore.	Inspection Report
2.2.3	*2kg @ 2km/s*	Gun performance curves simulations and benchmarks as described in 4.2.	Performance Envelope Report
2.2.4	*Vacuum*	Leak checks on every qualification shot demonstrating 1.0e-2 Torr.	Test Report
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with fast-closure demonstrating <1.3e-5 std cm^3/s of helium gas.	Test Report
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	• Strain gages results at key locations • Thermocouple results at key locations	Test Report
2.4.5	*T&F Diagnostics*	n/a	

Req	Keywords	Verification Evidence	Evidence Pool
2.5.1	*60 shots*	• Utilizing Method 2 in 4.5 establish a gun tube assembly fracture control plan with a factor of safety on shot life of 2.0. (60×2=120 shots) • NDE to demonstrate fidelity of fracture control plan after shots, 5, 10, and 15 or equivalent utilizing NDE. • Material Coupon testing for material properties • Experimental benchmarking of FEM simulations for shots 5, 10, and 15 or equivalent	• Structural Analysis Report • Analysis Benchmark Report
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	CAD drawings and actual hardware to demonstrate NNSS weight constraints are met.	CAD Assessment
2.8.2	*U1a Size*	CAD drawings and actual hardware to demonstrate NNSS size constraints are met.	CAD Assessment
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup, closure failure, and blast over pressure, will be completed to predict consequences.	Structural Analysis Report

6.5 Slip Tube Assembly

The slip tube assembly shall demonstrate structural integrity through 60 shots for a 3.5 in. diameter, 2 kg projectile with velocities up through 2.0 km/s. (Table 6.5)

Table 6.5 Slip Tube Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	Part inspection as outlined in 4.1 for the slip tube.	Inspection Report
2.2.3	*2kg @ 2km/s*	Gun performance curves simulations and benchmarks as described in 4.2.	Performance Envelope Report
2.2.4	*Vacuum*	Leak checks on every qualification shot demonstrating 1.0e-2 Torr.	Test Report
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with fast-closure demonstrating <1.3e-5 std cc/sec of helium gas.	Test Report
2.2.6	*Isolate Recoil*	High speed video to establish independent motion at slip joint	Test Report
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	• Dynamic, non-linear FEM to determine areas of high stress. • Utilizing Method 1 in 4.5 demonstrate factors of safety of 2.0 on yield and 3.0 on ultimate • Experimental benchmarking of FEM simulations for shots 5, 10, and 15 or equivalent. • Leak checks on every qualification shot demonstrating 1.0e-2 Torr. • Post-test leak checks on all qualification shots demonstrating <1.3e-5 std cm^3/s of helium gas.	• Structural Analysis Report • Analysis Benchmark Report

Req	Keywords	Verification Evidence	Evidence Pool
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup, closure failure, and blast over pressure will be completed to predict consequences.	Structural Analysis Report

6.6 Closure Valve Assembly

The closure valve assembly will demonstrate one time use structural integrity, required closure rates, and a positive post-test seal. (Table 6.6)

Table 6.6 Closure Valve Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	Part inspection as outlined in 4.1 for the fast closure entry and exit	Inspection Report
2.2.3	*2kg @ 2km/s*	Demonstrate closure over the entire range of projectile velocities and masses without projectile interference through component and system testing.	Performance Envelope Report
2.2.4	*Vacuum*	Leak checks on every qualification shot demonstrating 1.0e-2 Torr.	Test Report
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with fast-closure demonstrating <1.3e-5 std cm^3/s of helium gas.	Test Report
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	• Dynamic, non-linear FEM to determine areas of high stress and hydrocode simulations for pressure field. • Component testing to demonstrate sufficient closure rate, and post-shot seal with lateral loading. • Experimental benchmarking of FEM simulations for shots 5, 10, and 15 or equivalent. • System qualification shots to demonstrate structural integrity over the entire shot matrix • NDE or destructive tests to determine presence or lack of crack growth in most severe component test and most severe systems qualification test.	• Structural Analysis Report • Structural Benchmark Report
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	• Strain gages results at key locations • High-speed video	Test Report

Req	Keywords	Verification Evidence	Evidence Pool
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	Demonstration that assembled closure valve and confinement physical dimensions are consistent with entombment constraints	CAD Study
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup will be completed to predict consequences.	Structural Analysis Report

6.7 Spool Assembly

The spool assembly will demonstrate structural integrity, vacuum, and leak integrity associated with projectile passage and projectile and target debris backsplash. (Table 6.7)

Table 6.7 Spool Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	Leak checks on every qualification shot demonstrating 1.0e-2 Torr.	
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with fast-closure and non-closure demonstrating <1.3e-5 std cm^3/s of helium gas.	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	Part inspection as outlined in 4.1 for the spool bore diameter.	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feed-throughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	Demonstration that assembled spool and confinement physical dimensions are consistent with entombment constraints	Test Report
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	

Req	Keywords	Verification Evidence	Evidence Pool
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup, valve closure failure, an blast over pressure will be completed to predict consequences.	Structural Analysis Report

6.8 Target Chamber Assembly

The Target Chamber assembly shall survive one time structural event, demonstrate vacuum integrity pre-shot, and leak tests post-shots. It shall demonstrate diagnostic performance. (Table 6.8)

Table 6.8 Target Chamber Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	Leak checks on every qualification shot demonstrating 1.0e-2 Torr.	Test Report
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with closure valve closure and non-closure demonstrating <1.3e-5 std cm^3/s of helium gas	Test Report
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	• Complete dynamic, non-linear FEM to characterize stress field. • Simulations to characterize projectile and target breakup and resulting debris field. • Experimental benchmarking of FEM and hydrocode simulations for shots 5, 10, and 15 or equivalent. • System qualification shots to demonstrate structural integrity over the entire shot matrix. • Evaluation of post-test hardware to characterize debris damage for shots 5, 10, and 15 or equivalent.	• Structural Analysis Report • Analysis Benchmark Report
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	• Leak checks on every qualification shot demonstrating 1.0e-2 Torr. • post test leak checks on all qualification shots with closure valve closure and non-closure demonstrating <1.3e-5 std cm^3/s of helium gas • Video during shots	Test Report

Req	Keywords	Verification Evidence	Evidence Pool
2.4.2	*Target Diagnostics*	•	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	Demonstration that assembled Target Chamber and confinement physical dimensions are consistent with entombment constraints	Test Report
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup, valve closure failure, and blast over pressure will be completed to predict consequences.	Structural Analysis Report

6.9 Catch Tank Assembly

The catch tank assembly shall survive a one-time structural event, demonstrate vacuum integrity pre-shot, and leak tests post-shots. It shall stop the projectile and debris field without loss of pressure boundary integrity. (Table 6.9)

Table 6.9 Catch Can Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	Vacuum checks on every qualification shot demonstrating 1.0e-2 Torr.	Test Report
2.2.5	*Leak Check*	Post test leak checks on all qualification shots with fast-closure and non-closure demonstrating <1.3e-5 std cm^3/s of helium gas	Test Report
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	Post test leak checks on all qualification shots with fast-closure and non-closure demonstrating <1.3e-5 std cm^3/s of helium gas	Test Report
2.3.2	*Closure Valve Seal*	n/a	•
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	• Simulations to characterize projectile and target breakup and resulting debris field as well as penetration through the ballistic materials. • Experimental benchmarking of FEM and hydrocode simulations for shots 5, 10, and 15 or equivalent. • Evaluation of post-test hardware to characterize debris damage for all qualification shots.	• Structural Analysis Report • Analysis Benchmark Report
2.3.6	*Confinement*	• Strain gages results at key locations • Dynamic Pressure and Accelerometers • Video	Test Report
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	

Req	Keywords	Verification Evidence	Evidence Pool
2.7.1	*Modular Entomb*	Demonstration that Catch Tank assembly and confinement physical dimensions are consistent with entombment constraints	Test Report
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	Simulations of projectile breakup, valve closure failure, an blast over pressure will be completed to predict consequences.	Structural Analysis Report

6.10 Momentum Trap Assembly

The momentum trap shall survive 60 shots with prescribed hardware replacement post-shot. It will dissipate the Confinement System momentum without damaging the Confinement System pressure boundary or backstop. (Table 6.10)

Table 6.10 Momentum Trap Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	• Finite Element simulations of momentum trap performance demonstrating F.S. of 2.0 on yield and 3.0 on ultimate. • Instrumentation during qualification shots to benchmark FEM simulations • NDE after Qual shots 5, 10, and 15. • Momentum trap to stand interface visual inspections after each qualification shot	• Structural Analysis Report • Analysis Benchmark Report
2.4.1	*Feed-throughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	CAD drawings and actual hardware to demonstrate NNSS weight constraints.	CAD study

Req	Keywords	Verification Evidence	Evidence Pool
2.8.2	*U1a Size*	CAD drawings and actual hardware to demonstrate NNSS size constraints.	CAD study
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	n/a	

6.11 Confinement System Stand

The confinement system stand shall survive 60 shots and withstand a seismic event. It shall fit within the physical constraints at the NNSS U1a complex. (Table 6.11)

Table 6.11 Confinement System Stand Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feed-throughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	• FEM simulations of stand performance demonstrating F.S. of 2.0 on yield and 3.0 on ultimate. • Instrumentation during qualification shots to benchmark FEM simulations • NDE after Qual shots 5, 10, and 15.	• Structural Analysis Report • Structural Benchmark Report
2.6.1	*Seismic*	FEM and calculations to demonstrate compliance with seismic criteria DOE 1189 Appendix A at NNSS.	Structural Analysis Report
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	CAD drawings and actual hardware to demonstrate NNSS size and weight constraints	CAD study
2.8.2	*U1a Size*	CAD drawings and actual hardware to demonstrate NNSS size and weight constraints.	CAD study

Req	Keywords	Verification Evidence	Evidence Pool
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	FEM simulation of Blast overpressure for 2kg shot at 2km/s without endangerment of personnel	Structural Analysis Report

6.12 Entombment Assembly

The entombment assembly shall demonstrate a seal post-shot and maintain that seal through venting and entombment. It shall meet physical and weight limitations. (Table 6.12)

Table 6.12 Entombment Assembly Verification Evidence

Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	n/a	
2.2.5	*Leak Check*	n/a	
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	Post test leak checks on all qualification shots with entombment test component demonstrating <1.3e-5 std cm^3/s of helium gas. Entombment rehearsals with be staged for Prototype tests 12 and 13, and Physics Gun qualification tests 1-5.	Test Report
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	n/a	
2.7.1	*Modular Entomb*	Demonstration that entombment assembly and confinement physical dimensions and weight is consistent with entombment constraints and handling equipment. Entombment rehearsals will be staged for Prototype tests 12 and 13, and Physics Gun qualification tests 1-5	Test Report
2.7.2	*Entombment Venting*	n/a	
2.8.1	*U1a Weight*	n/a	
2.8.2	*U1a Size*	n/a	

Req	Keywords	Verification Evidence	Evidence Pool
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	n/a	

6.13 Gas Management System

The Gas Management System (GMS) shall accommodate the pre-experiment execution evacuation, and the post-experiment venting of the Gun and Confinement Systems. The GMS is isolated from the dynamic pressures of the Gun and Confinement systems by the isolation valves, which are considered part of the pressure boundary of the components that they are mounted on. The GMS shall meet physical size limitations. (Table 6.13)

Table 6.13 Gas Management System Verification Evidence

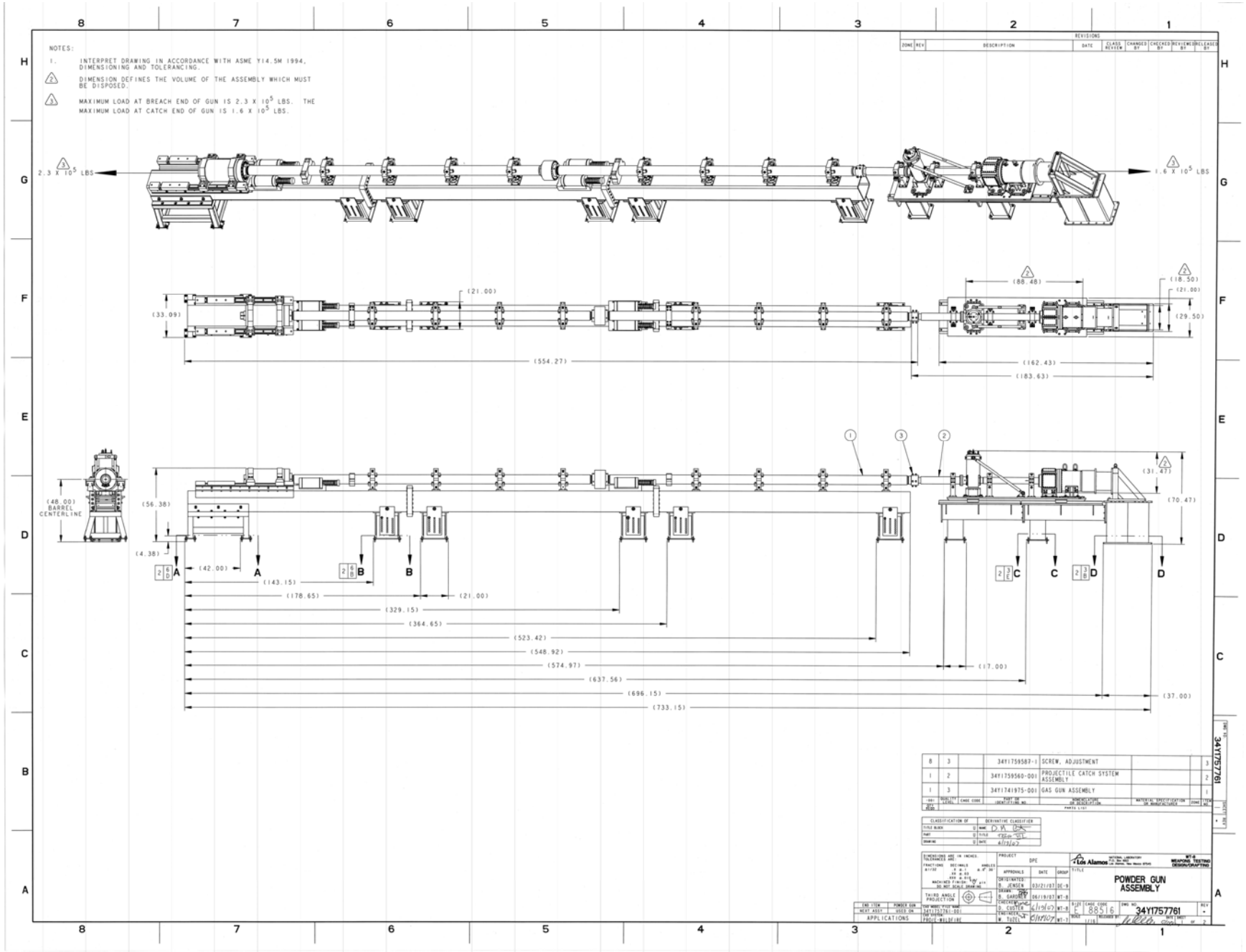
Req	Keywords	Verification Evidence	Evidence Pool
2.1.1	*Eng. Process*	Evidence of following W-SE-0027U for material selection, design, analysis, testing, inspection, and documentation	Eng. Processes Report
2.1.2	*System Safety*	Establish Component safety categorization	Eng. Processes Report
2.1.3	*Quality Designation*	Establish Quality designation per LANL P341-1	Eng. Processes Report
2.1.4	*Construction*	Establish construction protocols associated with W-EP-Q-001	Eng. Processes Report
2.2.1	*Gun System*	n/a	
2.2.2	*Bore Diameter*	n/a	
2.2.3	*2kg @ 2km/s*	n/a	
2.2.4	*Vacuum*	Shall be able to establish a vacuum level of 0.010 Torr, or lower, in the gun and Confinement Systems before an experiment being executed.	Test Report
2.2.5	*Leak Check*	The GMS shall be able to undergo leak checking to assess its operational sealing integrity per ASME B31.3.	Test Report
2.2.6	*Isolate Recoil*	n/a	
2.3.1	*Closure Valve Gases*	n/a	
2.3.2	*Closure Valve Seal*	n/a	
2.3.3	*Drift Tube Diameter*	n/a	
2.3.4	*Target Chamber*	n/a	
2.3.5	*Catch Tank Stop Pr.*	n/a	
2.3.6	*Confinement*	n/a	
2.4.1	*Feedthroughs*	n/a	
2.4.2	*Target Diagnostics*	n/a	
2.4.3	*Confinement Diag*	n/a	
2.4.4	*Gun Diagnostics*	n/a	
2.4.5	*T&F Diagnostics*	n/a	
2.5.1	*60 shots*	n/a	
2.6.1	*Seismic*	The GMS hardware shall be supported in a manner that enables it to meet compliance with seismic criteria DOE 1189 Appendix A at NNSS.	Structural Analysis Report
2.7.1	*Modular Entomb*	n/a	
2.7.2	*Entombment Venting*	The GMS shall support any additional venting operation required for the entombment process.	Test Report
2.8.1	*U1a Weight*	n/a	

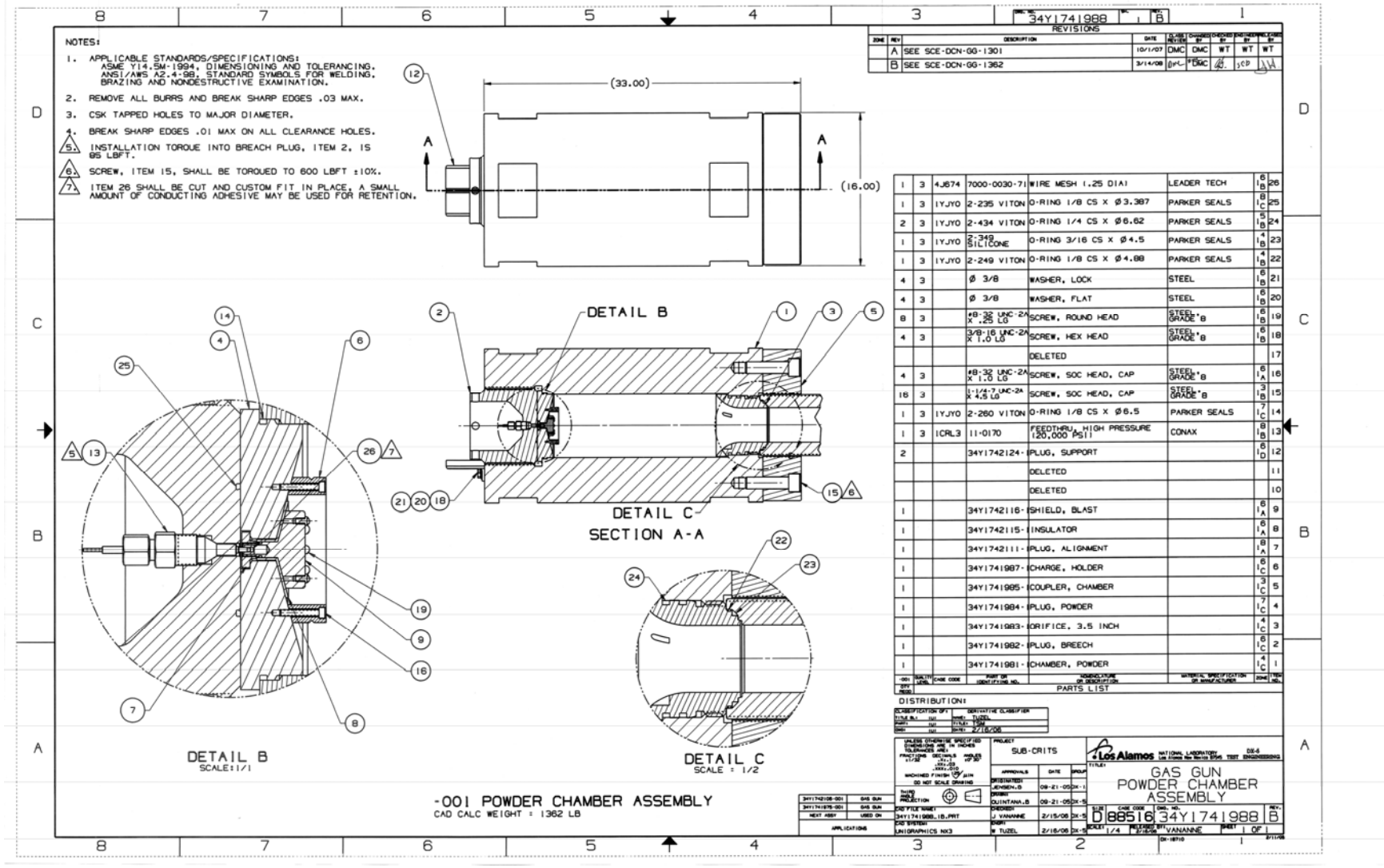
Req	Keywords	Verification Evidence	Evidence Pool
2.8.2	*U1a Size*	CAD drawings and actual hardware to demonstrate NNSS size constraints.	CAD Study
2.8.3	*Gun/Conf. Length*	n/a	
2.8.4	*U1a Geometry*	n/a	
2.8.5	*Assembly Height*	n/a	
2.8.6	*U1a Power*	n/a	
2.9.1	*Off-Normal Events*	n/a	

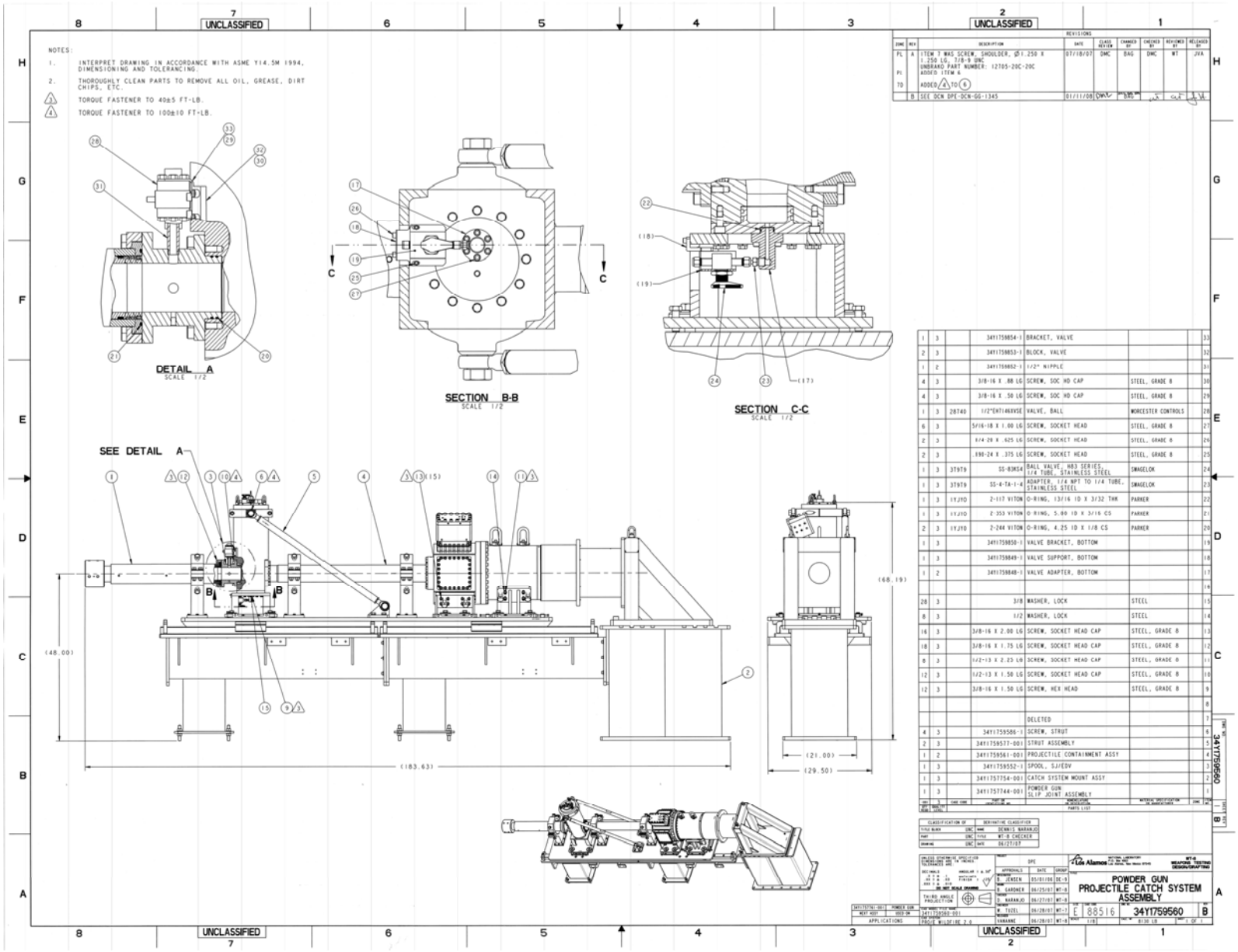
APPENDIX A: KEY ASSEMBLY DRAWINGS

Powder Gun Assembly:	34Y1757761
Gas Gun Powder Chamber Assembly:	34Y1741988 B
Powder Gun Projectile Catch System Assembly:	34Y1759560 B

(This drawing also includes the slip tube which is part of the gun system)


NOTES:
1. INTERPRET DRAWING IN ACCORDANCE WITH ASME Y14.5M 1994, DIMENSIONING AND TOLERANCING.
2 DIMENSION DEFINES THE VOLUME OF THE ASSEMBLY WHICH MUST BE DISPOSED.
3 MAXIMUM LOAD AT BREACH END OF GUN IS 2.3 X 10^5 LBS. THE MAXIMUM LOAD AT CATCH END OF GUN IS 1.6 X 10^5 LBS.
2.3 X 10^5 LBS
1.6 X 10^5 LBS
(21.00)
(33.09)
(88.48)
(18.50)
(21.00)
(29.50)
(554.27)
(162.43)
(183.63)
(48.00) BARREL CENTERLINE
(56.38)
(4.38)
(31.47)
(70.47)
(42.00)
(143.15)
(178.65)
(21.00)
(329.15)
(364.65)
(523.42)
(548.92)
(574.97)
(17.00)
(637.56)
(696.15)
(37.00)
(733.15)
A
B
C
D
34Y1759587-1 SCREW, ADJUSTMENT
34Y1759560-001 PROJECTILE CATCH SYSTEM ASSEMBLY
34Y1741975-001 GAS GUN ASSEMBLY
PARTS LIST
DERIVATIVE CLASSIFIER
Los Alamos
WT-8 WEAPONS TESTING DESIGN/DRAFTING
POWDER GUN ASSEMBLY
34Y1757761
APPLICATIONS


34Y1741988
REVISIONS
NOTES:
1. APPLICABLE STANDARDS/SPECIFICATIONS: ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING. ANSI/AWS A2.4-98, STANDARD SYMBOLS FOR WELDING, BRAZING AND NONDESTRUCTIVE EXAMINATION.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX.
3. CSK TAPPED HOLES TO MAJOR DIAMETER.
4. BREAK SHARP EDGES .01 MAX ON ALL CLEARANCE HOLES.
5. INSTALLATION TORQUE INTO BREACH PLUG, ITEM 2, IS 95 LBFT.
6. SCREW, ITEM 15, SHALL BE TORQUED TO 600 LBFT ±10%.
7. ITEM 26 SHALL BE CUT AND CUSTOM FIT IN PLACE. A SMALL AMOUNT OF CONDUCTING ADHESIVE MAY BE USED FOR RETENTION.
(33.00)
(16.00)
DETAIL B
DETAIL C
SECTION A-A
DETAIL B
SCALE: 1/1
DETAIL C
SCALE = 1/2
-001 POWDER CHAMBER ASSEMBLY
CAD CALC WEIGHT = 1362 LB
PARTS LIST
DISTRIBUTION:
SUB-CRITS
GAS GUN
POWDER CHAMBER
ASSEMBLY
D 88516 34Y1741988 B



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