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EXPLOSIVES PROCESS HAZARDS ANALYSIS

TEMPLATE
EXAMPLE FACILITY INFORMATION

ENERGETIC MATERIAL OPERATIONS

PROCESS HAZARD ANALYSIS

April 2012

This template was completed for NMT Coursework and does not necessitate a requirement for completion by Sandia facilities. Information contained herein is not based on a specific facility and is presented as example information only.

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Line Organization Lead Date

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Line Organization Manager Date

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Explosives Safety Representative Date

Contents

Acronyms

C	Degrees Celsius
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EIS	Explosive Inventory System
EMO	Energetic Material Operations
ESB`	Explosives Safety Board
ESD	Electrostatic Discharge
ESM	Explosive Safety Manual
HA	Hazards Analysis
HE	Hazard Evaluation
HNS	Hexanitrostilbene
IBD	Inter Building Distance
LPS	Lightning Protection System
NEC	National Electric Code
NEW	Net Explosives Weight
NNSA	National Nuclear Security Administration
OP	Operating Procedure
OSHA	Occupational Safety and Health Administration
PETN	Pentaerythritol tetranitrate
PGEWS	Potential Gradient
PHS	Primary Hazard Screen
PrHA	Process Hazards Analysis
QD	Quantity-Distance
SME	Subject Matter Expert
SNL	Sandia National Laboratories
TC	Thermoconductors
TNT	Trinitrotoluene
TWD	Technical Work Document

Introduction

The Sandia Explosive Safety Manual (ESM) and Department of Energy (DOE) ESM require the completion of a process hazards analysis (PrHA) before beginning any explosives synthesis, formulation, manufacturing, testing, or disposal operation. The PrHA requirements in the Sandia and DOE ESMs are based on the PrHA requirements (1910.119(3)) of Occupational Safety and Health Administration 29 CFR 1910.119(a) Process Safety Management of Highly Hazardous Chemicals.

The requirements of OSHA PSM are used as a guide for performing the PrHA. The PrHA is a qualitative analysis that considers the worst-case processes as the basis of the hazard analysis. The worst-case processes were selected based on the energetic material sensitivity, energetic material quantity, number of personnel potentially affected, and impact on other operations/activities.

This PrHA was completed as a team effort with the requisite team members including the team leader/facilitator, who is familiar with the PrHA methodology; the technical engineer and operator, who are familiar with the explosives process being reviewed; and the scribe, who writes notes of meetings and interviews as well as draft the report.

This report formally documents the PrHA for the [insert facility name] performing [insert process operation name].

PrHA Methodology

This PrHA was completed using a What If/Checklist Analysis combined methodology which is the preferred methodology of Sandia National Laboratories/New Mexico (Sandia) for performing hazards analysis. The What-If Analysis methodology is a brainstorming approach in which a group of experienced people familiar with the subject process ask questions or voice concerns about possible undesired events. The What-If/Checklist methodology provides a more systematic nature to the What-If Analysis [CCPS 1992].

The What-If/Checklist Analysis is used to systematically identify hazards, identify potential hazardous events of the process/activity using energetic materials, qualitatively identify consequence and frequency of the events, determine unmitigated and mitigated risk, and identify adequate controls to reduce the risk.

Per Sandia ESM, the PrHA considered the following potential impacts to energetic materials:

- Heat (e.g., radiation, convection, conduction, flame).
- Shock or Impact (e.g., drop, rough handling).
- Friction (e.g., machining, mixing, pinching, cutting).
- Electrical (e.g., AC/DC power, power supplies, batteries, RF, ESD, bonding, grounding, mating/un-mating of connectors, ground plan).

- Reaction (e.g., compatibility, confinement, contamination).
- Physical Environment (e.g., humidity, weather, lightning, PGEWS, location).

Attachment A provides the What If/Checklist analysis hazard evaluation table. The HE table identifies the potential events, consequences, and frequencies. **Attachment B** provides the Risk Binning Tables which are used to identify the unmitigated risk (consequence x frequency) and mitigated risk (consequence x frequency.

Facility/Activity Description

The PrHA scope includes the energetic material operations for the receipt, storage, preparation, handling, and testing for the [insert facility name] performing [insert process operation name].

[Insert facility description] The [example facility] provides a controlled environment in which to demonstrate the performance of system components containing small quantities explosives of under a variety of abnormal environments. The facility conducts testing under controlled environments include temperature extremes. The [example facility] includes general office space and control room in the main facility. The [example facility] includes a high bay area for receipt, handling, and storage of energetic materials. The [example facility] includes a bunker for storage of energetic materials. The [example facility] includes an indoor test cell for testing of energetic materials. Materials are tested in abnormal environments potentially outside of the melting point of the material; however, detonation is not a desired event. No energetic material is intentionally detonated. The [example facility] areas are equipped with fire detection and suppression systems as well as equipped with the appropriate electrical grounding and lightning protection systems.

Test items are delivered directly to the receiving area in DOT shipping containers. These containers are designed and tested to undergo stresses that exceed those usually associated with routine shipping, such as vehicle crashes, fires, etc. Deliveries are carried out by Corporate Storage personnel in approved vehicles and receipt takes place in accordance with applicable Sandia ESM requirements. Shipments are tracked through the Sandia Explosives Inventory System (EIS). The EIS records all receipts, onsite transfers, and shipments by tracking the movement of each individual article. The EIS also identifies each explosive type and quantity, and flags and records incompatibilities. Shipments of test items may arrive as a pallet with multiple containers or as a single shipping container. Following receipt, the pallet and/or shipping container(s) is moved from the receiving area to the bunker or test cell by forklift, pallet-jack, or rolling cart.

Test items with energetic material are stored in the bunker. The bunker provides an acceptable storage environment with an explosives storage cabinet. Because no explosive dusts or explosive gases are stored, the type of explosives found in the test items is consistent for use in facilities that are not designed with National Electrical Code (NEC) Class II Division II electrical. If explosives dusts or explosives with potential off-gas are to be tested, an alternative storage location meeting these design requirements will be identified.

The handling of test items includes movement of the test item both with and without the shipping container. Items with small quantities of explosives are moved to the bunker by hand and/or rolling cart. Handling of test items includes transport of the test items without the shipping container to the test cell using a forklift, pallet jack, rolling cart, or other handling device. Preparation and handling of the test item also includes the placement and testing of thermocouples (TCs) and other instrumentation wiring. TCs are attached to the item by welding (resistance spot welder) and/or by bonding to the test item. When welding is required the item shall not contain explosives. When TCs are attached without welding, a compatible bonding material is used. An explosive-rated Ohm meter and/or other tools are used by test personnel for testing of the thermocouples. The preparation and handling activities occur in the high bay, in proximity to test cell, and/or within the test cell prior to beginning testing.

Some tests are performed under normal thermal environments that do not degrade explosives. The remainder of the tests are conducted in abnormal thermal environments (i.e., above the thermal decomposition temperature of the explosive) such that none of the explosives survive the test. For these types of tests, the post-test temperature is raised to approximately 60 C above the decomposition temperature for approximately 30 minutes to ensure the explosive material is no longer explosive. Following confirmation by the Test Director or Explosives SME, personnel are allowed to reenter the test cell to remove the now non-explosive test item. The article is then returned to storage in the bunker for additional post-test analysis. Only one group of explosives is stored in the bunker at any given time.

Table 1 lists the identified explosive material classes in use. **Attachment C** lists the specific energetic material in use.

Table 1. Identified Energetic Materials

HC/D	Energetic Material	Energetic Operations
1.1	Mass Explosion Hazard	☒
1.2	Non-Mass Detonating	☐
1.3	Mass Fire	☐
1.4	Moderate Fire, No Blast	☐
1.5	Very Insensitive Explosives, Mass Explosion Hazard	☐
1.6	Extremely Insensitive Explosive, No Mass Explosive Hazard	☐

Table 2 lists the location, material type, large or small material quantity, and operation type for the energetic material operations.

Table 2. Example Energetic Operations

Location	Energetic Material	Quantity[1]	Energetic Operations[2]
High-Bay Areas	HC/D 1.1	Small ☒ Large ☐	Receipt ☒ Storage ☒ Preparation ☒ Handling ☒ Testing w/o Detonation ☐ Testing w/ Detonation ☐ Other ☐
Bunker	HC/D 1.1	Small ☒ Large ☐	Receipt ☐ Storage ☒ Preparation ☐ Handling ☒ Testing w/o Detonation ☐ Testing w/ Detonation ☐ Other ☐
Test Cell	HC/D 1.1	Small ☒ Large ☐	Receipt ☐ Storage ☐ Preparation ☒ Handling ☒ Testing w/o Detonation ☒ Testing w/ Detonation ☐ Other ☐

Examples of the different types of explosives in test items may include PETN and HNS as listed in **Attachment C**. Of those listed, PETN is the most heat sensitive explosive because the PETN degradation temperature is just over 140 C. The most thermally stable explosive listed is HNS which decomposes around 320 C. Explosives group A and D are not compatible for storage together. And Explosives group L may not be stored with other groups. The material types, quantities, and locations are consistent with the approved Explosives Site Plan/License [insert explosive site plan or building license]. The site plan is provided as **Attachment D**.

Summary Analysis

The PrHA is appropriate to the complexity of the described process and identifies, evaluates, and control the identified hazards. This PrHA was performed in a facilitated workshop on [insert date]. A What-If/Checklist Analysis methodology was used to systematically evaluate hypothetical events and hazards associated with the receipt, storage, preparation, handling, and testing of articles containing explosives. Scenarios were developed to evaluate events involving small quantities of explosives (i.e., 500 grams or

[1] Small quantity < 500g; large quantity > 500 g
[2] Testing w/ detonation means that detonation is a desired outcome of the operation.

less). The hazard evaluation table in **Attachment A** documents the analysis and includes an estimate of unmitigated and mitigated risks using consequence, frequency, and the risk binning tables provided at **Attachment 2**. The assignments of risk are based on consequence and frequency. The mitigated risk is based on derived controls that prevent and/or mitigate significant impact to the immediate worker.

Scenarios are mitigated to a maximum risk level IV but only those controls derived for use in reducing the scenario to a risk level III are credited herein. **Table 3** provides a summary description of the controls determined by the PrHA.

Table 3. Example Summary of Controls

Control	Credited	Function
Access Control	☒	Prevents workers from entering test cell during test event; limit number of workers in proximity to energetic materials when receiving, handling, and preparation.
Building Ground & Lightning Protection System	☐	Dissipates lightning strike per Sandia Explosives Safety Program.
Conditioning Unit Design	☒	Prevents thermal temperature from exceeding thermal decomposition temperature of explosives material through limit switch and thermal breaker.
DOT Shipping Container	☐	Protects test item with energetic materials from physical impact.
Explosives Safety Program	☐	Corporate Safety Management Program that specifically includes explosive-rated tools and Ohm meter
Explosive Site Plan	☐	DOD/DOE approved with compensatory measures including access control requirements.
Test OP	☒	Provides operating steps for the safe receipt, storage, handling, preparation, and testing of test items with energetic materials.
Test Item Configuration	☒	Documentation accompanying test item confirms that energetic materials are not sensitive to physical impact, shock, or low energy initiation of test items with energetic materials.
Training Program	☒	Provides training on operating steps for the safe receipt, storage, handling, preparation, and testing of test items with energetic materials.
Test Cell Design	☐	Contains energetic event 500 g TNT equivalent.

ATTACHMENT A

EXAMPLE WHAT-IF/CHECKLIST HAZARD EVALUATION TABLE

Example -- Hazard Evaluation (HE) Tables

Facility: [insert facility name] **Date:** [insert date]

Processes: Receipt, Storage, Preparation & Handling, and Testing of Energetic Material

Event ID	Process	Initiating Event	Event Description	Event Location	Consequence Unmitigated	Frequency Unmitigated	Risk Unmitigated	Controls	Consequence Mitigated	Frequency Mitigated	Risk Mitigated
H-7	Handling & Preparation	Electrical & Heat	Welding thermocouples on to Test Item cause either electrical initiation or heat exceeding thermal decomposition temperature of explosives resulting in energetic event.	Bunker	L	A	II	• Explosives Safety Program • Test Item configuration - No explosives present • Test OP • Training	L	U	III
H-8	Handling & Preparation	Electrical	[small qty exp] Use of non-explosive rated ohm meter to test thermocouples causes electrical initiation resulting in energetic event.	Bunker	L	U	III	• Explosives Safety Program • Test Item configuration - Initiating wire not exposed - High Voltage Required • Test OP • Training	L	U	III
H-9	Handling & Preparation	Thermal	[small qty exp] Conditioning unit exceeds thermal decomposition temperature of Test Item explosive resulting in energetic event.	Bunker	L	A	II	• Conditioning Unit Design - Limit Switch - Thermal Breaker • Explosives Safety Program • Test Item configuration • Test OP • Training	L	U	III
T-1	Testing	Thermal	[small qty exp] Temperature exceeds thermal decomposition temperature of Test Item explosive resulting in energetic event – anticipated outcome of test.	Test Cell	L	A	II	• Access Control • Explosives Safety Program • Test OP • Training	L	U	III

Example -- Hazard Evaluation (HE) Tables

Facility: [insert facility name] **Date:** [insert date]

Processes: Receipt, Storage, Preparation & Handling, and Testing of Energetic Material

Summary List of Derived Controls

Control	Credited Control	Required Risk Reduction
Access Control	√	Y
Building Ground & Lightning Protection System	√	N
Conditioning Unit Design	√	Y
DOT shipping container	√	Y
Explosives Safety Program	√	N
Explosive Site Plan	-	N
SNL Explosives Inventory System & Process	√	N
Test OP	√	Y
Test Item Configuration	√	Y
Training Program	√	Y
Fire Detection & Suppression	√	N
Test Cell Design	√	N

ATTACHMENT B

RISK BINNING DEFINITION TABLES

TABLE 1 – Consequence Guidelines for Consequence Level Onsite (Workers)

Abbreviation	Consequence Level	Description
H	High	Immediate worker fatality
M	Moderate	Life-threatening injuries
L	Low	Less than life-threatening injuries
N	Negligible	Minor medical treatment (such as cuts, bruises, contusions, and minor skin irritations)

TABLE 2 – Frequency Guidelines

Abbreviation	Frequency Level	Description
A	Anticipated	Expected to occur in lifetime of facility/operation.
U	Unlikely	May occur in lifetime of facility/operation.
EU	Extremely Unlikely	May occur in lifetime of facility/operation.
BEU	Beyond Extremely Unlikely	Not expected to occur in lifetime of facility/operation.

TABLE 3 – Risk Bins for Onsite Receptors

Likelihood → Consequence ↓	Anticipated (A)	Unlikely (U)	Extremely Unlikely (EU)	Beyond Extremely Unlikely (BEU)
High (H)	I	I	II	III
Moderate (M)	I	II	III	IV
Low (L)	II	III	IV	IV
Negligible (N)	III	IV	IV	IV

Note: Events classified as Risk Rank 1 or II, based on unmitigated risk, are carried forward for identification and discussion.

ATTACHMENT C

EXAMPLE ENERGETIC MATERIALS

Energetic Material	Description	MP (C) BP (C) AI (C)	Explosives Group	Heat	Shock/Impact	Friction	Electrical	Reaction	Physical Env
PETN	**Pentaerythritol tetranitrate** (**PETN**), also known as **PENT**, **PENTA**, **TEN**, **corpent**, **penthrite** (or—rarely and primarily in German—as **nitropenta**), is the nitrate ester of pentaerythritol, a polyol.	142 180 190	A[3]						
HNS	**Hexanitrostilbene** (HNS), also called **JD-X**, is a heat resistant high explosive developed at the Naval Ordnance Laboratory in the 1960s. Other names include 1,1'-(1,2-ethenediyl)bis[2,4,6-trinitrobenzene]; 1,2-bis-(2,4,6-trinitrophenyl)-ethylene; hexanitrodiphenylethylene.	316 - -	D[4]						

Note: Explosives group A and D are not compatible for storage together.

[3] Group A – Initiating explosives. Bulk initiating explosives that have the necessary sensitivity to friction, heat, or shock to make them suitable for use as initiating elements in an explosives train.

[4] Group D – High explosives (HE) and devices containing explosives without their own means of initiation and without a propelling charge, or articles containing a primary explosives substance and containing two or more effective protective features.

ATTACHMENT D

EXPLOSIVE SITE PLAN/BUILDING LICENSE

ATTACHMENT E

PRHA WORKSHOP PARTICIPANTS

PROCESS HAZARD ANALYSIS MEETING ROSTER

Role	*Required*	*Name*
PrHA Facilitator/Lead	☒	
Test Engineer #1	☒	
Test Engineer #2	☐	
Test Operator #1	☒	
Test Operator #2	☐	
Explosive Safety SME	☐	
Fire Protection SME	☐	
Safety Engineer SME	☐	
Industrial Hygiene SME	☐	
Safety Basis SME	☐	
Scribe	☒	
Other #1	☐	
Other #2	☐	