MANUAL

DOE M 440.1-1A

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DOE EXPLOSIVES SAFETY MANUAL

U.S. DEPARTMENT OF ENERGY

Office of Environment, Safety and Health

AVAILABLE ONLINE AT:
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INITIATED BY:
Office of Environment, Safety and Health

DOE EXPLOSIVES SAFETY MANUAL

1. PURPOSE. Department of Energy (DOE) policy requires that all DOE activities be conducted in a manner that protects the safety of the public and provides a safe and healthful workplace for employees. DOE has also prescribed that

   a. All personnel shall be protected in any explosives operation undertaken.

   b. The level of safety provided shall be at least equivalent to that of the best industrial or government practice, but in no case shall the level of safety be less than that developed through a DOE practice.

   c. The risk of death or serious injury shall be limited to the lowest practicable minimum, and

   d. DOE and National Nuclear Security Administration (NNSA) and their contractors shall continually review their explosives operation with the aim of achieving further refinements and improvement in safety practices and protective features.

   e. This Manual describes the Department's explosive safety requirements applicable to operations involving the development, testing, handling, and processing of explosives or assemblies containing explosives. It is intended to reflect the state-of-the-art in explosives safety. In addition, it is essential that applicable criteria and requirements for implementing this policy be readily available and known to those responsible for conducting DOE programs. This document shall be periodically reviewed and updated to establish new requirements as appropriate.

2. CANCELLATION. DOE M 440.1-1, *Explosives Safety Manual,* dated 3-29-96. Cancellation of a directive does not modify or otherwise affect any contractual obligation to comply with the directive. Canceled directives incorporated by reference in a contract remain in effect until the contract is modified to delete the references to the requirements in the canceled directives.

3. APPLICABILITY.

   a. DOE Elements.

      (1) Except for the exclusions in paragraph 3c, this Manual applies to all DOE elements with responsibility for DOE-owned or -leased facilities. (See Attachment 1 for a complete list of DOE elements as of the date of this Manual. This Manual automatically applies to DOE elements created after that date.) Except for the exclusions in paragraph 3c, the requirements in this Manual apply to all DOE elements that engage in developing, manufacturing, handling, storing, transporting, processing, or testing explosives, pyrotechnics and propellants, or assemblies containing

these materials. With the notable exception of onsite explosives storage and transportation, this description is not meant to include routine construction or routine tunnel blasting which are covered by OSHA safety requirements.

(2) The NNSA Administrator will ensure that NNSA employees and contractors comply with their respective responsibilities under this Manual.

b. DOE Contractors.

(1) The CRD (Attachment 2) sets forth requirements that are to be applied to contractors involved with developing, manufacturing, handling, storing, transporting, processing, or testing explosives, pyrotechnics and propellants, or assemblies containing these materials.

(2) Once notified, the contracting officer is responsible for incorporating the applicable requirements of the CRD into the laws, regulations, and DOE directives clause of each contract of contractors that perform work at or for any DOE facility affected by the facility safety hazards described in and requirements established by this Manual.

(3) Regardless of the performer of the work, the contractor is responsible for compliance with the requirements of the CRD that are incorporated in its contract. The prime contractor is responsible for flowing down the requirements of the CRD to subcontractors at any tier to the extent necessary to ensure the contractor's compliance with the requirements and the safe performance of work.

c. Exclusions.

(1) With the notable exception of onsite explosives storage and transportation of explosives or explosive assemblies, this Manual is not meant to govern routine construction or routine tunnel blasting which are covered by OSHA safety requirements.

(2) Pursuant to Executive Order (E.O.) 12344, Naval Nuclear Propulsion Program, the Director, Naval Nuclear Propulsion Program, will implement and oversee requirements of this Order for programs under the Director's cognizance as set forth in the Defense Procurement Reform Act of 1984 (P.L. 98-525) and the Military Lands Withdrawal Act of 1999 (P.L. 106-65).

(3) Requirements of this Manual do not apply to the Bonneville Power Administration.

4. CONTACT. Questions, comments, and suggestions concerning this Manual should be referred to the Office of Nuclear and Facility Safety Policy at 301-903-3190.

BY ORDER OF THE SECRETARY OF ENERGY:

CLAY SELL
Deputy Secretary

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ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
AHJ	Authority Having Jurisdiction
ASTM	American Society for Testing and Materials
ASTI	American National Standards Institute
BOE	Bureau of Explosives
DBA	Design Basis Accident
DDESB	Department of Defense Explosives Safety Board
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSC	Differential Scanning Calorimetry
DTA	Differential Thermal Analysis
EBW	Exploding Bridge Wire
EDC	Explosives Development Committee
EED	Electroexplosive Device
EIDS	Extremely Insensitive Detonating Substance
EOD	Explosive Ordnance Disposal
FMECA	Failure Modes, Effects, and Criticality Analysis
HAZOP	Hazard and Operability Study
HE	High Explosive
HMX	Cyclotetramethylene Tetranitramine
IHE	Insensitive High Explosive
LEL	Lower Explosive Limit
LFL	Lower Flammable Limit
LPS	Lightning Protection System
MCE	Maximum Credible Event
MSDS	Material Safety Data Sheet
NE	Nuclear Explosive
NEC	National Electric Code
NEO	Nuclear Explosive Operation
NEW	Net Explosive Weight
NEQ	Net Explosive Quantity
NFPA	National Fire Protection Association
NNSA	National Nuclear Security Administration
OSHA	Occupational Safety and Health Administration
PBX	Plastic Bonded Explosive

PEL	Permissible Explosive Limit
PETN	Pentaerythritol Tetranitrate
RDX	Cyclotrimethylene Trinitramine
SOP	Standard Operating Procedure
SPMS	Safety Performance Measurement System
SSR	Safe Secure Railcar
SST	Safe Secure Trailer
TATB	Triamino Trinitrobenzene
TMAC	Toxic Materials Advisory Committee
TNT	Trinitrotoluene
UL	Underwriters Laboratory
UN	United Nations
UXO	Unexploded Ordnance

CHAPTER I—INTRODUCTION

1.0 SCOPE, PURPOSE, AND JUSTIFICATION

a. This Manual prescribes the Department of Energy (DOE) safety standards and procedures used to implement the DOE safety policy contained in DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees* (current version) for operations involving explosives, pyrotechnics, and propellants, or assemblies containing these materials.

b. DOE explosives handling and processing operations are an integral part of DOE weapons and weapons-related development, manufacturing, and dismantlement activities. Safety in all operations associated with weapons development is an ongoing, prime concern and must continually be given high priority in all program direction and management. This Manual provides uniform guidance for all DOE and National Nuclear Security Administration (NNSA) facilities and installations involved in explosives handling or processing. DOE will update the Manual periodically to incorporate lessons learned, new technology, and suggestions for improvements. The Assistant Secretary for Environment, Safety and Health is responsible for this task.

c. Maintaining explosives safety in all operations within DOE is an ongoing process that, to be truly effective, must be given high priority in all program direction, management, and line activities. Due to the unique nature of DOE's active role in research and development in new explosives formulations, explosives synthesis, charge geometry, and explosives assemblies, as well as the proximity of explosives to weapon components, it is necessary to maintain the level of explosives safety standards commensurate with the risks.

d. This Manual establishes safety controls and standards not addressed in other existing DOE or non-DOE regulations to close the considerable safety gap created by DOE's unique activities to govern the DOE explosives safety process and ensure that explosives safety is commensurate with the actual risk. However, the Department of Defense (DoD), Occupational Safety and Health Administration (OSHA), and other nationally recognized standards, such as the National Fire Protection Association (NFPA) codes, provide the basic framework. Specific requirements from these documents are applicable and pertinent as determined by the "Authority Having Jurisdiction." Since the conception of the first DOE Explosives Safety Manual in 1978, and the formation of the expert DOE Explosives Safety Committee, no explosives-related fatalities have occurred in DOE and explosives safety practices have significantly improved. Continued maintenance of this Manual, combined with field adherence, will maintain the high level of explosives safety evidenced within DOE over the past two decades.

2.0 APPLICABILITY

a. This Manual applies to all DOE facilities engaged in developing, manufacturing, handling, storing, transporting, processing, or testing explosives, pyrotechnics, and propellants, or assemblies containing these materials, and to the safe management of such operations. With the exception of explosives storage and transportation, this Manual does not apply to commercial activities such as routine construction or routine tunnel blasting.

b. The design of all new explosives facilities shall conform to the requirements established in this Manual and implemented in the current version of DOE O 420.1B, *Facility Safety*. It is not intended that existing physical facilities be changed arbitrarily to comply with these provisions, except as required by law. Existing facilities that do not comply with these standards may continue to be used for the balance of their functional lives if the following two conditions are met:

(1) The current operation presents no significantly greater risk than that assumed when the facility was originally designed.

(2) It can be demonstrated clearly that a modification to bring the facility into compliance is not feasible.

c. However, in the case of a major renovation, the facility must be brought into compliance with current standards.

d. The requirements are presented as either mandatory or advisory. Mandatory requirements, denoted by the words “shall,” “must,” or “will,” must be followed unless the DOE Operations Officer or NNSA Site Manager grants an exemption. Advisory requirements denoted by “should” or “may,” may be deviated from with a written waiver granted by facility management.

3.0 EXEMPTIONS

a. An exemption is a written release from a mandatory safety requirement. Competent, knowledgeable, and experienced explosives safety engineers shall review all exemption requests. Approved exemption requests should feature methodologies to mitigate to the highest practical level the additional safety risks through additional engineering or administrative controls.

3.1 Each such request shall contain the following information:

a. Description of the condition.

b. Safety requirement necessitating deviation.

c. Reason why compliance cannot be achieved.

d. Steps taken to provide protection and to ameliorate the additional risk.

e. Statement of whether equivalent safety is provided and, if not, assessment of the residual risk.

f. Any proposed corrective action and schedule.

g. Duration of the exemption.

3.2 Exemptions Achieving Equivalent Safety

a. The DOE Operations Officer or NNSA Site Manager is permitted to grant exemptions from the mandatory requirements of this Manual provided compliance is impracticable and the facility operator has demonstrated that the conditions, practices, means, methods, or processes to be used are equivalent. Requests for exemptions shall be submitted to the DOE Operations Officer or NNSA Site Manager for action.

3.3 Exemptions Not Achieving Equivalent Safety

a. The DOE Operations Officer or NNSA Site Manager shall submit to the Program Secretarial Officer (PSO) all requests for exemptions from mandatory requirements for which equivalent protection of operating personnel, the public, and property cannot be achieved. The PSO, with the advice and recommendation from the Assistant Secretary for Environment, Safety and Health, shall make a final determination on the request for exemption. The DOE Operations Office or NNSA Site Manager may grant a temporary exemption while the PSO is processing an exemption request. The temporary exemption is limited to the shorter of 180 days from its granting or until the exemption is approved or denied. Exemptions will be reviewed for applicability and currency at intervals not to exceed 5 years.

4.0 WAIVERS

a. If an activity, operation, or process is determined to be out of compliance with the Manual's advisory requirements, but the activity, operation, or process is determined to be safe and necessary, facility management may grant written approval in the form of a waiver for an alternate solution. Waivers will be granted for the minimum time necessary; ongoing waivers shall be updated every three years. Facility management shall maintain a central file of active waivers and provide a copy of each waiver to the local DOE contracting officer.

4.1 <u>Each waiver shall contain, as a minimum, the following information:</u>

a. Description of the condition.

b. Safety standard requiring alternate solution.

c. Reason why compliance is not achieved.

d. Steps taken to provide alternate protection.

e. Any proposed corrective actions and schedule.

f. Waiver duration or expiration date.

5.0 MANUAL ADMINISTRATION AND MANAGEMENT

a. This Manual shall be kept current. The Office of Facility Safety shall ensure that this Manual is kept up-to-date and that the DOE Directives System maintains a current version online at http://www.directives.doe.gov.

b. The DOE Explosives Safety Committee, through the Office of Facility Safety, shall administer and manage this Manual.

5.1 DOE Explosives Safety Committee Organization

a. The DOE Explosives Safety Committee is composed of a member from each of the following: [The membership listing has been updated by the Chairman of the DOE Explosives Safety Committee to reflect reorganizations in DOE/NNSA. Current membership is available upon request from the site representative to the Committee, or from the Committee Chairman].

(1) DOE Office of Facility Safety

(2) NNSA Office of Military Application and Stockpile Support

(3) NNSA Service Center, Albuquerque

(4) NNSA Service Center

(5) NNSA Livermore Site Office

(6) NNSA Nevada Site Office

(7) NNSA Sandia Site Office

(8) NNSA Pantex Site Office

(9) DOE Idaho Field Office

(10) DOE Savannah River Office

(11) Los Alamos National Laboratory

(12) Lawrence Livermore National Laboratory

(13) Pantex Plant

(14) Kansas City Plant

(15) Idaho National Engineering and Environmental Laboratory

(16) Nevada Test Site

(17) Sandia National Laboratories

(18) Wackenhut Services, Savannah River Site

b. A representative of the DOE Office of Facility Safety shall chair the committee and will report directly to the DOE Director, Office of Facility Safety.

5.2 DOE Explosives Safety Committee Functions

a. The DOE Explosives Safety Committee shall perform the following functions:

(1) Review, evaluate, and act under authority delegated from the DOE Director, Office of Facility Safety, on proposed changes or revisions to this Manual.

(2) Evaluate and respond to requests for interpretations of the Manual.

(3) Meet periodically, as appropriate, to review and evaluate Manual adequacy and existing exemptions, and to initiate Manual changes as needed.

b. The DOE Explosive Safety Committee (at the local level its individual voting members) is (are) the "Authority Having Jurisdiction" over DOE explosives safety matters.

c. Changes to this Manual become effective once they have been approved by the DOE Explosives Safety Committee and the approval is published in the official minutes of committee meetings.

6.0 DEFINITIONS

For purposes of this Manual, the following terms are defined.

AIR TERMINAL. (1) A component of a Lightning Protection System (LPS) designed to accept direct attachment of the lightning flash and transfer the current to the down conductor. (See STRIKE TERMINATION DEVICE). (2) A strike termination device that is a receptor for attachment of flashes to the LPS and is listed for the purpose.

APPROVED. Complying with the provision(s) of this Manual and with instructions and details issued by the authority having jurisdiction or with those of other approving agencies specified herein.

ARM. A general term that implies the energizing of electronic and electrical circuitry, which in turn controls power sources or other components used to initiate explosives. The arming operation completes all steps preparatory to electrical initiation of explosives except the actual fire signal.

BARRICADE. An intervening approved barrier, natural or artificial, of such type, size, and construction as to limit in a prescribed manner the effect of an explosion on nearby buildings or personnel.

BAY. A location (e.g., room, cubicle, cell, or work area, etc.) containing a single type of explosives activity, which affords the required protection specified for appropriate hazard classification of the activity involved.

BLENDING. The mixing of solid materials (usually dry) by gravity flow, usually induced by vessel rotation.

BOND. An interconnection of metal objects, generally to the LPS. (See BONDING).

BONDED. The joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

BONDING. (1) An electrical connection between a metal object and an LPS component. This produces electrical continuity between the LPS and the object and minimizes electro-magnetic potential differences. Bonding is done to prevent sideflash. (2) An electrical connection between an electrically conductive object and an LPS component that is intended to significantly reduce potential differences created by lightning currents.

BOOSTER. Explosives used in an explosive train to amplify the shock output of the initiating device and cause detonation of the main explosive charge.

CASUAL. A person other than an operator who intermittently visits an explosives operation for the purpose of supervision, inspection, maintenance, etc. Casuals do not perform hands-on work with explosives but are otherwise involved with the explosives operation being performed.

Casuals are accounted for in the established personnel limits for the area and are provided a level of protection consistent with the explosion hazard of operations in adjacent areas.

CATENARY SYSTEM. An LPS consisting of overhead wire suspended from poles connected to a grounding system via down conductors. Its purpose is to intercept lightning flashes from the protected area.

CLEAR ZONE. The required maximum quantity-distance for the protection of personnel and facilities from the Potential Explosion Site (PES).

COMBUSTIBLE MATERIAL. Any material that, when ignited, will sustain burning.

COMPATIBILITY. The chemical property of materials to coexist without adverse reaction for an acceptable period of time. Compatibility in storage exists when storing materials together does not increase the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Storage compatibility groups are assigned to provide for segregated storage.

CONCURRENT OPERATIONS. Operations performed simultaneously and in close enough proximity that an incident with one operation could adversely influence the other.

CONDUCTOR. Usually a cable intended to be used to carry lightning currents between strike termination devices and ground terminals. The conductor also serves as a strike termination device for a catenary LPS. Conductors are usually heavy metallic cables but metallic building structural members, (e.g., steel I-beams) can also function as down conductors.

CONTACT OPERATIONS. An operation in which an operator and an explosive item are both present with no operational shield.

CONTROL POINT. The location used for personnel control and operation coordination in an explosives operating or test area.

CORING. A machining operation that removes material in the form of a cylinder by cutting at the circumference to create a hole or recover the material from the center of the cut.

COUNTERPOISE. A type of an earth electrode system consisting of conductor cables buried around the structure to be protected. Generally, a counterpoise will have more surface area contacting the earth than ground rod systems. Commonly called a ground ring electrode. (See EARTH ELECTRODE SYSTEM).

CRITICAL TEMPERATURE. Temperature above which the self-heating of an explosive causes a runaway reaction. It is dependent on mass, geometry, and thermal boundary conditions.

DANGER ZONE. That area around a test site where personnel could be in physical jeopardy due to overpressure, fragments, or firebrands released during an explosive test.

DEFLAGRATION. A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source.

Deflagration is a surface phenomenon with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction, and temperature and may cause transition into a detonation.

DETONATION. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium, forming a propagating shock wave that is originally of supersonic velocity. When the material is located on or near the surface of the ground, a detonation is normally characterized by a crater.

DIFFERENTIAL SCANNING CALORIMETRY (DSC). A technique in which the difference in energy inputs into a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program, or are held isothermally. The record is the differential scanning calorimetry or DSC curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal DTA curve.

DIFFERENTIAL THERMAL ANALYSIS (DTA). A technique in which the temperature difference between a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program or are held isothermally. The record is the DTA curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal differential thermal analysis (DTA) curve.

DIRECT CONTACT WITH EXPLOSIVES. Physical contact between an electrical instrument or equipment to bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device.

DOWN CONDUCTOR. A form of a main conductor designed to conduct the current of a lightning flash vertically down to the earth electrode system.

DRYING. The removal of volatiles from ingredients or mixtures.

DSC. See DIFFERENTIAL SCANNING CALORIMETRY.

DTA. See DIFFERENTIAL THERMAL ANALYSIS.

EARTH ELECTRODE SYSTEM. Sometimes called a ground terminal. (1) A component of an LPS that transfers the current of a lightning flash to the earth. The earth electrode system is connected to the down conductor and is in direct contact with the earth. Examples of earth electrode systems include ground rods, a counterpoise, buried metal plates, Ufer grounds, or other similar devices. The matrix of a Faraday-like shield acts as the earth (ground) electrode for an LPS. (2) The portion of an LPS, such as a ground rod, ground plate, or ground conductor, that is installed to provide electrical contact with earth.

EBW. See EXPLODING BRIDGEWIRE.

EED. See ELECTROEXPLOSIVE DEVICE.

ELECTRICAL BONDING. Electrical connection between two conductive objects intended to prevent development of an electrical potential between them.

ELECTROEXPLOSIVE DEVICE (EED). An EED is a device containing some reaction mixture (explosive or pyrotechnic) that is electrically initiated. The output of the initiation is heat, shock, or mechanical action. See also LOW-ENERGY EED.

EXPERIMENTAL OPERATING PROCEDURE. A procedure prepared for conducting a specific experiment a limited number of times under close technical supervision.

EXPLODING BRIDGEWIRE (EBW). An EED that is initiated by the discharge of a high current through the device bridgewire, causing the wire to explode and produce a shockwave. An EBW as defined herein is a device containing no primary explosive.

EXPLOSIVE. Any chemical compound or mechanical mixture which is designed to function as an explosive, or chemical compound which functions through self-reaction as an explosive, and which, when subjected to heat, impact, friction, shock, or other suitable initiation stimulus, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases that exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate. DOE explosives may be dyed various colors except pink, which is reserved for mock explosive.

EXPLOSIVE DECONTAMINATION. The removal of hazardous explosive material.

EXPLOSIVES FACILITY. A structure or defined area used for explosives storage or operations. Excluded are explosives presenting only localized, minimal hazards as determined by the Authority Having Jurisdiction. Examples of excluded items may include user quantities of small arms ammunition, commercial distress signals, or cartridges for cartridge actuated tools, etc.

EXTRUDING. Forcing a plastic-type material, under pressure, into a confined space or through a confined opening to produce a desired configuration.

FACILITY. A group of buildings or equipment used for explosive operations at one geographic location, generally owned by DOE.

FACILITY MANAGEMENT. Management staff of the facility operator (the contractor).

FACILITY OPERATOR. The organization having responsibility for conducting operations at a DOE facility.

FARADAY CAGE or FARADAY-LIKE SHIELD. An LPS where the area to be protected is enclosed by a heavy metal screen (like a birdcage) or continuous metallic structure with no unbonded metallic penetrations. On such a system, the lightning current flows on the exterior of the structure, not through the interior.

FIREBRAND. A projected burning or hot fragment whose thermal energy is transferred to a receptor.

FIRING PAD. The prepared site where explosive items are fired for test data acquisition.

FIRING SITE. Controlled access area where test firing of explosives is conducted.

FLAMMABLE LIQUID. Any liquid having a flash point below 60°C and a vapor pressure not exceeding 280 kPa (41 psia) at 37.8°C. This is the definition as applied in this Manual; it includes some materials defined as combustible liquids by the Department of Transportation (DOT) and/or NFPA 70, Flammable and Combustible Liquids Code.

FLASH. The total lightning event. A flash may involve several lightning strokes, generally using the same path through the air as the initial event.

FLASH POINT. The temperature at which a liquid or volatile solid gives off a vapor sufficient to form an ignitable mixture with air near the surface of the material or within the test vessel.

FORMULATION. (1) The operation of combining ingredients to produce a mixture of a final desired composition possessing specific physical and explosive properties. (2) An explosives composition.

GROUND RESISTANCE. The value (in ohms) of the resistance between an earth electrode system and earth.

GROUND RING ELECTRODE (GRE). An earth electrode system that encircles the structure, either on or buried in the earth. (See COUNTERPOISE and EARTH ELECTRODE SYSTEM).

GROUND ROD. A component of one type of earth electrode system, generally a cylindrical device of approximately 3/4-in. diameter by approximately 10-ft long driven into the soil. The ground rod is attached to the down conductor and dissipates a lightning flash's current into the earth.

GROUND TERMINAL. See EARTH ELECTRODE SYSTEM.

GROUNDED. (1) Connected to earth or some conducting body that serves in place of the earth. (2) Connected to earth or some conducting body that is connected to earth.

GROUNDING. Providing an electrical path to the earth, generally to the earth electrode system.

HEATING LIMITS. The conditions established for safely heating an explosive system (maximum temperature, heating time, heating rate, etc.). These limits are based on the estimated critical temperature of the explosive system with a suitable margin of safety.

HIGH-ENERGY INITIATOR. Exploding bridgewire systems, slapper detonators, and EEDs with similar energy requirements for initiation.

HIGH PRESSURE. Gas pressure greater than 3,000 psig (21 MPa gauge); liquid pressure greater than 5,000 psig (35 MPa gauge).

HOLE. (as applied to machine explosives). Any cavity that is more than one-half diameter deep, being cut by any tool with the direction of feed along the axis of rotation.

HOT WORK (thermal). Any operation requiring the use of a flame-producing device, an electrically heated tool producing a temperature higher than 109°C, or a mechanical tool that can produce sparks or heat explosives or explosives contamination to provide an initiation stimulus.

HYDROSTATIC PRESSING. The operation of compacting a material that is confined in a press by a diaphragm by hydraulically applying pressure to the diaphragm.

IHE. See INSENSITIVE HIGH EXPLOSIVES.

IHE SUBASSEMBLIES. IHE hemispheres or spheres with booster charges, with or without detonators that pass the DOE qualification tests listed in Table IX-3.

IHE WEAPONS. Weapons listed in DOE-DNA TP 20-7, Nuclear Safety Criteria (for Warhead Storage), as being exempt from storage and transportation limits are classified as IHE weapons when stored or transported alone or in combination with each other. This classification is valid only if the spacing between individual units is that provided by storage or shipping containers or, if not in containers, by the spacing specified in TP 20-7.

IMPEDANCE. The resistance and reactance to an electrical current.

INDIRECT CONTACT WITH EXPLOSIVES. When bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device make contact with electrical instrument or equipment through electrically conductive equipment or surfaces other than the equipment leads.

INDUCTANCE. (1) The property of a conductor that makes it oppose any current change through it. (2) A process where an object having electrical or magnetic energy can produce similar properties in a nearby object without direct contact.

INERT MATERIALS. Materials that show no exothermic decomposition when tested by DSC or DTA. Moreover, when tested by recognized compatibility tests, the inert material shall not show any incompatibility with energetic material with which it may be combined. Inert material shall neither alter the onset of exotherm of the DSC or DTA trace of the energetic material nor increase the rate of decomposition or gas evolution of the energetic material.

IN-PROCESS STORAGE MAGAZINE (facility, vault, rest house, etc.). See SERVICE MAGAZINE.

INHABITED BUILDING. A building or structure other than operating buildings, magazines, and auxiliary buildings occupied in whole or in part as a habitation for people or where people are accustomed to assemble, both within and outside DOE facilities. Land outside DOE facilities shall be considered as sites for inhabited buildings.

INHABITED BUILDING DISTANCE. The minimum distance permitted between explosives locations and inhabited buildings, administrative areas, site boundaries, main power stations, and other facilities of vital or strategic nature.

INITIATION STIMULUS. Energy input to an explosive in a form potentially capable of initiating a rapid decomposition reaction. Typical initiation stimuli are heat, friction, impact, electrical discharge, and shock.

INITIATION, WITH ITS OWN MEANS. Explosives or ammunition having their normal initiating device (e.g., detonators or squibs) assembled to them so that this device is considered to present a significant risk of activation during storage.

INITIATION, WITHOUT ITS OWN MEANS. Explosives or ammunition that (1) are not stored with an initiating device assembled to them; or (2) have the initiating device assembled to them, but (a) safety features preclude initiation of the explosives filler of the end item in the event of accidental functioning of the initiating device, or (b) the initiating device does not contain any primary explosives and has a high threshold of initiation (e.g., EBW or slapper detonators). The power source for the initiator should not be present within the assembly or system. If the initiator's power source is present, two or more management-certified safety devices connected in series shall be present to interrupt any flow of energy from the power source to the initiator.

INSENSITIVE HIGH EXPLOSIVES (IHE). Explosive substances that, although mass detonating, are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. The materials passing the DOE qualification tests in Table IX-1 are classified as IHE, and are listed in

INTEGRAL SYSTEM. An LPS that has strike termination devices mounted on the structure to be protected. These strike termination devices are connected to the earth electrode system via down conductors. Metallic structure members can serve as parts of the LPS.

INTERMEDIATE PRESSURE. Gas pressure from 150 to 3,000 psig (1 to 21 MPa gauge); liquid pressure from 1,500 to 5,000 psig (10 to 35 MPa gauge).

INTRALINE DISTANCE. The minimum distance permitted between any two operating buildings or sites within an operating line, at least one of which contains, or is designed to contain, explosives.

INTRINSICALLY SAFE. An apparatus or system whose circuits are incapable of producing any spark or thermal effect capable of causing ignition of a mixture of flammable or combustible material under test conditions described in ANSI/UL 913.

ISOSTATIC PRESSING. The operation of compacting a material in a sealed flexible container. The container is submerged in a pressure vessel, and the vessel is pressurized with liquid.

LABORATORY OPERATIONS. Experimental study, testing, and analysis of small quantities of energetic materials. Manufacturing processes with small quantities of materials are not included.

LEL. See LOWER EXPLOSIVE LIMIT.

LFL. See LOWER FLAMMABLE LIMIT.

LIGHTNING DETECTION SYSTEM, (LDS). A device or system to detect the presence of lightning activity in the general area.

LIGHTNING PROTECTION SYSTEM (LPS). A lightning protection system is a complete system of strike termination devices, conductors, ground terminals, interconnecting conductors, surge suppression devices, and other connectors or fittings required to complete the system.

LIGHTNING WARNING SYSTEM. A system that detects the presence and range of lightning activity and thereby issues an alert or warning advisory.

LOW-ENERGY EED. All EEDs except EBW detonators and slapper detonators.

LOW PRESSURE. Gas less than 150 psig (1 MPa gauge); liquid less than 1,500 psig (10 MPa gauge).

LOWER EXPLOSIVE LIMIT (LEL). The concentration of vapor or dust in air below which an explosion cannot occur.

LOWER FLAMMABLE LIMIT (LFL). The concentration of a vapor or dust in air below which a burning reaction cannot be sustained.

MACHINING. A forming operation accomplished by removing material with a mechanically operated cutting tool.

MACHINING OVERTEST. A test to evaluate the susceptibility of an explosive material to initiation during machining.

MAGAZINE. See SERVICE MAGAZINE or STORAGE MAGAZINE.

MAGAZINE DISTANCE. The minimum distance permitted between any two storage magazines. The distance required is determined by the type(s) of magazine and also the type and quantity of explosives stored therein.

MAST SYSTEM. An LPS system that consists of one or more poles with a strike termination device connected to an earth electrode system by down conductors. In the case of a metallic pole, the pole could serve as the strike termination device and down conductor. Its purpose is to intercept lightning flashes from the protected area.

MAXIMUM CREDIBLE EVENT (MCE). The MCE from a hypothesized accidental explosion or fire is the worst single event that is likely to occur from a given quantity and disposition of explosives or explosives devices. The event must be realistic with a reasonable probability of occurrence considering the explosive propagation, burning rate characteristics, and physical protection given to the items involved.

MELTING. Operations involving change in the physical state of explosives from solid to liquid.

MILLING. (1) Operations that either reduce solid material particle size by attrition or apply high shear mixing to incorporate solid materials into plastic binders. (2) A surface machining operation performed on a mill.

MIXING. A mechanical operation that combines dissimilar materials.

MOCK EXPLOSIVE. Substances bearing similar physical properties (texture, density, cohesion, etc.) to an explosive material. They are non-detonable. However, some are exothermic materials that will burn. Mock explosives are used to represent explosives for purposes such as dry run testing of equipment. DOE mock explosives are normally pink in color.

NET EXPLOSIVE WEIGHT (NEW). Net explosive weight expressed in pounds.

NEW (OR EXPERIMENTAL) EXPLOSIVES. Explosive, explosive mixture or explosive and binder mixture that the Explosives Development Committee (EDC) has not characterized.

NON-FACILITY PERSONNEL. Construction or maintenance personnel who do not have a continuing contract with DOE or NNSA or their agents at the facility concerned.

NON-OCCUPIED or UNOCCUPIED AREA. A location where occupancy is of a transitory nature such as building corridors, access ramps, and facility roads. Other examples are locations such as mechanical equipment rooms, equipment/parts staging/storage areas, decontamination areas and janitors closets, which typically have a low personnel density and an intermittent and relatively short-term duration of occupancy for assigned work but in which personnel are not normally permanently assigned.

NUCLEAR EXPLOSIVE (NE). An assembly containing fissionable and/or fusionable materials and main charge high-explosive parts or propellants capable of producing a nuclear detonation (e.g., a nuclear weapon or test device).

NUCLEAR EXPLOSIVE OPERATION (NEO). Any activity involving a nuclear explosive, including activities in which main charge high-explosive parts and pit are collocated.

OCCUPIED AREA. Any work area that can be reasonably considered integral to an explosives operating area to which personnel are assigned or in which work is performed, however intermittently. Examples of areas to be considered as occupied are assembly/disassembly cells or bays, explosives operating bays, radiography control and film processing rooms, offices, break areas and rest rooms.

OPERATIONAL SHIELD. A barricade constructed to protect personnel, material, or equipment from the effects of a possible fire or explosion occurring at a particular operation.

PENETRATION. A conductive object that passes through the zone of protection or exterior surface of an LPS.

PERSONNEL BARRIER. A device designed to limit or prevent personnel access to a building or an area during hazardous operations.

POTENTIAL EXPLOSION SITE (PES). The location of a quantity of ammunition and explosives that will create a blast, fragment, thermal, or debris hazard in the event of an accidental explosion of its contents.

PRESSING. The operation of increasing the density of explosive material by applying pressure.

PRIMARY EXPLOSIVE. A sensitive explosive which nearly always detonates by simple ignition from such means as a spark, flame, impact and other primary heat sources of appropriate magnitude. Examples are mercury fulminate, lead azide, and lead styphnate, and other materials of similar sensitivities.

PROGRAM SECRETARIAL OFFICER. A senior program official, which includes the Assistant Secretaries or Office Directors at the Assistant Secretary level for DOE or the Deputy or Associate Administrators for NNSA.

PROPELLANT. Explosive composition used to propel projectiles and rockets and to generate gases for powering auxiliary devices.

PUBLIC TRAFFIC ROUTE DISTANCE. The minimum separation distance required between a potential explosion site and any public street, road, highway, passenger railroad, or navigable waterway (including roads on DOE-controlled land open to public travel).

PUNCH AND DIE PRESSING. The operation of compacting a material confined by a die by forcing a punch or punches into the die and against the material.

PYROTECHNIC MATERIAL. Physical mixtures of finely divided fuels and oxidizer powders; may include various organic binders and color intensifiers. The material is intended to produce an effect by heat, light, sound, gas or smoke, or a combination of these as the result of non-detonative, self-sustaining exothermic chemical reactions.

RATED ELECTRICAL EQUIPMENT, FIXTURES, INSTRUMENTATION AND MATERIALS. As used in the *DOE Explosives Safety Manua*l, "rated" refers to those items used in explosives locations that meet identified standards or have been tested and found suitable for use in Class I or Class II hazardous atmosphere. For an item to be considered "rated," a nationally recognized testing laboratory shall have approved its use (for example, Factory Mutual) or listed it for use (for example, Underwriters Laboratory) in the appropriate Class I or Class II hazardous atmosphere. "Rated" items are used to provide protection in explosives locations where the National Electrical Code Article 500 does not normally apply.

REMOTE OPERATION. An operation performed in a manner that will protect personnel in the event of an accidental explosion. This can be accomplished by distance, shielding, barricades, or a combination thereof.

RESISTANCE. The property of a conductor to oppose the flow of an electric current and change electric energy into heat. For lightning protection purposes low resistance values are desired. Resistance is measured in ohms.

RETURN STROKE. That part of a lightning flash where high electric currents are developed as the negatively charged leader encounters the positively charged return stroke. The phase of lightning that produces electric current, heat, a light flash and thunder.

RISK. A measure of the combination of the probability and consequences of the hazards of an operation, expressed in qualitative or quantitative terms.

ROLLING SPHERE ZONE OF PROTECTION MODEL. A theoretical concept describing the area protected by an LPS where an imaginary sphere (100-ft radius for explosive facilities) approaches an LPS from all angles and directions. The protected area is the area of the curve between where the curve is tangent to the ground, and the curve touches the LPS. For example, with the rolling sphere method the area protected by a mast system looks like a teepee.

SAFETY ANALYSIS. A document prepared to systematically identify the hazards of a DOE operation; describe and analyze the adequacy of measures taken to eliminate, control, or mitigate identified hazards; and analyze and evaluate potential accidents and their associated risks.

SCREENING. An operation using screens to separate particles of differing sizes.

SECONDARY EXPLOSIVES. An explosive substance which is relatively insensitive (when compared to primary explosives), which is usually initiated by primary explosives with or without the aid of boosters or supplementary charges. Such explosives may react as a deflagrating or as a detonating explosive. Examples are TNT, plastic bonded formulations, and other materials of similar sensitivity.

SERVICE MAGAZINE, REST HOUSE, ETC. An auxiliary building or suitable designated room (vault) used for the intermediate storage of explosives materials not exceeding the minimum amount necessary for safe and efficient operation.

SHUNT. An electrical interconnection of various portions of EED circuitry to prevent the development of an electrical charge differential between the parts.

SIDEFLASH. (1) The phenomena where lightning current will jump through a non-conductive medium to attach to improperly bonded metallic objects. (2) An electrical spark, caused by differences of potential, which occurs between conductive metal bodies or between conductive metal bodies and a component of an LPS or ground.

SITE PLAN. A formal explosives facility and operations safety document to be prepared by Facility Management for DOE/NNSA approval of explosives facilities siting and operations before the operation starts. This document becomes the authorization basis for explosives facility operations.

SITE PLANNING. The process of performing and documenting an analysis of planned and existing facilities and missions involving ammunition and explosives, or occurring within the

hazard zones created by explosives. It may include evaluations of blast hazards; fragment hazards; protective construction; grounding, bonding, and lightning protection systems; electrical installations; natural or man-made terrain features; or other mission or local requirements. Effective site planning relies heavily on explosives safety standards, but it also incorporates survivability and operational considerations, and economic, security, environmental, and legal criteria to meet the goals and needs of the DOE community.

SLAPPER DETONATOR. An EED initiated by a rapid discharge of a high current through a metal foil. The expansion of the metal vapor causes a plastic or metal covering to be propelled across an air gap and detonate a high-density explosive pellet.

SMALL ARMS AMMUNITION. (1) Ammunition designed to be fired from a pistol, revolver, rifle, or shotgun held by the hand or to the shoulder; (2) Ammunition of caliber less than 20 mm with incendiary, solid, inert, or empty projectiles (with or without tracers) designed to be fired from machine guns or cannons; (3) Blank cartridges.

SOP. See STANDARD (STANDING) OPERATING PROCEDURE.

SPECIAL OPERATING PROCEDURE. A procedure prepared for performance of a specific task on a one-time basis, or for situations not encountered in normal operation.

STANDARD (STANDING) OPERATING PROCEDURE (SOP). A procedure prepared for operation of a facility or performance of a task on a routine basis.

STORAGE MAGAZINE. A structure designed or specifically designated for the long-term storage of explosives or ammunition.

STRIKE TERMINATION DEVICE. (1) A component or feature of an LPS that is intended to accept the direct attachment of a lightning flash or strike. Strike termination devices include overhead wires or grids, air terminals, or a building's (grounded) steel structural elements. (2) A component of an LPS that intercepts lightning flashes and connects them to a path to ground. Strike termination devices include air terminals, metal masts, permanent metal parts of structures, and overhead ground wires installed in catenary LPSs.

STROKE. The high electric current phase of a lightning strike. The term is better defined as the return stroke.

SUBSTANTIAL DIVIDING WALL. An interior wall designed to prevent the propagation of an accidental detonation on one side of a wall to explosives on the other side.

SURGE SUPPRESSION DEVICE. Also called a surge protector. (1) A device used on power and communication lines to attenuate, suppress or divert lightning induced electrical energy to ground. (2) A protective device used to limiting surge voltages by discharging or bypassing surge current. It can also prevent continued flow of follow current while remaining capable of discharging or bypassing surge current.

SYNTHESIS. The chemical operation or operations required to produce a desired chemical compound.

TARGET. The area, structure, or material into which a projectile is fired.

TNT EQUIVALENT. A measure of the blast effects from explosion of a given quantity of material expressed in terms of the weight of TNT that would produce the same blast effects when detonated.

TRANSFER IMPEDANCE. (1) A transmittance expressed as the ratio of the voltage at a pair of terminals divided by the driving current, with all other terminals terminated in a specified way. (2) A transmittance expressed as the ratio of the electric field on the interior of a shielded enclosure divided by the current density on the exterior of the shield.

TRANSIENT. Any person within inhabited building distance but not inside an explosives bay or other occupied areas (offices, break areas, shops, etc.). A transient's presence within IBD of an explosives operation is transitory in nature, or to complete a relatively short-term, nonexplosives related work assignment in an area in which personnel are not permanently assigned, such as a building corridor, access ramp, or roadway. Transients are not accounted for in established personnel limits for any explosives operating area and are afforded a level of protection only from Class I explosion hazard activities.

UFER GROUND. An LPS ground produced by electrodes encased in concrete. This can be a coil of cable encased in concrete or even the reinforcing steel in the footers or floor of buildings. (See EARTH ELECTRODE SYSTEM).

UNEXPLODED ORDNANCE (UXO). Explosive ordnance which has been primed, fuzed, armed, or otherwise prepared for action, and which has been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material and remains unexploded either by malfunction, design, or for any other cause.

UNITED NATIONS (UN) CLASS 1 EXPLOSIVES. (1) Explosive substances (a substance that is not itself an explosive but that can form an explosive atmosphere of gas, vapor, or dust is not included in Class 1), except those that are too dangerous to transport or those where the predominant hazard is appropriate to another class; (2) Explosive articles, except devices containing explosive substances in such quantity or of such a character that their inadvertent or accidental ignition or initiation during transport shall not cause any effect external to the device either by projection, fire, smoke, heat, or loud noise; and (3) Substances and articles not mentioned under (1) and (2) that are manufactured with a view of producing a practical, explosive or pyrotechnic effect.

ZONE OF PROTECTION. (1) The area considered statistically safe from the direct attachment of a lightning strike as defined by the rolling sphere zone of protection model. (2) The space adjacent to an LPS that is substantially immune to direct lightning flashes.

CHAPTER II—OPERATIONAL SAFETY

1.0 GENERAL OPERATIONS SAFETY GUIDELINES

1.1 Protection of Explosives

a. Explosives are energetic materials that can react violently and should be protected from abnormal stimuli or environments, including:

(1) Friction forces.

(2) Excessive pressures and temperatures.

(3) Impact, shock, and pinching.

(4) Deformation.

(5) Electrical sparks, abrasive or welding sparks, and open flame.

(6) Contamination.

(7) Contact with incompatible materials.

1.2 Equipment Checks

a. Before being used in the explosives process, and at established intervals, processing and test equipment shall be checked for

(1) Proper design.

(2) Proper function.

(3) Specified clearances between parts in relative motion.

(4) Abnormal metal-to-metal rubbing of moving parts potentially contacting explosive materials.

(5) Cracks, voids, or screw threads where explosives may accumulate.

(6) Contamination that is incompatible with the materials to be introduced.

b. This checkout may require the use of mock explosives in process or test conditions.

c. Explosive materials must not be pinched or confined between equipment lids or covers and their mating surfaces. These surfaces shall be cleaned before cover placement. This includes pressing operations.

1.3 Inspection Frequency

a. When this Manual calls for an inspection, but the inspection interval is not specified, local facility management shall establish the inspection interval. Inspection intervals shall be modified when experience dictates a need.

1.4 Laboratory Operations

a. The special safety guidelines applicable to general laboratory operations involving explosive materials are contained in section 21.0 of this chapter.

1.5 Toxicity Hazards

a. Explosives materials, explosives components (additives or adhesives), and materials such as organic solvents used in explosives processing can be toxic when inhaled, ingested or absorbed through the skin. The most frequently reported effect from working with explosives is a skin rash resulting from skin contact with explosives materials, or with solvents and adhesives used with explosives operations. This is the most frequently reported effect from working with these materials. The following general precautions should be used to prevent overexposure to these materials during explosives processing and handling:

(1) Know the health hazard and controls before beginning operations.

(2) Evaluate the operation during startup to assure that occupational exposure limits are not exceeded; routine operations should be monitored periodically.

(3) Handle materials in a well ventilated area; local exhaust ventilation is preferred.

(4) Avoid skin contact; use appropriate protective clothing.

(5) Practice good personal cleanliness; wash before eating, smoking, or using toilet facilities; end-of-shift showers may be required for some operators.

1.6 Hazard Identification and Communication

a. Before beginning explosives operations, managers shall ensure the following:

(1) Identify and maintain a current list of explosives and other hazardous materials used in conjunction with their operations.

(2) Determine the hazardous properties and toxicity of these materials through the use of the manufacturer's Material Safety Data Sheets (MSDS) or other information sources and through consultation with the facility Industrial Hygiene staff. For explosives without published toxicological data, guidance can be obtained through the DOE Toxic Materials

Advisory Committee (TMAC). Health hazard information must be available and communicated to employees who work with or generate hazardous materials.

(3) Educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation. This training should be a part of the employee training and qualification program specified in Chapter V.

1.7 Process Hazard Analysis

a. Before beginning any explosives synthesis, formulation, manufacturing, testing, or disposal operation, a process hazard analysis shall be performed. A single process hazard analysis may be performed for similar processes performed in a single facility, provided that the "worst-case" process is the basis for the hazard analysis. If required, a shield or other protective measure shall be employed. Selection criteria for the worst-case process are:

(1) Sensitivity of materials.

(2) Quantity of materials.

(3) Number of personnel potentially affected.

(4) Impact on other operations/activities.

b. The process hazard analysis shall be performed as a team effort. The team shall consist of a minimum of three personnel, and preferably no more than seven personnel. The team shall include at least one engineer and one operator, and should have the following makeup:

(1) Team Leader, who is familiar with the analysis methodology used.

(2) Technical Member(s), who is familiar with the process being analyzed.

(3) Scribe, who writes notes of meetings and interviews and drafts reports.

c. The facility manager or team leader may select the analysis methodology used, which should be one of the following:

(1) Preliminary Hazard Analysis.

(2) Checklist (usually for similar batch operations).

(3) What-if Analysis.

(4) Hazard and Operability Study (HAZOP).

(5) Failure Modes, Effects, and Criticality Analysis (FMECA).

(6) Fault Tree Analysis.

(7) Event Tree Analysis.

d. The process hazard analysis shall be formally documented.

e. Employees and employee representatives shall be consulted on the process hazard analysis. The result of the process hazard analysis shall be provided to employees involved in or affected by the operation.

f. The process hazard analysis shall be updated and revalidated at least every five years by a team meeting the criteria in section 1.7b.

g. The facility manager shall be responsible for establishing a system to address the team's findings and recommendations promptly. Corrective actions, schedules for corrective actions, and completion of corrective actions shall be formally documented. Such documentation shall be filed with the process hazard analysis.

h. Files containing process hazard analyses, updates, and corrective actions status shall be maintained for the life of the process.

2.0 WORK ENVIRONMENT

2.1 General Requirements

a. Workspace shall be adequate to perform operations safely and efficiently.

b. Work shall be organized to eliminate clutter in the area while operations are being performed.

c. Walkways should be kept clear.

d. In work environments where solid, bare explosive pieces are handled, the floor should be cushioned, and all hard objects that explosives could strike in a handling incident should be cushioned where practical. Physical safety systems demonstrated to preclude the explosives from being dropped or struck could meet these requirements.

e. A procedure should be established to account for hand tools that may be inadvertently dropped into an explosives processing operation, thus creating a hazard.

f. Personnel shall be assigned in such a manner that each worker's presence is monitored frequently and assistance can be provided or aid summoned in the event of an emergency.

g. Safety analyses of explosives facilities and operations shall be performed. The safety analysis shall be performed during the design of new explosives facilities or the redesign of existing facilities. Facility management shall prepare and obtain DOE/NNSA approval of the Site Plan. The Site Plan shall include the result of this analysis.

h. Noisy environments caused by explosives testing operations or process and handling equipment shall be evaluated. Areas with noise above the allowable occupational exposure limits must be posted and appropriate control measures instituted (e.g., engineering controls, protective equipment, and a hearing conservation program).

2.2 Emergency Exit Requirements for Explosives Operations

a. Exit requirements for any building or structure containing explosives shall comply with the intent of the Life Safety Code, NFPA 101, except as otherwise permitted in this section.

2.2.1 *Building or Structure Occupancy*

a. In determining occupancies:

(1) Explosives operating buildings shall be classified as industrial occupancies (NFPA 101, Chapter 40).

(2) Explosives storage or staging buildings or structures shall be classified as storage occupancies (NFPA 101, Chapter 42).

2.2.2 ***Hazard of Contents Classification***

a. The hazard of contents classification of any explosives occupancy shall be determined using the guidelines given in NFPA 101 and the following requirements:

(1) High-hazard explosives contents are those which, because of form, character, or volume, are likely to burn with extreme rapidity can release poisonous fumes or explosions in a fire. The expectation of poisonous fumes or explosions is to be determined on a case-by-case basis. Operating buildings containing propellant, pyrotechnic, or explosive powders shall be classified as high-hazard occupancies unless a reduced hazard classification can be justified.

(2) Reduced-hazard explosives contents are those that burn with rapidity that is moderate or less and will not produce poisonous vapors. This criterion shall be documented by a hazard analysis.

2.2.3 ***Personnel Protective Restrictions and Requirements***

a. DOE occupancies containing high explosives dictate that personnel be protected from blast overpressures and fragments (and spread of plutonium in some occupancies) from an accidental detonation. Accidental detonation of explosives is usually the result of stimuli other than a fire.

b. Non-compliance with some NFPA 101 provisions (such as those covering exit doors, exit travel distance, number and location of exits, and common path of travel to exits), is authorized where required to provide protection from blast overpressure and fragments. When NFPA 101 requirements are not met the following additional personnel-protective restrictions or requirements should be imposed:

(1) The building and means of egress should be protected by supervised automatic sprinkler systems connected to sound evacuation alarms. This requirement is not applicable to explosives storage magazines, firing chambers, or rooms used as firing chambers, within explosives operating buildings.

(2) Explosives operating buildings and their means of egress should have automatic, early warning fire detection systems connected to sound evacuation alarms where such early warning might reasonably aid in prevention or mitigation of personnel injury. This requirement is not applicable to explosives storage magazines, firing chambers, or rooms used as firing chambers within explosives operating buildings.

(3) Personnel limits within the explosives work area (bay, cell, etc.) shall be established and controlled. These should not exceed 20 for reduced-hazard occupancies or 6 for high-hazard occupancies. The need for personnel in numbers greater than these limits shall be documented in a hazards analysis based on the criteria of section 2.2.5 of this chapter.

2.2.4 ***Requirements for Existing Facilities***

a. Existing facilities may deviate from current NFPA 101 requirements in the following situations:

(1) Current code requirements were not in effect when the building was constructed. The building, however, is still required to meet the code of record.

(2) Deviations were made to meet the level-of-protection and design criteria in Chapter VI, section 6, of this Manual.

(3) Building construction predates both current and level-of-protection criteria, but a hazards analysis has shown the risk of operations to be at an acceptable risk.

(4) The risk from deviation has been analyzed and accepted by current hazards analysis.

NOTE: Those facilities requiring hazards analysis to determine whether a deviation from the Life Safety Code is acceptable shall follow the considerations and criteria described in section 2.2.5 of this chapter.

2.2.5 ***Requirements for New Facilities***

a. New facilities shall comply with the requirements of NFPA 101, except when deviation is necessary to provide personnel protection from blast overpressure and fragments per Chapter VI of this Manual.

2.2.5.1 If deviations from NFPA 101 requirements are made, the Fire Hazards Analysis required by Chapter VI of this Manual shall document the following aspects related to each explosives operation, bay, and/or workroom where a deviation exists.

a. Clear pathways to exit in explosives bay or workroom.

b. Potential for sustained fire from the presence of combustible and flammable materials and the presence of ignition sources in work environments.

c. Total time required to exit the bay or workroom.

2.2.5.2 The criteria considered acceptable for the components of the analysis in section 2.2.5.1 of this chapter are, respectively:

a. No obstruction shall limit the width of the pathway to less than 36 in.

b. Combustible and flammable material quantities shall be minimized, justified, documented, and reviewed by site fire protection personnel and approved by line management. Ignition sources shall be identified and eliminated where possible.

c. The total time for six people to exit the workroom or bay, including the opening of doors where necessary, is 30 seconds or less. The total time for twenty people to exit the workroom or bay is 90 seconds or less. Noncompliance with this criterion shall be evaluated and justified during the conceptual design review.

2.2.6 ***Single Exits***

a. Where NFPA 101 requires at least two exits, but provisions for personnel protection from a blast will not permit at least two exits from a room or structure, a single exit is acceptable, provided the requirements of sections 2.2.3 and 2.2.4 of this chapter and the following are met:

(1) The path of exit travel shall be arranged so it is not through or toward a hazardous operation.

(2) A room containing a high-hazard explosive occupancy shall not exceed 500 ft^2, and the occupant load of the room shall be restricted to two operators and two transients.

(3) A room containing a reduced-hazard explosive occupancy shall not exceed 1,000 ft^2.

b. Explosives storage magazines may have only single exits for the purpose of maintaining integrity of design. The conditions of this section do not apply to these magazines.

2.2.7 ***Blast-Resistant Doors***

a. Blast-resistant doors required to protect personnel from the effects of an accidental detonation may be located in the means of egress, provided the requirements of sections 2.2.3 through 2.2.5 of this chapter and the following are met:

(1) Where power-operated doors are required to accomplish unlatching and opening, they shall have redundant features or be capable of being opened manually (to permit exit travel) or closed where necessary to safeguard exits.

(2) The time required to fully open or close a door shall be as short as reasonably possible.

(3) A revolving door is acceptable if a secondary means of escape (with swinging doors) is provided at the same location. The revolving door must also be prevented from rotating at too rapid a rate to permit orderly exit of personnel.

(4) The following exceptions to NFPA 101 may be allowed when justified and documented.

(a) Swinging doors may exceed 48 in. wide.

(b) The NFPA-required swinging doors adjacent to a revolving blast door can be omitted.

(c) Revolving blast doors need to be designed to collapse into book-fold position.

(d) Where fire-rated doors are required, blast doors are considered to have the required fire rating.

(e) An airlock with two or more doors that is intended during routine operations to prevent continuous and unobstructed passage by allowing the release of only one door at a time shall be permitted in a means of egress. In such cases, there shall be provisions to allow for continuous and unobstructed travel during an emergency egress condition.

(f) Panic hardware is not required on blast doors.

2.2.8 ***Slide Escapes***

a. Slide escapes should be provided for elevated explosives operating locations from which rapid exit may be vital and cannot be obtained by

other means. Slide escapes should be located on opposite sides of the explosives operation to reduce the likelihood of personnel being trapped by fire between them and a single slide.

b. Exits to slide escapes must open onto platforms that are not less than 3 ft^2, and the platforms must be equipped with guardrails. The slides shall begin at the outside edge of the platform, not at the edge of the buildings. Slide escape landings shall be located at selected places leading directly to escape routes that are free from tripping hazards, low guy lines, drains, ditches, or other obstructions. Manually or automatically controlled devices (trips) that sound an alarm in the operating building shall be installed at or near the entrances to slide escapes. These devices may also actuate deluge valves and water curtains in the building or room affected. Recommended slide escape specifications:

(1) Angle, 40 to 50 degrees horizontal.

(2) Slide depth, 24 in.

(3) Radius at bottom of slide, 12 in.

(4) Height at lower end of slide, not over 24 in. above the landing.

c. If necessary, the end of the slide shall have a horizontal run sufficient to prevent employee injury from exit speed without the use of landing cushions, which are unsatisfactory in cold weather. One foot of horizontal run is required for a 15-ft-long slide. One additional foot of horizontal run will be provided for each additional 5 ft of slide length. The juncture of the two sections must be well rounded. Metal sheets constructing the slide must overlap in the direction of travel.

3.0 BUILDING AND EQUIPMENT MAINTENANCE

3.1 Cleaning

a. Structures containing explosives shall be kept clean and orderly.

b. Explosives and explosives dust shall not be allowed to accumulate on structural members, radiators, heating coils, utility lines, equipment, or electrical fixtures.

c. To maintain safe conditions, there shall be a regular cleaning program for building interiors to prevent the accumulation of explosives dust and waste. This program should not be conducted in any bay where a hazardous operation is being conducted.

d. In buildings containing explosives, floors should be cleaned with hot water or a water-steam mix wherever practical. Non-abrasive sweeping compounds that are compatible with the explosives involved may be used when a water-steam mix or hot water is not practical. Such sweeping compounds may be combustible but must not be volatile (closed-cup flash point must not be lower than 110°C). Sweeping compounds containing wax shall not be used on conductive flooring. Where nitrated organic explosives (which may form sensitive explosive compounds with some alkalis) are involved, the use of cleaning agents containing those alkalis is prohibited.

e. Before beginning explosives decontamination activities involving large amounts of organic solvents (generally over 1L), provisions must be made for adequate ventilation or respiratory protection, fire protection, and adequate protective clothing.

3.2 Maintenance and Repair

a. Records shall be maintained for inspection, repair, and servicing of process and handling equipment and fire protection systems.

b. Maintenance operations involving major repairs, changes, or the use of hazardous equipment should not be performed within bays (rooms) while explosives are present. Before beginning such maintenance, explosives should be removed and the area prepared. An approval procedure shall be established to ensure that the area has been inspected and is safe for these operations.

c. Non-facility personnel performing maintenance or construction operations shall be at least intraline distance from any explosives operation and should be at least intraline distance from any building containing explosives. This requirement does not apply to personnel making job site inspections or equipment repairs requiring less than eight hours (e.g., technical

representatives, architect-engineering surveyors, etc.). Providing equivalent protection may satisfy the intraline distance separation requirement. Transportation of explosives is permitted on roadways at less than intraline distance.

d. Facility management shall determine the minimum practical distance by which non-facility personnel (e.g., technical representatives, service representatives, architect-engineering surveyors, etc.) shall be separated from explosives operations while making job site inspections or equipment repairs requiring less than eight hours. Facility management shall control explosives operations so that the chance of an explosion shall be kept to a minimum. The rationale for establishing the minimum practicable distance and additional control measures taken shall be documented and maintained until operations have been completed and personnel have permanently vacated the work site. All such personnel shall be informed of the risk of working at less than intraline distance and shall agree to accept such risk.

e. New equipment or equipment subjected to major repair or modification shall be test-operated, and handling equipment shall be tested before being returned to operations. *The DOE Hoisting and Rigging Standard* (DOE-STD-1090-current version) may be used as a guide.

f. Only authorized personnel shall perform maintenance work.

g. Before resuming operations following maintenance, the area shall be cleaned and approved by the operations supervisor.

3.3 Hot Work Permits

a. Where explosives are involved, a written permit shall be required for the temporary use of portable, heat-producing equipment that generates temperatures higher than 228°F (109°C). Explosives decontamination of the immediately affected work areas and explosives removal shall be required before beginning hot work operations. The permit should state the location, time, duration, purpose of use, details of safety, and fire-fighting equipment required. The permit shall be available at the named location for checkout by supervisory personnel.

(1) Permits shall be authorized by signature of personnel designated by local facility management. Designated personnel should be qualified by experience in explosives work, fire prevention, and general safety precautions, in particular, the purging of equipment, presence of flammable mixtures, and the avoidance of electrical and mechanical hazards that could be incident to repair work.

(2) Personnel designated to sign the hot work permit should represent supervision of the work location, supervision of personnel performing

the hot work, and a third group independent of the first two (usually the safety and fire protection group).

(3) An individual should remain at the site of a cutting or welding job for approximately 30 minutes after the job has been completed to extinguish or report any fires that develop. Designated supervision should inspect the job site before, during, and after completion of the job.

4.0 REMOTE OPERATIONS

4.1 Personnel Protection

a. Explosives operations judged to present a significant level of risk to be performed remotely shall be conducted in facilities where the construction of the operating bay or the control room affords sufficient protection to personnel to prevent serious injuries. Chapter VI, section 4.2.1d specifies criteria for the prevention of serious injuries.

b. Prevention of serious injury from a remote operation applies to both transient personnel and personnel involved in the operations.

4.2 Access and Equipment Controls

a. Procedures and equipment shall be used to prevent entry into a hazardous bay or area in which a remote operation is occurring or to prevent the operation from proceeding when personnel enter, as follows:

(1) Roads shall be blocked at a minimum of the public traffic route distance from buildings where hazardous (remote) operations are being performed. Public traffic route separation may be satisfied by providing equivalent protection.

(2) Corridors leading to bays in which hazardous (remote) operations are being performed shall be marked to warn of the danger. Barriers shall also be set up.

(3) Visual methods such as closed circuit television should be used to monitor remote operations and to enable viewing of the operating area conditions before entering. Remote audio monitoring and video recording should also be considered.

(4) Interlocking of remote operating equipment to access doors should be required for each remote operation.

(5) Lights or similar warning devices shall conspicuously identify buildings or bays in which remote operations are performed to indicate when remote operations are under way.

5.0 GENERAL EXPLOSIVES AREA CONTROLS

5.1 Smoking, Matches, Lighters, Metal Articles

a. There shall be no smoking in explosives storage, processing, or test areas, except in designated locations.

b. No matches, lighters, or other fire-, flame-, or spark-producing devices shall be taken into an explosives control area except with written authorization. If authorized to be carried, matches shall be contained in a metal carrying device too large to fit into pockets. Kitchen "strike anywhere" matches shall not be used.

c. Operating personnel should not carry metal articles (e.g., keys, jewelry, knives, coins, etc.) in explosives processing areas where such items could constitute a hazard if dropped into the process operation.

5.2 Cooking and Eating

a. Food or beverages shall not be consumed in explosives buildings, except in designated areas.

b. There shall be no personal dishes or utensils in an explosives building, except in designated eating areas.

c. Coffee pots, hot plates, ovens (including microwaves), and portable electric heaters shall not be permitted in rooms where:

(1) Explosives may be present.

(2) Combustible vapors or dust may be present.

(3) Smoking or drinking is prohibited because toxic materials are present.

(4) Electrical classification of appliances is not compatible with the area.

5.3 Access to Explosives Areas

a. Access control procedures shall be established for entry to all explosives areas.

6.0 PROTECTION OF ELECTROEXPLOSIVE DEVICES (EED) FROM ELECTROMAGNETIC RADIATION

a. EEDs are vulnerable to initiation from a variety of sources. One potential hazard associated with EEDs is the accidental initiation by stray electromagnetic energy. This hazard exists when an electromagnetic field of sufficient intensity is generated to induce or otherwise couple currents and/or voltages of magnitudes large enough to initiate electroexplosive devices or other sensitive explosive components of weapon systems, or other explosive devices. This unintended actuation could have safety (premature firing) or reliability (duding) consequences.

b. A large number of these devices are initiated by low levels of electrical energy and are susceptible to unintentional initiation by many forms of direct or induced stray electrical energy, such as from lightning discharges, static electricity, or tribo-electric (friction generated) effects, and radio frequency (RF) energy. Hazards from lightning discharges are covered in Chapter X. Lightning protection systems and requirements normally preclude the inadvertent initiation of EEDs by direct lightning strikes. Precautions for static electricity discharges are addressed in section 7 of this chapter. Stray energy, such as transients and other forms of induced energy, can be imposed on circuits affecting EEDs from other subsystems by various methods. Examples are inductive or capacitive coupling; sneak ground circuits; defective components or wiring; errors in design, modification, or maintenance.

c. The degree to which EEDs are susceptible to unintentional initiation by exposure to the radiated fields of RF emitters depends on many variables. These variables include the ability of the leads, circuit, or installation to capture RF energy; the type and characteristics of RF energy; and methods of coupling which can introduce this energy into the EED.

d. Emitter operating frequencies, power levels, modulation, and illumination angles are some of the factors that affect the vulnerability of EEDs to RF energy.

e. As a precautionary measure, EEDs should normally be left inside their containers until ready for use. Shorting clips or other safety devices should not be removed until the EED is actually ready for use.

f. For precautionary separation distances, see Chapter II, section 13, Tables II-1, II-2, and II-3.

7.0 STATIC ELECTRICITY

7.1 General

a. Positive steps must be taken to control or eliminate static electricity in areas where materials that are ignitable by static spark discharge are processed or handled. This includes spark-sensitive explosives, propellants, and pyrotechnics as well as solvent vapors, and flammable gases.

7.2 Bonding and Grounding of Equipment

a. Bonding straps can be used to bridge locations where electrical continuity may be broken by the presence of oil on bearings, paint, or rust at any contact point. Pressure contact alone is not adequate grounding for permanent equipment in contact with conductive floors or tabletops. Static grounds shall not be made to gas, steam, or air lines; dry pipe sprinkler systems; or air terminals of lightning protection systems. Static grounds can be made to water pipes, ground cones, buried copper plates, or driven ground rods of lightning protection systems. If a structure is equipped with a lightning protection system, all grounds shall be interconnected. Wires used as static ground conductors should be at least No. 10 AWG or equivalent.

7.3 Testing Bonded Equipment Grounds

a. Grounding systems shall be tested for electrical resistance and continuity after installation has been completed and, in the case of active equipment, at intervals to be locally determined. If the equipment has been inactive for more than one month, the ground system shall be visually inspected for continuity before reactivation of the system. All exposed explosives or hazardous materials shall be removed before testing. When testing for resistance-to-ground, equipment should be considered as a unit except in the case of an electrically isolated device or a belt-driven machine. In measuring the total resistance-to-ground for belt-driven machinery (to assure compliance with the section below), resistance of the belting is to be excluded. The maximum resistance-to-ground permitted for different types of equipment is as follows in section 7.3b.

b. Hazardous locations (operations where a static spark discharge may be dangerous). All conductive parts of equipment shall be bonded; in the case of grounded equipment, bonding shall be such that resistance to ground does not exceed 25 ohms, unless resistance is not to exceed 10 ohms because of a lightning protection installation. For existing equipment, the rate of static generation should be considered before making changes in grounding systems. The resistance of conductive rubber hose should not exceed 250,000 ohms.

7.4 Conductive Floors, Shoes, Mats and Wristbands

a. Conductive floors and shoes should be used for grounding personnel in operations involving explosives (propellants, pyrotechnics, lead azide, lead styphnate, mercury fulminate, CP, etc.) that are sensitive to initiation by the electrostatic spark discharge from a person. Static discharge from a person may ignite many flammable liquids and air mixtures. In areas where personnel come into the proximity of (i.e., possible contact with) static-sensitive explosives or vapors, conductive floors shall be installed except where adequate housekeeping, dust collection, ventilation, or solvent recovery methods eliminate the hazards of dust-air or flammable vapor-air mixtures. Conductive floors may also be required in areas where operations involve EEDs that contain a static-sensitive explosive.

b. Conductive floors are not required throughout an entire building or room if the hazard is localized. In such cases, conductive mats or runners may be used where required. These mats or runners shall meet all specifications and test requirements that apply to conductive floors. Conductive wristbands may be substituted for conductive mats and footwear at fixed, grounded or bonded workstations or outdoor locations.

7.5 Conductive Floor, Work Surface, and Wristband Specifications

a. Conductive floors must be made of non-sparking material such as conductive rubber or conductive flooring composition and shall meet the following requirements:

(1) The flooring and its grounding system must provide for electrical resistance not to exceed 1,000,000 ohms (measured as specified in section 7.6 of this chapter).

(2) The surface of the installed floor must be free from cracks and reasonably smooth. The material must not slough off, wrinkle, or buckle under operating conditions. Conductive tiles are not recommended for use in areas where explosives dust can cause contamination. The large number of joints and the tendency of tiles to loosen provide areas in which explosive dust can become lodged, making normal cleanup procedures difficult.

(3) Where conductive floors and shoes are required, resistance between the ground and the wearer shall not exceed 1,000,000 ohms, (i.e., total resistance of conductive shoes on a person, plus the resistance of floor to ground). (See Figure II-1 for testing method.) Where conductive floors and shoes are required, tabletops on which exposed explosives or dusts are encountered should be covered with a properly grounded or bonded conductive material that meets the same requirements as those for flooring.

(4) Conductive floors must be compatible with the explosive materials to be processed.

(5) Conductive wristbands shall not exceed a resistance between the wearer and ground or bonding point of 1,200,000 ohms. This resistance shall be measured with a suitably calibrated ohmmeter. Wristbands shall be of a design that maintains electrical contact with the wearer when used.

(6) Table-top work surface mats that are not part of a total conductive system (section 7.5a(3) shall have a resistance not to exceed 1,200,000 ohms. This resistance shall be measured by a method similar to that outlined in section 7.6 and records shall be maintained.

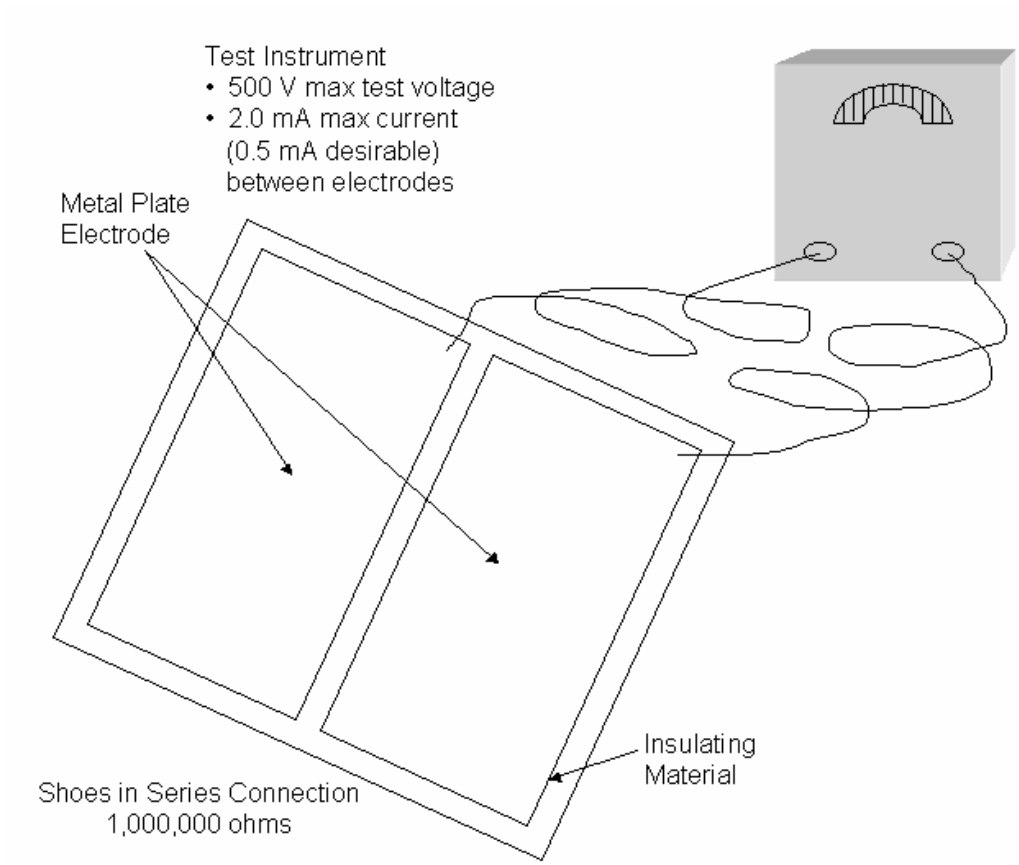


Figure II-1. Testing Shoes on Wearer

7.6 Conductive Floor Tests

a. Initial tests shall be made of all conductive floors, and subsequent tests shall be made at least semi-annually. Test results shall be permanently recorded and a copy filed in a central location. Instruments used in making tests shall be used only when the room is free from exposed explosives and flammable gas mixtures.

b. Maximum floor resistance shall be measured with a suitably calibrated ohmmeter that operates on a normal open circuit output voltage of 500 volts DC and a short circuit current of 2.5 milliamperes with an effective internal resistance of approximately 200,000 ohms. Minimum floor resistance will be measured with an ohmmeter suitably calibrated for the task.

c. Each electrode shall weigh 2.3 kg and shall have a dry, flat, circular contact area 6.5 cm in diameter, which shall comprise a surface of aluminum or tinfoil 1.3- to 2.5-mm thick, backed by a layer of rubber 0.6- to 0.65-cm thick and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240-68).

d. The floor shall be clean and dry. "Electrode jelly" such as brushless shaving soap or saline solution shall not be used.

e. The resistance of the floor shall be more than 5,000 ohms in areas with 110 volt service and 10,000 ohms in areas with 220 volt service, and less than 1,000,000 ohms in all areas, as measured between a permanent ground connection and an electrode placed at any point on the floor and also as measured between two electrodes placed 3 ft apart at any points on the floor. Measurements shall be made at five or more locations in each room. If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five seconds shall be considered as the measured value.

7.7 Humidification

a. Humidification to prevent static electricity accumulations and subsequent discharges is usually effective if the relative humidity is above 60 percent. However, due to the possibility of spontaneous ignition, certain materials such as metallic powders and some pyrotechnic mixtures cannot be exposed to air with 60 percent relative humidity. Where this technique is used to prevent static electricity accumulations, a daily preoperational check of the humidity levels will be accomplished before work starts.

7.8 Ground Fault Circuit Interrupter

a. Ground fault circuit interrupter protection shall be provided in static grounded areas where personnel may come in contact with AC-powered electrical equipment.

8.0 ELECTRICAL EQUIPMENT AND WIRING

8.1 Location/Operation Electrical Hazard Classification

a. The National Electrical Code (NEC) shall be followed in all situations where the code normally applies. Although the NEC does not specifically address explosives, Article 500, Hazardous (Classified) Locations, requirements for the design and installation of electrical equipment and wiring in "classified" locations shall be used as guidance for the installation of rated equipment and fixtures where required by this section. The use of rated wiring, fixtures, equipment, and instrumentation where the code normally does not apply, provides additional safety for work with explosives materials by (1) restricting electrical ignition sources, such as sparks, electrical faults (shorts, power surges, etc.), (2) controlling surface temperatures of electrical items, and (3) reducing the potential for electrically initiated fires. Rated wiring, fixtures, equipment, and instrumentation shall be used for the operations specified below unless demonstrated unnecessary through analysis for a specific operation and location. The analysis shall be performed and documented per sections 8.4 and 8.6 of this chapter.

b. Explosives do not normally fit the NEC definitions for groupings, classes, divisions, and area classifications. In order to apply Article 500 as a guide, vapors containing explosives shall be treated as Group D (unless NEC requires a higher classification because of other components of the vapor) and dusts of explosives or solid explosives shall be treated as Group G. Class, division, and area classification determinations shall be based on the explosives operation being performed, as specified below, and not on the location or surrounding atmosphere, nor its potential for producing an ignitable or explosive mixture. Maximum temperature limits shall be based on the thermal analysis of the explosives used in the operation. Division 1 items can be substituted for Division 2 items, but never Division 2 for Division 1 items. Where there is a conflict between the requirements of the code and requirements of this Manual, the more stringent of the two applies.

c. Rated wiring, equipment and instruments shall be approved for use by a nationally recognized testing laboratory. Rated items shall have labels and/or clearly identifiable markings to show Class, Division, Group, and Temperature Range for which they are approved. Equipment approved for one Hazard Class is not interchangeable with another Hazard Class.

d. The operations discussed below shall comply with the recommended class/division unless it is determined unnecessary through documented analysis for a specific operation and location.

(1) Class I, Division 1 wiring, fixtures, process equipment, and instrumentation are recommended for operations involving flammable

gases or chemicals/materials expected to produce flammable vapors with explosives present.

(2) Class I, Division 1 and Class II, Division 1 (dual rated) wiring, fixtures, process equipment, and instrumentation are recommended for synthesis, formulation, mixing, wet blending, and casting explosives, heating/drying of uncased explosives, plus any explosives processing that is expected to produce sublimation.

(3) Class II, Division 1 wiring, fixtures, process equipment, and instrumentation are recommended for screening, grinding, blending, pressing, dry machining explosives, and weighing of explosives powders, the use of explosive or ignitable dust mixtures with explosives present, plus any explosives process that is expected to produce dust from explosives that is suspended in the air.

(4) Class II, Division 2 wiring, fixtures, process equipment, and instrumentation are recommended for storage, inspection, assembly, and wet machining of explosives, heating of fully encased explosives, plus, any explosives operation capable of producing dust of explosives that can accumulate on electrical equipment or apparatus. Class II, Division 1 or dual-rated equipment and wiring can be substituted.

(5) General Purpose wiring, fixtures, process equipment, and instrumentation are allowed for shipping and receiving operations with fully encased explosives or explosives packaged in DOT/DoD approved shipping containers and areas in explosives facilities where no explosives are present. Examples are offices, control rooms, halls, rest rooms, and mechanical equipment rooms. General Purpose Areas may be established in explosives locations if facility management can determine, based on documented analysis of the processes involved and the separation between explosives operations requiring Class I or Class II rated electrical wiring, fixtures, process equipment, and instrumentation and the General Purpose Area is established and maintained such that:

(a) Migration of explosive or ignitable gases, vapors or dust mixtures into the General Purpose Area from the rated area (not to be confused with the NEC Classified locations) will not occur under normal operating conditions.

(b) Ignition energy that may be developed in the General Purpose Area will not be transferred to the rated area (not to be confused with the NEC Classified locations), even under electrical fault conditions.

(6) Due to the potential for unacceptable consequences concerning operations with nuclear explosives, subassemblies, or components, they shall be evaluated in accordance with section 8.0 of this chapter to determine the appropriate electrical hazard classification.

(7) Facility management shall evaluate, by using the principles given above, all explosives operations not specified elsewhere in this section to determine the appropriate electrical classification. The analysis shall be documented.

8.2 Electrical Supply System

a. Mutual hazards may exist where explosives facilities are located near electrical supply lines and stepping equipment. To protect against these hazards, the NEC (NFPA 70) and the following requirements apply to all new construction or major modifications, and should be considered for existing facilities. Quantity distance requirements are based on air blast overpressure only, and fragment distances are not considered. Electric supply lines that can be interrupted without loss of power, i.e., power is rerouted through existing lines and/or networks, can be separated from explosives sites in accordance with section 8.2a(1)(c) below.

(1) Electric transmission lines (those carrying 69 kV or more) and the tower or poles supporting them shall be located no closer to explosives facilities than:

(a) Inhabited-building distance if the line in question is part of a grid/system serving a large, offsite area.

(b) Public traffic route distance if loss of the line will not create serious social or economic hardships to offsite areas.

(c) Electric distribution lines (those carrying less than 69 kV) and the tower or poles supporting them shall be located no closer to explosives facilities than public traffic route distance.

(3) Aboveground, DOE-controlled electric service lines required to be in close proximity to a combustible constructed or uncovered explosives facility shall be no closer to that facility than the length of the lines between the poles or towers supporting the lines, unless an effective means is provided to ensure that broken, energized lines cannot come into contact with the facility or its appurtenances. Acceptable controls include, but are not limited to, geographic terrain features, instantaneous circuit interrupters, cable trays, and linking lines together. Equivalent underground service lines shall be located as specified in Chapter VI, section 3.2.4 and Table VI-2.

(4) Electric lines serving explosives facilities shall be installed underground from a point not less than 50 ft away from such facilities.

(5) Unmanned privately owned or contractor-owned electrical substations (not to include building transformers and associated switch gear) shall be no closer to explosives facilities than public traffic route distances.

(6) Certain types of auxiliary power facilities, transformer stations, etc., present fire hazards to explosives facilities. Transformers and associated electrical switching apparatus serving one explosives facility or complex that do not present a fire hazard to the facility (i.e., dry-type, "less flammable" oil-insulated, etc.) shall be located as specified by NFPA 70 and Factory Mutual Data Sheet 5-4/14-18. Normal oil-insulated transformers shall be located at least 50 ft from an explosives facility or as specified in DoD 6055.9-STD.

(7) Uninterrupted Power Supply (UPS) should be provided if electrical power is critical to an explosives operation during a power shut down or interruption.

8.3 Building Electrical Service Entrance

a. Each electrical service entrance for explosives facilities should be provided with the following protection.

(1) Arrestors

(a) Lightning arrestors shall be the appropriate size and class for the application and system voltages and shall be provided on the primary side of the transformer located in, on, or near the facility. See Chapter X for additional lightning protection guidance.

(b) Surge arrestors and surge capacitors shall be provided on the supply side of the main service disconnect.

(2) Grounding

b. The lightning arrestor, surge arrestor, surge capacitors, service entrance ground, and building ground shall be interconnected. This interconnection shall be made outside the building.

8.4 Permanent Wiring, Fixtures and Equipment

a. Permanent facility wiring includes installed electrical wiring, communications wiring, security systems wiring, and fire protection systems alarm and response wiring. Permanent equipment includes the installed electrical fixtures and equipment associated with permanent wiring. Permanent equipment also

includes equipment such as HVAC, hoods, vacuum pumps, hydraulic pumps, etc.

b. New Facilities and Renovations

(1) All permanent equipment and wiring of a room shall conform to section 8.1 of this chapter for the operations for which the room is designed.

(2) To maintain maximum, long-term flexibility of use of facilities, facility management is encouraged to consider installing dual-rated (i.e., Class I, Division 1 and Class II, Division 1) permanent wiring and equipment in explosives operating rooms. As a minimum, installation should allow for easy conversion to dual-rated wiring and equipment.

(3) Rated electrical fixtures shall not be painted.

(4) Where equipment cannot meet the above requirements, the equipment should be located outside the hazardous environment. Otherwise, the equipment shall be analyzed and controlled as specified for electrical equipment and instrumentation in section 8.6 of this chapter.

c. Existing Facilities

(1) Permanent wiring and equipment shall meet the requirements in effect at the time the facility was built. The wiring and equipment shall be brought into conformance with section 8.4b of this chapter If remodeling or renovation would affect the wiring or equipment.

(2) As a minimum, the permanent wiring and equipment shall meet the requirements of section 8.1 of this chapter for the explosives operations performed.

(3) Where equipment cannot meet the above requirements, the equipment should be located outside the hazardous environment. Otherwise, the equipment shall be analyzed and controlled as specified for electrical equipment and instrumentation in section 8.6 of this chapter.

8.5 Flexible Cords/Wiring

a. Wiring from the permanent premises wiring to process equipment or process instrumentation should be rated for actual explosives operation being performed, per section 8.1 of this chapter. As a minimum, flexible cords shall be hard usage service cord. Splices are not allowed. In addition, all flexible cords, receptacles, and attachment plugs must be equipped with three prongs so that the third prong (green wire) acts as ground. The cord shall be supported so that there is no tension on the terminal connections. Seals shall be provided where the cord enters explosion-proof enclosures. For Hazard Class I or Class II, Division I or

dual-rated operations, the cord shall also be equipped with explosion-proof attachment plugs. Flexible cords shall not be used where fixed installed electrical wiring is required by equipment design.

8.6 Electrical Equipment and Instrumentation

a. Non-permanent electrical equipment and instrumentation shall comply with the following:

(1) Process instrumentation and process equipment should be rated for the actual environment based on the explosives operation being performed as defined in section 8.1 of this chapter.

(2) If the thermal properties of an explosive are such that Group G or Group D equipment provides inadequate surface temperature limits, special protection shall be provided, or the equipment shall be excluded from the hazardous location. This equipment shall not have a surface temperature exceeding the lowest onset of the exotherm of the explosive, as determined by the differential thermal analysis (DTA) test or the differential scanning calorimetry (DSC) test in section 12.1.1c of this chapter and Chapter VIII, section 2.2d. Approved instrumentation and equipment shall be administratively controlled and marked accordingly.

(3) When Hazard Class I or II, as applicable, equipment or instrumentation is required but not available, the substitute equipment should be purged or pressurized in accordance with NFPA 496, or be determined intrinsically safe (without regard to voltage) in accordance with NEC Article 504/ANSI 913/NFPA 493 by facility management, or in Hazard Class II locations, sealed to prevent explosives contamination. When the equipment is purged or sealed, the surface temperature shall not exceed 120°C for normal operations, or 165°C for overload conditions.

(4) All electrical equipment or instrumentation in hazardous locations that do not meet the requirements of section 8.6a(3) above shall be evaluated and documented as to their suitability for use in the specific area and operation. The following are suggested areas for evaluation:

(a) Malfunction of electrical equipment or process instrumentation.

1 Consequences of electrical initiated fire.

2 Initiation of explosives by electrical current.

(b) Initiation of explosives by electrical fault.

(c) Breach of containment resulting in exposed explosives or spillage of explosives.

(d) Ignition sources arising from physical damage to the wiring method used (e.g., crushing by forklift or other material handling equipment, frayed cords, etc.).

(e) Exposed electrical conductors or connectors that could make contact with leg wires or cables of explosive devices during routine handling.

(f) Exposed electrical conductors or connectors on which explosives dust or vapors could collect.

(g) Collection of explosives dust on or in the equipment.

(h) Sensitivity to heat and spark, and thermal stability of explosives involved.

(5) If the equipment is purged, the airflow shall be monitored per NFPA 496 and interlocked to the equipment, or alarmed, if operator shutdown of the machine can be reliably performed immediately upon receipt of that alarm.

(6) A waiver is not required when the wiring, equipment or instrumentation meets the requirements of either section 8.6a(3) or 8.6a(4) of this chapter. If the wiring, equipment or instrumentation cannot meet these criteria or has not been evaluated by facility management, it shall meet the appropriate electrical hazard class requirements.

b. Watertight equipment (that would pass a NEMA 4 hose test) should be provided in those locations where water-explosives mixtures may come in contact with the electrical equipment and wiring.

8.7 Electrical Requirements for Outdoor Test Areas

a. Requirements for outdoor test areas shall be contained in the specific test procedures.

8.8 Hand-held, Battery-Powered Lights and Instruments

a. Flashlights and hand lanterns, powered by low-voltage dry cell batteries and "miners cap lamps" approved as "permissible" by the U.S. Bureau of Mines and by UL for NEC Class I hazardous locations, are authorized for use in both Class I and Class II locations. Devices that provide "cold light" through chemical action are acceptable for use in any location.

b. Hand-held instruments, watches, calculators, hearing aids, cameras, self-contained flashes, and communication devices powered by low-voltage dry cell batteries are authorized for use in the vicinity of Hazard Class II,

Division 2 rated hazardous operations and during setup of Hazard Class I or Class II, Division 1 hazardous operations. They shall be evaluated as to their intrinsic safety and approved by facility management prior to use during Hazard Class I or Class II, Division 1 hazardous operations.

c. Hand-held, battery-operated equipment shall not come in direct or indirect contact with bare explosives. Batteries shall not be removed or replaced in hazard rated areas (section 8.1 of this chapter).

8.9 Non-Rated Extension Lighting

a. When it is necessary to use extension lights within 10 ft of exposed explosives, where no airborne dust exists, the following requirements shall apply:

(1) Lights shall be mounted on heavy tripod stands.

(2) The lights shall be fitted with exterior globes to prevent the falling of hot sparks or particles that might ignite the explosives.

(3) The lights shall be fitted with adequate guards to protect the globes from physical damage.

(4) The wire providing power to the lights shall be positioned so as to prevent vehicles and personnel damaging the cord.

(5) The flexible cord shall comply with section 8.5 of this chapter.

(6) The light stand shall be secured to prevent tipping.

(7) Neither the light nor the power cord shall be allowed to come in direct or indirect contact with the explosives.

(8) Lights shall be positioned outside the fall-down distance to the explosives.

8.10 Laboratories

a. Permanent wiring and equipment for existing laboratory areas are not required to meet the requirements of section 8.4 of this chapter, except as noted in section 8.4c(1).

b. Process equipment used for synthesis, heating, drying, mechanical mixing, and blending shall be dual-rated. Weighing equipment shall be Class II, Division 1 or mechanical. These operations shall be isolated from non-rated

wiring, electrical equipment, and instrumentation in a manner that prevents dust or vapors reaching an ignition source.

c. When laboratory equipment cannot meet the requirements of section 8.10b of this chapter, apply section 8.6a(3) or 8.6a(4) of this chapter.

8.11 Modifications

a. Operating buildings and magazines are constructed to perform a specific function that dictates the requirements for electrical installation. Procedures shall be established by each DOE facility to control the use and modification of electrical equipment in explosives areas and ensure that uniform standards are adhered to throughout the facility.

9.0 VACUUM EQUIPMENT

9.1 General

a. Precautions shall be taken to prevent explosives from entering any vacuum system not specifically designed to collect explosives.

9.2 Labeling

a. All vacuum lines used for explosives operations should be labeled to warn maintenance personnel that explosive residue may be present in these lines. One suggested label is:

DANGER, MAY CONTAIN EXPLOSIVES

9.3 Disassembly

a. All vacuum lines that are potentially contaminated with explosives shall be disassembled according to approved operating procedures. Disassembly should be accomplished at flanged connections or elastomeric tubing whenever practical. No attempt should be made to disassemble a vacuum line at a threaded connection. The design or installation of any new vacuum lines shall not employ demountable, internal screwed, or threaded fittings or connections unless welded or fixed permanently in place.

9.4 Traps or Filters

a. Vacuum pumps used to evacuate processes for explosives operations shall be equipped with primary and secondary intake line traps or filters to prevent explosives from contaminating the pump.

10.0 EXPLOSIVES DUST EXHAUST VENTILATION AND COLLECTION SYSTEMS

10.1 General

a. Exhaust ventilation should be used to control explosives dust (or other hazardous materials used in or resulting from explosives operations) that could be hazardous to operating personnel or contaminate the operating area. Exhaust ventilation used to remove explosives dust requires an approved dust collection system to prevent the release of the dust outside the building.

10.2 Exhaust Ventilation

a. Exhaust ventilation and collection systems that control explosives dust and materials associated with explosives production shall be designed to meet minimum requirements established in the ACGIH Ventilation Manual (most current edition) and this Manual. The exhaust ventilation system should have sufficient capture and adequate makeup air to reduce exposure to explosives dusts, or materials used in conjunction with explosives, to as low as reasonably achievable. This is particularly important when toxicity information and occupational exposure limits are not available for the explosives in use.

10.3 Dust Collection Systems

a. A "wet collector" that moistens the dust close to the point of origin and keeps it wet until the dust is removed for disposal is preferred. A "dry type collector" is permitted when authorized by a Standard Operating Procedure (SOP).

b. Dust collectors shall be designed to prevent explosives dust from reaching any mechanical power source of the collection system.

c. All conductive portions of the collection system shall be grounded and bonded.

d. A dust collection system shall not have screw threads, recesses, or cracks that may be exposed to explosives contamination.

e. Dust collection lines should be equipped with flanged connectors and inspection ports.

f. Pipes or ducts through which explosives are conveyed shall have long radius bends with a centerline radius at least four times the diameter of the ducts or pipes.

g. Dust collectors shall be emptied and cleaned on a regular basis as system use warrants and must be inspected periodically.

10.4 Dust Collection Location

a. Wherever practical, dry-type explosives dust collection chambers should be located outside operating buildings, in the open, or in buildings exclusively set aside for the purpose.

b. Stationary and portable wet-type collectors may be placed in the explosives operating bays or cubicles, provided the quantity of explosives in the collectors does not exceed 2 kg.

11.0 DRAINS AND SUMPS

11.1 Collection

a. All drain lines handling explosive wastes shall be provided with sumps, clarifiers, weirs or basins of adequate design and capacity for removal of explosives by settling. The drains shall be of adequate capacity, free of pockets, and have sufficient slope (at least 1/4 in./ft) to prevent the settling out of explosives in the line until it reaches the sump, clarifier, weir or other settling basin.

b. Drain gutters within buildings may be constructed with a slope of 1/8 in./ft. However, a satisfactory program of cleaning must be developed to assure removal of all hazardous material from drain gutters.

c. Sumps must be designed to prevent suspended and settleable solid explosive material from being carried in the wash waters beyond the sumps. The design shall allow sufficient settling time on the basis of the settling rate of the material and the usual flow rate. Sumps shall be constructed so that the overflow will not disturb any floating solids. The design must also permit easy removal of collected explosives and retention of those explosives that float on water (until they can be skimmed off). When using settling basins to supplement sumps, they will be cleaned periodically and a log will be maintained.

d. Explosives collection trays for sumps will be constructed of nonferrous metal. Hoisting equipment used to lift trays will be designed to prevent the trays from binding on the sides of the sump. Bolted sump tanks or other types of construction that permit the explosives to settle in obscure or hidden spaces are prohibited.

e. Drains between the source of explosive and the sump shall be troughs with rounded bottoms and removable ventilated covers to facilitate inspection for accumulation of explosives. This requirement applies to all new construction and major modifications and should be considered for existing facilities. Short sections of closed pipe or trough are permitted if they can be visually inspected for blockage or explosives buildup. Explosives or explosives-contaminated waste liquids shall not be released into closed drains and sewers.

f. Drains shall be inspected periodically and necessary steps taken to prevent the buildup of explosive deposits.

11.2 Effluent

a. Drains containing explosive waste materials must not be connected in a manner that allows such wastes to empty into the normal sewage systems carrying inert or sanitary wastes.

b. Care must be taken to avoid the possibility of deposition of explosives from sump effluent due to drying, temperature changes, or interaction with other industrial contaminations. When handling explosives that are appreciably soluble in water, sweeping and other dry collecting measures shall be used to keep such out of the drainage system.

c. The combination of sumps, settling ponds, and other systems must remove explosives so that outflows meet environmental standards.

12.0 PROCESSING

12.1 Heating, Drying, and Thermal Conditioning

12.1.1 *General*

a. Heating explosives is potentially dangerous for several reasons:

(1) Elevated temperature can increase an explosive's sensitivity to other stimuli such as impact, shock, friction and static electricity.

(2) At or above the explosive's critical temperature (see definition in Chapter I, section 6.0) a runaway chemical reaction may occur that can produce an explosion or fire.

(3) Elevated temperature of an explosive in a sealed container can cause gas generation and pressure rupture of the containment even at temperatures below the critical temperature.

(4) Chemically incompatible or reactive materials, which may be present as accidental contaminants, as components of the formulation, or in external contact with the explosive, can intensify the preceding dangers or cause them to occur at lower temperatures.

(5) Nonuniform heating can cause excessively hot regions in the explosives. Causes may include inadequate agitation of fluid explosives, nonuniform heaters, and nonuniform heat conduction.

b. Critical temperature is a system property that depends on a combination of the explosive's chemical decomposition reactions, its mass and shape, heat transfer and other thermal characteristics of the system, and the confinement or pressure of decomposition products, especially gases. Several different methods of thermal analysis can be used to determine or estimate the critical temperature. The process is typically quite complex because of the complexity of normally occurring chemical reactions. For operational safety, a conservative estimate (i.e., lower limit) of the critical temperature for a heating operation shall be made (uncertainties of 10 to 25°C being common). Analogy of one explosive or system to another similar system with a reliable thermal analysis may be used to determine safe heating temperatures and heating times (heating limits).

c. The DTA, DSC (differential scanning calorimetry), or other comparable techniques can be used to measure the temperature of the onset of an exothermic reaction in an explosive. The test results can be used to rank

the thermal stability of explosives and as part of a thermal analysis. Because of the complexity of chemical decomposition, however, the DTA/DSC exotherm has no systematic relationship to the critical temperature and is unreliable for estimating safe heating limits. Exotherm temperature is always considerably above critical temperature and usually increases with the heating rate of the test. Where the DTA/DSC exotherm is specified as a standard for temperature control, the test heating rate shall not exceed 10°C per minute. DTA/DSC shall not be used as a sole means for establishing heating limits (except as specified in section 8.6a(4) of this chapter).

d. Each facility shall conduct or obtain thermal analysis of any explosives system before the explosive is heated in a contact operation or in association with hazardous radioactive materials as described in section 13.6.2 of this chapter. From this analysis, a heating limit for the explosives system shall be established which the EDC shall approve. All factors in sections a and b, above, shall be considered. Any significant change in the geometry or an increase in mass should be considered a new explosives system. For a contact operation, the maximum temperature should be set at least 10°C below the critical temperature. For heating explosives in association with hazardous radioactive materials, the maximum temperature should be set at least 20°C below the critical temperature. Facility management may approve heating to a temperature greater than the above specifications if a documented analysis of the explosive's thermal characteristics indicates that an acceptable time or temperature safety factor is still present for a specific operation. These operations shall be conducted remotely.

e. Heating controls for each operation shall be established and specified in written operating procedures. Specified conditions should be set at the lowest temperatures and heating times to do the job efficiently and should not exceed the heating limit for the explosives system. Factors to consider when establishing heating controls include the heating limit and accuracy of the estimated critical temperature, accuracy of the temperature control equipment, and the likelihood of incompatible chemical contamination and other operational parameters.

12.1.2 *Heating and Drying Equipment*

a. Heat should be done by steam, hot water, friction air, or electrically heated transfer fluid. Redundant, automatic heat controls shall limit temperatures.

b. In systems heated by steam only, the requirements for redundant, automatic heat controls shall be satisfied if a pressure-reducing valve, pressure relief valve, and thermostatic valve on the system control the steam pressure.

c. In electricity heated systems, a manual reset secondary overtemperature system consisting of a controller, failsafe sensor, and an interrupting device shall be provided to interrupt the heat supply source if the primary system fails. The secondary interrupter shall be separate from the primary interrupter. The upper limit of the primary controller is determined by the desired operating temperature limit. The secondary (override) controller is set at a higher temperature but should not exceed the maximum temperature determined by the heating limit specified for the explosives system as determined in section 12.1.1d of this chapter.

d. Visual and/or audible alarms should be provided to alert operating personnel to abnormal temperature conditions. The heating of explosives should be monitored at all times.

e. The air or gas used to condition exposed explosives shall not be recirculated if directly heated by electrical resistance elements.

f. Drying or heating ovens should be vented to a safe location outdoors. Water wash or filtration of the exhaust may be required. If exhaust fans are used, they shall be interlocked with the heat source.

12.1.3 ***Heating and Drying Operations***

a. Heating and drying shall be performed under the mildest set of conditions that will accomplish the task safely and efficiently. A thermal analysis shall be made and a written procedure prepared consistent with section 12.1.1. The procedure shall include controls on the mass and geometry (thickness of the layer, etc.) of the material that may be heated.

b. Except as described in section 12.1.3c, below, drying shall be achieved by circulating a warm, dry gas—either air or inert—over or through the material.

c. Small samples may be dried by placement in desiccators or by subjecting them to vacuum. Vacuum drying of larger items should be preceded by drying at atmospheric pressure to remove quantities of moisture or solvent before vacuum is applied to remove the final traces of moisture or solvent. Explosives having a vapor pressure exceeding 1 x 10-4 mm Hg at the drying temperature shall not be subjected to vacuum drying. A cold trap shall be used for vacuum drying where the vapor pressure of the explosives is unknown.

d. A vapor-air mixture within explosive concentration limits shall be avoided. Such a vapor-air mixture can be controlled by providing sufficient airflow to maintain a vapor concentration well below the

lower flammability limit or by using an inert atmosphere. For inert atmosphere, positive purge shall be used to preclude oxygen leakage into the unit. If vapor concentrations approaching a flammable level are anticipated, they shall be monitored. Airflow shall be controlled to prevent dusting.

e. When heating explosives whose vapor pressure may cause undesired condensation of explosives on equipment parts, heating shall be conducted in a manner to control condensation of the explosive material. This control should be accomplished by heating the exhaust system or by circulating the air at a rate that will keep the explosives concentration below the level at which condensation could occur.

f. The proper operation of heater controls shall be verified on a regular schedule established by site management.

12.2 Pressing

a. Explosives pressing operations subject explosives to high pressures to achieve a physical change. Pressing of explosives formulations is done routinely to consolidate explosive materials into configurations required for test assemblies or weapon systems. Two common types of pressing operations commonly performed are isostatic/hydrostatic and punch and die. The following safety guidelines apply to these types of pressing operations.

12.2.1 *General*

a. Explosives pressing operations shall be conducted as remote operations.

b. The correct functioning of press interlock systems shall be verified at regular intervals.

c. Pressing mandrels, punches and dies used in explosives operations shall be examined regularly during periods of use for evidence of structural failure. Suitable nondestructive test methods shall be used to perform the examination. Site management shall establish intervals between inspections for each tooling design before committing the tooling to use. The inspection interval and updating should be based on experience with similar tooling designs and configurations. All new or modified mandrels, punches, and dies shall be inspected before their first use. At least one pressing cycle should be completed with mock explosives before proceeding to explosives.

d. Pressure controllers and indicators shall be calibrated periodically to ensure accurate control and monitoring of pressing operations.

e. Press parts that contact explosive materials shall be cleaned thoroughly to remove residual explosives before use with a different explosive formulation.

f. Temperature control for heated presses and dies shall comply with the requirements of sections 12.1.2a and 12.1.2b of this chapter.

g. All pressing assemblies shall be designed or procedural controls established to minimize or eliminate the extrusion of explosives between two mating metal surfaces during the pressing operation.

h. Operations with explosive powders should be performed in a manner that reduces the release of explosives dust and thereby reduces operator exposure and general room contamination. For operations involving large amounts of powders, local exhaust ventilation with a dust collection system should be provided. Respiratory protection to prevent inhalation of explosives dust may be required when adequate ventilation is not available.

12.2.2 ***Isostatic/Hydrostatic Pressing***

a. Before an elastomeric container or mandrel constructed of a new material is introduced into a pressing operation (where it will contact explosives), the material shall be evaluated for compatibility with the explosives.

b. All pressing vessels shall be examined for evidence of cracking or other signs of incipient structural failure at regular use intervals by suitable nondestructive test methods. Local management shall establish examination intervals.

c. Before large-scale pressings of new explosives or explosives formulations, the materials shall be evaluated for thermal stability (see scaleup procedures, Chapter VIII). "New explosives or explosives formulations" refer to those that are "new" to large-scale pressing. Stability test results shall be used to assist in establishing safe pressing conditions for the specific pressing size.

d. For isostatic pressing, procedural controls shall be established to ensure that:

(1) An acceptable vacuum can be obtained on the mandrel assembly to prevent adiabatic heating during pressing; and

(2) Air is bled out of the press before pressurization.

e. Consideration should be given to the use of fire-resistant hydraulic fluids. New fluids must be checked to ensure compatibility with the explosives used.

12.2.3 *Punch and Die Pressing*

a. All pressing punches and dies shall be inspected visually for damage, deformation, and cleanliness before installation on a press. Any questionable condition shall be resolved before the pressing proceeds to ensure that the operation's safety is not compromised.

b. All punches, dies, and press attachment fixtures shall be designed to minimize the possibility of the punch being misaligned with the die (resulting in gouging of a die surface during pressing). Press setup procedures shall provide for operator verification of proper alignment before pressing.

c. The responsible user of a gauging section capable of performing the necessary measurements shall control punches and dies, which should be maintained in matched sets. A group other than the user should check critical punch and die dimensions before initial use and at suitable intervals thereafter. Suitable check intervals for each punch and die design should be determined as in section 12.2.1c of this chapter.

12.3 <u>Extruding</u>

a. Extrusion operations involve the flow of plastic explosives material under pressure into a cavity in a component of an assembly. The following general safety guidelines apply to this type of extrusion operation.

(1) Extrusion operations shall be conducted remotely. Contact extrusion may be performed only when extruding nonexplosive or mock materials or when hand-extruding small quantities with no metal-to-metal contact. Precautions shall be taken to prevent personnel from being injured by the rupture of pressurized equipment.

(2) The explosive shall be protected against extrusion beyond the tooling cavity. Precautions shall be taken to prevent foreign material from entering the explosives.

(3) New designs and significant design changes in equipment, tooling or components shall be tested by mock explosives extrusion before actual explosives extrusion.

(4) Pressure controllers and indicators shall be calibrated periodically to ensure that proper sealing and extrusion pressures are maintained.

(5) Extrusion press parts shall be cleaned thoroughly of residual explosives remaining from the previous operation before the press is loaded with a different explosive formulation.

(6) Hand-loading of extrudable explosives is covered in section 12.8.2 of this section.

12.4 Machining

a. Explosives machining is a class of operation that involves cutting of the explosive material, often in conjunction with harder inert materials. Heat buildup from friction at the cutting surface can result in thermal initiation of the explosive substance. Precautions must be taken to limit this buildup and to facilitate the dissipation of thermal energy.

12.4.1 *Equipment Requirements*

a. Interlocks shall be provided for wet machining operations to ensure coolant flow before machine operation. The coolant flow shall be monitored and the equipment automatically and safely shut down if loss-of-coolant flow is detected. The interlocks shall be protected from tampering and unauthorized disabling by physical means, or supervisory control.

b. The vacuum on vacuum chuck holding fixtures shall be monitored and interlocked with the equipment for automatic shutdown of machining in the event of vacuum loss.

c. Tool path controls (stops, limits, design patterns, etc.) shall be provided to prevent the unplanned travel path of a tool or work piece. Positive means or secondary verification shall control and limit equipment speed and feed rates.

d. Pressure-relief devices should be installed on pneumatically or hydraulically powered equipment to ensure safe operation.

e. Metal chip waste from machining operations should be kept separate from explosives waste. When this is not possible, mixed explosives and metal waste should be completely segregated from unmixed waste and held for separate disposal.

f. Dull or damaged tools shall not be used. A cutting tool inspection and control program shall be established for explosives machining operations.

g. Consideration will be given to additional safety control devices (i.e., design patterns, safety templates, chip thickness sensors, tool pressure sensors, etc.), depending on the type of machining operations, size of explosives pieces, types of explosives, and other factors.

h. The "machining overtest" shall be considered a testing operation (see section 12.4.4e of this section) and shall be exempt from equipment requirements.

12.4.2 ***Contact or Remote Operations***

a. The following explosives may be contact machined if a compatible, nontoxic, noncombustible coolant is used. Explosives not listed below shall be machined remotely.

(1) Amatol

(2) Baratol

(3) Boracitol

(4) Explosive D

(5) Octol with no more than 75 percent HMX

(6) Pentolite with no more than 50 percent PETN

(7) RDX/TNT compositions with no more than 75 percent RDX. These compositions include Composition B, Composition B-3, and 75/25 Cyclotol.

(8) TATB and TATB compositions with an inert plastic binder

(9) TNT

b. Explosive assemblies composed of any combination of explosives listed in the above section and the following nonexplosive materials may be contact machined if a compatible, nontoxic, noncombustible coolant is used. If an assembly contains an explosive not listed in the above section or a nonexplosive material not listed below, the assembly shall be machined remotely:

(1) Foamed plastics.

(2) Solid plastics.

(3) Adhesives.

(4) Amorphous graphite.

(5) Calcium sulfate casting powder.

(6) Explosives mockup.

c. On any explosive, with certain exceptions for IHE and explosives machined by fluid jet (see section 12.4.2e of this section), the following operations shall be performed remotely:

(1) Drilling of holes smaller than 5 cm in diameter, except for IHE, where drilling of holes smaller than 5 mm shall be done remotely.

(2) Coring operations (except contact operations on those explosives listed in section 12.4.2a of this chapter, when the requirements of section 12.4.5b of this chapter are met and a coolant is used).

(3) Machining of any metal/explosives interface.

(4) Machining IHE subassemblies with Hazard Class/Division 1.1 boosters installed.

(5) Dry machining, except that IHE booster pellets may be contact machined provided a dust collection system (see section 10.0 of this chapter) is used.

(6) Machining of explosives in Phase II or earlier stage of scaleup (see Chapter VIII).

d. Machining of primary explosives shall be avoided. Alternative methods, such as forming or pressing to final dimensions, should be used to achieve the desired shape.

e. IHE, PBX 9404, and LX-10 may be contact-machined by high-pressure fluid jet. The fluid-jet system pressure shall not exceed 20,000 psig. The velocity of the fluid jet shall not exceed 520 m per second (theoretical). The jet nozzle orifice diameter shall not exceed 0.010 in. The system machining fluid shall be water and shall not contain any abrasives. See section 12.15 of this section for use of low-pressure fluids.

f. Concurrent contact machining operations in the same bay should not be permitted. However, concurrent IHE contact machining is permitted when other explosives are not present.

g. Provisions shall be made to monitor remote machining operations visually. Consideration should be given to video recording and audio monitoring.

12.4.3 ***Setup and Preparation***

a. The following precautions are provided for preparation and setup before beginning the machining operation.

(1) Before setting up the explosive work piece, the equipment shall be checked for proper function and the absence of interference between stationary and moving parts.

(2) A mock explosive should be used to test the equipment function of any operation using new tooling or new part programs.

(3) The explosive component to be machined shall be inspected by radiography or other suitable nondestructive test methods for cracks, voids, and high-density foreign objects. The component shall also be checked for proper size.

(4) Caution shall be exercised during setup and adjustment to avoid pinching, dropping, crushing, or otherwise applying abnormal forces to explosives present. Special care must be given to mounting and centering a part on a vacuum chuck. Special attention must be given to the proper functioning of the vacuum system and its surface holding area.

(5) Limits on machine speed, depth of cut, and feed rate shall be set before the machine is activated.

(6) Interlocks shall be functional before the machine is used to machine explosives. They should be tested once per shift.

12.4.4 ***Operations Guidelines***

a. The minimum tool speed necessary for safe and efficient operation should be maintained. The following maximums shall apply:

(1) The relative velocity between the explosives surface and the cutting tool shall not exceed 65 m per minute;

(2) Work pieces or cutting tools shall not be rotated at speeds exceeding 525 rpm; and

(3) The feed rate of the cutting tool or work piece shall not exceed 1 mm per revolution.

b. The work piece, fixture, cutting tools, equipment, floor, troughs, drains, etc., should be cleaned frequently to prevent accumulation of explosive wastes.

(1) Approved measures should be taken to prevent rust and minimize deterioration of precision surfaces.

(2) All tools, equipment, fixtures, and parts should be cleaned before removal from the work area for storage.

c. For contact machining operations, coolant shall be used to aid in removing heat and cutting waste. Coolant should be used for remote operations when practical.

(1) Coolant should be used on explosives/inert assemblies. When the explosives portion is included in the cut, coolant shall be used for contact machining. Coolant is not required if the explosives portion of the assembly is contained (no bare explosives) and is not included in the cut, or the machining is conducted remotely.

(2) Spray mist coolant may be used during machining of the explosive-containing assemblies if the explosives portion is not included in the cut.

d. All visible explosives shall be removed from the machine before maintenance or repairs. No safeguards or interlocks shall be removed or made inoperative, except by authorized personnel.

e. Before submitting an explosive for contact machining approval, a machining overtest program shall be conducted to identify the machinability and associated hazards. These HE qualification tests should be performed in facilities set aside for these purposes.

(1) Machining overtest shall be conducted remotely.

(2) Operations performed during sample preparation may include gaging and assembly, but shall not include any contact cutting, scraping, or other material-removing operations on explosives specimens.

12.4.5 ***Specific Machining Operations***

a. Drilling

(1) Drilling operations should be set up to maximize the ease of achieving and maintaining proper alignment and to facilitate removal of explosives chips, fines, and powder.

(2) The fluting length on the drill bit shall exceed the depth of the hole to be drilled by a minimum of 1.3 cm or one hole diameter, whichever is greater.

(3) The depth of a hole shall not be extended more than 1.5 times the hole diameter (up to a maximum of 2 cm) during a single insertion of the drill into the material. After each insertion, it may be advisable to withdraw the drill completely and remove loose explosives from the cavity and drill bit before reinserting.

(4) Coolant flow (when used) shall be directed to the explosives/cutting edge interface. Drill bits with coolant channels to the tip of the drill should be used. Pulsating pressure types of coolant supplies are recommended for drills of 6-mm diameter or less to remove drill fines.

b. Coring

(1) Coolant flow (when used) shall be directed at the explosives/cutting edge interface.

(2) If the hole is not positioned to provide continuous breakout, the coring shall be accomplished incrementally. When done in increments, no more than 1.5 times the diameter of the hole shall be cored at one time. Before the maximum distance has been cored, the tool shall be totally retracted from the hole and cleaned. The hole shall be flushed with coolant.

c. Sawing

(1) The feed rate of the saw blade or work piece shall not exceed 7.5 cm per minute.

(2) For band saws, coolant flow should be directed onto the saw blade at the cutting interface, guide rollers, and the drive wheel/saw blade interface. For circular saws, the coolant flow should be directed at the explosives/cutting edge interface.

12.5 Dry Screening

a. Dry explosives often require screening for size classification or to remove extraneous objects. Magnetic separators are often advisable to remove ferrous materials that may have passed through the screens. The following guidelines shall be observed for screening operations and equipment:

(1) Operations using mechanical screens shall be performed remotely. Equipment shall be designed and operations performed to avoid subjecting explosive materials to pinching, friction, or impact.

(2) Screening small samples may be performed as a contact operation if approved by written procedures.

(3) Equipment shall be electrically bonded and grounded. Resistance-to-ground shall be 10 ohms or less and shall be inspected on a regular basis. Equipment used to transfer electrostatic-sensitive explosives to or from screens shall be conductive and electrically bonded to the screen during transfer.

(4) Operations and equipment shall be set up to minimize and control dust generation.

(5) Operating areas and equipment therein shall be cleaned frequently to avoid accumulation of explosives dust.

(6) Precautions shall be taken to prevent metals from rubbing together when the screens vibrate. Vibrating equipment shall be inspected frequently for developing cracks subject to contamination by explosives.

12.6 Blending

a. Dry blending of explosives shall be performed remotely. However, dry, hand blending of small samples may be performed as a contact operation when approved by facility management.

b. Equipment should be designed and operations performed to minimize generation and dispersion of explosives dust.

c. Equipment shall be electrically bonded to provide a continuous path-to-ground. Resistance-to-ground shall be 10 ohms or less and shall be inspected regularly. Equipment used to transfer electrostatic-sensitive explosives to or from blenders shall be conductive and electrically bonded to the blender during transfer.

12.7 Melting

a. The heat for melting explosives shall be supplied by saturated steam, hot water, or another temperature-controlled medium. The steam pressure shall be controlled in accordance with section 12.1.2b of this section.

b. Temperatures for contact melting of TNT-based explosives (except those containing PETN, e.g., pentolite) and keeping them molten shall not exceed 121°C. The temperature limit for TNT explosives containing PETN shall be 109°C.

c. Feeding of the melt kettle and the melting operation shall be controlled or regulated to prevent the formation of large chunks of explosives.

d. Alarms shall be provided on the melt temperature and on melt kettle agitation when the operation will be left unattended. Alarms shall sound if the temperature exceeds the specifications of section 12.7b above, or if agitation ceases.

e. Wherever possible, valves, piping, and threaded bolts and fasteners should be eliminated from melted explosives handling systems.

f. Provisions should be made for emergency emptying of melt kettles in the event of temperature control problems or power failures.

g. Melt kettles shall be constructed with corrosion-resistant materials. Construction shall not contain blind holes, threads, or cracks in areas exposed to melted explosives. Welds shall be inspected and found free of cracks and porosity.

12.8 Assembly and Disassembly

a. Hand tools and electrical and pneumatic tools that may subject the explosives to abnormal frictional forces, pinching, or excessive pressure, or cause significant deformation, shall not be used during assembly or disassembly. However, they may be used on nonexplosive components.

12.8.1 *Assembly Operations*

a. During assembly operations, the operator should be alert for mismated parts and misaligned components. Hard surfaces that will contact explosives shall be precisely machined to mate with the explosives, lined with cushioning material, or otherwise configured to keep sharp corners or projections from being forced into explosives.

12.8.2 *Loading Assemblies with Plastic or Extrudable Explosives*

a. The workability and plasticity of plastic and extrudable explosives improves with increased temperature. Plastic explosive Compositions C-3 and C-4 may be softened by warming to between 21°C and 38°C before working. Extrudable explosives LX-13 and extex should be kept as cool as practical to prevent premature curing.

b. Contamination of these explosives with abrasive or foreign substances shall be avoided.

c. The assembly shall be loaded with small increments of explosives and may be tamped with suitable nonmetallic tools to eliminate air voids.

12.8.3 *Disassembly Operations*

a. Before beginning disassembly, the device's condition shall be assessed to determine if it can be safely handled.

b. Disassembly operations shall be planned before actual disassembly. Possible problem areas caused by method of construction or physical condition shall be considered. A safety procedure for each unique disassembly shall be written and reviewed.

c. If disassembly would normally cause release of the pressure or if there is a credible hazard of the pressure causing components to fly apart,

before beginning disassembly, pressurized units shall be thoroughly depressurized.

d. If approved for use, compressed air shall be applied cautiously during disassembly to avoid causing to fly apart. This may require remote operation. Use hydraulic pressure if possible.

12.8.4 *Personnel Protection for Disassembly Operations*

a. Operators and all other personnel shall be provided complete protection from disassembly operations involving conditions known or expected to require the use of abnormal force. Such operations require either remote operation or the use of an operational shield. The shielding shall be designed to protect personnel at other operations or locations from blast and missiles arising from a possible explosion.

b. When disassembly requires that the operator be protected by an operational shield, disassembly shall be defined as complete separation (threads or other connections) of component parts. For example, parts shall not be loosened while the operator is properly protected and then separated without the same protection.

12.9 <u>Inspection</u>

a. This section deals with the following types of explosives inspection operations:

(1) Inspecting incoming explosives raw materials and pressed explosive billets for foreign bodies or cracks that could cause operating or safety problems in processing operations; and

(2) Measuring physical parameters of explosive pieces and assemblies.

b. To enhance the safety of process operations, positive steps shall be taken to assure the proper identification of explosives used and to prevent foreign material from entering the operation via the explosives raw materials or via materials in process (i.e., pressed explosive billets). Some of the means by which this can be accomplished include:

(1) Screening.

(2) Visual inspection.

(3) Magnetic separation.

(4) Radiographic inspection.

(5) Chemical analysis.

c. The following principles shall be followed in the design and operation of explosives inspection equipment.

(1) Pinch points shall be eliminated or steps taken to preclude explosives contamination of pinch points.

(2) Threaded fasteners or threads of measuring equipment shall be protected from explosives contamination. Care shall be taken to prevent parts of the measuring or handling equipment from becoming loose and getting into the explosives.

(3) Inspection fixtures shall be designed to secure the explosives piece or assembly securely to prevent toppling, rolling, or dropping during measurement operations. This is especially critical if the explosives assembly is in motion (i.e., spinning, vibrating, etc.) during measurement.

12.10 Synthesis

a. Synthesis and other chemical processing of new explosives compounds are ongoing activities at DOE weapons facilities. Synthesis operations are conducted both on laboratory and pilot scales. The Explosives Development Committee (EDC, Chapter VIII) will approve new operations and materials. In the laboratory, the new material will initially be prepared on a small scale and characterized as to sensitivity, physical, and explosive properties. Also, the laboratory will develop processing techniques for the material. If laboratory studies determine that the explosive is of continuing interest, it may be advanced to the Pilot Plant where processing techniques will be refined and scaled up. The Pilot Plant will produce sufficient material for larger-scale physical, explosive, and sensitivity characterizations.

12.10.1 *Laboratory-Scale Synthesis*

a. Before initiation of work, the professional staff member who is directing or conducting the synthesis shall analyze each explosives or potential explosives experiment for the type and magnitude of hazards. This staff member shall be responsible for planning the proper selection of conditions, quantity of explosives, and safety devices to be employed.

b. Experiments should be designed to minimize the amount of explosives involved and to use the mildest conditions that will yield the desired information.

c. New explosives materials shall be afforded extra protection against impact, pinching, friction, pressure, sparks, contamination, and deterioration. If it is necessary to subject explosives to any of these

conditions, the operation shall be conducted remotely or adequate personnel shielding shall be provided.

12.10.2 ***Pilot- or Processing-Scale Synthesis***

a. When operations are conducted using flammable or toxic liquids or gases, local ventilation shall be provided to prevent hazardous vapor concentrations from forming in the work area.

b. Alarms should be provided for coolant flow to the reactor, for reaction vessel agitation, and for reactor temperature. These alarms should be energized whenever coolant supply or agitation is critical to prevent a runaway reaction. When agitation is critical, the reactor should be equipped with at least two sources of power to maintain agitation in the event of failure. For example, a reactor might employ an air or inert gas bubble tube as a backup for a mechanical agitator.

c. The reaction vessel should be equipped with an emergency system. Upon activation, the emergency system will automatically cool the vessel or will open or close a vessel dump valve as required by the process. Contact operations should be conducted with a means to activate the emergency system manually.

d. The building exhaust ventilation system shall be operating during all synthesis operations involving flammable liquids.

e. An alarm or monitor should be provided for the critical exhaust ventilation system to warn operating personnel if airflow rates drop below a predetermined level.

f. Emergency plans shall be established for the synthesis area, specifying action to be taken in the event an alarm sounds.

g. Before operations begin, all equipment shall be set up and checked for proper function. Now or infrequently used equipment shall be tested in a “dry run” before being used with any hazardous material.

h. All explosives synthesis process equipment shall be maintained routinely. Equipment with defects that could affect safe operations shall be tagged to prevent its use until repairs are completed.

i. Before starting any process operation, the transfer lines to be used should be properly labeled and their function specified in the operating procedure.

j. Transfer hoses and portable equipment not involved in the process shall be removed from the work area and stored in their proper places.

k. All control valves shall be correctly identified according to function.

l. Safety equipment and clothing shall be worn as defined in operating procedures.

m. Agitator blades on reactors and mixers shall be inspected regularly for proper clearance to ensure that there is no pinch point or metal-to-metal contact. Local facility management shall set up and approve the inspection schedule.

n. Explosives warning signs shall be conspicuously displayed on any processing vessel in which explosive materials are to be left overnight.

o. Any vessel that can be sealed and that can operate above atmospheric pressure shall be equipped with overpressure protection.

p. All closed vessels should be purged with inert gas before flammable liquids are introduced.

q. Inert gas pressure should be used to transfer flammable liquids when gravity flow or pumping is not practical.

12.11 Formulation

a. Formulation operations considered in this section involve combining compounds or mixtures when one or more of the ingredients are explosive. Combining ingredients is commonly accomplished at DOE explosives handling facilities to obtain some desired physical property, combination of properties, or reaction parameters.

12.11.1 *General*

a. Explosives may be loaded into mixers, mills, and deaerators as an operator-attended, contact operation. However, the starting, operating, and stopping of such equipment with explosives present shall be accomplished remotely. As an exception, mixing-type operations involving a low energy transfer may be allowed as a contact operation (e.g., slurry coating and melt agitation).

b. Equipment used for explosives formulation shall be checked for proper operation before adding explosives. Equipment shall be examined for proper clearances and for metal-to-metal rubbing of moving parts with

the potential to contact explosives. Bearings should be sealed to preclude explosives contamination.

c. Fast-action deluge systems shall be considered for equipment (e.g., mixers, mills, and deaerators) used for easily ignitable explosives formulations.

d. Hot water, cold water, or steam, can be applied to mixers and mills. Heating fluid temperatures shall not exceed known safe operating temperatures for the explosives involved. When roll milling, allowance shall also be made for viscous shear heating of the explosives in process. Heated systems shall comply with the requirements of sections 12.1.2a and 12.1.2b of this section.

12.11.2 ***Mixing***

a. Mixer seals and gaskets shall be checked on a regular schedule and cleaned or replaced as required.

b. Checks should be made to ensure that maximum particle sizes of ingredients or hard agglomerates of proposed mixes are less than the blade-to-blade or blade-to-bowl clearances.

c. Initial cleaning with solvents used for dissolving or suspending the explosives residues shall be done remotely (except for melt-mix or slurry coating vessels).

d. Explosive powders and plastic-bonded explosives formulations may be mixed wet in a contact operation. This can be accomplished if the wet mixture cannot be initiated with energy sources available and the viscosity is kept low and the possibility of isolated portions of the mix becoming dry is precluded.

12.11.3 ***Ball or Jar Milling***

a. Balls that are porous or contain cavities shall not be permitted in mills for grinding explosives.

b. Grinding media contaminated with explosives slurry shall be protected from excessive impact when emptying of the mill.

c. After grinding, a careful inspection shall be made to ensure that the explosive is free of grinding media. Dispose of any explosives contaminated with broken media.

d. After separating the explosive, the grinding media shall be thoroughly cleaned and inspected before reuse or disposal.

12.11.4 *Roll Milling*

a. Positive stops should be installed on roll mills to prevent rolls from rubbing against each other.

b. Before starting a milling operation on a roll mill, the contact of the scraper blade with the roll should be adjusted to the minimum pressure necessary to perform the operation.

c. Roll gaps should be set as wide as possible while still allowing adequate working of the material. The minimum gap setting shall be 0.1 mm.

d. Roll rpm should be held at the minimum required to process the material adequately.

e. All roll mills that may be contact operated (e.g., with nonexplosive materials) shall be equipped with emergency stop devices (breaker bar, or chain) within easy reach of the operator.

12.12 Concurrent Contact Operations

a. The preferred setup for explosives operations is to perform each operation in a separate location to preclude any adverse operation interaction. Because such an arrangement is frequently impractical, concurrent operations may be permitted if the following conditions exist:

(1) Potential equipment-operator interactions between the two operations have been analyzed and the risk is not appreciably greater than that for both operations considered separately.

(2) Explosive materials in either operation are not exposed to stress conditions such as elevated temperature (melting or heat conditioning), elevated pressures (pressing or extruding), or deformation/shear (machining or cutting).

(3) Mixing of materials in the concurrent operations will not create compatibility problems.

(4) Each operator is aware at all times of concurrent operations in his or her area.

12.13 Contamination Prevention

a. Precautions shall be taken to avoid mutual contamination when two or more incompatible explosives or materials are handled on a single line or within one building or room. This includes vacuum systems and explosives scrap collection. Inadvertent mixing of incompatible explosives materials can be

hazardous not only to manufacturing facilities and personnel but also to the user if such materials are loaded into explosives devices.

b. When two or more explosives are used in a line or within a building and mixing is not intended, the materials shall be segregated in separate locations. Containers shall be clearly marked with the weight and contents identified. Care shall be exercised to properly segregate material in service magazines and in operating buildings.

c. When a different explosive is to be used in process equipment, the equipment shall be thoroughly cleaned, and excess explosive from the previous job should be removed from the bay. This eliminates the hazards caused by mixing materials.

d. In any explosives operation, permanent service lines shall be labeled as to their contents. Valves and switches on service lines whose operation can result in a hazardous situation shall be labeled as to their function.

12.14 Hand-Cutting and Finishing Operations

a. Hand-cutting finishing, which may include cutting, trimming, coring, and lapping (surface polishing) explosive materials shall be performed using the mildest energy input that will accomplish the task safely and efficiently. The facility EDC shall review and approve the safety of hand-cutting and finishing operations, which shall then be incorporated into an operating procedure before starting the operation.

12.15 Use of Low-Pressure Fluids

a. Low-pressure fluids (liquid pressure less than 1,500 psig) may be handled as in contact operations to aid explosives dissolution, rinsing, system flushing and similar operations under the following conditions:

(1) The fluid system shall have a pressure relief device installed to prevent system overpressurization.

(2) Low-pressure fluid operations may be used with those explosives whose impact sensitivity is less than PETN. Such operations may be used on other explosives only after analyzing the energies involved.

(3) Solvents shall be compatible with the explosive material. Controls for their use shall be specified in operating procedures.

(4) For use of pressures above 1,500 psig, see section 12.4.2e of this chapter.

13.0 TESTING

13.1 General

a. This section covers the following types of testing operations.

(1) Explosives test shots, gun firings (both small arms and large caliber), and environmental, physical-property, and sensitivity testing of explosives specimens.

(2) Explosives-related experiments or tests for which the explosive material is used to provide desired results such as a seismic yield, overpressure effects, pulse energy, or other special applications.

13.2 Test Planning

13.2.1 *Hazards Analysis*

a. Proposed testing programs shall be examined for all foreseeable hazards involved in the test. This shall be done with knowledge of the construction and operation of all standard and nonstandard equipment to be used, as well as the type of explosives involved.

b. Tests that are unique in their application or pose obvious hazards shall adhere to the requirements contained in Chapter VII, section 2.1.

c. Large-scale tests with the potential to propel missiles off Government land shall receive a formal risk analysis of the worst-case conditions for each test type. Such analysis shall address the probability and potential severity of hazards with respect to injury and property damage.

13.2.2 *Firing Areas*

a. A secured firing area (danger zone) shall be established for each test to protect personnel from hazardous blast overpressure, firebrands, fragments, or projectiles from an explosives shot or gun firing. The danger zone can be determined by the application of the principles outlined in DoD 6055.9-STD.

b. Selected firing areas shall minimize the potential for secondary fires and adverse effects to the environment.

13.3 Test Firing

13.3.1 *General Range Standards*

a. Each DOE explosives test site shall establish procedures to ensure that site personnel and transients are not exposed to firebrands, fragments, or

excessive blast overpressure from a test shot. In establishing these procedures, the following guidelines shall be considered.

b. During testing operations, personnel access to each test site shall be controlled. Unattended roadblocks, gates or doors used to prevent personnel from entering the danger zone during a test should be interlocked or locked with specially controlled keys.

c. Before test firing, all firing site personnel and visitors shall be accounted for and in a safe place.

d. A visual inspection of the danger zone shall be performed immediately before each test shot or series of shots as applicable, to ensure that no transients are present.

e. The danger zone shall be free of service personnel (e.g., telephone repairmen, surveyors, or road maintenance crews, etc.) during test operations. The control point shall notify service personnel of the specific requirements under which they may safely work in the area when testing is not in progress. In addition, the control point shall notify firing site personnel of the presence and location of service personnel in their areas.

f. Clearance for a test or test series shall be coordinated with all test sites and other areas that could be affected. A warning shall be provided to every affected area immediately before each firing.

g. Detonation of very large explosive shots, numerous smaller shots, or gun firings may result in hearing damage and may exceed the DOE allowable limits for impulse noise. Perform a noise evaluation of these activities to ensure that adequate hearing protection is provided to those involved.

h. During test operations, all personnel assigned to the test area shall be continuously alert for movement of personnel, vehicles, and aircraft.

i. Test firings often create hazardous conditions for aircraft operating in the airspace near the danger zone. If this airspace is subject to air traffic, precautions shall be taken to ensure that the airspace is clear of traffic at the time of firing.

j. Each firing site shall establish personnel limits based on the number of people actually needed to conduct an operation and the number of casuals that should be present. The responsible person at the firing site shall enforce these personnel limits.

k. Testing of explosives can result in personnel exposure to toxic decomposition products such as carbon monoxide, hydrogen chloride, hydrogen fluoride, hydrogen cyanide, and nitrogen oxides. It is good practice to allow the detonation cloud to disperse before leaving protective bunkers. Fragment-danger-zone distances are normally adequate to allow cloud dispersal and protect outside personnel from excessive exposure.

l. For testing that can result in abnormally long hazardous conditions following the test, the procedure shall require a suitable waiting period before personnel leave their shelter or safe haven area.

13.3.2 *Test Setup*

a. When and where possible, test setup work should be done before receipt of explosives. Such work includes the following:

(1) Firing site safety devices (at both the bunker and remote from the firing bunker) shall be checked at regular intervals. Such safety devices include warning lights, door and gate firing circuit interlocks, emergency firing circuit cutoff switches, and grounding.

(2) All firing pad and shot stand setup work that requires power tools or other potential spark-producing devices should be completed. The firing pad shall be cleared of all unnecessary gear. Special precautions and procedures will be developed and implemented if power tools or other spark-producing devices are needed after explosives are delivered to the firing pad.

(3) If a special structure is required, as much work as possible should be accomplished on the structure, including assembly of all materials.

(4) When possible, all diagnostic equipment shall be set up, checked, and tested in a dry run.

13.3.3 *Pin Switches and Other Non-initiating Circuits*

a. Whenever pin switches and other non-initiating circuits are checked (such as for charging current or leakage) and are in contact with or in close proximity to explosives, the check should be performed remotely. Other non-initiating electrical circuits include strain gauges, pressure transducers, thermocouples, etc., that may be affixed to or close to the explosives within an assembly. A continuity-only (resistance) check may

be accomplished as a contact operation with an electrical instrument approved for use with the particular explosive device. When low-firing-current actuators are involved, it may be advisable to conduct these tests remotely (see section 13.8 of this section).

13.3.4 ***Lightning Storms***

a. All operations at open, test-firing areas shall be discontinued during lightning storms when explosives are present. Completion of a test after receiving a lightning alert may be allowed only if test preparation has progressed to the point that discontinuing testing represents a greater personnel exposure than completing testing.

13.3.5 ***Low-Energy Electroexplosive Devices***

a. When using hot-wire or low-energy EEDs for a test firing, the following apply:

(1) Procedures shall be established to ensure that RF, FM, and television transmitters with sufficient output energy to initiate an EED at the test site are either restricted to a safe distance from the site or not operated. Table II-2, and Table II-3 specify minimum safe distances for several types of transmitters at several output power levels.

(2) Blasting caps and other low-firing-current igniters or detonators shall be kept separate from explosives at all times, except during actual test charge assembly and setup.

(3) At all times wiring systems for the explosive charge and any low-firing-current initiators shall be kept insulated from all sources of extraneous current unless the weapon components have an exposed electrical ground by design. Connections made using weapon wiring connectors or cables are acceptable without further modification. Shunts shall be left on low-energy initiators or lead wires until connections are made. Connections shall be taped or otherwise insulated.

(4) Test units containing low-firing-current actuators or detonators shall be clearly marked. No contact operations involving electrical testing shall be permitted on this type of unit unless an electrical meter for the specific application is used.

Table II-1. Minimum Safe Distances Between RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distances (feet)	
	Commercial AM broadcast transmitters	HF transmitters other than AM broadcast
100	750	750
500	750	1,700
1,000	750	2,400
4,000	750	4,800
5,000	850	5,500
10,000	1,300	7,600
25,000	2,000	12,000
50,000[a]	2,800	17,000
100,000	3,900	24,000
500,000[b]	8,800	55,000

[a] Present maximum power of U.S. broadcast transmitters in commercial AM Broadcast Frequency Range (0.535 to 1.605 MHz).
[b] Present maximum for International Broadcast.

Table II-2. Minimum Safe Distances between TV and FM Broadcasting Transmitters and Electric Blasting Operations

Effective radiative power (watts)	Minimum safe distances (feet)		
	Channels 2-6 and FM	Channels 7-13	UHF
Up to 1,000	1,000	750	600
10,000	1,800	1,300	600
100,000[a]	3,200	2,300	1,100
316,000[b]	4,300	3,000	1,450
1,000,000	5,800	4,000	2,000
5,000,000[c]	9,000	6,200	3,500
10,000,000	10,200	7,400	6,000
100,000,000	-----	-----	-----

[a] Present maximum power, Channel 2 to 6 and FM.
[b] Present maximum power, Channel 7 to 13.
[c] Present maximum power, Channel 14 to 83.

Table II-3. Minimum Safe Distances Between Mobile RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distances (feet)				
	MF[a]	HF[a]	VHF(1)[a]	VHF(2)[a]	UHF[a]
5[b]	33	105	82	27	18
10	46	148	116	38	25
50	102	331	259	85	55
100	144	468	366	120	78
180[c]	193	627	491	161	104
250	228	739	579	190	123
500[d]	322	1,045	818	268	174
600[e]	353	1,145	897	294	190
1,000[f]	455	1,478	1,157	379	245
10,000[g]	1,438	4,673	3,659	1,198	775

[a]

MF	1.6 to 3.4 MHz	Industrial
HF	28 to 29.7 MHz	Amateur
VHF(1)	35 to 44 MHz	Public Use
	50 to 54 MHz	Amateur
VHF(2)	144 to 148 MHz	Amateur
	150.8 to 161.6 MHz	Public Use
UHF	450 to 460 MHz	Public Use

[b] Citizens band radio (walkie-talkie), 26.96 to 27.23 MHz use the HF distances. Cellular telephones: minimum safe distance; 10 ft (HERO calculation).

[c] Maximum power for 2-way mobile units in VHF, 150.8 to 161.6 MHz range, and for 2-way mobile and fixed-station units in UHF, 450 to 460 MHz range.

[d] Maximum power for major VHF 2-way mobile and fixed-station units in 35 to 44 MHz range.

[e] Maximum power for 2-way fixed-station units in VHF, 150.8 to 161.6 MHz range.

[f] Maximum power for amateur radio mobile units.

[g] Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

13.3.6 *Explosives Storage in Firing Areas*

a. Explosives or ammunition storage at a firing area shall be located such that ignition, explosion, or detonation is improbable if a fire, unplanned explosion, or detonation occurs in the area.

b. Tests that require storage of explosives or ammunition at the firing site beyond a day's event shall conform to the requirements of section 17.0 of this chapter.

13.3.7 *Warning Signals*

a. Each DOE explosives testing facility shall use standard audible signals to warn personnel of any impending firing in a test area. Each facility shall establish signals, which facility management shall approve.

13.3.8 ***Grass Fires***

a. Before conducting a test shot at an outside firing pad, an evaluation shall be made to determine the need to control grass fires that the test may initiate.

13.3.9 ***Firing Leads***

a. All detonator lead wires shall be electrically insulated. During setup on the firing point, firing leads or cables of low-energy detonators for explosive assemblies shall be kept properly shorted.

13.3.10 ***Unattended Test Assemblies***

a. When necessary, a test assembly may be left unattended on the firing pad during off-shift hours under the following minimum conditions:

(1) If explosives are present, appropriate safety warning signs shall be displayed at all entrances to the firing pad.

(2) Protective services and fire department personnel shall be notified of the explosives location. This location must be in a controlled-access or secured area.

(3) If low-energy detonators are present on the assembly, their leads or cables shall be shorted.

13.3.11 ***Post-firing Controls***

a. If the firing appears to be normal, test personnel shall remain in the protective shelter for a suitable waiting period. The test procedure shall specify the waiting period, which shall be sufficient to assure adequate dissipation of smoke and dust. In some cases, developing and analyzing the diagnostic film for misfires may be helpful.

b. During the waiting period, all power to the firing units shall be turned off or disconnected. Whenever possible, detonator cables should be disconnected from the firing units and shunted and grounded, and the firing unit capacitor grounded.

c. After the waiting period, one qualified person shall inspect the firing pad in person or by remote TV to determine the results of the shot before other personnel leave the shelter.

d. If the inspection confirms that safe conditions exist, the lead person shall signal “all clear.”

e. When a partial detonation or a test misfire occurs or is suspected, the firing area shall be inspected for unreacted explosives after the minimum waiting period (see section 13.7 of this chapter).

f. Recovered explosives from a destructive test shall be placed in an explosives storage magazine as Storage Compatibility Group L unless a documented analysis determines that the explosives do not present a special risk.

13.3.12 ***Contamination of Firing Areas***

a. Test firing areas are subject to explosives contamination from incomplete or failed detonations when the explosives are subjected to varying forms of energy input. Although most of this contamination will be cleaned up in the post-shot inspection, the following steps shall be taken to reduce the hazards from residual explosives contamination:

(1) A contamination zone for each firing area shall be established and permanently annotated on facility site plans.

(2) Personnel access to explosives-contaminated areas shall be controlled.

(3) Service personnel shall not work in the area without the permission of testing-area management and only when supervised by a management-approved person.

13.3.13 ***Test Range Firing Circuit Criteria***

a. The following criteria are guidelines for the design of electrical circuits used to arm and initiate squibs, igniters, detonators and similar EEDs during test firing:

(1) Fire control circuits shall include both an ARM switch and a FIRE switch. For low-firing-current initiators, the safe mode of the arming circuit should interrupt the firing circuit and short-circuit and ground the EED terminals. Manual shorting and grounding is permitted.

(2) Each electrical ARM and FIRE circuit shall include an interlock device consisting of a safety plug or a key-operated switch to prevent inadvertent energization.

(3) The safety plug design and configuration shall be unique for its application and used to prevent unauthorized or accidental activation of a firing circuit. Key-operated switches for ARM and FIRE circuits shall be designed to lock in the safe (OFF) position

when the control key is removed. Duplicate keys or safety plugs shall not be permitted in any one test area.

(4) During shot-preparation the key or safety plug for a firing site shall be in the control of the lead operator at all times.

(5) FIRE control circuits in test areas shall be documented for operational control purposes. Documentation shall include complete wiring diagrams, electrical schematics, and cable function lists. All changes or modifications to FIRE control circuits shall be reviewed for safety and approved by other appropriate departments before being incorporated into the circuits.

(6) Each FIRE control circuit shall be isolated from all other circuits. A shielded, twisted pair of wires with an outer insulating jacket or coaxial cable should be employed for each circuit.

(7) All sequential timers used in firing circuits shall be "failsafe." Failure of a component or circuit must not energize the firing circuit.

(8) Test current from the electrical instruments used to perform resistance checks shall not exceed 10 percent of the no-fire rating of the EED in the circuit.

(9) Firing circuits shall be marked clearly or otherwise distinctively identified, and shall be installed so as to prevent inadvertent energization by other circuits.

13.4 Test Firing in Tanks or Chambers

a. Small quantities of explosives may be detonated in cubicles or in pressure vessels. The following requirements apply to such vessels.

(1) The firing vessel and flanges shall be capable of withstanding and confining the effects of the explosion and properly safeguarding personnel. When new firing chambers are designed and put into service, a safety factor to their operational weight limit must be included during certification testing. This overtest load should be based on a percentage of the operational explosives weight limit. For example, a certification test should be performed with an appropriate explosive material weighing 125 percent TNT equivalency of the intended operating limit.

(2) The firing circuit should be interlocked with the vessel access door latch so that the door must be closed and latched before the explosive can be fired.

(3) Qualified engineering personnel shall periodically inspect the vessel to ensure that its structural integrity is maintained after repeated detonations.

(4) Test firing is often conducted inside large containment vessels that allow personnel entry but provide a confined working space and limited egress. The SOP must include requirements for ventilating and evaluating the tank or chamber's atmosphere before personnel entry.

13.5 Gun Firings

a. Work, adjustment, or observation shall not be permitted on a gun while a live round is in the firing chamber. The only exception is to check azimuth and elevation.

b. Precautions shall be taken to protect personnel or equipment against hazards resulting from errors in assembly or preparation of equipment and ammunition. In particular, the following areas shall be checked.

(1) Adequate filling of hydraulic recoil mechanisms.

(2) Safe function of the firing mechanisms. (Firing mechanisms, particularly electric firing mechanisms, shall be tested before use to ensure that merely inserting a round or closing of the breech will not result in firing).

(3) Absence of obstructions in the bore.

c. Test weapons other than manually-fired small arms should be equipped for remote control of the safety and for remote cocking. The safety shall not be advanced to the fire position and the weapon shall not be cocked until all personnel are in a safe location.

d. Guns used to fire projectiles at explosives targets shall meet the following criteria.

(1) The gun shall be rigidly mounted so that that the impact area is defined and controlled.

(2) The target shall have an adequate backstop.

(3) Provision should be made to remotely move the gun, remotely remove the propellant charge, or remove the explosives from the line of fire if the gun misfires, unless the hazardous effects of an accidental detonation of the explosive target is contained or effectively shielded from personnel.

(4) Provisions shall be made to collect and remove undetonated explosives from the chamber or area.

e. When using hydrogen gas to fire a light gas gun, the operation shall be remote while hydrogen is present in the gun pressure tanks or in the gun barrel and catch

tank after firing. The hydrogen shall be purged from the entire system with inert gas and the atmosphere checked before personnel are allowed to reenter the gun bay.

13.6 Ballistic, Environmental, Physical Property and Sensitivity Testing

13.6.1 *Checkout of Dynamic Engineering Test Equipment for Explosive Assemblies*

a. To minimize the possibility of an incident during dynamic testing of explosive assemblies, load-bearing members of the test equipment or explosive assembly should be proof-tested and examined if:

(1) The test equipment is new or has undergone a design modification;

(2) Existing test equipment is to be used under unusually severe test conditions (i.e., conditions of velocity, vibration, pressure, load, etc.); or

(3) A new or modified explosive assembly is to be tested that affects the loading characteristics of the equipment.

b. Proof-testing of the explosive assembly or test equipment should be conducted before running tests involving systems with explosives.

c. At a minimum, proof-testing should consist of the following sequence of checkouts:

(1) Check out load-bearing members (lifting devices, hold-down mechanisms, fixtures, vehicle cases) to at least 125 percent of rated load using simulated loads (see section 14.4 of this chapter).

(2) "Dry run" tests of actual systems with mock materials in place of explosives and hazardous radioactive materials.

d. If a part failure occurs in either of the checkout tests in sections 13.6.1c(1) and (2), tests involving explosives or radioactive material shall be run until additional checkout tests have demonstrated that the cause of failure has been eliminated.

13.6.2 *Testing of Explosives and Hazardous Radioactive Materials*

a. Explosives and hazardous radioactive materials (i.e., plutonium, enriched uranium, etc.) shall not be included in the same test or operation if the test or operation is not contained and involves the following:

NOTE 1: Depleted uranium and natural thorium are not considered hazardous radioactive materials for this purpose.

NOTE 2: Nuclear Explosive Operations, covered by DOE 452.2 Series Orders, current version, are exempted from this requirement.

(1) Application of high-energy stimuli (i.e., high shock, impact, or friction levels) to the explosive.

(2) Heating the explosive to within 10°C of the heating limit determined for the explosive system without hazardous radioactive materials consistent with section 12.1.1d of this chapter.

(3) Intimate contact of incompatible material with the explosive as determined by compatibility testing.

(4) Unacceptably high risk of accidental application of stimuli listed in section (1), (2), or (3) above.

13.6.3 ***Heating of Explosives Test Specimens***

a. Before heating an explosive, a thermal analysis shall be conducted and a written procedure prepared consistent with section 12.1.1 of this chapter. See section 12.1.2 of this chapter for requirements on heating equipment.

b. Contact operations on explosives specimens undergoing thermal conditioning may be permitted if:

(1) The specimen will not be subjected to excessive friction, impact, or spark stimuli during normal operations or during a credible accident scenario.

(2) The explosive involved has satisfied appropriate scaleup sensitivity and stability criteria (see Chapter VIII) and has sufficient handling history to reveal any special characteristics affecting safe use.

c. If an explosives test specimen in a contact operation is discovered to have exceeded the established heating limit for the explosive system, the test shall be terminated and the specimen cooled to ambient temperature. A procedure should be prepared and approved for the required corrective action (i.e., disassembly or disposal).

13.6.4 ***Instrumentation***

a. Instrumentation directly applied to explosives in a test specimen shall be physically disconnected, isolated, or grounded before personnel may enter the test cell. Only instrumentation channels that contain devices that limit the current below the level capable of initiating the explosive are exempt.

b. Environmental control transducer leads, not attached to the test specimen and permanently installed in an approved control system, do not need to be grounded or disconnected.

13.6.5 ***Explosives Limits***

a. Explosives specimens shall not be permitted to accumulate in a test cell beyond the quantity required to sustain the test. For short-term testing (less than one day), specimens present shall not exceed a 4-hour supply.

13.6.6 ***Drop Testing***

a. After an explosives drop test, personnel shall wait a minimum of 5 minutes before leaving the control bunker to inspect the test pad. If smoke or flame is observed at the drop test area, entry shall not be permitted until at least 30 minutes after all visual signs have disappeared.

13.7 Test Failures and Misfires

13.7.1 ***Explosives Misfire***

a. If no audible detonation is heard after once pulsing the firing circuit, the firing circuitry and detonators may be checked for continuity. This checking shall be accomplished from within the control bunker or from a protected location. If the firing circuits and detonators appear operative, one or more attempts to fire may be made.

b. If the shot still does not fire, the following precautions shall be taken:

(1) Disconnect and de-energize all electrical power sources connected to the shot.

(2) Ensure that all personnel in the danger zone are aware of the misfire and that they must remain under cover until released.

(3) Before personnel are permitted to leave the cover of the bunker, a pre-established waiting period shall be observed. A minimum 30-minute waiting period is advised.

(4) A carefully prepared review of the situation should be initiated in consultation with another knowledgeable person.

(5) After an agreement has been reached and before other personnel are permitted to leave the cover of the bunker, one qualified person should carefully approach and examine the setup to verify that it is safe.

13.7.2 *Misfire of a Remotely Fired Gun*

a. When a misfire occurs, several more attempts to fire the gun may be made. If subsequent attempts are also unsuccessful, the following precautions should be taken.

(1) Disconnect all electrical circuitry to the gun to ensure that the firing system cannot be energized.

(2) Before approaching a light-gas driven gun, ensure that it is in a safe condition by venting all pressure in the gun breech. To reduce the risk of a gas explosion if the driving gas is flammable, the gun breech shall be purged with inert gas after venting.

(3) An appropriate waiting period shall be observed before permitting personnel to approach to the gun. The waiting period shall be at least 10 minutes.

(4) When approaching the gun, if there is any indication that powder is burning, personnel shall return to a safe area and observe an additional waiting period of at least 20 minutes.

(5) The gun shall not be approached within the known recoil distance behind the breech or from the front. Approach to and work on the gun shall be from the sides.

(6) For separate loading guns (i.e., propellant charge is loaded separate from projectiles), the propellant igniter shall be disconnected from the firing mechanism and removed from the gun before any other gun operations.

(7) If possible, the powder chamber of the gun shall be checked for the presence of pressure and vented to the atmosphere before opening the chamber.

b. If an unforeseen failure situation arises (e.g., the explosive projectile is stuck in the bore), an emergency procedure shall be prepared and followed to resolve the situation.

13.8 <u>Electrical Instruments for Use with Explosives Systems</u>

a. (Except those covered by DOE O 452.2B, current version, *Safety of Nuclear Explosive Operations)*

13.8.1 *Classification*

a. Test instruments shall be categorized based on electrical characteristics that affect safe use with explosives systems. Specifically, the

instrument categories shall be established so that each category can be safely applied to one or more of the following classes of explosives systems:

(1) low-energy or hot-wire initiators (blasting caps, actuators, squibs, etc.);

(2) high-energy initiators (EBWs, slappers, etc.); and

(3) non-initiating electrical circuits.

b. Test instruments not meeting the safety criteria may be used on an explosive system only if the activity is considered a remote operation and adequate personnel shielding or separation distance is provided.

13.8.2 ***Certification***

a. Each DOE facility where electrical test instruments are used on explosives systems shall establish a formal system for reviewing and certifying these instruments. Procedures should also be established for marking instruments to show approved uses and restrictions.

b. Each individual test instrument designated for use on explosives systems shall be certified and prominently labeled with its approved use and with a warning if its use is restricted.

c. Certified instruments shall be inspected and calibrated at prescribed intervals or whenever the instrument is opened for servicing or repair. Access to internal circuitry of certified instruments shall be controlled to prevent unauthorized repairs, maintenance, or alteration.

d. Each DOE facility using electrical instruments to test explosives systems shall maintain records of all instrument types certified. These records should include type, manufacturer, model, electrical specifications, wiring diagrams, and failure mode analyses. DOE facilities management shall notify the Explosives Safety Committee chairperson in writing when new electrical instruments have been approved for use with initiating systems. The chairperson shall disseminate this information to all committee members.

13.8.3 ***Electrical Instruments for Use with Initiating Electrical Circuits***

a. Instruments in this category are used with electrical initiation circuits connected to EEDs and may be further categorized for use with either low-energy initiators or high-energy initiators. Test instruments used for this purpose shall be current-limited. Before being used on initiating circuits, each instrument wiring diagram and internal circuitry design shall be analyzed, examined, and certified for the following:

(1) The output current through resistance equivalent to that of the class's minimum resistance initiator should not exceed 1 percent and shall not exceed 10 percent of the no-fire rating for the class's most sensitive initiator. The current-limiting features of test instruments shall be internal to the instrument and shall not depend on test circuit load characteristics.

(2) The internal circuitry shall ensure isolation features that require a minimum of two independent failure modes before the specified output current can be exceeded.

(3) A comprehensive (point-to-point, if possible) wiring check should be made to ensure that the wiring corresponds to the diagram and that all components are functioning properly and within specifications.

13.8.4 *Electrical Instruments for Use with Non-initiating Electrical Circuits*

a. Instruments in this category are used with electrical circuits connected to strain gauges, pin switches, pressure transducers, thermocouples, electrical components, etc., that are affixed to or within an assembly with explosives. These instruments shall meet the following requirements:

(1) Each specific use of the instrument shall be analyzed to ensure no credible scenario exists whereby the normal test energy from the instrument can ignite explosives charges or initiators in the test. Guidance on operational requirements is contained in sections 13.3.3 and 13.6.4 of this chapter.

(2) Where an instrument is used to make measurements on sensors directly applied to explosives, (e.g., bonded strain gauges or pin switches) the instrument shall be certified and have met the requirements of section 13.8.3 of this section.

(3) Instruments used with non-initiating electrical circuits shall be marked prominently with restrictions on use. Many of these instruments do not meet the requirements for use with initiating systems and must be marked to prevent their use on this type of circuit.

14.0 MATERIALS HANDLING

14.1 General

a. The distance that explosive materials can fall, if accidentally dropped during handling, shall be maintained at a minimum.

b. Hard surfaces and edges of equipment that could be accidentally struck by dropped consolidated explosives should be padded with cushioning mats or coverings whenever possible and needed. (Protective padding includes both sheet material on work surfaces and on equipment and approved floor coverings).

c. Explosives handling shall be permitted only in areas free of obstructions and where the walkway surfaces provide positive footing with no slipping or tripping hazards (e.g., explosives shall not be handled on snowy or icy walkways).

d. Incompatible explosives and materials shall not be handled together.

e. Detonators, actuators, EEDs, and other items normally shipped as Hazard Class/Division 1.4 explosives, should be kept in non-propagating trays or containers unless handled individually.

f. Dry explosive materials that generate dust shall be transported in closed containers.

g. Containers of explosives or explosive assemblies shall be labeled to identify contents during handling, storage, and transportation.

h. Explosives items that cannot be identified and labeled shall be stored as Hazard Class/Division, Storage Compatibility Group 1.1L. A material analysis shall be performed to identify the material before it is returned to inventory or disposed of in accordance with regulatory requirements.

i. Components or devices that contain explosives should not be labeled or marked "inert" or "dummy." Nonconforming items shall be labeled/tagged indicating that they contain explosives. New components or devices containing explosives shall not be labeled or marked "inert" or "dummy."

14.2 Manual Handling of Bare Consolidated Explosives

a. Manual handling shall be minimized as follows:

(1) One person may lift or carry up to 25 kg of explosive only if it can be securely gripped.

(2) Two people may lift or carry 50 kg of explosive only if manual lifting and handling tooling is provided.

(3) Explosive items weighing over 50 kg or that cannot be securely gripped should not be manually handled.

b. Explosives should not be carried up or down stairs except when in protective containers.

c. Operations shall be arranged to minimize the handling distance in all manual explosives handling situations.

14.3 Carts or Hand Trucks

a. Explosives that cannot be handled manually shall be moved only on suitable carts or hand trucks. Carts used to handle bare explosives shall be provided with a padded surface to support the explosives. These carts shall be equipped with either a lip, sides of sufficient height, or tiedown straps to prevent the explosives from sliding or rolling off the cart. The cart-explosive load combination shall have a center of gravity low enough to prevent tipping if the cart suddenly stops.

b. Explosives handling carts or hand trucks should be equipped with brakes. Carts containing explosives shall be positively secured (e.g., setting wheel brakes or chocking) when the cart is stationary.

14.4 Mechanical Handling Equipment

a. All mechanical handling equipment (i.e., cranes, hoists, slings, etc.) used to lift and move explosives or assemblies containing explosives shall be initially proof-tested, periodically inspected, and maintained in first-class working condition. The *DOE Hoisting and Rigging Standard* (DOE-STD-1090-current version) may be used as a guide for testing, inspection, and maintenance.

b. Equipment for vacuum lifting of consolidated explosives must comply with the following requirements:

(1) The lifting equipment shall be designed so that the explosives cannot be dislodged from the vacuum head by jerks or other irregular motions in the hoisting apparatus or bumping of other equipment.

(2) Equipment shall be designed to monitor the available vacuum and to control loss of vacuum if the power or vacuum source fails.

(3) Any handling where a loss of vacuum would allow the explosive to drop an excessive distance shall incorporate some safety device (i.e., collar, net, or strap) to prevent dropping. “Excessive distance” shall be defined as a distance greater than the minimum drop height giving drop-skid initiation for the explosive being handled. “Initiation” in the drop-skid test refers to any indication of sample decomposition. An alternative method of protection can be a cushioning surface under and over all items that may be struck by the falling explosives.

15.0 MATERIALS RECEIPT

a. The following guidelines shall apply to the inspection, receipt, and unloading of explosives materials.

15.1 Motor Vehicles

a. A competent person using an approved checklist at a designated inspection station shall carefully inspect incoming motor vehicles loaded with explosives.

(1) When an inspection reveals that an incoming tractor is in unsatisfactory condition, the tractor should be disconnected from the trailer at the inspection station and moved to a position where it will not endanger any other explosives.

(2) When inspection reveals that a trailer or its load is in an unsatisfactory condition, the trailer shall be moved to a location that, for the particular material involved, is at least inhabited-building distance for the particular material involved from inert and administration areas, hazardous locations, and the facility boundary. At this location, the unsatisfactory condition shall be corrected before the vehicle is moved to its destination within the facility. When moving from the inspection station to the isolated location, the route should be as far as possible from built-up areas and areas with high personnel concentrations.

(3) Vehicles that cannot be immediately dispatched to points where they are to be unloaded may be moved to a holding yard that shall be sited in accordance with Chapter VI, section 3.2.3.

(4) Incoming or outgoing explosives loaded trailers that cannot be exchanged directly between the carrier and DOE facilities may be moved to an interchange yard. Quantity-distance provisions do not apply if the trailers are moved expeditiously.

b. Vehicles shall not be backed up to a dock on which explosives are resting and could be damaged.

c. The receiving facility's doors should be closed while the motor vehicle is in motion or the engine is running. This requirement does not apply to vehicles equipped with spark arrestors or when no exposed explosives are present.

d. Once the vehicle is in position, the engine shall be shut off, the brakes set, and the wheels chocked.

e. After unloading, the vehicle shall be inspected for loose explosives materials. Any spilled material shall be cleaned up after the inspection. Spills involving

liquid explosives or explosives in solution shall be reported immediately to the building supervisor. Appropriate cleanup procedures shall be used.

15.2 Railcars

a. Railcars containing explosives and ammunition entering a DOE facility must be inspected. This inspection comprises the examination of the outside and underside of each car for damage such as defective brakes, couplings, wheel flanges, etc.; for unauthorized and suspicious articles; and to confirm the individual car numbers and seal numbers against bills of lading.

(1) Cars of ammunition or explosives showing a defect that could affect the facility or contents of the car should be removed to the suspect car spur for additional inspection [see Chapter VI, section 3.2.3a(2)].

(2) Cars that satisfactorily pass inspection may be considered reasonably safe, but care must be exercised in breaking car seals and opening car doors because of possible damage or shifted cargo, leaking containers, etc. Interior inspection should be conducted at the unloading point.

15.3 Damaged Shipments

a. Explosives shipments shall be inspected for damage before storage.

b. Contents of a damaged or broken container shall be removed to another container. Spilled materials shall be cleaned up before continuing with loading or unloading.

c. Any shipment received in damaged condition as a result of inadequate or improper blocking and bracing or as a result of not being loaded in accordance with DOT requirements shall not be reshipped until the damage is corrected.

16.0 TRANSPORTATION

16.1 Equipment and Operations

16.1.1 *General*

a. Qualified explosives handlers shall load and unload explosives (see Chapter V, section 3.0)

b. Explosives shipped on common carriers shall be packaged and shipped in accordance with DOT regulations.

c. Explosives containing items transported by special agents in DOE approved secure transporters are governed by DOE Orders 452.2A *Safety of Nuclear Explosives Operations* and 460.1A *Packaging and Transportation Safety*.

d. Section 161.K of *The Atomic Energy Act of 1954* as amended and Title 18 USC, Chapter 40, section 845 govern security and emergency vehicles carrying explosives in support of approved contingency plans.

e. When transferring explosives within facilities, open body vehicles (other than flat bed types) shall have sides and tailgates or rear doors that are strong and securely fastened to safely retain the explosives.

f. The cargo on partly or completely loaded vehicles (including flat bed types) shall be blocked, braced, chocked, tied down, or otherwise secured to prevent shifting during transit.

g. Precautions shall be taken to prevent the exhausts of motor vehicles from igniting explosive material. When a motor vehicle approaches within 25 ft of the doors of a structure through which a shipment is to be moved, the doors shall be kept closed until the motor has been turned off, unless the vehicle is equipped with an exhaust spark arrestor or there are no explosives exposed. Explosives packaged in DOT or onsite containers are not considered exposed.

h. No explosives shall be loaded or unloaded from a motor vehicle while the motor is running unless the motor is required to provide power to vehicle accessories used in loading and unloading operations and is equipped with an exhaust spark arrestor.

i. Onsite movements of explosives shall be in accordance with this Manual and local onsite packaging and transportation procedures. Where there is a conflict, this Manual shall take precedence.

16.1.2 ***Motor Vehicles***

a. Offsite shipments

(1) DOT regulations govern commercial motor vehicle shipments on public highways. Motor vehicle shipments from a DOE installation that meet the DOT definition of "in commerce" comply in full with the applicable portions of DOT regulations, and with state and municipal regulations, except as provided for in these regulations. A qualified inspector shall inspect and approve for compliance with an approved checklist any motor vehicle that may be loaded with explosives (Hazard Class/Division 1.1, 1.2, and 1.3) and is designated for movement over public highways. After loading, the cargo shall be inspected and approved.

(2) Before motor vehicles loaded with explosive materials leave a DOE facility, drivers shall be informed of the nature of their cargo and appropriate measures to take if the vehicle or load becomes involved in a fire.

(3) Drivers of explosive laden vehicles shall meet the pertinent requirements of 49 CFR Parts 390-397.

b. Onsite shipments

(1) All DOE vehicles used to transport explosives onsite should be equipped with the following:

(a) Appropriate Hazard/Class placards plainly visible from all directions. Placards are required for Class/Division 1.4, 1.5, 1.6 explosives when the gross weight exceeds 1000 lbs.

(b) Adequate tie-down bolts, rings, and straps to secure the explosives load.

(c) The cargo area where the explosives are loaded shall be void of any sharp projections. (Non-sparking lining is desirable when hauling explosives in transfer containers that are not DOT approved.)

(d) A quick-disconnect switch on the battery, if explosives are left loaded on the vehicle overnight.

(e) Two fully charged and serviceable fire extinguishers with a minimum rating of 2A:10BC, with one extinguisher

mounted on the outside of the vehicle. Only one extinguisher is required for the transport of Hazard Class/Division 1.4 explosives.

(f) Rear view mirrors on both sides of the vehicle.

(g) One set of chock blocks.

(2) Normal shipments of explosive materials on site shall be packaged in DOT approved containers/packages or in approved onsite containers (refer to Chapter II, section 17.5 for specifics).

(3) Onsite shipments of explosive-designed systems related to experiments or tests that by their nature are not conducive to the requirements of 16.1.2b(2) shall be governed by Chapter II, section 13.2.1 of this Manual and the following:

(a) For shipping purposes, placards and labels shall reflect the appropriate Hazard Classification/Division as assigned by the designated onsite classification authority.

(b) The appropriate authority shall review and approve the designed method of transport for the system.

(c) Drivers shall be knowledgeable of the unique aspects of the system being transported or shall be accompanied by an explosives handler qualified by training and experience to handle the system.

(4) After the EDC has determined that new or developmental explosives meet the necessary testing to establish that they are not forbidden explosives and are at the proper phase of development for the quantity of material being requested, onsite transport shall conform to section 16.1.2b(2) or 16.1.2b(3) of this section.

(5) Security patrol and response vehicles are authorized to transport only the minimum quantity of munitions needed to support approved contingency plans and to execute their security duties. Whenever possible, support munitions required for defense against hostile forces should be pre-positioned in readily accessible magazines.

(6) Security vehicles armed with a combination of up to 25 lbs net explosives weight of Hazard Class/Division 1.1 and 1.2 munitions shall be exempt from explosives

quantity-distance requirements when executing approved contingency plans or security duties. Vehicles so armed will not be used for administrative purposes and will be separated from inhabited facilities and property lines by a minimum of 125 ft when temporarily out of security service. The vehicle shall be downloaded into properly sited magazines or approved facilities when parked for periods in excess of 4 hours. Operation of vehicles loaded with explosives will be restricted to onsite locations and transported explosives must be secured within the vehicle. Smoking in explosives loaded vehicles is prohibited. These vehicles shall be downloaded into properly sited magazines or approved facilities prior to repair or maintenance, except under emergency response conditions.

(7) Security force personnel shall be allowed to transport on their person Hazard Class/Division 1.1 and 1.2 munitions issued to them for personal use in the execution of approved contingency plans and security duties without regard to explosives quantity-distance requirements. Appropriate safety precautions for the ammunition handling shall be observed. Munitions shall be placed in an approved location if temporarily removed from the uniform/load bearing equipment worn to carry such items.

16.1.3 ***Railcars***

a. A railcar must not be loaded with any Hazard Class/Division 1.1 and 1.2 explosives unless it has been thoroughly inspected by a carrier employee qualified to certify that the railcar conforms to DOT regulations. After the carrier has furnished a certified car, the shipper or an authorized employee of the shipper must inspect the interior before starting to load any such car and after loading to certify that the vehicle is in proper condition. A certificate will be completed and signed where applicable. Shipments of Hazard Class/Division 1.3 explosives may be loaded in a closed car or container car in good condition (i.e., sparks cannot enter the car and the roof does not have unprotected decayed wood that constitutes a fire hazard). Wooden-floored cars must be equipped with spark shields. Such cars do not require a car certificate, but must display a placard in accordance with DOT regulations.

b. The railcar certificate, printed on strong tag board measuring 7 by 7 in. or 6 by 8 in., must be executed in triplicate. The carrier must file the original in a separate file at the forwarding station, and the other two must be attached to the car, one to each outer side on a fixed placard board or as otherwise provided.

16.1.4 ***Materials Handling Equipment***

a. Gasoline-powered materials-handling equipment (e.g., forklifts, etc.) may be used only in areas where all explosives are properly packaged and only if equipped in the following manner.

(1) Backfire deflectors shall be the oil-bath or screen type (certain types of air cleaners will serve the purpose) and shall be attached securely on the throat of the carburetor.

(2) A tight-fitting, properly vented cap, shall be in place on the gasoline fill pipe at all times (except during refueling).

(3) A flame arrestor shall be installed in the fill pipe.

(4) If necessary, a deflector plate shall be installed to prevent any gasoline tank overflow from reaching the motor or the exhaust pipe.

(5) On gravity feed systems or on pump systems where siphoning might occur, a shutoff valve shall be installed at the fuel tank or in the feed line to permit shutting off the flow of gasoline in an emergency or a break in the fuel line or carburetor.

(6) Provisions shall be made to prevent fuel lines from rupturing due to vibration.

b. Diesel-powered equipment may be used if all the precautions for gasoline-powered equipment (as specified above) are followed.

c. Battery-powered equipment for handling explosive material shall comply with the criteria listed below.

(1) Battery-powered equipment and its use in hazardous locations shall comply with OSHA standards. All equipment shall be appropriately labeled for ready identification.

(2) Types E, EE, ES, and EX rated, battery-powered equipment are satisfactory for handling all classes of properly packaged ammunition and explosives. Types EE and ES battery-powered equipment may be used to handle packaged explosives or components in corridors or ramps connecting hazardous operations, provided the ramps and corridors are not Class I or II, Division 1, hazardous locations (NEC). Type EE equipment is authorized for use in Class II, Division 2, Group G hazardous locations, and Type ES equipment may be

authorized with facility management's approval (see NFPA 505, Powered Industrial Trucks).

(3) Only Type EX equipment is approved for use in specifically named Class I, Division 1, Group D or Class II, Division 1, Group G hazardous locations. At this time, EX equipment does not carry a dual rating and shall only be used in hazardous areas for which it is specifically rated.

16.2 General Operation Guidelines

a. Explosives-containing items transported by special agents in SSTs are governed by DOE Orders 452.2 and 460.1 series documents.

b. Drivers shall be given special training that emphasizes caution, road courtesy, and defensive driving.

c. The operator of an explosives-transport vehicle shall have proper training in the general safety precautions for explosives handling.

d. Congested areas should be avoided.

e. Road vehicles shall stop at all railroad crossings.

f. No personnel shall ride in the cargo area. Loose items (e.g., handling gear) in the cargo compartments are prohibited.

g. No smoking is allowed in or within 25 ft of any vehicle containing explosives. Matches, lighters, or other fire-, flame-, or spark-producing devices shall not be in the vehicle or carried by personnel in the vehicle.

h. The vehicle shall be subjected to regular maintenance checks.

i. Before shipment by commercial carrier, explosives materials shall be classified by testing or analogy in accordance with DOT regulations.

j. Other than when opened for inspection, containers of explosives shall not be opened or repaired on any transportation vehicle.

k. Except for emergency situations, fueling or maintenance of vehicles containing explosives is forbidden.

l. Each facility shall establish traffic rules governing the operation of explosives-transport vehicles and the operation of other onsite vehicles in the vicinity of explosives-transport vehicles.

m. Industrial trucks shall not be used in locations where high concentrations of dusts or sublimation of explosives may result in contaminated surfaces (e.g.,

screening buildings, pouring bays, melt-pour units, drilling bays, consolidating bays, and explosive washout facilities).

16.3 Emergency Conditions

a. Explosives should not be transported in hazardous conditions (e.g., storms, icy roads, or poor visibility), unless an emergency plan is in effect to provide instruction and guidelines while an explosives-transport vehicle is in transit. The plan should address the following issues:

(1) Parking the vehicle.

(2) Safeguarding the vehicle from other traffic.

(3) Notifying appropriate authorities of the emergency situation.

(4) Leaving the vehicle unattended.

b. A plan shall be prepared to address mechanical breakdowns. The plan shall address the following issues:

(1) Removing the vehicle from the road as far as practical.

(2) Posting emergency reflectors, signals, etc. (carrying flares on the vehicle is not permitted).

(3) Reporting the problem.

(4) Maintaining surveillance of the vehicle.

(5) If necessary, removing the vehicle load to facilitate repair of the vehicle.

c. If an explosives-carrying vehicle is involved in an accident, the following steps should be taken:

(1) Inspect the load for evidence of fire.

(2) If there is a fire, but the explosives material is not presently or imminently involved, attempt to prevent the fire from spreading to the load. The fire may be fought using the vehicle's fire extinguishers. Ensure the security of explosives items removed from the vehicle.

(3) If a fire presently or imminently involves the explosives load, evacuate all personnel to a pre-established safe distance. Block or divert traffic from the vicinity of the accident. Evacuate potentially affected area residents.

(4) Unless the explosive cargo is imminently involved in fire, the operator is to stay with the vehicle until the cargo is properly dispositioned.

(5) Notify the fire department or fire brigade of the accident immediately and inform them of the general type and approximate quantity of explosives involved.

(6) Inform the proper authorities of the accident.

17.0 EXPLOSIVES STORAGE

17.1 Storage Magazine Facilities

a. Permanent explosives facilities shall comply fully with TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," and DOE/TIC-11268, "A Manual for the Prediction of Blast and Fragment Loading of Structures." Portable magazines should be ventilated and resistant to water, fire, and, theft. They can be made of any material that meets these guidelines. (Portable facilities that comply with 27 CFR 55.203 and 55.207 through 55.211, "Bureau of Alcohol, Tobacco and Firearms," (BATF) meet this criteria.) Portable magazines shall be sited per DoD 6055.9-STD as above ground magazines.

b. Placards shall be posted on or near each magazine door, specifying explosive and personnel limits and general safety precautions that should be observed during work in the magazine.

c. Vegetation around storage magazines should be controlled to minimize potential damage to the magazine (see Chapter VI, section 5.1).

d. At least two fire extinguishers, minimum rating 2A:10BC and winterized where necessary, should be provided and maintained for immediate use by personnel working around a magazine. These extinguishers may be located in the area or available on an explosives transportation vehicle. The purpose of these extinguishers is to fight small external fires or magazine fires that do not involve explosives.

e. Suitably rated telephone or other emergency communication equipment should be provided in magazine storage areas. All communication equipment located outdoors should be protected from the weather.

f. Temperature control

(1) In general, storage magazines should not be heated unless heating is necessary to prevent damage caused by sudden temperature changes or when dimensional changes of components are undesirable.

(2) Magazines requiring heat should be heated with steam, hot water, or electrically heated hot water. Some magazines with tight temperature controls may require both heating and air conditioning. Electrical systems with forced air through ducts may be allowed if the systems are located exterior to any explosive hazard.

(3) Heating coils shall be arranged so that explosives material cannot come into contact with the coils. They shall be equipped with covers designed to prevent storage of materials on top of the coils.

(4) Maximum and minimum temperature monitors should be provided in all heated magazines.

17.2 Storage Magazine Operations

a. Explosives items shall be properly packaged and stored in either DOT-approved manufacturers' containers/packages or in specified onsite containers (see section 17.5 of this chapter).

b. Explosives may be stored on magazine shelves. The bottom of the container should not be more than 2 m off the floor, except as permitted by section 17.2c of this section.

c. Explosives and explosives containers in storage shall be positioned safely and securely. If explosives containers must be stacked, they shall be placed in stable arrays.

d. Load limits shall be established for shelving in magazines containing explosives. If overloading is possible, the loading conditions shall be posted.

e. Materials shall not be left suspended by booms, cranes, or hoists in any explosives storage facility.

f. Stored explosives should be segregated by lot designation. Stacks of explosives should be arranged so that air freely circulates to all parts of the stack. To prevent moisture accumulation, pallets or appropriate dunnage should be used to ensure that containers are not stacked directly on the magazine floor.

g. Aisles shall be wide enough to accommodate inspection, inventory, sampling, and materials handling operations of the stored explosives containers.

h. Crews shall not be permitted to work in a position that requires passing the work aisle or the position of a second crew to reach the exit. Unobstructed aisles shall be maintained to permit rapid exit of personnel.

i. Each crew working in a magazine must have their own exit route that does not interfere with exit routes for other crews.

j. Magazines shall be locked at all times except when permissible operations are in progress or opened for ventilation. Personnel shall be present while the magazine

is open for ventilation. All exit doors shall be unlocked and open when personnel are working in the magazine.

k. Each magazine shall be inventoried at least annually to determine the total weight of explosives present (to assure this weight conforms to allowable quantity-distance constraints) and to remove and destroy materials that are not properly identified or labeled.

l. The liquid level in storage containers for wet explosives shall be checked and replenished as necessary at least once a year. A log of the checks shall be maintained.

m. Empty containers, tools, conveyors, lift trucks, skids, etc., should not be stored in a magazine containing explosives.

n. Combustible materials such as excess dunnage, packing material, and boxes shall not be stored in a magazine containing explosives.

o. Flammable liquids shall not be stored or used in explosives magazines unless the liquid is an explosive, is needed as an explosives-wetting agent, or is an integral part of an explosives device.

p. Operations in and around magazines shall be prohibited when an electrical storm is in progress and minimized when it is evident that such a storm is approaching.

q. Explosives-handling operations shall not be performed when magazine entranceways are icy or do not provide adequate footing for any other reason.

r. Unless excepted, no operation in which hazardous materials are involved shall be permitted in any magazine. The following exceptions are recognized.

(1) Those operations incident to storage or removal from storage.

(2) Inspection and surveillance sampling of compatibility Group D materials, and Group C materials consisting of bulk propellants and IHE, provided that each storage container sampled is in good condition (i.e., the container is not leaking, no evidence exists of explosives contamination at the closure or of seal failure, and the closure is mechanically sound and free of excessive corrosion, etc.). Only one container of explosives shall be opened at one time in a magazine.

(3) Adding liquid to adjust the liquid composition level in which a Group D explosive is stored. (Water and alcohol mixtures may be used). If only water is added to the explosive, the water should be

distilled or deionized. Bacteria present in untreated water may produce gas during storage).

17.3 Storage Review Program

a. Each facility shall establish a program to review the explosive materials stored at that facility. Explosives may degrade during prolonged storage, increasing the hazards of handling or use. The following procedure is provided as an example.

(1) A storage review date should be assigned to each bulk explosive placed in storage. The storage review date should be shown on or adjacent to the identification tag or sticker attached to every container or package of explosive in storage or should be listed in the inventory records.

(2) Storage review intervals should be based, whenever possible, on stability data. A safe storage interval should be considered as that time period, at maximum anticipated storage temperature, during which an explosive material can be conservatively expected to show an acceptable level of decomposition.

(3) Facility management should designate or create a storage review committee to establish and approve storage review intervals for all explosives stored at the DOE facility. Also, the committee should prescribe for each explosive appropriate tests to evaluate the safety of handling and processing the material after it has exceeded its storage review interval. These tests may be referred to as "stability tests," although sensitivity, or other types of testing, may be included in the material evaluation program. In some cases, the review committee may simply require periodic stability testing rather than establishing a storage review interval (i.e., nitrocellulose, single- and double-base propellants, etc.).

(4) To store a new explosive, to increase (or decrease) the review interval for a previously approved material, or to use different stability test data for an explosive, the following procedure should be used:

(a) A responsible person should communicate the request to the storage review committee.

(b) If the request concerns storage of a new explosive, the individual should recommend a storage review interval and stability-evaluation testing.

(c) Supporting data should be supplied with the recommended review interval and proposed stability tests for the explosive.

(d) The storage review committee should review the request and supporting data and then prescribe a storage review interval and stability tests as appropriate.

(e) A new explosive should be assigned an interim storage review and stability test interval before Phase II scaleup (see Chapter VIII).

(f) The following general guidelines are offered to assist the storage review committee in establishing review intervals when there is insufficient stability information to predict storage life.

1 If no information is available on a new material relative to storage stability, a review interval of 90 days or less should be assigned.

2 A new formulation should be assigned a storage review interval not exceeding that of its least stable component.

3 If the compound or formulation is new to DOE but DoD agencies have extensive experience with it, the DoD information should be used conservatively.

4 For a formulation or ingredient with a manufacturer-assigned shelf life, a review interval that exceeds the recommended shelf life should not be assigned unless additional DOE tests indicate such storage is warranted.

(5) A storage review interval of up to 20 years should be permissible for an explosive if a conservative evaluation of stability data indicates that such an interval is justified.

17.4 Storage Compatibility

a. Explosives shall not be stored with materials or items that increase the risk of initiation or decomposition. Examples are mixed storage of explosives with flammable or combustible materials, acids, or corrosives.

b. Different types of explosives may be stored in the same magazine if they are compatible. Explosives shall be assigned to a storage compatibility group when they can be stored together without significantly increasing either the

probability of an accident or, for a given quantity of explosive, the magnitude of such an accident.

c. Each type of explosive shall be assigned to an appropriate storage compatibility group (A through G, L, and S) for the purpose of storage at DOE facilities. The nine groups are defined in the following sections. These definitions and Table II-4 *Storage Compatibility Mixing Chart*, are in accordance with the principles and tables in DoD 6055.9-STD, DoD *Ammunition and Explosives Safety Standards*. Table II-4 presents some examples of commonly used materials that are assigned to each storage compatibility group. This list does not enumerate all materials that may be included in each group.

(1) **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. Examples are lead azide, lead styphnate, mercury fulminate, and tetracene.

(2) **Group B**—Detonators and similar initiating devices not containing two or more independent safety features. Items containing initiating explosives that are designed to initiate or continue the functioning of an explosives train. Examples are detonators (all types, excluding EBWs and slappers), blasting caps, small arms primers, and fuzes.

(3) **Group C—**Bulk propellants, propellant charges, and devices containing propellant with or without their own means of initiation. Items that will deflagrate, explode, or detonate upon initiation. Examples are single-, double-, triple-base, and composite propellants, rocket motors (solid propellant), and ammunition with inert projectiles.

(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. This group shall include explosives and ammunition that can be expected to explode or detonate when any given item or component thereof is initiated.

(5) **Group E**—Explosives devices without their own means of initiation and with propelling charge (other than one containing a flammable or hypergolic liquid). Examples are artillery ammunition and rockets.

(6) **Group F—**Explosives devices with their own means of initiation and with or without propelling charge.

(7) **Group G**—Pyrotechnic materials and devices containing pyrotechnic materials. Examples are devices that when functioning, result in an incendiary, illumination, lachrymatory, smoke, or sound effect.

(8) **Group H**—Ammunition containing both explosives and WP or other pyrophoric material. Ammunition in this group contains fillers, which are spontaneously flammable when exposed to the atmosphere. Examples are WP, plasticized white phosphorus (PWP), or other ammunition containing pyrophoric material.

(9) **Group J—**Ammunition containing both explosives and flammable liquids or gels. Ammunition in this group contain flammable liquids or gels other than those that are spontaneously flammable when exposed to water or the atmosphere. Examples are liquid or gel filled incendiary ammunition, fuel-air explosive (FAE) devices, flammable liquid fueled missiles, and torpedoes.

(10) **Group K**—Ammunition containing both explosives and toxic chemical agents. Ammunition in this group contain chemicals specifically designed for incapacitating effects more severe than lachrymation. Examples are artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent.

(11) **Group L**—Explosives or ammunition not included in other compatibility groups which present a special risk, requiring isolation of each type. This group shall include explosives or ammunition having characteristics that do not permit storage with other similar or dissimilar materials. Examples are damaged explosives, suspect explosives, and explosives, explosive devices or containers that have undergone severe testing unless documented determination is made that these items do not present a special risk; fuel/air explosive devices, and water-activated devices. Also included are experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures and salvaged explosives until they have been established to be compatible with the original materials. Types presenting similar hazards may be stored together.

(12) **Group N**—Hazard Division 1.6 ammunition containing only extremely insensitive detonating substances (EIDS).

(13) **Group S**—Explosives, explosive devices, or ammunition presenting no significant hazard. Explosives or ammunition so designed or packed that when in storage any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder fire fighting. Examples include: explosive switches or valves and small arms ammunition.

d. Mixing of Storage Compatibility Groups may be permitted as indicated in Table II-5. Items from Storage Compatibility Groups B, C, D, E, F, G, and S may be combined in storage if the items are in approved containers and if the net quantity of explosives in the items (or in bulk) does not exceed 1,000 lb. Each article of Storage Compatibility Groups B and F shall be segregated in storage from those of other compatibility groups by means that will prevent propagation of those articles.

e. Newly synthesized compounds and mixtures shall be stored in Group L storage facilities. After more complete evaluation, the EDC shall assign those compounds or mixtures of continuing interest (see Chapter VIII, section 1.1) to the appropriate compatibility group, and stored according to the following considerations:

(1) The material's sensitivity to initiating stimuli (i.e., friction, impact, spark, shock, and thermal) is similar to that of other explosives in the group.

(2) The material's reactions and the effects of these reactions, in the event of application of initiating stimuli, are similar to other members of the group.

(3) The material is chemically compatible with other materials in the group. Sensitivity and compatibility testing is described in Chapter VIII.

f. As an alternate to Table II-4 and Table II-5, samples of explosives up to 4.4 lbs (2 kg) total, may be stored in the same cubicle if the cubicle walls are designed to prevent propagation. The material shall be stored in separate cubicles in one of the following categories:

(1) High explosives.

(2) Propellants.

(3) Detonators, actuators, and similar devices.

(4) Primary and static-sensitive explosives.

Table II-4. Storage Compatibility Groups for Explosives and Explosive-Containing Devices

Group A Initiating explosives.	
• CP (5-Cyanotetrazolpentaamine Cobalt III Perchlorate)	
• HMX (Cyclotetramethylene tetranitramine) (dry)	• PETN (Pentaerythritol tetranitrate) (dry)
• Lead azide	• RDX (Cyclotrimethylene trinitamine) (dry)
• Lead styphnate	• TATNB (Triaziodotrinitrobenzene)
• Mercury fulminate	• Tetracene
Group B Detonators and similar initiating devices.	
• MDF (mild detonating fuse) detonator assemblies	• Blasting caps
• Detonators excluding EBWs and slappers	• Pressure cartridges
• Explosive bolts	• Primers
• Fragmenting actuators	• Squibs
• Igniters	
Group C Bulk propellant, propellant charges, and devices containing propellants with or without their own means of initiation. This Group also includes some IHEs.	
• Smokeless powder	• TATB (Wet)
• Pistol and rifle powder	• LX-17
• Rocket-motor solid propellants	• PBX-9502
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 explosive substance and containing two or more effective protective features.	
• Ammonium picrate (wet)	• HMX (Cyclotetramethylene tetranitramine)
• Baratol	• HMX/wax (formulated with at least 1 percent wax)
• Black Powder	• HNS (Hexanitrostilbene)
• Boracitol	• Linear-shaped charge
• Compositions A, B, and C (all types)	• Methyl dinitorpentanoate
• Cyclotols (not to exceed a maximum of 85 percent RDX)	• Nitroguanidine
• DATB (diaminotrinitrobenzene)	• Octol
• Detasheet	• Pentolite
• Detonating cord (primacord or mild detonating fuse)	• PETN (Pentaerythritol tetranitrate) (wet)
• Bis-Dinitropropyl adipate	• PETN/extrudable binder
• Bis-Dinitropropyl glutarate	• Plastic Bonded Explosives, PBX (a Group D explosive formulated with a desensitizing plastic binder)
• Bis-Dinitropropyl maleate	
• Dinitropropane	
• Dinitropropanol	• Potassium picrate
• Dinitropropyl acrylate monomer (DNPA)	• RDX (Cyclotrimethylene trinitramine) (wet)
• Dinitropropyl acrylate polymer (PDNPA)	• TATB (Triamino trinitrobenzene)(dry)
• EBW and slapper detonators	• TATB/DATB mixtures
• Elastomeric plastic bonded explosives	• Tetryl
• Explosive D	• TNT (Trinitrotoluene)

Table II-4. Storage Compatibility Groups for Explosives and Explosive-Containing Devices (cont.)

Group E	**Explosives devices without their own means of initiation and with propelling charge.** • Artillery ammunition • Rockets (e.g., 66-mm LAW)
Group F	**Explosives devices with their own means of initiation and with or without propelling charge.**
Group G	**Pyrotechnic material and devices that produce an incendiary, illumination, lachrymatory, smoke, or sound effect.** • Smoke pots • Flares • Incendiary ammunition
Group K	**Ammunition containing both explosives and toxic chemical agents.**
Group L	**Explosives or ammunition not included in other compatibility groups that present a special risk requiring isolation of each type.** • Damaged or suspect explosives, explosive devices or containers. • Experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and some salvaged explosives.
Group N	**Hazard Division 1.6 articles containing only extremely insensitive detonating substances (EIDS).**
Group S	**Explosives and Ammunition that presents no significant hazard. Items are packaged or designed so that any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder firefighting. Examples include the following:** • Cable cutters • Cartridge actuated valves • Linear actuators (e.g., dimple, piston, bellows motors) • Safety fuze • Small arms ammunition
Materials and Systems that need not be stored or labeled as explosives unless they are near other explosives that could initiate them.	When near explosives, these materials become Group D, unless otherwise indicated. • FEFO/SOL (35 wt percent or less FEFO in ethyl acetate) • FEFO/solution • Group D explosives in inert solvents (explosive concentration not exceeding 25 wt percent) • Nitrates; treat as Group C when with other explosives • Perchlorates; treat as Group C when with other explosives • Small arms ammunition classified for shipment by DOT as ORM-D (Other Regulated Material Class D) rather than Hazard Class/Division 1.4 explosives. Normally consists of ammunition not exceeding 50 caliber for handguns and rifles and 8 gauge for shotguns.

Table II-5. Storage Compatibility Mixing Chart

Groups	A	B	C	D	E	F	G	H	J	K	L	N	S
A	X	Z											
B	Z	X	Z	Z	Z	Z	Z					X	X
C		Z	X	X	X	Z	Z					X	X
D		Z	X	X	X	Z	Z					X	X
E		Z	X	X	X	Z	Z					X	X
F		Z	Z	Z	Z	X	Z					X	X
G		Z	Z	Z	Z	Z	X					X	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	X	X					X	X
S		X	X	X	X	X	X	X	X			X	X

NOTES:
- An "x" in a block of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to the following sections.
- A "z" in a block of the above chart indicates that when warranted by operational considerations or magazine availability, and when safety is not sacrificed, these groups may be combined in storage. Combinations that violate the principles of section 17.4.0 in Chapter II require justification by an exemption.
- No mark in a block indicates that combined storage is not permitted. L compatibility group types presenting similar hazards may be stored together but not mixed with other groups.
- K compatibility group requires not only separate storage from other groups, but also may require separate storage within the group.

17.5 Containers (Onsite)

a. Explosives containers shall be designed and constructed so they will not leak and will protect their contents from excessive movement, external stimuli, contamination, or spillage during handling, transportation (including transportation to disposal sites), and storage. Container closures shall prevent spilling or leakage of contents if the container is overturned. Screw-type container closures should not be used.

b. Explosives containers should be constructed of, or lined with, nonabsorbent materials that are compatible with the explosive contents. Use of glass containers is discouraged, except for small samples, and shall be used only when the explosive reacts with other materials or when a high degree of purity is required.

c. Metal containers for materials that are potential dust producers shall be constructed without seams or rivet heads. Seams or rivet heads can provide locations for dust accumulation.

d. Containers for cast or pressed explosives pieces that are larger than 1 ft (0.3 m) at their greatest dimension or weigh more than 11 lb (5 kg) loaded should be provided with handles or some other type of handhold. If the loaded container weighs more than 110 lb (50 kg), provisions should be made to allow handling by mechanical handling equipment.

e. Containers shall be labeled with the applicable UN hazard classification code and clearly marked to identify the contents.

f. Whenever possible, explosive pellets and items containing small quantities of explosives (e.g., detonators) shall be packaged in containers constructed so the functioning of one item will not propagate to the remaining items in the container. When a nonpropagating array is not possible, the pellets or detonators shall be stored inside a closed container and shall be labeled to indicate the total weight of the explosive contents.

g. Container closures shall be the type that will not apply excessive pinching or rubbing forces to explosives during closing and opening. The closures and surfaces of container openings shall be kept clean of explosives contamination to minimize any hazard during closing and opening.

h. Explosives and ammunition in damaged containers shall not be stored in a magazine with other explosives and ammunition. Damaged containers shall be repaired, or the contents transferred to new or undamaged containers, or the container plus contents moved to a Group L storage magazine.

i. Open containers and containers with covers not securely fastened shall not be stored in magazines. Containers that have been opened shall be properly closed before being returned to storage.

17.6 Storage in Buildings Other Than Storage Magazines

17.6.1 *Packing and Shipping Buildings*

a. In buildings specifically designated for packing and shipping, explosives may be stored subject to the following rules.

(1) Incoming shipments shall be distributed as soon as practical after receipt and shall not be allowed to accumulate.

(2) Items for outgoing shipments should not be accumulated before receipt of orders covering each specific shipment.

(3) Separate rooms shall be provided for the temporary storage of explosives awaiting shipment and for their preparation for shipment (i.e., assembling, crating, marking, etc.). The rooms shall be divided by walls or separated to prevent an explosion in the preparation area from propagating to the temporary storage area.

(4) The combined total amount of explosives permitted in shipping/receiving buildings, platforms, and transportation vehicles shall be based on quantity-distance constraints. When an adequate barricade (sufficient to prevent sympathetic detonation) is in place between transportation vehicles and the adjoining building or platform, quantities on each side of the barricade may be considered individually to determine quantity-distance requirements.

(5) If required by operational necessity, explosives and pyrotechnics that are part of the work in process within the building may be stored during non-operational hours in operating buildings provided:

(a) Explosives limits are not exceeded.

(b) Containers of bulk explosives or pyrotechnics are properly secured and covered.

(c) Processing equipment, such as hoppers and pipelines, is empty.

17.6.2 ***Service Magazines***

a. The guidelines for storage magazines presented in sections 17.1 through 17.5 of this chapter shall also apply to service magazines, except as modified below:

(1) An explosives item should be stored for no longer than necessary in a service magazine (with a maximum of 180 days).

(2) Service magazine inventory should be reviewed every three months. Any material that has been in the service magazine for a period approaching 180 days and is not expected to be used immediately should be disposed of or removed to an appropriate storage magazine.

(3) When practical, explosives stored in service magazines shall be in containers. Unpackaged explosives-containing devices and unsealed bulk explosives containers may be present in a service

magazine. However, these items and unsealed containers shall be stored in a manner that renders them stable and unlikely to be dropped or spilled.

(4) Minimum/maximum temperature monitors are not normally required for service magazines.

17.6.3 ***Warehouses***

a. Hazard Class 1.4 materials (see Chapter VI, section 3.1) packaged as Hazard Class/Division 1.4, Storage Compatibility Group S, may be stored in warehouses if they are placed in segregated and specifically designated areas.

b. Articles in Hazard Class/Division 1.4 and Storage Compatibility Group S are considered inert for storage purposes and are not subject to quantity-distance requirements as long as they are stored with inert items or other Hazard Class/Division 1.4S items only. This applies only if Hazard Class/Division 1.4 and Storage Compatibility Group S articles remain in their original packaging container or are proven to be self-contained. When stored with items in a Storage Compatibility Group other than S, normal quantity-distance requirements must be observed.

17.6.4 ***Pre-positioned Storage of Security Response Munitions***

a. When required for defense against hostile forces, and in support of response and contingency plans, limited quantities of authorized response force munitions may be pre-positioned at locations other than bulk-storage magazine areas.

b. Compliance with Quantity-Distance and compatibility criteria is not required during a heightened security condition.

c. Munitions will be kept in their original shipping containers unless operational necessity dictates otherwise.

d. Personnel charged with the responsibility of overseeing storage of munitions at guard stations and contingency deployment sites shall be trained in explosives storage and transportation, as required in Chapter V of this Manual.

e. When Hazard Class/Division 1.2 is stored inside or at less than inhabited-building distance from inhabited buildings, fragment barriers will be provided. Minimally acceptable fragment barriers are: 0.25 in. (6.35 mm) of mild steel plate, one layer of sand bags, 12 in. (.3 m) of loose sand or dirt, or other equivalent protection.

18.0 DECONTAMINATION AND CLEANING

18.1 General

a. Operating procedures shall specifically cover decontamination. These procedures should cover methods, inspection, marking, control, dismantling, maintenance, final disposition, etc.

b. Hot water or steam may be used to clean or remove explosives contamination from equipment. If necessary, solvents that have been tested for and are compatible with explosives can be used. Operating procedures must specify controls for their use. When cleaning or removing explosives material from equipment, work surfaces, and floors, only clean cloth rags, paper wipes, and approved non-metallic brushes or scrapers should be used in conjunction with hot water, steam, and solvents.

c. Disposal of waste generated during decontamination shall be coordinated with site environmental/waste management personnel.

18.2 Cleaning Contaminated Equipment

a. Items to be cleaned should be positioned so that water and residue will drain directly into an approved collection system. See sections 19.0 and 20.0 of this chapter for guidance concerning waste collection and waste disposal.

b. Personal decontaminating facilities and equipment shall use personal protective equipment as required. Emergency shower and eyewash shall be provided where needed.

c. Exhaust ventilation may be required to remove toxic explosives fumes, vapors, or steam from the decontamination area.

18.3 Cleaning Screw Threads

a. To avoid the necessity of cleaning explosives from threads, explosives processing techniques shall be designed to prevent explosives from being deposited on threaded fasteners. When screw threads are required, covering or protection (i.e., RTV cement) over the exposed threads should be provided.

b. Threads should be cleaned by judicious use of approved non-metal “picks,” solvent, hot water, or steam. Soaking in solvents and applying penetrating oil may be useful.

c. After decontaminating threads of screws, bolts, pipe, etc., operator protection may still be required to facilitate safe disassembly.

18.4 Final Decontamination and Disposal of Equipment

a. If the item to be decontaminated has only smooth, flat surfaces (i.e., no cracks, seams, voids, or other places where explosive residue may be inaccessible), hot water, steam, or solvents may be employed to effect total decontamination. Any explosives contamination of concern will be visible to the unaided eye and will have dimensions (length, width, and depth).

b. If the item to be decontaminated has tight places where explosives may remain lodged following normal cleaning procedures, the item shall be subjected to final decontamination techniques that may include partial disassembly.

(1) Items undergoing final decontamination by thermal techniques shall be subjected to sustained heating at a temperature at least 60°C higher than required for decomposition of the most thermally stable explosive substance present. The item shall be kept at that temperature for a sufficient period of time to ensure that all parts have reached the temperature and all explosives material is decomposed. Thermal decomposition is usually accomplished by placing the items to be decontaminated in a high-temperature sustained fire (see TB 700-4, *Decontamination of Facilities and Equipment*). This operation shall be conducted remotely or with operator protection.

(2) Final decontamination also may be accomplished by immersing the item in a chemical cleaning agent. The period of immersion shall be sufficient to ensure that all explosive material is chemically decomposed. The chemical cleaning agent shall be one that the Department of the Army TM 9-1300-214 (*Military Explosives*) has approved for use. Chemical cleaning agents for decontamination or destruction of explosives should not be used for more than about 1 oz. (or about 28 g) of explosives. Reference U.S. Department of the Army TM 9-1300-214 for decontaminating chemicals for explosives and for color tests for identification of energetic materials.

(3) Before subjecting an item to final decontamination by thermal or chemical techniques, as much explosive as possible shall have been removed by approved means (hot water, steam, and approved solvents in conjunction with cloth or paper wipes and non-metallic brushes or scrapers).

18.5 Inspection

a. After decontamination procedures are complete and before transfer to a nonexplosive area, the item shall be inspected. The degree of decontamination shall be determined/documented and the item shall be labeled to indicate its decontaminated state. Representatives of at least two departments, such as operations or safety, should accomplish the inspection.

18.6 Identification and Control of Decontaminated Items

a. Decontaminated items shall be marked to indicate the degree of decontamination and stored separately from non-contaminated items until final disposition is made.

b. Degrees of decontamination shall be designated and all items shall be tagged and/or marked with this designation.

c. Guidelines for establishing a system to designation degrees of decontamination are provided below.

(1) **X**—A single X indicates that the facilities or equipment have been partially decontaminated. Additional decontamination processes are required before facilities or equipment are moved or any maintenance, repair, etc., is performed. The X rating would apply to facilities, rooms, bays, or equipment that have been subjected to routine decontamination performed by an operator at the close of the workday.

(2) **XXX**—Three Xs indicate the equipment or facilities have been examined and decontaminated by approved procedures; no contamination can be detected by appropriate instrumentation, test solutions, or by visual inspection on easily accessible surfaces or in concealed housings, etc., and are considered safe for the intended use. Items decontaminated to this degree cannot be furnished to qualified DOE, DoD, or industry users or be in direct contact with an open flame (cutting, welding, high temperature heating devices), or operations which generate extreme heat, such as drilling and machining unless the following two conditions are met:

(a) It has been determined that decontamination to the XXXXX level will destroy the item's usefulness.

(b) Decontamination to a degree less than XXXXX in combination with administrative and technical safeguards will eliminate risk of injury. As a minimum, an approved SOP setting forth the specific operational limitations, precautions, and monitoring necessary to assure safety will be available and decontamination will be performed under the direction of the inspectors who will certify decontamination.

(3) **XXXXX**—Five Xs indicate the equipment or facilities are completely decontaminated, hazard-free, and may be released for general use or to the general public.

(4) **0**—A zero indicates the item, although located in a contaminated area, was never directly exposed to contamination.

d. Reference U.S. Department of the Army TB 700-4, "Decontamination of Facilities and Equipment" for decontamination methods and marking.

18.7 Decontamination of Real Estate

a. For decontamination of real estate reference DoD 6055.9-STD.

18.8 Decontamination and Cleaning References

a. In addition to this Manual, the following are reference sources for decontamination and cleaning.

(1) DoD 6055.9-STD, "Department of Defense Ammunition and Explosives Safety Standard," Assistant Secretary of Defense (Force Management and Personnel), Chairman Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(2) Department of the Army Technical Bulletin TB 700-4, "Decontamination of Facilities and Equipment," Army AG Publications Center, St. Louis, MO.

(3) Department of the Army Technical Manual TM 9-1300-214, "Military Explosives," Army AG Publications Center, St. Louis, MO.

19.0 WASTE COLLECTION

19.1 General

a. Provision shall be made to remove explosives waste from areas where explosive waste is generated. Removal of explosives waste may be accomplished by collecting dust/fines or chips in a wet or dry vacuum system or a slurry of water or nonflammable solvent, or by collecting solid waste in receptacles (see also Chapter II, sections 9.0, 10.0, and 11.0).

b. Explosives waste shall be collected and maintained separately from conventional waste.

c. Mixing of incompatible explosive waste shall be avoided. Receptacles shall be clearly labeled to indicate the type of waste permissible.

19.2 Solid Wastes

a. Areas where solid explosives wastes are not removed by vacuum or liquid systems shall be equipped with a seamless or lined receptacle to collect explosives wastes. The receptacle should never be more than half full.

b. Explosives waste shall be removed from the collection point on a regularly and frequently enough to keep aggregate levels within explosive weight limits.

c. Rubbish not contaminated by explosives or containing noncombustible materials shall not be placed in an explosives waste receptacle.

d. Explosives-contaminated rubbish shall be placed in separate waste containers and segregated as combustibles and noncombustibles.

e. Before being transported, explosives waste shall be packaged to prevent spills, leaks, or exposure to initiation stimuli. Incompatible materials shall not be packaged together. All packages of explosives waste shall be labeled clearly to indicate the nature and approximate quantity of contents.

19.3 Vacuum Collection of Explosives Dusts

a. Explosives dusts should be collected by a vacuum system, preferably the wet type. Dust in a wet vacuum should be maintained in wet form using a wetting agent that is kept close to the point of origin and kept wet in the collection system until removed for disposal. Water-soluble explosives such as Explosive D should be collected in a dry vacuum system.

b. Storage compatibility Group A explosives may be collected by a wet vacuum system, provided they are maintained in a wet form using a wetting agent that is kept close to the point of intake. Use of a vacuum system to collect these more

sensitive materials should be confined to operations involving small quantities of explosives.

c. Dry-type dust collection chambers, except portable units, should be located in the open, outside operating buildings, or may be inside if adequate shielding is provided. The quantity of explosives collected shall not exceed the capacity of the shielding to protect operating personnel. The degree of barricading and the appropriate intraline distance shall determine this limit.

d. If dry dust collection outside a building is not practical, a separate room or shielded area within the building shall be designated for this purpose. This room or shielded area shall not contain other operations or be used as a communicating corridor or passageway between other operating locations within the building when explosives are being collected.

e. Stationary and portable wet-type collectors may be placed in the explosives operating bays or cubicles if the quantity of explosives in the collectors does not exceed 4.4 lbs (2 kg). If placed in separate cubicles, the explosive weight limits may be increased by an amount determined by the extent of the cubicle walls' capabilities to serve as operational shields.

f. Collection systems and chambers shall be designed to prevent explosives from being pinched between metal parts. See sections 9.0 and 10.0 of this chapter for additional design information.

g. Two collection chambers shall be installed ahead of the pump or exhauster in series to prevent explosives dust from entering the vacuum producer in dry vacuum collection systems. In addition, non-sparking fans and dust-tight motors shall be used.

h. Dry-type portable vacuum collectors shall not be located in bays or cubicles where explosives are present or in enclosed ramps, but may be positioned outside the building or in a separate cubicle. The building or cubicle walls shall provide adequate shielding for at least 4.4 lbs (2 kg) of explosives. Shielding and quantity-distance constraints shall define the explosives limits.

i. Explosives dust shall be removed from the collection chamber periodically to eliminate unnecessary and hazardous explosives concentrations. The entire system should be cleaned periodically, dismantling the parts if necessary. A cleaning schedule shall be established for the collection chamber and the entire system using the operating hours as a basis.

j. The entire explosives-dust collecting system shall be electrically bonded and grounded with resistance-to-ground not exceeding 10 ohms. The grounds shall be tested periodically.

19.4 Explosives Slurries

a. Machine tools shall be fitted with wet boxes to catch and direct water and explosives fines to an explosives waste gutter system.

b. Wastewater that might contain explosives materials shall be kept from contaminating potable water or conventional wastewater systems.

c. Settling tanks shall be inspected regularly to monitor the waste accumulation. Records of waste removal shall be kept.

d. When pumping settled explosives from a slurry-settling tank, the operation shall be arranged to preclude exposure of the explosive material to pinching.

e. Explosives materials in settling basins shall be kept wet until removed. The materials shall be maintained wet until spread out for disposal. Explosives materials containing powdered metals shall be kept sufficiently wet to prevent a dangerous temperature rise resulting from a reaction of the metal with water. The possibility of hydrogen generation in this situation must be anticipated. If an explosive or flammable gas can be generated, then proper ventilation shall be supplied to prevent an explosive or flammable mixture from accumulating.

19.5 Metal Scrap

a. Metal scrap shall be inspected to detect explosives-contaminated items and a qualified reviewer shall certify that the scrap is free of explosives before disposition.

b. When scrap is found to be contaminated with explosives, it shall be decontaminated in accordance with final decontamination procedures (see section 18.4 of this chapter).

19.6 Explosives Recovery and Reuse

a. Salvaged explosives materials shall be thoroughly inspected by operating supervisors and reused, screened, reprocessed, or destroyed as the situation warrants.

b. Salvaged explosives materials shall be classified as Storage Compatibility Group L until they have been established to be compatible with the original material.

20.0 WASTE DISPOSAL

20.1 Preparation for Open Burning

a. Preparations to burn or place explosives waste on a pad or in a pit shall not begin until 24 hours after the previous burn at the same burning point. The only exception is if the burning area has been thoroughly soaked with water and inspected by qualified personnel to assure personnel safety during subsequent burning operations. In any case, the burning point shall be inspected for residual embers or hot spots before loading with explosives.

b. Before beginning preparations, firing controls shall be disconnected power sources and circuits shunted and grounded.

c. Some explosives give off toxic vapors or fumes when destroyed by burning. Proper respiratory protective equipment shall be worn when such hazards are likely.

d. Incompatible explosives materials shall not be in the same pit or on the same pad at the same time.

e. Personnel engaged in burning explosives should be provided with non-static producing cotton clothing.

f. Containers of explosives materials shall not be opened less than 10 ft (3 m) from each other.

g. Empty explosives waste containers that are to be reused shall be situated an adequate distance from the burning point to prevent charring or damage during the destruction operation.

h. Based on past experience or analysis, a layer of excelsior or similar material may need to be placed on the bottom of the pit or pad where the explosives waste will be placed.

i. Powdered, granular, or slurry form explosives should be placed in a layer not more than 8 cm thick. Water-wet initiating explosives (storage compatibility Group A) shall not be allowed to dry completely.

j. Wood, heating oil, LPG, or natural gas is authorized to ensure complete combustion of the explosives waste material.

k. The ignition train should be set up to burn upwind, except that the ignition train for burning IHE may be set to burn downwind.

l. The firing circuit shall require a key for completion. Only one copy of the firing key shall exist, and it shall be in the lead operator's possession.

m. Radio transmitters and cellular phones in the control shelter and vehicles at the burning site shall be turned off during setup and firing of low energy electrical squibs to provide protection against radio frequency currents.

n. Precautions shall be taken to ensure that extraneous electrical currents from any source will not unintentionally activate the firing system.

o. The burn shall be primed after all other preparation work is complete and with a minimum number of personnel present.

p. Ignition shall be accomplished remotely.

20.2 Destruction by Burning or Flashing

a. Open burning operations will comply with the requirements of applicable Federal, State, and local air pollution, hazardous waste, and other environmental regulations and permits.

b. Explosives waste may be destroyed by remote burning if it can be done with little chance of detonation. Explosives-contaminated waste may be burned remotely in a wire cage.

c. An open furnace or burning area for explosives should be used to destroy wet-machining cuttings and classified parts. The same furnace or burning area may also be used for flashing casings after washout of an explosive charge.

d. Explosives should not be burned in closed containers or casings, or in large pieces likely to detonate. Special attention should be given to the placement and orientation of large items and those in closed containers or casings. Approved incinerators may be used to destroy small devices such as detonators, actuators, etc.

e. Concurrent burning operations shall not be conducted within 150 ft (45 m) of each other.

f. When several pads are burned, the downwind pad shall be ignited first, followed by the others in succession.

20.3 Ignition System Malfunctions

a. If the ignition system fails to fire, check the circuit's continuity. If no open circuits are detected, refire.

b. If the squibs fire but fail to ignite the ignition train, remotely survey the area, and wait at least 30 minutes. When it appears safe to emerge from the control shelter, disconnect, shunt, and ground the firing circuit, and inspect the squibs, firing system, or ignition train.

20.4 Post-burn Operations

a. No entry should be allowed into the disposal area until eight hours have elapsed unless it can be determined visually that all explosives have been destroyed.

b. Squib firing lines shall be disconnected, shunted, and grounded before personnel can enter the burn area.

c. Unburned or partially burned explosives material remaining in the pit or pad may be moved or repositioned for further burning. The material shall not be raked or otherwise insulted. The burning operation shall be repeated to destroy any remaining explosive waste.

d. At least 24 hours shall elapse before ashes are collected and the pit is prepared for another burn.

20.5 Disposal Area

a. Explosives waste destruction operations shall be separated from magazines, inhabited buildings, public traffic routes, and occupied operating buildings to ensure that personnel and facilities are not exposed to hazardous blast overpressure, fire brands, fragments, or projectiles from burning or detonation of explosives. The following separation distances shall apply:

(1) Destruction by open burning or flashing shall not be performed within 2395 ft (730 m), unless carried out in pits or with other aids for limiting the range of fragments and debris if an accidental detonation occurs. In no case may the pit be located at less than 670 ft (204 m) for weights of 100 lbs (45 kg) or less and 1250 ft (381 m) for weights exceeding 100 lbs (45 kg). Sites should be located taking into account the direction of the prevailing winds to prevent sparks from being blown toward explosives locations.

(2) The size of the danger zone for destruction by open detonation shall be determined by the formula

$$D(ft) = 328\ W^{1/3}\ [D(m) = 131\ Q^{1/3}]$$

(3) The minimum separation distance shall be:

(a)	Non-fragmenting explosive materials	1250 ft (381 m)
(b)	Fragmenting explosive materials	2500 ft (762 m)
(c)	Bombs/projectiles with 5 in. caliber or greater	4000 ft (1220 m)

(d) If known, the maximum fragment (debris) throw distances with an applicable safety factor may be used to replace the 2500 ft (762 m) and 4000 ft (1220 m) minimum separation distances but not below 1250 ft (381 m).

(4) Self-contained destruction facilities fully analyzed for the intended NEW are exempt from the above requirements.

b. The maximum quantity of explosives that may be destroyed at one time shall be determined by starting with a small quantity, gradually increasing until an optimum amount, consistent with safe and efficient operation, is reached.

c. Explosives waste and ordinary rubbish shall not be destroyed in the same destruction area at the same time.

d. During destruction operations, the area within 200 ft (60 m) of the destruction point shall be kept clear of dry grass, leaves, and other extraneous combustible material. This clearance may be reduced to fire brand distance if aids to limit the range of fragments and debris are provided for the destruction points used within the disposal area.

e. Explosive waste awaiting destruction shall be stored at least intraline distance from the explosives being destroyed.

f. Trucks transporting explosives to the burning disposal area shall meet the requirements of Chapter II, section 16.0. Upon arrival at the burning grounds, explosives containers will be distributed to trays or other disposal locations. Vehicles shall be moved to a safe location as soon as explosives items have been removed. Explosives containers shall not be opened until vehicles have been withdrawn.

g. Provisions for emergency fire fighting shall be readily available at the waste disposal area.

h. The burning grounds shall be serviced with telephones or two-way radio communication.

20.6 Destruction by Detonation

a. Cased explosives should be removed from cases and burned or the cased item destroyed by detonation. Detonators, primary explosives, and other explosives that might detonate if burned should also be destroyed by detonation.

b. A high-energy detonator (e.g., an EBW) should initiate the detonation.

20.7 Use of Solvents

a. Solvent immersion may be used to prepare small quantities of explosives and explosive detonators for destruction.

b. Items to be destroyed shall be soaked in suitable, compatible solvents until all the explosives material is dissolved. Saturated solvent solutions shall not be reused.

c. Solvent-explosives mixtures shall be destroyed by burning.

21.0 LABORATORY OPERATIONS

21.1 General

a. Safety guidelines presented in this section are applicable to general laboratory operations involving explosive materials. Laboratory operations shall be conducted in a manner that maintains employee exposures to hazardous chemicals at or below the permissible exposure limits (PELs) and complies with the facility chemical hygiene plan.

b. Laboratory personnel shall conduct work involving explosives materials only in accordance with the provisions of written operating procedures (see Chapter VII). Laboratory operations shall comply with the requirements of NFPA 45, *Fire Protection for Laboratories Using Chemicals*.

c. The quantity of explosives present in a laboratory shall be the minimum required for the operations and should be at or below assigned limits. Storage of material not in process is allowed provided the material is secured when the laboratory is unoccupied. The material shall be configured to preclude exceeding the maximum credible event (MCE).

d. Open flames shall be prohibited in laboratories where explosives or flammable solvent vapors are or may be present unless allowed by an approved hazards assessment or procedure.

e. Disposal of explosives through laboratory drains shall be forbidden unless the drain plumbing has no traps and is designed to handle explosives (i.e., is provided with a sump or other device for the collection of solids). Even if a drain is designed to handle explosives, deliberate disposal of explosives in these drains should be avoided. These drains should be used only to clean up explosives spills. Special care should be exercised to prevent entrance of compounds into drains that may react with iron or rust to form sensitive salts (e.g., picrates and picric acid).

f. Solvents or other flammable substances shall be protected against electrical sparks, heat, and open flames.

g. Suitable guards shall be provided for all glass or fragile equipment that must withstand reduced or elevated pressure.

21.2 Safety Shields

a. If a laboratory operation involves an explosion hazard, personnel should be protected by safety shields or the operation should be performed remotely. Table II-5 lists shields that have been tested and found acceptable for the indicated quantities of explosive.

NOTE: Shields listed in Table II-5 were not tested for metal-fragment penetration (unless specifically indicated) and thus may not offer effective protection when the explosive is closely confined in a heavy-walled metal container. ("Heavy-walled" is defined here as wall thickness to diameter ratio greater than 0.01.)

Table II-5. Safety Shields for Explosive Laboratory Operations*

Shield	Minimum distance from explosive (cm)	Explosives limit
Leather gloves, jackets, or coats, and plastic face shields	----	50 mg
3 mm tempered glass	8	50 mg
7 mm Lucite/equivalent material	15	2.5 g
20 mm Lucite/equivalent material	15	10 g
15 mm laminated resistant glass	20	20 g
25.4 mm Lexan/Lexguard	30	50 g
2 units each of 25.4 mm plate glass laminated with 12.4 mm polycarbonate with a 9.5 mm air gap between units (glass sides facing the explosive)	30	50 g (steel confined)

* Recent blast testing has shown that laminated tempered glass is superior to monolithic tempered glass, and polycarbonate is superior to acrylic plastics, such as Lucite. Laminated tempered glass is recommended instead of monolithic tempered glass and polycarbonate is recommended in lieu of acrylic. The shields are recommended to be of equal or greater thickness than those listed in the table. Proof testing is highly recommended. When designing and/or replacing a safety shield with a polycarbonate, it should be UV stabilized, treated for abrasion resistance, and have met Mil Spec P-46144C. When designing or replacing a safety shield with laminated glass, it should be coated with a 0.1 mm fragment-resistant film on the viewer's side to minimize spalling. The shield, shield frame, and anchoring system shall be designed to resist maximum credible overpressure and fragments.

b. If an experiment poses a metal-fragment hazard (as opposed to a glass-fragment hazard) and the experiment cannot be conducted remotely, the proposed shield should be tested and approved under conditions simulating an explosion in the experimental setup but with at least 125 percent of the anticipated explosive content.

c. The shield shall be anchored to the hood frame or bench top when it is being used for protection against more than 0.16 oz (5 grams) of TNT equivalent.

d. Other shields may be used after successfully passing a test of 125 percent of the rated explosive charge and being approved.

e. For confined areas, a blast vent having less strength than the shield should be provided.

f. When explosives operations require personnel to reach around a shield to manipulate equipment, exposure shall be minimized.

21.3 Heating Operations

a. During synthesis, formulation, or experimental work, heat may be applied to initiate or maintain reaction, to increase solubility, etc., if the principles below are followed:

(1) Heat shall be applied indirectly using steam, a water bath, oil bath, or an approved laboratory electrical heating device such as a mantle.

(2) Utmost caution shall be exercised to ensure that reactive material does not come in direct contact with the heating elements.

(3) If an experiment must be conducted behind a shield, any heating device shall be mounted so that temperature can be controlled from the operator side of the shield. The heating device should be mounted so it can be separated quickly from the reaction vessel without operator exposure. Consideration should be given during design of the experiment to providing emergency cooling for the reaction vessel or its contents.

(4) Heating of explosives with devices without proper controls shall be monitored at all times. If the operator must leave for any reason, the heating device should be turned off. Heating systems that will be operated unattended shall have dual controls, an override shutoff, or some other protection against failure of the primary heating control. Systems capable of totally containing the effects of an explosion may be exempted from this requirement.

b. Periodic checks should be made to ensure that an experiment is proceeding satisfactorily and that the apparatus is not boiling dry, malfunctioning, etc. In the case of remotely controlled operations, provisions shall be made for observation, using mirrors, television monitors, etc.

21.4 Laboratory Setups

a. Good workmanship and laboratory practice shall be exercised in making and operating laboratory setups. In particular, the following guidelines apply:

(1) Equipment and apparatus shall be clean, in good condition, and in good working order.

(2) All glassware and apparatus shall be inspected for cracks, defects, etc., before use. Defective or damaged equipment shall be removed from service.

(3) Setups shall be geometrically and structurally stable.

(4) Work areas should be as neat and uncluttered as possible.

21.5 Low Concentration of Explosives in Solution

a. After explosives are in dilute solution (less than 25 percent explosives by weight), the primary hazard shall be considered as that associated with the solvent and not the explosive. Where supported by technical data and approved by the Explosives Development Committee (EDC), a solvent/explosives solution greater than 25 percent may also be similarly classified.

b. If the explosive recrystallizes or precipitates out of solution, safety guidelines for pure explosives shall apply.

21.6 Explosives Sample Control

a. Samples shall be delivered to a laboratory only at specific designated locations.

b. Each sample shall be properly identified and labeled.

c. Upon completion of required tests or analyses, the sample should be removed from the laboratory.

d. A safety information sheet should accompany all samples of new experimental explosive material submitted to a laboratory for analysis.

22.0 EMERGENCY CONTROL

22.1 Placarding and Fire Symbols

a. Placards and fire symbols (as specified in DoD 6055.9-STD or the NFPA 704 Standard) shall be displayed consistently on buildings and work areas throughout an entire facility to warn of potential hazards from explosives and to provide information for emergency situations.

22.2 Explosives Emergency Control Plans

a. Each installation shall have a facility-specific written plan for the control of emergencies involving explosives (The plan may be need to be broken down for each operating area). An explosives emergency control plan may be part of the facility's overall emergency control plan. All facility personnel shall be trained in the plan's content applicable to their area. The plan shall be available to all personnel for ready reference.

b. Emergency situations that should be covered include the following:

(1) Fires and explosions.

(2) Floods.

(3) Extreme weather conditions.

(4) Conditions resulting in environmental disturbances.

(5) Civil disturbance.

(6) Threats and bomb scares.

(7) Enemy attack.

(8) Other emergencies that require rapid mobilization of personnel and equipment to minimize death and injury to personnel or to prevent the spread of damage and destruction.

c. The plan should address:

(1) Reporting an emergency.

(2) Criteria for activating the emergency plan.

(3) Authority and responsibility for administration and execution of the plan.

(4) Mobilization of personnel to respond to an emergency or disaster.

(5) Roles of operating personnel in responding to an emergency.

(6) Procedures for responding to an emergency or disaster.

(7) Accounting for evacuation of personnel.

(8) Plant and document security.

CHAPTER III—EXPLOSIVES AND PERSONNEL LIMITS AND CONTROL

1.0 EXPLOSIVES LIMITS

a. The quantity of explosives at an operating location shall be the minimum necessary to carry out the operation safely and efficiently. When practical, this quantity shall be subdivided and separated to prevent propagation of detonation. Supplies exceeding this minimum quantity shall be removed from the operating area.

b. In no case shall the quantity of explosives permitted in an operating building exceed the maximum permitted by quantity-distance criteria. Quantity-distance criteria and guidelines for application of these criteria are presented in Chapter VI of this Manual.

2.0 PERSONNEL LIMITS

a. The number of personnel at an operating location shall be the minimum consistent with safe and efficient operation. In establishing personnel limits, the following principles shall be followed:

(1) Only jobs not necessary to the performance of a hazardous explosives operation should not be performed in the same location as the hazardous operation. Only personnel needed for the hazardous operations shall be allowed in hazardous locations.

(2) Personnel limits shall allow for necessary casuals.

(3) Sufficient personnel shall be available to perform a hazardous operation safely and to obtain help and aid the injured if an accident occurs.

(4) No person shall perform explosives work with a high risk of serious injury alone. Prompt and easy communications with other employees shall be provided. Facility management shall specify explosives activities that may be performed alone.

3.0 LIMIT CONTROL

3.1 Posting and Recording

a. All rooms, bays, and buildings containing explosives shall have posted in a conspicuous place a standardized placard stating the maximum amount of explosives and the maximum number of workers and casuals permitted in the control unit at any one time.

b. Maximum explosives and personnel limits for all buildings and bays for each explosives area shall be documented and maintained on file.

3.2 Limit Review and Approvals

a. Management personnel with authority and jurisdiction over an operating bay or building shall review explosives and personnel limits for each location periodically and recommend changes as required. When the use of a location changes, personnel and explosives weight limits shall be reviewed and limits reestablished as required.

b. Changes in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures (see Chapter VII). A procedure shall be established for the approval of temporary changes in explosives and personnel limits for an operating location.

3.3 Personnel Controls

a. A system shall be established to control the presence of personnel within explosive operating areas. The movement of transients in the vicinity of an explosives operating area should be controlled when their presence creates a congestion problem or other safety concern.

3.4 Explosives Control

a. A verifiable system shall be established to control the amount of explosives present in an explosives facility.

4.0 INSENSITIVE HIGH EXPLOSIVE LIMITS

a. When no other explosives are present, IHE weight limitations shall be based on separation distances for Hazard Class 1.6 explosives (see Chapter VI, section 3.1) or equivalent protection provided by facility design features. The quantity of IHE at an operating location shall be the minimum necessary to carry out the operation safely and efficiently.

b. IHE limits for pressing, dry blending, dry milling, dry screening, and certain machining operations (see Chapter II, section 12.4.2c), should be the same as those established for HE operations.

CHAPTER IV—PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT

1.0 CLOTHING AND PERSONAL EQUIPMENT

1.1 Clothing

a. Each operation shall be analyzed to determine when personnel working with explosives and toxic materials must wear approved coveralls or laboratory coats to prevent contact with these materials and prevent contaminating personal apparel. Flame-retardant coveralls may be desired for explosives operations with the potential for flash fire. These coveralls shall not have cuffs and should not have metallic fasteners. Written procedures shall include protective clothing and equipment requirements.

b. Cotton or other antistatic outer and undergarments, including socks, should be worn where generation of static electricity would create a hazard.

1.2 Footwear

a. Personnel working in areas where electrostatic-sensitive explosive powders or materials are handled shall wear conductive, non-sparking footwear. Exception: personnel working on electrical or electronic equipment shall not wear conductive footwear unless protected by insulated mats, ground fault circuit interrupters (GFCI), etc. Personnel working in other areas where explosives contamination may be present shall wear non-sparking footwear or bootie shoe coverings.

1.3 Respirators

a. Approved respiratory protection shall be worn when exhaust ventilation is unavailable or does not adequately control airborne particulate, gases, or vapors released during explosives operations. The employee shall have current approval to wear respiratory protection (medical exam, respirator fitting, and training).

1.4 Eye Protection

a. Personnel working in or visiting eye hazard areas shall wear suitable eye protection devices, particularly when EEDs are handled. Explosive operations shall be evaluated for eye hazard risks. Contact lenses shall not be considered appropriate eye protection.

1.5 Gloves

a. Skin contact with some explosives and associated materials can result in dermatitis or absorption across the skin barrier. Operations where these materials are present must be evaluated for skin contact hazards and the need for the proper gloves.

2.0 MAINTENANCE AND TESTING

2.1 Equipment Maintenance and Inspection

a. Personal protective equipment shall be properly maintained. The operator's life may depend on the equipment functioning properly. An appropriate inspection schedule shall be established.

2.2 Conductivity Testing

a. When conductive footwear is worn, the conductivity shall be tested initially and regularly thereafter to ensure continued conductivity from person to ground.

2.3 Cleaning and Disinfecting

a. Provision shall be made to launder and disinfect protective garments and devices. This is especially important for equipment worn about the face. Because laundering affects the flame-retardant properties of fabric, flame-retardant coveralls should be tested to establish the maximum number of laundering cycles permitted.

2.4 Contaminated Clothing

a. Contaminated clothing should be wiped or dusted to remove as much contamination as possible. Compressed air shall not be used for this purpose. If obvious contamination remains, personnel shall change their clothing.

CHAPTER V—TRAINING

1.0 GENERAL

a. Personnel shall be properly trained before they are assigned to explosives operations or operate any explosives-transport vehicle. The training for explosives work, which serves to assist in conducting work safely and developing safety awareness, shall ensure that personnel:

(1) Develop and maintain a safe attitude towards work with explosives.

(2) Define and understand the potential hazards involved.

(3) Learn correct skills to perform tasks safely.

(4) Are prepared for unexpected hazardous conditions.

(5) Read and understand the appropriate operating procedures.

2.0 SUPERVISORY RESPONSIBILITY

a. The supervisor shall be responsible for:

(1) Determining the required training for personnel.

(2) Verifying that training has qualified the worker to perform assigned tasks safely and efficiently.

(3) Ensuring that the worker can perform required emergency duties.

(4) Providing on-the-job training.

(5) Continually updating worker training.

3.0 TRAINING AND QUALIFICATION PROGRAMS

a. Each organization shall have a training and qualification program with established qualification requirements. Paragraph 3.0b below is an example.

b. Completion of training should qualify the worker to perform a task for a specific period of time. The following items should govern maintenance of qualifications.

(1) At the end of the initial qualification period, qualification may be extended for subsequent specific time periods if:

(a) The worker has successfully performed the task during the preceding six months and has read and understands the current operating procedures; or

(b) The worker has completed refresher training and is again found to be qualified by his or her supervisor.

(2) Retraining in areas of weakness should be required of workers who do not demonstrate job proficiency or who subsequently violate safe practices.

(3) When an operating procedure is modified, all personnel using that procedure should be retrained in the modified procedure.

(4) An employee should not be permitted to continue working with explosives if the supervisor, with counsel from medical personnel, determines that he or she is unable to perform the task safely. Possible reasons include:

(a) Physical injury or illness.

(b) Disease.

(c) Mental or emotional disturbances.

(5) Training records should be maintained for each worker, with the following information included:

(a) Description and dates of training received.

(b) Description and dates of refresher training.

(c) A signed “statement of understanding” for operating procedures.

(d) Attendance at safety meetings and participation on safety committees.

(e) Qualification review by supervisor.

(6) The supervisor may temporarily authorize an employee who has not completed the required training to perform a task under the following conditions:

(a) The supervisor determines that the employee has a working knowledge adequate to perform the task safely.

(b) A qualified person directly supervises the work.

c. Hazardous materials information and training programs are required for personnel who work with explosives and hazardous materials used in conjunction with explosives operation. Training should include:

(1) Information on physical and health hazards.

(2) The purpose and proper use of engineering controls, work practice controls and protective equipment.

(3) Labeling systems and MSDS terms.

(4) Methods to detect the presence or release of hazardous materials in the work area.

4.0 UNEXPLODED ORDNANCE (UXO) TRAINING

a. Personnel in charge of UXO removal or disposal should be US citizens and shall have successfully completed training at a United States Military Explosives Ordnance Disposal (EOD) school. Personnel shall provide documentation of completed training and have a minimum of 18 months operational EOD experience. All personnel engaged in operations shall be thoroughly trained in applicable UXO recognition and explosives safety.

b. Personnel performing UXO removal or disposal shall have completed training at a US Military EOD school or have equivalent training or experience. All other personnel engaged in operations shall be trained thoroughly in applicable UXO recognition and explosives safety.

c. Personnel not involved in UXO operations, but requiring access to areas known or suspected to contain UXOs shall be required to have completed UXO awareness training and shall be escorted by personnel qualified under section 4.0a or b above. The UXO HE Awareness video (EPL 122) is recommended for the awareness training.

5.0 REFERENCES

a. OT-525, Personnel Qualifications, Commanding Officer, Naval Explosive Ordnance Disposal Technology Division, 2008 Stump Neck Road, Indian Head, MD 20640-5070

b. UXO High Explosives Awareness Video (EPL 122), Sandia National Laboratories/New Mexico Environmental Restoration Program.

CHAPTER VI—QUANTITY-DISTANCE AND LEVEL-OF-PROTECTION CRITERIA FOR EXPLOSIVES ACTIVITIES

1.0 GENERAL

a. This chapter establishes quantity-distance and level-of-protection criteria for all DOE operations involving explosives. These criteria provide specific levels of personnel and property protection from the effects of potential fires and explosions within and outside of DOE installations.

b. The cardinal principle to be observed at any location or in any operation involving explosives, ammunition, severe fire hazards, or toxic materials is to limit, in a manner consistent with safe and efficient operation, the exposure to a minimum number of personnel, for a minimum time, and to a minimum amount of the hazardous material.

c. The Facility Management shall ensure that ammunition and explosives safety site plans are submitted, as specified in sections 1.1 and 1.2 to DOE for review and approval. DOE review and approval will be conducted by the Authority Having Jurisdiction for explosives safety within the Operations/Site Office.

1.1 For New Explosives Facilities and Operations and Explosives Facilities Undergoing Major Modifications:

a. Preliminary Site Plan must be developed and submitted for DOE/NNSA approval before CD-1 approval and the Final Site Plan submitted and approved before CD-4 (See DOE O 413.3)

b. For a facility where the risk associated with the operation is increased, with an increase in explosive weight or a major modification or level of protection, a new site plan shall be required and approved prior to start of operations.

1.2 For Existing Explosives Facilities and Operations:

a. A Site Plan must be developed and submitted for review by DOE/NNSA local authority as soon as possible but not later than two (2) years from approval of DOE M 440.1-1A (Revision 9) of the *DOE Explosives Safety Manual*. The Site plan shall contain the following information:

(1) A Quantity Distance (QD) Chart containing the following:

(a) Each sited facility (PES) listing maximum Net Explosives Weight for each applicable Hazard Division

(b) Actual and required distance to exposed sites (ES)

(c) QD criteria used for siting each PES – ES relationship

(2) Map showing each PES, its clear zone, and all ESs within the clear zone.

(3) Personnel Limits for the explosives facility.

(4) Brief description of explosives and nonexplosives operations within the clear zone.

(5) Statement that the current operation presents no significantly greater risk than that assumed when the facility was originally constructed and

(6) If the facility does not meet current criteria for the operation being conducted, provide a statement:

(a) Why it is not feasible to bring the facility up to current standards and

(b) That the current operation presents no significantly greater risk than that assumed when the facility was originally constructed.

b. A letter of transmittal shall accompany each site plan or group of site plans. The letter should contain the reason for submittal (preliminary or final siting of new facility, site plan/plans for grandfathered facility/facilities, change in operation with increased or decreased QD requirement) and a request for site plan approval. For a grandfathered facility, note whether the facility meets current criteria for the operation being conducted.

c. If the siting has any unique characteristics explain what they are and what criteria is being applied. (Example: If a facility is built to control blast effects and fragments, QD to other facilities will not apply).

2.0 APPLICABILITY OF CRITERIA

2.1 Specific Applications

a. Criteria presented in this chapter shall be used to:

(1) Establish maximum explosives limits for explosives facilities and operations.

(2) Plan explosives activities in existing facilities.

(3) Design and site new facilities and operations.

2.2 Explosives Limits

a. Explosives limits shall never exceed the minimum required for efficient, safe operation (see Chapter III).

2.3 Areas Where Criteria Are Not Applicable

a. The quantity-distance and level-of-protection criteria defined in section 4.0 of this chapter are not applicable to portable buildings used at specified nuclear test shot locations.

3.0 QUANTITY-DISTANCE CRITERIA

a. Quantity-distance criteria must account for the types and severity of hazards each explosive material presents, the construction and orientation of facilities to which the criteria are applied, and the degree of protection desired for personnel and facilities adjacent to the explosives operations.

b. The hazard classification system recommended by the UN defines the types and severities of explosives hazards. The guidelines presented below specify minimum degrees of protection for various facility categories and describe how quantity-distance tables are to be applied to facilities of various construction and orientation with respect to adjacent facilities.

3.1 Hazard Classes and Class Division

a. Explosives shall be classified based on their reactions to specific initiating influences. Personnel shall use the UN recommended hazard classification system for DOE explosives classification. The UN system consists of nine classes for dangerous goods, with explosives included in Class 1. The explosives hazard class is further subdivided into divisions based on the character and predominance of the associated hazards and their potential for causing personnel casualties or property damage. Table VI-1 lists the six divisions of Class 1.

Table VI-1. Divisions of Class 1

Hazard Class and Division Designators	Hazards
1.1	Mass detonating
1.2	Non-mass explosion, fragment producing
1.3	Mass fire, minor blast or fragment
1.4	Moderate fire, no significant blast or fragment
1.5	Explosive substance, very insensitive (with a mass explosion hazard)
1.6	Explosive article, extremely insensitive

b. When required to properly describe the hazard, a numerical figure in parentheses shall be placed to the left of the division designators 1.1 through 1.3 [e.g., (18) 1.1, (08) 1.2, and (06) 1.3]; this number indicates the minimum separation distance (in hundreds of feet) for specified levels of protection from explosive items for inhabited buildings, public traffic routes, and personnel in the open. A minimum distance number shall be

used for all items in Class 1, Division 2, as shown in the applicable tables. Figure IV-1 illustrates the use of the UN hazards classification system and lists the storage compatibility group opposite each hazard class. The listed compatibility group is typical for the expected compatibility to hazard class relationships. Note: The two classification systems apply to different concerns.

(1) Compatibility groupings define which explosives may be stored together safely without increasing the risk of initiation.

(2) Hazard classifications indicate the initiation effects of the various explosives.

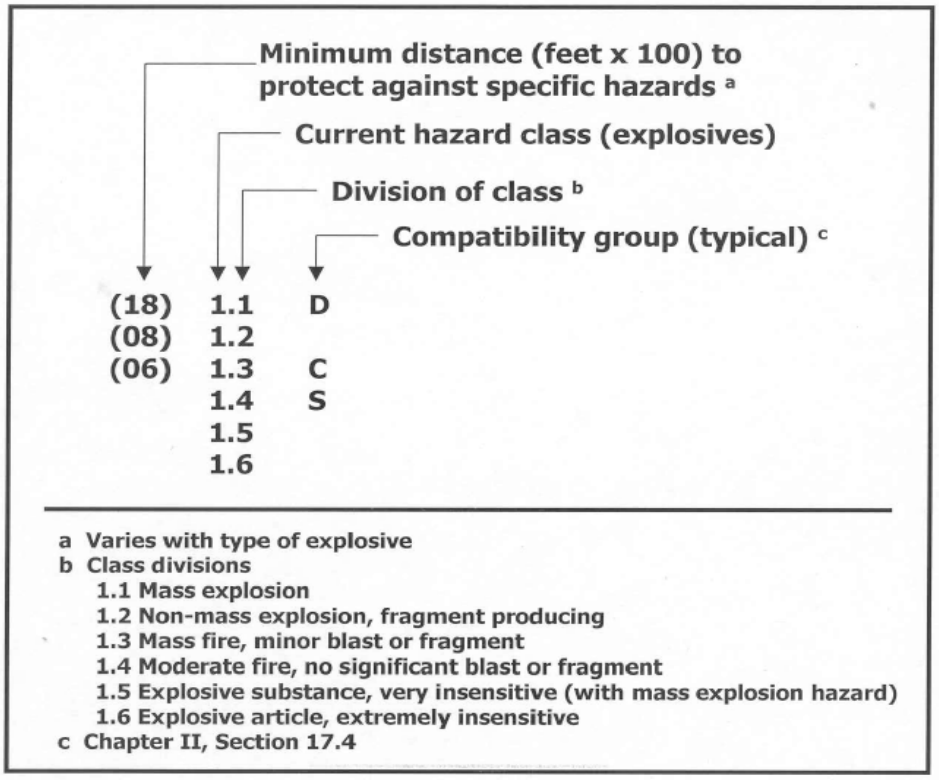


Figure VI-1. Application of Hazard Classification System

c. Classification tests (described by TB 700-2, *Explosives Hazard Classification Procedures*) and additional tests (as desired), including United Nations ST/SG/AC.10/1 and ST/SG/AC/10/11, shall be used to assign energetic materials to the appropriate compatibility groups and hazard divisions. Supplemental tests may be used to characterize material hazards more fully if material properties or anticipated material environment are expected to significantly influence the explosives classification.

d. Although DOT Hazard classifications require the use of the Bureau of Explosives' (BOE) Impact Apparatus to determine impact sensitivity, other impact apparatus may be used, providing:

(1) Test results for at least two reference explosives are compared to results for the reference explosives on the BOE Impact Apparatus; and

(2) A minimum of 10 trials each is run for the reference explosives and the explosives being classified.

3.2 Establishing Quantity of Explosives and Distances

3.2.1 *General*

a. The principles and tables presented in DoD 6055.9-STD, *DoD Ammunition and Explosives Safety Standards*, shall be used to determine the following:

(1) The total quantities of explosives in adjacent magazines, operating buildings, or other explosives facilities that must be applied to quantity distance tables.

(2) When the levels of protection required by section 4.0 of this chapter differ from the requirements of DoD 6055.9-STD, section 4.0 shall take precedence.

(3) The minimum separation distances required for the facilities are based on the desired level of protection and total quantities of explosives.

(4) The total quantity of explosives is determined by defining and examining the maximum credible event (MCE). If an explosives event occurs, the MCE is the largest credible amount of explosives that could be involved (not necessarily the total quantity of explosives present).

3.2.2 *Use of Metric System*

a. Throughout DoD 6055.9-STD, the NEW is used to calculate distance using the formula $D=KW^{1/3}$, when D is the distance in feet, K is a factor based on the risk assumed or permitted, and W is the NEW in pounds.

b. When metric units are used, the symbol Q denotes net explosive quantity (NEQ) expressed in kilograms. In the formula $D=KQ^{1/3}$, the distance D is expressed in meters. Thus, the respective units of K are $ft/lb^{1/3}$ and $m/kg^{1/3}$ in the two systems. The value of K in English units is approximately 2.5 times its value in metric units [e.g., if $D(m)=6Q^{1/3}$, then $D(ft)=15W^{1/3}$].

3.2.3 *Railcars and Transport Vehicles*

a. Explosives-loaded railcars, motor vehicles, and other transport vehicles in holding yards are considered aboveground magazines for quantity-distance purposes. They shall be kept in groups, and each group shall be limited to a maximum of 250,000 lb (113,398 kg) of high explosives.

(1) When a railcar receiving yard or point is the site where explosives will be interchanged between the common carrier and the facility rail system, quantity-distance provisions do not apply provided that the cars are moved expeditiously to a suitable location.

(2) When inspection of a railcar of explosives indicates a hazardous or potentially hazardous condition, the railcar should be moved at once to a suspect car spur track or an isolated section of track. This spur or section of track should be accessible directly from the inspection point. The distance between the spur or track and facility boundaries, classification yards, inhabited buildings, administration areas, operating buildings, magazines, inert storage locations, and public traffic routes should be the inhabited-building distance based on the maximum quantity of explosives that the facility can receive in one railcar. Only one car is permitted at this location at any time.

(3) Incoming motor vehicles carrying explosives shall be inspected at a station remote from hazardous and populated areas.

3.2.4 *Utilities Installations*

a. Permanent DOE-controlled underground utilities installations (excluding building service lines) should be separated from explosives locations containing Hazard Class/Division 1.1 materials (see Table VI-2).

b. Privately owned or operated utilities installations (aboveground and underground) shall be separated from explosives locations by at least public traffic route distances. Installations that include structures should be separated from explosives facilities by inhabited-building distance.

c. Certain auxiliary power facilities, transformer stations, etc., present fire hazards to explosives facilities. Transformers and associated electrical switching apparatus serving one explosives facility or complex that do not present a fire hazard to the facility (i.e., dry-type, “less flammable”

oil-insulated, etc.) shall be located as specified in NFPA 70 and FM Data Sheet 5-4/14-18.

d. Normal oil-insulated transformers shall be located at least 50 ft (15 m) from an explosives facility or as specified in DoD 6055.9-STD.

Table VI-2 . Quantity-Distance Separation for Protection of Underground Service Installations

Quantity of explosives (maximum pounds)	Distance	
	Meters	Feet
100	26	80
200	26	80
500	26	80
1,000	26	80
2,000	26	80
5,000	26	80
10,000	26	80
20,000	28	85
50,000	36	110
100,000	46	140
250,000	62	190

Note: If the potential donor building is designed to contain the effects of an explosion, the formula $D=3.0\ W^{1/3}$ can be used to determine separation distances for less than 20,000 lbs.

3.2.5 *Petroleum Storage Tanks*

a. Above ground tanks containing 500 gal or less of petroleum that serve equipment (such as oil heaters or diesel generators) located in or near explosives buildings shall be located a minimum of 50 ft (15 m) from explosives locations and comply with NFPA 30. Tanks located near intentional detonation areas should be barricaded. Similar underground tanks complying with NFPA 30 do not require separation from explosives facilities. In both cases, the tanks shall be equipped with an anti-siphoning device, unless siphoning is impossible.

4.0 LEVEL-OF-PROTECTION CRITERIA

4.1 Hazard Classes

a. The level of protection required for an explosives activity shall be based on the hazard class (accident potential) for the explosives activity involved. These four hazard classes are defined for explosives activities as follows:

(1) **Class I** consists of those explosives activities with a high accident potential. Remote operations are required because any personnel exposure is unacceptable for Class I activities.

(a) In general, Class I includes activities where energies that may interface with explosives are approaching the upper safety limits, or the loss of control of the interfacing energy is likely to exceed the safety limits for the explosives involved. Class I includes those research and development activities with safety implications have not been fully characterized.

(b) Examples of Class I activities are screening, blending, pressing, extrusion, drilling of holes, dry machining, machining explosives and metal in combination, some environmental testing, new explosives development and processes, explosives disposal, and destructive testing.

(2) **Class II** consists of explosives activities with moderate accident potential because of the explosives type, condition of the explosives, or nature of the operations involved. Class II activities have an accident potential greater than Class III activities, but personnel exposure in contact operations is acceptable.

(a) Class II includes activities where the energies that do or may interface with the explosives are normally well within the safety boundaries for the explosives involved, but where the loss of control of these energies could approach the safety limits.

(b) Examples of Class II activities are weighing, some wet machining, assembly and disassembly, some environmental testing, and some packaging operations.

(3) **Class III** consists of explosives activities with low accident potential such as activities during storage and operations incidental to storage or removal from storage.

(4) **Class IV** consists of those explosives activities with IHE or IHE subassemblies. Although mass detonating, this explosive type is so insensitive that the probability of accidental initiation or transition from

burning to detonation is negligible. If the containers are heated in a fire, IHE reactions will be limited to pressure ruptures of the containers. Most processing and storage activities with IHE and IHE subassemblies are Class IV. However, the following examples of explosives activities with IHE and IHE subassemblies remain Class I:

(a) Pressing.

(b) Some machining (see Chapter II, section 12.4.2c).

(c) Dry blending.

(d) Dry milling.

(e) Dry screening.

4.2 Required Level of Protection

a. Each bay (i.e., storage, handling, or processing building) that houses an explosives activity shall have a protection level based on the hazard class determined for the activity. The level of protection may be provided by equipment design, structural design, operation separation, or provision of operational shields. The levels of protection required for each hazard class are as follows and shall be required for new facilities or redesign of any existing facilities when changes in activities will result in a more hazardous class.

4.2.1 *Explosives Bay*

a. **Class IV**. Bays for Class IV (negligible probability of accidental initiation) activities shall provide protection from fire hazards effects. This protection may be achieved by Hazard Class/Division 1.3 aboveground-magazine distance separation or by a design that contains the effects of an accident. Because accidental detonation is not considered credible, Class IV bays shall be sited and designed as acceptors rather than donors for the effects of blast overpressure, structural collapse, and missiles (hazardous fragments).

b. **Class III**. Bays for Class III (low accident potential) activities shall provide protection from explosion propagation from bay to bay within buildings and between buildings that are located at intraline or magazine distance. If intermediate storage of explosives is within an operating building containing Class II or Class I operations, the intermediate storage or staging bay will require Class II level of protection. Examples of Class II activities include weighing, assembly and disassembly, some wet machining, some environmental testing, and some packaging operations. Minimum separation distances may be reduced when explosives bays are

designed to adequately contain the effects of an accident (blast pressures and missiles).

c. **Class II**. Bays for Class II (moderate accident potential) activities shall comply with the requirements for Class III bays, and in addition provide protection to prevent fatalities and severe personnel injuries in all occupied areas other than the bay of occurrence. (For Class II, access ramps and plant roads are not considered occupied areas). Prevention of fatalities and severe injuries is satisfied when personnel in occupied areas other than the bay of occurrence will not be exposed to the following:

(1) Overpressures greater than 100 kPa (15 psi) maximal effective pressure.

(2) Structural collapse resulting from overpressure or debris impact. Structural collapse is a structural component's failure as a direct result of a facility losing structural integrity. This collapse must not result in explosives propagation, fatalities, or severe personal injuries.

(3) Missiles (hazardous fragments) generated in acceptor-occupied areas. Hazardous fragments that can cause fatalities and severe injuries are defined as those having greater than 58 ft-lb impact energy. The threshold pressure for eardrum rupture is 34 kPa (5 psi); one-half of the threshold pressure for lung damage is 100 kPa (15 psi). (See Chapter I of TM 5-1300).

d. **Class I**. Bays for Class I (high accident potential) activities shall comply with the requirements for Class II bays, and in addition provide protection to prevent serious personal injuries, including personnel performing the activity, personnel in other occupied areas, and transients. This protection can be achieved by controlling blast and debris through suppression, containment, or establishing an exclusion area with positive access control. Serious injury prevention is satisfied when personnel will not be exposed to:

(1) Overpressures greater than 34 kPa (5 psi) maximal effective pressure, which should not exceed 16 kPa (2.3 psi) peak positive incident pressure;[1]

(2) Structural collapse of a facility or building from overpressure or debris impact. Structural collapse a structural component's failure as a direct result of loss of structural integrity. This

[1] This value is specified in DoD 6055.9-STD as required protection for all personnel exposed to remote operations (16kPa is also the overpressure for public-traffic-route distance).

collapse must not result in explosion propagation, fatalities, or severe personal injuries.

(3) Missiles (hazardous fragments)—hazardous fragments that can cause serious injuries are defined as those having greater than 11 ft-lb impact energy.

(4) Thermal fluxes greater than 0.3 cal/cm^2/sec. This value is specified in DoD 6055.9-STD, Chapter 4, as required protection for all personnel assigned to perform remote operations.

4.2.2 ***Bays for Joint Explosives-Plutonium Activities***

a. Bays for joint explosives-plutonium activities shall comply with the requirements of section 4.2.1 of this chapter for the class of explosives activity involved and DOE DNA TP 20-7. Because the plutonium has contamination potential, the bays shall also comply with the following:

(1) Bays for Uncased Explosives—Plutonium Activities. Where it is necessary to store, handle, or process uncased explosives components and plutonium in the same bay, the enclosing structure and its ventilation, electrical, fire protection, and utility systems shall be designed to assure that, if all the explosives present should detonate, radiation exposures shall comply with the current version of DOE O 420.1B standards for hypothesized accidental releases. The safety analysis report shall govern the quantity of plutonium allowed in such a bay. Activities may be performed in Class IV bays if IHE, IHE subassemblies, or IHE weapons are present; however, criticality considerations shall govern the quantity of plutonium allowed.

(2) Bays for Cased Explosives—Plutonium Activities. When handling or processing cased high-explosive components that contain plutonium, the enclosing structure shall be designed as a Class II explosives bay. Storage shall conform to Class III requirements. The plutonium quantity shall be limited to 25 kg per bay. Plutonium limits for magazines are specified in DOE DNA TP 20-7. Activities may be performed in Class IV bays if only IHE, IHE subassemblies, or IHE weapons are present; however, criticality considerations shall govern the quantity of plutonium allowed.

5.0 FIRE PROTECTION

5.1 Vegetation Control

a. Vegetation around storage magazines and explosives operating facilities should be controlled to minimize potential damage to the magazine or facility from erosion or grass, brush, or forest fires. A firebreak at least 50-ft (15-m) wide and free from combustible material should be maintained around each aboveground magazine or explosives operating facility. If an aboveground magazine or explosive facility exterior is fire resistant, the firebreak can have vegetation, but the growth must be controlled to prevent rapid transmission of fire to the magazine or facility. Maintaining the firebreaks around earth-covered magazines and cutting grass covering these structures is only required around ventilators to prevent transmission of a fire into a structure.

5.2 Fire Protection Criteria

a. The following fire protection criteria shall be required for all new facilities or redesign of existing facilities where changes in activities will result in a higher hazardous classification.

(1) Automatic fire suppression systems shall be installed in all buildings containing HE and plutonium, except storage magazines.

(2) For buildings containing explosives, but no plutonium, facility management shall determine the need for fire suppression systems based on maximum fire loss criteria and program mission interruptions and delays as outlined in the current versions of DOE O 420.1B, *Facility Safety*; DOE O 430.1B, *Real Property Asset Management*; and DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*.

(3) Where fire suppression is required, each explosives bay shall have an individual feed with its controls protected outside the bay and located to enable system operation if a detonation occurs in any bay.

(4) Transmitted fire alarms shall distinguish between explosives and nonexplosives areas through the use of annunciator panels at safe locations; small non-HE areas do not need separately transmitted alarms.

6.0 EXPLOSIVES FACILITY SITING AND DESIGN CRITERIA REFERENCES

a. Permanent explosives facilities shall comply fully with TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," and DOE/TIC-11268, "A Manual for the Prediction of Blast and Fragment Loading of Structures." Portable magazines should be ventilated and resistant to water, fire, and theft. Portable magazines can be made of any material that meets these guidelines. [Portable facilities that comply with 27 CFR 55.206, "Bureau of Alcohol, Tobacco and Firearms" (BATF) meet this criteria.] Portable magazines shall be sited per DoD 6055.9-STD as above ground magazines.

b. Blast-resistant design for personnel and facility protection shall be based on the TNT equivalency of the maximum quantity of explosives and propellants. In accordance with TM 5-1300, the TNT equivalency shall be increased by 20 percent for design purposes.

c. For an unproven facility design, either a validated model or full-scale test is required to ensure structural adequacy unless a high degree of confidence can be provided by calculations or other means. The contract administrator (Head of Field Organization) with competent engineering review shall concur in any determination regarding test requirements.

d. The design of new facilities, or those with major modifications, shall conform to the DOE explosives safety requirements. For a tabular summary of the protective design types established by these criteria, see Table VI-3. Protective construction design features are specified in TM 5-1300 and DOE/TIC-11268.

e. Studies necessary to provide the technical basis for location, engineering, design, and operation (under normal and potential design basis accident conditions) of buildings shall follow the stricter of this Manual or DoD 6055.9-STD, *DoD Ammunition and Explosives Safety Standards*, for establishing explosives quantity-distance separation.

6.1 <u>Site and General Construction Plans for Ammunition and Explosives Facilities</u>

a. Site and general construction plans for ammunition and explosives facilities as well as plans for changes in utilization of facilities or mission changes that adversely affect the explosives Q-D requirements shall be submitted to the Operations/Site Office for review and approval. Plans shall be forwarded for:

(1) New construction or major modifications of facilities for ammunition and explosives activities. Modifications or rehabilitation plans for existing facilities do not require submission to the Operations/Site Office when the plans do not introduce additional hazards or do not increase the net explosives capacity or chemical agent hazard for which the facility was designed or sited.

(2) Facilities for activities not involving ammunition or explosives that are in such proximity to ammunition and explosives as to be exposed to hazards or for which a reasonable doubt may exit regarding possible exposure to hazards.

(3) Facilities for activities not involving ammunition and explosives that become exposed to blast, fire, or fragment hazards; or potential toxic chemical agent release due to change in facility mission or facilities usage.

b. When the review of site and general construction plans is required, the Facility Management shall:

(1) Indicate specifically in the letter of transmittal its approval of the proposal, along with changes, modifications, or specific precautionary measures considered necessary.

(2) Comply with applicable requirements of DoD 6055.9-STD for site plan submission.

(3) A copy of the complete site plan and the final safety submission, together with Operations/Site Office letter(s) of approval, must be retained as a permanent record at the facility/site of origin. The information may be subject to review during the DOE surveys. Facility maps shall be kept current with the latest site plan approval and reconciled with the facility master planning document.

c. DoD 6055.9-STD requires that the minimum distance for protection from hazardous fragments to facility boundaries, critical facility, and inhabited structures shall be 1,250 ft for explosives quantities of 101 to 20,000 lb and 670 ft for 100 lbs or less of Hazard Class/Division 1.1 explosives, unless it can be shown that there will be no hazardous fragments or debris at lesser distances. The methods of calculation presented in the Department of Defense Explosives Safety Board (DDESB) Technical Paper No. 13 may be used to establish a smaller fragment exclusion zone. It is not intended that these minimum fragment distances be applied to operating facilities or dedicated support functions within an operating line. For these exposures, the DOE criteria presented in this Manual, for Class I, II, III, or IV activities with appropriate quantity-distance separations are the required protection levels.

d. In addition to this Manual, the following are resource documents for the siting and design of explosives facilities:

(1) DOE O 420.1B, *Facility Safety*, (current version), U.S. Department of Energy, Washington, D.C. 20545.

(2) DOE O 430.1B, *Real Property Asset Management*, (current version), Office of Project and Facilities Management, U.S. Department of Energy, Washington, D.C. 20545.

(3) 10 CFR 830, *Nuclear Safety Management*.

(4) TM 5-1300, NAVFAC P-397, AFM 88-22, *Structures to Resist the Effects of Accidental Explosions*, Departments of the Army, the Navy, and the Air Force, Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(5) DOE/TIC-11268, *A Manual for the Prediction of Blast and Fragment Loading of Structures*, U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120.

(6) DoD 6055.9-STD, *Department of Defense Ammunition and Explosives Safety Standards*, Assistant Secretary of Defense (Manpower, Installations, and Logistics), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(7) DDESB, Technical Paper No. 13, *Prediction of Building Debris for Quantity-Distance Siting*, April 1991, Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(8) AMC-R-385-100, *AMC Safety Manual*, Headquarters, United States Army Materiel Command, 5001 Eisenhower Avenue, Alexandria, VA 22333.

(9) TR-828, *Blast Environment from Fully and Partially Vented Explosions in Cubicles*, W.A. Keenan and J.E. Tancreto, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

(10) AD 411445, *Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations*, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

(11) AFWL-TR-74-102, *The Air Force Manual for Design and Analysis of Hardened Structures*, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; AD B004152,

Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

(12) HNDM-1110-01-2, *Suppressive Shields, Structural Design and Analysis Handbook*, U.S. Army Corps of Engineers, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807.

Table VI-3. Explosives Facilities: Protective Design Requirements by Activity Type

Type of Activity	DOE M 440.1-1 Operational Requirement for Activity Involved	Explosion Protection for Personnel in Other Occupied Areas Including Adjacent Bay	Explosion Protection for All Personnel (Remote Operation)	Control of Plutonium in Event of Explosion	High-Level Protection from Natural Phenomena	Normal Protection from Natural Phenomena[1]	Radiological Considerations
Class I Activities[2]							
Explosives Only	X	X	X			X	
HE-Pu Cased							
HE-Pu Uncased							
Class II Activities							
Explosives Only	X	X				X	
HE-Pu Cased	X	X					
HE-Pu Uncased	X	X		X	X		X
Class III Activities							
Explosives Only	X					X	
HE-Pu Cased			NOT PERMITTED				
HE-Pu Uncased			NOT PERMITTED				
Class IV Activities							
Explosives Only	X[3]					X	
HE-Pu Cased	X[3]					X	X
HE-Pu Uncased	X[3]					X	
Support Area	X					X	

1 These facilities need only be designed to provide protection acceptable with normal DOE loss criteria.

2 Class I activities with either cased or uncased HE-Pu are not permitted, except where such activities are justified from a nuclear explosives safety study performed in accordance with DOE O 452.1C, *Nuclear Explosive and Weapon Surety Program*, 10-10-90.

3 Class IV bays need only be sited and designed to withstand the effects of blast overpressure, structural collapse, and missiles (hazardous fragments) from an adjacent bay.

Definitions of explosives hazard classes by activity are in the glossary.

CHAPTER VII—OPERATING PROCEDURES

1.0 GENERAL

1.1 Requirements

a. This chapter establishes requirements for preparing and controlling procedures used for operations involving explosives at DOE installations. These requirements minimize the probability of an incident resulting from operations using outdated, inapplicable, or incomplete procedures, or from operations performed in violation of established practices.

b. This chapter also specifies that procedures must be generated for all explosives operations because the step-by-step reasoning process that is used in developing the procedure will identify many safety-related problem areas that might be overlooked otherwise. In addition, the approval system for new or revised procedures also provides other viewpoints and knowledge that may not be available to the originator and may need incorporation into the procedure.

1.2 Types of Procedures

a. This chapter describes two general types of operating procedures:

(1) Standard operating procedures (SOPs). Standard operating procedures are formalized documents prepared for performance of a task on a routine basis. Existing and applicable Department of Defense (DoD) ordnance publications (see section 3.0 for references) will be reviewed for application of unexploded ordnance (UXO) work. Revisions to these documents will invalidate the DoD procedures. If the documents are not appropriate for the situation, then changes may be made, subject to the [DOE] review and approval process.

(2) Nonstandard procedures, which include experimental and special procedures. Experimental and special procedures are documents prepared for performance of a task on a limited basis. For the purpose of this Manual, special procedures are those written to correct a problem encountered in an explosive operation.

2.0 GUIDELINES

a. The following general guidelines should be used in creating operating procedures.

2.1 Before Operation

a. Before starting any operation involving explosives, a hazard analysis shall be undertaken to identify any abnormal problems that will require special training, equipment, or procedures to safeguard personnel conducting the operation.

b. A thorough review shall be conducted in accordance with Chapter II, section 1.7, which will establish if the operation is safe to field. A Safety Analysis Report (SAR) is not required for UXO cleanups. For nonstandard cleanups, such as mass burial or radiation contamination, a Safety Assessment (SA) is required, along with SOPs/special procedures that include the additional precautions to be taken.

c. General operating procedures shall be written and approved for each activity to ensure consistency and safety of operations.

2.2 Supervisory Responsibility

a. Supervisory personnel shall be responsible for enforcing the provisions of all procedures used in their jurisdiction.

2.3 Preparation

a. Responsible personnel with knowledge of the operations involved shall prepare the procedures.

b. All material called out in the procedure and operational steps shall be checked for compliance with the guidance in this Manual and other DOE directives that may be applicable per DOE O 440.1A.

c. The specific types of equipment and building or area in which the operation is to be conducted should be designated in the procedure, when applicable.

d. If similar operations in the same area involve differences in equipment or process, supplemental procedures or sections shall be written.

2.4 Approval

a. New or revised operating procedures shall be reviewed and approved prior to use. Each operator should establish levels of approval required based on the operation's inherent risk. As a minimum, review and approval requirements shall include line and safety organizations.

b. Work control processes shall be in place prior to any operational activities.

2.5 Control

a. Distribution of procedures shall be controlled to ensure that each operating area has the most current revision. Superseded or inactive procedures shall be removed from operating areas. No operation shall be performed with superseded, inactive, or unapproved procedures.

b. Files of active procedures should be maintained.

2.6 Audits

a. An audit system should be established that will routinely evaluate the adequacy, availability, and currency of procedures. Also, audits should include an evaluation of operator knowledge and compliance with procedures.

b. Groups conducting the audits should include personnel from other than the operating department or division using the procedure.

2.7 Reviews

a. Appropriate departments should review active procedures at least annually.

b. If a procedure is no longer completely applicable to an operation or if new safety considerations (i.e., compatibility, toxicity, ignition sources, etc.) have been identified, the procedure shall be revised.

c. A procedure not expected to be used during the coming year may be placed in an inactive procedure file.

d. Before an inactive procedure can be reactivated, it shall be reviewed and approved. Minimum approval shall be the same as that required for a new or revised procedure (see section 2.4 of this chapter).

2.8 Content of Standard Operating Procedures

a. The following presentation is intended to specify content of procedures, not the format or organization. Each operator should develop its own system for preparing safety procedures.

2.8.1 *General Operating Procedures*

a. Introduction. The introduction to the procedure should include the following:

(1) A statement of the scope, defining what facilities and equipment are covered.

(2) The name of the department and individual responsible for the operation.

(3) If the procedure serves as the basis for an exemption or waiver from the requirements of this Manual, a statement to this effect and a specific reference to the standard involved.

b. Safety and Health. The safety section of the procedure should present the following information or reference a safety manual that specifies the requirements:

(1) General safety rules to be observed and techniques to be applied that will ensure safety of operations, prevent personnel injury or illness, and prevent equipment damage. In particular, this SOP section should describe the facility's personnel control features that protect personnel from exposure to hazardous operations, toxic materials, or tests.

(2) The number of personnel (workers and casuals) and explosives weight limits.

(3) Additional or specific emergency controls not addressed by the facility emergency plan.

c. Operations. The operations section should consist of general directions for operation of all major explosives-handling equipment. Particular emphasis should be placed on safety interlocks and controls, and their proper use. If operation of a particular item of equipment or of an area requires that no other operation be performed simultaneously in the same area, this requirement shall be stated clearly in the procedure.

2.8.2 ***Unit Operating Procedures***

a. Introduction. The procedure introduction should include the following:

(1) A statement of the nature of the operation and its objectives.

(2) The name of the department responsible for the operation and the procedure.

(3) A description of the range of work the procedure authorizes.

(4) If the procedure serves as the basis for an exemption or waiver from the standards of this Manual, a statement to this effect and a specific reference to the standard involved.

b. Materials and Equipment. The materials and equipment section should present the following information:

(1) All significant tools, supplies, chemicals, and equipment necessary to perform the operation should be listed in the SOP or in a separate required document.

(2) Specifications for approved chemicals, supplies, tooling, and equipment should be referenced where applicable.

(3) An explanation of any specific hazard involved in the handling of chemicals or explosives, or a reference to a document that describes the hazards should be included.

c. Safety. The safety section should present the following information or reference a safety manual that specifies the requirements:

(1) Safety rules specific to the operation.

(2) Protective equipment that must be used during the operation.

(3) Emergency controls applicable to the operation not considered in the general operating procedures.

d. Operations. The operations section should consist of sequential directions written or pictured in clear, concise steps that describe how to perform a particular operation. If a particular operation requires that no other operation be performed simultaneously in the same work area, this requirement shall be stated clearly in the procedure.

2.9 Content of Special or Experimental Procedures

a. In addition to the applicable requirements listed in section 2.8 of this chapter, the following shall also be addressed:

(1) Field operations remote to normally occupied areas shall include procedures to ensure prompt response of both fire and medical emergency services or those services shall be staged at the event site.

(2) Personnel involved with the operation shall be briefed or trained on any unique aspects of the operation and emergency procedures.

b. When a special or experimental operation will be conducted a number of times, an SOP should be written and approved.

3.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in UXO operations.

(1) 60-Series Publications, Commanding Officer, Naval Explosive Ordnance Disposal Technology Division, 2008 Stump Neck Road, Indian Head, MD 20640-5070

(2) OE CX Interim Guidance, US Army Corps of Engineers, Huntsville Center, P.O. Box 1600, Huntsville, AL 35807-4301.

CHAPTER VIII—FORMULATION SCALEUP

1.0 EXPLOSIVES DEVELOPMENT PROGRAM

1.1 Explosives Development Committee

a. A committee shall be established at each DOE facility engaged in explosives development to be the approving authority for each phase of an explosives development program. This committee will be referred to in this Manual as the Explosives Development Committee (EDC), but it may have a different name at each DOE facility. Individuals chosen to serve on the EDC should have considerable experience in explosives handling, processing, chemistry, sensitivity, and safety.

1.2 Phase-by-Phase Approvals

a. The EDC shall review and approve data generated in each phase of a development project that involves a new explosive or new explosive formulation before the next phase begins.

1.3 Modified Formulations

a. Compositional modifications to previously evaluated explosive formulations shall be approved by the EDC. However, the EDC may approve minor modifications to the explosives formulation for a given phase of development without requiring all of the developmental steps and tests.

1.4 Sensitivity Data from Another Laboratory

a. If comparable sensitivity data for the subject material are available from another laboratory, the EDC may waive some developmental phase tests.

2.0 DEVELOPMENT PROCEDURES

2.1 General

a. All DOE explosives handling facilities shall establish an administrative procedure that defines the basic steps for developing and evaluating new explosives and explosive formulations. The procedure shall require that each development effort proceed in phases from small to large quantities. The quantities of materials that may be handled in each phase shall be limited. The EDC shall be responsible for establishing criteria for acceptable explosive behavior in each test of each phase of the explosives development procedure. The development procedure should consist of three phases plus a synthesis phase and compatibility testing, when required. Guidelines for establishing this procedure are proposed in the following sections. Table VIII-1 summarizes these guidelines.

2.2 Synthesis Phase

a. Before mixing a new explosive with other materials, the sensitivity and stability of the explosive should be determined and should comply with the criteria set by the EDC. Recommended tests include the following:

(1) Drop-weight impact.

(2) Friction.

(3) Spark.

(4) Thermal stability-these tests should include two or more of the following:

2.2.1.1 Differential thermal analysis or differential scanning calorimetry.

2.2.1.2 Thermal gravimetric analysis.

2.2.1.3 Gas evolution rate at elevated temperature (chemical reactivity test, vacuum stability, etc.).

2.2.1.4 Time-to-explosion analysis.

2.3 Compatibility Testing

a. If a proposed formulation contains new ingredients (explosive or nonexplosive), the new ingredients should be tested for compatibility with the other ingredients before preparing batches for Phase I testing. Compatibility tests should include any of the stability tests listed under section 2.2a(4) of this chapter.

b. No more than 2 g of the new formulation should be prepared, handled, or stored before compatibility testing.

c. Formulations for compatibility testing should be processed remotely, whenever possible.

Table VIII-1. Scaleup Procedure Guidelines for New Explosives and Formulations

Quantity of New Material[a]	Recommended Data[a]	Data Desired	Additional Recommendations
Synthesis			
Specified by the lab performing the synthesis	Impact, Friction, spark, thermal stability	Before using the new ingredient in a formulation	----
Formulation			
Compatibility Testing: 2g	Thermal compatibility of new ingredient with other ingredients of formulation	Before proceeding to Phase I	Materials should be processed remotely
Phase I			
10g	Impact, friction, thermal stability	Before nonremote processing and handling in Phase I or scaleup to Phase II	Materials should be processed remotely before passing sensitivity and stability tests
Phase II			
500g[b]	Compatibility,[c] impact, friction, spark, thermal stability, thermal characterization before elevated temperature pressing	[d, e]	[f]
Phase III			
Specified by EDC	Compatibility, high-speed machining, drop, skid	Before Phase III machining or handling of billets 7 kg or greater	Composition of formulation shall be fixed

[a] Quantities and recommended data apply to both new formulations and explosive ingredients.

[b] The EDC may allow more than 500 g in Phase II where larger quantities are needed for some tests.

[c] Compatibility of explosives and formulations with materials contacting the explosives in test and production assemblies.

[d] Before proceeding to Phase II if the composition of a formulation is modified so that the composition is no longer within the limits specified by the EDC.

[e] Before proceeding to Phase III if:

(1) The formulation to be scaled up to Phase III differs from that tested in Phase I or

(2) The explosive or formulation prepared for Phase II development is produced by techniques different from those used in Phase I.

[f] Materials investigated in this phase should be produced by techniques similar to those that will be used to produce larger batches in a subsequent phase.

2.4 Phase I—Preliminary Explosives Testing

a. The total quantity of material that may be processed, handled, or stored at any one time in Phase I should not exceed 10 g. Whenever possible, this material should be processed remotely.

b. The new explosive or formulation should be subjected to sensitivity and stability tests. As a minimum, drop-weight impact, friction, spark sensitivity, and thermal stability tests should be run. Thermal stability testing need not be performed here if one or more of the compatibility tests listed under section 2.2a(4) of this chapter have already been conducted on the new formulation.

c. If the new explosive or formulation is acceptable in the above tests, it may be scaled up to Phase II. The EDC may impose handling or processing restrictions or precautions on the material if its performance in any of the above tests is questionable.

d. After Phase I testing of a formulation is complete, the EDC should define, on the basis of the test results, what variations in composition are permissible during Phase II development without retesting.

2.5 Phase II—Experimental Characterization and Development

a. The total quantity of materials that may be processed or handled at any one time in Phase II should not exceed 16.075 oz (500 grams). No limit exists on the quantity that may be stored, other than the storage facility limits for Group L explosives.

b. Materials investigated in Phase II should be produced by techniques similar to those that will be used to produce larger batches in a subsequent scaleup phase.

c. A thermal characterization test and evaluation should be run before pressing the new material at elevated temperature.

d. The Phase I sensitivity and stability tests should be rerun in Phase II if the following conditions apply:

(1) The formulation to be scaled up to Phase III differs from that tested in Phase I. In this case, testing should be completed before Phase III scaleup.

(2) The explosive or formulation prepared for Phase II development is produced by techniques different than those used in Phase I. Testing should be completed before Phase III scaleup.

(3) During Phase II, the composition of a formulation is modified to an extent that the composition is no longer within the limits specified by the EDC (see section 2.4d of this chapter). Testing should be completed before proceeding with Phase II.

(4) The compatibility of explosives and formulations with materials contacting the explosives in test and production devices shall be evaluated before any such device is assembled. If compatibility testing is required, one or more of the tests listed under section 2.2a(4) of this chapter should be recommended.

2.6 Phase III – Full-Scale Testing and Production

a. The maximum quantity of materials that may be processed or handled in Phase III should be defined in the EDC grant of authorization to proceed with Phase III. No limit is imposed for the storage facilities except the limits imposed by the quantity-distance tables.

b. All additional testing necessary to define storage compatibility grouping should be completed before committing bulk quantities of the material to storage, (see Chapter II, section 17.4).

c. During Phase III development, the composition of all formulations should be fixed.

d. Any new explosive material that is to be contact machined shall be subjected to a machining overtest. Reaction threshold should be determined if possible.

e. If billets of 15.4 lb (7 kg) or greater are to be produced in Phase III, drop-skid testing should be performed and EDC criteria for this test should be met.

f. Section 2.5d of this chapter should also apply to Phase III development.

CHAPTER IX—INSENSITIVE HIGH EXPLOSIVES QUALIFICATION

1.0 INSENSITIVE HIGH EXPLOSIVES (IHE)

a. Some explosive substances, although mass detonating, are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. Any explosive that is a candidate for classification as an IHE shall be subjected to the DOE qualification tests listed in Table IX-1or Recommendations on the Transport of Hazardous Goods-Tests and Criteria, Test Series 7. Test procedures, where not specified, are contained in MHSMP-84-22*, IHE Material Qualification Tests, Description and Criteria*. The DOE laboratory or operator shall submit test data for each explosive requested for this classification through the appropriate Operations Office to the DOE Office of Facility Safety. The DOE Explosives Safety Committee will independently analyze the data and recommend action on including the explosive in Table IX-2 as an approved IHE.

Table IX-1. DOE IHE Qualification Tests.

1. Drop-weight impact test[a]	Comparable to or less sensitive than Explosive D (ammonium picrate). Minimum of 20 drops per test series.
2. Friction test[b]	No reaction on Pantex friction machine (10 trials).
3. Spark test[a]	No reaction at minimum of 0.25 joules (10 trials)
4. Ignition and unconfined burning test (small scale burn)	TB 700-2 test procedures, any shape, minimum thermal path of 25 mm, no explosion.
5. Card gap test[b]	No reaction at Explosive D 50 percent gap thickness (or less) using a Pantex modified NOL card gap test (6 trials). The test diameter must be greater than the unconfined failure (critical) diameter of the candidate IHE.
6. Detonation (cap) test	TB 700-2 test procedures—no detonation (5 trials).
7. Cookoff	No reaction of more than a pressure release using the large-scale ODTX test conducted such that a reaction must occur in not less than 4 hours (6 trials).
8. Spigot test[b]	No reaction for 120-ft drop in LANL test (3 trials).
9. Skid test[b]	No reaction up to 20-ft (or sample failure) drop at 14-15 degrees test angle using standard size billets (3 trials at worst case condition).
10. Susan test	Less than or equal to 10 percent TNT output at a minimum of 333 m/sec (3 trials).
11. Bullet impact	No violent reaction with 5.56 mm and .50 cal. projectile impact on material in schedule 40 steel pipe with closures on each end (6 trials in axial orientation).

[a] These tests are not applicable to compacted explosives
[b] These tests are not applicable for explosives powders.

Table IX-2. Approved IHEs

TATB
TATB/KEL-F Formulations

b. New candidate explosives formulations will not be classified by analogy as IHE until reviewed by the DOE Explosives Safety Committee. The general guidelines for requesting and obtaining an IHE approval by analogy are:

(1) All requests, including rationale, must be submitted in writing to the DOE Explosives Safety Committee for analysis and recommended action.

(2) Approved IHEs with complete test data must be used for baseline comparison purposes.

c. More specific guidelines will depend on circumstances surrounding the specific analogy request.

d. When a partial analogy can be drawn, only partial testing is needed depending on the type and extent of change in the candidate IHE relative to the baseline IHE and the potential effects of these changes on specific initiation mechanisms (shock, thermal, mechanical, impact, electrostatic, etc.). A candidate IHE can be placed in one of the following categories to define the tests required for approval:

(1) CASE I (partial testing required). The candidate IHE formulation substitution of the inert binder component of the approved baseline IHE with a new inert binder component. Sufficient testing is required to verify that no chemical incompatibilities have been introduced that would de-stabilize the base IHE. In this case, test data normally generated by the requesting facility during their explosive development scaleup phasing process may be submitted for approval in lieu of the qualification tests of Table IX-1. During the development phase, the facility EDC may dictate restrictions consistent with an IHE internal to their facility only. Final approval as an IHE must be obtained through the DOE Explosives Safety Committee. Tests 1, 2, 3, and 7 of Table IX-1or equivalent are required as a minimum.

(2) CASE II (all IHE tests of Table IX-1 required; analogy inappropriate). The candidate IHE involves the addition of an

untested (IHE tests) energetic component to the approved baseline IHE.

OR

(3) The candidate IHE involves the same energetic and inert components as the approved baseline IHE, the only change being a volume- percent increase in the energetic component content.

e. In deliberating the approval request, the DOE Explosives Safety Committee will consider any data available over and above that required by Table IX-1.

2.0 IHE SUBASSEMBLIES

a. IHE subassemblies are composed of IHE hemispheres or spheres with booster charges, with or without detonators. Successful completion of the applicable DOE qualification tests listed in Table IX-3 is required for classification as an IHE subassembly. The DOE requestor shall submit a test plan defining specific test procedures for candidates for this classification through the appropriate Site Office to the DOE Explosives Safety Committee for review. On approval of the plan, tests shall be run and the DOE Explosives Safety Committee shall independently analyze the data and recommend approval or disapproval. DOE Headquarters will then issue a memorandum to appropriate Site Offices and DOE contractors classifying those configurations meeting the required test criteria as IHE subassemblies. Approved IHE subassemblies are listed in Table IX-4. Subassemblies will not be classified as IHE Subassemblies by analogy until reviewed by the DOE Explosives Safety Committee. When no other explosives are present in the same location, these subassemblies are classified as Class 1.6 explosives (see Table IX-5) for storage and processing.

Table IX-3. DOE Qualification Tests for IHE Subassemblies*

1. Spigot test	No burning or violent reaction of main charge of 120-ft drop on booster in LANL test (3 trials).
2. Bonfire	No detonation or violent reaction of main charge when engulfed in a fire (3 trials).
3. Slow cookoff	No detonation or violent reaction of main charge when slowly heated to a reaction (3 trials).
4. Multiple bullet impact	No detonation or violent reaction of main charge with a 3-round burst of 7.62 mm projectile impact on booster (3 trials).
5. Skid test	No burning or violent reaction of main charge up to a 20-ft (or sample failure) drop at 14 to 15 degrees test angle using subassembly configuration modified for impact on the booster (3 trials at worst case condition).

* Tests are not required for subassemblies when main charge and booster charge explosives have been qualified as IHE by tests in Table IX-1.

Note: The test plan shall specify applicable testing for cased and/or uncased configurations with or without detonators.

Table IX-4. Approved IHE Subassemblies

B61*3/4/6/7/8/10/11	W80*	W81*	B83*
W84	W87	W89	

*Approval limited to boosters of the size tested or smaller. Any redesign that dimensionally increases the booster size requires resubmission of an experimental plan and additional testing as another IHE subassembly.

Table IX-5. IHE Hazard Classification

IHE bulk powder (onsite)	1.3C
IHE consolidated charges w/o boosters or dets	1.6N
IHE nuclear explosive assemblies and subassemblies with boosters, with or without dets	1.6N
IHE articles with 1.1 items	1.1
IHE articles with 1.2 items	1.2
IHE articles with 1.3 items	Note 2
IHE articles with 1.4 items	1.6N
IHE articles at less than magazine distance from Division 1.1	1.1
IHE articles at less than magazine distance from Division 1.2	1.2

Note 1 IHE can be stored with mock HE without regard to the quantity of mock high explosives unless the mock explosive is a flammable solid (hazard division 4.1).
Note 2 Division 1.3 or 1.6, whichever is most restrictive.

3.0 IHE WEAPONS

a. IHE weapons are those weapons listed in DOE DNA TP 20-7 that are exempt from storage and transportation limits when stored or transported alone or in combination with each other. This classification is valid only if storage containers provide adequate spacing between individual units. TP 20-7 specifies the spacing requirements for materials stored or transported out of containers. These weapons are classified as Class 1.6 explosives for storage, processing and transportation purposes.

4.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in the IHE and IHE subassembly testing required by Table IX-1and Table IX-3:

(1) TB 700-2, NAVSEA INST 8020.8A, TO 11A-1-47, DLAR 8220.1, *Department of Defense Explosives Hazard Classification Procedures,* Departments of the Army, the Navy, the Air Force, and the Defense Logistics Agency, Washington, D.C.

(2) Mason & Hanger-Silas Mason Publication 84-22 (MHSMP-84-22), *IHE Material Qualification Tests, Description and Criteria* (Rev 1, July 1985), National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

(3) *Recommendations on the Transport of Hazardous Goods-Tests and Criteria*, Second Edition, ST/SG/AC.10/11/Rev.1, LABELMASTER, Chicago, IL, 60646 USA.

(4) Mason & Hanger-Silas Mason Publication (MHSMP-86-16), *IHE Subassembly Test Results for the B-83, B-61, 3/4/6/7/8, W80, W81, and W85*, June 1996, Robert S. Slape, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

CHAPTER X—ELECTRICAL STORMS AND LIGHTING PROTECTION

1.0 ELECTRICAL STORM HAZARDS

a. The primary focus of this chapter is to provide protection to explosives in event of an electrical storm, and to personnel working in explosives areas, and personnel near those explosives areas from the consequences of an explosives incident resulting from a lightning strike. Lightning presents a hazard to explosives in at least five ways:

(1) The electrical current produced by a voltage gradient resulting from a lightning strike could initiate the explosives directly.

(2) The surface flashover or arcing of the generated electrical current between conductive surfaces that are not at equilibrium could initiate the explosives directly by the heat, sparks, and molten metal generated by the arc.

(3) This same arcing could cause damage or fires in electrical fixtures and equipment.

(4) The lightning could initiate a fire involving combustible materials in the facility, including the containers around explosives.

(5) The spalling generated by the heat of the current flowing through the structural components of the facility could initiate, by impact, unprotected explosives. In addition, lightning could affect support systems such as fire protection and security. Lightning can reach a structure not only by direct strike, but also indirectly by coupling to a conductor that penetrates the structure.

b. This chapter summarizes the minimum requirements for design, maintenance, testing, and inspection of lightning protection systems (LPSs) and lightning detection systems. Only lightning protection systems described in this chapter shall be used. The DOE Explosives Safety Committee must specifically approve use of non-conventional systems, such as streamer emission and charge dissipation systems. Protection from lightning induced hazards can best be achieved by enclosing the explosives in an interconnected network of good conductors, such that the exterior fields, currents, and voltages are reduced. This method of protection is similar to a Faraday cage and is called a “Faraday-like shield” LPS. A second method or layer of protection is achieved by providing a sufficiently large sideflash separation (standoff) distance between the explosives and any electrical conductor within

the structure (including the walls and ceiling) to preclude the possibility of current flowing onto the explosives or arcing to them. (Note: As part of the Faraday-like shield LPS, a minimum sideflash separation distance is required from the boundaries of the structure.) A third method involves directing the current away from the structure and directly to ground by use of air terminals, masts or catenaries, and down conductors. When none of the above methods of lightning protection are provided, personnel can be protected by evacuating them an appropriate distance as specified in section 6.0 of this chapter.

c. Facilities have five years from the issuance of DOE M 440.1-1A (Revision 9) of this Manual to fully implement for existing structures those requirements and recommendations of sections 2.0 through 4.0 that were not contained in Revision 8 of this Manual or NFPA 780. Neither waivers nor exemptions are required for such items during the implementation period. New structures and conversion of an LPS to a Faraday cage-style shield shall comply with the most current requirements.

2.0 LIGHTNING PROTECTION SYSTEMS

a. A properly designed and installed lightning protection system (LPS) meeting the requirements below and maintained per section 3.0 is required for all explosives structures except as identified in section 4.0.

2.1 Lightning Protection System Basic Design

a. Lightning protection system design consists of the use of strike termination means, low impedance paths to ground, and earth electrode systems, coupled with bonding of all conductive penetrations into the protected area, surge suppression, and sideflash protection. Metallic elements of the structure meeting the material requirements of NFPA 780 are allowed to serve as strike termination devices, down conductors, or parts of the earth electrode system. Facility Management, the Authority Having Jurisdiction, and a person competent in lightning protection system theory and design shall approve design variations from those specified below.

b. Design of lightning protection systems per NFPA 780 shall be based on a 100-ft (30.5-m) striking distance ("Rolling Sphere"). The zone of protection provided by an LPS is the space beneath the LPS that is substantially immune to direct lightning attachment. The LPS design shall ensure that explosives facilities and their associated components that require lightning protection are within the LPS zone of protection. Structural elements of the building meeting the material requirements of NFPA 780 are authorized to serve as the LPS or parts of the LPS.

c. Design parameters for a Faraday cage and Faraday shield-like LPS shall be based, as a minimum, on a one percent threat level and include the following:

(1) Return stroke amplitude = 200 kA

(2) Rise rate = 400 kA/μsec

(3) Number of strokes per flash = 26 max

(4) Striking Distance = 30.5 m (100 ft)

(5) Burn through of 0.19 in. (4.8 mm) for steel, 0.20 in. (5 mm) for copper, and 0.28 in. (7 mm) for aluminum.

(6) Action = $3x10^6$ $amps^2$-sec.

2.2 Lightning Protection Subsystems

a. An approved LPS consists of the following subsystems:

(1) A strike termination device to intercept the direct attachment of a lightning flash and connects it to a path to ground. A strike termination device may include metal masts, air terminals, overhead wires (catenary) or permanent metal parts of a building.

(2) Down conductors to interconnect the strike termination devices and form paths from each strike termination device to the earth electrode system (e.g., heavy metallic cables, metallic building structural members).

(3) An earth electrode system to transfer lightning current to the earth. The earth electrode system is connected to the down conductor and is in direct contact with the earth. Examples of earth electrode systems include ground rods, a ground ring (counterpoise), buried metal plates, and an Ufer ground or other similar devices.

(4) Surge suppression devices (SSDs) to limit harmful energy due to lightning or power line transients from entering a structure via power and metallic signal lines and initiating an explosion or fire. SSD attenuates, suppresses or diverts lightning induced electrical energy to the earth electrode system.

2.3 Approved Lightning Protection Systems

a. The approved types of LPS are Mast, Catenary, Integral Air Terminal, and Faraday cage or Faraday-like shield systems. Faraday cage or Faraday-like shield systems are preferred for new structures where applicable. The main features of each type system are summarized below.

2.3.1 *Mast System*

a. A Mast System consists of one or more poles with a strike termination device connected to an earth electrode system by down conductors. It provides a zone of protection as shown in Figure X-1 for a single mast. The principal design parameters include:

(1) The minimum mast separation distance from the structure is 6 ft (1.8 m) or the formula as defined in NFPA 780 (2004), D = h/6, whichever is greater where the h is the height of the mast of structure considered.

(2) Non-metallic masts require a metal air terminal or metal cap installed at the top that is connected to the earth electrode system by at least two down conductors installed on opposite sides of the mast. (Note: Mast guy wires are allowed to serve as down conductors, provided they are connected to the earth electrode system.

(3) Metallic masts serve as both air terminal and down conductors, and will be connected to the earth electrode system with two independent main size conductors attached approximately symmetrically to (i.e., opposite sides of) the mast base.

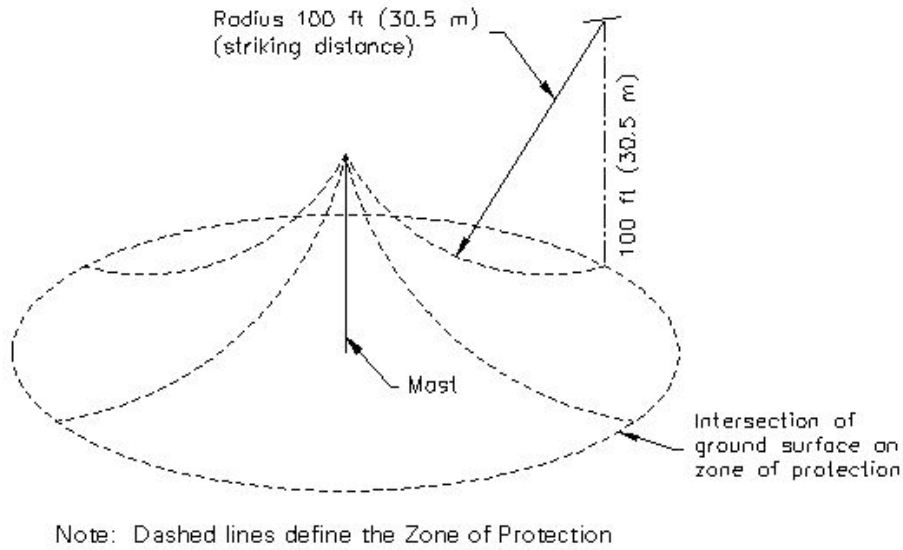


Figure X-1. Single Mast Zone of Protection

2.3.2 ***Catenary System***

a. The Catenary LPS consists of wires (cables) stretched between the tops of two or more masts (see Figure X-2). The main design parameters include:

(1) Each wire shall be an electrically continuous run of main size conductor [e.g., copper-clad or galvanized steel cable with a minimum diameter of 0.25 in. (6.4 mm)] bonded to all down conductors.

(2) Non-metallic masts require a metal air terminal or metal cap installed at the top that is connected to the earth electrode system by at least two down conductors installed on opposite sides of the mast. (Note: Mast guy wires are allowed to serve as down conductors, provided they are connected to the earth electrode system.)

(3) Metallic masts serve as both air terminal and down conductors themselves, and shall be connected to the earth electrode system by two main size conductors attached approximately symmetrically to (i.e., opposite sides of) the mast base.

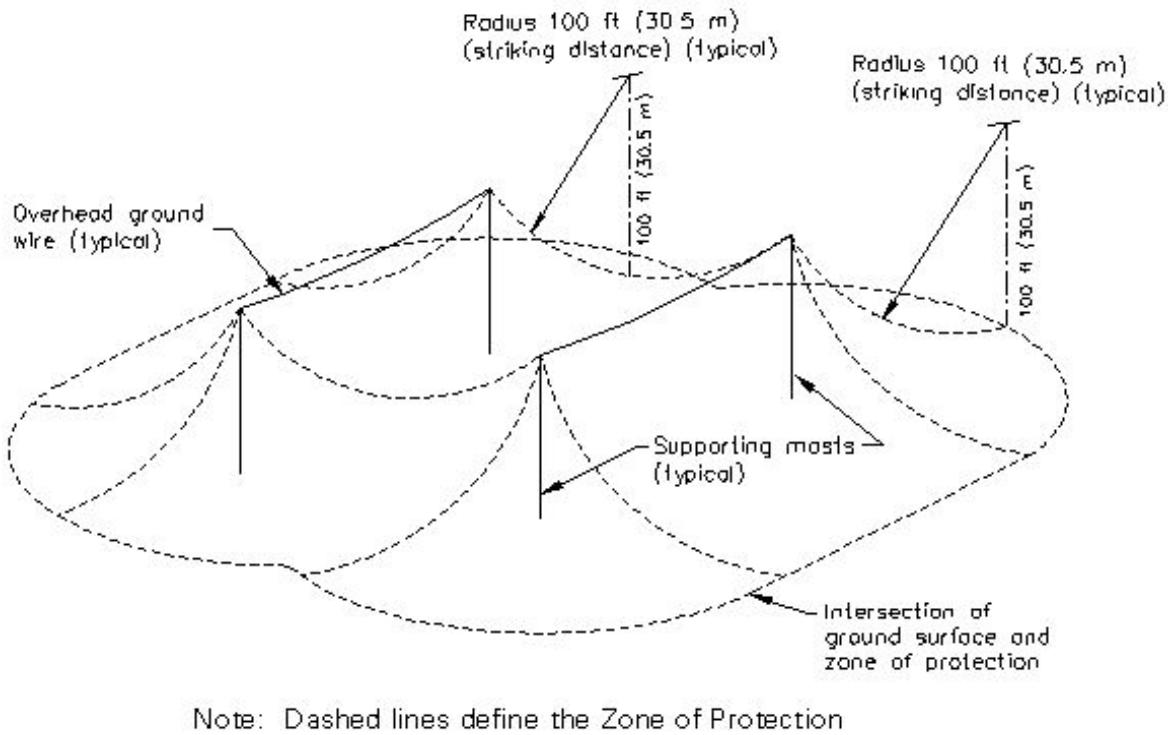


Figure X-2. Example of Catenary System Zone of Protection

(4) The minimum vertical separation between an overhead wire and the protected structure, including its projections, shall be the greater of 6 ft (1.8 m) or as defined in NFPA 780 (2004), as D = (L/6n).

Where:

D = Sideflash distance from a catenary

L = Length of lightning protection conductor between its grounded point and the point being calculated.

n = 1.00 where there is a single overhead ground wire that exceeds 200 ft (60 m) in horizontal length.

n = 1.50 where there is a single overhead wire or more than one wire interconnected above the structure to be protected, such that only two down conductors are located greater than 20 ft (6 m) and less than 100 ft (30 m) apart.

n = 2.25 where there are more than two dozen conductors spaced more than 25 ft (7.6 m) apart within a 100-ft (30-m)

wide area that are interconnected above the structure being protected.

(5) Deflections of the wire resulting from wind, ice, or other weather conditions shall be considered in determining the separation distance. The supporting mast will be at least 6 ft (1.8 m) from the structure.

2.3.3 *Integral Air Terminal System*

a. An integral LPS is one that has the strike termination devices mounted on the structure to be protected. These strike termination devices are connected to the earth electrode system via down conductors. Metallic structural members can serve as parts of the LPS. However, sideflash protection is required. (See bonding distance formula in NFPA 780). An example of this system is shown in Figure X-3. The relevant design parameters are:

(1) The down conductors of integral systems shall be installed in as nearly a vertical position as possible.

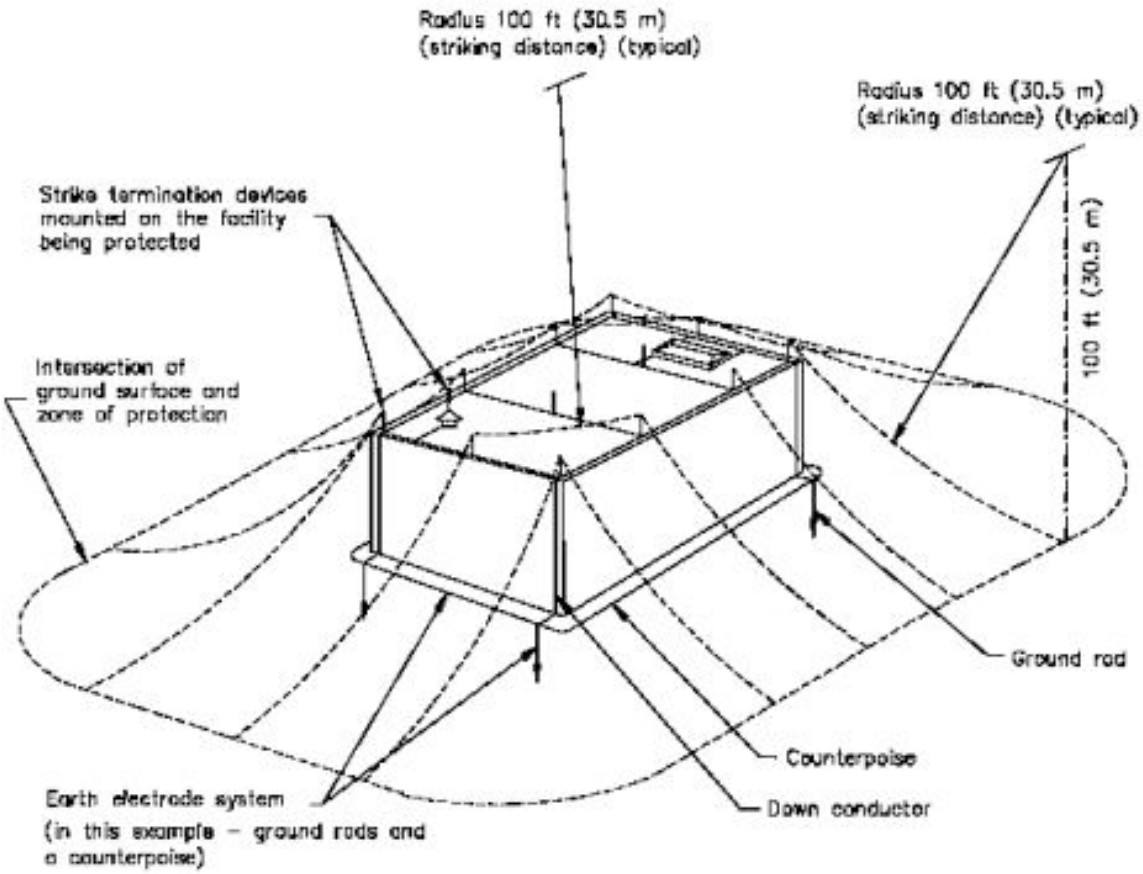
(2) No bend of a conductor shall form an included angle of less than 90 degrees, nor shall it have a radius of bend less than 8 in. (203 mm).

(3) The number of conductors and configuration of the connections between air terminals are as required by NFPA 780.

(4) Air terminals height and location are as required by NFPA 780.

2.3.4 *Faraday Cage and Faraday-like Shield*

a. The preferred method of protecting explosives operations from lightning flashes, as well as from other external sources of electromagnetic radiation, is to enclose the operations or facility inside a Faraday cage. A Faraday cage is an enclosure composed of a continuous grid of conductors, such that the voltage between any two points inside the enclosure is zero, when immersed in an electrostatic field. A Faraday cage or Faraday-like shield LPS is one where the protected volume is enclosed by a heavy metal screen (i.e., similar to a birdcage) or continuous metallic structure with all metallic penetrations bonded. The lightning current flows on the exterior of the structure not through the interior. A Faraday-like shield (which is not an ideal Faraday cage) is formed by a continuous conductive matrix that is properly bonded and grounded.



Notes:

1. The design of integral air termination systems will be in accordance with NFPA 780.
2. The design of the earth electrode system will be governed primarily by soil conditions at the site and the actions needed to meet required minimum resistance-to-earth values.
3. Solid lines indicate conductors connecting air terminals on the roof, down conductors, and the grounding system.
4. Dashed lines define the Zone of Protection.

Figure X-3. Integral System Zone of Protection

(1) Examples of Faraday-like shields include:

(a) Steel arch magazines where the steel arches and reinforcing bars (rebar) of the concrete end-walls and floor are electrically continuous and meet spacing requirements.

(b) Earth covered magazines and operating buildings where the reinforcing bars (rebar) of the concrete walls, floors, and ceiling are electrically continuous and meet spacing requirements.

(c) Reinforced concrete buildings where the reinforcing bars (rebar) of the concrete walls, ceiling, and floor of are electrically continuous and meet spacing requirements.

(d) The metal shell of prefabricated portable magazines and metal buildings.

(2) The main design parameters are:

(a) The structural components of buildings shall be electrically bonded together (i.e., walls, floor, roof, door and window frames) via built in attachments such as rebar welded or wired together, or by adding external bonding wires between components. The techniques commonly used and approved in the construction industry are acceptable for this purpose. (If welds are used, a structural engineer should verify that they do not adversely affect structural response).

(b) The structural components should be electrically bonded at intervals no greater than 3 ft unless testing shows otherwise. Bonding distances may vary based on building design. Use of greater than the nominal bonding distance requires an electromagnetic characterization of the building's transfer impedance to determine the specific bonding distances.

(c) A freestanding structure that is determined by a competent expert to be a Faraday cage or Faraday-like Shield may not require strike termination devices, down conductors or grounding systems. Structures that satisfy the Faraday cage/Shield definition have suitable down conductors and grounding components within the structure's design. However use of a strike termination device on these structures provides a preferred point of attachment for lightning and could prevent structural damage, such as concrete spall, in the event of a direct lightning strike attachment).

2.4 Lightning Protection Subsystem Criteria

2.4.1 *Components of Strike Termination System*

a. Air Terminal: An air terminal is the component of an LPS used to intercept lightning strikes. Air terminals include vertical spikes attached to the structure (commonly referred to as Franklin Rods), overhead wires (as used with catenary systems) or grids, and for earth covered magazines only, overhead air vents.

(1) When used as air terminals, air vents shall be (a) fabricated from metal 3/16 in. (4.8 mm) thick or greater and be electrically continuous with the steel reinforcing rod of the magazine or (b) designed to trap any molten metal a strike might produce. In all cases air vents on earth covered magazines shall be bonded to the structure as discussed in section 2.4.3.

(2) On structures modified to a verified Faraday-like shield LPS where an NFPA 780 LPS system exists, it is recommended that air terminals be maintained as they provide a preferred point of attachment for lightning strikes. If they are bonded to the Faraday cage, conductive downlines need only be maintained and visibly inspected to the point of juncture with the grounding system (i.e., ground rods or counterpoises). When Facility Management makes the determination that the NFPA 780 system will be retained, a visible inspection shall be performed on the same schedule as maintenance of the Faraday-like shield LPS. Electrical resistance and resistance to earth testing will not be required.

(3) Air terminals on an integral LPS shall consist of a cylindrical rod or tube of material and size as specified in NFPA 780. They can be pointed or blunt, but the optimal tip radius of curvature for interception of lightning strikes is 3/16 in. (4.8 mm) minimum to1/2 in. (12.7 mm) maximum.

b. Conductors: Conductors provide low impedance paths from air terminals to the earth electrode system.

(1) Where wires are used as down conductors, they shall meet the requirements of NFPA 780.

(2) Lightning conductors should run vertical or horizontal. If run upwards, they must have a rise of no more than 1/4 pitch.

(3) In a Faraday cage based LPS, the structural elements have a higher current carrying capacity and lower impedance to ground than wire down conductors. Structures with such an LPS do not require wire down conductors. When a structure with an existing air terminal LPS is modified to a verified Faraday cage based LPS, it is recommended air terminals be maintained as they provide a preferred point of attachment. If they are bonded to the Faraday cage, conductive downlines need only be maintained and visibly inspected to the point of juncture with the grounding system (i.e., ground rods or counterpoises). When Facility Management makes the

determination that the NFPA 780 system will be retained, a visible inspection shall be performed on the same schedule as maintenance on the Faraday-like shield LPS. Electrical resistance and resistance to earth testing will not be required.

2.4.2 ***Grounding***

a. Lightning protection systems, to include integral and catenary systems, but with the exception of Faraday cage or Faraday-like Shield systems, require an earth electrode (ground) system to dissipate the electrical energy of a lightning strike to the earth. The use of an earth electrode systems with a Faraday-like shield lightning protection system is not required as the floor of such a structure acts as the earth (ground) electrode; however, electrical safety grounding requirements do apply. Examples of earth electrode systems include ground rods, a ring electrode (counterpoise) system, buried metal plates, or Ufer grounds.

(1) The resistance of a lightning protection grounding system will not exceed that specified in section 3.0 below.

(2) When multiple ground rods are used as a grounding system, the rods will be separated by a distance so that they do not influence each other.

(3) All other grounding systems, e.g., AC power, electronic multi-point, electronic single-point, will be bonded to the lightning protection grounding system.

(4) In cases where some other installed system requires a lower resistance to ground than specified in section 3.0 below, the lower requirement will govern.

(5) See the following documents for specific guidance:

(a) National Electric Code, Article 250, Grounding

(b) IEEE 80, Guide for Safety in AC Substation Grounding

(c) NFPA 780 Standard for the Installation of Lightning Protection Systems

2.4.3 ***Bonding***

a. Bonding provides a physical and electrical connection from all parts of the LPS to the ground connection. Bonding produces electrical continuity between the LPS and metallic objects to minimize

potential differences. Methods of bonding include mechanical, compression and thermal connections.

(1) NFPA 780 requirements for bonding to the LPS that specifically need to be addressed include:

(a) Metallic gates and fences if they cross or are within sideflash distance of a LPS or are within 6 ft (1.8 m) of an explosives structure.

(b) Railroad tracks if they cross or come with in sideflash distance or 6 ft of an explosives structure's LPS or enter an explosives structure. If the tracks are used to carry electrical signals, they should have insulated joints immediately external to the bond of the LPS ground loop conductor. If the tracks enter an explosives structure, they also should be bonded to the metal frame of the structure or equivalent.

(c) All shielded cabling, power cabling, communication lines, data lines, and electrical conduit will be buried underground in conduit for a minimum of 50 ft (15.2 m) before entering the structure. These and other metallic utility lines and pipes will be electrically bonded to the LPS or the structural steel of the building as close as reasonably achievable, as determined by a competent expert, to the point of entry.

(d) Metallic penetrations within the zone of protection that are within sideflash distance of a component of the LPS or within sideflash distance of an item that is bonded to the LPS.

(e) Utilities (gas, water, power, signal) entering the structure from exterior to the LPS. (Apply NFPA cathodic protection guidance to prevent excessive corrosion.)

(f) Potential presence of ground loops.

b. All metallic penetrations into a Faraday cage or shield shall be bonded to the nearest structural member or LPS component that is integrally bonded to the earth (ground) electrode system. Bonding connections shall be as close to the point of entry as reasonably achievable. More than one bond may be required in some situations where a conductive penetration passes a structural member inside the structure. The bond resistance should be less than that specified in section 3.3.

c. Other metal masses that are integrated into the structure of the building (e.g., ventilators, steel doors, metal doorframes, steel reinforcing bars, etc.) shall be bonded to the nearest structural member or LPS component that is integrally bonded to the earth (ground) electrode system. Interior metal masses (desks, cabinets, etc) should be bonded if required by the competent expert.

d. Lightning protection system bonds should be as short and as direct as reasonably achievable to minimize inductance. Route the bonds as close to the rebar as reasonably achievable.

e. To preclude confusion between LPS bonding and electrical safety grounding, the following key differences should be understood:

(1) Lightning bonds must be as specified in NFPA 780 Table 3.1 or equivalent.

(2) Lightning clamps and fasteners must comply with UL-96 and UL-96A, and be listed for use with LPS.

f. Do not paint LPS bonds and conductors.

g. Bond resistance shall be as specified in section 3.3.

2.4.4 ***Surge Suppression for Incoming Conductors***

a. Surge suppression devices shall be provided in accordance with NFPA and the provisions of this Manual on each power line, signal line, or communication line conductor entering the LPS protected structure. They shall be located between the respective conductor and the structure ground and/or Faraday cage, as close as reasonably achievable to the point where the conductor penetrates the LPS zone of protection or the structure. All cabling, power cabling, communication lines, data lines, and electrical conduit shall be buried underground in metallic conduit for a minimum of 50 ft (15.2 m) before entering an explosives structure. These and other metallic utility lines and pipes shall be electrically bonded to the LPS or structural steel of the building as close as reasonably achievable to their entry point.

b. Surge suppression designed for specific equipment does not necessarily provide adequate protection for an explosives structure. It is the responsibility of the Facility Management to provide additional surge and/or transient protection for sensitive equipment located in and about the structure. This additional protection may or may not be incorporated in a surge suppression device. If it is

incorporated, the additional protection shall not decrease or compromise the protection intended by this Manual.

(1) All lightning protection systems shall include surge suppression for all incoming metallic power, communications, instrumentation lines, and other electrical conductors, including low voltage lines or extensions, in addition to any NEC requirements for surge suppression.

(2) Conductors leading from the surge suppression devices shall be kept separated from conductors leading to the surge suppression device. All leads will be as short as reasonably achievable. (Note: Coupling mechanisms include inductive, capacitive and breakdown. Refer to IEEE 1100-1999, *Recommended Practice for Powering and Grounding Sensitive Electronic Equipment* [Emerald Book] for location, sizing requirements and installation details).

(3) Surge suppression devices should be located as close as reasonably achievable to the panel. For new structures, the panel shall be located as close as reasonably achievable to the area being protected.

2.4.5 *Sideflash (Arcing) Protection*

a. Sideflash is an electrical spark caused by differences of potential that occurs between conductive metal bodies or between conductive metal bodies and a component of the LPS or earth electrode system. Sideflash presents direct and indirect hazards to explosives and hazardous environments. The direct hazard is the electrical energy transferred from the structure or its LPS to the explosives. Indirect hazards are the heat and the electromagnetic fields generated by the electrical energy. The heat can cause concrete to spall or ignition of combustible materials. Electromagnetic fields could induce electrical currents on or in the explosives. To prevent unintentional initiation of explosives by either the direct or the indirect effects of sideflash, protection should be provided explosives unless analysis of operations shows otherwise. Separating the explosives from the LPS, or the walls and conductive penetrations of the structures provides protection against consequences of sideflash. Appropriate separation (standoff) distances shall be determined and applied for each structure by Facility Management based on the following:

(1) NFPA 780 shall be used to determine sideflash protection for all structures other than those with a Faraday-like shield LPS.

(2) For Faraday-like shield structures, in general, explosives and dunnage should be in contact with no more than one interior surface, and shall not be closer than the distance calculated using transfer impedance analysis and a safety factor of two from any other interior surface. This contact surface is normally the floor, shelf, or workbench.

(3) Sideflash separation distance shall be applied as given below:

(a) All sideflash separation distances shall be measured from the outermost surface of the container, packing, device or equipment holding the explosive that is nearest the structural surface, penetration, or penetration extension in question. Measure from the surface of the explosive itself only when the explosive is bare.

(b) When sideflash separation distance from structural elements and penetrations is maintained, wooden boxes, fiberboard drums, and metal outer containers provide adequate protection from effects of lightning current flow. Sideflash separation distances do not apply to separation between containers of explosives. Containers are authorized to be in direct contact with each other.

3.0 INSPECTION AND TESTING OF LIGHTNING PROTECTION SYSTEMS

3.1 Initial Installation or Approval

3.1.1 *Structures with Catenary, Integral, or Mast Lightning Protection Systems.*

a. Structures shall be inspected to determine that:

(1) The LPS complies with the current requirements of NFPA 780 Chapter 3, Chapter 6, Appendix B, and Appendix K.

(2) All required bonds are in place and secure.

(3) Surge suppression devices are installed and functional, as required in section 2.4.4 of this chapter.

b. The resistance of each required bond and the earth electrode system shall be tested to ensure that they meet the requirements of section 3.3.1 of this chapter.

3.1.2 *Structures with Faraday-like Shield Lightning Protection System*

a. Proper bonding or electrical continuity of the structure's walls, ceiling and floor shall be validated by measuring the transfer impedance versus the frequency using an appropriate test instrument approved per section 3.3.3 of this chapter.

b. Proper bonding of all conductive penetrations as required in section 2.4.3 of this chapter shall be validated through inspection of building documentation and specifications, inspection of the facility, and by the use of resistance readings, as specified in section 3.3.2 of this chapter, or other instrument approved by a competent expert and the Authority Having Jurisdiction.

c. Protection of all AC power lines, communication, and data lines that penetrate the structure by surge suppressors, as required in section 2.4.4 of this chapter, shall be validated by review of the building documentation and specifications and by inspection of the lines.

3.2 Periodic Inspections and Testing

3.2.1 *Structures with Catenary, Integral, or Mast Lightning Protection Systems*

a. Elements of the lightning protection system shall be visually inspected as specified in NFPA 780 Appendices B and K. The visual inspection of

lightning protection systems should be conducted every seven months and shall be conducted at least annually. Any evidence of corrosion, broken wires or connections, or any other problem that would negate the system's usefulness will be noted and repaired.

b. A visual inspection shall be performed of applicable surge suppression devices and other LPS components after all lightning flash events where there are visible indications on the structure of a lightning strike and any time there is modification, maintenance or repair to the structure, or penetration that could affect the SSD or LPS component.

c. Resistance-to-earth testing of the earth electrode ground system should be conducted every 14 months and shall be conducted at least every 47 months to afford testing during all seasons. It shall also be tested any time major modification, maintenance, or repair to the structure, or LPS components require the bond or connection to be broken. Tests shall be performed as specified below and in section 3.3.1 of this chapter in accordance with Facility Management developed procedures.

d. Electrical resistance measurements of visible external bonds shall be taken, as a minimum, every 14 months and shall be taken at least every 47 months to afford testing during all seasons. Visible internal bonds shall be tested at least every five years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could have affected the integrity of the bonds; and any time modification, maintenance, or repair to the structure, penetration or LPS components require the bond or connection to be broken.

3.2.2 ***Structures with Faraday Cage or Faraday-like Shield Lightning Protection System***

a. Bonds (where feasible) and surge suppressors shall be visually inspected as a minimum every two years to validate the installation and serviceability.

b. A visual inspection shall be performed of applicable surge suppression devices and other LPS components after all lightning flash events where there are visible indications on the structure of a lightning strike and any time there is modification, maintenance, or repair to the structure, or penetration that could affect the SSD or LPS component.

c. Electrical resistance measurements of visible bonds shall be taken, as a minimum, once every five years. Such measurements are also required when there are visible indications on the structure that a act of nature such as an earthquake, tornado, flood, etc. or other act could have affected the integrity of the bonds; and any time modification, maintenance, or repair

to the structure, penetration or LPS components require the bond or connection to be broken.

d. Transfer impedance measurements, as determined by Facility Management, shall be taken, as a minimum, once every fifteen years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could affect the integrity of the internal structure bonds; and any time there is major modification, maintenance, or repair to the structure.

3.3 Acceptable Electrical Test Measurements

3.3.1 *Structures with Catenary, Integral, or Mast NFPA 780 Lightning Protection Systems*

a. Required earth electrode ground resistance-to-earth readings shall be 25 ohms or less. Corrective action shall be initiated when the threshold resistance (25 ohms.) is exceeded unless it is not feasible to meet the threshold resistance criterion. In that case, Facility Management is authorized to establish alternative resistance standards without waiver or exemption. However, before taking this option reasonable means to improve the grounding system must be considered. Alternative standards must include determination of a baseline system resistance and a testing methodology with criteria to determine system serviceability. Testing shall be conducted only with instruments designed specifically for resistance-to-earth testing.

b. The resistance of required bonds shall not exceed 1 ohm. Larger readings require tightening or resecuring the bonds.

3.3.2 *Structures with Faraday Cage/Faraday-like Shield Lightning Protection System*

a. The bond resistance should be less than 1.00 ohm. Although a resistance of 1.00 ohm or lower is preferred, a 1.5-ohm resistance is acceptable where necessary for joining of existing structural elements by rebar bonding. Larger readings require tightening or resecuring the bonds.

3.3.3 *Test Instruments*

a. Resistance measurement instruments shall be capable of measuring within plus or minus 10 percent of the required reading.

3.3.4 *Alternative Testing*

a. In lieu of taking resistance readings, other instruments capable of showing the continuity of the bond are authorized for use when approved by a competent expert and the Authority Having Jurisdiction. The providers of

the equipment used must demonstrate the explosives and electro-magnetic radiation (EMR) safety of the instruments and equipment. The minimum safe separation distance from all explosives and the test equipment during testing also must be provided. The scientific principles of the measurement, the accuracy of the particular instrumentation system, and mathematical algorithms employed must be peer reviewed by an independent and dispassionate group of technical experts. The instrument must show that as a minimum, the bond drains 75 percent of the induced current flow. Complete test plans and procedures must be formulated.

3.4 Procedures

a. Facility Management and the Authority Having Jurisdiction must approve all testing procedures.

3.5 Documentation and Trend Analysis

a. A record of all resistance or transfer impedance measurements at all required points and of visual inspections should be maintained for the life of the facility and shall be maintained for at least six inspection and testing cycles. In addition, those records specified in NFPA 780 Appendix B shall be maintained for an equivalent time. The records shall be reviewed for trend analysis. A diagram of the structure or room showing all points requiring measurements or visual inspection and location of surge suppressors should be prepared.

b. Trend analysis shall be conducted on resistance-to-earth test results to identify significant increases in the resistance of the LPS. Corrective action shall be initiated before the threshold resistance is exceeded unless it is not feasible to meet the threshold resistance criterion. However, trend analysis shall continue and all reasonable measures shall be implemented and documented to maintain the lowest possible resistance.

3.6 Training

a. Personnel responsible for maintenance, inspection, and testing of lightning protection systems must be knowledgeable of and properly trained in the fundamentals described in NFPA 780 and this Manual.

4.0 LIGHTNING PROTECTION EXCEPTIONS

a. The requirements of sections 2.0 and 3.0 for lightning protection systems do not apply in the following cases. Neither a waiver nor an exemption is required:

(1) A documented analysis approved by Facility Management and the Authority Having Jurisdiction demonstrates that the cumulative annual risk of a lightning strike to the structure in question or to any of the metallic penetrations of that structure is low.

(2) Explosives operations served by a local lightning warning system (LWS) where:

(a) Facility Management is willing to accept, in the event lightning does strike the unprotected structure or the structure's penetrations, the potential injuries, the damage, the loss of use of the structure, and the impact on other explosives operations at the Facility; and

(b) Facility Management is willing to accept the impact of shutting down all operations in other structures and the area within public traffic route (remote) distance of the structure without an approved LPS during a lightning threat; and

(c) The Facility has a local effective lightning warning system (LWS) and lightning warning plan (LWP).

(3) Totally, metal lined storage structures (such as magazettes) with metal doors making metal-to-metal contact at least every linear foot and having a metallic thickness of at least 3/16-in. (4.8-mm) steel or 9/32-in. (7-mm) aluminum are the equivalent of a near perfect Faraday cage. As such, they are exempt from LPS requirements.

(4) Facilities or operations where personnel are not expected to sustain injury and the resulting economic loss of the structure, its contents or surrounding structures is acceptable to Facility Management.

5.0 LIGHTNING THREAT DETECTION

a. Facility Management shall ensure that a plan is established for (1) detecting when lightning is in the near vicinity and when there is a potential for lightning and (2) notifying appropriate personnel of these conditions. Lightning Threat Detection Systems (LTDS) are generally of three types—those that detect the electrical gradient buildup, those that detect actual cloud to cloud or cloud to ground electrical discharges, and an independent weather monitoring service, such as the National Lightning Detection Network (NLDN) or NEXRAD Radar, that notifies the Facility when lightning is in the vicinity. The use of two or more systems provides more reliable detection of lightning threats and is recommended. A LTDS should be in use and serviceable when Facility Management chooses to evacuate explosives areas.

b. Facility Management shall establish a plan for maintenance and testing of the LTDS. This plan should incorporate the manufacturer's recommendations and should include, where applicable:

(1) Cross checking the cloud to ground detector with the National Lightning Detection Network or a similar weather information source.

(2) Calibration of electric field monitors.

6.0 LIGHTNING THREAT ACTIONS

a. Facility Management shall evaluate their explosives operations to determine the time required (1) to safely shut down explosive operations where required, or (2) to evacuate personnel from the areas specified in section 6.0d below to safe locations, or (3) to relocate explosives to a safe sideflash separation (standoff) distance. These times and local storm movement and tracking history are fundamental to establishing the minimum lightning detection bounding limits and the respective threat levels. The use of two threat levels allows initiation of a lightning threat alert (LTA) or similar threat identifier when lightning or a potential for lightning is detected within the lower threat level. When lightning or a potential for lightning is detected within the higher level threat parameters, a lightning threat warning (LTW) or similar threat identifier can be initiated.

b. When operations are required to continue in buildings without a LPS during a lightning threat, before the start of further operations, explosives should be moved and kept at least a distance established by Facility Management following review by a competent expert from the walls, ceiling and penetrations of the structure. (See UL 96A.)

c. Facility Management shall determine in advance of any lightning threat those activities that shall be terminated and at what threat level the termination for each identified activity shall begin.

(1) For an LTA, Facility Management shall evaluate terminating the following activities:

(a) Activities involving AC powered electrical equipment in direct or indirect contact with explosives regardless of the form of LPS installed.

(b) Explosives operations in an unprotected building or outside (some activities may be safer to proceed to a planned detonation or to a safe mode for the explosive).

(c) Work with exposed electrostatic discharge sensitive (0.1 joule or less) EEDs in structures not equipped with a Faraday-like shield LPS.

(d) Explosives work in structures not equipped with a Faraday-like shield LPS and where any explosives are at a sideflash separation (standoff) distance less than that specified above or by NFPA 780.

(2) For an LTW, Facility Management shall evaluate stopping the following activities in addition to those specified in Chapter X, section 6.0c(1).

(a) Activities involving AC powered electrical equipment in direct or indirect contact with explosives regardless of the form of LPS installed.

(b) Outside activities involving explosives.

(c) Activities within "magazine areas" (area dedicated solely to magazines). See Chapter II, section 17.2o for other requirements.

(d) Activities where extensions of penetrations, bonded or not, are in direct or indirect contact with the explosives.

(e) Positions of hoists, without non-conductive links, and other movable conductive projections into a facility that can be moved or retracted to a maximum distance from explosives or explosive devices.

(f) Explosives operations in structure not equipped with a LPS.

(g) Positions of hoists, without non-conductive links, and other movable conductive projections into a facility that can be moved or retracted to a maximum distance from explosives or explosive devices.

d. Facility Management shall determine in advance of any lightning threat those structures and areas that must be evacuated and at what threat level the evacuation should begin. Facility Management should evaluate evacuating the following areas as a minimum:

(1) Explosives structures without a LPS.

(2) Magazine areas.

(3) Structures not equipped with a Faraday-like shield LPSs and containing exposed electrostatic discharge sensitive (0.1 joule or less) EEDs.

(4) Structures not equipped with a Faraday-like shield LPS and containing exposed electrostatic discharge sensitive (0.1 joule or less) explosives.

(5) Parked explosives laden vehicles and rail cars.

(6) All buildings and areas within public traffic route distance (based on a 2.3 psi (15.8 kPa) and the applicable fragment distance as given in DoD 6055.9-STD) of an explosive structure not equipped with a LPS.

e. When Facility Management determines that evacuation of personnel from and around explosives structures is required, the following shall apply:

(1) DOE, NNSA, and DOE/NNSA contractor/subcontractor personnel in the identified buildings and areas shall be evacuated to at least public traffic route distance.

(2) Non-DOE and Non-NNSA contractor/subcontractor personnel shall evacuate to Inhabited Building distance.

(3) The evacuation distances shall be based on the maximum operating quantities and Class/Division of explosives approved for the structure and on applicable psi and fragment distances as given in DoD 6055.9-STD.

(4) In lieu of evacuation, DOE, NNSA, DOE/NNSA contractor/subcontractor, and non-DOE/NNSA contractor personnel are authorized to take shelter in a room or building that provides protection from overpressures in excess of 15.8 kPa (2.3 psi), fragments, and structural collapse in event of an explosion of any adjacent structure containing explosives and not equipped with a LPS.

(5) During evacuation periods, personnel are allowed, at Facility Management's discretion, to pass within the specified distance of explosives structures not equipped with a LPS if required for evacuation or to gain access to or leave other operating areas.

7.0 SHUTDOWN OF OPERATIONS

a. When operations must be terminated during electrical storms, the following should apply:

(1) Process equipment containing explosives should be stopped as soon as safety permits.

(2) If a building or bay must be evacuated, the minimum number of personnel needed to safely shut down operations that cannot be shut down immediately is authorized to remain at the building. As soon as shutdown is completed, they shall evacuate.

(3) Explosives testing can continue as long as personnel are not required to leave the test shelter.

8.0 LIGHTNING WARNING AND PROTECTION PLAN

a. Facility Management shall develop and implement a Lightning Warning and Protection Plan (LWPP). Based on the above requirements of this chapter, the LWPP shall address as a minimum:

8.1 Evaluation of Lightning Risk

a. A uniform site wide methodology should be applied to all the Facility's structures being evaluated to determine if lightning protection is required for a specific structure.

b. The level of risk that Facility Management is willing to accept for a structure not to have lightning protection. A uniform site wide risk criteria should be applied to all the facility's structures.

8.2 Lightning Protection System Installation

a. Identification of the Facility's site wide competent expert and reviewer on lightning protection systems design, installation, and testing.

b. Acceptable lightning protection systems.

c. Facility's policy on the installation, retention, and maintenance of air terminals and wire down conductors when the Faraday-like shield of lightning protection system is installed.

d. Techniques and procedures for initial installation of each approved lightning protection system. These, as a minimum, shall include specifications on bonding, surge suppression, separation between bonds and type of conductors, etc.

e. Techniques and procedures for retrofitting structures to a Faraday-like shield form of lightning protection, if a decision is made to retrofit the structure.

8.3 LPS Inspection and Maintenance

a. Procedures for inspecting and validating that installed lightning protection meets the requirements of this Manual and the LWPP. This area shall include acceptable test instruments, calibration requirements, and acceptable measurement readings.

b. Required visual inspection, electrical testing, and transfer impedance testing and their frequency for the elements of the lightning protection system.

c. Procedures for documenting and maintaining documentation of required visual inspection, electrical testing, and transfer impedance testing of all elements of the lightning protection system.

d. Required training and qualification of personnel maintaining, inspecting, and testing the lightning protection systems.

8.4 Sideflash Separation (Standoff) Distances

a. Acceptable sideflash separation (standoff) distances for each explosives structure.

b. Methodology for calculating the distances.

8.5 Lightning Threat

a. Levels of threat.

b. Bounding criteria for each threat level, (including safe shutdown, most attainable safe mode of explosive, and evacuation time).

c. Responsibilities for calling a threat.

d. Actions required at each level of threat.

e. Methods of notification of personnel to include those non-related personnel that might be within Inhabited Building Distance of an explosives facility.

f. Operations to be shut down during each level of the alert.

g. Areas to be evacuated.

h. Identification of safe or sheltered areas.

i. Actions taken by personnel transporting explosives on site.

j. Identification of safe parking areas for vehicles transporting explosives on site.

k. When, by whom, how threat is canceled and resumption of activities.

l. Methods and requirements for testing and evaluating lightning detection equipment.

m. Required training of personnel maintaining, inspecting, and testing the lightning detection systems.

n. Required training of personnel making decisions regarding lightning threat alerts.

9.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in implementing the requirements and recommendations of this chapter.

(1) IEEE 80, Guide for Safety in AC Substation Grounding.

(2) IEEE 1100, Recommended Practice for Powering and Grounding Sensitive Electronic Equipment.

(3) Lightning Protection System Electrical Characterization Results for Pantex Cell 12-44.1, Kimball Merewether, Paris Holmes, James Selberg, Sandia Technical Memorandum, Sandia National Laboratories, Albuquerque, New Mexico, February, 2002.

(4) Lightning Protection System for HE Facilities at LLNL – Certification Template Lawrence Livermore National Laboratory, Todd J, Clancy, Mike M. Ong, Charlie G. Brown, Livermore, CA., December 2005.

(5) Maximum Lightning Induced Voltages and Recommended Isolation Distances in Nuclear Explosive Areas at Pantex, Kimball Merewether, Sandia National Laboratories, Albuquerque, New Mexico, December, 1997.

(6) Measured Response of Explosive Storage Structures M38, M41, 832B and 832D at Lawrence Livermore National Laboratories Site 300 to Direct Flash Attachment of Lightning, Dr. Marvin E. Morris, September 22, 1998.

(7) MIL-HDBK-419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities, Volumes 1 and 2, US Department of Defense.

(8) NFPA 70, National Electrical Code.

(9) NFPA 780, Standard for the Installation of Lightning Protection Systems.

(10) Pantex Lightning Protection Project Team Final Report, Scruggs, Merewether, Ong, Yactor et al, Pantex Plant, Amarillo, Texas, April, 1999.

(11) Rocket-Triggered Lightning Studies for the Protection of Critical Assets; Marvin E. Morris, Richard J. Fisher, George H Schnetzer, Kimball O. Merewether, and Roy E. Jorgenson; IEEE Transactions On Industry Applications, Vol. 30, No. 3, May-June 1994.

(12) RPT-MIS-273038, Pantex Lightning Protection Project Team Final Report, Revision 1, April 1999.

(13) UFC 3-570-01, Unified Facilities Criteria, Static and Lightning Protection Systems.

(14) UL 96, Standard for Safety, Lightning Protection Components.

(15) UL 96A, Standard for Safety for Installation Requirements for Lightning Protection Systems.

APPENDIX A—REFERENCES

American Conference of Government Industrial Hygienists (ACHIH), ACHIH Ventilation Manual.

American National Standards Institute (ANSI), National Electrical Safety Code, ANSI C2.

American Society for Testing and Materials (ASTM) D-2240-86, Standard Method for Rubber Property—Durometer Hardness.

Defense Logistics Agency, Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations, AD, 411445, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

Defense Logistics Agency, The Air Force Manual for Design and Analysis of Hardened Structures, AFWL-TR-74-102, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; ADB004152, Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

Departments of the Army, the Navy, and the Air Force; Structures to Resist the Effects of Accidental Explosions; TM 5-1300, NAVFAC P-397, AFM 88-22; Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Departments of the Army, the Navy, the Air Force, and the Defense Logistics Agency, Department of Defense Ammunition and Explosives Hazard Classification Procedures, TB 700-2.

Department of Commerce, IHE Material Qualification Tests, Description, and Criteria, Rev. 1, July 1985, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

Department of Defense (DoD) Department of Defense Ammunition and Explosives Safety Standards, DoD 6055.9-STD, Assistant Secretary of Defense. (Force Management and Personnel), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Department of Energy (DOE), DOE Hoisting and Rigging Standard, DOE-STD-1090 (current version).

DOE, A Manual for the Prediction of Blast and Fragment Loading of Structures, DOE/TIC-11268, U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120.

DOE, Nuclear Safety Criteria (for Warhead Storage), DOE-DNA TP-20-7, Classified.

Keenan, W.A. and J.E. Tancreto, Blast Environment from Fully and Partially Vented Explosions in Cubicles, TR-828, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

National Electrical Manufacturers Association (NEMA), Enclosures for Electrical Equipment (1000 Volts Maximum), NEMA Publication No. 250-1979, 2101 L Street N.W., Washington, D.C. 20037.

National Fire Protection Association (NFPA), Fire Protection for Laboratories Using Chemicals, NFPA 45.

NFPA, National Electrical Code, NFPA 70, ANSI C1.

NFPA, Life Safety Code, NFPA 101.

NFPA, Purged and Pressurized Enclosures for Electrical Equipment, NFPA 496.

NFPA, Powered Industrial Trucks, NFPA 505.

NFPA, Identification of the Fire Hazards of Materials, NFPA 704.

NFPA, Lightning Protection Code, NFPA 780.

Title 49 CFR, Parts 171-177, Transportation, Hazardous Materials Regulations, and Parts 300-399 (for Driver Selection and Training).

U.S. Army Corps of Engineers, Suppressive Shields, Structural Design and Analysis Handbook, HNDM-1110-1-2, U.S. Army Corps of Engineering, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807.

APPENDIX B—INDEX

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DOE ORGANIZATIONS TO WHICH DOE M 440.1-1A IS APPLICABLE

Office of Environment, Safety and Health
Office of Environmental Management
Office of Security and Safety Performance Assurance
National Nuclear Security Administration
Office of Nuclear Energy, Science and Technology
Office of Science
Office of Security

DOE ORGANIZATIONS TO WHICH DOE M 440.1-1A IS NOT APPLICABLE

Office of the Secretary
Chief Information Officer
Office of Civilian Radioactive Waste Management
Office of Congressional and Intergovernmental Affairs
Office of Counterintelligence
Departmental Representative to the Defense Nuclear Facilities Safety Board
Office of Economic Impact and Diversity
Office of Energy Efficiency and Renewable Energy
Energy Information Administration
Office of Fossil Energy
Office of General Counsel
Office of Hearings and Appeals
Office of the Inspector General
Office of Intelligence
Office of Management, Budget and Evaluation and Chief Financial Officer
Office of Policy and International Affairs
Office of Public Affairs
Secretary of Energy Advisory Board
Office of Worker and Community Transition
Office of Energy Assurance
Bonneville Power Administration
Southeastern Power Administration
Southwestern Power Administration
Western Area Power Administration

CONTRACTOR REQUIREMENTS DOCUMENT
DOE M 440.1-1A, *DOE EXPLOSIVES SAFETY MANUAL*

Regardless of the performer of the work, contractors with the CRD incorporated into their contracts are responsible for compliance with the requirements of the CRD. Affected contractors also are responsible for flowing down the requirements of the CRD to subcontracts at any tier to the extent necessary and sufficient to ensure the contractor's compliance with the requirements.

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ACGIH	American Conference of Government Industrial Hygienists
AHJ	Authority Having Jurisdiction
ASTM	American Society for Testing and Materials
ASTI	American National Standards Institute
BOE	Bureau of Explosives
DBA	Design Basis Accident
DDESB	Department of Defense Explosives Safety Board
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSC	Differential Scanning Calorimetry
DTA	Differential Thermal Analysis
EBW	Exploding Bridge Wire
EDC	Explosives Development Committee
EED	Electroexplosive Device
EIDS	Extremely Insensitive Detonating Substance
EOD	Explosive Ordnance Disposal
FMECA	Failure Modes, Effects, and Criticality Analysis
HAZOP	Hazard and Operability Study
HE	High Explosive
HMX	Cyclotetramethylene Tetranitramine
IHE	Insensitive High Explosive
LEL	Lower Explosive Limit
LFL	Lower Flammable Limit
LPS	Lightning Protection System
MCE	Maximum Credible Event
MSDS	Material Safety Data Sheet
NE	Nuclear Explosive
NEC	National Electric Code
NEO	Nuclear Explosive Operation
NEW	Net Explosive Weight
NEQ	Net Explosive Quantity
NFPA	National Fire Protection Association
NNSA	National Nuclear Security Administration
OSHA	Occupational Safety and Health Administration
PBX	Plastic Bonded Explosive

PEL	Permissible Explosive Limit
PETN	Pentaerythritol Tetranitrate
RDX	Cyclotrimethylene Trinitramine
SOP	Standard Operating Procedure
SPMS	Safety Performance Measurement System
SSR	Safe Secure Railcar
SST	Safe Secure Trailer
TATB	Triamino Trinitrobenzene
TMAC	Toxic Materials Advisory Committee
TNT	Trinitrotoluene
UL	Underwriters Laboratory
UN	United Nations
UXO	Unexploded Ordnance

CHAPTER I—INTRODUCTION

1.0 SCOPE, PURPOSE, AND JUSTIFICATION

a. This Manual prescribes the Department of Energy (DOE) safety standards and procedures used to implement the DOE safety policy contained in DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees* (current version) for operations involving explosives, pyrotechnics, and propellants, or assemblies containing these materials.

b. DOE explosives handling and processing operations are an integral part of DOE weapons and weapons-related development, manufacturing, and dismantlement activities. Safety in all operations associated with weapons development is an ongoing, prime concern and must continually be given high priority in all program direction and management. This Manual provides uniform guidance for all DOE and National Nuclear Security Administration (NNSA) facilities and installations involved in explosives handling or processing. DOE will update the Manual periodically to incorporate lessons learned, new technology, and suggestions for improvements. The Assistant Secretary for Environment, Safety and Health is responsible for this task.

c. Maintaining explosives safety in all operations within DOE is an ongoing process that, to be truly effective, must be given high priority in all program direction, management, and line activities. Due to the unique nature of DOE's active role in research and development in new explosives formulations, explosives synthesis, charge geometry, and explosives assemblies, as well as the proximity of explosives to weapon components, it is necessary to maintain the level of explosives safety standards commensurate with the risks.

d. This Manual establishes safety controls and standards not addressed in other existing DOE or non-DOE regulations to close the considerable safety gap created by DOE's unique activities to govern the DOE explosives safety process and ensure that explosives safety is commensurate with the actual risk. However, the Department of Defense (DoD), Occupational Safety and Health Administration (OSHA), and other nationally recognized standards, such as the National Fire Protection Association (NFPA) codes, provide the basic framework. Specific requirements from these documents are applicable and pertinent as determined by the "Authority Having Jurisdiction." Since the conception of the first DOE Explosives Safety Manual in 1978, and the formation of the expert DOE Explosives Safety Committee, no explosives-related fatalities have occurred in DOE and explosives safety practices have significantly improved. Continued maintenance of this Manual, combined with field adherence, will maintain the high level of explosives safety evidenced within DOE over the past two decades.

2.0 APPLICABILITY

a. This Manual applies to all DOE facilities engaged in developing, manufacturing, handling, storing, transporting, processing, or testing explosives, pyrotechnics, and propellants, or assemblies containing these materials, and to the safe management of such operations. With the exception of explosives storage and transportation, this Manual does not apply to commercial activities such as routine construction or routine tunnel blasting.

b. The design of all new explosives facilities shall conform to the requirements established in this Manual and implemented in the current version of DOE O 420.1B, *Facility Safety*. It is not intended that existing physical facilities be changed arbitrarily to comply with these provisions, except as required by law. Existing facilities that do not comply with these standards may continue to be used for the balance of their functional lives if the following two conditions are met:

(1) The current operation presents no significantly greater risk than that assumed when the facility was originally designed.

(2) It can be demonstrated clearly that a modification to bring the facility into compliance is not feasible.

c. However, in the case of a major renovation, the facility must be brought into compliance with current standards.

d. The requirements are presented as either mandatory or advisory. Mandatory requirements, denoted by the words “shall,” “must,” or “will,” must be followed unless the DOE Operations Officer or NNSA Site Manager grants an exemption. Advisory requirements denoted by “should” or “may,” may be deviated from with a written waiver granted by facility management.

3.0 EXEMPTIONS

a. An exemption is a written release from a mandatory safety requirement. Competent, knowledgeable, and experienced explosives safety engineers shall review all exemption requests. Approved exemption requests should feature methodologies to mitigate to the highest practical level the additional safety risks through additional engineering or administrative controls.

3.1 Each such request shall contain the following information:

a. Description of the condition.

b. Safety requirement necessitating deviation.

c. Reason why compliance cannot be achieved.

d. Steps taken to provide protection and to ameliorate the additional risk.

e. Statement of whether equivalent safety is provided and, if not, assessment of the residual risk.

f. Any proposed corrective action and schedule.

g. Duration of the exemption.

3.2 Exemptions Achieving Equivalent Safety

a. The DOE Operations Officer or NNSA Site Manager is permitted to grant exemptions from the mandatory requirements of this Manual provided compliance is impracticable and the facility operator has demonstrated that the conditions, practices, means, methods, or processes to be used are equivalent. Requests for exemptions shall be submitted to the DOE Operations Officer or NNSA Site Manager for action.

3.3 Exemptions Not Achieving Equivalent Safety

a. The DOE Operations Officer or NNSA Site Manager shall submit to the Program Secretarial Officer (PSO) all requests for exemptions from mandatory requirements for which equivalent protection of operating personnel, the public, and property cannot be achieved. The PSO, with the advice and recommendation from the Assistant Secretary for Environment, Safety and Health, shall make a final determination on the request for exemption. The DOE Operations Office or NNSA Site Manager may grant a temporary exemption while the PSO is processing an exemption request. The temporary exemption is limited to the shorter of 180 days from its granting or until the exemption is approved or denied. Exemptions will be reviewed for applicability and currency at intervals not to exceed 5 years.

4.0 WAIVERS

a. If an activity, operation, or process is determined to be out of compliance with the Manual's advisory requirements, but the activity, operation, or process is determined to be safe and necessary, facility management may grant written approval in the form of a waiver for an alternate solution. Waivers will be granted for the minimum time necessary; ongoing waivers shall be updated every three years. Facility management shall maintain a central file of active waivers and provide a copy of each waiver to the local DOE contracting officer.

4.1 <u>Each waiver shall contain, as a minimum, the following information</u>:

a. Description of the condition.

b. Safety standard requiring alternate solution.

c. Reason why compliance is not achieved.

d. Steps taken to provide alternate protection.

e. Any proposed corrective actions and schedule.

f. Waiver duration or expiration date.

5.0 MANUAL ADMINISTRATION AND MANAGEMENT

a. This Manual shall be kept current. The Office of Facility Safety shall ensure that this Manual is kept up-to-date and that the DOE Directives System maintains a current version online at http://www.directives.doe.gov.

b. The DOE Explosives Safety Committee, through the Office of Facility Safety, shall administer and manage this Manual.

5.1 DOE Explosives Safety Committee Organization

a. The DOE Explosives Safety Committee is composed of a member from each of the following: [The membership listing has been updated by the Chairman of the DOE Explosives Safety Committee to reflect reorganizations in DOE/NNSA. Current membership is available upon request from the site representative to the Committee, or from the Committee Chairman].

(1) DOE Office of Facility Safety

(2) NNSA Office of Military Application and Stockpile Support

(3) NNSA Service Center, Albuquerque

(4) NNSA Service Center

(5) NNSA Livermore Site Office

(6) NNSA Nevada Site Office

(7) NNSA Sandia Site Office

(8) NNSA Pantex Site Office

(9) DOE Idaho Field Office

(10) DOE Savannah River Office

(11) Los Alamos National Laboratory

(12) Lawrence Livermore National Laboratory

(13) Pantex Plant

(14) Kansas City Plant

(15) Idaho National Engineering and Environmental Laboratory

(16) Nevada Test Site

(17) Sandia National Laboratories

(18) Wackenhut Services, Savannah River Site

b. A representative of the DOE Office of Facility Safety shall chair the committee and will report directly to the DOE Director, Office of Facility Safety.

5.2 <u>DOE Explosives Safety Committee Functions</u>

a. The DOE Explosives Safety Committee shall perform the following functions:

(1) Review, evaluate, and act under authority delegated from the DOE Director, Office of Facility Safety, on proposed changes or revisions to this Manual.

(2) Evaluate and respond to requests for interpretations of the Manual.

(3) Meet periodically, as appropriate, to review and evaluate Manual adequacy and existing exemptions, and to initiate Manual changes as needed.

b. The DOE Explosive Safety Committee (at the local level its individual voting members) is (are) the "Authority Having Jurisdiction" over DOE explosives safety matters.

c. Changes to this Manual become effective once they have been approved by the DOE Explosives Safety Committee and the approval is published in the official minutes of committee meetings.

6.0 DEFINITIONS

For purposes of this Manual, the following terms are defined.

AIR TERMINAL. (1) A component of a Lightning Protection System (LPS) designed to accept direct attachment of the lightning flash and transfer the current to the down conductor. (See STRIKE TERMINATION DEVICE). (2) A strike termination device that is a receptor for attachment of flashes to the LPS and is listed for the purpose.

APPROVED. Complying with the provision(s) of this Manual and with instructions and details issued by the authority having jurisdiction or with those of other approving agencies specified herein.

ARM. A general term that implies the energizing of electronic and electrical circuitry, which in turn controls power sources or other components used to initiate explosives. The arming operation completes all steps preparatory to electrical initiation of explosives except the actual fire signal.

BARRICADE. An intervening approved barrier, natural or artificial, of such type, size, and construction as to limit in a prescribed manner the effect of an explosion on nearby buildings or personnel.

BAY. A location (e.g., room, cubicle, cell, or work area, etc.) containing a single type of explosives activity, which affords the required protection specified for appropriate hazard classification of the activity involved.

BLENDING. The mixing of solid materials (usually dry) by gravity flow, usually induced by vessel rotation.

BOND. An interconnection of metal objects, generally to the LPS. (See BONDING).

BONDED. The joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

BONDING. (1) An electrical connection between a metal object and an LPS component. This produces electrical continuity between the LPS and the object and minimizes electro-magnetic potential differences. Bonding is done to prevent sideflash. (2) An electrical connection between an electrically conductive object and an LPS component that is intended to significantly reduce potential differences created by lightning currents.

BOOSTER. Explosives used in an explosive train to amplify the shock output of the initiating device and cause detonation of the main explosive charge.

CASUAL. A person other than an operator who intermittently visits an explosives operation for the purpose of supervision, inspection, maintenance, etc. Casuals do not perform hands-on work with explosives but are otherwise involved with the explosives operation being performed.

Casuals are accounted for in the established personnel limits for the area and are provided a level of protection consistent with the explosion hazard of operations in adjacent areas.

CATENARY SYSTEM. An LPS consisting of overhead wire suspended from poles connected to a grounding system via down conductors. Its purpose is to intercept lightning flashes from the protected area.

CLEAR ZONE. The required maximum quantity-distance for the protection of personnel and facilities from the Potential Explosion Site (PES).

COMBUSTIBLE MATERIAL. Any material that, when ignited, will sustain burning.

COMPATIBILITY. The chemical property of materials to coexist without adverse reaction for an acceptable period of time. Compatibility in storage exists when storing materials together does not increase the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Storage compatibility groups are assigned to provide for segregated storage.

CONCURRENT OPERATIONS. Operations performed simultaneously and in close enough proximity that an incident with one operation could adversely influence the other.

CONDUCTOR. Usually a cable intended to be used to carry lightning currents between strike termination devices and ground terminals. The conductor also serves as a strike termination device for a catenary LPS. Conductors are usually heavy metallic cables but metallic building structural members, (e.g., steel I-beams) can also function as down conductors.

CONTACT OPERATIONS. An operation in which an operator and an explosive item are both present with no operational shield.

CONTROL POINT. The location used for personnel control and operation coordination in an explosives operating or test area.

CORING. A machining operation that removes material in the form of a cylinder by cutting at the circumference to create a hole or recover the material from the center of the cut.

COUNTERPOISE. A type of an earth electrode system consisting of conductor cables buried around the structure to be protected. Generally, a counterpoise will have more surface area contacting the earth than ground rod systems. Commonly called a ground ring electrode. (See EARTH ELECTRODE SYSTEM).

CRITICAL TEMPERATURE. Temperature above which the self-heating of an explosive causes a runaway reaction. It is dependent on mass, geometry, and thermal boundary conditions.

DANGER ZONE. That area around a test site where personnel could be in physical jeopardy due to overpressure, fragments, or firebrands released during an explosive test.

DEFLAGRATION. A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source.

Deflagration is a surface phenomenon with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction, and temperature and may cause transition into a detonation.

DETONATION. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium, forming a propagating shock wave that is originally of supersonic velocity. When the material is located on or near the surface of the ground, a detonation is normally characterized by a crater.

DIFFERENTIAL SCANNING CALORIMETRY (DSC). A technique in which the difference in energy inputs into a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program, or are held isothermally. The record is the differential scanning calorimetry or DSC curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal DTA curve.

DIFFERENTIAL THERMAL ANALYSIS (DTA). A technique in which the temperature difference between a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program or are held isothermally. The record is the DTA curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal differential thermal analysis (DTA) curve.

DIRECT CONTACT WITH EXPLOSIVES. Physical contact between an electrical instrument or equipment to bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device.

DOWN CONDUCTOR. A form of a main conductor designed to conduct the current of a lightning flash vertically down to the earth electrode system.

DRYING. The removal of volatiles from ingredients or mixtures.

DSC. See DIFFERENTIAL SCANNING CALORIMETRY.

DTA. See DIFFERENTIAL THERMAL ANALYSIS.

EARTH ELECTRODE SYSTEM. Sometimes called a ground terminal. (1) A component of an LPS that transfers the current of a lightning flash to the earth. The earth electrode system is connected to the down conductor and is in direct contact with the earth. Examples of earth electrode systems include ground rods, a counterpoise, buried metal plates, Ufer grounds, or other similar devices. The matrix of a Faraday-like shield acts as the earth (ground) electrode for an LPS. (2) The portion of an LPS, such as a ground rod, ground plate, or ground conductor, that is installed to provide electrical contact with earth.

EBW. See EXPLODING BRIDGEWIRE.

EED. See ELECTROEXPLOSIVE DEVICE.

ELECTRICAL BONDING. Electrical connection between two conductive objects intended to prevent development of an electrical potential between them.

ELECTROEXPLOSIVE DEVICE (EED). An EED is a device containing some reaction mixture (explosive or pyrotechnic) that is electrically initiated. The output of the initiation is heat, shock, or mechanical action. See also LOW-ENERGY EED.

EXPERIMENTAL OPERATING PROCEDURE. A procedure prepared for conducting a specific experiment a limited number of times under close technical supervision.

EXPLODING BRIDGEWIRE (EBW). An EED that is initiated by the discharge of a high current through the device bridgewire, causing the wire to explode and produce a shockwave. An EBW as defined herein is a device containing no primary explosive.

EXPLOSIVE. Any chemical compound or mechanical mixture which is designed to function as an explosive, or chemical compound which functions through self-reaction as an explosive, and which, when subjected to heat, impact, friction, shock, or other suitable initiation stimulus, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases that exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate. DOE explosives may be dyed various colors except pink, which is reserved for mock explosive.

EXPLOSIVE DECONTAMINATION. The removal of hazardous explosive material.

EXPLOSIVES FACILITY. A structure or defined area used for explosives storage or operations. Excluded are explosives presenting only localized, minimal hazards as determined by the Authority Having Jurisdiction. Examples of excluded items may include: user quantities of small arms ammunition, commercial distress signals, or cartridges for cartridge actuated tools, etc.

EXTRUDING. Forcing a plastic-type material, under pressure, into a confined space or through a confined opening to produce a desired configuration.

FACILITY. A group of buildings or equipment used for explosive operations at one geographic location, generally owned by DOE.

FACILITY MANAGEMENT. Management staff of the facility operator (the contractor).

FACILITY OPERATOR. The organization having responsibility for conducting operations at a DOE facility.

FARADAY CAGE or FARADAY-LIKE SHIELD. An LPS where the area to be protected is enclosed by a heavy metal screen (like a birdcage) or continuous metallic structure with no unbonded metallic penetrations. On such a system, the lightning current flows on the exterior of the structure, not through the interior.

FIREBRAND. A projected burning or hot fragment whose thermal energy is transferred to a receptor.

FIRING PAD. The prepared site where explosive items are fired for test data acquisition.

FIRING SITE. Controlled access area where test firing of explosives is conducted.

FLAMMABLE LIQUID. Any liquid having a flash point below 60°C and a vapor pressure not exceeding 280 kPa (41 psia) at 37.8°C. This is the definition as applied in this Manual; it includes some materials defined as combustible liquids by the Department of Transportation (DOT) and/or NFPA 70, Flammable and Combustible Liquids Code.

FLASH. The total lightning event. A flash may involve several lightning strokes, generally using the same path through the air as the initial event.

FLASH POINT. The temperature at which a liquid or volatile solid gives off a vapor sufficient to form an ignitable mixture with air near the surface of the material or within the test vessel.

FORMULATION. (1) The operation of combining ingredients to produce a mixture of a final desired composition possessing specific physical and explosive properties. (2) An explosives composition.

GROUND RESISTANCE. The value (in ohms) of the resistance between an earth electrode system and earth.

GROUND RING ELECTRODE (GRE). An earth electrode system that encircles the structure, either on or buried in the earth. (See COUNTERPOISE and EARTH ELECTRODE SYSTEM).

GROUND ROD. A component of one type of earth electrode system, generally a cylindrical device of approximately 3/4-in. diameter by approximately 10-ft long driven into the soil. The ground rod is attached to the down conductor and dissipates a lightning flash's current into the earth.

GROUND TERMINAL. See EARTH ELECTRODE SYSTEM.

GROUNDED. (1) Connected to earth or some conducting body that serves in place of the earth. (2) Connected to earth or some conducting body that is connected to earth.

GROUNDING. Providing an electrical path to the earth, generally to the earth electrode system.

HEATING LIMITS. The conditions established for safely heating an explosive system (maximum temperature, heating time, heating rate, etc.). These limits are based on the estimated critical temperature of the explosive system with a suitable margin of safety.

HIGH-ENERGY INITIATOR. Exploding bridge wire systems, slapper detonators, and EEDs with similar energy requirements for initiation.

HIGH PRESSURE. Gas pressure greater than 3,000 psig (21 MPa gauge); liquid pressure greater than 5,000 psig (35 MPa gauge).

HOLE. (as applied to machine explosives). Any cavity that is more than one-half diameter deep, being cut by any tool with the direction of feed along the axis of rotation.

HOT WORK (thermal). Any operation requiring the use of a flame-producing device, an electrically heated tool producing a temperature higher than 109°C, or a mechanical tool that can produce sparks or heat explosives or explosives contamination to provide an initiation stimulus.

HYDROSTATIC PRESSING. The operation of compacting a material that is confined in a press by a diaphragm by hydraulically applying pressure to the diaphragm.

IHE. See INSENSITIVE HIGH EXPLOSIVES.

IHE SUBASSEMBLIES. IHE hemispheres or spheres with booster charges, with or without detonators that pass the DOE qualification tests listed in Table IX-3.

IHE WEAPONS. Weapons listed in DOE-DNA TP 20-7, Nuclear Safety Criteria (for Warhead Storage), as being exempt from storage and transportation limits are classified as IHE weapons when stored or transported alone or in combination with each other. This classification is valid only if the spacing between individual units is that provided by storage or shipping containers or, if not in containers, by the spacing specified in TP 20-7.

IMPEDANCE. The resistance and reactance to an electrical current.

INDIRECT CONTACT WITH EXPLOSIVES. When bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device make contact with electrical instrument or equipment through electrically conductive equipment or surfaces other than the equipment leads.

INDUCTANCE. (1) The property of a conductor that makes it oppose any current change through it. (2) A process where an object having electrical or magnetic energy can produce similar properties in a nearby object without direct contact.

INERT MATERIALS. Materials that show no exothermic decomposition when tested by DSC or DTA. Moreover, when tested by recognized compatibility tests, the inert material shall not show any incompatibility with energetic material with which it may be combined. Inert material shall neither alter the onset of exotherm of the DSC or DTA trace of the energetic material nor increase the rate of decomposition or gas evolution of the energetic material.

IN-PROCESS STORAGE MAGAZINE (facility, vault, rest house, etc.). See SERVICE MAGAZINE.

INHABITED BUILDING. A building or structure other than operating buildings, magazines, and auxiliary buildings occupied in whole or in part as a habitation for people or where people are accustomed to assemble, both within and outside DOE facilities. Land outside DOE facilities shall be considered as sites for inhabited buildings.

INHABITED BUILDING DISTANCE. The minimum distance permitted between explosives locations and inhabited buildings, administrative areas, site boundaries, main power stations, and other facilities of vital or strategic nature.

INITIATION STIMULUS. Energy input to an explosive in a form potentially capable of initiating a rapid decomposition reaction. Typical initiation stimuli are heat, friction, impact, electrical discharge, and shock.

INITIATION, WITH ITS OWN MEANS. Explosives or ammunition having their normal initiating device (e.g., detonators or squibs) assembled to them so that this device is considered to present a significant risk of activation during storage.

INITIATION, WITHOUT ITS OWN MEANS. Explosives or ammunition that (1) are not stored with an initiating device assembled to them; or (2) have the initiating device assembled to them, but (a) safety features preclude initiation of the explosives filler of the end item in the event of accidental functioning of the initiating device, or (b) the initiating device does not contain any primary explosives and has a high threshold of initiation (e.g., EBW or slapper detonators). The power source for the initiator should not be present within the assembly or system. If the initiator's power source is present, two or more management-certified safety devices connected in series shall be present to interrupt any flow of energy from the power source to the initiator.

INSENSITIVE HIGH EXPLOSIVES (IHE). Explosive substances that, although mass detonating, are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. The materials passing the DOE qualification tests in Table IX-1 are classified as IHE, and are listed in

INTEGRAL SYSTEM. An LPS that has strike termination devices mounted on the structure to be protected. These strike termination devices are connected to the earth electrode system via down conductors. Metallic structure members can serve as parts of the LPS.

INTERMEDIATE PRESSURE. Gas pressure from 150 to 3,000 psig (1 to 21 MPa gauge); liquid pressure from 1,500 to 5,000 psig (10 to 35 MPa gauge).

INTRALINE DISTANCE. The minimum distance permitted between any two operating buildings or sites within an operating line, at least one of which contains, or is designed to contain, explosives.

INTRINSICALLY SAFE. An apparatus or system whose circuits are incapable of producing any spark or thermal effect capable of causing ignition of a mixture of flammable or combustible material under test conditions described in ANSI/UL 913.

ISOSTATIC PRESSING. The operation of compacting a material in a sealed flexible container. The container is submerged in a pressure vessel, and the vessel is pressurized with liquid.

LABORATORY OPERATIONS. Experimental study, testing, and analysis of small quantities of energetic materials. Manufacturing processes with small quantities of materials are not included.

LEL. See LOWER EXPLOSIVE LIMIT.

LFL. See LOWER FLAMMABLE LIMIT.

LIGHTNING DETECTION SYSTEM, (LDS). A device or system to detect the presence of lightning activity in the general area.

LIGHTNING PROTECTION SYSTEM (LPS). A lightning protection system is a complete system of strike termination devices, conductors, ground terminals, interconnecting conductors, surge suppression devices, and other connectors or fittings required to complete the system.

LIGHTNING WARNING SYSTEM. A system that detects the presence and range of lightning activity and thereby issues an alert or warning advisory.

LOW-ENERGY EED. All EEDs except EBW detonators and slapper detonators.

LOW PRESSURE. Gas less than 150 psig (1 MPa gauge); liquid less than 1,500 psig (10 MPa gauge).

LOWER EXPLOSIVE LIMIT (LEL). The concentration of vapor or dust in air below which an explosion cannot occur.

LOWER FLAMMABLE LIMIT (LFL). The concentration of a vapor or dust in air below which a burning reaction cannot be sustained.

MACHINING. A forming operation accomplished by removing material with a mechanically operated cutting tool.

MACHINING OVERTEST. A test to evaluate the susceptibility of an explosive material to initiation during machining.

MAGAZINE. See SERVICE MAGAZINE or STORAGE MAGAZINE.

MAGAZINE DISTANCE. The minimum distance permitted between any two storage magazines. The distance required is determined by the type(s) of magazine and also the type and quantity of explosives stored therein.

MAST SYSTEM. An LPS system that consists of one or more poles with a strike termination device connected to an earth electrode system by down conductors. In the case of a metallic pole, the pole could serve as the strike termination device and down conductor. Its purpose is to intercept lightning flashes from the protected area.

MAXIMUM CREDIBLE EVENT (MCE). The MCE from a hypothesized accidental explosion or fire is the worst single event that is likely to occur from a given quantity and disposition of explosives or explosives devices. The event must be realistic with a reasonable probability of occurrence considering the explosive propagation, burning rate characteristics, and physical protection given to the items involved.

MELTING. Operations involving change in the physical state of explosives from solid to liquid.

MILLING. (1) Operations that either reduce solid material particle size by attrition or apply high shear mixing to incorporate solid materials into plastic binders; (2) A surface machining operation performed on a mill.

MIXING. A mechanical operation that combines dissimilar materials.

MOCK EXPLOSIVE. Substances bearing similar physical properties (texture, density, cohesion, etc.) to an explosive material. They are non-detonable. However, some are exothermic materials that will burn. Mock explosives are used to represent explosives for purposes such as dry run testing of equipment. DOE mock explosives are normally pink in color.

NET EXPLOSIVE WEIGHT (NEW). Net explosive weight expressed in pounds.

NEW (OR EXPERIMENTAL) EXPLOSIVES. Explosive, explosive mixture or explosive and binder mixture that the Explosives Development Committee (EDC) has not characterized.

NON-FACILITY PERSONNEL. Construction or maintenance personnel who do not have a continuing contract with DOE or NNSA or their agents at the facility concerned.

NON-OCCUPIED or UNOCCUPIED AREA. A location where occupancy is of a transitory nature such as building corridors, access ramps, and facility roads. Other examples are locations such as mechanical equipment rooms, equipment/parts staging/storage areas, decontamination areas and janitors closets, which typically have a low personnel density and an intermittent and relatively short term duration of occupancy for assigned work but in which personnel are not normally permanently assigned.

NUCLEAR EXPLOSIVE (NE). An assembly containing fissionable and/or fusionable materials and main charge high-explosive parts or propellants capable of producing a nuclear detonation (e.g., a nuclear weapon or test device).

NUCLEAR EXPLOSIVE OPERATION (NEO). Any activity involving a nuclear explosive, including activities in which main charge high-explosive parts and pit are collocated.

OCCUPIED AREA. Any work area that can be reasonably considered integral to an explosives operating area to which personnel are assigned or in which work is performed, however intermittently. Examples of areas to be considered as occupied are assembly/disassembly cells or bays, explosives operating bays, radiography control and film processing rooms, offices, break areas and rest rooms.

OPERATIONAL SHIELD. A barricade constructed to protect personnel, material, or equipment from the effects of a possible fire or explosion occurring at a particular operation.

PENETRATION. A conductive object that passes through the zone of protection or exterior surface of an LPS.

PERSONNEL BARRIER. A device designed to limit or prevent personnel access to a building or an area during hazardous operations.

POTENTIAL EXPLOSION SITE (PES). The location of a quantity of ammunition and explosives that will create a blast, fragment, thermal, or debris hazard in the event of an accidental explosion of its contents.

PRESSING. The operation of increasing the density of explosive material by applying pressure.

PRIMARY EXPLOSIVE. A sensitive explosive which nearly always detonates by simple ignition from such means as a spark, flame, impact and other primary heat sources of appropriate magnitude. Examples are mercury fulminate, lead azide, and lead styphnate, and other materials of similar sensitivities.

PROGRAM SECRETARIAL OFFICER. A senior program official, which includes the Assistant Secretaries or Office Directors at the Assistant Secretary level for DOE or the Deputy or Associate Administrators for NNSA.

PROPELLANT. Explosive composition used to propel projectiles and rockets and to generate gases for powering auxiliary devices.

PUBLIC TRAFFIC ROUTE DISTANCE. The minimum separation distance required between a potential explosion site and any public street, road, highway, passenger railroad, or navigable waterway (including roads on DOE-controlled land open to public travel).

PUNCH AND DIE PRESSING. The operation of compacting a material confined by a die by forcing a punch or punches into the die and against the material.

PYROTECHNIC MATERIAL. Physical mixtures of finely divided fuels and oxidizer powders; may include various organic binders and color intensifiers. The material is intended to produce an effect by heat, light, sound, gas or smoke, or a combination of these as the result of non-detonative, self-sustaining exothermic chemical reactions.

RATED ELECTRICAL EQUIPMENT, FIXTURES, INSTRUMENTATION AND MATERIALS. As used in the *DOE Explosives Safety Manua*l, "rated" refers to those items used in explosives locations that meet identified standards or have been tested and found suitable for use in Class I or Class II hazardous atmosphere. For an item to be considered "rated," a nationally recognized testing laboratory shall have approved its use (for example, Factory Mutual) or listed it for use (for example, Underwriters Laboratory) in the appropriate Class I or Class II hazardous atmosphere. "Rated" items are used to provide protection in explosives locations where the National Electrical Code Article 500 does not normally apply.

REMOTE OPERATION. An operation performed in a manner that will protect personnel in the event of an accidental explosion. This can be accomplished by distance, shielding, barricades, or a combination thereof.

RESISTANCE. The property of a conductor to oppose the flow of an electric current and change electric energy into heat. For lightning protection purposes low resistance values are desired. Resistance is measured in ohms.

RETURN STROKE. That part of a lightning flash where high electric currents are developed as the negatively charged leader encounters the positively charged return stroke. The phase of lightning that produces electric current, heat, a light flash and thunder.

RISK. A measure of the combination of the probability and consequences of the hazards of an operation, expressed in qualitative or quantitative terms.

ROLLING SPHERE ZONE OF PROTECTION MODEL. A theoretical concept describing the area protected by an LPS where an imaginary sphere (100-ft radius for explosive facilities) approaches an LPS from all angles and directions. The protected area is the area of the curve between where the curve is tangent to the ground, and the curve touches the LPS. For example, with the rolling sphere method the area protected by a mast system looks like a teepee.

SAFETY ANALYSIS. A document prepared to systematically identify the hazards of a DOE operation; describe and analyze the adequacy of measures taken to eliminate, control, or mitigate identified hazards; and analyze and evaluate potential accidents and their associated risks.

SCREENING. An operation using screens to separate particles of differing sizes.

SECONDARY EXPLOSIVES. An explosive substance which is relatively insensitive (when compared to primary explosives), which is usually initiated by primary explosives with or without the aid of boosters or supplementary charges. Such explosives may react as a deflagrating or as a detonating explosive. Examples are TNT, plastic bonded formulations, and other materials of similar sensitivity.

SERVICE MAGAZINE, REST HOUSE, ETC. An auxiliary building or suitable designated room (vault) used for the intermediate storage of explosives materials not exceeding the minimum amount necessary for safe and efficient operation.

SHUNT. An electrical interconnection of various portions of EED circuitry to prevent the development of an electrical charge differential between the parts.

SIDEFLASH. (1) The phenomena where lightning current will jump through a non-conductive medium to attach to improperly bonded metallic objects. (2) An electrical spark, caused by differences of potential, which occurs between conductive metal bodies or between conductive metal bodies and a component of an LPS or ground.

SITE PLAN. A formal explosives facility and operations safety document to be prepared by Facility Management for DOE/NNSA approval of explosives facilities siting and operations before the operation starts. This document becomes the authorization basis for explosives facility operations.

SITE PLANNING. The process of performing and documenting an analysis of planned and existing facilities and missions involving ammunition and explosives, or occurring within the

hazard zones created by explosives. It may include evaluations of blast hazards; fragment hazards; protective construction; grounding, bonding, and lightning protection systems; electrical installations; natural or man-made terrain features; or other mission or local requirements. Effective site planning relies heavily on explosives safety standards, but it also incorporates survivability and operational considerations, and economic, security, environmental, and legal criteria to meet the goals and needs of the DOE community.

SLAPPER DETONATOR. An EED initiated by a rapid discharge of a high current through a metal foil. The expansion of the metal vapor causes a plastic or metal covering to be propelled across an air gap and detonate a high-density explosive pellet.

SMALL ARMS AMMUNITION. (1) Ammunition designed to be fired from a pistol, revolver, rifle, or shotgun held by the hand or to the shoulder; (2) Ammunition of caliber less than 20 mm with incendiary, solid, inert, or empty projectiles (with or without tracers) designed to be fired from machine guns or cannons; (3) Blank cartridges.

SOP. See STANDARD (STANDING) OPERATING PROCEDURE.

SPECIAL OPERATING PROCEDURE. A procedure prepared for performance of a specific task on a one-time basis, or for situations not encountered in normal operation.

STANDARD (STANDING) OPERATING PROCEDURE (SOP). A procedure prepared for operation of a facility or performance of a task on a routine basis.

STORAGE MAGAZINE. A structure designed or specifically designated for the long-term storage of explosives or ammunition.

STRIKE TERMINATION DEVICE. (1) A component or feature of an LPS that is intended to accept the direct attachment of a lightning flash or strike. Strike termination devices include overhead wires or grids, air terminals, or a building's (grounded) steel structural elements. (2) A component of an LPS that intercepts lightning flashes and connects them to a path to ground. Strike termination devices include air terminals, metal masts, permanent metal parts of structures, and overhead ground wires installed in catenary LPSs.

STROKE. The high electric current phase of a lightning strike. The term is better defined as the return stroke.

SUBSTANTIAL DIVIDING WALL. An interior wall designed to prevent the propagation of an accidental detonation on one side of a wall to explosives on the other side.

SURGE SUPPRESSION DEVICE. Also called a surge protector. (1) A device used on power and communication lines to attenuate, suppress or divert lightning induced electrical energy to ground. (2) A protective device used to limiting surge voltages by discharging or bypassing surge current. It can also prevent continued flow of follow current while remaining capable of discharging or bypassing surge current.

SYNTHESIS. The chemical operation or operations required to produce a desired chemical compound.

TARGET. The area, structure, or material into which a projectile is fired.

TNT EQUIVALENT. A measure of the blast effects from explosion of a given quantity of material expressed in terms of the weight of TNT that would produce the same blast effects when detonated.

TRANSFER IMPEDANCE. (1) A transmittance expressed as the ratio of the voltage at a pair of terminals divided by the driving current, with all other terminals terminated in a specified way. (2) A transmittance expressed as the ratio of the electric field on the interior of a shielded enclosure divided by the current density on the exterior of the shield.

TRANSIENT. Any person within inhabited building distance but not inside an explosives bay or other occupied areas (offices, break areas, shops, etc.). A transient's presence within IBD of an explosives operation is transitory in nature, or to complete a relatively short-term, nonexplosives related work assignment in an area in which personnel are not permanently assigned, such as a building corridor, access ramp, or roadway. Transients are not accounted for in established personnel limits for any explosives operating area and are afforded a level of protection only from Class I explosion hazard activities.

UFER GROUND. An LPS ground produced by electrodes encased in concrete. This can be a coil of cable encased in concrete or even the reinforcing steel in the footers or floor of buildings. (See EARTH ELECTRODE SYSTEM).

UNEXPLODED ORDNANCE (UXO). Explosive ordnance which has been primed, fuzed, armed, or otherwise prepared for action, and which has been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material and remains unexploded either by malfunction, design, or for any other cause.

UNITED NATIONS (UN) CLASS 1 EXPLOSIVES. (1) Explosive substances (a substance that is not itself an explosive but that can form an explosive atmosphere of gas, vapor, or dust is not included in Class 1), except those that are too dangerous to transport or those where the predominant hazard is appropriate to another class; (2) Explosive articles, except devices containing explosive substances in such quantity or of such a character that their inadvertent or accidental ignition or initiation during transport shall not cause any effect external to the device either by projection, fire, smoke, heat, or loud noise; and (3) Substances and articles not mentioned under (1) and (2) that are manufactured with a view of producing a practical, explosive or pyrotechnic effect.

ZONE OF PROTECTION. (1) The area considered statistically safe from the direct attachment of a lightning strike as defined by the rolling sphere zone of protection model. (2) The space adjacent to an LPS that is substantially immune to direct lightning flashes.

CHAPTER II—OPERATIONAL SAFETY

1.0 GENERAL OPERATIONS SAFETY GUIDELINES

1.1 Protection of Explosives

a. Explosives are energetic materials that can react violently and should be protected from abnormal stimuli or environments, including:

(1) Friction forces.

(2) Excessive pressures and temperatures.

(3) Impact, shock, and pinching.

(4) Deformation.

(5) Electrical sparks, abrasive or welding sparks, and open flame.

(6) Contamination.

(7) Contact with incompatible materials.

1.2 Equipment Checks

a. Before being used in the explosives process, and at established intervals, processing and test equipment shall be checked for

(1) Proper design.

(2) Proper function.

(3) Specified clearances between parts in relative motion.

(4) Abnormal metal-to-metal rubbing of moving parts potentially contacting explosive materials.

(5) Cracks, voids, or screw threads where explosives may accumulate.

(6) Contamination that is incompatible with the materials to be introduced.

b. This checkout may require the use of mock explosives in process or test conditions.

c. Explosive materials must not be pinched or confined between equipment lids or covers and their mating surfaces. These surfaces shall be cleaned before cover placement. This includes pressing operations.

1.3 Inspection Frequency

a. When this Manual calls for an inspection, but the inspection interval is not specified, local facility management shall establish the inspection interval. Inspection intervals shall be modified when experience dictates a need.

1.4 Laboratory Operations

a. The special safety guidelines applicable to general laboratory operations involving explosive materials are contained in section 21.0 of this chapter.

1.5 Toxicity Hazards

a. Explosives materials, explosives components (additives or adhesives), and materials such as organic solvents used in explosives processing can be toxic when inhaled, ingested or absorbed through the skin. The most frequently reported effect from working with explosives is a skin rash resulting from skin contact with explosives materials, or with solvents and adhesives used with explosives operations. This is the most frequently reported effect from working with these materials. The following general precautions should be used to prevent overexposure to these materials during explosives processing and handling:

(1) Know the health hazard and controls before beginning operations.

(2) Evaluate the operation during startup to assure that occupational exposure limits are not exceeded; routine operations should be monitored periodically.

(3) Handle materials in a well ventilated area; local exhaust ventilation is preferred.

(4) Avoid skin contact; use appropriate protective clothing.

(5) Practice good personal cleanliness; wash before eating, smoking, or using toilet facilities; end-of-shift showers may be required for some operators.

1.6 Hazard Identification and Communication

a. Before beginning explosives operations, managers shall ensure the following:

(1) Identify and maintain a current list of explosives and other hazardous materials used in conjunction with their operations.

(2) Determine the hazardous properties and toxicity of these materials through the use of the manufacturer's Material Safety Data Sheets (MSDS) or other information sources and through consultation with the facility Industrial Hygiene staff. For explosives without published toxicological data, guidance can be obtained through the DOE Toxic Materials

Advisory Committee (TMAC). Health hazard information must be available and communicated to employees who work with or generate hazardous materials.

(3) Educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation. This training should be a part of the employee training and qualification program specified in Chapter V.

1.7 Process Hazard Analysis

a. Before beginning any explosives synthesis, formulation, manufacturing, testing, or disposal operation, a process hazard analysis shall be performed. A single process hazard analysis may be performed for similar processes performed in a single facility, provided that the "worst-case" process is the basis for the hazard analysis. If required, a shield or other protective measure shall be employed. Selection criteria for the worst-case process are:

(1) Sensitivity of materials.

(2) Quantity of materials.

(3) Number of personnel potentially affected.

(4) Impact on other operations/activities.

b. The process hazard analysis shall be performed as a team effort. The team shall consist of a minimum of three personnel, and preferably no more than seven personnel. The team shall include at least one engineer and one operator, and should have the following makeup:

(1) Team Leader, who is familiar with the analysis methodology used.

(2) Technical Member(s), who is familiar with the process being analyzed.

(3) Scribe, who writes notes of meetings and interviews and drafts reports.

c. The facility manager or team leader may select the analysis methodology used, which should be one of the following:

(1) Preliminary Hazard Analysis.

(2) Checklist (usually for similar batch operations).

(3) What-if Analysis.

(4) Hazard and Operability Study (HAZOP).

(5) Failure Modes, Effects, and Criticality Analysis (FMECA).

(6) Fault Tree Analysis.

(7) Event Tree Analysis.

d. The process hazard analysis shall be formally documented.

e. Employees and employee representatives shall be consulted on the process hazard analysis. The result of the process hazard analysis shall be provided to employees involved in or affected by the operation.

f. The process hazard analysis shall be updated and revalidated at least every five years by a team meeting the criteria in section 1.7b.

g. The facility manager shall be responsible for establishing a system to address the team's findings and recommendations promptly. Corrective actions, schedules for corrective actions, and completion of corrective actions shall be formally documented. Such documentation shall be filed with the process hazard analysis.

h. Files containing process hazard analyses, updates, and corrective actions status shall be maintained for the life of the process.

2.0 WORK ENVIRONMENT

2.1 General Requirements

a. Workspace shall be adequate to perform operations safely and efficiently.

b. Work shall be organized to eliminate clutter in the area while operations are being performed.

c. Walkways should be kept clear.

d. In work environments where solid, bare explosive pieces are handled, the floor should be cushioned, and all hard objects that explosives could strike in a handling incident should be cushioned where practical. Physical safety systems demonstrated to preclude the explosives from being dropped or struck could meet these requirements.

e. A procedure should be established to account for hand tools that may be inadvertently dropped into an explosives processing operation, thus creating a hazard.

f. Personnel shall be assigned in such a manner that each worker's presence is monitored frequently and assistance can be provided or aid summoned in the event of an emergency.

g. Safety analyses of explosives facilities and operations shall be performed. The safety analysis shall be performed during the design of new explosives facilities or the redesign of existing facilities. Facility management shall prepare and obtain DOE/NNSA approval of the Site Plan. The Site Plan shall include the result of this analysis.

h. Noisy environments caused by explosives testing operations or process and handling equipment shall be evaluated. Areas with noise above the allowable occupational exposure limits must be posted and appropriate control measures instituted (e.g., engineering controls, protective equipment, and a hearing conservation program).

2.2 Emergency Exit Requirements for Explosives Operations

a. Exit requirements for any building or structure containing explosives shall comply with the intent of the Life Safety Code, NFPA 101, except as otherwise permitted in this section.

2.2.1 *Building or Structure Occupancy*

a. In determining occupancies:

(1) Explosives operating buildings shall be classified as industrial occupancies (NFPA 101, Chapter 40).

(2) Explosives storage or staging buildings or structures shall be classified as storage occupancies (NFPA 101, Chapter 42).

2.2.2 ***Hazard of Contents Classification***

a. The hazard of contents classification of any explosives occupancy shall be determined using the guidelines given in NFPA 101 and the following requirements:

(1) High-hazard explosives contents are those which, because of form, character, or volume, are likely to burn with extreme rapidity can release poisonous fumes or explosions in a fire. The expectation of poisonous fumes or explosions is to be determined on a case-by-case basis. Operating buildings containing propellant, pyrotechnic, or explosive powders shall be classified as high-hazard occupancies unless a reduced hazard classification can be justified.

(2) Reduced-hazard explosives contents are those that burn with rapidity that is moderate or less and will not produce poisonous vapors. This criterion shall be documented by a hazard analysis.

2.2.3 ***Personnel Protective Restrictions and Requirements***

a. DOE occupancies containing high explosives dictate that personnel be protected from blast overpressures and fragments (and spread of plutonium in some occupancies) from an accidental detonation. Accidental detonation of explosives is usually the result of stimuli other than a fire.

b. Non-compliance with some NFPA 101 provisions (such as those covering exit doors, exit travel distance, number and location of exits, and common path of travel to exits), is authorized where required to provide protection from blast overpressure and fragments. When NFPA 101 requirements are not met the following additional personnel-protective restrictions or requirements should be imposed:

(1) The building and means of egress should be protected by supervised automatic sprinkler systems connected to sound evacuation alarms. This requirement is not applicable to explosives storage magazines, firing chambers, or rooms used as firing chambers, within explosives operating buildings.

(2) Explosives operating buildings and their means of egress should have automatic, early warning fire detection systems connected to sound evacuation alarms where such early warning might reasonably aid in prevention or mitigation of personnel injury. This requirement is not applicable to explosives storage magazines, firing chambers, or rooms used as firing chambers within explosives operating buildings.

(3) Personnel limits within the explosives work area (bay, cell, etc.) shall be established and controlled. These should not exceed 20 for reduced-hazard occupancies or 6 for high-hazard occupancies. The need for personnel in numbers greater than these limits shall be documented in a hazards analysis based on the criteria of section 2.2.5 of this chapter.

2.2.4 ***Requirements for Existing Facilities***

a. Existing facilities may deviate from current NFPA 101 requirements in the following situations:

(1) Current code requirements were not in effect when the building was constructed. The building, however, is still required to meet the code of record.

(2) Deviations were made to meet the level-of-protection and design criteria in Chapter VI, section 6, of this Manual.

(3) Building construction predates both current and level-of-protection criteria, but a hazards analysis has shown the risk of operations to be at an acceptable risk.

(4) The risk from deviation has been analyzed and accepted by current hazards analysis.

NOTE: Those facilities requiring hazards analysis to determine whether a deviation from the Life Safety Code is acceptable shall follow the considerations and criteria described in section 2.2.5 of this chapter.

2.2.5 ***Requirements for New Facilities***

a. New facilities shall comply with the requirements of NFPA 101, except when deviation is necessary to provide personnel protection from blast overpressure and fragments per Chapter VI of this Manual.

2.2.5.1 If deviations from NFPA 101 requirements are made, the Fire Hazards Analysis required by Chapter VI of this Manual shall document the following aspects

related to each explosives operation, bay, and/or workroom where a deviation exists.

a. Clear pathways to exit in explosives bay or workroom.

b. Potential for sustained fire from the presence of combustible and flammable materials and the presence of ignition sources in work environments.

c. Total time required to exit the bay or workroom.

2.2.5.2 The criteria considered acceptable for the components of the analysis in section 2.2.5.1 of this chapter are, respectively:

a. No obstruction shall limit the width of the pathway to less than 36 in.

b. Combustible and flammable material quantities shall be minimized, justified, documented, and reviewed by site fire protection personnel and approved by line management. Ignition sources shall be identified and eliminated where possible.

c. The total time for six people to exit the workroom or bay, including the opening of doors where necessary, is 30 seconds or less. The total time for twenty people to exit the workroom or bay is 90 seconds or less. Noncompliance with this criterion shall be evaluated and justified during the conceptual design review.

2.2.6 ***Single Exits***

a. Where NFPA 101 requires at least two exits, but provisions for personnel protection from a blast will not permit at least two exits from a room or structure, a single exit is acceptable, provided the requirements of sections 2.2.3 and 2.2.4 of this chapter and the following are met:

(1) The path of exit travel shall be arranged so it is not through or toward a hazardous operation.

(2) A room containing a high-hazard explosive occupancy shall not exceed 500 ft^2, and the occupant load of the room shall be restricted to two operators and two transients.

(3) A room containing a reduced-hazard explosive occupancy shall not exceed 1,000 ft^2.

b. Explosives storage magazines may have only single exits for the purpose of maintaining integrity of design. The conditions of this section do not apply to these magazines.

2.2.7 ***Blast-Resistant Doors***

a. Blast-resistant doors required to protect personnel from the effects of an accidental detonation may be located in the means of egress, provided the requirements of sections 2.2.3 through 2.2.5 of this chapter and the following are met:

(1) Where power-operated doors are required to accomplish unlatching and opening, they shall have redundant features or be capable of being opened manually (to permit exit travel) or closed where necessary to safeguard exits.

(2) The time required to fully open or close a door shall be as short as reasonably possible.

(3) A revolving door is acceptable if a secondary means of escape (with swinging doors) is provided at the same location. The revolving door must also be prevented from rotating at too rapid a rate to permit orderly exit of personnel.

(4) The following exceptions to NFPA 101 may be allowed when justified and documented.

(a) Swinging doors may exceed 48 in. wide.

(b) The NFPA-required swinging doors adjacent to a revolving blast door can be omitted.

(c) Revolving blast doors need to be designed to collapse into book-fold position.

(d) Where fire-rated doors are required, blast doors are considered to have the required fire rating.

(e) An airlock with two or more doors that is intended during routine operations to prevent continuous and unobstructed passage by allowing the release of only one door at a time shall be permitted in a means of egress. In such cases, there shall be provisions to allow for continuous and unobstructed travel during an emergency egress condition.

(f) Panic hardware is not required on blast doors.

2.2.8 ***Slide Escapes***

a. Slide escapes should be provided for elevated explosives operating locations from which rapid exit may be vital and cannot be obtained by

other means. Slide escapes should be located on opposite sides of the explosives operation to reduce the likelihood of personnel being trapped by fire between them and a single slide.

b. Exits to slide escapes must open onto platforms that are not less than 3 ft^2, and the platforms must be equipped with guardrails. The slides shall begin at the outside edge of the platform, not at the edge of the buildings. Slide escape landings shall be located at selected places leading directly to escape routes that are free from tripping hazards, low guy lines, drains, ditches, or other obstructions. Manually or automatically controlled devices (trips) that sound an alarm in the operating building shall be installed at or near the entrances to slide escapes. These devices may also actuate deluge valves and water curtains in the building or room affected. Recommended slide escape specifications:

(1) Angle, 40 to 50 degrees horizontal.

(2) Slide depth, 24 in.

(3) Radius at bottom of slide, 12 in.

(4) Height at lower end of slide, not over 24 in. above the landing.

c. If necessary, the end of the slide shall have a horizontal run sufficient to prevent employee injury from exit speed without the use of landing cushions, which are unsatisfactory in cold weather. One foot of horizontal run is required for a 15-ft-long slide. One additional foot of horizontal run will be provided for each additional 5 ft of slide length. The juncture of the two sections must be well rounded. Metal sheets constructing the slide must overlap in the direction of travel.

3.0 BUILDING AND EQUIPMENT MAINTENANCE

3.1 Cleaning

a. Structures containing explosives shall be kept clean and orderly.

b. Explosives and explosives dust shall not be allowed to accumulate on structural members, radiators, heating coils, utility lines, equipment, or electrical fixtures.

c. To maintain safe conditions, there shall be a regular cleaning program for building interiors to prevent the accumulation of explosives dust and waste. This program should not be conducted in any bay where a hazardous operation is being conducted.

d. In buildings containing explosives, floors should be cleaned with hot water or a water-steam mix wherever practical. Non-abrasive sweeping compounds that are compatible with the explosives involved may be used when a water-steam mix or hot water is not practical. Such sweeping compounds may be combustible but must not be volatile (closed-cup flash point must not be lower than 110°C). Sweeping compounds containing wax shall not be used on conductive flooring. Where nitrated organic explosives (which may form sensitive explosive compounds with some alkalis) are involved, the use of cleaning agents containing those alkalis is prohibited.

e. Before beginning explosives decontamination activities involving large amounts of organic solvents (generally over 1L), provisions must be made for adequate ventilation or respiratory protection, fire protection, and adequate protective clothing.

3.2 Maintenance and Repair

a. Records shall be maintained for inspection, repair, and servicing of process and handling equipment and fire protection systems.

b. Maintenance operations involving major repairs, changes, or the use of hazardous equipment should not be performed within bays (rooms) while explosives are present. Before beginning such maintenance, explosives should be removed and the area prepared. An approval procedure shall be established to ensure that the area has been inspected and is safe for these operations.

c. Non-facility personnel performing maintenance or construction operations shall be at least intraline distance from any explosives operation and should be at least intraline distance from any building containing explosives. This requirement does not apply to personnel making job site inspections or equipment repairs requiring less than eight hours (e.g., technical

representatives, architect-engineering surveyors, etc.). Providing equivalent protection may satisfy the intraline distance separation requirement. Transportation of explosives is permitted on roadways at less than intraline distance.

d. Facility management shall determine the minimum practical distance by which non-facility personnel (e.g., technical representatives, service representatives, architect-engineering surveyors, etc.) shall be separated from explosives operations while making job site inspections or equipment repairs requiring less than eight hours. Facility management shall control explosives operations so that the chance of an explosion shall be kept to a minimum. The rationale for establishing the minimum practicable distance and additional control measures taken shall be documented and maintained until operations have been completed and personnel have permanently vacated the work site. All such personnel shall be informed of the risk of working at less than intraline distance and shall agree to accept such risk.

e. New equipment or equipment subjected to major repair or modification shall be test-operated, and handling equipment shall be tested before being returned to operations. *The DOE Hoisting and Rigging Standard* (DOE-STD-1090-current version) may be used as a guide.

f. Only authorized personnel shall perform maintenance work.

g. Before resuming operations following maintenance, the area shall be cleaned and approved by the operations supervisor.

3.3 Hot Work Permits

a. Where explosives are involved, a written permit shall be required for the temporary use of portable, heat-producing equipment that generates temperatures higher than 228°F (109°C). Explosives decontamination of the immediately affected work areas and explosives removal shall be required before beginning hot work operations. The permit should state the location, time, duration, purpose of use, details of safety, and fire-fighting equipment required. The permit shall be available at the named location for checkout by supervisory personnel.

(1) Permits shall be authorized by signature of personnel designated by local facility management. Designated personnel should be qualified by experience in explosives work, fire prevention, and general safety precautions, in particular, the purging of equipment, presence of flammable mixtures, and the avoidance of electrical and mechanical hazards that could be incident to repair work.

(2) Personnel designated to sign the hot work permit should represent supervision of the work location, supervision of personnel performing

the hot work, and a third group independent of the first two (usually the safety and fire protection group).

(3) An individual should remain at the site of a cutting or welding job for approximately 30 minutes after the job has been completed to extinguish or report any fires that develop. Designated supervision should inspect the job site before, during, and after completion of the job.

4.0 REMOTE OPERATIONS

4.1 Personnel Protection

a. Explosives operations judged to present a significant level of risk to be performed remotely shall be conducted in facilities where the construction of the operating bay or the control room affords sufficient protection to personnel to prevent serious injuries. Chapter VI, section 4.2.1d specifies criteria for the prevention of serious injuries.

b. Prevention of serious injury from a remote operation applies to both transient personnel and personnel involved in the operations.

4.2 Access and Equipment Controls

a. Procedures and equipment shall be used to prevent entry into a hazardous bay or area in which a remote operation is occurring or to prevent the operation from proceeding when personnel enter, as follows:

(1) Roads shall be blocked at a minimum of the public traffic route distance from buildings where hazardous (remote) operations are being performed. Public traffic route separation may be satisfied by providing equivalent protection.

(2) Corridors leading to bays in which hazardous (remote) operations are being performed shall be marked to warn of the danger. Barriers shall also be set up.

(3) Visual methods such as closed circuit television should be used to monitor remote operations and to enable viewing of the operating area conditions before entering. Remote audio monitoring and video recording should also be considered.

(4) Interlocking of remote operating equipment to access doors should be required for each remote operation.

(5) Lights or similar warning devices shall conspicuously identify buildings or bays in which remote operations are performed to indicate when remote operations are under way.

5.0 GENERAL EXPLOSIVES AREA CONTROLS

5.1 Smoking, Matches, Lighters, Metal Articles

a. There shall be no smoking in explosives storage, processing, or test areas, except in designated locations.

b. No matches, lighters, or other fire-, flame-, or spark-producing devices shall be taken into an explosives control area except with written authorization. If authorized to be carried, matches shall be contained in a metal carrying device too large to fit into pockets. Kitchen "strike anywhere" matches shall not be used.

c. Operating personnel should not carry metal articles (e.g., keys, jewelry, knives, coins, etc.) in explosives processing areas where such items could constitute a hazard if dropped into the process operation.

5.2 Cooking and Eating

a. Food or beverages shall not be consumed in explosives buildings, except in designated areas.

b. There shall be no personal dishes or utensils in an explosives building, except in designated eating areas.

c. Coffee pots, hot plates, ovens (including microwaves), and portable electric heaters shall not be permitted in rooms where:

(1) Explosives may be present.

(2) Combustible vapors or dust may be present.

(3) Smoking or drinking is prohibited because toxic materials are present.

(4) Electrical classification of appliances is not compatible with the area.

5.3 Access to Explosives Areas

a. Access control procedures shall be established for entry to all explosives areas.

6.0 PROTECTION OF ELECTROEXPLOSIVE DEVICES (EED) FROM ELECTROMAGNETIC RADIATION

a. EEDs are vulnerable to initiation from a variety of sources. One potential hazard associated with EEDs is the accidental initiation by stray electromagnetic energy. This hazard exists when an electromagnetic field of sufficient intensity is generated to induce or otherwise couple currents and/or voltages of magnitudes large enough to initiate electroexplosive devices or other sensitive explosive components of weapon systems, or other explosive devices. This unintended actuation could have safety (premature firing) or reliability (duding) consequences.

b. A large number of these devices are initiated by low levels of electrical energy and are susceptible to unintentional initiation by many forms of direct or induced stray electrical energy, such as from lightning discharges, static electricity, or tribo-electric (friction generated) effects, and radio frequency (RF) energy. Hazards from lightning discharges are covered in Chapter X. Lightning protection systems and requirements normally preclude the inadvertent initiation of EEDs by direct lightning strikes. Precautions for static electricity discharges are addressed in section 7 of this chapter. Stray energy, such as transients and other forms of induced energy, can be imposed on circuits affecting EEDs from other subsystems by various methods. Examples are inductive or capacitive coupling; sneak ground circuits; defective components or wiring; errors in design, modification, or maintenance.

c. The degree to which EEDs are susceptible to unintentional initiation by exposure to the radiated fields of RF emitters depends on many variables. These variables include the ability of the leads, circuit, or installation to capture RF energy; the type and characteristics of RF energy; and methods of coupling which can introduce this energy into the EED.

d. Emitter operating frequencies, power levels, modulation, and illumination angles are some of the factors that affect the vulnerability of EEDs to RF energy.

e. As a precautionary measure, EEDs should normally be left inside their containers until ready for use. Shorting clips or other safety devices should not be removed until the EED is actually ready for use.

f. For precautionary separation distances, see Chapter II, section 13, Tables II-1, II-2, and II-3.

7.0 STATIC ELECTRICITY

7.1 General

a. Positive steps must be taken to control or eliminate static electricity in areas where materials that are ignitable by static spark discharge are processed or handled. This includes spark-sensitive explosives, propellants, and pyrotechnics as well as solvent vapors, and flammable gases.

7.2 Bonding and Grounding of Equipment

a. Bonding straps can be used to bridge locations where electrical continuity may be broken by the presence of oil on bearings, paint, or rust at any contact point. Pressure contact alone is not adequate grounding for permanent equipment in contact with conductive floors or tabletops. Static grounds shall not be made to gas, steam, or air lines; dry pipe sprinkler systems; or air terminals of lightning protection systems. Static grounds can be made to water pipes, ground cones, buried copper plates, or driven ground rods of lightning protection systems. If a structure is equipped with a lightning protection system, all grounds shall be interconnected. Wires used as static ground conductors should be at least No. 10 AWG or equivalent.

7.3 Testing Bonded Equipment Grounds

a. Grounding systems shall be tested for electrical resistance and continuity after installation has been completed and, in the case of active equipment, at intervals to be locally determined. If the equipment has been inactive for more than one month, the ground system shall be visually inspected for continuity before reactivation of the system. All exposed explosives or hazardous materials shall be removed before testing. When testing for resistance-to-ground, equipment should be considered as a unit except in the case of an electrically isolated device or a belt-driven machine. In measuring the total resistance-to-ground for belt-driven machinery (to assure compliance with the section below), resistance of the belting is to be excluded. The maximum resistance-to-ground permitted for different types of equipment is as follows in section 7.3b.

b. Hazardous locations (operations where a static spark discharge may be dangerous). All conductive parts of equipment shall be bonded; in the case of grounded equipment, bonding shall be such that resistance to ground does not exceed 25 ohms, unless resistance is not to exceed 10 ohms because of a lightning protection installation. For existing equipment, the rate of static generation should be considered before making changes in grounding systems. The resistance of conductive rubber hose should not exceed 250,000 ohms.

7.4 Conductive Floors, Shoes, Mats and Wristbands

a. Conductive floors and shoes should be used for grounding personnel in operations involving explosives (propellants, pyrotechnics, lead azide, lead styphnate, mercury fulminate, CP, etc.) that are sensitive to initiation by the electrostatic spark discharge from a person. Static discharge from a person may ignite many flammable liquids and air mixtures. In areas where personnel come into the proximity of (i.e., possible contact with) static-sensitive explosives or vapors, conductive floors shall be installed except where adequate housekeeping, dust collection, ventilation, or solvent recovery methods eliminate the hazards of dust-air or flammable vapor-air mixtures. Conductive floors may also be required in areas where operations involve EEDs that contain a static-sensitive explosive.

b. Conductive floors are not required throughout an entire building or room if the hazard is localized. In such cases, conductive mats or runners may be used where required. These mats or runners shall meet all specifications and test requirements that apply to conductive floors. Conductive wristbands may be substituted for conductive mats and footwear at fixed, grounded or bonded workstations or outdoor locations.

7.5 Conductive Floor, Work Surface, and Wristband Specifications

a. Conductive floors must be made of non-sparking material such as conductive rubber or conductive flooring composition and shall meet the following requirements:

(1) The flooring and its grounding system must provide for electrical resistance not to exceed 1,000,000 ohms (measured as specified in section 7.6 of this chapter).

(2) The surface of the installed floor must be free from cracks and reasonably smooth. The material must not slough off, wrinkle, or buckle under operating conditions. Conductive tiles are not recommended for use in areas where explosives dust can cause contamination. The large number of joints and the tendency of tiles to loosen provide areas in which explosive dust can become lodged, making normal cleanup procedures difficult.

(3) Where conductive floors and shoes are required, resistance between the ground and the wearer shall not exceed 1,000,000 ohms, (i.e., total resistance of conductive shoes on a person, plus the resistance of floor to ground). (See Figure II-1 for testing method.) Where conductive floors and shoes are required, tabletops on which exposed explosives or dusts are encountered should be covered with a properly grounded or bonded conductive material that meets the same requirements as those for flooring.

(4) Conductive floors must be compatible with the explosive materials to be processed.

(5) Conductive wristbands shall not exceed a resistance between the wearer and ground or bonding point of 1,200,000 ohms. This resistance shall be measured with a suitably calibrated ohmmeter. Wristbands shall be of a design that maintains electrical contact with the wearer when used.

(6) Table-top work surface mats that are not part of a total conductive system (section 7.5a(3) shall have a resistance not to exceed 1,200,000 ohms. This resistance shall be measured by a method similar to that outlined in section 7.6 and records shall be maintained.

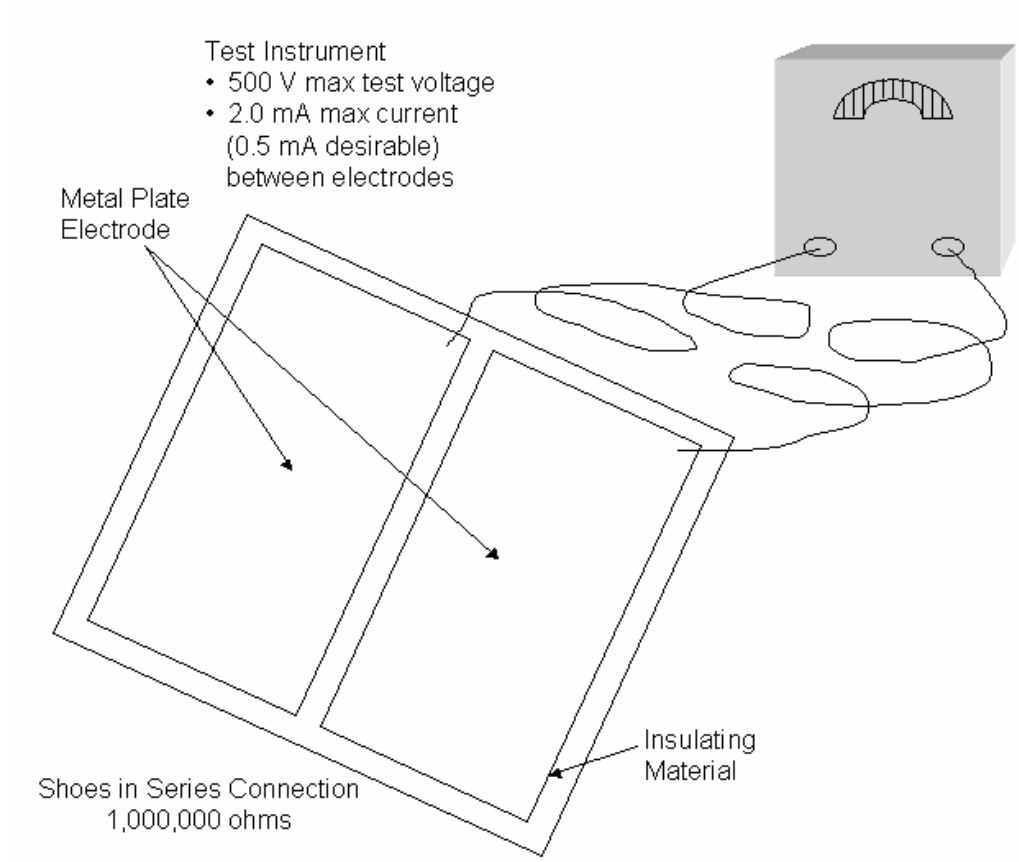


Figure II-1. Testing Shoes on Wearer

7.6 Conductive Floor Tests

a. Initial tests shall be made of all conductive floors, and subsequent tests shall be made at least semi-annually. Test results shall be permanently recorded and a copy filed in a central location. Instruments used in making tests shall be used only when the room is free from exposed explosives and flammable gas mixtures.

b. Maximum floor resistance shall be measured with a suitably calibrated ohmmeter that operates on a normal open circuit output voltage of 500 volts DC and a short circuit current of 2.5 milliamperes with an effective internal resistance of approximately 200,000 ohms. Minimum floor resistance will be measured with an ohmmeter suitably calibrated for the task.

c. Each electrode shall weigh 2.3 kg and shall have a dry, flat, circular contact area 6.5 cm in diameter, which shall comprise a surface of aluminum or tinfoil 1.3- to 2.5-mm thick, backed by a layer of rubber 0.6- to 0.65-cm thick and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240-68).

d. The floor shall be clean and dry. "Electrode jelly" such as brushless shaving soap or saline solution shall not be used.

e. The resistance of the floor shall be more than 5,000 ohms in areas with 110 volt service and 10,000 ohms in areas with 220 volt service, and less than 1,000,000 ohms in all areas, as measured between a permanent ground connection and an electrode placed at any point on the floor and also as measured between two electrodes placed 3 ft apart at any points on the floor. Measurements shall be made at five or more locations in each room. If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five seconds shall be considered as the measured value.

7.7 Humidification

a. Humidification to prevent static electricity accumulations and subsequent discharges is usually effective if the relative humidity is above 60 percent. However, due to the possibility of spontaneous ignition, certain materials such as metallic powders and some pyrotechnic mixtures cannot be exposed to air with 60 percent relative humidity. Where this technique is used to prevent static electricity accumulations, a daily preoperational check of the humidity levels will be accomplished before work starts.

7.8 Ground Fault Circuit Interrupter

a. Ground fault circuit interrupter protection shall be provided in static grounded areas where personnel may come in contact with AC-powered electrical equipment.

8.0 ELECTRICAL EQUIPMENT AND WIRING

8.1 Location/Operation Electrical Hazard Classification

a. The National Electrical Code (NEC) shall be followed in all situations where the code normally applies. Although the NEC does not specifically address explosives, Article 500, Hazardous (Classified) Locations, requirements for the design and installation of electrical equipment and wiring in "classified" locations shall be used as guidance for the installation of rated equipment and fixtures where required by this section. The use of rated wiring, fixtures, equipment, and instrumentation where the code normally does not apply, provides additional safety for work with explosives materials by (1) restricting electrical ignition sources, such as sparks, electrical faults (shorts, power surges, etc.), (2) controlling surface temperatures of electrical items, and (3) reducing the potential for electrically initiated fires. Rated wiring, fixtures, equipment, and instrumentation shall be used for the operations specified below unless demonstrated unnecessary through analysis for a specific operation and location. The analysis shall be performed and documented per sections 8.4 and 8.6 of this chapter.

b. Explosives do not normally fit the NEC definitions for groupings, classes, divisions, and area classifications. In order to apply Article 500 as a guide, vapors containing explosives shall be treated as Group D (unless NEC requires a higher classification because of other components of the vapor) and dusts of explosives or solid explosives shall be treated as Group G. Class, division, and area classification determinations shall be based on the explosives operation being performed, as specified below, and not on the location or surrounding atmosphere, nor its potential for producing an ignitable or explosive mixture. Maximum temperature limits shall be based on the thermal analysis of the explosives used in the operation. Division 1 items can be substituted for Division 2 items, but never Division 2 for Division 1 items. Where there is a conflict between the requirements of the code and requirements of this Manual, the more stringent of the two applies.

c. Rated wiring, equipment and instruments shall be approved for use by a nationally recognized testing laboratory. Rated items shall have labels and/or clearly identifiable markings to show Class, Division, Group, and Temperature Range for which they are approved. Equipment approved for one Hazard Class is not interchangeable with another Hazard Class.

d. The operations discussed below shall comply with the recommended class/division unless it is determined unnecessary through documented analysis for a specific operation and location.

(1) Class I, Division 1 wiring, fixtures, process equipment, and instrumentation are recommended for operations involving flammable

gases or chemicals/materials expected to produce flammable vapors with explosives present.

(2) Class I, Division 1 and Class II Division 1 (dual rated) wiring, fixtures, process equipment, and instrumentation are recommended for synthesis, formulation, mixing, wet blending, and casting explosives, heating/drying of uncased explosives, plus any explosives processing that is expected to produce sublimation.

(3) Class II, Division 1 wiring, fixtures, process equipment, and instrumentation are recommended for screening, grinding, blending, pressing, dry machining explosives, and weighing of explosives powders, the use of explosive or ignitable dust mixtures with explosives present, plus any explosives process that is expected to produce dust from explosives that is suspended in the air.

(4) Class II, Division 2 wiring, fixtures, process equipment, and instrumentation are recommended for storage, inspection, assembly, and wet machining of explosives, heating of fully encased explosives, plus, any explosives operation capable of producing dust of explosives that can accumulate on electrical equipment or apparatus. Class II, Division 1 or dual-rated equipment and wiring can be substituted.

(5) General Purpose wiring, fixtures, process equipment, and instrumentation are allowed for shipping and receiving operations with fully encased explosives or explosives packaged in DOT/DoD approved shipping containers and areas in explosives facilities where no explosives are present. Examples are: offices, control rooms, halls, rest rooms, and mechanical equipment rooms. General Purpose Areas may be established in explosives locations if facility management can determine, based on documented analysis of the processes involved and the separation between explosives operations requiring Class I or Class II rated electrical wiring, fixtures, process equipment, and instrumentation and the General Purpose Area is established and maintained such that:

(a) Migration of explosive or ignitable gases, vapors or dust mixtures into the General Purpose Area from the rated area (not to be confused with the NEC Classified locations) will not occur under normal operating conditions.

(b) Ignition energy that may be developed in the General Purpose Area will not be transferred to the rated area (not to be confused with the NEC Classified locations), even under electrical fault conditions.

(6) Due to the potential for unacceptable consequences concerning operations with nuclear explosives, subassemblies, or components, they shall be evaluated in accordance with section 8.0 of this chapter to determine the appropriate electrical hazard classification.

(7) Facility management shall evaluate, by using the principles given above, all explosives operations not specified elsewhere in this section to determine the appropriate electrical classification. The analysis shall be documented.

8.2 Electrical Supply System

a. Mutual hazards may exist where explosives facilities are located near electrical supply lines and stepping equipment. To protect against these hazards, the NEC (NFPA 70) and the following requirements apply to all new construction or major modifications, and should be considered for existing facilities. Quantity distance requirements are based on air blast overpressure only, and fragment distances are not considered. Electric supply lines that can be interrupted without loss of power, i.e., power is rerouted through existing lines and/or networks, can be separated from explosives sites in accordance with section 8.2a(1)(c) below.

(1) Electric transmission lines (those carrying 69 kV or more) and the tower or poles supporting them shall be located no closer to explosives facilities than:

(a) Inhabited-building distance if the line in question is part of a grid/system serving a large, offsite area.

(b) Public traffic route distance if loss of the line will not create serious social or economic hardships to offsite areas.

(c) Electric distribution lines (those carrying less than 69 kV) and the tower or poles supporting them shall be located no closer to explosives facilities than public traffic route distance.

(3) Aboveground, DOE-controlled electric service lines required to be in close proximity to a combustible constructed or uncovered explosives facility shall be no closer to that facility than the length of the lines between the poles or towers supporting the lines, unless an effective means is provided to ensure that broken, energized lines cannot come into contact with the facility or its appurtenances. Acceptable controls include, but are not limited to, geographic terrain features, instantaneous circuit interrupters, cable trays, and linking lines together. Equivalent underground service lines shall be located as specified in Chapter VI, section 3.2.4 and Table VI-2.

(4) Electric lines serving explosives facilities shall be installed underground from a point not less than 50 ft away from such facilities.

(5) Unmanned privately owned or contractor-owned electrical substations (not to include building transformers and associated switch gear) shall be no closer to explosives facilities than public traffic route distances.

(6) Certain types of auxiliary power facilities, transformer stations, etc., present fire hazards to explosives facilities. Transformers and associated electrical switching apparatus serving one explosives facility or complex that do not present a fire hazard to the facility (i.e., dry-type, "less flammable" oil-insulated, etc.) shall be located as specified by NFPA 70 and Factory Mutual Data Sheet 5-4/14-18. Normal oil-insulated transformers shall be located at least 50 ft from an explosives facility or as specified in DoD 6055.9-STD.

(7) Uninterrupted Power Supply (UPS) should be provided if electrical power is critical to an explosives operation during a power shut down or interruption.

8.3 Building Electrical Service Entrance

a. Each electrical service entrance for explosives facilities should be provided with the following protection.

(1) Arrestors

(a) Lightning arrestors shall be the appropriate size and class for the application and system voltages and shall be provided on the primary side of the transformer located in, on, or near the facility. See Chapter X for additional lightning protection guidance.

(b) Surge arrestors and surge capacitors shall be provided on the supply side of the main service disconnect.

(2) Grounding

b. The lightning arrestor, surge arrestor, surge capacitors, service entrance ground, and building ground shall be interconnected. This interconnection shall be made outside the building.

8.4 Permanent Wiring, Fixtures and Equipment

a. Permanent facility wiring includes installed electrical wiring, communications wiring, security systems wiring, and fire protection systems alarm and response wiring. Permanent equipment includes the installed electrical fixtures and equipment associated with permanent wiring. Permanent equipment also

includes equipment such as HVAC, hoods, vacuum pumps, hydraulic pumps, etc.

b. New Facilities and Renovations

(1) All permanent equipment and wiring of a room shall conform to section 8.1 of this chapter for the operations for which the room is designed.

(2) To maintain maximum, long-term flexibility of use of facilities, facility management is encouraged to consider installing dual-rated (i.e., Class I, Division 1 and Class II, Division 1) permanent wiring and equipment in explosives operating rooms. As a minimum, installation should allow for easy conversion to dual-rated wiring and equipment.

(3) Rated electrical fixtures shall not be painted.

(4) Where equipment cannot meet the above requirements, the equipment should be located outside the hazardous environment. Otherwise, the equipment shall be analyzed and controlled as specified for electrical equipment and instrumentation in section 8.6 of this chapter.

c. Existing Facilities

(1) Permanent wiring and equipment shall meet the requirements in effect at the time the facility was built. The wiring and equipment shall be brought into conformance with section 8.4b of this chapter If remodeling or renovation would affect the wiring or equipment.

(2) As a minimum, the permanent wiring and equipment shall meet the requirements of section 8.1 of this chapter for the explosives operations performed.

(3) Where equipment cannot meet the above requirements, the equipment should be located outside the hazardous environment. Otherwise, the equipment shall be analyzed and controlled as specified for electrical equipment and instrumentation in section 8.6 of this chapter.

8.5 Flexible Cords/Wiring

a. Wiring from the permanent premises wiring to process equipment or process instrumentation should be rated for actual explosives operation being performed, per section 8.1 of this chapter. As a minimum, flexible cords shall be hard usage service cord. Splices are not allowed. In addition, all flexible cords, receptacles, and attachment plugs must be equipped with three prongs so that the third prong (green wire) acts as ground. The cord shall be supported so that there is no tension on the terminal connections. Seals shall be provided where the cord enters explosion-proof enclosures. For Hazard Class I or Class II, Division I or

dual-rated operations, the cord shall also be equipped with explosion-proof attachment plugs. Flexible cords shall not be used where fixed installed electrical wiring is required by equipment design.

8.6 Electrical Equipment and Instrumentation

a. Non-permanent electrical equipment and instrumentation shall comply with the following:

(1) Process instrumentation and process equipment should be rated for the actual environment based on the explosives operation being performed as defined in section 8.1 of this chapter.

(2) If the thermal properties of an explosive are such that Group G or Group D equipment provides inadequate surface temperature limits, special protection shall be provided, or the equipment shall be excluded from the hazardous location. This equipment shall not have a surface temperature exceeding the lowest onset of the exotherm of the explosive, as determined by the differential thermal analysis (DTA) test or the differential scanning calorimetry (DSC) test in section 12.1.1c of this chapter and Chapter VIII, section 2.2d. Approved instrumentation and equipment shall be administratively controlled and marked accordingly.

(3) When Hazard Class I or II, as applicable, equipment or instrumentation is required but not available, the substitute equipment should be purged or pressurized in accordance with NFPA 496, or be determined intrinsically safe (without regard to voltage) in accordance with NEC Article 504/ANSI 913/NFPA 493 by facility management, or in Hazard Class II locations, sealed to prevent explosives contamination. When the equipment is purged or sealed, the surface temperature shall not exceed 120°C for normal operations, or 165°C for overload conditions.

(4) All electrical equipment or instrumentation in hazardous locations that do not meet the requirements of section 8.6a(3) above shall be evaluated and documented as to their suitability for use in the specific area and operation. The following are suggested areas for evaluation:

(a) Malfunction of electrical equipment or process instrumentation.

1 Consequences of electrical initiated fire.

2 Initiation of explosives by electrical current.

(b) Initiation of explosives by electrical fault.

(c) Breach of containment resulting in exposed explosives or spillage of explosives.

(d) Ignition sources arising from physical damage to the wiring method used (e.g., crushing by forklift or other material handling equipment, frayed cords, etc.).

(e) Exposed electrical conductors or connectors that could make contact with leg wires or cables of explosive devices during routine handling.

(f) Exposed electrical conductors or connectors on which explosives dust or vapors could collect.

(g) Collection of explosives dust on or in the equipment.

(h) Sensitivity to heat and spark, and thermal stability of explosives involved.

(5) If the equipment is purged, the airflow shall be monitored per NFPA 496 and interlocked to the equipment, or alarmed, if operator shutdown of the machine can be reliably performed immediately upon receipt of that alarm.

(6) A waiver is not required when the wiring, equipment or instrumentation meets the requirements of either section 8.6a(3) or 8.6a(4) of this chapter. If the wiring, equipment or instrumentation cannot meet these criteria or has not been evaluated by facility management, it shall meet the appropriate electrical hazard class requirements.

b. Watertight equipment (that would pass a NEMA 4 hose test) should be provided in those locations where water-explosives mixtures may come in contact with the electrical equipment and wiring.

8.7 Electrical Requirements for Outdoor Test Areas

a. Requirements for outdoor test areas shall be contained in the specific test procedures.

8.8 Hand-held, Battery-Powered Lights and Instruments

a. Flashlights and hand lanterns, powered by low-voltage dry cell batteries and "miners cap lamps" approved as "permissible" by the U.S. Bureau of Mines and by UL for NEC Class I hazardous locations, are authorized for use in both Class I and Class II locations. Devices that provide "cold light" through chemical action are acceptable for use in any location.

b. Hand-held instruments, watches, calculators, hearing aids, cameras, self-contained flashes, and communication devices powered by low-voltage dry cell batteries are authorized for use in the vicinity of Hazard Class II,

Division 2 rated hazardous operations and during setup of Hazard Class I or Class II, Division 1 hazardous operations. They shall be evaluated as to their intrinsic safety and approved by facility management prior to use during Hazard Class I or Class II, Division 1 hazardous operations.

c. Hand-held, battery-operated equipment shall not come in direct or indirect contact with bare explosives. Batteries shall not be removed or replaced in hazard rated areas (section 8.1 of this chapter).

8.9 Non-Rated Extension Lighting

a. When it is necessary to use extension lights within 10 ft of exposed explosives, where no airborne dust exists, the following requirements shall apply:

(1) Lights shall be mounted on heavy tripod stands.

(2) The lights shall be fitted with exterior globes to prevent the falling of hot sparks or particles that might ignite the explosives.

(3) The lights shall be fitted with adequate guards to protect the globes from physical damage.

(4) The wire providing power to the lights shall be positioned so as to prevent vehicles and personnel damaging the cord.

(5) The flexible cord shall comply with section 8.5 of this chapter.

(6) The light stand shall be secured to prevent tipping.

(7) Neither the light nor the power cord shall be allowed to come in direct or indirect contact with the explosives.

(8) Lights shall be positioned outside the fall-down distance to the explosives.

8.10 Laboratories

a. Permanent wiring and equipment for existing laboratory areas are not required to meet the requirements of section 8.4 of this chapter, except as noted in section 8.4c(1).

b. Process equipment used for synthesis, heating, drying, mechanical mixing, and blending shall be dual-rated. Weighing equipment shall be Class II, Division 1 or mechanical. These operations shall be isolated from non-rated

wiring, electrical equipment, and instrumentation in a manner that prevents dust or vapors reaching an ignition source.

c. When laboratory equipment cannot meet the requirements of section 8.10b of this chapter, apply section 8.6a(3) or 8.6a(4) of this chapter.

8.11 Modifications

a. Operating buildings and magazines are constructed to perform a specific function that dictates the requirements for electrical installation. Procedures shall be established by each DOE facility to control the use and modification of electrical equipment in explosives areas and ensure that uniform standards are adhered to throughout the facility.

9.0 VACUUM EQUIPMENT

9.1 General

a. Precautions shall be taken to prevent explosives from entering any vacuum system not specifically designed to collect explosives.

9.2 Labeling

a. All vacuum lines used for explosives operations should be labeled to warn maintenance personnel that explosive residue may be present in these lines. One suggested label is:

DANGER, MAY CONTAIN EXPLOSIVES

9.3 Disassembly

a. All vacuum lines that are potentially contaminated with explosives shall be disassembled according to approved operating procedures. Disassembly should be accomplished at flanged connections or elastomeric tubing whenever practical. No attempt should be made to disassemble a vacuum line at a threaded connection. The design or installation of any new vacuum lines shall not employ demountable, internal screwed, or threaded fittings or connections unless welded or fixed permanently in place.

9.4 Traps or Filters

a. Vacuum pumps used to evacuate processes for explosives operations shall be equipped with primary and secondary intake line traps or filters to prevent explosives from contaminating the pump.

10.0 EXPLOSIVES DUST EXHAUST VENTILATION AND COLLECTION SYSTEMS

10.1 General

a. Exhaust ventilation should be used to control explosives dust (or other hazardous materials used in or resulting from explosives operations) that could be hazardous to operating personnel or contaminate the operating area. Exhaust ventilation used to remove explosives dust requires an approved dust collection system to prevent the release of the dust outside the building.

10.2 Exhaust Ventilation

a. Exhaust ventilation and collection systems that control explosives dust and materials associated with explosives production shall be designed to meet minimum requirements established in the ACGIH Ventilation Manual (most current edition) and this Manual. The exhaust ventilation system should have sufficient capture and adequate makeup air to reduce exposure to explosives dusts, or materials used in conjunction with explosives, to as low as reasonably achievable. This is particularly important when toxicity information and occupational exposure limits are not available for the explosives in use.

10.3 Dust Collection Systems

a. A "wet collector" that moistens the dust close to the point of origin and keeps it wet until the dust is removed for disposal is preferred. A "dry type collector" is permitted when authorized by a Standard Operating Procedure (SOP).

b. Dust collectors shall be designed to prevent explosives dust from reaching any mechanical power source of the collection system.

c. All conductive portions of the collection system shall be grounded and bonded.

d. A dust collection system shall not have screw threads, recesses, or cracks that may be exposed to explosives contamination.

e. Dust collection lines should be equipped with flanged connectors and inspection ports.

f. Pipes or ducts through which explosives are conveyed shall have long radius bends with a centerline radius at least four times the diameter of the ducts or pipes.

g. Dust collectors shall be emptied and cleaned on a regular basis as system use warrants and must be inspected periodically.

10.4 Dust Collection Location

a. Wherever practical, dry-type explosives dust collection chambers should be located outside operating buildings, in the open, or in buildings exclusively set aside for the purpose.

b. Stationary and portable wet-type collectors may be placed in the explosives operating bays or cubicles, provided the quantity of explosives in the collectors does not exceed 2 kg.

11.0 DRAINS AND SUMPS

11.1 Collection

a. All drain lines handling explosive wastes shall be provided with sumps, clarifiers, weirs or basins of adequate design and capacity for removal of explosives by settling. The drains shall be of adequate capacity, free of pockets, and have sufficient slope (at least 1/4 in./ft) to prevent the settling out of explosives in the line until it reaches the sump, clarifier, weir or other settling basin.

b. Drain gutters within buildings may be constructed with a slope of 1/8 in./ft. However, a satisfactory program of cleaning must be developed to assure removal of all hazardous material from drain gutters.

c. Sumps must be designed to prevent suspended and settleable solid explosive material from being carried in the wash waters beyond the sumps. The design shall allow sufficient settling time on the basis of the settling rate of the material and the usual flow rate. Sumps shall be constructed so that the overflow will not disturb any floating solids. The design must also permit easy removal of collected explosives and retention of those explosives that float on water (until they can be skimmed off). When using settling basins to supplement sumps, they will be cleaned periodically and a log will be maintained.

d. Explosives collection trays for sumps will be constructed of nonferrous metal. Hoisting equipment used to lift trays will be designed to prevent the trays from binding on the sides of the sump. Bolted sump tanks or other types of construction that permit the explosives to settle in obscure or hidden spaces are prohibited.

e. Drains between the source of explosive and the sump shall be troughs with rounded bottoms and removable ventilated covers to facilitate inspection for accumulation of explosives. This requirement applies to all new construction and major modifications and should be considered for existing facilities. Short sections of closed pipe or trough are permitted if they can be visually inspected for blockage or explosives buildup. Explosives or explosives-contaminated waste liquids shall not be released into closed drains and sewers.

f. Drains shall be inspected periodically and necessary steps taken to prevent the buildup of explosive deposits.

11.2 Effluent

a. Drains containing explosive waste materials must not be connected in a manner that allows such wastes to empty into the normal sewage systems carrying inert or sanitary wastes.

b. Care must be taken to avoid the possibility of deposition of explosives from sump effluent due to drying, temperature changes, or interaction with other industrial contaminations. When handling explosives that are appreciably soluble in water, sweeping and other dry collecting measures shall be used to keep such out of the drainage system.

c. The combination of sumps, settling ponds, and other systems must remove explosives so that outflows meet environmental standards.

12.0 PROCESSING

12.1 Heating, Drying, and Thermal Conditioning

12.1.1 *General*

a. Heating explosives is potentially dangerous for several reasons:

(1) Elevated temperature can increase an explosive's sensitivity to other stimuli such as impact, shock, friction, and static electricity.

(2) At or above the explosive's critical temperature (see definition in Chapter I, section 6.0) a runaway chemical reaction may occur that can produce an explosion or fire.

(3) Elevated temperature of an explosive in a sealed container can cause gas generation and pressure rupture of the containment even at temperatures below the critical temperature.

(4) Chemically incompatible or reactive materials, which may be present as accidental contaminants, as components of the formulation, or in external contact with the explosive, can intensify the preceding dangers or cause them to occur at lower temperatures.

(5) Nonuniform heating can cause excessively hot regions in the explosives. Causes may include inadequate agitation of fluid explosives, nonuniform heaters, and nonuniform heat conduction.

b. Critical temperature is a system property that depends on a combination of the explosive's chemical decomposition reactions, its mass and shape, heat transfer and other thermal characteristics of the system, and the confinement or pressure of decomposition products, especially gases. Several different methods of thermal analysis can be used to determine or estimate the critical temperature. The process is typically quite complex because of the complexity of normally occurring chemical reactions. For operational safety, a conservative estimate (i.e., lower limit) of the critical temperature for a heating operation shall be made (uncertainties of 10 to 25°C being common). Analogy of one explosive or system to another similar system with a reliable thermal analysis may be used to determine safe heating temperatures and heating times (heating limits).

c. The DTA, DSC (differential scanning calorimetry), or other comparable techniques can be used to measure the temperature of the onset of an exothermic reaction in an explosive. The test results can be used to rank the thermal stability of explosives and as part of a thermal analysis. Because of the complexity of chemical decomposition, however, the DTA/DSC exotherm has no systematic relationship to the critical

temperature and is unreliable for estimating safe heating limits. Exotherm temperature is always considerably above critical temperature and usually increases with the heating rate of the test. Where the DTA/DSC exotherm is specified as a standard for temperature control, the test heating rate shall not exceed 10°C per minute. DTA/DSC shall not be used as a sole means for establishing heating limits (except as specified in section 8.6a(4) of this chapter).

d. Each facility shall conduct or obtain thermal analysis of any explosives system before the explosive is heated in a contact operation or in association with hazardous radioactive materials as described in section 13.6.2 of this chapter. From this analysis, a heating limit for the explosives system shall be established which the EDC shall approve. All factors in sections a and b, above, shall be considered. Any significant change in the geometry or an increase in mass should be considered a new explosives system. For a contact operation, the maximum temperature should be set at least 10°C below the critical temperature. For heating explosives in association with hazardous radioactive materials, the maximum temperature should be set at least 20°C below the critical temperature. Facility management may approve heating to a temperature greater than the above specifications if a documented analysis of the explosive's thermal characteristics indicates that an acceptable time or temperature safety factor is still present for a specific operation. These operations shall be conducted remotely.

e. Heating controls for each operation shall be established and specified in written operating procedures. Specified conditions should be set at the lowest temperatures and heating times to do the job efficiently and should not exceed the heating limit for the explosives system. Factors to consider when establishing heating controls include the heating limit and accuracy of the estimated critical temperature, accuracy of the temperature control equipment, and the likelihood of incompatible chemical contamination and other operational parameters.

12.1.2 *Heating and Drying Equipment*

a. Heat should be done by steam, hot water, friction air, or electrically heated transfer fluid. Redundant, automatic heat controls shall limit temperatures.

b. In systems heated by steam only, the requirements for redundant, automatic heat controls shall be satisfied if a pressure-reducing valve, pressure relief valve, and thermostatic valve on the system control the steam pressure.

c. In electricity heated systems, a manual reset secondary overtemperature system consisting of a controller, failsafe sensor, and an interrupting device shall be provided to interrupt the heat supply source if the primary system fails. The secondary interrupter shall be separate from the primary

interrupter. The upper limit of the primary controller is determined by the desired operating temperature limit. The secondary (override) controller is set at a higher temperature but should not exceed the maximum temperature determined by the heating limit specified for the explosives system as determined in section 12.1.1d of this chapter.

d. Visual and/or audible alarms should be provided to alert operating personnel to abnormal temperature conditions. The heating of explosives should be monitored at all times.

e. The air or gas used to condition exposed explosives shall not be recirculated if directly heated by electrical resistance elements.

f. Drying or heating ovens should be vented to a safe location outdoors. Water wash or filtration of the exhaust may be required. If exhaust fans are used, they shall be interlocked with the heat source.

12.1.3 ***Heating and Drying Operations***

a. Heating and drying shall be performed under the mildest set of conditions that will accomplish the task safely and efficiently. A thermal analysis shall be made and a written procedure prepared consistent with section 12.1.1. The procedure shall include controls on the mass and geometry (thickness of the layer, etc.) of the material that may be heated.

b. Except as described in section 12.1.3c, below, drying shall be achieved by circulating a warm, dry gas—either air or inert—over or through the material.

c. Small samples may be dried by placement in desiccators or by subjecting them to vacuum. Vacuum drying of larger items should be preceded by drying at atmospheric pressure to remove quantities of moisture or solvent before vacuum is applied to remove the final traces of moisture or solvent. Explosives having a vapor pressure exceeding 1 x 10-4 mm Hg at the drying temperature shall not be subjected to vacuum drying. A cold trap shall be used for vacuum drying where the vapor pressure of the explosives is unknown.

d. A vapor-air mixture within explosive concentration limits shall be avoided. Such a vapor-air mixture can be controlled by providing sufficient airflow to maintain a vapor concentration well below the lower flammability limit or by using an inert atmosphere. For inert atmosphere, positive purge shall be used to preclude oxygen leakage into the unit. If vapor concentrations approaching a flammable level are anticipated, they shall be monitored. Airflow shall be controlled to prevent dusting.

e. When heating explosives whose vapor pressure may cause undesired condensation of explosives on equipment parts, heating shall be conducted in a manner to control condensation of the explosive material. This control should be accomplished by heating the exhaust system or by circulating the air at a rate that will keep the explosives concentration below the level at which condensation could occur.

f. The proper operation of heater controls shall be verified on a regular schedule established by site management.

12.2 Pressing

a. Explosives pressing operations subject explosives to high pressures to achieve a physical change. Pressing of explosives formulations is done routinely to consolidate explosive materials into configurations required for test assemblies or weapon systems. Two common types of pressing operations commonly performed are isostatic/hydrostatic and punch and die. The following safety guidelines apply to these types of pressing operations.

12.2.1 *General*

a. Explosives pressing operations shall be conducted as remote operations.

b. The correct functioning of press interlock systems shall be verified at regular intervals.

c. Pressing mandrels, punches and dies used in explosives operations shall be examined regularly during periods of use for evidence of structural failure. Suitable nondestructive test methods shall be used to perform the examination. Site management shall establish intervals between inspections for each tooling design before committing the tooling to use. The inspection interval and updating should be based on experience with similar tooling designs and configurations. All new or modified mandrels, punches, and dies shall be inspected before their first use. At least one pressing cycle should be completed with mock explosives before proceeding to explosives.

d. Pressure controllers and indicators shall be calibrated periodically to ensure accurate control and monitoring of pressing operations.

e. Press parts that contact explosive materials shall be cleaned thoroughly to remove residual explosives before use with a different explosive formulation.

f. Temperature control for heated presses and dies shall comply with the requirements of sections 12.1.2a and 12.1.2b of this chapter.

g. All pressing assemblies shall be designed or procedural controls established to minimize or eliminate the extrusion of explosives between two mating metal surfaces during the pressing operation.

h. Operations with explosive powders should be performed in a manner that reduces the release of explosives dust and thereby reduces operator exposure and general room contamination. For operations involving large amounts of powders, local exhaust ventilation with a dust collection system should be provided. Respiratory protection to prevent inhalation of explosives dust may be required when adequate ventilation is not available.

12.2.2 ***Isostatic/Hydrostatic Pressing***

a. Before an elastomeric container or mandrel constructed of a new material is introduced into a pressing operation (where it will contact explosives), the material shall be evaluated for compatibility with the explosives.

b. All pressing vessels shall be examined for evidence of cracking or other signs of incipient structural failure at regular use intervals by suitable nondestructive test methods. Local management shall establish examination intervals.

c. Before large-scale pressings of new explosives or explosives formulations, the materials shall be evaluated for thermal stability (see scaleup procedures, Chapter VIII). "New explosives or explosives formulations" refer to those that are "new" to large-scale pressing. Stability test results shall be used to assist in establishing safe pressing conditions for the specific pressing size.

d. For isostatic pressing, procedural controls shall be established to ensure that:

(1) An acceptable vacuum can be obtained on the mandrel assembly to prevent adiabatic heating during pressing; and

(2) Air is bled out of the press before pressurization.

e. Consideration should be given to the use of fire-resistant hydraulic fluids. New fluids must be checked to ensure compatibility with the explosives used.

12.2.3 ***Punch and Die Pressing***

a. All pressing punches and dies shall be inspected visually for damage, deformation, and cleanliness before installation on a press. Any questionable condition shall be resolved before the pressing proceeds to ensure that the operation's safety is not compromised.

b. All punches, dies, and press attachment fixtures shall be designed to minimize the possibility of the punch being misaligned with the die (resulting in gouging of a die surface during pressing). Press setup procedures shall provide for operator verification of proper alignment before pressing.

c. The responsible user of a gauging section capable of performing the necessary measurements shall control punches and dies, which should be maintained in matched sets. A group other than the user should check critical punch and die dimensions before initial use and at suitable intervals thereafter. Suitable check intervals for each punch and die design should be determined as in section 12.2.1c of this chapter.

12.3 Extruding

a. Extrusion operations involve the flow of plastic explosives material under pressure into a cavity in a component of an assembly. The following general safety guidelines apply to this type of extrusion operation.

(1) Extrusion operations shall be conducted remotely. Contact extrusion may be performed only when extruding nonexplosive or mock materials or when hand-extruding small quantities with no metal-to-metal contact. Precautions shall be taken to prevent personnel from being injured by the rupture of pressurized equipment.

(2) The explosive shall be protected against extrusion beyond the tooling cavity. Precautions shall be taken to prevent foreign material from entering the explosives.

(3) New designs and significant design changes in equipment, tooling, or components shall be tested by mock explosives extrusion before actual explosives extrusion.

(4) Pressure controllers and indicators shall be calibrated periodically to ensure that proper sealing and extrusion pressures are maintained.

(5) Extrusion press parts shall be cleaned thoroughly of residual explosives remaining from the previous operation before the press is loaded with a different explosive formulation.

(6) Hand-loading of extrudable explosives is covered in section 12.8.2 of this section.

12.4 Machining

a. Explosives machining is a class of operation that involves cutting of the explosive material, often in conjunction with harder inert materials. Heat buildup from friction at the cutting surface can result in thermal initiation of the explosive

substance. Precautions must be taken to limit this buildup and to facilitate the dissipation of thermal energy.

12.4.1 ***Equipment Requirements***

a. Interlocks shall be provided for wet machining operations to ensure coolant flow before machine operation. The coolant flow shall be monitored and the equipment automatically and safely shut down if loss-of-coolant flow is detected. The interlocks shall be protected from tampering and unauthorized disabling by physical means, or supervisory control.

b. The vacuum on vacuum chuck holding fixtures shall be monitored and interlocked with the equipment for automatic shutdown of machining in the event of vacuum loss.

c. Tool path controls (stops, limits, design patterns, etc.) shall be provided to prevent the unplanned travel path of a tool or work piece. Positive means or secondary verification shall control and limit equipment speed and feed rates.

d. Pressure-relief devices should be installed on pneumatically or hydraulically powered equipment to ensure safe operation.

e. Metal chip waste from machining operations should be kept separate from explosives waste. When this is not possible, mixed explosives and metal waste should be completely segregated from unmixed waste and held for separate disposal.

f. Dull or damaged tools shall not be used. A cutting tool inspection and control program shall be established for explosives machining operations.

g. Consideration will be given to additional safety control devices (i.e., design patterns, safety templates, chip thickness sensors, tool pressure sensors, etc.), depending on the type of machining operations, size of explosives pieces, types of explosives, and other factors.

h. The "machining overtest" shall be considered a testing operation (see section 12.4.4e of this section) and shall be exempt from equipment requirements.

12.4.2 ***Contact or Remote Operations***

a. The following explosives may be contact machined if a compatible, nontoxic, noncombustible coolant is used. Explosives not listed below shall be machined remotely.

(1) Amatol

(2) Baratol

(3) Boracitol

(4) Explosive D

(5) Octol with no more than 75 percent HMX

(6) Pentolite with no more than 50 percent PETN

(7) RDX/TNT compositions with no more than 75 percent RDX. These compositions include: Composition B, Composition B-3, and 75/25 Cyclotol.

(8) TATB and TATB compositions with an inert plastic binder

(9) TNT

b. Explosive assemblies composed of any combination of explosives listed in the above section and the following nonexplosive materials may be contact machined if a compatible, nontoxic, noncombustible coolant is used. If an assembly contains an explosive not listed in the above section or a nonexplosive material not listed below, the assembly shall be machined remotely:

(1) Foamed plastics.

(2) Solid plastics.

(3) Adhesives.

(4) Amorphous graphite.

(5) Calcium sulfate casting powder.

(6) Explosives mockup.

c. On any explosive, with certain exceptions for IHE and explosives machined by fluid jet (see section 12.4.2e of this section), the following operations shall be performed remotely:

(1) Drilling of holes smaller than 5 cm in diameter, except for IHE, where drilling of holes smaller than 5 mm shall be done remotely.

(2) Coring operations (except contact operations on those explosives listed in section 12.4.2a of this chapter, when the requirements of section 12.4.5b of this chapter are met and a coolant is used).

(3) Machining of any metal/explosives interface.

(4) Machining IHE subassemblies with Hazard Class/Division 1.1 boosters installed.

(5) Dry machining, except that IHE booster pellets may be contact machined provided a dust collection system (see section 10.0 of this chapter) is used.

(6) Machining of explosives in Phase II or earlier stage of scaleup (see Chapter VIII).

d. Machining of primary explosives shall be avoided. Alternative methods, such as forming or pressing to final dimensions, should be used to achieve the desired shape.

e. IHE, PBX 9404, and LX-10 may be contact-machined by high-pressure fluid jet. The fluid-jet system pressure shall not exceed 20,000 psig. The velocity of the fluid jet shall not exceed 520 m per second (theoretical). The jet nozzle orifice diameter shall not exceed 0.010 in. The system machining fluid shall be water and shall not contain any abrasives. See section 12.15 of this section for use of low-pressure fluids.

f. Concurrent contact machining operations in the same bay should not be permitted. However, concurrent IHE contact machining is permitted when other explosives are not present.

g. Provisions shall be made to monitor remote machining operations visually. Consideration should be given to video recording and audio monitoring.

12.4.3 ***Setup and Preparation***

a. The following precautions are provided for preparation and setup before beginning the machining operation.

(1) Before setting up the explosive work piece, the equipment shall be checked for proper function and the absence of interference between stationary and moving parts.

(2) A mock explosive should be used to test the equipment function of any operation using new tooling or new part programs.

(3) The explosive component to be machined shall be inspected by radiography or other suitable nondestructive test methods for cracks, voids, and high-density foreign objects. The component shall also be checked for proper size.

(4) Caution shall be exercised during setup and adjustment to avoid pinching, dropping, crushing, or otherwise applying abnormal forces to explosives present. Special care must be given to mounting and centering a part on a vacuum chuck. Special attention must be given to the proper functioning of the vacuum system and its surface holding area.

(5) Limits on machine speed, depth of cut, and feed rate shall be set before the machine is activated.

(6) Interlocks shall be functional before the machine is used to machine explosives. They should be tested once per shift.

12.4.4 ***Operations Guidelines***

a. The minimum tool speed necessary for safe and efficient operation should be maintained. The following maximums shall apply:

(1) The relative velocity between the explosives surface and the cutting tool shall not exceed 65 m per minute;

(2) Work pieces or cutting tools shall not be rotated at speeds exceeding 525 rpm; and

(3) The feed rate of the cutting tool or work piece shall not exceed 1 mm per revolution.

b. The work piece, fixture, cutting tools, equipment, floor, troughs, drains, etc., should be cleaned frequently to prevent accumulation of explosive wastes.

(1) Approved measures should be taken to prevent rust and minimize deterioration of precision surfaces.

(2) All tools, equipment, fixtures, and parts should be cleaned before removal from the work area for storage.

c. For contact machining operations, coolant shall be used to aid in removing heat and cutting waste. Coolant should be used for remote operations when practical.

(1) Coolant should be used on explosives/inert assemblies. When the explosives portion is included in the cut, coolant shall be used for contact machining. Coolant is not required if the explosives portion of the assembly is contained (no bare explosives) and is not included in the cut, or the machining is conducted remotely.

(2) Spray mist coolant may be used during machining of the explosive-containing assemblies if the explosives portion is not included in the cut.

d. All visible explosives shall be removed from the machine before maintenance or repairs. No safeguards or interlocks shall be removed or made inoperative, except by authorized personnel.

e. Before submitting an explosive for contact machining approval, a machining overtest program shall be conducted to identify the machinability and associated hazards. These HE qualification tests should be performed in facilities set aside for these purposes.

(1) Machining overtest shall be conducted remotely.

(2) Operations performed during sample preparation may include gaging and assembly, but shall not include any contact cutting, scraping, or other material-removing operations on explosives specimens.

12.4.5 ***Specific Machining Operations***

a. Drilling

(1) Drilling operations should be set up to maximize the ease of achieving and maintaining proper alignment and to facilitate removal of explosives chips, fines, and powder.

(2) The fluting length on the drill bit shall exceed the depth of the hole to be drilled by a minimum of 1.3 cm or one hole diameter, whichever is greater.

(3) The depth of a hole shall not be extended more than 1.5 times the hole diameter (up to a maximum of 2 cm) during a single insertion of the drill into the material. After each insertion, it may be advisable to withdraw the drill completely and remove loose explosives from the cavity and drill bit before reinserting.

(4) Coolant flow (when used) shall be directed to the explosives/cutting edge interface. Drill bits with coolant channels to the tip of the drill should be used. Pulsating pressure types of coolant supplies are recommended for drills of 6-mm diameter or less to remove drill fines.

b. Coring

(1) Coolant flow (when used) shall be directed at the explosives/cutting edge interface.

(2) If the hole is not positioned to provide continuous breakout, the coring shall be accomplished incrementally. When done in increments, no more than 1.5 times the diameter of the hole shall be cored at one time. Before the maximum distance has been cored, the tool shall be totally retracted from the hole and cleaned. The hole shall be flushed with coolant.

c. Sawing

(1) The feed rate of the saw blade or work piece shall not exceed 7.5 cm per minute.

(2) For band saws, coolant flow should be directed onto the saw blade at the cutting interface, guide rollers, and the drive wheel/saw blade interface. For circular saws, the coolant flow should be directed at the explosives/cutting edge interface.

12.5 Dry Screening

a. Dry explosives often require screening for size classification or to remove extraneous objects. Magnetic separators are often advisable to remove ferrous materials that may have passed through the screens. The following guidelines shall be observed for screening operations and equipment:

(1) Operations using mechanical screens shall be performed remotely. Equipment shall be designed and operations performed to avoid subjecting explosive materials to pinching, friction, or impact.

(2) Screening small samples may be performed as a contact operation if approved by written procedures.

(3) Equipment shall be electrically bonded and grounded. Resistance-to-ground shall be 10 ohms or less and shall be inspected on a regular basis. Equipment used to transfer electrostatic-sensitive explosives to or from screens shall be conductive and electrically bonded to the screen during transfer.

(4) Operations and equipment shall be set up to minimize and control dust generation.

(5) Operating areas and equipment therein shall be cleaned frequently to avoid accumulation of explosives dust.

(6) Precautions shall be taken to prevent metals from rubbing together when the screens vibrate. Vibrating equipment shall be inspected frequently for developing cracks subject to contamination by explosives.

12.6 Blending

a. Dry blending of explosives shall be performed remotely. However, dry, hand blending of small samples may be performed as a contact operation when approved by facility management.

b. Equipment should be designed and operations performed to minimize generation and dispersion of explosives dust.

c. Equipment shall be electrically bonded to provide a continuous path-to-ground. Resistance-to-ground shall be 10 ohms or less and shall be inspected regularly. Equipment used to transfer electrostatic-sensitive explosives to or from blenders shall be conductive and electrically bonded to the blender during transfer.

12.7 Melting

a. The heat for melting explosives shall be supplied by saturated steam, hot water, or another temperature-controlled medium. The steam pressure shall be controlled in accordance with section 12.1.2b of this section.

b. Temperatures for contact melting of TNT-based explosives (except those containing PETN, e.g., pentolite) and keeping them molten shall not exceed 121°C. The temperature limit for TNT explosives containing PETN shall be 109°C.

c. Feeding of the melt kettle and the melting operation shall be controlled or regulated to prevent the formation of large chunks of explosives.

d. Alarms shall be provided on the melt temperature and on melt kettle agitation when the operation will be left unattended. Alarms shall sound if the temperature exceeds the specifications of section 12.7b above, or if agitation ceases.

e. Wherever possible, valves, piping, and threaded bolts and fasteners should be eliminated from melted explosives handling systems.

f. Provisions should be made for emergency emptying of melt kettles in the event of temperature control problems or power failures.

g. Melt kettles shall be constructed with corrosion-resistant materials. Construction shall not contain blind holes, threads, or cracks in areas exposed to melted explosives. Welds shall be inspected and found free of cracks and porosity.

12.8 Assembly and Disassembly

a. Hand tools and electrical and pneumatic tools that may subject the explosives to abnormal frictional forces, pinching, or excessive pressure, or cause significant deformation, shall not be used during assembly or disassembly. However, they may be used on nonexplosive components.

12.8.1 ***Assembly Operations***

a. During assembly operations, the operator should be alert for mismated parts and misaligned components. Hard surfaces that will contact explosives shall be precisely machined to mate with the explosives, lined with cushioning material, or otherwise configured to keep sharp corners or projections from being forced into explosives.

12.8.2 ***Loading Assemblies with Plastic or Extrudable Explosives***

a. The workability and plasticity of plastic and extrudable explosives improves with increased temperature. Plastic explosive Compositions C-3 and C-4 may be softened by warming to between 21°C and 38°C before working. Extrudable explosives LX-13 and extex should be kept as cool as practical to prevent premature curing.

b. Contamination of these explosives with abrasive or foreign substances shall be avoided.

c. The assembly shall be loaded with small increments of explosives and may be tamped with suitable nonmetallic tools to eliminate air voids.

12.8.3 ***Disassembly Operations***

a. Before beginning disassembly, the device's condition shall be assessed to determine if it can be safely handled.

b. Disassembly operations shall be planned before actual disassembly. Possible problem areas caused by method of construction or physical condition shall be considered. A safety procedure for each unique disassembly shall be written and reviewed.

c. If disassembly would normally cause release of the pressure or if there is a credible hazard of the pressure causing components to fly apart, before beginning disassembly, pressurized units shall be thoroughly depressurized.

d. If approved for use, compressed air shall be applied cautiously during disassembly to avoid causing to fly apart. This may require remote operation. Use hydraulic pressure if possible.

12.8.4 ***Personnel Protection for Disassembly Operations***

a. Operators and all other personnel shall be provided complete protection from disassembly operations involving conditions known or expected to require the use of abnormal force. Such operations require either remote operation or the use of an operational shield. The

shielding shall be designed to protect personnel at other operations or locations from blast and missiles arising from a possible explosion.

b. When disassembly requires that the operator be protected by an operational shield, disassembly shall be defined as complete separation (threads or other connections) of component parts. For example, parts shall not be loosened while the operator is properly protected and then separated without the same protection.

12.9 Inspection

a. This section deals with the following types of explosives inspection operations:

(1) Inspecting incoming explosives raw materials and pressed explosive billets for foreign bodies or cracks that could cause operating or safety problems in processing operations; and

(2) Measuring physical parameters of explosive pieces and assemblies.

b. To enhance the safety of process operations, positive steps shall be taken to assure the proper identification of explosives used and to prevent foreign material from entering the operation via the explosives raw materials or via materials in process (i.e., pressed explosive billets). Some of the means by which this can be accomplished include:

(1) Screening.

(2) Visual inspection.

(3) Magnetic separation.

(4) Radiographic inspection.

(5) Chemical analysis.

c. The following principles shall be followed in the design and operation of explosives inspection equipment.

(1) Pinch points shall be eliminated or steps taken to preclude explosives contamination of pinch points.

(2) Threaded fasteners or threads of measuring equipment shall be protected from explosives contamination. Care shall be taken to prevent parts of the measuring or handling equipment from becoming loose and getting into the explosives.

(3) Inspection fixtures shall be designed to secure the explosives piece or assembly securely to prevent toppling, rolling, or dropping during measurement operations. This is especially critical if the explosives assembly is in motion (i.e., spinning, vibrating, etc.) during measurement.

12.10 Synthesis

a. Synthesis and other chemical processing of new explosives compounds are ongoing activities at DOE weapons facilities. Synthesis operations are conducted both on laboratory and pilot scales. The Explosives Development Committee (EDC, Chapter VIII) will approve new operations and materials. In the laboratory, the new material will initially be prepared on a small scale and characterized as to sensitivity, physical, and explosive properties. Also, the laboratory will develop processing techniques for the material. If laboratory studies determine that the explosive is of continuing interest, it may be advanced to the Pilot Plant where processing techniques will be refined and scaled up. The Pilot Plant will produce sufficient material for larger-scale physical, explosive, and sensitivity characterizations.

12.10.1 *Laboratory-Scale Synthesis*

a. Before initiation of work, the professional staff member who is directing or conducting the synthesis shall analyze each explosives or potential explosives experiment for the type and magnitude of hazards. This staff member shall be responsible for planning the proper selection of conditions, quantity of explosives, and safety devices to be employed.

b. Experiments should be designed to minimize the amount of explosives involved and to use the mildest conditions that will yield the desired information.

c. New explosives materials shall be afforded extra protection against impact, pinching, friction, pressure, sparks, contamination, and deterioration. If it is necessary to subject explosives to any of these conditions, the operation shall be conducted remotely or adequate personnel shielding shall be provided.

12.10.2 *Pilot- or Processing-Scale Synthesis*

a. When operations are conducted using flammable or toxic liquids or gases, local ventilation shall be provided to prevent hazardous vapor concentrations from forming in the work area.

b. Alarms should be provided for coolant flow to the reactor, for reaction vessel agitation, and for reactor temperature. These alarms should be energized whenever coolant supply or agitation is critical to prevent a runaway reaction. When agitation is critical, the reactor should be

equipped with at least two sources of power to maintain agitation in the event of failure. For example, a reactor might employ an air or inert gas bubble tube as a backup for a mechanical agitator.

c. The reaction vessel should be equipped with an emergency system. Upon activation, the emergency system will automatically cool the vessel or will open or close a vessel dump valve as required by the process. Contact operations should be conducted with a means to activate the emergency system manually.

d. The building exhaust ventilation system shall be operating during all synthesis operations involving flammable liquids.

e. An alarm or monitor should be provided for the critical exhaust ventilation system to warn operating personnel if airflow rates drop below a predetermined level.

f. Emergency plans shall be established for the synthesis area, specifying action to be taken in the event an alarm sounds.

g. Before operations begin, all equipment shall be set up and checked for proper function. Now or infrequently used equipment shall be tested in a "dry run" before being used with any hazardous material.

h. All explosives synthesis process equipment shall be maintained routinely. Equipment with defects that could affect safe operations shall be tagged to prevent its use until repairs are completed.

i. Before starting any process operation, the transfer lines to be used should be properly labeled and their function specified in the operating procedure.

j. Transfer hoses and portable equipment not involved in the process shall be removed from the work area and stored in their proper places.

k. All control valves shall be correctly identified according to function.

l. Safety equipment and clothing shall be worn as defined in operating procedures.

m. Agitator blades on reactors and mixers shall be inspected regularly for proper clearance to ensure that there is no pinch point or metal-to-metal contact. Local facility management shall set up and approve the inspection schedule.

n. Explosives warning signs shall be conspicuously displayed on any processing vessel in which explosive materials are to be left overnight.

o. Any vessel that can be sealed and that can operate above atmospheric pressure shall be equipped with overpressure protection.

p. All closed vessels should be purged with inert gas before flammable liquids are introduced.

q. Inert gas pressure should be used to transfer flammable liquids when gravity flow or pumping is not practical.

12.11 Formulation

a. Formulation operations considered in this section involve combining compounds or mixtures when one or more of the ingredients are explosive. Combining ingredients is commonly accomplished at DOE explosives handling facilities to obtain some desired physical property, combination of properties, or reaction parameters.

12.11.1 *General*

a. Explosives may be loaded into mixers, mills, and deaerators as an operator-attended, contact operation. However, the starting, operating, and stopping of such equipment with explosives present shall be accomplished remotely. As an exception, mixing-type operations involving a low energy transfer may be allowed as a contact operation (e.g., slurry coating and melt agitation).

b. Equipment used for explosives formulation shall be checked for proper operation before adding explosives. Equipment shall be examined for proper clearances and for metal-to-metal rubbing of moving parts with the potential to contact explosives. Bearings should be sealed to preclude explosives contamination.

c. Fast-action deluge systems shall be considered for equipment (e.g., mixers, mills, and deaerators) used for easily ignitable explosives formulations.

d. Hot water, cold water, or steam, can be applied to mixers and mills. Heating fluid temperatures shall not exceed known safe operating temperatures for the explosives involved. When roll milling, allowance shall also be made for viscous shear heating of the explosives in process. Heated systems shall comply with the requirements of sections 12.1.2a and 12.1.2b of this section.

12.11.2 *Mixing*

a. Mixer seals and gaskets shall be checked on a regular schedule and cleaned or replaced as required.

b. Checks should be made to ensure that maximum particle sizes of ingredients or hard agglomerates of proposed mixes are less than the blade-to-blade or blade-to-bowl clearances.

c. Initial cleaning with solvents used for dissolving or suspending the explosives residues shall be done remotely (except for melt-mix or slurry coating vessels).

d. Explosive powders and plastic-bonded explosives formulations may be mixed wet in a contact operation. This can be accomplished if the wet mixture cannot be initiated with energy sources available and the viscosity is kept low and the possibility of isolated portions of the mix becoming dry is precluded.

12.11.3 ***Ball or Jar Milling***

a. Balls that are porous or contain cavities shall not be permitted in mills for grinding explosives.

b. Grinding media contaminated with explosives slurry shall be protected from excessive impact when emptying of the mill.

c. After grinding, a careful inspection shall be made to ensure that the explosive is free of grinding media. Dispose of any explosives contaminated with broken media.

d. After separating the explosive, the grinding media shall be thoroughly cleaned and inspected before reuse or disposal.

12.11.4 ***Roll Milling***

a. Positive stops should be installed on roll mills to prevent rolls from rubbing against each other.

b. Before starting a milling operation on a roll mill, the contact of the scraper blade with the roll should be adjusted to the minimum pressure necessary to perform the operation.

c. Roll gaps should be set as wide as possible while still allowing adequate working of the material. The minimum gap setting shall be 0.1 mm.

d. Roll rpm should be held at the minimum required to process the material adequately.

e. All roll mills that may be contact operated (e.g., with nonexplosive materials) shall be equipped with emergency stop devices (breaker bar, or chain) within easy reach of the operator.

12.12 Concurrent Contact Operations

a. The preferred setup for explosives operations is to perform each operation in a separate location to preclude any adverse operation interaction. Because such an arrangement is frequently impractical, concurrent operations may be permitted if the following conditions exist:

(1) Potential equipment-operator interactions between the two operations have been analyzed and the risk is not appreciably greater than that for both operations considered separately.

(2) Explosive materials in either operation are not exposed to stress conditions such as elevated temperature (melting or heat conditioning), elevated pressures (pressing or extruding), or deformation/shear (machining or cutting).

(3) Mixing of materials in the concurrent operations will not create compatibility problems.

(4) Each operator is aware at all times of concurrent operations in his or her area.

12.13 Contamination Prevention

a. Precautions shall be taken to avoid mutual contamination when two or more incompatible explosives or materials are handled on a single line or within one building or room. This includes vacuum systems and explosives scrap collection. Inadvertent mixing of incompatible explosives materials can be hazardous not only to manufacturing facilities and personnel but also to the user if such materials are loaded into explosives devices.

b. When two or more explosives are used in a line or within a building and mixing is not intended, the materials shall be segregated in separate locations. Containers shall be clearly marked with the weight and contents identified. Care shall be exercised to properly segregate material in service magazines and in operating buildings.

c. When a different explosive is to be used in process equipment, the equipment shall be thoroughly cleaned, and excess explosive from the previous job should be removed from the bay. This eliminates the hazards caused by mixing materials.

d. In any explosives operation, permanent service lines shall be labeled as to their contents. Valves and switches on service lines whose operation can result in a hazardous situation shall be labeled as to their function.

12.14 Hand-Cutting and Finishing Operations

a. Hand-cutting finishing, which may include cutting, trimming, coring, and lapping (surface polishing) explosive materials shall be performed using the mildest energy input that will accomplish the task safely and efficiently. The facility EDC shall review and approve the safety of hand-cutting and finishing operations, which shall then be incorporated into an operating procedure before starting the operation.

12.15 Use of Low-Pressure Fluids

a. Low-pressure fluids (liquid pressure less than 1,500 psig) may be handled as in contact operations to aid explosives dissolution, rinsing, system flushing and similar operations under the following conditions:

(1) The fluid system shall have a pressure relief device installed to prevent system overpressurization.

(2) Low-pressure fluid operations may be used with those explosives whose impact sensitivity is less than PETN. Such operations may be used on other explosives only after analyzing the energies involved.

(3) Solvents shall be compatible with the explosive material. Controls for their use shall be specified in operating procedures.

(4) For use of pressures above 1,500 psig, see section 12.4.2e of this chapter.

13.0 TESTING

13.1 General

a. This section covers the following types of testing operations.

(1) Explosives test shots, gun firings (both small arms and large caliber), and environmental, physical-property, and sensitivity testing of explosives specimens.

(2) Explosives-related experiments or tests for which the explosive material is used to provide desired results such as a seismic yield, overpressure effects, pulse energy, or other special applications.

13.2 Test Planning

13.2.1 *Hazards Analysis*

a. Proposed testing programs shall be examined for all foreseeable hazards involved in the test. This shall be done with knowledge of the construction and operation of all standard and nonstandard equipment to be used, as well as the type of explosives involved.

b. Tests that are unique in their application or pose obvious hazards shall adhere to the requirements contained in Chapter VII, section 2.1.

c. Large-scale tests with the potential to propel missiles off Government land shall receive a formal risk analysis of the worst-case conditions for each test type. Such analysis shall address the probability and potential severity of hazards with respect to injury and property damage.

13.2.2 *Firing Areas*

a. A secured firing area (danger zone) shall be established for each test to protect personnel from hazardous blast overpressure, firebrands, fragments, or projectiles from an explosives shot or gun firing. The danger zone can be determined by the application of the principles outlined in DoD 6055.9-STD.

b. Selected firing areas shall minimize the potential for secondary fires and adverse effects to the environment.

13.3 Test Firing

13.3.1 *General Range Standards*

a. Each DOE explosives test site shall establish procedures to ensure that site personnel and transients are not exposed to firebrands, fragments, or

excessive blast overpressure from a test shot. In establishing these procedures, the following guidelines shall be considered.

b. During testing operations, personnel access to each test site shall be controlled. Unattended roadblocks, gates or doors used to prevent personnel from entering the danger zone during a test should be interlocked or locked with specially controlled keys.

c. Before test firing, all firing site personnel and visitors shall be accounted for and in a safe place.

d. A visual inspection of the danger zone shall be performed immediately before each test shot or series of shots as applicable, to ensure that no transients are present.

e. The danger zone shall be free of service personnel (e.g., telephone repairmen, surveyors, or road maintenance crews, etc.) during test operations. The control point shall notify service personnel of the specific requirements under which they may safely work in the area when testing is not in progress. In addition, the control point shall notify firing site personnel of the presence and location of service personnel in their areas.

f. Clearance for a test or test series shall be coordinated with all test sites and other areas that could be affected. A warning shall be provided to every affected area immediately before each firing.

g. Detonation of very large explosive shots, numerous smaller shots, or gun firings may result in hearing damage and may exceed the DOE allowable limits for impulse noise. Perform a noise evaluation of these activities to ensure that adequate hearing protection is provided to those involved.

h. During test operations, all personnel assigned to the test area shall be continuously alert for movement of personnel, vehicles, and aircraft.

i. Test firings often create hazardous conditions for aircraft operating in the airspace near the danger zone. If this airspace is subject to air traffic, precautions shall be taken to ensure that the airspace is clear of traffic at the time of firing.

j. Each firing site shall establish personnel limits based on the number of people actually needed to conduct an operation and the number of casuals that should be present. The responsible person at the firing site shall enforce these personnel limits.

k. Testing of explosives can result in personnel exposure to toxic decomposition products such as carbon monoxide, hydrogen chloride, hydrogen fluoride, hydrogen cyanide, and nitrogen oxides. It is good practice to allow the detonation cloud to disperse before leaving protective bunkers. Fragment-danger-zone distances are normally adequate to allow cloud dispersal and protect outside personnel from excessive exposure.

l. For testing that can result in abnormally long hazardous conditions following the test, the procedure shall require a suitable waiting period before personnel leave their shelter or safe haven area.

13.3.2 ***Test Setup***

a. When and where possible, test setup work should be done before receipt of explosives. Such work includes the following:

(1) Firing site safety devices (at both the bunker and remote from the firing bunker) shall be checked at regular intervals. Such safety devices include warning lights, door and gate firing circuit interlocks, emergency firing circuit cutoff switches, and grounding.

(2) All firing pad and shot stand setup work that requires power tools or other potential spark-producing devices should be completed. The firing pad shall be cleared of all unnecessary gear. Special precautions and procedures will be developed and implemented if power tools or other spark-producing devices are needed after explosives are delivered to the firing pad.

(3) If a special structure is required, as much work as possible should be accomplished on the structure, including assembly of all materials.

(4) When possible, all diagnostic equipment shall be set up, checked, and tested in a dry run.

13.3.3 ***Pin Switches and Other Non-initiating Circuits***

a. Whenever pin switches and other non-initiating circuits are checked (such as for charging current or leakage) and are in contact with or in close proximity to explosives, the check should be performed remotely. Other non-initiating electrical circuits include strain gauges, pressure transducers, thermocouples, etc., that may be affixed to or close to the explosives within an assembly. A continuity-only (resistance) check may be accomplished as a contact operation with an

electrical instrument approved for use with the particular explosive device. When low-firing-current actuators are involved, it may be advisable to conduct these tests remotely (see section 13.8 of this section).

13.3.4 ***Lightning Storms***

a. All operations at open, test-firing areas shall be discontinued during lightning storms when explosives are present. Completion of a test after receiving a lightning alert may be allowed only if test preparation has progressed to the point that discontinuing testing represents a greater personnel exposure than completing testing.

13.3.5 ***Low-Energy Electroexplosive Devices***

a. When using hot-wire or low-energy EEDs for a test firing, the following apply:

(1) Procedures shall be established to ensure that RF, FM, and television transmitters with sufficient output energy to initiate an EED at the test site are either restricted to a safe distance from the site or not operated. Table II-2, and Table II-3 specify minimum safe distances for several types of transmitters at several output power levels.

(2) Blasting caps and other low-firing-current igniters or detonators shall be kept separate from explosives at all times, except during actual test charge assembly and setup.

(3) At all times wiring systems for the explosive charge and any low-firing-current initiators shall be kept insulated from all sources of extraneous current unless the weapon components have an exposed electrical ground by design. Connections made using weapon wiring connectors or cables are acceptable without further modification. Shunts shall be left on low-energy initiators or lead wires until connections are made. Connections shall be taped or otherwise insulated.

(4) Test units containing low-firing-current actuators or detonators shall be clearly marked. No contact operations involving electrical testing shall be permitted on this type of unit unless an electrical meter for the specific application is used.

Table II-1. Minimum Safe Distances Between RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distances (feet)	
	Commercial AM broadcast transmitters	HF transmitters other than AM broadcast
100	750	750
500	750	1,700
1,000	750	2,400
4,000	750	4,800
5,000	850	5,500
10,000	1,300	7,600
25,000	2,000	12,000
50,000[a]	2,800	17,000
100,000	3,900	24,000
500,000[b]	8,800	55,000

[a] Present maximum power of U.S. broadcast transmitters in commercial AM Broadcast Frequency Range (0.535 to 1.605 MHz).
[b] Present maximum for International Broadcast.

Table II-2. Minimum Safe Distances between TV and FM Broadcasting Transmitters and Electric Blasting Operations

Effective radiative power (watts)	Minimum safe distances (feet)		
	Channels 2-6 and FM	Channels 7-13	UHF
Up to 1,000	1,000	750	600
10,000	1,800	1,300	600
100,000[a]	3,200	2,300	1,100
316,000[b]	4,300	3,000	1,450
1,000,000	5,800	4,000	2,000
5,000,000[c]	9,000	6,200	3,500
10,000,000	10,200	7,400	6,000
100,000,000	-----	-----	-----

[a] Present maximum power, Channel 2 to 6 and FM.
[b] Present maximum power, Channel 7 to 13.
[c] Present maximum power, Channel 14 to 83.

Table II-3. Minimum Safe Distances Between Mobile RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distances (feet)				
	MF[a]	HF[a]	VHF(1)[a]	VHF(2)[a]	UHF[a]
5[b]	33	105	82	27	18
10	46	148	116	38	25
50	102	331	259	85	55
100	144	468	366	120	78
180[c]	193	627	491	161	104
250	228	739	579	190	123
500[d]	322	1,045	818	268	174
600[e]	353	1,145	897	294	190
1,000[f]	455	1,478	1,157	379	245
10,000[g]	1,438	4,673	3,659	1,198	775

[a]

MF	1.6 to 3.4 MHz	Industrial
HF	28 to 29.7 MHz	Amateur
VHF(1)	35 to 44 MHz	Public Use
	50 to 54 MHz	Amateur
VHF(2)	144 to 148 MHz	Amateur
	150.8 to 161.6 MHz	Public Use
UHF	450 to 460 MHz	Public Use

[b] Citizens band radio (walkie-talkie), 26.96 to 27.23 MHz use the HF distances. Cellular telephones: minimum safe distance; 10 ft (HERO calculation).

[c] Maximum power for 2-way mobile units in VHF, 150.8 to 161.6 MHz range, and for 2-way mobile and fixed-station units in UHF, 450 to 460 MHz range.

[d] Maximum power for major VHF 2-way mobile and fixed-station units in 35 to 44 MHz range.

[e] Maximum power for 2-way fixed-station units in VHF, 150.8 to 161.6 MHz range.

[f] Maximum power for amateur radio mobile units.

[g] Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

13.3.6 *Explosives Storage in Firing Areas*

a. Explosives or ammunition storage at a firing area shall be located such that ignition, explosion, or detonation is improbable if a fire, unplanned explosion, or detonation occurs in the area.

b. Tests that require storage of explosives or ammunition at the firing site beyond a day's event shall conform to the requirements of section 17.0 of this chapter.

13.3.7 ***Warning Signals***

a. Each DOE explosives testing facility shall use standard audible signals to warn personnel of any impending firing in a test area. Each facility shall establish signals, which facility management shall approve.

13.3.8 ***Grass Fires***

a. Before conducting a test shot at an outside firing pad, an evaluation shall be made to determine the need to control grass fires that the test may initiate.

13.3.9 ***Firing Leads***

a. All detonator lead wires shall be electrically insulated. During setup on the firing point, firing leads or cables of low-energy detonators for explosive assemblies shall be kept properly shorted.

13.3.10 ***Unattended Test Assemblies***

a. When necessary, a test assembly may be left unattended on the firing pad during off-shift hours under the following minimum conditions:

(1) If explosives are present, appropriate safety warning signs shall be displayed at all entrances to the firing pad.

(2) Protective services and fire department personnel shall be notified of the explosives location. This location must be in a controlled-access or secured area.

(3) If low-energy detonators are present on the assembly, their leads or cables shall be shorted.

13.3.11 ***Post-firing Controls***

a. If the firing appears to be normal, test personnel shall remain in the protective shelter for a suitable waiting period. The test procedure shall specify the waiting period, which shall be sufficient to assure adequate dissipation of smoke and dust. In some cases, developing and analyzing the diagnostic film for misfires may be helpful.

b. During the waiting period, all power to the firing units shall be turned off or disconnected. Whenever possible, detonator cables should be disconnected from the firing units and shunted and grounded, and the firing unit capacitor grounded.

c. After the waiting period, one qualified person shall inspect the firing pad in person or by remote TV to determine the results of the shot before other personnel leave the shelter.

d. If the inspection confirms that safe conditions exist, the lead person shall signal "all clear."

e. When a partial detonation or a test misfire occurs or is suspected, the firing area shall be inspected for unreacted explosives after the minimum waiting period (see section 13.7 of this chapter).

f. Recovered explosives from a destructive test shall be placed in an explosives storage magazine as Storage Compatibility Group L unless a documented analysis determines that the explosives do not present a special risk.

13.3.12 ***Contamination of Firing Areas***

a. Test firing areas are subject to explosives contamination from incomplete or failed detonations when the explosives are subjected to varying forms of energy input. Although most of this contamination will be cleaned up in the post-shot inspection, the following steps shall be taken to reduce the hazards from residual explosives contamination:

(1) A contamination zone for each firing area shall be established and permanently annotated on facility site plans.

(2) Personnel access to explosives-contaminated areas shall be controlled.

(3) Service personnel shall not work in the area without the permission of testing-area management and only when supervised by a management-approved person.

13.3.13 ***Test Range Firing Circuit Criteria***

a. The following criteria are guidelines for the design of electrical circuits used to arm and initiate squibs, igniters, detonators and similar EEDs during test firing:

(1) Fire control circuits shall include both an ARM switch and a FIRE switch. For low-firing-current initiators, the safe mode of the arming circuit should interrupt the firing circuit and short-circuit and ground the EED terminals. Manual shorting and grounding is permitted.

(2) Each electrical ARM and FIRE circuit shall include an interlock device consisting of a safety plug or a key-operated switch to prevent inadvertent energization.

(3) The safety plug design and configuration shall be unique for its application and used to prevent unauthorized or accidental activation of a firing circuit. Key-operated switches for ARM and FIRE circuits shall be designed to lock in the safe (OFF) position when the control key is removed. Duplicate keys or safety plugs shall not be permitted in any one test area.

(4) During shot-preparation the key or safety plug for a firing site shall be in the control of the lead operator at all times.

(5) FIRE control circuits in test areas shall be documented for operational control purposes. Documentation shall include complete wiring diagrams, electrical schematics, and cable function lists. All changes or modifications to FIRE control circuits shall be reviewed for safety and approved by other appropriate departments before being incorporated into the circuits.

(6) Each FIRE control circuit shall be isolated from all other circuits. A shielded, twisted pair of wires with an outer insulating jacket or coaxial cable should be employed for each circuit.

(7) All sequential timers used in firing circuits shall be "failsafe." Failure of a component or circuit must not energize the firing circuit.

(8) Test current from the electrical instruments used to perform resistance checks shall not exceed 10 percent of the no-fire rating of the EED in the circuit.

(9) Firing circuits shall be marked clearly or otherwise distinctively identified, and shall be installed so as to prevent inadvertent energization by other circuits.

13.4 Test Firing in Tanks or Chambers

a. Small quantities of explosives may be detonated in cubicles or in pressure vessels. The following requirements apply to such vessels.

(1) The firing vessel and flanges shall be capable of withstanding and confining the effects of the explosion and properly safeguarding personnel. When new firing chambers are designed and put into service, a safety factor to their operational weight limit must be included during certification testing. This overtest load should be based on a percentage of

the operational explosives weight limit. For example, a certification test should be performed with an appropriate explosive material weighing 125 percent TNT equivalency of the intended operating limit.

(2) The firing circuit should be interlocked with the vessel access door latch so that the door must be closed and latched before the explosive can be fired.

(3) Qualified engineering personnel shall periodically inspect the vessel to ensure that its structural integrity is maintained after repeated detonations.

(4) Test firing is often conducted inside large containment vessels that allow personnel entry but provide a confined working space and limited egress. The SOP must include requirements for ventilating and evaluating the tank or chamber's atmosphere before personnel entry.

13.5 Gun Firings

a. Work, adjustment, or observation shall not be permitted on a gun while a live round is in the firing chamber. The only exception is to check azimuth and elevation.

b. Precautions shall be taken to protect personnel or equipment against hazards resulting from errors in assembly or preparation of equipment and ammunition. In particular, the following areas shall be checked.

(1) Adequate filling of hydraulic recoil mechanisms.

(2) Safe function of the firing mechanisms. (Firing mechanisms, particularly electric firing mechanisms, shall be tested before use to ensure that merely inserting a round or closing of the breech will not result in firing).

(3) Absence of obstructions in the bore.

c. Test weapons other than manually-fired small arms should be equipped for remote control of the safety and for remote cocking. The safety shall not be advanced to the fire position and the weapon shall not be cocked until all personnel are in a safe location.

d. Guns used to fire projectiles at explosives targets shall meet the following criteria.

(1) The gun shall be rigidly mounted so that that the impact area is defined and controlled.

(2) The target shall have an adequate backstop.

(3) Provision should be made to remotely move the gun, remotely remove the propellant charge, or remove the explosives from the line of fire if

the gun misfires, unless the hazardous effects of an accidental detonation of the explosive target is contained or effectively shielded from personnel.

(4) Provisions shall be made to collect and remove undetonated explosives from the chamber or area.

e. When using hydrogen gas to fire a light gas gun, the operation shall be remote while hydrogen is present in the gun pressure tanks or in the gun barrel and catch tank after firing. The hydrogen shall be purged from the entire system with inert gas and the atmosphere checked before personnel are allowed to reenter the gun bay.

13.6 Ballistic, Environmental, Physical Property and Sensitivity Testing

13.6.1 *Checkout of Dynamic Engineering Test Equipment for Explosive Assemblies*

a. To minimize the possibility of an incident during dynamic testing of explosive assemblies, load-bearing members of the test equipment or explosive assembly should be proof-tested and examined if:

(1) The test equipment is new or has undergone a design modification;

(2) Existing test equipment is to be used under unusually severe test conditions (i.e., conditions of velocity, vibration, pressure, load, etc.); or

(3) A new or modified explosive assembly is to be tested that affects the loading characteristics of the equipment.

b. Proof-testing of the explosive assembly or test equipment should be conducted before running tests involving systems with explosives.

c. At a minimum, proof-testing should consist of the following sequence of checkouts:

(1) Check out load-bearing members (lifting devices, hold-down mechanisms, fixtures, vehicle cases) to at least 125 percent of rated load using simulated loads (see section 14.4 of this chapter).

(2) “Dry run” tests of actual systems with mock materials in place of explosives and hazardous radioactive materials.

d. If a part failure occurs in either of the checkout tests in sections 13.6.1c(1) and (2), tests involving explosives or radioactive material shall be run until additional checkout tests have demonstrated that the cause of failure has been eliminated.

13.6.2 ***Testing of Explosives and Hazardous Radioactive Materials***

a. Explosives and hazardous radioactive materials (i.e., plutonium, enriched uranium, etc.) shall not be included in the same test or operation if the test or operation is not contained and involves the following:

NOTE 1: Depleted uranium and natural thorium are not considered hazardous radioactive materials for this purpose.

NOTE 2: Nuclear Explosive Operations, covered by DOE 452.2 Series Orders, current version, are exempted from this requirement.

(1) Application of high-energy stimuli (i.e., high shock, impact, or friction levels) to the explosive.

(2) Heating the explosive to within 10°C of the heating limit determined for the explosive system without hazardous radioactive materials consistent with section 12.1.1d of this chapter.

(3) Intimate contact of incompatible material with the explosive as determined by compatibility testing.

(4) Unacceptably high risk of accidental application of stimuli listed in section (1), (2), or (3) above.

13.6.3 ***Heating of Explosives Test Specimens***

a. Before heating an explosive, a thermal analysis shall be conducted and a written procedure prepared consistent with section 12.1.1 of this chapter. See section 12.1.2 of this chapter for requirements on heating equipment.

b. Contact operations on explosives specimens undergoing thermal conditioning may be permitted if:

(1) The specimen will not be subjected to excessive friction, impact, or spark stimuli during normal operations or during a credible accident scenario.

(2) The explosive involved has satisfied appropriate scaleup sensitivity and stability criteria (see Chapter VIII) and has sufficient handling history to reveal any special characteristics affecting safe use.

c. If an explosives test specimen in a contact operation is discovered to have exceeded the established heating limit for the explosive system, the test shall be terminated and the specimen cooled to ambient temperature. A procedure should be prepared and approved for the required corrective action (i.e., disassembly or disposal).

13.6.4 ***Instrumentation***

a. Instrumentation directly applied to explosives in a test specimen shall be physically disconnected, isolated, or grounded before personnel may enter the test cell. Only instrumentation channels that contain devices that limit the current below the level capable of initiating the explosive are exempt.

b. Environmental control transducer leads, not attached to the test specimen and permanently installed in an approved control system, do not need to be grounded or disconnected.

13.6.5 ***Explosives Limits***

a. Explosives specimens shall not be permitted to accumulate in a test cell beyond the quantity required to sustain the test. For short-term testing (less than one day), specimens present shall not exceed a 4-hour supply.

13.6.6 ***Drop Testing***

a. After an explosives drop test, personnel shall wait a minimum of 5 minutes before leaving the control bunker to inspect the test pad. If smoke or flame is observed at the drop test area, entry shall not be permitted until at least 30 minutes after all visual signs have disappeared.

13.7 Test Failures and Misfires

13.7.1 ***Explosives Misfire***

a. If no audible detonation is heard after once pulsing the firing circuit, the firing circuitry and detonators may be checked for continuity. This checking shall be accomplished from within the control bunker or from a protected location. If the firing circuits and detonators appear operative, one or more attempts to fire may be made.

b. If the shot still does not fire, the following precautions shall be taken:

(1) Disconnect and de-energize all electrical power sources connected to the shot.

(2) Ensure that all personnel in the danger zone are aware of the misfire and that they must remain under cover until released.

(3) Before personnel are permitted to leave the cover of the bunker, a pre-established waiting period shall be observed. A minimum 30-minute waiting period is advised.

(4) A carefully prepared review of the situation should be initiated in consultation with another knowledgeable person.

(5) After an agreement has been reached and before other personnel are permitted to leave the cover of the bunker, one qualified person should carefully approach and examine the setup to verify that it is safe.

13.7.2 *Misfire of a Remotely Fired Gun*

a. When a misfire occurs, several more attempts to fire the gun may be made. If subsequent attempts are also unsuccessful, the following precautions should be taken.

(1) Disconnect all electrical circuitry to the gun to ensure that the firing system cannot be energized.

(2) Before approaching a light-gas driven gun, ensure that it is in a safe condition by venting all pressure in the gun breech. To reduce the risk of a gas explosion if the driving gas is flammable, the gun breech shall be purged with inert gas after venting.

(3) An appropriate waiting period shall be observed before permitting personnel to approach to the gun. The waiting period shall be at least 10 minutes.

(4) When approaching the gun, if there is any indication that powder is burning, personnel shall return to a safe area and observe an additional waiting period of at least 20 minutes.

(5) The gun shall not be approached within the known recoil distance behind the breech or from the front. Approach to and work on the gun shall be from the sides.

(6) For separate loading guns (i.e., propellant charge is loaded separate from projectiles), the propellant igniter shall be disconnected from the firing mechanism and removed from the gun before any other gun operations.

(7) If possible, the powder chamber of the gun shall be checked for the presence of pressure and vented to the atmosphere before opening the chamber.

b. If an unforeseen failure situation arises (e.g., the explosive projectile is stuck in the bore), an emergency procedure shall be prepared and followed to resolve the situation.

13.8 Electrical Instruments for Use with Explosives Systems

a. (Except those covered by DOE O 452.2B, current version, *Safety of Nuclear Explosive Operations)*

13.8.1 *Classification*

a. Test instruments shall be categorized based on electrical characteristics that affect safe use with explosives systems. Specifically, the instrument categories shall be established so that each category can be safely applied to one or more of the following classes of explosives systems:

(1) low-energy or hot-wire initiators (blasting caps, actuators, squibs, etc.);

(2) high-energy initiators (EBWs, slappers, etc.); and

(3) non-initiating electrical circuits.

b. Test instruments not meeting the safety criteria may be used on an explosive system only if the activity is considered a remote operation and adequate personnel shielding or separation distance is provided.

13.8.2 *Certification*

a. Each DOE facility where electrical test instruments are used on explosives systems shall establish a formal system for reviewing and certifying these instruments. Procedures should also be established for marking instruments to show approved uses and restrictions.

b. Each individual test instrument designated for use on explosives systems shall be certified and prominently labeled with its approved use and with a warning if its use is restricted.

c. Certified instruments shall be inspected and calibrated at prescribed intervals or whenever the instrument is opened for servicing or repair. Access to internal circuitry of certified instruments shall be controlled to prevent unauthorized repairs, maintenance, or alteration.

d. Each DOE facility using electrical instruments to test explosives systems shall maintain records of all instrument types certified. These records should include type, manufacturer, model, electrical specifications, wiring diagrams, and failure mode analyses. DOE facilities management shall notify the Explosives Safety Committee chairperson in writing when new electrical instruments have been approved for use with initiating systems. The chairperson shall disseminate this information to all committee members.

13.8.3 ***Electrical Instruments for Use with Initiating Electrical Circuits***

a. Instruments in this category are used with electrical initiation circuits connected to EEDs and may be further categorized for use with either low-energy initiators or high-energy initiators. Test instruments used for this purpose shall be current-limited. Before being used on initiating circuits, each instrument wiring diagram and internal circuitry design shall be analyzed, examined, and certified for the following:

(1) The output current through resistance equivalent to that of the class's minimum resistance initiator should not exceed 1 percent and shall not exceed 10 percent of the no-fire rating for the class's most sensitive initiator. The current-limiting features of test instruments shall be internal to the instrument and shall not depend on test circuit load characteristics.

(2) The internal circuitry shall ensure isolation features that require a minimum of two independent failure modes before the specified output current can be exceeded.

(3) A comprehensive (point-to-point, if possible) wiring check should be made to ensure that the wiring corresponds to the diagram and that all components are functioning properly and within specifications.

13.8.4 ***Electrical Instruments for Use with Non-initiating Electrical Circuits***

a. Instruments in this category are used with electrical circuits connected to strain gauges, pin switches, pressure transducers, thermocouples, electrical components, etc., that are affixed to or within an assembly with explosives. These instruments shall meet the following requirements:

(1) Each specific use of the instrument shall be analyzed to ensure no credible scenario exists whereby the normal test energy from the instrument can ignite explosives charges or initiators in the test. Guidance on operational requirements is contained in sections 13.3.3 and 13.6.4 of this chapter.

(2) Where an instrument is used to make measurements on sensors directly applied to explosives, (e.g., bonded strain gauges or pin switches) the instrument shall be certified and have met the requirements of section 13.8.3 of this section.

(3) Instruments used with non-initiating electrical circuits shall be marked prominently with restrictions on use. Many of these instruments do not meet the requirements for use with initiating systems and must be marked to prevent their use on this type of circuit.

14.0 MATERIALS HANDLING

14.1 General

a. The distance that explosive materials can fall, if accidentally dropped during handling, shall be maintained at a minimum.

b. Hard surfaces and edges of equipment that could be accidentally struck by dropped consolidated explosives should be padded with cushioning mats or coverings whenever possible and needed. (Protective padding includes both sheet material on work surfaces and on equipment and approved floor coverings).

c. Explosives handling shall be permitted only in areas free of obstructions and where the walkway surfaces provide positive footing with no slipping or tripping hazards (e.g., explosives shall not be handled on snowy or icy walkways).

d. Incompatible explosives and materials shall not be handled together.

e. Detonators, actuators, EEDs, and other items normally shipped as Hazard Class/Division 1.4 explosives, should be kept in non-propagating trays or containers unless handled individually.

f. Dry explosive materials that generate dust shall be transported in closed containers.

g. Containers of explosives or explosive assemblies shall be labeled to identify contents during handling, storage, and transportation.

h. Explosives items that cannot be identified and labeled shall be stored as Hazard Class/Division, Storage Compatibility Group 1.1L. A material analysis shall be performed to identify the material before it is returned to inventory or disposed of in accordance with regulatory requirements.

i. Components or devices that contain explosives should not be labeled or marked "inert" or "dummy." Nonconforming items shall be labeled/tagged indicating that they contain explosives. New components or devices containing explosives shall not be labeled or marked "inert" or "dummy."

14.2 Manual Handling of Bare Consolidated Explosives

a. Manual handling shall be minimized as follows:

(1) One person may lift or carry up to 25 kg of explosive only if it can be securely gripped.

(2) Two people may lift or carry 50 kg of explosive only if manual lifting and handling tooling is provided.

(3) Explosive items weighing over 50 kg or that cannot be securely gripped should not be manually handled.

b. Explosives should not be carried up or down stairs except when in protective containers.

c. Operations shall be arranged to minimize the handling distance in all manual explosives handling situations.

14.3 Carts or Hand Trucks

a. Explosives that cannot be handled manually shall be moved only on suitable carts or hand trucks. Carts used to handle bare explosives shall be provided with a padded surface to support the explosives. These carts shall be equipped with either a lip, sides of sufficient height, or tiedown straps to prevent the explosives from sliding or rolling off the cart. The cart-explosive load combination shall have a center of gravity low enough to prevent tipping if the cart suddenly stops.

b. Explosives handling carts or hand trucks should be equipped with brakes. Carts containing explosives shall be positively secured (e.g., setting wheel brakes or chocking) when the cart is stationary.

14.4 Mechanical Handling Equipment

a. All mechanical handling equipment (i.e., cranes, hoists, slings, etc.) used to lift and move explosives or assemblies containing explosives shall be initially proof-tested, periodically inspected, and maintained in first-class working condition. The *DOE Hoisting and Rigging Standard* (DOE-STD-1090-current version) may be used as a guide for testing, inspection, and maintenance.

b. Equipment for vacuum lifting of consolidated explosives must comply with the following requirements:

(1) The lifting equipment shall be designed so that the explosives cannot be dislodged from the vacuum head by jerks or other irregular motions in the hoisting apparatus or bumping of other equipment.

(2) Equipment shall be designed to monitor the available vacuum and to control loss of vacuum if the power or vacuum source fails.

(3) Any handling where a loss of vacuum would allow the explosive to drop an excessive distance shall incorporate some safety device (i.e., collar, net, or strap) to prevent dropping. “Excessive distance” shall be defined as a distance greater than the minimum drop height giving drop-skid initiation for the explosive being handled. “Initiation” in the drop-skid test refers to any indication of sample decomposition. An alternative method of protection can be a cushioning surface under and over all items that may be struck by the falling explosives.

15.0 MATERIALS RECEIPT

a. The following guidelines shall apply to the inspection, receipt, and unloading of explosives materials.

15.1 Motor Vehicles

a. A competent person using an approved checklist at a designated inspection station shall carefully inspect incoming motor vehicles loaded with explosives.

(1) When an inspection reveals that an incoming tractor is in unsatisfactory condition, the tractor should be disconnected from the trailer at the inspection station and moved to a position where it will not endanger any other explosives.

(2) When inspection reveals that a trailer or its load is in an unsatisfactory condition, the trailer shall be moved to a location that, for the particular material involved, is at least inhabited-building distance for the particular material involved from inert and administration areas, hazardous locations, and the facility boundary. At this location, the unsatisfactory condition shall be corrected before the vehicle is moved to its destination within the facility. When moving from the inspection station to the isolated location, the route should be as far as possible from built-up areas and areas with high personnel concentrations.

(3) Vehicles that cannot be immediately dispatched to points where they are to be unloaded may be moved to a holding yard that shall be sited in accordance with Chapter VI, section 3.2.3.

(4) Incoming or outgoing explosives loaded trailers that cannot be exchanged directly between the carrier and DOE facilities may be moved to an interchange yard. Quantity-distance provisions do not apply if the trailers are moved expeditiously.

b. Vehicles shall not be backed up to a dock on which explosives are resting and could be damaged.

c. The receiving facility's doors should be closed while the motor vehicle is in motion or the engine is running. This requirement does not apply to vehicles equipped with spark arrestors or when no exposed explosives are present.

d. Once the vehicle is in position, the engine shall be shut off, the brakes set, and the wheels chocked.

e. After unloading, the vehicle shall be inspected for loose explosives materials. Any spilled material shall be cleaned up after the inspection. Spills involving

liquid explosives or explosives in solution shall be reported immediately to the building supervisor. Appropriate cleanup procedures shall be used.

15.2 Railcars

a. Railcars containing explosives and ammunition entering a DOE facility must be inspected. This inspection comprises the examination of the outside and underside of each car for damage such as defective brakes, couplings, wheel flanges, etc.; for unauthorized and suspicious articles; and to confirm the individual car numbers and seal numbers against bills of lading.

(1) Cars of ammunition or explosives showing a defect that could affect the facility or contents of the car should be removed to the suspect car spur for additional inspection [see Chapter VI, section 3.2.3a(2)].

(2) Cars that satisfactorily pass inspection may be considered reasonably safe, but care must be exercised in breaking car seals and opening car doors because of possible damage or shifted cargo, leaking containers, etc. Interior inspection should be conducted at the unloading point.

15.3 Damaged Shipments

a. Explosives shipments shall be inspected for damage before storage.

b. Contents of a damaged or broken container shall be removed to another container. Spilled materials shall be cleaned up before continuing with loading or unloading.

c. Any shipment received in damaged condition as a result of inadequate or improper blocking and bracing or as a result of not being loaded in accordance with DOT requirements shall not be reshipped until the damage is corrected.

16.0 TRANSPORTATION

16.1 Equipment and Operations

16.1.1 *General*

a. Qualified explosives handlers shall load and unload explosives (see Chapter V, section 3.0)

b. Explosives shipped on common carriers shall be packaged and shipped in accordance with DOT regulations.

c. Explosives containing items transported by special agents in DOE approved secure transporters are governed by DOE Orders 452.2A *Safety of Nuclear Explosives Operations* and 460.1A *Packaging and Transportation Safety*.

d. Section 161.K of *The Atomic Energy Act of 1954* as amended and Title 18 USC, Chapter 40, section 845 govern security and emergency vehicles carrying explosives in support of approved contingency plans.

e. When transferring explosives within facilities, open body vehicles (other than flat bed types) shall have sides and tailgates or rear doors that are strong and securely fastened to safely retain the explosives.

f. The cargo on partly or completely loaded vehicles (including flat bed types) shall be blocked, braced, chocked, tied down, or otherwise secured to prevent shifting during transit.

g. Precautions shall be taken to prevent the exhausts of motor vehicles from igniting explosive material. When a motor vehicle approaches within 25 ft of the doors of a structure through which a shipment is to be moved, the doors shall be kept closed until the motor has been turned off, unless the vehicle is equipped with an exhaust spark arrestor or there are no explosives exposed. Explosives packaged in DOT or onsite containers are not considered exposed.

h. No explosives shall be loaded or unloaded from a motor vehicle while the motor is running unless the motor is required to provide power to vehicle accessories used in loading and unloading operations and is equipped with an exhaust spark arrestor.

i. Onsite movements of explosives shall be in accordance with this Manual and local onsite packaging and transportation procedures. Where there is a conflict, this Manual shall take precedence.

16.1.2 ***Motor Vehicles***

a. Offsite shipments

(1) DOT regulations govern commercial motor vehicle shipments on public highways. Motor vehicle shipments from a DOE installation that meet the DOT definition of "in commerce" comply in full with the applicable portions of DOT regulations, and with state and municipal regulations, except as provided for in these regulations. A qualified inspector shall inspect and approve for compliance with an approved checklist any motor vehicle that may be loaded with explosives (Hazard Class/Division 1.1, 1.2, and 1.3) and is designated for movement over public highways. After loading, the cargo shall be inspected and approved.

(2) Before motor vehicles loaded with explosive materials leave a DOE facility, drivers shall be informed of the nature of their cargo and appropriate measures to take if the vehicle or load becomes involved in a fire.

(3) Drivers of explosive laden vehicles shall meet the pertinent requirements of 49 CFR Parts 390-397.

b. Onsite shipments

(1) All DOE vehicles used to transport explosives onsite should be equipped with the following:

(a) Appropriate Hazard/Class placards plainly visible from all directions. Placards are required for Class/Division 1.4, 1.5, 1.6 explosives when the gross weight exceeds 1000 lbs.

(b) Adequate tie-down bolts, rings, and straps to secure the explosives load.

(c) The cargo area where the explosives are loaded shall be void of any sharp projections. (Non-sparking lining is desirable when hauling explosives in transfer containers that are not DOT approved.)

(d) A quick-disconnect switch on the battery, if explosives are left loaded on the vehicle overnight.

(e) Two fully charged and serviceable fire extinguishers with a minimum rating of 2A:10BC, with one

extinguisher mounted on the outside of the vehicle. Only one extinguisher is required for the transport of Hazard Class/Division 1.4 explosives.

(f) Rear view mirrors on both sides of the vehicle.

(g) One set of chock blocks.

(2) Normal shipments of explosive materials on site shall be packaged in DOT approved container/packages or in approved onsite containers (refer to Chapter II, section 17.5 for specifics).

(3) Onsite shipments of explosive-designed systems related to experiments or tests that by their nature are not conducive to the requirements of 16.1.2b(2) shall be governed by Chapter II, section 13.2.1 of this Manual and the following:

(a) For shipping purposes, placards and labels shall reflect the appropriate Hazard Classification/ Division as assigned by the designated onsite classification authority.

(b) The appropriate authority shall review and approve the designed method of transport for the system.

(c) Drivers shall be knowledgeable of the unique aspects of the system being transported or shall be accompanied by an explosives handler qualified by training and experience to handle the system.

(4) After the EDC has determined that new or developmental explosives meet the necessary testing to establish that they are not forbidden explosives and are at the proper phase of development for the quantity of material being requested, onsite transport shall conform to section 16.1.2b(2) or 16.1.2b(3) of this section.

(5) Security patrol and response vehicles are authorized to transport only the minimum quantity of munitions needed to support approved contingency plans and to execute their security duties. Whenever possible, support munitions required for defense against hostile forces should be pre-positioned in readily accessible magazines.

(6) Security vehicles armed with a combination of up to 25 lbs net explosives weight of Hazard Class/Division 1.1 and 1.2

munitions shall be exempt from explosives quantity-distance requirements when executing approved contingency plans or security duties. Vehicles so armed will not be used for administrative purposes and will be separated from inhabited facilities and property lines by a minimum of 125 ft when temporarily out of security service. The vehicle shall be downloaded into properly sited magazines or approved facilities when parked for periods in excess of 4 hours. Operation of vehicles loaded with explosives will be restricted to onsite locations and transported explosives must be secured within the vehicle. Smoking in explosives loaded vehicles is prohibited. These vehicles shall be downloaded into properly sited magazines or approved facilities prior to repair or maintenance, except under emergency response conditions.

(7) Security force personnel shall be allowed to transport on their person Hazard Class/Division 1.1 and 1.2 munitions issued to them for personal use in the execution of approved contingency plans and security duties without regard to explosives quantity-distance requirements. Appropriate safety precautions for the ammunition handling shall be observed. Munitions shall be placed in an approved location if temporarily removed from the uniform/load bearing equipment worn to carry such items.

16.1.3 ***Railcars***

a. A railcar must not be loaded with any Hazard Class/Division 1.1 and 1.2 explosives unless it has been thoroughly inspected by a carrier employee qualified to certify that the railcar conforms to DOT regulations. After the carrier has furnished a certified car, the shipper or an authorized employee of the shipper must inspect the interior before starting to load any such car and after loading to certify that the vehicle is in proper condition. A certificate will be completed and signed where applicable. Shipments of Hazard Class/Division 1.3 explosives may be loaded in a closed car or container car in good condition (i.e., sparks cannot enter the car and the roof does not have unprotected decayed wood that constitutes a fire hazard). Wooden-floored cars must be equipped with spark shields. Such cars do not require a car certificate, but must display a placard in accordance with DOT regulations.

b. The railcar certificate, printed on strong tag board measuring 7 by 7 in. or 6 by 8 in., must be executed in triplicate. The carrier must file the original in a separate file at the forwarding station, and the

other two must be attached to the car, one to each outer side on a fixed placard board or as otherwise provided.

16.1.4 ***Materials Handling Equipment***

a. Gasoline-powered materials-handling equipment (e.g., forklifts, etc.) may be used only in areas where all explosives are properly packaged and only if equipped in the following manner.

(1) Backfire deflectors shall be the oil-bath or screen type (certain types of air cleaners will serve the purpose) and shall be attached securely on the throat of the carburetor.

(2) A tight-fitting, properly vented cap, shall be in place on the gasoline fill pipe at all times (except during refueling).

(3) A flame arrestor shall be installed in the fill pipe.

(4) If necessary, a deflector plate shall be installed to prevent any gasoline tank overflow from reaching the motor or the exhaust pipe.

(5) On gravity feed systems or on pump systems where siphoning might occur, a shutoff valve shall be installed at the fuel tank or in the feed line to permit shutting off the flow of gasoline in an emergency or a break in the fuel line or carburetor.

(6) Provisions shall be made to prevent fuel lines from rupturing due to vibration.

b. Diesel-powered equipment may be used if all the precautions for gasoline-powered equipment (as specified above) are followed.

c. Battery-powered equipment for handling explosive material shall comply with the criteria listed below.

(1) Battery-powered equipment and its use in hazardous locations shall comply with OSHA standards. All equipment shall be appropriately labeled for ready identification.

(2) Types E, EE, ES, and EX rated, battery-powered equipment are satisfactory for handling all classes of properly packaged ammunition and explosives. Types EE and ES battery-powered equipment may be used to handle packaged explosives or components in corridors or ramps connecting hazardous operations, provided the ramps and corridors are not Class I or II, Division 1, hazardous locations (NEC).

Type EE equipment is authorized for use in Class II, Division 2, Group G hazardous locations, and Type ES equipment may be authorized with facility management's approval (see NFPA 505, Powered Industrial Trucks).

(3) Only Type EX equipment is approved for use in specifically named Class I, Division 1, Group D or Class II, Division 1, Group G hazardous locations. At this time, EX equipment does not carry a dual rating and shall only be used in hazardous areas for which it is specifically rated.

16.2 General Operation Guidelines

a. Explosives-containing items transported by special agents in SSTs are governed by DOE Orders 452.2 and 460.1 series documents.

b. Drivers shall be given special training that emphasizes caution, road courtesy, and defensive driving.

c. The operator of an explosives-transport vehicle shall have proper training in the general safety precautions for explosives handling.

d. Congested areas should be avoided.

e. Road vehicles shall stop at all railroad crossings.

f. No personnel shall ride in the cargo area. Loose items (e.g., handling gear) in the cargo compartments are prohibited.

g. No smoking is allowed in or within 25 ft of any vehicle containing explosives. Matches, lighters, or other fire-, flame-, or spark-producing devices shall not be in the vehicle or carried by personnel in the vehicle.

h. The vehicle shall be subjected to regular maintenance checks.

i. Before shipment by commercial carrier, explosives materials shall be classified by testing or analogy in accordance with DOT regulations.

j. Other than when opened for inspection, containers of explosives shall not be opened or repaired on any transportation vehicle.

k. Except for emergency situations, fueling or maintenance of vehicles containing explosives is forbidden.

l. Each facility shall establish traffic rules governing the operation of explosives-transport vehicles and the operation of other onsite vehicles in the vicinity of explosives-transport vehicles.

m. Industrial trucks shall not be used in locations where high concentrations of dusts or sublimation of explosives may result in contaminated surfaces (e.g., screening buildings, pouring bays, melt-pour units, drilling bays, consolidating bays, and explosive washout facilities).

16.3 Emergency Conditions

a. Explosives should not be transported in hazardous conditions (e.g., storms, icy roads, or poor visibility), unless an emergency plan is in effect to provide instruction and guidelines while an explosives-transport vehicle is in transit. The plan should address the following issues:

(1) Parking the vehicle.

(2) Safeguarding the vehicle from other traffic.

(3) Notifying appropriate authorities of the emergency situation.

(4) Leaving the vehicle unattended.

b. A plan shall be prepared to address mechanical breakdowns. The plan shall address the following issues:

(1) Removing the vehicle from the road as far as practical.

(2) Posting emergency reflectors, signals, etc. (carrying flares on the vehicle is not permitted).

(3) Reporting the problem.

(4) Maintaining surveillance of the vehicle.

(5) If necessary, removing the vehicle load to facilitate repair of the vehicle.

c. If an explosives-carrying vehicle is involved in an accident, the following steps should be taken:

(1) Inspect the load for evidence of fire.

(2) If there is a fire, but the explosives material is not presently or imminently involved, attempt to prevent the fire from spreading to the load. The fire may be fought using the vehicle's fire extinguishers. Ensure the security of explosives items removed from the vehicle.

(3) If a fire presently or imminently involves the explosives load, evacuate all personnel to a pre-established safe distance. Block or

divert traffic from the vicinity of the accident. Evacuate potentially affected area residents.

(4) Unless the explosive cargo is imminently involved in fire, the operator is to stay with the vehicle until the cargo is properly dispositioned.

(5) Notify the fire department or fire brigade of the accident immediately and inform them of the general type and approximate quantity of explosives involved.

(6) Inform the proper authorities of the accident.

17.0 EXPLOSIVES STORAGE

17.1 Storage Magazine Facilities

a. Permanent explosives facilities shall comply fully with TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," and DOE/TIC-11268, "A Manual for the Prediction of Blast and Fragment Loading of Structures." Portable magazines should be ventilated and resistant to water, fire, and, theft. They can be made of any material that meets these guidelines. (Portable facilities that comply with 27 CFR 55.203 and 55.207 through 55.211, "Bureau of Alcohol, Tobacco and Firearms," (BATF) meet this criteria.) Portable magazines shall be sited per DoD 6055.9-STD as above ground magazines.

b. Placards shall be posted on or near each magazine door, specifying explosive and personnel limits and general safety precautions that should be observed during work in the magazine.

c. Vegetation around storage magazines should be controlled to minimize potential damage to the magazine (see Chapter VI, section 5.1).

d. At least two fire extinguishers, minimum rating 2A:10BC and winterized where necessary, should be provided and maintained for immediate use by personnel working around a magazine. These extinguishers may be located in the area or available on an explosives transportation vehicle. The purpose of these extinguishers is to fight small external fires or magazine fires that do not involve explosives.

e. Suitably rated telephone or other emergency communication equipment should be provided in magazine storage areas. All communication equipment located outdoors should be protected from the weather.

f. Temperature control

(1) In general, storage magazines should not be heated unless heating is necessary to prevent damage caused by sudden temperature changes or when dimensional changes of components are undesirable.

(2) Magazines requiring heat should be heated with steam, hot water, or electrically heated hot water. Some magazines with tight temperature controls may require both heating and air conditioning. Electrical systems with forced air through ducts may be allowed if the systems are located exterior to any explosive hazard.

(3) Heating coils shall be arranged so that explosives material cannot come into contact with the coils. They shall be equipped with covers designed to prevent storage of materials on top of the coils.

(4) Maximum and minimum temperature monitors should be provided in all heated magazines.

17.2 Storage Magazine Operations

a. Explosives items shall be properly packaged and stored in either DOT-approved manufacturers' container/packages or in specified onsite containers (see section 17.5 of this chapter).

b. Explosives may be stored on magazine shelves. The bottom of the container should not be more than 2 m off the floor, except as permitted by section 17.2c of this section.

c. Explosives and explosives containers in storage shall be positioned safely and securely. If explosives containers must be stacked, they shall be placed in stable arrays.

d. Load limits shall be established for shelving in magazines containing explosives. If overloading is possible, the loading conditions shall be posted.

e. Materials shall not be left suspended by booms, cranes, or hoists in any explosives storage facility.

f. Stored explosives should be segregated by lot designation. Stacks of explosives should be arranged so that air freely circulates to all parts of the stack. To prevent moisture accumulation, pallets or appropriate dunnage should be used to ensure that containers are not stacked directly on the magazine floor.

g. Aisles shall be wide enough to accommodate inspection, inventory, sampling, and materials handling operations of the stored explosives containers.

h. Crews shall not be permitted to work in a position that requires passing the work aisle or the position of a second crew to reach the exit. Unobstructed aisles shall be maintained to permit rapid exit of personnel.

i. Each crew working in a magazine must have their own exit route that does not interfere with exit routes for other crews.

j. Magazines shall be locked at all times except when permissible operations are in progress or opened for ventilation. Personnel shall be present while the

magazine is open for ventilation. All exit doors shall be unlocked and open when personnel are working in the magazine.

k. Each magazine shall be inventoried at least annually to determine the total weight of explosives present (to assure this weight conforms to allowable quantity-distance constraints) and to remove and destroy materials that are not properly identified or labeled.

l. The liquid level in storage containers for wet explosives shall be checked and replenished as necessary at least once a year. A log of the checks shall be maintained.

m. Empty containers, tools, conveyors, lift trucks, skids, etc., should not be stored in a magazine containing explosives.

n. Combustible materials such as excess dunnage, packing material, and boxes shall not be stored in a magazine containing explosives.

o. Flammable liquids shall not be stored or used in explosives magazines unless the liquid is an explosive, is needed as an explosives-wetting agent, or is an integral part of an explosives device.

p. Operations in and around magazines shall be prohibited when an electrical storm is in progress and minimized when it is evident that such a storm is approaching.

q. Explosives-handling operations shall not be performed when magazine entranceways are icy or do not provide adequate footing for any other reason.

r. Unless excepted, no operation in which hazardous materials are involved shall be permitted in any magazine. The following exceptions are recognized.

(1) Those operations incident to storage or removal from storage.

(2) Inspection and surveillance sampling of compatibility Group D materials, and Group C materials consisting of bulk propellants and IHE, provided that each storage container sampled is in good condition (i.e., the container is not leaking, no evidence exists of explosives contamination at the closure or of seal failure, and the closure is mechanically sound and free of excessive corrosion, etc.). Only one container of explosives shall be opened at one time in a magazine.

(3) Adding liquid to adjust the liquid composition level in which a Group D explosive is stored. (Water and alcohol mixtures may be

used). If only water is added to the explosive, the water should be distilled or deionized. Bacteria present in untreated water may produce gas during storage).

17.3 <u>Storage Review Program</u>

a. Each facility shall establish a program to review the explosive materials stored at that facility. Explosives may degrade during prolonged storage, increasing the hazards of handling or use. The following procedure is provided as an example.

(1) A storage review date should be assigned to each bulk explosive placed in storage. The storage review date should be shown on or adjacent to the identification tag or sticker attached to every container or package of explosive in storage or should be listed in the inventory records.

(2) Storage review intervals should be based, whenever possible, on stability data. A safe storage interval should be considered as that time period, at maximum anticipated storage temperature, during which an explosive material can be conservatively expected to show an acceptable level of decomposition.

(3) Facility management should designate or create a storage review committee to establish and approve storage review intervals for all explosives stored at the DOE facility. Also, the committee should prescribe for each explosive appropriate tests to evaluate the safety of handling and processing the material after it has exceeded its storage review interval. These tests may be referred to as "stability tests," although sensitivity, or other types of testing, may be included in the material evaluation program. In some cases, the review committee may simply require periodic stability testing rather than establishing a storage review interval (i.e., nitrocellulose, single- and double-base propellants, etc.).

(4) To store a new explosive, to increase (or decrease) the review interval for a previously approved material, or to use different stability test data for an explosive, the following procedure should be used:

(a) A responsible person should communicate the request to the storage review committee.

(b) If the request concerns storage of a new explosive, the individual should recommend a storage review interval and stability-evaluation testing.

(c) Supporting data should be supplied with the recommended review interval and proposed stability tests for the explosive.

(d) The storage review committee should review the request and supporting data and then prescribe a storage review interval and stability tests as appropriate.

(e) A new explosive should be assigned an interim storage review and stability test interval before Phase II scaleup (see Chapter VIII).

(f) The following general guidelines are offered to assist the storage review committee in establishing review intervals when there is insufficient stability information to predict storage life.

1 If no information is available on a new material relative to storage stability, a review interval of 90 days or less should be assigned.

2 A new formulation should be assigned a storage review interval not exceeding that of its least stable component.

3 If the compound or formulation is new to DOE but DoD agencies have extensive experience with it, the DoD information should be used conservatively.

4 For a formulation or ingredient with a manufacturer-assigned shelf life, a review interval that exceeds the recommended shelf life should not be assigned unless additional DOE tests indicate such storage is warranted.

(5) A storage review interval of up to 20 years should be permissible for an explosive if a conservative evaluation of stability data indicates that such an interval is justified.

17.4 Storage Compatibility

a. Explosives shall not be stored with materials or items that increase the risk of initiation or decomposition. Examples are mixed storage of explosives with flammable or combustible materials, acids, or corrosives.

b. Different types of explosives may be stored in the same magazine if they are compatible. Explosives shall be assigned to a storage compatibility group when they can be stored together without significantly increasing

either the probability of an accident or, for a given quantity of explosive, the magnitude of such an accident.

c. Each type of explosive shall be assigned to an appropriate storage compatibility group (A through G, L, and S) for the purpose of storage at DOE facilities. The nine groups are defined in the following sections. These definitions and Table II-4 *Storage Compatibility Mixing Chart*, are in accordance with the principles and tables in DoD 6055.9-STD, DoD *Ammunition and Explosives Safety Standards*. Table II-4 presents some examples of commonly used materials that are assigned to each storage compatibility group. This list does not enumerate all materials that may be included in each group.

(1) **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. Examples are lead azide, lead styphnate, mercury fulminate, and tetracene.

(2) **Group B**—Detonators and similar initiating devices not containing two or more independent safety features. Items containing initiating explosives that are designed to initiate or continue the functioning of an explosives train. Examples are detonators (all types, excluding EBWs and slappers), blasting caps, small arms primers, and fuzes.

(3) **Group C—**Bulk propellants, propellant charges, and devices containing propellant with or without their own means of initiation. Items that will deflagrate, explode, or detonate upon initiation. Examples are single-, double-, triple-base, and composite propellants, rocket motors (solid propellant), and ammunition with inert projectiles.

(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. This group shall include explosives and ammunition that can be expected to explode or detonate when any given item or component thereof is initiated.

(5) **Group E**—Explosives devices without their own means of initiation and with propelling charge (other than one containing a flammable or hypergolic liquid). Examples are artillery ammunition and rockets.

(6) **Group F—**Explosives devices with their own means of initiation and with or without propelling charge.

(7) **Group G**—Pyrotechnic materials and devices containing pyrotechnic materials. Examples are devices that when functioning, result in an incendiary, illumination, lachrymatory, smoke, or sound effect.

(8) **Group H**—Ammunition containing both explosives and WP or other pyrophoric material. Ammunition in this group contains fillers, which are spontaneously flammable when exposed to the atmosphere. Examples are WP, plasticized white phosphorus (PWP), or other ammunition containing pyrophoric material.

(9) **Group J—**Ammunition containing both explosives and flammable liquids or gels. Ammunition in this group contain flammable liquids or gels other than those that are spontaneously flammable when exposed to water or the atmosphere. Examples are liquid or gel filled incendiary ammunition, fuel-air explosive (FAE) devices, flammable liquid fueled missiles, and torpedoes.

(10) **Group K**—Ammunition containing both explosives and toxic chemical agents. Ammunition in this group contain chemicals specifically designed for incapacitating effects more severe than lachrymation. Examples are artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent.

(11) **Group L**—Explosives or ammunition not included in other compatibility groups which present a special risk, requiring isolation of each type. This group shall include explosives or ammunition having characteristics that do not permit storage with other similar or dissimilar materials. Examples are damaged explosives, suspect explosives, and explosives, explosive devices or containers that have undergone severe testing unless documented determination is made that these items do not present a special risk; fuel/air explosive devices, and water-activated devices. Also included are experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures and salvaged explosives until they have been established to be compatible with the original materials. Types presenting similar hazards may be stored together.

(12) **Group N**—Hazard Division 1.6 ammunition containing only extremely insensitive detonating substances (EIDS).

(13) **Group S**—Explosives, explosive devices, or ammunition presenting no significant hazard. Explosives or ammunition so designed or packed that when in storage any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder fire fighting. Examples include: explosive switches or valves and small arms ammunition.

d. Mixing of Storage Compatibility Groups may be permitted as indicated in Table II-5. Items from Storage Compatibility Groups B, C, D, E, F, G, and S may be combined in storage if the items are in approved containers and if the net quantity of explosives in the items (or in bulk) does not exceed 1,000 lb. Each article of Storage Compatibility Groups B and F shall be segregated in storage from those of other compatibility groups by means that will prevent propagation of those articles.

e. Newly synthesized compounds and mixtures shall be stored in Group L storage facilities. After more complete evaluation, the EDC shall assign those compounds or mixtures of continuing interest (see Chapter VIII, section 1.1) to the appropriate compatibility group, and stored according to the following considerations:

(1) The material's sensitivity to initiating stimuli (i.e., friction, impact, spark, shock, and thermal) is similar to that of other explosives in the group.

(2) The material's reactions and the effects of these reactions, in the event of application of initiating stimuli, are similar to other members of the group.

(3) The material is chemically compatible with other materials in the group. Sensitivity and compatibility testing is described in Chapter VIII.

f. As an alternate to Table II-4 and Table II-5, samples of explosives up to 4.4 lbs (2 kg) total, may be stored in the same cubicle if the cubicle walls are designed to prevent propagation. The material shall be stored in separate cubicles in one of the following categories:

(1) High explosives.

(2) Propellants.

(3) Detonators, actuators, and similar devices.

(4) Primary and static-sensitive explosives.

Table II-4. Storage Compatibility Groups for Explosives and Explosive-Containing Devices

Group A Initiating explosives.	
• CP (5-Cyanotetrazolpentaamine Cobalt III Perchlorate)	
• HMX (Cyclotetramethylene tetranitramine) (dry)	• PETN (Pentaerythritol tetranitrate) (dry)
• Lead azide	• RDX (Cyclotrimethylene trinitamine) (dry)
• Lead styphnate	• TATNB (Triaziodotrinitrobenzene)
• Mercury fulminate	• Tetracene
Group B Detonators and similar initiating devices.	
• MDF (mild detonating fuse) detonator assemblies	• Blasting caps
• Detonators excluding EBWs and slappers	• Pressure cartridges
• Explosive bolts	• Primers
• Fragmenting actuators	• Squibs
• Igniters	
Group C Bulk propellant, propellant charges, and devices containing propellants with or without their own means of initiation. This Group also includes some IHEs.	
• Smokeless powder	• TATB (Wet)
• Pistol and rifle powder	• LX-17
• Rocket-motor solid propellants	• PBX-9502
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 explosive substance and containing two or more effective protective features.	
• Ammonium picrate (wet)	• HMX (Cyclotetramethylene tetranitramine)
• Baratol	• HMX/wax (formulated with at least 1 percent wax)
• Black Powder	• HNS (Hexanitrostilbene)
• Boracitol	• Linear-shaped charge
• Compositions A, B, and C (all types)	• Methyl dinitorpentanoate
• Cyclotols (not to exceed a maximum of 85 percent RDX)	• Nitroguanidine
• DATB (diaminotrinitrobenzene)	• Octol
• Detasheet	• Pentolite
• Detonating cord (primacord or mild detonating fuse)	• PETN (Pentaerythritol tetranitrate) (wet)
• Bis-Dinitropropyl adipate	• PETN/extrudable binder
• Bis-Dinitropropyl glutarate	• Plastic Bonded Explosives, PBX (a Group D explosive formulated with a desensitizing plastic binder)
• Bis-Dinitropropyl maleate	
• Dinitropropane	
• Dinitropropanol	• Potassium picrate
• Dinitropropyl acrylate monomer (DNPA)	• RDX (Cyclotrimethylene trinitramine) (wet)
• Dinitropropyl acrylate polymer (PDNPA)	• TATB (Triamino trinitrobenzene)(dry)
• EBW and slapper detonators	• TATB/DATB mixtures
• Elastomeric plastic bonded explosives	• Tetryl
• Explosive D	• TNT (Trinitrotoluene)

Table II-4. Storage Compatibility Groups for Explosives and Explosive-Containing Devices (cont.)

Group E	**Explosives devices without their own means of initiation and with propelling charge.** • Artillery ammunition • Rockets (e.g., 66-mm LAW)
Group F	**Explosives devices with their own means of initiation and with or without propelling charge.**
Group G	**Pyrotechnic material and devices that produce an incendiary, illumination, lachrymatory, smoke, or sound effect.** • Smoke pots • Flares • Incendiary ammunition
Group K	**Ammunition containing both explosives and toxic chemical agents.**
Group L	**Explosives or ammunition not included in other compatibility groups that present a special risk requiring isolation of each type.** • Damaged or suspect explosives, explosive devices or containers. • Experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and some salvaged explosives.
Group N	**Hazard Division 1.6 articles containing only extremely insensitive detonating substances (EIDS).**
Group S	**Explosives and Ammunition that presents no significant hazard. Items are packaged or designed so that any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder firefighting. Examples include the following:** • Cable cutters • Cartridge actuated valves • Linear actuators (e.g., dimple, piston, bellows motors) • Safety fuze • Small arms ammunition
Materials and Systems that need not be stored or labeled as explosives unless they are near other explosives that could initiate them.	When near explosives, these materials become Group D, unless otherwise indicated. • FEFO/SOL (35 wt percent or less FEFO in ethyl acetate) • FEFO/solution • Group D explosives in inert solvents (explosive concentration not exceeding 25 wt percent) • Nitrates; treat as Group C when with other explosives • Perchlorates; treat as Group C when with other explosives • Small arms ammunition classified for shipment by DOT as ORM-D (Other Regulated Material Class D) rather than Hazard Class/Division 1.4 explosives. Normally consists of ammunition not exceeding 50 caliber for handguns and rifles and 8 gauge for shotguns.

Table II-5. Storage Compatibility Mixing Chart

Groups	A	B	C	D	E	F	G	H	J	K	L	N	S
A	X	Z											
B	Z	X	Z	Z	Z	Z	Z					X	X
C		Z	X	X	X	Z	Z					X	X
D		Z	X	X	X	Z	Z					X	X
E		Z	X	X	X	Z	Z					X	X
F		Z	Z	Z	Z	X	Z					X	X
G		Z	Z	Z	Z	Z	X					X	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	X	X					X	X
S		X	X	X	X	X	X	X	X			X	X

NOTES:
- An "x" in a block of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to the following sections.
- A "z" in a block of the above chart indicates that when warranted by operational considerations or magazine availability, and when safety is not sacrificed, these groups may be combined in storage. Combinations that violate the principles of section 17.4.0 in Chapter II require justification by an exemption.
- No mark in a block indicates that combined storage is not permitted. L compatibility group types presenting similar hazards may be stored together but not mixed with other groups.
- K compatibility group requires not only separate storage from other groups, but also may require separate storage within the group.

17.5 Containers (Onsite)

a. Explosives containers shall be designed and constructed so they will not leak and will protect their contents from excessive movement, external stimuli, contamination, or spillage during handling, transportation (including transportation to disposal sites), and storage. Container closures shall prevent spilling or leakage of contents if the container is overturned. Screw-type container closures should not be used.

b. Explosives containers should be constructed of, or lined with, nonabsorbent materials that are compatible with the explosive contents. Use of glass containers is discouraged, except for small samples, and shall be used only when the explosive reacts with other materials or when a high degree of purity is required.

c. Metal containers for materials that are potential dust producers shall be constructed without seams or rivet heads. Seams or rivet heads can provide locations for dust accumulation.

d. Containers for cast or pressed explosives pieces that are larger than 1 ft (0.3 m) at their greatest dimension or weigh more than 11 lb (5 kg) loaded should be provided with handles or some other type of handhold. If the loaded container weighs more than 110 lb (50 kg), provisions should be made to allow handling by mechanical handling equipment.

e. Containers shall be labeled with the applicable UN hazard classification code and clearly marked to identify the contents.

f. Whenever possible, explosive pellets and items containing small quantities of explosives (e.g., detonators) shall be packaged in containers constructed so the functioning of one item will not propagate to the remaining items in the container. When a nonpropagating array is not possible, the pellets or detonators shall be stored inside a closed container and shall be labeled to indicate the total weight of the explosive contents.

g. Container closures shall be the type that will not apply excessive pinching or rubbing forces to explosives during closing and opening. The closures and surfaces of container openings shall be kept clean of explosives contamination to minimize any hazard during closing and opening.

h. Explosives and ammunition in damaged containers shall not be stored in a magazine with other explosives and ammunition. Damaged containers shall be repaired, or the contents transferred to new or undamaged containers, or the container plus contents moved to a Group L storage magazine.

i. Open containers and containers with covers not securely fastened shall not be stored in magazines. Containers that have been opened shall be properly closed before being returned to storage.

17.6 Storage in Buildings Other Than Storage Magazines

17.6.1 *Packing and Shipping Buildings*

a. In buildings specifically designated for packing and shipping, explosives may be stored subject to the following rules.

(1) Incoming shipments shall be distributed as soon as practical after receipt and shall not be allowed to accumulate.

(2) Items for outgoing shipments should not be accumulated before receipt of orders covering each specific shipment.

(3) Separate rooms shall be provided for the temporary storage of explosives awaiting shipment and for their preparation for shipment (i.e., assembling, crating, marking, etc.). The rooms shall be divided by walls or separated to prevent an explosion in the preparation area from propagating to the temporary storage area.

(4) The combined total amount of explosives permitted in shipping/receiving buildings, platforms, and transportation vehicles shall be based on quantity-distance constraints. When an adequate barricade (sufficient to prevent sympathetic detonation) is in place between transportation vehicles and the adjoining building or platform, quantities on each side of the barricade may be considered individually to determine quantity-distance requirements.

(5) If required by operational necessity, explosives and pyrotechnics that are part of the work in process within the building may be stored during non-operational hours in operating buildings provided:

(a) Explosives limits are not exceeded.

(b) Containers of bulk explosives or pyrotechnics are properly secured and covered.

(c) Processing equipment, such as hoppers and pipelines, is empty.

17.6.2 ***Service Magazines***

a. The guidelines for storage magazines presented in sections 17.1 through 17.5 of this chapter shall also apply to service magazines, except as modified below:

(1) An explosives item should be stored for no longer than necessary in a service magazine (with a maximum of 180 days).

(2) Service magazine inventory should be reviewed every three months. Any material that has been in the service magazine for a period approaching 180 days and is not expected to be used immediately should be disposed of or removed to an appropriate storage magazine.

(3) When practical, explosives stored in service magazines shall be in containers. Unpackaged explosives-containing devices and unsealed bulk explosives containers may be present in a service

magazine. However, these items and unsealed containers shall be stored in a manner that renders them stable and unlikely to be dropped or spilled.

(4) Minimum/maximum temperature monitors are not normally required for service magazines.

17.6.3 ***Warehouses***

a. Hazard Class 1.4 materials (see Chapter VI, section 3.1) packaged as Hazard Class/Division 1.4, Storage Compatibility Group S, may be stored in warehouses if they are placed in segregated and specifically designated areas.

b. Articles in Hazard Class/Division 1.4 and Storage Compatibility Group S are considered inert for storage purposes and are not subject to quantity-distance requirements as long as they are stored with inert items or other Hazard Class/Division 1.4S items only. This applies only if Hazard Class/Division 1.4 and Storage Compatibility Group S articles remain in their original packaging container or are proven to be self-contained. When stored with items in a Storage Compatibility Group other than S, normal quantity-distance requirements must be observed.

17.6.4 ***Pre-positioned Storage of Security Response Munitions***

a. When required for defense against hostile forces, and in support of response and contingency plans, limited quantities of authorized response force munitions may be pre-positioned at locations other than bulk-storage magazine areas.

b. Compliance with Quantity-Distance and compatibility criteria is not required during a heightened security condition.

c. Munitions will be kept in their original shipping containers unless operational necessity dictates otherwise.

d. Personnel charged with the responsibility of overseeing storage of munitions at guard stations and contingency deployment sites shall be trained in explosives storage and transportation, as required in Chapter V of this Manual.

e. When Hazard Class/Division 1.2 is stored inside or at less than inhabited-building distance from inhabited buildings, fragment barriers will be provided. Minimally acceptable fragment barriers are: 0.25 in. (6.35 mm) of mild steel plate, one layer of sand bags, 12 in. (.3 m) of loose sand or dirt, or other equivalent protection.

18.0 DECONTAMINATION AND CLEANING

18.1 General

a. Operating procedures shall specifically cover decontamination. These procedures should cover methods, inspection, marking, control, dismantling, maintenance, final disposition, etc.

b. Hot water or steam may be used to clean or remove explosives contamination from equipment. If necessary, solvents that have been tested for and are compatible with explosives can be used. Operating procedures must specify controls for their use. When cleaning or removing explosives material from equipment, work surfaces, and floors, only clean cloth rags, paper wipes, and approved non-metallic brushes or scrapers should be used in conjunction with hot water, steam, and solvents.

c. Disposal of waste generated during decontamination shall be coordinated with site environmental/waste management personnel.

18.2 Cleaning Contaminated Equipment

a. Items to be cleaned should be positioned so that water and residue will drain directly into an approved collection system. See sections 19.0 and 20.0 of this chapter for guidance concerning waste collection and waste disposal.

b. Personal decontaminating facilities and equipment shall use personal protective equipment as required. Emergency shower and eyewash shall be provided where needed.

c. Exhaust ventilation may be required to remove toxic explosives fumes, vapors, or steam from the decontamination area.

18.3 Cleaning Screw Threads

a. To avoid the necessity of cleaning explosives from threads, explosives processing techniques shall be designed to prevent explosives from being deposited on threaded fasteners. When screw threads are required, covering or protection (i.e., RTV cement) over the exposed threads should be provided.

b. Threads should be cleaned by judicious use of approved non-metal “picks,” solvent, hot water, or steam. Soaking in solvents and applying penetrating oil may be useful.

c. After decontaminating threads of screws, bolts, pipe, etc., operator protection may still be required to facilitate safe disassembly.

18.4 Final Decontamination and Disposal of Equipment

a. If the item to be decontaminated has only smooth, flat surfaces (i.e., no cracks, seams, voids, or other places where explosive residue may be inaccessible), hot water, steam, or solvents may be employed to effect total decontamination. Any explosives contamination of concern will be visible to the unaided eye and will have dimensions (length, width, and depth).

b. If the item to be decontaminated has tight places where explosives may remain lodged following normal cleaning procedures, the item shall be subjected to final decontamination techniques that may include partial disassembly.

(1) Items undergoing final decontamination by thermal techniques shall be subjected to sustained heating at a temperature at least 60°C higher than required for decomposition of the most thermally stable explosive substance present. The item shall be kept at that temperature for a sufficient period of time to ensure that all parts have reached the temperature and all explosives material is decomposed. Thermal decomposition is usually accomplished by placing the items to be decontaminated in a high-temperature sustained fire (see TB 700-4, *Decontamination of Facilities and Equipment*). This operation shall be conducted remotely or with operator protection.

(2) Final decontamination also may be accomplished by immersing the item in a chemical cleaning agent. The period of immersion shall be sufficient to ensure that all explosive material is chemically decomposed. The chemical cleaning agent shall be one that the Department of the Army TM 9-1300-214 (*Military Explosives*) has approved for use. Chemical cleaning agents for decontamination or destruction of explosives should not be used for more than about 1 oz. (or about 28 g) of explosives. Reference U.S. Department of the Army TM 9-1300-214 for decontaminating chemicals for explosives and for color tests for identification of energetic materials.

(3) Before subjecting an item to final decontamination by thermal or chemical techniques, as much explosive as possible shall have been removed by approved means (hot water, steam, and approved solvents in conjunction with cloth or paper wipes and non-metallic brushes or scrapers).

18.5 Inspection

a. After decontamination procedures are complete and before transfer to a nonexplosive area, the item shall be inspected. The degree of decontamination shall be determined/documented and the item shall be labeled to indicate its decontaminated state. Representatives of at least two departments, such as operations or safety, should accomplish the inspection.

18.6 Identification and Control of Decontaminated Items

a. Decontaminated items shall be marked to indicate the degree of decontamination and stored separately from non-contaminated items until final disposition is made.

b. Degrees of decontamination shall be designated and all items shall be tagged and/or marked with this designation.

c. Guidelines for establishing a system to designation degrees of decontamination are provided below.

(1) **X**—A single X indicates that the facilities or equipment have been partially decontaminated. Additional decontamination processes are required before facilities or equipment are moved or any maintenance, repair, etc., is performed. The X rating would apply to facilities, rooms, bays, or equipment that have been subjected to routine decontamination performed by an operator at the close of the workday.

(2) **XXX**—Three Xs indicate the equipment or facilities have been examined and decontaminated by approved procedures; no contamination can be detected by appropriate instrumentation, test solutions, or by visual inspection on easily accessible surfaces or in concealed housings, etc., and are considered safe for the intended use. Items decontaminated to this degree cannot be furnished to qualified DOE, DoD, or industry users or be in direct contact with an open flame (cutting, welding, high temperature heating devices), or operations which generate extreme heat, such as drilling and machining unless the following two conditions are met:

(a) It has been determined that decontamination to the XXXXX level will destroy the item's usefulness.

(b) Decontamination to a degree less than XXXXX in combination with administrative and technical safeguards will eliminate risk of injury. As a minimum, an approved SOP setting forth the specific operational limitations, precautions, and monitoring necessary to assure safety will be available and decontamination will be performed under the direction of the inspectors who will certify decontamination.

(3) **XXXXX**—Five Xs indicate the equipment or facilities are completely decontaminated, hazard-free, and may be released for general use or to the general public.

(4) **0**—A zero indicates the item, although located in a contaminated area, was never directly exposed to contamination.

d. Reference U.S. Department of the Army TB 700-4, "Decontamination of Facilities and Equipment" for decontamination methods and marking.

18.7 Decontamination of Real Estate

a. For decontamination of real estate reference DoD 6055.9-STD.

18.8 Decontamination and Cleaning References

a. In addition to this Manual, the following are reference sources for decontamination and cleaning.

(1) DoD 6055.9-STD, "Department of Defense Ammunition and Explosives Safety Standard," Assistant Secretary of Defense (Force Management and Personnel), Chairman Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(2) Department of the Army Technical Bulletin TB 700-4, "Decontamination of Facilities and Equipment," Army AG Publications Center, St. Louis, MO.

(3) Department of the Army Technical Manual TM 9-1300-214, "Military Explosives," Army AG Publications Center, St. Louis, MO.

19.0 WASTE COLLECTION

19.1 General

a. Provision shall be made to remove explosives waste from areas where explosive waste is generated. Removal of explosives waste may be accomplished by collecting dust/fines or chips in a wet or dry vacuum system or a slurry of water or nonflammable solvent, or by collecting solid waste in receptacles (see also Chapter II, sections 9.0, 10.0, and 11.0).

b. Explosives waste shall be collected and maintained separately from conventional waste.

c. Mixing of incompatible explosive waste shall be avoided. Receptacles shall be clearly labeled to indicate the type of waste permissible.

19.2 Solid Wastes

a. Areas where solid explosives wastes are not removed by vacuum or liquid systems shall be equipped with a seamless or lined receptacle to collect explosives wastes. The receptacle should never be more than half full.

b. Explosives waste shall be removed from the collection point on a regularly and frequently enough to keep aggregate levels within explosive weight limits.

c. Rubbish not contaminated by explosives or containing noncombustible materials shall not be placed in an explosives waste receptacle.

d. Explosives-contaminated rubbish shall be placed in separate waste containers and segregated as combustibles and noncombustibles.

e. Before being transported, explosives waste shall be packaged to prevent spills, leaks, or exposure to initiation stimuli. Incompatible materials shall not be packaged together. All packages of explosives waste shall be labeled clearly to indicate the nature and approximate quantity of contents.

19.3 Vacuum Collection of Explosives Dusts

a. Explosives dusts should be collected by a vacuum system, preferably the wet type. Dust in a wet vacuum should be maintained in wet form using a wetting agent that is kept close to the point of origin and kept wet in the collection system until removed for disposal. Water-soluble explosives such as Explosive D should be collected in a dry vacuum system.

b. Storage compatibility Group A explosives may be collected by a wet vacuum system, provided they are maintained in a wet form using a wetting agent that is kept close to the point of intake. Use of a vacuum system to collect these more

sensitive materials should be confined to operations involving small quantities of explosives.

c. Dry-type dust collection chambers, except portable units, should be located in the open, outside operating buildings, or may be inside if adequate shielding is provided. The quantity of explosives collected shall not exceed the capacity of the shielding to protect operating personnel. The degree of barricading and the appropriate intraline distance shall determine this limit.

d. If dry dust collection outside a building is not practical, a separate room or shielded area within the building shall be designated for this purpose. This room or shielded area shall not contain other operations or be used as a communicating corridor or passageway between other operating locations within the building when explosives are being collected.

e. Stationary and portable wet-type collectors may be placed in the explosives operating bays or cubicles if the quantity of explosives in the collectors does not exceed 4.4 lbs (2 kg). If placed in separate cubicles, the explosive weight limits may be increased by an amount determined by the extent of the cubicle walls' capabilities to serve as operational shields.

f. Collection systems and chambers shall be designed to prevent explosives from being pinched between metal parts. See sections 9.0 and 10.0 of this chapter for additional design information.

g. Two collection chambers shall be installed ahead of the pump or exhauster in series to prevent explosives dust from entering the vacuum producer in dry vacuum collection systems. In addition, non-sparking fans and dust-tight motors shall be used.

h. Dry-type portable vacuum collectors shall not be located in bays or cubicles where explosives are present or in enclosed ramps, but may be positioned outside the building or in a separate cubicle. The building or cubicle walls shall provide adequate shielding for at least 4.4 lbs (2 kg) of explosives. Shielding and quantity-distance constraints shall define the explosives limits.

i. Explosives dust shall be removed from the collection chamber periodically to eliminate unnecessary and hazardous explosives concentrations. The entire system should be cleaned periodically, dismantling the parts if necessary. A cleaning schedule shall be established for the collection chamber and the entire system using the operating hours as a basis.

j. The entire explosives-dust collecting system shall be electrically bonded and grounded with resistance-to-ground not exceeding 10 ohms. The grounds shall be tested periodically.

19.4 Explosives Slurries

a. Machine tools shall be fitted with wet boxes to catch and direct water and explosives fines to an explosives waste gutter system.

b. Wastewater that might contain explosives materials shall be kept from contaminating potable water or conventional wastewater systems.

c. Settling tanks shall be inspected regularly to monitor the waste accumulation. Records of waste removal shall be kept.

d. When pumping settled explosives from a slurry-settling tank, the operation shall be arranged to preclude exposure of the explosive material to pinching.

e. Explosives materials in settling basins shall be kept wet until removed. The materials shall be maintained wet until spread out for disposal. Explosives materials containing powdered metals shall be kept sufficiently wet to prevent a dangerous temperature rise resulting from a reaction of the metal with water. The possibility of hydrogen generation in this situation must be anticipated. If an explosive or flammable gas can be generated, then proper ventilation shall be supplied to prevent an explosive or flammable mixture from accumulating.

19.5 Metal Scrap

a. Metal scrap shall be inspected to detect explosives-contaminated items and a qualified reviewer shall certify that the scrap is free of explosives before disposition.

b. When scrap is found to be contaminated with explosives, it shall be decontaminated in accordance with final decontamination procedures (see section 18.4 of this chapter).

19.6 Explosives Recovery and Reuse

a. Salvaged explosives materials shall be thoroughly inspected by operating supervisors and reused, screened, reprocessed, or destroyed as the situation warrants.

b. Salvaged explosives materials shall be classified as Storage Compatibility Group L until they have been established to be compatible with the original material.

20.0 WASTE DISPOSAL

20.1 Preparation for Open Burning

a. Preparations to burn or place explosives waste on a pad or in a pit shall not begin until 24 hours after the previous burn at the same burning point. The only exception is if the burning area has been thoroughly soaked with water and inspected by qualified personnel to assure personnel safety during subsequent burning operations. In any case, the burning point shall be inspected for residual embers or hot spots before loading with explosives.

b. Before beginning preparations, firing controls shall be disconnected power sources and circuits shunted and grounded.

c. Some explosives give off toxic vapors or fumes when destroyed by burning. Proper respiratory protective equipment shall be worn when such hazards are likely.

d. Incompatible explosives materials shall not be in the same pit or on the same pad at the same time.

e. Personnel engaged in burning explosives should be provided with non-static producing cotton clothing.

f. Containers of explosives materials shall not be opened less than 10 ft (3 m) from each other.

g. Empty explosives waste containers that are to be reused shall be situated an adequate distance from the burning point to prevent charring or damage during the destruction operation.

h. Based on past experience or analysis, a layer of excelsior or similar material may need to be placed on the bottom of the pit or pad where the explosives waste will be placed.

i. Powdered, granular, or slurry form explosives should be placed in a layer not more than 8 cm thick. Water-wet initiating explosives (storage compatibility Group A) shall not be allowed to dry completely.

j. Wood, heating oil, LPG, or natural gas is authorized to ensure complete combustion of the explosives waste material.

k. The ignition train should be set up to burn upwind, except that the ignition train for burning IHE may be set to burn downwind.

l. The firing circuit shall require a key for completion. Only one copy of the firing key shall exist, and it shall be in the lead operator's possession.

m. Radio transmitters and cellular phones in the control shelter and vehicles at the burning site shall be turned off during setup and firing of low energy electrical squibs to provide protection against radio frequency currents.

n. Precautions shall be taken to ensure that extraneous electrical currents from any source will not unintentionally activate the firing system.

o. The burn shall be primed after all other preparation work is complete and with a minimum number of personnel present.

p. Ignition shall be accomplished remotely.

20.2 Destruction by Burning or Flashing

a. Open burning operations will comply with the requirements of applicable Federal, State, and local air pollution, hazardous waste, and other environmental regulations and permits.

b. Explosives waste may be destroyed by remote burning if it can be done with little chance of detonation. Explosives-contaminated waste may be burned remotely in a wire cage.

c. An open furnace or burning area for explosives should be used to destroy wet-machining cuttings and classified parts. The same furnace or burning area may also be used for flashing casings after washout of an explosive charge.

d. Explosives should not be burned in closed containers or casings, or in large pieces likely to detonate. Special attention should be given to the placement and orientation of large items and those in closed containers or casings. Approved incinerators may be used to destroy small devices such as detonators, actuators, etc.

e. Concurrent burning operations shall not be conducted within 150 ft (45 m) of each other.

f. When several pads are burned, the downwind pad shall be ignited first, followed by the others in succession.

20.3 Ignition System Malfunctions

a. If the ignition system fails to fire, check the circuit's continuity. If no open circuits are detected, refire.

b. If the squibs fire but fail to ignite the ignition train, remotely survey the area, and wait at least 30 minutes. When it appears safe to emerge from the control shelter, disconnect, shunt, and ground the firing circuit, and inspect the squibs, firing system, or ignition train.

20.4 Post-burn Operations

a. No entry should be allowed into the disposal area until eight hours have elapsed unless it can be determined visually that all explosives have been destroyed.

b. Squib firing lines shall be disconnected, shunted, and grounded before personnel can enter the burn area.

c. Unburned or partially burned explosives material remaining in the pit or pad may be moved or repositioned for further burning. The material shall not be raked or otherwise insulted. The burning operation shall be repeated to destroy any remaining explosive waste.

d. At least 24 hours shall elapse before ashes are collected and the pit is prepared for another burn.

20.5 Disposal Area

a. Explosives waste destruction operations shall be separated from magazines, inhabited buildings, public traffic routes, and occupied operating buildings to ensure that personnel and facilities are not exposed to hazardous blast overpressure, fire brands, fragments, or projectiles from burning or detonation of explosives. The following separation distances shall apply:

(1) Destruction by open burning or flashing shall not be performed within 2395 ft (730 m), unless carried out in pits or with other aids for limiting the range of fragments and debris if an accidental detonation occurs. In no case may the pit be located at less than 670 ft (204 m) for weights of 100 lbs (45 kg) or less and 1250 ft (381 m) for weights exceeding 100 lbs (45 kg). Sites should be located taking into account the direction of the prevailing winds to prevent sparks from being blown toward explosives locations.

(2) The size of the danger zone for destruction by open detonation shall be determined by the formula

$$D(ft) = 328\ W^{1/3}\ [D(m) = 131\ Q^{1/3}].$$

(3) The minimum separation distance shall be:

(a)	Non-fragmenting explosive materials	1250 ft (381 m)
(b)	Fragmenting explosive materials	2500 ft (762 m)
(c)	Bombs/projectiles with 5 in. caliber or greater	4000 ft (1220 m)

(d) If known, the maximum fragment (debris) throw distances with an applicable safety factor may be used to replace the 2500 ft (762 m) and 4000 ft (1220 m) minimum separation distances but not below 1250 ft (381 m).

(4) Self-contained destruction facilities fully analyzed for the intended NEW are exempt from the above requirements.

b. The maximum quantity of explosives that may be destroyed at one time shall be determined by starting with a small quantity, gradually increasing until an optimum amount, consistent with safe and efficient operation, is reached.

c. Explosives waste and ordinary rubbish shall not be destroyed in the same destruction area at the same time.

d. During destruction operations, the area within 200 ft (60 m) of the destruction point shall be kept clear of dry grass, leaves, and other extraneous combustible material. This clearance may be reduced to fire brand distance if aids to limit the range of fragments and debris are provided for the destruction points used within the disposal area.

e. Explosive waste awaiting destruction shall be stored at least intraline distance from the explosives being destroyed.

f. Trucks transporting explosives to the burning disposal area shall meet the requirements of Chapter II, section 16.0. Upon arrival at the burning grounds, explosives containers will be distributed to trays or other disposal locations. Vehicles shall be moved to a safe location as soon as explosives items have been removed. Explosives containers shall not be opened until vehicles have been withdrawn.

g. Provisions for emergency fire fighting shall be readily available at the waste disposal area.

h. The burning grounds shall be serviced with telephones or two-way radio communication.

20.6 Destruction by Detonation

a. Cased explosives should be removed from cases and burned or the cased item destroyed by detonation. Detonators, primary explosives, and other explosives that might detonate if burned should also be destroyed by detonation.

b. A high-energy detonator (e.g., an EBW) should initiate the detonation.

20.7 Use of Solvents

a. Solvent immersion may be used to prepare small quantities of explosives and explosive detonators for destruction.

b. Items to be destroyed shall be soaked in suitable, compatible solvents until all the explosives material is dissolved. Saturated solvent solutions shall not be reused.

c. Solvent-explosives mixtures shall be destroyed by burning.

21.0 LABORATORY OPERATIONS

21.1 General

a. Safety guidelines presented in this section are applicable to general laboratory operations involving explosive materials. Laboratory operations shall be conducted in a manner that maintains employee exposures to hazardous chemicals at or below the permissible exposure limits (PELs) and complies with the facility chemical hygiene plan.

b. Laboratory personnel shall conduct work involving explosives materials only in accordance with the provisions of written operating procedures (see Chapter VII). Laboratory operations shall comply with the requirements of NFPA 45, *Fire Protection for Laboratories Using Chemicals*.

c. The quantity of explosives present in a laboratory shall be the minimum required for the operations and should be at or below assigned limits. Storage of material not in process is allowed provided the material is secured when the laboratory is unoccupied. The material shall be configured to preclude exceeding the maximum credible event (MCE).

d. Open flames shall be prohibited in laboratories where explosives or flammable solvent vapors are or may be present unless allowed by an approved hazards assessment or procedure.

e. Disposal of explosives through laboratory drains shall be forbidden unless the drain plumbing has no traps and is designed to handle explosives (i.e., is provided with a sump or other device for the collection of solids). Even if a drain is designed to handle explosives, deliberate disposal of explosives in these drains should be avoided. These drains should be used only to clean up explosives spills. Special care should be exercised to prevent entrance of compounds into drains that may react with iron or rust to form sensitive salts (e.g., picrates and picric acid).

f. Solvents or other flammable substances shall be protected against electrical sparks, heat, and open flames.

g. Suitable guards shall be provided for all glass or fragile equipment that must withstand reduced or elevated pressure.

21.2 Safety Shields

a. If a laboratory operation involves an explosion hazard, personnel should be protected by safety shields or the operation should be performed remotely. Table II-5 lists shields that have been tested and found acceptable for the indicated quantities of explosive.

NOTE: Shields listed in Table II-5 were not tested for metal-fragment penetration (unless specifically indicated) and thus may not offer effective protection when the explosive is closely confined in a heavy-walled metal container. ("Heavy-walled" is defined here as wall thickness to diameter ratio greater than 0.01.)

Table II-5. Safety Shields for Explosive Laboratory Operations*

Shield	Minimum distance from explosive (cm)	Explosives limit
Leather gloves, jackets, or coats, and plastic face shields	----	50 mg
3 mm tempered glass	8	50 mg
7 mm Lucite/equivalent material	15	2.5 g
20 mm Lucite/equivalent material	15	10 g
15 mm laminated resistant glass	20	20 g
25.4 mm Lexan/Lexguard	30	50 g
2 units each of 25.4 mm plate glass laminated with 12.4 mm polycarbonate with a 9.5 mm air gap between units (glass sides facing the explosive)	30	50 g (steel confined)

* Recent blast testing has shown that laminated tempered glass is superior to monolithic tempered glass, and polycarbonate is superior to acrylic plastics, such as Lucite. Laminated tempered glass is recommended instead of monolithic tempered glass and polycarbonate is recommended in lieu of acrylic. The shields are recommended to be of equal or greater thickness than those listed in the table. Proof testing is highly recommended. When designing and/or replacing a safety shield with a polycarbonate, it should be UV stabilized, treated for abrasion resistance, and have met Mil Spec P-46144C. When designing or replacing a safety shield with laminated glass, it should be coated with a 0.1 mm fragment-resistant film on the viewer's side to minimize spalling. The shield, shield frame, and anchoring system shall be designed to resist maximum credible overpressure and fragments.

b. If an experiment poses a metal-fragment hazard (as opposed to a glass-fragment hazard) and the experiment cannot be conducted remotely, the proposed shield should be tested and approved under conditions simulating an explosion in the experimental setup but with at least 125 percent of the anticipated explosive content.

c. The shield shall be anchored to the hood frame or bench top when it is being used for protection against more than 0.16 oz (5 grams) of TNT equivalent.

d. Other shields may be used after successfully passing a test of 125 percent of the rated explosive charge and being approved.

e. For confined areas, a blast vent having less strength than the shield should be provided.

f. When explosives operations require personnel to reach around a shield to manipulate equipment, exposure shall be minimized.

21.3 Heating Operations

a. During synthesis, formulation, or experimental work, heat may be applied to initiate or maintain reaction, to increase solubility, etc., if the principles below are followed:

(1) Heat shall be applied indirectly using steam, a water bath, oil bath, or an approved laboratory electrical heating device such as a mantle.

(2) Utmost caution shall be exercised to ensure that reactive material does not come in direct contact with the heating elements.

(3) If an experiment must be conducted behind a shield, any heating device shall be mounted so that temperature can be controlled from the operator side of the shield. The heating device should be mounted so it can be separated quickly from the reaction vessel without operator exposure. Consideration should be given during design of the experiment to providing emergency cooling for the reaction vessel or its contents.

(4) Heating of explosives with devices without proper controls shall be monitored at all times. If the operator must leave for any reason, the heating device should be turned off. Heating systems that will be operated unattended shall have dual controls, an override shutoff, or some other protection against failure of the primary heating control. Systems capable of totally containing the effects of an explosion may be exempted from this requirement.

b. Periodic checks should be made to ensure that an experiment is proceeding satisfactorily and that the apparatus is not boiling dry, malfunctioning, etc. In the case of remotely controlled operations, provisions shall be made for observation, using mirrors, television monitors, etc.

21.4 Laboratory Setups

a. Good workmanship and laboratory practice shall be exercised in making and operating laboratory setups. In particular, the following guidelines apply:

(1) Equipment and apparatus shall be clean, in good condition, and in good working order.

(2) All glassware and apparatus shall be inspected for cracks, defects, etc., before use. Defective or damaged equipment shall be removed from service.

(3) Setups shall be geometrically and structurally stable.

(4) Work areas should be as neat and uncluttered as possible.

21.5 Low Concentration of Explosives in Solution

a. After explosives are in dilute solution (less than 25 percent explosives by weight), the primary hazard shall be considered as that associated with the solvent and not the explosive. Where supported by technical data and approved by the Explosives Development Committee (EDC), a solvent/explosives solution greater than 25 percent may also be similarly classified.

b. If the explosive recrystallizes or precipitates out of solution, safety guidelines for pure explosives shall apply.

21.6 Explosives Sample Control

a. Samples shall be delivered to a laboratory only at specific designated locations.

b. Each sample shall be properly identified and labeled.

c. Upon completion of required tests or analyses, the sample should be removed from the laboratory.

d. A safety information sheet should accompany all samples of new experimental explosive material submitted to a laboratory for analysis.

22.0 EMERGENCY CONTROL

22.1 Placarding and Fire Symbols

a. Placards and fire symbols (as specified in DoD 6055.9-STD or the NFPA 704 Standard) shall be displayed consistently on buildings and work areas throughout an entire facility to warn of potential hazards from explosives and to provide information for emergency situations.

22.2 Explosives Emergency Control Plans

a. Each installation shall have a facility-specific written plan for the control of emergencies involving explosives (The plan may be need to be broken down for each operating area). An explosives emergency control plan may be part

of the facility's overall emergency control plan. All facility personnel shall be trained in the plan's content applicable to their area. The plan shall be available to all personnel for ready reference.

b. Emergency situations that should be covered include the following:

(1) Fires and explosions.

(2) Floods.

(3) Extreme weather conditions.

(4) Conditions resulting in environmental disturbances.

(5) Civil disturbance.

(6) Threats and bomb scares.

(7) Enemy attack.

(8) Other emergencies that require rapid mobilization of personnel and equipment to minimize death and injury to personnel or to prevent the spread of damage and destruction.

c. The plan should address:

(1) Reporting an emergency.

(2) Criteria for activating the emergency plan.

(3) Authority and responsibility for administration and execution of the plan.

(4) Mobilization of personnel to respond to an emergency or disaster.

(5) Roles of operating personnel in responding to an emergency.

(6) Procedures for responding to an emergency or disaster.

(7) Accounting for evacuation of personnel.

(8) Plant and document security.

CHAPTER III—EXPLOSIVES AND PERSONNEL LIMITS AND CONTROL

1.0 EXPLOSIVES LIMITS

a. The quantity of explosives at an operating location shall be the minimum necessary to carry out the operation safely and efficiently. When practical, this quantity shall be subdivided and separated to prevent propagation of detonation. Supplies exceeding this minimum quantity shall be removed from the operating area.

b. In no case shall the quantity of explosives permitted in an operating building exceed the maximum permitted by quantity-distance criteria. Quantity-distance criteria and guidelines for application of these criteria are presented in Chapter VI of this Manual.

2.0 PERSONNEL LIMITS

a. The number of personnel at an operating location shall be the minimum consistent with safe and efficient operation. In establishing personnel limits, the following principles shall be followed:

(1) Only jobs not necessary to the performance of a hazardous explosives operation should not be performed in the same location as the hazardous operation. Only personnel needed for the hazardous operations shall be allowed in hazardous locations.

(2) Personnel limits shall allow for necessary casuals.

(3) Sufficient personnel shall be available to perform a hazardous operation safely and to obtain help and aid the injured if an accident occurs.

(4) No person shall perform explosives work with a high risk of serious injury alone. Prompt and easy communications with other employees shall be provided. Facility management shall specify explosives activities that may be performed alone.

3.0 LIMIT CONTROL

3.1 Posting and Recording

a. All rooms, bays, and buildings containing explosives shall have posted in a conspicuous place a standardized placard stating the maximum amount of explosives and the maximum number of workers and casuals permitted in the control unit at any one time.

b. Maximum explosives and personnel limits for all buildings and bays for each explosives area shall be documented and maintained on file.

3.2 Limit Review and Approvals

a. Management personnel with authority and jurisdiction over an operating bay or building shall review explosives and personnel limits for each location periodically and recommend changes as required. When the use of a location changes, personnel and explosives weight limits shall be reviewed and limits reestablished as required.

b. Changes in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures (see Chapter VII). A procedure shall be established for the approval of temporary changes in explosives and personnel limits for an operating location.

3.3 Personnel Controls

a. A system shall be established to control the presence of personnel within explosive operating areas. The movement of transients in the vicinity of an explosives operating area should be controlled when their presence creates a congestion problem or other safety concern.

3.4 Explosives Control

a. A verifiable system shall be established to control the amount of explosives present in an explosives facility.

4.0 INSENSITIVE HIGH EXPLOSIVE LIMITS

a. When no other explosives are present, IHE weight limitations shall be based on separation distances for Hazard Class 1.6 explosives (see Chapter VI, section 3.1) or equivalent protection provided by facility design features. The quantity of IHE at an operating location shall be the minimum necessary to carry out the operation safely and efficiently.

b. IHE limits for pressing, dry blending, dry milling, dry screening, and certain machining operations (see Chapter II, section 12.4.2c), should be the same as those established for HE operations.

CHAPTER IV—PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT

1.0 CLOTHING AND PERSONAL EQUIPMENT

1.1 Clothing

a. Each operation shall be analyzed to determine when personnel working with explosives and toxic materials must wear approved coveralls or laboratory coats to prevent contact with these materials and prevent contaminating personal apparel. Flame-retardant coveralls may be desired for explosives operations with the potential for flash fire. These coveralls shall not have cuffs and should not have metallic fasteners. Written procedures shall include protective clothing and equipment requirements.

b. Cotton or other antistatic outer and undergarments, including socks, should be worn where generation of static electricity would create a hazard.

1.2 Footwear

a. Personnel working in areas where electrostatic-sensitive explosive powders or materials are handled shall wear conductive, non-sparking footwear. Exception: personnel working on electrical or electronic equipment shall not wear conductive footwear unless protected by insulated mats, ground fault circuit interrupters (GFCI), etc. Personnel working in other areas where explosives contamination may be present shall wear non-sparking footwear or bootie shoe coverings.

1.3 Respirators

a. Approved respiratory protection shall be worn when exhaust ventilation is unavailable or does not adequately control airborne particulate, gases, or vapors released during explosives operations. The employee shall have current approval to wear respiratory protection (medical exam, respirator fitting, and training).

1.4 Eye Protection

a. Personnel working in or visiting eye hazard areas shall wear suitable eye protection devices, particularly when EEDs are handled. Explosive operations shall be evaluated for eye hazard risks. Contact lenses shall not be considered appropriate eye protection.

1.5 Gloves

a. Skin contact with some explosives and associated materials can result in dermatitis or absorption across the skin barrier. Operations where these materials are present must be evaluated for skin contact hazards and the need for the proper gloves.

2.0 MAINTENANCE AND TESTING

2.1 Equipment Maintenance and Inspection

a. Personal protective equipment shall be properly maintained. The operator's life may depend on the equipment functioning properly. An appropriate inspection schedule shall be established.

2.2 Conductivity Testing

a. When conductive footwear is worn, the conductivity shall be tested initially and regularly thereafter to ensure continued conductivity from person to ground.

2.3 Cleaning and Disinfecting

a. Provision shall be made to launder and disinfect protective garments and devices. This is especially important for equipment worn about the face. Because laundering affects the flame-retardant properties of fabric, flame-retardant coveralls should be tested to establish the maximum number of laundering cycles permitted.

2.4 Contaminated Clothing

a. Contaminated clothing should be wiped or dusted to remove as much contamination as possible. Compressed air shall not be used for this purpose. If obvious contamination remains, personnel shall change their clothing.

CHAPTER V—TRAINING

1.0 GENERAL

a. Personnel shall be properly trained before they are assigned to explosives operations or operate any explosives-transport vehicle. The training for explosives work, which serves to assist in conducting work safely and developing safety awareness, shall ensure that personnel:

(1) Develop and maintain a safe attitude towards work with explosives.

(2) Define and understand the potential hazards involved.

(3) Learn correct skills to perform tasks safely.

(4) Are prepared for unexpected hazardous conditions.

(5) Read and understand the appropriate operating procedures.

2.0 SUPERVISORY RESPONSIBILITY

a. The supervisor shall be responsible for:

(1) Determining the required training for personnel.

(2) Verifying that training has qualified the worker to perform assigned tasks safely and efficiently.

(3) Ensuring that the worker can perform required emergency duties.

(4) Providing on-the-job training.

(5) Continually updating worker training.

3.0 TRAINING AND QUALIFICATION PROGRAMS

a. Each organization shall have a training and qualification program with established qualification requirements. Paragraph 3.0b below is an example.

b. Completion of training should qualify the worker to perform a task for a specific period of time. The following items should govern maintenance of qualifications.

(1) At the end of the initial qualification period, qualification may be extended for subsequent specific time periods if:

(a) The worker has successfully performed the task during the preceding six months and has read and understands the current operating procedures; or

(b) The worker has completed refresher training and is again found to be qualified by his or her supervisor.

(2) Retraining in areas of weakness should be required of workers who do not demonstrate job proficiency or who subsequently violate safe practices.

(3) When an operating procedure is modified, all personnel using that procedure should be retrained in the modified procedure.

(4) An employee should not be permitted to continue working with explosives if the supervisor, with counsel from medical personnel, determines that he or she is unable to perform the task safely. Possible reasons include:

(a) Physical injury or illness.

(b) Disease.

(c) Mental or emotional disturbances.

(5) Training records should be maintained for each worker, with the following information included:

(a) Description and dates of training received.

(b) Description and dates of refresher training.

(c) A signed “statement of understanding” for operating procedures.

(d) Attendance at safety meetings and participation on safety committees.

(e) Qualification review by supervisor.

(6) The supervisor may temporarily authorize an employee who has not completed the required training to perform a task under the following conditions:

(a) The supervisor determines that the employee has a working knowledge adequate to perform the task safely.

(b) A qualified person directly supervises the work.

c. Hazardous materials information and training programs are required for personnel who work with explosives and hazardous materials used in conjunction with explosives operation. Training should include:

(1) Information on physical and health hazards.

(2) The purpose and proper use of engineering controls, work practice controls and protective equipment.

(3) Labeling systems and MSDS terms.

(4) Methods to detect the presence or release of hazardous materials in the work area.

4.0 UNEXPLODED ORDNANCE (UXO) TRAINING

a. Personnel in charge of UXO removal or disposal should be US citizens and shall have successfully completed training at a United States Military Explosives Ordnance Disposal (EOD) school. Personnel shall provide documentation of completed training and have a minimum of 18 months operational EOD experience. All personnel engaged in operations shall be thoroughly trained in applicable UXO recognition and explosives safety.

b. Personnel performing UXO removal or disposal shall have completed training at a US Military EOD school or have equivalent training or experience. All other personnel engaged in operations shall be trained thoroughly in applicable UXO recognition and explosives safety.

c. Personnel not involved in UXO operations, but requiring access to areas known or suspected to contain UXOs shall be required to have completed UXO awareness training and shall be escorted by personnel qualified under section 4.0a or b above. The UXO HE Awareness video (EPL 122) is recommended for the awareness training.

5.0 REFERENCES

a. OT-525, Personnel Qualifications, Commanding Officer, Naval Explosive Ordnance Disposal Technology Division, 2008 Stump Neck Road, Indian Head, MD 20640-5070

b. UXO High Explosives Awareness Video (EPL 122), Sandia National Laboratories/New Mexico Environmental Restoration Program.

CHAPTER VI—QUANTITY-DISTANCE AND LEVEL-OF-PROTECTION CRITERIA FOR EXPLOSIVES ACTIVITIES

1.0 GENERAL

a. This chapter establishes quantity-distance and level-of-protection criteria for all DOE operations involving explosives. These criteria provide specific levels of personnel and property protection from the effects of potential fires and explosions within and outside of DOE installations.

b. The cardinal principle to be observed at any location or in any operation involving explosives, ammunition, severe fire hazards, or toxic materials is to limit, in a manner consistent with safe and efficient operation, the exposure to a minimum number of personnel, for a minimum time, and to a minimum amount of the hazardous material.

c. The Facility Management shall ensure that ammunition and explosives safety site plans are submitted, as specified in sections 1.1 and 1.2 to DOE for review and approval. DOE review and approval will be conducted by the Authority Having Jurisdiction for explosives safety within the Operations/Site Office.

1.1 For New Explosives Facilities and Operations and Explosives Facilities Undergoing Major Modifications:

a. Preliminary Site Plan must be developed and submitted for DOE/NNSA approval before CD-1 approval and the Final Site Plan submitted and approved before CD-4 (See DOE O 413.3)

b. For a facility where the risk associated with the operation is increased, with an increase in explosive weight or a major modification or level of protection, a new site plan shall be required and approved prior to start of operations.

1.2 For Existing Explosives Facilities and Operations:

a. A Site Plan must be developed and submitted for review by DOE/NNSA local authority as soon as possible but not later than two (2) years from approval of DOE M 440.1-1A (Revision 9) of the *DOE Explosives Safety Manual*. The Site plan shall contain the following information:

(1) A Quantity Distance (QD) Chart containing the following:

(a) Each sited facility (PES) listing maximum Net Explosives Weight for each applicable Hazard Division

(b) Actual and required distance to exposed sites (ES)

(c) QD criteria used for siting each PES – ES relationship

(2) Map showing each PES, its clear zone, and all ESs within the clear zone.

(3) Personnel Limits for the explosives facility.

(4) Brief description of explosives and nonexplosives operations within the clear zone.

(5) Statement that the current operation presents no significantly greater risk than that assumed when the facility was originally constructed and

(6) If the facility does not meet current criteria for the operation being conducted, provide a statement:

(a) Why it is not feasible to bring the facility up to current standards and

(b) That the current operation presents no significantly greater risk than that assumed when the facility was originally constructed.

b. A letter of transmittal shall accompany each site plan or group of site plans. The letter should contain the reason for submittal (preliminary or final siting of new facility, site plan/plans for grandfathered facility/facilities, change in operation with increased or decreased QD requirement) and a request for site plan approval. For a grandfathered facility, note whether the facility meets current criteria for the operation being conducted.

c. If the siting has any unique characteristics explain what they are and what criteria is being applied. (Example: If a facility is built to control blast effects and fragments, QD to other facilities will not apply).

2.0 APPLICABILITY OF CRITERIA

2.1 Specific Applications

a. Criteria presented in this chapter shall be used to:

(1) Establish maximum explosives limits for explosives facilities and operations.

(2) Plan explosives activities in existing facilities.

(3) Design and site new facilities and operations.

2.2 Explosives Limits

a. Explosives limits shall never exceed the minimum required for efficient, safe operation (see Chapter III).

2.3 Areas Where Criteria Are Not Applicable

a. The quantity-distance and level-of-protection criteria defined in section 4.0 of this chapter are not applicable to portable buildings used at specified nuclear test shot locations.

3.0 QUANTITY-DISTANCE CRITERIA

a. Quantity-distance criteria must account for the types and severity of hazards each explosive material presents, the construction and orientation of facilities to which the criteria are applied, and the degree of protection desired for personnel and facilities adjacent to the explosives operations.

b. The hazard classification system recommended by the UN defines the types and severities of explosives hazards. The guidelines presented below specify minimum degrees of protection for various facility categories and describe how quantity-distance tables are to be applied to facilities of various construction and orientation with respect to adjacent facilities.

3.1 Hazard Classes and Class Division

a. Explosives shall be classified based on their reactions to specific initiating influences. Personnel shall use the UN recommended hazard classification system for DOE explosives classification. The UN system consists of nine classes for dangerous goods, with explosives included in Class 1. The explosives hazard class is further subdivided into divisions based on the character and predominance of the associated hazards and their potential for causing personnel casualties or property damage. Table VI-1 lists the six divisions of Class 1.

Table VI-1. Divisions of Class 1

Hazard Class and Division Designators	Hazards
1.1	Mass detonating
1.2	Non-mass explosion, fragment producing
1.3	Mass fire, minor blast or fragment
1.4	Moderate fire, no significant blast or fragment
1.5	Explosive substance, very insensitive (with a mass explosion hazard)
1.6	Explosive article, extremely insensitive

b. When required to properly describe the hazard, a numerical figure in parentheses shall be placed to the left of the division designators 1.1 through 1.3 [e.g., (18) 1.1, (08) 1.2, and (06) 1.3]; this number indicates the minimum separation distance (in hundreds of feet) for specified levels of protection from explosive items for inhabited buildings, public traffic routes, and personnel in the open. A minimum distance number shall be used for all items in Class 1, Division 2, as shown in the applicable tables. Figure IV-1 illustrates the use of the UN hazards

classification system and lists the storage compatibility group opposite each hazard class. The listed compatibility group is typical for the expected compatibility to hazard class relationships. Note: The two classification systems apply to different concerns.

(1) Compatibility groupings define which explosives may be stored together safely without increasing the risk of initiation.

(2) Hazard classifications indicate the initiation effects of the various explosives.

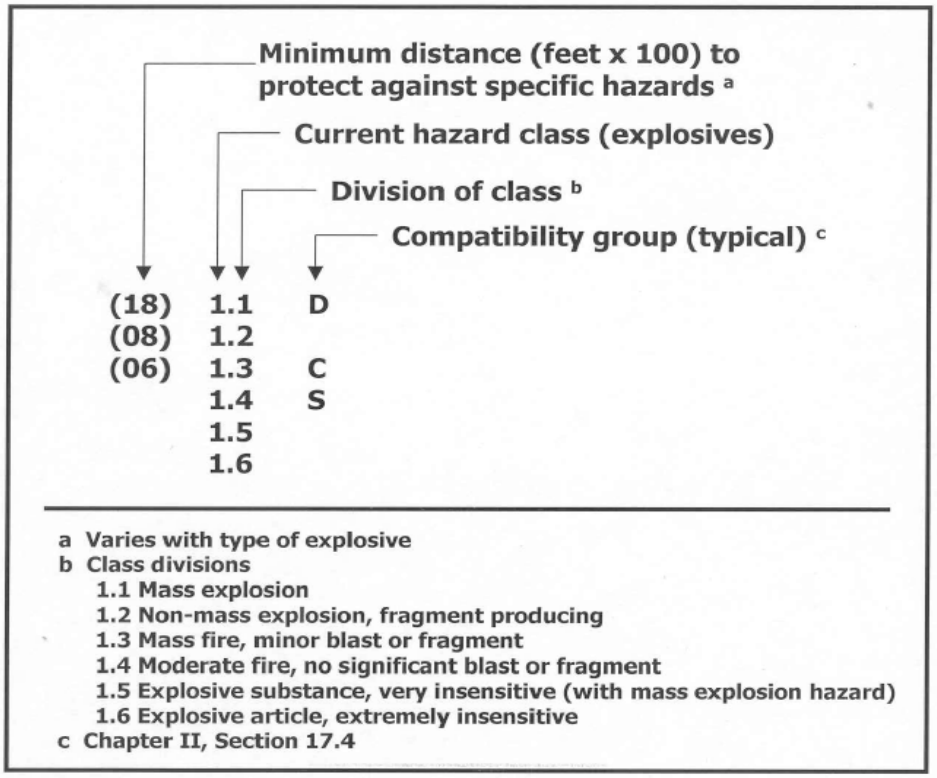


Figure VI-1. Application of Hazard Classification System

c. Classification tests (described by TB 700-2, *Explosives Hazard Classification Procedures*) and additional tests (as desired), including United Nations ST/SG/AC.10/1 and ST/SG/AC/10/11, shall be used to assign energetic materials to the appropriate compatibility groups and hazard divisions. Supplemental tests may be used to characterize material hazards more fully if material properties or anticipated material environment are expected to significantly influence the explosives classification.

d. Although DOT Hazard classifications require the use of the Bureau of Explosives' (BOE) Impact Apparatus to determine impact sensitivity, other impact apparatus may be used, providing:

(1) Test results for at least two reference explosives are compared to results for the reference explosives on the BOE Impact Apparatus; and

(2) A minimum of 10 trials each is run for the reference explosives and the explosives being classified.

3.2 Establishing Quantity of Explosives and Distances

3.2.1 *General*

a. The principles and tables presented in DoD 6055.9-STD, *DoD Ammunition and Explosives Safety Standards*, shall be used to determine the following:

(1) The total quantities of explosives in adjacent magazines, operating buildings, or other explosives facilities that must be applied to quantity distance tables.

(2) When the levels of protection required by section 4.0 of this chapter differ from the requirements of DoD 6055.9-STD, section 4.0 shall take precedence.

(3) The minimum separation distances required for the facilities are based on the desired level of protection and total quantities of explosives.

(4) The total quantity of explosives is determined by defining and examining the maximum credible event (MCE). If an explosives event occurs, the MCE is the largest credible amount of explosives that could be involved (not necessarily the total quantity of explosives present).

3.2.2 *Use of Metric System*

a. Throughout DoD 6055.9-STD, the NEW is used to calculate distance using the formula $D=KW^{1/3}$, when D is the distance in feet, K is a factor based on the risk assumed or permitted, and W is the NEW in pounds.

b. When metric units are used, the symbol Q denotes net explosive quantity (NEQ) expressed in kilograms. In the formula $D=KQ^{1/3}$, the distance D is expressed in meters. Thus, the respective units of K are $ft/lb^{1/3}$ and $m/kg^{1/3}$ in the two systems. The value of K in English units is approximately 2.5 times its value in metric units [e.g., if $D(m) = 6Q^{1/3}$, then $D(ft) = 15W^{1/3}$].

3.2.3 *Railcars and Transport Vehicles*

a. Explosives-loaded railcars, motor vehicles, and other transport vehicles in holding yards are considered aboveground magazines for quantity-distance purposes. They shall be kept in groups, and each group shall be limited to a maximum of 250,000 lb (113,398 kg) of high explosives.

(1) When a railcar receiving yard or point is the site where explosives will be interchanged between the common carrier and the facility rail system, quantity-distance provisions do not apply provided that the cars are moved expeditiously to a suitable location.

(2) When inspection of a railcar of explosives indicates a hazardous or potentially hazardous condition, the railcar should be moved at once to a suspect car spur track or an isolated section of track. This spur or section of track should be accessible directly from the inspection point. The distance between the spur or track and facility boundaries, classification yards, inhabited buildings, administration areas, operating buildings, magazines, inert storage locations, and public traffic routes should be the inhabited-building distance based on the maximum quantity of explosives that the facility can receive in one railcar. Only one car is permitted at this location at any time.

(3) Incoming motor vehicles carrying explosives shall be inspected at a station remote from hazardous and populated areas.

3.2.4 *Utilities Installations*

a. Permanent DOE-controlled underground utilities installations (excluding building service lines) should be separated from explosives locations containing Hazard Class/Division 1.1 materials (see Table VI-2).

b. Privately owned or operated utilities installations (aboveground and underground) shall be separated from explosives locations by at least public traffic route distances. Installations that include structures should be separated from explosives facilities by inhabited-building distance.

c. Certain auxiliary power facilities, transformer stations, etc., present fire hazards to explosives facilities. Transformers and associated electrical switching apparatus serving one explosives facility or complex that do not present a fire hazard to the facility (i.e., dry-type, “less flammable”

oil-insulated, etc.) shall be located as specified in NFPA 70 and FM Data Sheet 5-4/14-18.

d. Normal oil-insulated transformers shall be located at least 50 ft (15 m) from an explosives facility or as specified in DoD 6055.9-STD.

Table VI-2 . Quantity-Distance Separation for Protection of Underground Service Installations

Quantity of explosives (maximum pounds)	Distance	
	Meters	Feet
100	26	80
200	26	80
500	26	80
1,000	26	80
2,000	26	80
5,000	26	80
10,000	26	80
20,000	28	85
50,000	36	110
100,000	46	140
250,000	62	190

Note: If the potential donor building is designed to contain the effects of an explosion, the formula $D=3.0\ W^{1/3}$ can be used to determine separation distances for less than 20,000lbs.

3.2.5 *Petroleum Storage Tanks*

a. Above ground tanks containing 500 gal or less of petroleum that serve equipment (such as oil heaters or diesel generators) located in or near explosives buildings shall be located a minimum of 50 ft (15 m) from explosives locations and comply with NFPA 30. Tanks located near intentional detonation areas should be barricaded. Similar underground tanks complying with NFPA 30 do not require separation from explosives facilities. In both cases, the tanks shall be equipped with an anti-siphoning device, unless siphoning is impossible.

4.0 LEVEL-OF-PROTECTION CRITERIA

4.1 Hazard Classes

a. The level of protection required for an explosives activity shall be based on the hazard class (accident potential) for the explosives activity involved. These four hazard classes are defined for explosives activities as follows:

(1) **Class I** consists of those explosives activities with a high accident potential. Remote operations are required because any personnel exposure is unacceptable for Class I activities.

(a) In general, Class I includes activities where energies that may interface with explosives are approaching the upper safety limits, or the loss of control of the interfacing energy is likely to exceed the safety limits for the explosives involved. Class I includes those research and development activities with safety implications have not been fully characterized.

(b) Examples of Class I activities are screening, blending, pressing, extrusion, drilling of holes, dry machining, machining explosives and metal in combination, some environmental testing, new explosives development and processes, explosives disposal, and destructive testing.

(2) **Class II** consists of explosives activities with moderate accident potential because of the explosives type, condition of the explosives, or nature of the operations involved. Class II activities have an accident potential greater than Class III activities, but personnel exposure in contact operations is acceptable.

(a) Class II includes activities where the energies that do or may interface with the explosives are normally well within the safety boundaries for the explosives involved, but where the loss of control of these energies could approach the safety limits.

(b) Examples of Class II activities are weighing, some wet machining, assembly and disassembly, some environmental testing, and some packaging operations.

(3) **Class III** consists of explosives activities with low accident potential such as activities during storage and operations incidental to storage or removal from storage.

(4) **Class IV** consists of those explosives activities with IHE or IHE subassemblies. Although mass detonating, this explosive type is so insensitive that the probability of accidental initiation or transition from

burning to detonation is negligible. If the containers are heated in a fire, IHE reactions will be limited to pressure ruptures of the containers. Most processing and storage activities with IHE and IHE subassemblies are Class IV. However, the following examples of explosives activities with IHE and IHE subassemblies remain Class I:

(a) Pressing.

(b) Some machining (see Chapter II, section 12.4.2c).

(c) Dry blending.

(d) Dry milling.

(e) Dry screening.

4.2 Required Level of Protection

a. Each bay (i.e., storage, handling, or processing building) that houses an explosives activity shall have a protection level based on the hazard class determined for the activity. The level of protection may be provided by equipment design, structural design, operation separation, or provision of operational shields. The levels of protection required for each hazard class are as follows and shall be required for new facilities or redesign of any existing facilities when changes in activities will result in a more hazardous class.

4.2.1 *Explosives Bay*

a. **Class IV**. Bays for Class IV (negligible probability of accidental initiation) activities shall provide protection from fire hazards effects. This protection may be achieved by Hazard Class/Division 1.3 aboveground-magazine distance separation or by a design that contains the effects of an accident. Because accidental detonation is not considered credible, Class IV bays shall be sited and designed as acceptors rather than donors for the effects of blast overpressure, structural collapse, and missiles (hazardous fragments).

b. **Class III**. Bays for Class III (low accident potential) activities shall provide protection from explosion propagation from bay to bay within buildings and between buildings that are located at intraline or magazine distance. If intermediate storage of explosives is within an operating building containing Class II or Class I operations, the intermediate storage or staging bay will require Class II level of protection. Examples of Class II activities include weighing, assembly and disassembly, some wet machining, some environmental testing, and some packaging operations. Minimum separation distances may be reduced when explosives bays are

designed to adequately contain the effects of an accident (blast pressures and missiles).

c. **Class II**. Bays for Class II (moderate accident potential) activities shall comply with the requirements for Class III bays, and in addition provide protection to prevent fatalities and severe personnel injuries in all occupied areas other than the bay of occurrence. (For Class II, access ramps and plant roads are not considered occupied areas). Prevention of fatalities and severe injuries is satisfied when personnel in occupied areas other than the bay of occurrence will not be exposed to the following:

(1) Overpressures greater than 100 kPa (15 psi) maximal effective pressure.

(2) Structural collapse resulting from overpressure or debris impact. Structural collapse is a structural component's failure as a direct result of a facility losing structural integrity. This collapse must not result in explosives propagation, fatalities, or severe personal injuries.

(3) Missiles (hazardous fragments) generated in acceptor-occupied areas. Hazardous fragments that can cause fatalities and severe injuries are defined as those having greater than 58 ft-lb impact energy. The threshold pressure for eardrum rupture is 34 kPa (5 psi); one-half of the threshold pressure for lung damage is 100 kPa (15 psi). (See Chapter I of TM 5-1300).

d. **Class I**. Bays for Class I (high accident potential) activities shall comply with the requirements for Class II bays, and in addition provide protection to prevent serious personal injuries, including personnel performing the activity, personnel in other occupied areas, and transients. This protection can be achieved by controlling blast and debris through suppression, containment, or establishing an exclusion area with positive access control. Serious injury prevention is satisfied when personnel will not be exposed to:

(1) Overpressures greater than 34 kPa (5 psi) maximal effective pressure, which should not exceed 16 kPa (2.3 psi) peak positive incident pressure;[1]

(2) Structural collapse of a facility or building from overpressure or debris impact. Structural collapse a structural component's failure as a direct result of loss of structural integrity. This

[1] This value is specified in DoD 6055.9-STD as required protection for all personnel exposed to remote operations (16kPa is also the overpressure for public-traffic-route distance).

collapse must not result in explosion propagation, fatalities, or severe personal injuries.

(3) Missiles (hazardous fragments)—hazardous fragments that can cause serious injuries are defined as those having greater than 11 ft-lb impact energy.

(4) Thermal fluxes greater than 0.3 cal/cm^2/sec.This value is specified in DoD 6055.9-STD, Chapter 4, as required protection for all personnel assigned to perform remote operations.

4.2.2 ***Bays for Joint Explosives-Plutonium Activities***

a. Bays for joint explosives-plutonium activities shall comply with the requirements of section 4.2.1 of this chapter for the class of explosives activity involved and DOE DNA TP 20-7. Because the plutonium has contamination potential, the bays shall also comply with the following:

(1) Bays for Uncased Explosives—Plutonium Activities. Where it is necessary to store, handle, or process uncased explosives components and plutonium in the same bay, the enclosing structure and its ventilation, electrical, fire protection, and utility systems shall be designed to assure that if all the explosives present should detonate, radiation exposures shall comply with the current version of DOE O 420.1B standards for hypothesized accidental releases. The safety analysis report shall govern the quantity of plutonium allowed in such a bay. Activities may be performed in Class IV bays if IHE, IHE subassemblies, or IHE weapons are present; however, criticality considerations shall govern the quantity of plutonium allowed.

(2) Bays for Cased Explosives—Plutonium Activities. When handling or processing cased high-explosive components that contain plutonium, the enclosing structure shall be designed as a Class II explosives bay. Storage shall conform to Class III requirements. The plutonium quantity shall be limited to 25 kg per bay. Plutonium limits for magazines are specified in DOE DNA TP 20-7. Activities may be performed in Class IV bays if only IHE, IHE subassemblies, or IHE weapons are present; however, criticality considerations shall govern the quantity of plutonium allowed.

5.0 FIRE PROTECTION

5.1 Vegetation Control

a. Vegetation around storage magazines and explosives operating facilities should be controlled to minimize potential damage to the magazine or facility from erosion or grass, brush, or forest fires. A firebreak at least 50-ft (15-m) wide and free from combustible material should be maintained around each aboveground magazine or explosives operating facility. If an aboveground magazine or explosive facility exterior is fire resistant, the firebreak can have vegetation, but the growth must be controlled to prevent rapid transmission of fire to the magazine or facility. Maintaining the firebreaks around earth-covered magazines and cutting grass covering these structures is only required around ventilators to prevent transmission of a fire into a structure.

5.2 Fire Protection Criteria

a. The following fire protection criteria shall be required for all new facilities or redesign of existing facilities where changes in activities will result in a higher hazardous classification.

(1) Automatic fire suppression systems shall be installed in all buildings containing HE and plutonium, except storage magazines.

(2) For buildings containing explosives but no plutonium, facility management shall determine the need for fire suppression systems based on maximum fire loss criteria and program mission interruptions and delays as outlined in the current versions of DOE O 420.1B, *Facility Safety*; DOE O 430.1B, *Real Property Asset Management*; and DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*.

(3) Where fire suppression is required, each explosives bay shall have an individual feed with its controls protected outside the bay and located to enable system operation if a detonation occurs in any bay.

(4) Transmitted fire alarms shall distinguish between explosives and nonexplosives areas through the use of annunciator panels at safe locations; small non-HE areas do not need separately transmitted alarms.

6.0 EXPLOSIVES FACILITY SITING AND DESIGN CRITERIA REFERENCES

a. Permanent explosives facilities shall comply fully with TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," and DOE/TIC-11268, "A Manual for the Prediction of Blast and Fragment Loading of Structures." Portable magazines should be ventilated and resistant to water, fire, and theft. Portable magazines can be made of any material that meets these guidelines. [Portable facilities that comply with 27 CFR 55.206, "Bureau of Alcohol, Tobacco and Firearms" (BATF) meet this criteria.] Portable magazines shall be sited per DoD 6055.9-STD as above ground magazines.

b. Blast-resistant design for personnel and facility protection shall be based on the TNT equivalency of the maximum quantity of explosives and propellants. In accordance with TM 5-1300, the TNT equivalency shall be increased by 20 percent for design purposes.

c. For an unproven facility design, either a validated model or full-scale test is required to ensure structural adequacy unless a high degree of confidence can be provided by calculations or other means. The contract administrator (Head of Field Organization) with competent engineering review shall concur in any determination regarding test requirements.

d. The design of new facilities, or those with major modifications, shall conform to the DOE explosives safety requirements. For a tabular summary of the protective design types established by these criteria, see Table VI-3. Protective construction design features are specified in TM 5-1300 and DOE/TIC-11268.

e. Studies necessary to provide the technical basis for location, engineering, design, and operation (under normal and potential design basis accident conditions) of buildings shall follow the stricter of this Manual or DoD 6055.9-STD, *DoD Ammunition and Explosives Safety Standards*, for establishing explosives quantity-distance separation.

6.1 <u>Site and General Construction Plans for Ammunition and Explosives Facilities</u>

a. Site and general construction plans for ammunition and explosives facilities as well as plans for changes in utilization of facilities or mission changes that adversely affect the explosives Q-D requirements shall be submitted to the Operations/Site Office for review and approval. Plans shall be forwarded for:

(1) New construction or major modifications of facilities for ammunition and explosives activities. Modifications or rehabilitation plans for existing facilities do not require submission to the Operations/Site Office when the plans do not introduce additional hazards or do not increase the net explosives capacity or chemical agent hazard for which the facility was designed or sited.

(2) Facilities for activities not involving ammunition or explosives that are in such proximity to ammunition and explosives as to be exposed to hazards or for which a reasonable doubt may exit regarding possible exposure to hazards.

(3) Facilities for activities not involving ammunition and explosives that become exposed to blast, fire, or fragment hazards; or potential toxic chemical agent release due to change in facility mission or facilities usage.

b. When the review of site and general construction plans is required, the Facility Management shall:

(1) Indicate specifically in the letter of transmittal its approval of the proposal, along with changes, modifications, or specific precautionary measures considered necessary.

(2) Comply with applicable requirements of DoD 6055.9-STD for site plan submission.

(3) A copy of the complete site plan and the final safety submission, together with Operations/Site Office letter(s) of approval, must be retained as a permanent record at the facility/site of origin. The information may be subject to review during the DOE surveys. Facility maps shall be kept current with the latest site plan approval and reconciled with the facility master planning document.

c. DoD 6055.9-STD requires that the minimum distance for protection from hazardous fragments to facility boundaries, critical facility, and inhabited structures shall be 1,250 ft for explosives quantities of 101 to 20,000 lb and 670 ft for 100 lb or less of Hazard Class/Division 1.1 explosives, unless it can be shown that there will be no hazardous fragments or debris at lesser distances. The methods of calculation presented in the Department of Defense Explosives Safety Board (DDESB) Technical Paper No. 13 may be used to establish a smaller fragment exclusion zone. It is not intended that these minimum fragment distances be applied to operating facilities or dedicated support functions within an operating line. For these exposures, the DOE criteria presented in this Manual, for Class I, II, III, or IV activities with appropriate quantity-distance separations are the required protection levels.

d. In addition to this Manual, the following are resource documents for the siting and design of explosives facilities:

(1) DOE O 420.1B, *Facility Safety*, (current version), U.S. Department of Energy, Washington, D.C. 20545.

(2) DOE O 430.1B, *Real Property Asset Management*, (current version), Office of Project and Facilities Management, U.S. Department of Energy, Washington, D.C. 20545.

(3) 10 CFR 830, *Nuclear Safety Management*.

(4) TM 5-1300, NAVFAC P-397, AFM 88-22, *Structures to Resist the Effects of Accidental Explosions*, Departments of the Army, the Navy, and the Air Force, Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(5) DOE/TIC-11268, *A Manual for the Prediction of Blast and Fragment Loading of Structures*, U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120.

(6) DoD 6055.9-STD, *Department of Defense Ammunition and Explosives Safety Standards*, Assistant Secretary of Defense (Manpower, Installations, and Logistics), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(7) DDESB, Technical Paper No. 13, *Prediction of Building Debris for Quantity-Distance Siting*, April 1991, Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

(8) AMC-R-385-100, *AMC Safety Manual*, Headquarters, United States Army Materiel Command, 5001 Eisenhower Avenue, Alexandria, VA 22333.

(9) TR-828, *Blast Environment from Fully and Partially Vented Explosions in Cubicles*, W.A. Keenan and J.E. Tancreto, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

(10) AD 411445, *Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations*, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

(11) AFWL-TR-74-102, *The Air Force Manual for Design and Analysis of Hardened Structures*, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; AD B004152,

Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

(12) HNDM-1110-01-2, *Suppressive Shields, Structural Design and Analysis Handbook*, U.S. Army Corps of Engineers, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807.

Table VI-3. Explosives Facilities: Protective Design Requirements by Activity Type

Type of Activity	DOE M 440.1-1 Operational Requirement for Activity Involved	Explosion Protection for Personnel in Other Occupied Areas Including Adjacent Bay	Explosion Protection for All Personnel (Remote Operation)	Control of Plutonium in Event of Explosion	High-Level Protection from Natural Phenomena	Normal Protection from Natural Phenomena[1]	Radiological Considerations
Class I Activities[2]							
Explosives Only	X	X	X			X	
HE-Pu Cased							
HE-Pu Uncased							
Class II Activities							
Explosives Only	X	X				X	
HE-Pu Cased	X	X					
HE-Pu Uncased	X	X		X	X		X
Class III Activities							
Explosives Only	X					X	
HE-Pu Cased			NOT PERMITTED				
HE-Pu Uncased			NOT PERMITTED				
Class IV Activities							
Explosives Only	X[3]					X	
HE-Pu Cased	X[3]					X	X
HE-Pu Uncased	X[3]					X	
Support Area	X					X	

1 These facilities need only be designed to provide protection acceptable with normal DOE loss criteria.

2 Class I activities with either cased or uncased HE-Pu are not permitted, except where such activities are justified from a nuclear explosives safety study performed in accordance with DOE O 452.1C, *Nuclear Explosive and Weapon Surety Program*, 10-10-90.

3 Class IV bays need only be sited and designed to withstand the effects of blast overpressure, structural collapse, and missiles (hazardous fragments) from an adjacent bay.

Definitions of explosives hazard classes by activity are in the glossary.

CHAPTER VII—OPERATING PROCEDURES

1.0 GENERAL

1.1 Requirements

a. This chapter establishes requirements for preparing and controlling procedures used for operations involving explosives at DOE installations. These requirements minimize the probability of an incident resulting from operations using outdated, inapplicable, or incomplete procedures, or from operations performed in violation of established practices.

b. This chapter also specifies that procedures must be generated for all explosives operations because the step-by-step reasoning process that is used in developing the procedure will identify many safety-related problem areas that might be overlooked otherwise. In addition, the approval system for new or revised procedures also provides other viewpoints and knowledge that may not be available to the originator and may need incorporation into the procedure.

1.2 Types of Procedures

a. This chapter describes two general types of operating procedures:

(1) Standard operating procedures (SOPs). Standard operating procedures are formalized documents prepared for performance of a task on a routine basis. Existing and applicable Department of Defense (DoD) ordnance publications (see section 3.0 for references) will be reviewed for application of unexploded ordnance (UXO) work. Revisions to these documents will invalidate the DoD procedures. If the documents are not appropriate for the situation, then changes may be made, subject to the [DOE] review and approval process.

(2) Nonstandard procedures, which include experimental and special procedures. Experimental and special procedures are documents prepared for performance of a task on a limited basis. For the purpose of this Manual, special procedures are those written to correct a problem encountered in an explosive operation.

2.0 GUIDELINES

a. The following general guidelines should be used in creating operating procedures.

2.1 Before Operation

a. Before starting any operation involving explosives, a hazard analysis shall be undertaken to identify any abnormal problems that will require special training, equipment, or procedures to safeguard personnel conducting the operation.

b. A thorough review shall be conducted in accordance with Chapter II, section 1.7, which will establish if the operation is safe to field. A Safety Analysis Report (SAR) is not required for UXO cleanups. For nonstandard cleanups, such as mass burial or radiation contamination, a Safety Assessment (SA) is required, along with SOPs/special procedures that include the additional precautions to be taken.

c. General operating procedures shall be written and approved for each activity to ensure consistency and safety of operations.

2.2 Supervisory Responsibility

a. Supervisory personnel shall be responsible for enforcing the provisions of all procedures used in their jurisdiction.

2.3 Preparation

a. Responsible personnel with knowledge of the operations involved shall prepare the procedures.

b. All material called out in the procedure and operational steps shall be checked for compliance with the guidance in this Manual and other DOE directives that may be applicable per DOE O 440.1A.

c. The specific types of equipment and building or area in which the operation is to be conducted should be designated in the procedure, when applicable.

d. If similar operations in the same area involve differences in equipment or process, supplemental procedures or sections shall be written.

2.4 Approval

a. New or revised operating procedures shall be reviewed and approved prior to use. Each operating contractor should establish levels of approval required based on the operation's inherent risk. As a minimum, review and approval requirements shall include line and safety organizations.

b. Work control processes shall be in place prior to any operational activities.

2.5 Control

a. Distribution of procedures shall be controlled to ensure that each operating area has the most current revision. Superseded or inactive procedures shall be removed from operating areas. No operation shall be performed with superseded, inactive, or unapproved procedures.

b. Files of active procedures should be maintained.

2.6 Audits

a. An audit system should be established that will routinely evaluate the adequacy, availability, and currency of procedures. Also, audits should include an evaluation of operator knowledge and compliance with procedures.

b. Groups conducting the audits should include personnel from other than the operating department or division using the procedure.

2.7 Reviews

a. Appropriate departments should review active procedures at least annually.

b. If a procedure is no longer completely applicable to an operation or if new safety considerations (i.e., compatibility, toxicity, ignition sources, etc.) have been identified, the procedure shall be revised.

c. A procedure not expected to be used during the coming year may be placed in an inactive procedure file.

d. Before an inactive procedure can be reactivated, it shall be reviewed and approved. Minimum approval shall be the same as that required for a new or revised procedure (see section 2.4 of this chapter).

2.8 Content of Standard Operating Procedures

a. The following presentation is intended to specify content of procedures, not the format or organization. Each operating contractor should develop its own system for preparing safety procedures.

2.8.1 *General Operating Procedures*

a. Introduction. The introduction to the procedure should include the following:

(1) A statement of the scope, defining what facilities and equipment are covered.

(2) The name of the department and individual responsible for the operation.

(3) If the procedure serves as the basis for an exemption or waiver from the requirements of this Manual, a statement to this effect and a specific reference to the standard involved.

b. Safety and Health. The safety section of the procedure should present the following information or reference a safety manual that specifies the requirements:

(1) General safety rules to be observed and techniques to be applied that will ensure safety of operations, prevent personnel injury or illness, and prevent equipment damage. In particular, this SOP section should describe the facility's personnel control features that protect personnel from exposure to hazardous operations, toxic materials, or tests.

(2) The number of personnel (workers and casuals) and explosives weight limits.

(3) Additional or specific emergency controls not addressed by the facility emergency plan.

c. Operations. The operations section should consist of general directions for operation of all major explosives-handling equipment. Particular emphasis should be placed on safety interlocks and controls, and their proper use. If operation of a particular item of equipment or of an area requires that no other operation be performed simultaneously in the same area, this requirement shall be stated clearly in the procedure.

2.8.2 ***Unit Operating Procedures***

a. Introduction. The procedure introduction should include the following:

(1) A statement of the nature of the operation and its objectives.

(2) The name of the department responsible for the operation and the procedure.

(3) A description of the range of work the procedure authorizes.

(4) If the procedure serves as the basis for an exemption or waiver from the standards of this Manual, a statement to this effect and a specific reference to the standard involved.

b. Materials and Equipment. The materials and equipment section should present the following information:

(1) All significant tools, supplies, chemicals, and equipment necessary to perform the operation should be listed in the SOP or in a separate required document.

(2) Specifications for approved chemicals, supplies, tooling, and equipment should be referenced where applicable.

(3) An explanation of any specific hazard involved in the handling of chemicals or explosives, or a reference to a document that describes the hazards should be included.

c. Safety. The safety section should present the following information or reference a safety manual that specifies the requirements:

(1) Safety rules specific to the operation.

(2) Protective equipment that must be used during the operation.

(3) Emergency controls applicable to the operation not considered in the general operating procedures.

d. Operations. The operations section should consist of sequential directions written or pictured in clear, concise steps that describe how to perform a particular operation. If a particular operation requires that no other operation be performed simultaneously in the same work area, this requirement shall be stated clearly in the procedure.

2.9 Content of Special or Experimental Procedures

a. In addition to the applicable requirements listed in section 2.8 of this chapter, the following shall also be addressed:

(1) Field operations remote to normally occupied areas shall include procedures to ensure prompt response of both fire and medical emergency services or those services shall be staged at the event site.

(2) Personnel involved with the operation shall be briefed or trained on any unique aspects of the operation and emergency procedures.

b. When a special or experimental operation will be conducted a number of times, an SOP should be written and approved.

3.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in UXO operations.

(1) 60-Series Publications, Commanding Officer, Naval Explosive Ordnance Disposal Technology Division, 2008 Stump Neck Road, Indian Head, MD 20640-5070

(2) OE CX Interim Guidance, US Army Corps of Engineers, Huntsville Center, P.O. Box 1600, Huntsville, AL 35807-4301.

CHAPTER VIII—FORMULATION SCALEUP

1.0 EXPLOSIVES DEVELOPMENT PROGRAM

1.1 Explosives Development Committee

a. A committee shall be established at each DOE facility engaged in explosives development to be the approving authority for each phase of an explosives development program. This committee will be referred to in this Manual as the Explosives Development Committee (EDC), but it may have a different name at each DOE facility. Individuals chosen to serve on the EDC should have considerable experience in explosives handling, processing, chemistry, sensitivity, and safety.

1.2 Phase-by-Phase Approvals

a. The EDC shall review and approve data generated in each phase of a development project that involves a new explosive or new explosive formulation before the next phase begins.

1.3 Modified Formulations

a. Compositional modifications to previously evaluated explosive formulations shall be approved by the EDC. However, the EDC may approve minor modifications to the explosives formulation for a given phase of development without requiring all of the developmental steps and tests.

1.4 Sensitivity Data from Another Laboratory

a. If comparable sensitivity data for the subject material are available from another laboratory, the EDC may waive some developmental phase tests.

2.0 DEVELOPMENT PROCEDURES

2.1 General

a. All DOE explosives handling facilities shall establish an administrative procedure that defines the basic steps for developing and evaluating new explosives and explosive formulations. The procedure shall require that each development effort proceed in phases from small to large quantities. The quantities of materials that may be handled in each phase shall be limited. The EDC shall be responsible for establishing criteria for acceptable explosive behavior in each test of each phase of the explosives development procedure. The development procedure should consist of three phases plus a synthesis phase and compatibility testing, when required. Guidelines for establishing this procedure are proposed in the following sections. Table VIII-1 summarizes these guidelines.

2.2 Synthesis Phase

a. Before mixing a new explosive with other materials, the sensitivity and stability of the explosive should be determined and should comply with the criteria set by the EDC. Recommended tests include the following:

(1) Drop-weight impact.

(2) Friction.

(3) Spark.

(4) Thermal stability-these tests should include two or more of the following:

2.2.1.1 Differential thermal analysis or differential scanning calorimetry.

2.2.1.2 Thermal gravimetric analysis.

2.2.1.3 Gas evolution rate at elevated temperature (chemical reactivity test, vacuum stability, etc.).

2.2.1.4 Time-to-explosion analysis.

2.3 Compatibility Testing

a. If a proposed formulation contains new ingredients (explosive or nonexplosive), the new ingredients should be tested for compatibility with the other ingredients before preparing batches for Phase I testing. Compatibility tests should include any of the stability tests listed under section 2.2a(4) of this chapter.

b. No more than 2 g of the new formulation should be prepared, handled, or stored before compatibility testing.

c. Formulations for compatibility testing should be processed remotely, whenever possible.

Table VIII-1. Scaleup Procedure Guidelines for New Explosives and Formulations

Quantity of New Material[a]	Recommended Data[a]	Data Desired	Additional Recommendations
Synthesis			
Specified by the lab performing the synthesis	Impact, Friction, spark, thermal stability	Before using the new ingredient in a formulation	----
Formulation			
Compatibility Testing: 2g	Thermal compatibility of new ingredient with other ingredients of formulation	Before proceeding to Phase I	Materials should be processed remotely
Phase I			
10g	Impact, friction, thermal stability	Before nonremote processing and handling in Phase I or scaleup to Phase II	Materials should be processed remotely before passing sensitivity and stability tests
Phase II			
500g[b]	Compatibility,[c] impact, friction, spark, thermal stability, thermal characterization before elevated temperature pressing	[d, e]	[f]
Phase III			
Specified by EDC	Compatibility, high-speed machining, drop, skid	Before Phase III machining or handling of billets 7 kg or greater	Composition of formulation shall be fixed

[a] Quantities and recommended data apply to both new formulations and explosive ingredients.

[b] The EDC may allow more than 500 g in Phase II where larger quantities are needed for some tests.

[c] Compatibility of explosives and formulations with materials contacting the explosives in test and production assemblies.

[d] Before proceeding to Phase II if the composition of a formulation is modified so that the composition is no longer within the limits specified by the EDC.

[e] Before proceeding to Phase III if:

(1) The formulation to be scaled up to Phase III differs from that tested in Phase I, or

(2) The explosive or formulation prepared for Phase II development is produced by techniques different from those used in Phase I.

[f] Materials investigated in this phase should be produced by techniques similar to those that will be used to produce larger batches in a subsequent phase.

2.4 Phase I—Preliminary Explosives Testing

a. The total quantity of material that may be processed, handled, or stored at any one time in Phase I should not exceed 10 g. Whenever possible, this material should be processed remotely.

b. The new explosive or formulation should be subjected to sensitivity and stability tests. As a minimum, drop-weight impact, friction, spark sensitivity, and thermal stability tests should be run. Thermal stability testing need not be performed here if one or more of the compatibility tests listed under section 2.2a(4) of this chapter have already been conducted on the new formulation.

c. If the new explosive or formulation is acceptable in the above tests, it may be scaled up to Phase II. The EDC may impose handling or processing restrictions or precautions on the material if its performance in any of the above tests is questionable.

d. After Phase I testing of a formulation is complete, the EDC should define, on the basis of the test results, what variations in composition are permissible during Phase II development without retesting.

2.5 Phase II—Experimental Characterization and Development

a. The total quantity of materials that may be processed or handled at any one time in Phase II should not exceed 16.075 oz (500 grams). No limit exists on the quantity that may be stored, other than the storage facility limits for Group L explosives.

b. Materials investigated in Phase II should be produced by techniques similar to those that will be used to produce larger batches in a subsequent scaleup phase.

c. A thermal characterization test and evaluation should be run before pressing the new material at elevated temperature.

d. The Phase I sensitivity and stability tests should be rerun in Phase II if the following conditions apply:

(1) The formulation to be scaled up to Phase III differs from that tested in Phase I. In this case, testing should be completed before Phase III scaleup.

(2) The explosive or formulation prepared for Phase II development is produced by techniques different than those used in Phase I. Testing should be completed before Phase III scaleup.

(3) During Phase II, the composition of a formulation is modified to an extent that the composition is no longer within the limits specified by the EDC, (see section 2.4d of this chapter). Testing should be completed before proceeding with Phase II.

(4) The compatibility of explosives and formulations with materials contacting the explosives in test and production devices shall be evaluated before any such device is assembled. If compatibility testing is required, one or more of the tests listed under section 2.2a(4) of this chapter should be recommended.

2.6 Phase III – Full-Scale Testing and Production

a. The maximum quantity of materials that may be processed or handled in Phase III should be defined in the EDC grant of authorization to proceed with Phase III. No limit is imposed for the storage facilities except the limits imposed by the quantity-distance tables.

b. All additional testing necessary to define storage compatibility grouping should be completed before committing bulk quantities of the material to storage, (see Chapter II, section 17.4).

c. During Phase III development, the composition of all formulations should be fixed.

d. Any new explosive material that is to be contact machined shall be subjected to a machining overtest. Reaction threshold should be determined if possible.

e. If billets of 15.4 lb (7 kg) or greater are to be produced in Phase III, drop-skid testing should be performed and EDC criteria for this test should be met.

f. Section 2.5d of this chapter should also apply to Phase III development.

CHAPTER IX—INSENSITIVE HIGH EXPLOSIVES QUALIFICATION

1.0 INSENSITIVE HIGH EXPLOSIVES (IHE)

a. Some explosive substances, although mass detonating, are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. Any explosive that is a candidate for classification as an IHE shall be subjected to the DOE qualification tests listed in Table IX-1or Recommendations on the Transport of Hazardous Goods-Tests and Criteria, Test Series 7. Test procedures, where not specified, are contained in MHSMP-84-22*, IHE Material Qualification Tests, Description and Criteria*. The DOE laboratory or contractor shall submit test data for each explosive requested for this classification through the appropriate Operations Office to the DOE Office of Facility Safety. The DOE Explosives Safety Committee will independently analyze the data and recommend action on including the explosive in Table IX-2 as an approved IHE.

Table IX-1. DOE IHE Qualification Tests.

1. Drop-weight impact test[a]	Comparable to or less sensitive than Explosive D (ammonium picrate). Minimum of 20 drops per test series.
2. Friction test[b]	No reaction on Pantex friction machine (10 trials).
3. Spark test[a]	No reaction at minimum of 0.25 joules (10 trials)
4. Ignition and unconfined burning test (small scale burn)	TB 700-2 test procedures, any shape, minimum thermal path of 25 mm, no explosion.
5. Card gap test[b]	No reaction at Explosive D 50 percent gap thickness (or less) using a Pantex modified NOL card gap test (6 trials). The test diameter must be greater than the unconfined failure (critical) diameter of the candidate IHE.
6. Detonation (cap) test	TB 700-2 test procedures—no detonation (5 trials).
7. Cookoff	No reaction of more than a pressure release using the large-scale ODTX test conducted such that a reaction must occur in not less than 4 hours (6 trials).
8. Spigot test[b]	No reaction for 120-ft drop in LANL test (3 trials).
9. Skid test[b]	No reaction up to 20-ft (or sample failure) drop at 14-15 degrees test angle using standard size billets (3 trials at worst case condition).
10. Susan test	Less than or equal to 10 percent TNT output at a minimum of 333 m/sec (3 trials).
11. Bullet impact	No violent reaction with 5.56 mm and .50 cal. projectile impact on material in schedule 40 steel pipe with closures on each end (6 trials in axial orientation).

[a] These tests are not applicable to compacted explosives
[b] These tests are not applicable for explosives powders.

Table IX-2. Approved IHEs

TATB
TATB/KEL-F Formulations

b. New candidate explosives formulations will not be classified by analogy as IHE until reviewed by the DOE Explosives Safety Committee. The general guidelines for requesting and obtaining an IHE approval by analogy are:

(1) All requests, including rationale, must be submitted in writing to the DOE Explosives Safety Committee for analysis and recommended action.

(2) Approved IHEs with complete test data must be used for baseline comparison purposes.

c. More specific guidelines will depend on circumstances surrounding the specific analogy request.

d. When a partial analogy can be drawn, only partial testing is needed depending on the type and extent of change in the candidate IHE relative to the baseline IHE and the potential effects of these changes on specific initiation mechanisms (shock, thermal, mechanical, impact, electrostatic, etc.). A candidate IHE can be placed in one of the following categories to define the tests required for approval:

(1) CASE I (partial testing required). The candidate IHE formulation substitution of the inert binder component of the approved baseline IHE with a new inert binder component. Sufficient testing is required to verify that no chemical incompatibilities have been introduced that would de-stabilize the base IHE. In this case, test data normally generated by the requesting facility during their explosive development scaleup phasing process may be submitted for approval in lieu of the qualification tests of Table IX-1. During the development phase, the facility EDC may dictate restrictions consistent with an IHE internal to their facility only. Final approval as an IHE must be obtained through the DOE Explosives Safety Committee. Tests 1, 2, 3, and 7 of Table IX-1or equivalent are required as a minimum.

(2) CASE II (all IHE tests of Table IX-1 required; analogy inappropriate). The candidate IHE involves the addition of an

untested (IHE tests) energetic component to the approved baseline IHE.

OR

(3) The candidate IHE involves the same energetic and inert components as the approved baseline IHE, the only change being a volume- percent increase in the energetic component content.

e. In deliberating the approval request, the DOE Explosives Safety Committee will consider any data available over and above that required by Table IX-1.

2.0 IHE SUBASSEMBLIES

a. IHE Subassemblies are composed of IHE hemispheres or spheres with booster charges, with or without detonators. Successful completion of the applicable DOE qualification tests listed in Table IX-3 is required for classification as an IHE subassembly. The DOE contractor shall submit a test plan defining specific test procedures for candidates for this classification through the appropriate Site Office to the DOE Explosives Safety Committee for review. On approval of the plan, tests shall be run and the DOE Explosives Safety Committee shall independently analyze the data and recommend approval or disapproval. DOE Headquarters will then issue a memorandum to appropriate Site Offices and DOE contractors classifying those configurations meeting the required test criteria as IHE subassemblies. Approved IHE subassemblies are listed in Table IX-4. Subassemblies will not be classified as IHE Subassemblies by analogy until reviewed by the DOE Explosives Safety Committee. When no other explosives are present in the same location, these subassemblies are classified as Class 1.6 explosives (see Table IX-5) for storage and processing.

Table IX-3. DOE Qualification Tests for IHE Subassemblies*

1. Spigot test	No burning or violent reaction of main charge of 120-ft drop on booster in LANL test (3 trials).
2. Bonfire	No detonation or violent reaction of main charge when engulfed in a fire (3 trials).
3. Slow cookoff	No detonation or violent reaction of main charge when slowly heated to a reaction (3 trials).
4. Multiple bullet impact	No detonation or violent reaction of main charge with a 3-round burst of 7.62 mm projectile impact on booster (3 trials).
5. Skid test	No burning or violent reaction of main charge up to a 20-ft (or sample failure) drop at 14 to 15 degrees test angle using subassembly configuration modified for impact on the booster (3 trials at worst case condition).

* Tests are not required for subassemblies when main charge and booster charge explosives have been qualified as IHE by tests in Table IX-1.

Note: The test plan shall specify applicable testing for cased and/or uncased configurations with or without detonators.

Table IX-4. Approved IHE Subassemblies

B61*3/4/6/7/8/10/11	W80*	W81*	B83*
W84	W87	W89	

*Approval limited to boosters of the size tested or smaller. Any redesign that dimensionally increases the booster size requires resubmission of an experimental plan and additional testing as another IHE subassembly.

Table IX-5. IHE Hazard Classification

IHE bulk powder (onsite)	1.3C
IHE consolidated charges w/o boosters or dets	1.6N
IHE nuclear explosive assemblies and subassemblies with boosters, with or without dets	1.6N
IHE articles with 1.1 items	1.1
IHE articles with 1.2 items	1.2
IHE articles with 1.3 items	Note 2
IHE articles with 1.4 items	1.6N
IHE articles at less than magazine distance from Division 1.1	1.1
IHE articles at less than magazine distance from Division 1.2	1.2

Note 1 IHE can be stored with mock HE without regard to the quantity of mock high explosives unless the mock explosive is a flammable solid (hazard division 4.1).
Note 2 Division 1.3 or 1.6, whichever is most restrictive.

3.0 IHE WEAPONS

a. IHE weapons are those weapons listed in DOE DNA TP 20-7 that are exempt from storage and transportation limits when stored or transported alone or in combination with each other. This classification is valid only if storage containers provide adequate spacing between individual units. TP 20-7 specifies the spacing requirements for materials stored or transported out of containers. These weapons are classified as Class 1.6 explosives for storage, processing and transportation purposes.

4.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in the IHE and IHE subassembly testing required by Table IX-1and Table IX-3:

(1) TB 700-2, NAVSEA INST 8020.8A, TO 11A-1-47, DLAR 8220.1, *Department of Defense Explosives Hazard Classification Procedures,* Departments of the Army, the Navy, the Air Force, and the Defense Logistics Agency, Washington, D.C.

(2) Mason & Hanger-Silas Mason Publication 84-22 (MHSMP-84-22), *IHE Material Qualification Tests, Description and Criteria* (Rev 1, July 1985), National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

(3) *Recommendations on the Transport of Hazardous Goods-Tests and Criteria*, Second Edition, ST/SG/AC.10/11/Rev.1, LABELMASTER, Chicago, IL, 60646 USA.

(4) Mason & Hanger-Silas Mason Publication (MHSMP-86-16)*, IHE Subassembly Test Results for the B-83, B-61, 3/4/6/7/8, W80, W81, and W85*, June 1996, Robert S. Slape, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

CHAPTER X—ELECTRICAL STORMS AND LIGHTING PROTECTION

1.0 ELECTRICAL STORM HAZARDS

a. The primary focus of this chapter is to provide protection to explosives in event of an electrical storm, and to personnel working in explosives areas, and personnel near those explosives areas from the consequences of an explosives incident resulting from a lightning strike. Lightning presents a hazard to explosives in at least five ways:

(1) The electrical current produced by a voltage gradient resulting from a lightning strike could initiate the explosives directly.

(2) The surface flashover or arcing of the generated electrical current between conductive surfaces that are not at equilibrium could initiate the explosives directly by the heat, sparks, and molten metal generated by the arc.

(3) This same arcing could cause damage or fires in electrical fixtures and equipment.

(4) The lightning could initiate a fire involving combustible materials in the facility, including the containers around explosives.

(5) The spalling generated by the heat of the current flowing through the structural components of the facility could initiate, by impact, unprotected explosives. In addition, lightning could affect support systems such as fire protection and security. Lightning can reach a structure not only by direct strike, but also indirectly by coupling to a conductor that penetrates the structure.

b. This chapter summarizes the minimum requirements for design, maintenance, testing, and inspection of lightning protection systems (LPSs) and lightning detection systems. Only lightning protection systems described in this chapter shall be used. The DOE Explosives Safety Committee must specifically approve use of non-conventional systems, such as streamer emission and charge dissipation systems. Protection from lightning induced hazards can best be achieved by enclosing the explosives in an interconnected network of good conductors, such that the exterior fields, currents, and voltages are reduced. This method of protection is similar to a Faraday cage and is called a “Faraday-like shield” LPS. A second method or layer of protection is achieved by providing a sufficiently large sideflash separation (standoff) distance between the explosives and any electrical conductor within

the structure (including the walls and ceiling) to preclude the possibility of current flowing onto the explosives or arcing to them. (Note: As part of the Faraday-like shield LPS, a minimum sideflash separation distance is required from the boundaries of the structure.) A third method involves directing the current away from the structure and directly to ground by use of air terminals, masts or catenaries, and down conductors. When none of the above methods of lightning protection are provided, personnel can be protected by evacuating them an appropriate distance as specified in section 6.0 of this chapter.

c. Facilities have five years from the issuance of DOE M 440.1-1A (Revision 9) of this Manual to fully implement for existing structures those requirements and recommendations of sections 2.0 through 4.0 that were not contained in Revision 8 of this Manual or NFPA 780. Neither waivers nor exemptions are required for such items during the implementation period. New structures and conversion of an LPS to a Faraday cage-style shield shall comply with the most current requirements.

2.0 LIGHTNING PROTECTION SYSTEMS

a. A properly designed and installed lightning protection system (LPS) meeting the requirements below and maintained per section 3.0 is required for all explosives structures except as identified in section 4.0.

2.1 Lightning Protection System Basic Design

a. Lightning protection system design consists of the use of strike termination means, low impedance paths to ground, and earth electrode systems, coupled with bonding of all conductive penetrations into the protected area, surge suppression, and sideflash protection. Metallic elements of the structure meeting the material requirements of NFPA 780 are allowed to serve as strike termination devices, down conductors, or parts of the earth electrode system. Facility Management, the Authority Having Jurisdiction, and a person competent in lightning protection system theory and design shall approve design variations from those specified below.

b. Design of lightning protection systems per NFPA 780 shall be based on a 100-ft (30.5-m) striking distance ("Rolling Sphere"). The zone of protection provided by an LPS is the space beneath the LPS that is substantially immune to direct lightning attachment. The LPS design shall ensure that explosives facilities and their associated components that require lightning protection are within the LPS zone of protection. Structural elements of the building meeting the material requirements of NFPA 780 are authorized to serve as the LPS or parts of the LPS.

c. Design parameters for a Faraday cage and Faraday shield-like LPS shall be based, as a minimum, on a one percent threat level and include the following:

(1) Return stroke amplitude = 200 kA

(2) Rise rate = 400 kA/μsec

(3) Number of strokes per flash = 26 max

(4) Striking Distance = 30.5 m (100 ft)

(5) Burn through of 0.19 in. (4.8 mm) for steel, 0.20 in. (5 mm) for copper, and 0.28 in. (7 mm) for aluminum.

(6) Action = $3x10^6$ $amps^2$-sec.

2.2 Lightning Protection Subsystems

a. An approved LPS consists of the following subsystems:

(1) A strike termination device to intercept the direct attachment of a lightning flash and connects it to a path to ground. A strike termination device may include metal masts, air terminals, overhead wires (catenary) or permanent metal parts of a building.

(2) Down conductors to interconnect the strike termination devices and form paths from each strike termination device to the earth electrode system (e.g., heavy metallic cables, metallic building structural members).

(3) An earth electrode system to transfer lightning current to the earth. The earth electrode system is connected to the down conductor and is in direct contact with the earth. Examples of earth electrode systems include ground rods, a ground ring (counterpoise), buried metal plates, and an Ufer ground or other similar devices.

(4) Surge suppression devices (SSDs) to limit harmful energy due to lightning or power line transients from entering a structure via power and metallic signal lines and initiating an explosion or fire. SSD attenuates, suppresses or diverts lightning induced electrical energy to the earth electrode system.

2.3 Approved Lightning Protection Systems

a. The approved types of LPS are Mast, Catenary, Integral Air Terminal, and Faraday cage or Faraday-like shield systems. Faraday cage or Faraday-like shield systems are preferred for new structures where applicable. The main features of each type system are summarized below.

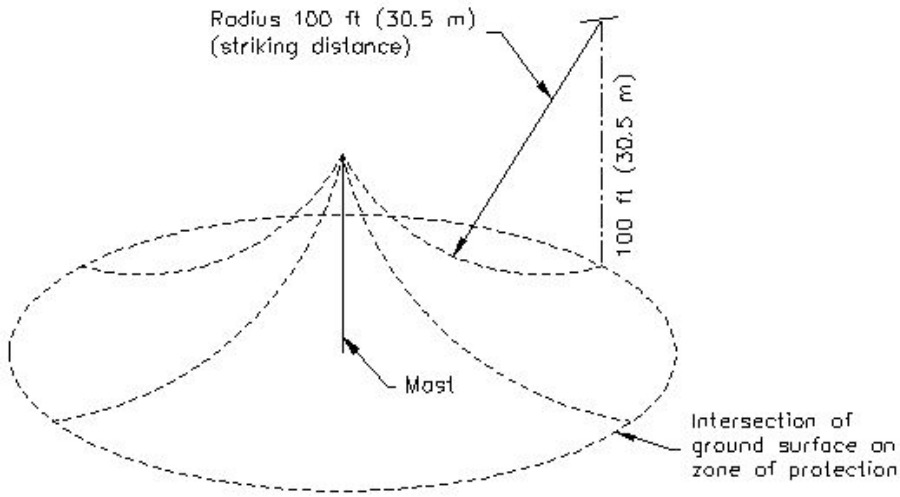
2.3.1 *Mast System*

a. A Mast System consists of one or more poles with a strike termination device connected to an earth electrode system by down conductors. It provides a zone of protection as shown in Figure X-1 for a single mast. The principal design parameters include:

(1) The minimum mast separation distance from the structure is 6 ft (1.8 m) or the formula as defined in NFPA 780 (2004), D = h/6, whichever is greater where the h is the height of the mast of structure considered.

(2) Non-metallic masts require a metal air terminal or metal cap installed at the top that is connected to the earth electrode system by at least two down conductors installed on opposite sides of the mast. (Note: Mast guy wires are allowed to serve as down conductors, provided they are connected to the earth electrode system.

(3) Metallic masts serve as both air terminal and down conductors, and will be connected to the earth electrode system with two independent main size conductors attached approximately symmetrically to (i.e., opposite sides of) the mast base.



Note: Dashed lines define the Zone of Protection

Figure X-1. Single Mast Zone of Protection

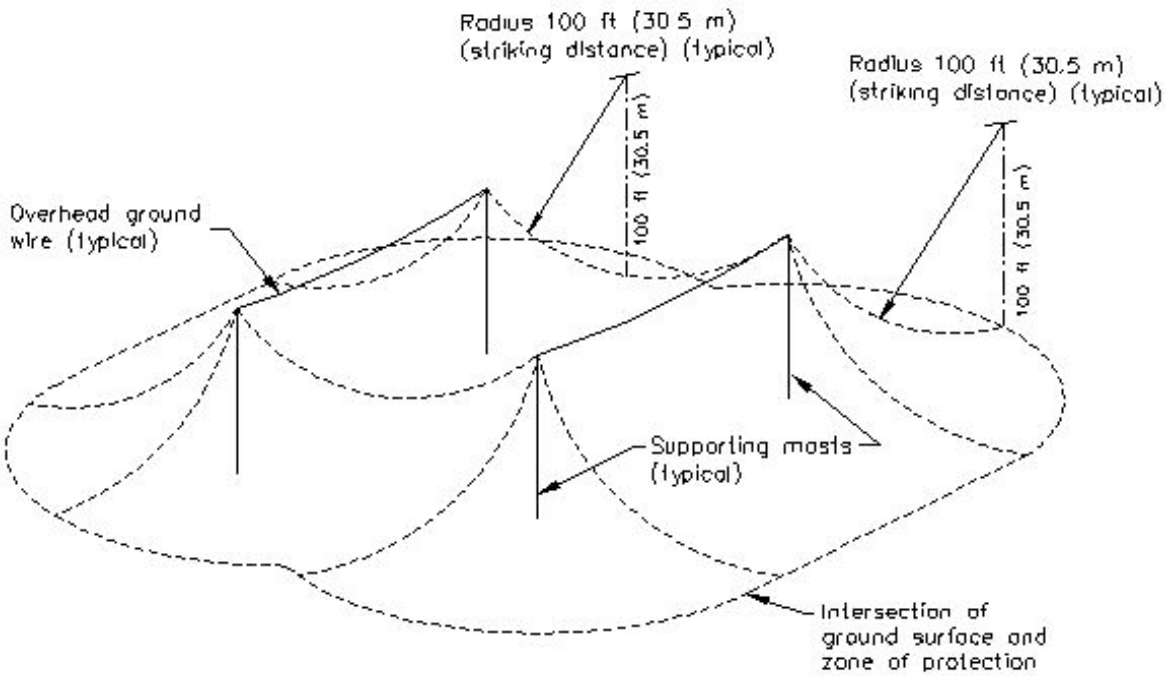
2.3.2 ***Catenary System***

a. The Catenary LPS consists of wires (cables) stretched between the tops of two or more masts (see Figure X-2). The main design parameters include:

(1) Each wire shall be an electrically continuous run of main size conductor [e.g., copper-clad or galvanized steel cable with a minimum diameter of 0.25 in. (6.4 mm)] bonded to all down conductors.

(2) Non-metallic masts require a metal air terminal or metal cap installed at the top that is connected to the earth electrode system by at least two down conductors installed on opposite sides of the mast. (Note: Mast guy wires are allowed to serve as down conductors, provided they are connected to the earth electrode system.)

(3) Metallic masts serve as both air terminal and down conductors themselves, and shall be connected to the earth electrode system by two main size conductors attached approximately symmetrically to (i.e., opposite sides of) the mast base.



Note: Dashed lines define the Zone of Protection

Figure X-2. Example of Catenary System Zone of Protection

(4) The minimum vertical separation between an overhead wire and the protected structure, including its projections, shall be the greater of 6 ft (1.8 m) or as defined in NFPA 780 (2004), as D = (L/6n).

Where:

D = Sideflash distance from a catenary

L = Length of lightning protection conductor between its grounded point and the point being calculated.

n = 1.00 where there is a single overhead ground wire that exceeds 200 ft (60 m) in horizontal length.

n = 1.50 where there is a single overhead wire or more than one wire interconnected above the structure to be protected, such that only two down conductors are located greater than 20 ft (6 m) and less than 100 ft (30 m) apart.

n = 2.25 where there are more than two dozen conductors spaced more than 25 ft (7.6 m) apart within a 100-ft- (30-m-) wide

area that are interconnected above the structure being protected.

(5) Deflections of the wire resulting from wind, ice, or other weather conditions shall be considered in determining the separation distance. The supporting mast will be at least 6 ft (1.8 m) from the structure.

2.3.3 *Integral Air Terminal System*

a. An integral LPS is one that has the strike termination devices mounted on the structure to be protected. These strike termination devices are connected to the earth electrode system via down conductors. Metallic structural members can serve as parts of the LPS. However, sideflash protection is required. (See bonding distance formula in NFPA 780). An example of this system is shown in Figure X-3. The relevant design parameters are:

(1) The down conductors of integral systems shall be installed in as nearly a vertical position as possible.

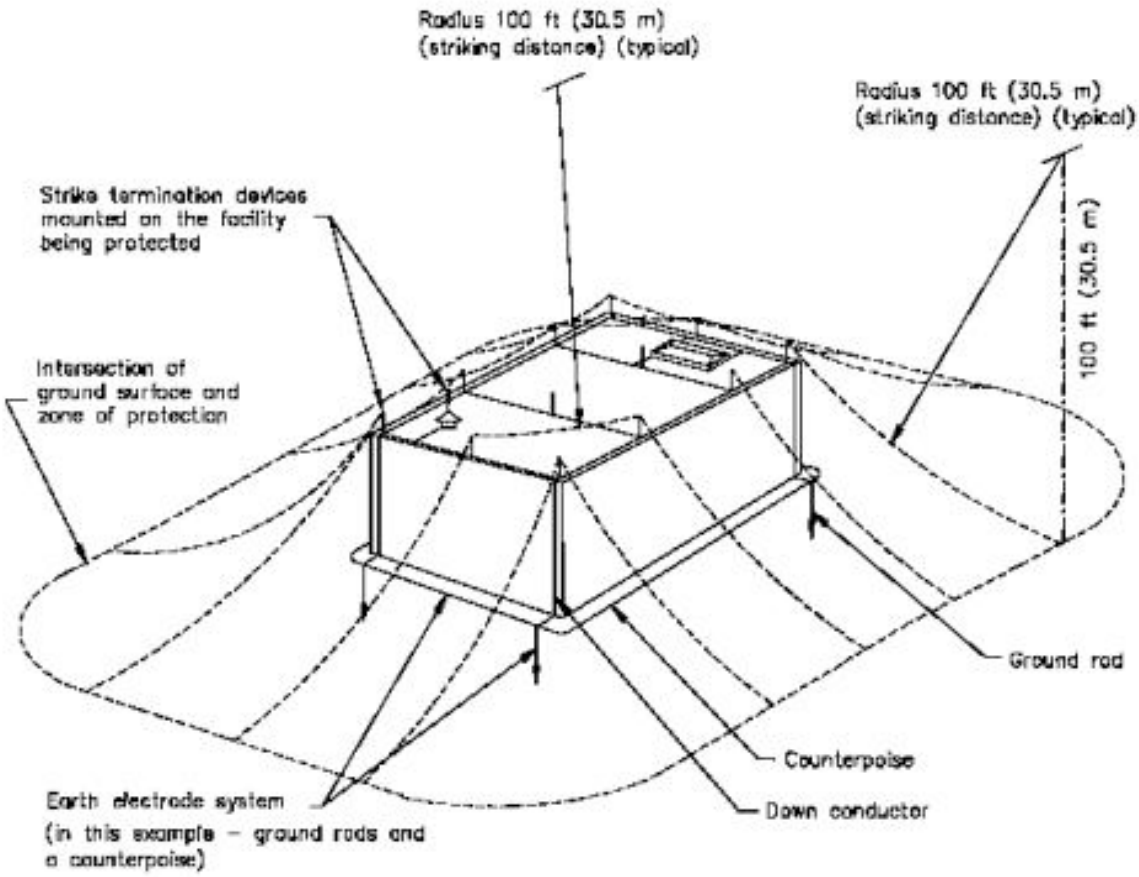
(2) No bend of a conductor shall form an included angle of less than 90 degrees, nor shall it have a radius of bend less than 8 in. (203 mm).

(3) The number of conductors, and configuration of the connections between air terminals, are as required by NFPA 780.

(4) Air terminals height and location are as required by NFPA 780.

2.3.4 *Faraday Cage and Faraday-like Shield*

a. The preferred method of protecting explosives operations from lightning flashes, as well as from other external sources of electromagnetic radiation, is to enclose the operations or facility inside a Faraday cage. A Faraday cage is an enclosure composed of a continuous grid of conductors, such that the voltage between any two points inside the enclosure is zero, when immersed in an electrostatic field. A Faraday cage or Faraday-like shield LPS is one where the protected volume is enclosed by a heavy metal screen (i.e., similar to a birdcage) or continuous metallic structure with all metallic penetrations bonded. The lightning current flows on the exterior of the structure not through the interior. A Faraday-like shield (which is not an ideal Faraday cage) is formed by a continuous conductive matrix that is properly bonded and grounded.



Notes:

1. The design of integral air termination systems will be in accordance with NFPA 780.
2. The design of the earth electrode system will be governed primarily by soil conditions at the site and the actions needed to meet required minimum resistance-to-earth values.
3. Solid lines indicate conductors connecting air terminals on the roof, down conductors, and the grounding system.
4. Dashed lines define the Zone of Protection.

Figure X-3. Integral System Zone of Protection

(1) Examples of Faraday-like shields include:

(a) Steel arch magazines where the steel arches and reinforcing bars (rebar) of the concrete end-walls and floor are electrically continuous and meet spacing requirements.

(b) Earth covered magazines and operating buildings where the reinforcing bars (rebar) of the concrete

walls, floors, and ceiling are electrically continuous and meet spacing requirements.

(c) Reinforced concrete buildings where the reinforcing bars (rebar) of the concrete walls, ceiling, and floor of are electrically continuous and meet spacing requirements.

(d) The metal shell of prefabricated portable magazines and metal buildings.

(2) The main design parameters are:

(a) The structural components of buildings shall be electrically bonded together (i.e., walls, floor, roof, door and window frames) via built in attachments such as rebar welded or wired together, or by adding external bonding wires between components. The techniques commonly used and approved in the construction industry are acceptable for this purpose. (If welds are used, a structural engineer should verify that they do not adversely affect structural response).

(b) The structural components should be electrically bonded at intervals no greater than 3 ft unless testing shows otherwise. Bonding distances may vary based on building design. Use of greater than the nominal bonding distance requires an electromagnetic characterization of the building's transfer impedance to determine the specific bonding distances.

(c) A freestanding structure that is determined by a competent expert to be a Faraday cage or Faraday-like Shield may not require strike termination devices, down conductors or grounding systems. Structures that satisfy the Faraday cage/Shield definition have suitable down conductors and grounding components within the structure's design. However, use of a strike termination device on these structures provides a preferred point of attachment for lightning and could prevent structural damage, such as concrete spall, in the event of a direct lightning strike attachment).

2.4 Lightning Protection Subsystem Criteria

2.4.1 *Components of Strike Termination System*

a. Air Terminal: An air terminal is the component of an LPS used to intercept lightning strikes. Air terminals include vertical spikes attached to the structure (commonly referred to as Franklin Rods), overhead wires (as used with catenary systems) or grids, and for earth covered magazines only, overhead air vents.

(1) When used as air terminals, air vents shall be (a) fabricated from metal 3/16-in. (4.8-mm) thick or greater and be electrically continuous with the steel reinforcing rod of the magazine or (b) designed to trap any molten metal a strike might produce. In all cases air vents on earth covered magazines shall be bonded to the structure as discussed in section 2.4.3.

(2) On structures modified to a verified Faraday-like shield LPS where an NFPA 780 LPS system exists, it is recommended that air terminals be maintained as they provide a preferred point of attachment for lightning strikes. If they are bonded to the Faraday cage, conductive downlines need only be maintained and visibly inspected to the point of juncture with the grounding system (i.e., ground rods or counterpoises). When Facility Management makes the determination that the NFPA 780 system will be retained, a visible inspection shall be performed on the same schedule as maintenance of the Faraday-like shield LPS. Electrical resistance and resistance to earth testing will not be required.

(3) Air terminals on an integral LPS shall consist of a cylindrical rod or tube of material and size as specified in NFPA 780. They can be pointed or blunt, but the optimal tip radius of curvature for interception of lightning strikes is 3/16 in. (4.8 mm) minimum to 1/2 in. (12.7 mm) maximum.

b. Conductors: Conductors provide low impedance paths from air terminals to the earth electrode system.

(1) Where wires are used as down conductors, they shall meet the requirements of NFPA 780.

(2) Lightning conductors should run vertical or horizontal. If run upwards, they must have a rise of no more than 1/4 pitch.

(3) In a Faraday cage based LPS, the structural elements have a higher current carrying capacity and lower impedance to ground than wire down conductors. Structures with such an LPS do not require wire down conductors. When a structure with an existing air terminal LPS is modified to a verified Faraday cage based LPS, it is recommended air terminals be maintained as they provide a preferred point of attachment. If they are bonded to the Faraday cage, conductive downlines need only be maintained and visibly inspected to the point of juncture with the grounding system (i.e., ground rods or counterpoises). When Facility Management makes the determination that the NFPA 780 system will be retained, a visible inspection shall be performed on the same schedule as maintenance on the Faraday-like shield LPS. Electrical resistance and resistance to earth testing will not be required.

2.4.2 ***Grounding***

a. Lightning protection systems, to include integral and catenary systems, but with the exception of Faraday cage or Faraday-like Shield systems, require an earth electrode (ground) system to dissipate the electrical energy of a lightning strike to the earth. The use of an earth electrode systems with a Faraday-like shield lightning protection system is not required as the floor of such a structure acts as the earth (ground) electrode; however, electrical safety grounding requirements do apply. Examples of earth electrode systems include ground rods, a ring electrode (counterpoise) system, buried metal plates, or Ufer grounds.

(1) The resistance of a lightning protection grounding system will not exceed that specified in section 3.0 below.

(2) When multiple ground rods are used as a grounding system, the rods will be separated by a distance so that they do not influence each other.

(3) All other grounding systems, e.g., AC power, electronic multi-point, electronic single-point, will be bonded to the lightning protection grounding system.

(4) In cases where some other installed system requires a lower resistance to ground than specified in section 3.0 below, the lower requirement will govern.

(5) See the following documents for specific guidance:

(a) National Electric Code, Article 250, Grounding

(b) IEEE 80, Guide for Safety in AC Substation Grounding

(c) NFPA 780 Standard for the Installation of Lightning Protection Systems

2.4.3 ***Bonding***

a. Bonding provides a physical and electrical connection from all parts of the LPS to the ground connection. Bonding produces electrical continuity between the LPS and metallic objects to minimize potential differences. Methods of bonding include mechanical, compression and thermal connections.

(1) NFPA 780 requirements for bonding to the LPS that specifically need to be addressed include:

(a) Metallic gates and fences if they cross or are within sideflash distance of a LPS or are within 6 ft (1.8 m) of an explosives structure.

(b) Railroad tracks if they cross or come with in sideflash distance or 6 ft of an explosives structure's LPS or enter an explosives structure. If the tracks are used to carry electrical signals, they should have insulated joints immediately external to the bond of the LPS ground loop conductor. If the tracks enter an explosives structure, they also should be bonded to the metal frame of the structure or equivalent.

(c) All shielded cabling, power cabling, communication lines, data lines, and electrical conduit will be buried underground in conduit for a minimum of 50 ft (15.2 m) before entering the structure. These and other metallic utility lines and pipes will be electrically bonded to the LPS or the structural steel of the building as close as reasonably achievable, as determined by a competent expert, to the point of entry.

(d) Metallic penetrations within the zone of protection that are within sideflash distance of a component of the LPS or within sideflash distance of an item that is bonded to the LPS.

(e) Utilities (gas, water, power, signal) entering the structure from exterior to the LPS. (Apply

NFPA cathodic protection guidance to prevent excessive corrosion.)

(f) Potential presence of ground loops.

b. All metallic penetrations into a Faraday cage or shield shall be bonded to the nearest structural member or LPS component that is integrally bonded to the earth (ground) electrode system. Bonding connections shall be as close to the point of entry as reasonably achievable. More than one bond may be required in some situations where a conductive penetration passes a structural member inside the structure. The bond resistance should be less than that specified in section 3.3.

c. Other metal masses that are integrated into the structure of the building (e.g., ventilators, steel doors, metal doorframes, steel reinforcing bars, etc.) shall be bonded to the nearest structural member or LPS component that is integrally bonded to the earth (ground) electrode system. Interior metal masses (desks, cabinets, etc) should be bonded if required by the competent expert.

d. Lightning protection system bonds should be as short and as direct as reasonably achievable to minimize inductance. Route the bonds as close to the rebar as reasonably achievable.

e. To preclude confusion between LPS bonding and electrical safety grounding, the following key differences should be understood:

(1) Lightning bonds must be as specified in NFPA 780 Table 3.1 or equivalent.

(2) Lightning clamps and fasteners must comply with UL-96 and UL-96A, and be listed for use with LPS.

f. Do not paint LPS bonds and conductors.

g. Bond resistance shall be as specified in section 3.3.

2.4.4 ***Surge Suppression for Incoming Conductors***

a. Surge suppression devices shall be provided in accordance with NFPA and the provisions of this Manual on each power line, signal line, or communication line conductor entering the LPS protected structure. They shall be located between the respective conductor and the structure ground and/or Faraday cage, as close as reasonably achievable to the point where the conductor penetrates the LPS zone of protection or the structure. All cabling, power cabling, communication lines, data lines, and electrical conduit shall be buried underground in metallic conduit for a minimum of 50 ft (15.2 m)

before entering an explosives structure. These and other metallic utility lines and pipes shall be electrically bonded to the LPS or structural steel of the building as close as reasonably achievable to their entry point.

b. Surge suppression designed for specific equipment does not necessarily provide adequate protection for an explosives structure. It is the responsibility of the Facility Management to provide additional surge and/or transient protection for sensitive equipment located in and about the structure. This additional protection may or may not be incorporated in a surge suppression device. If it is incorporated, the additional protection shall not decrease or compromise the protection intended by this Manual.

(1) All lightning protection systems shall include surge suppression for all incoming metallic power, communications, instrumentation lines, and other electrical conductors, including low voltage lines or extensions, in addition to any NEC requirements for surge suppression.

(2) Conductors leading from the surge suppression devices shall be kept separated from conductors leading to the surge suppression device. All leads will be as short as reasonably achievable. (Note: Coupling mechanisms include inductive, capacitive and breakdown. Refer to IEEE 1100-1999, *Recommended Practice for Powering and Grounding Sensitive Electronic Equipment* [Emerald Book] for location, sizing requirements and installation details).

(3) Surge suppression devices should be located as close as reasonably achievable to the panel. For new structures, the panel shall be located as close as reasonably achievable to the area being protected.

2.4.5 *Sideflash (Arcing) Protection*

a. Sideflash is an electrical spark caused by differences of potential that occurs between conductive metal bodies or between conductive metal bodies and a component of the LPS or earth electrode system. Sideflash presents direct and indirect hazards to explosives and hazardous environments. The direct hazard is the electrical energy transferred from the structure or its LPS to the explosives. Indirect hazards are the heat and the electromagnetic fields generated by the electrical energy. The heat can cause concrete to spall or ignition of combustible materials. Electromagnetic fields could induce electrical currents on or in the explosives. To prevent unintentional initiation

of explosives by either the direct or the indirect effects of sideflash, protection should be provided explosives unless analysis of operations shows otherwise. Separating the explosives from the LPS, or the walls and conductive penetrations of the structures provides protection against consequences of sideflash. Appropriate separation (standoff) distances shall be determined and applied for each structure by Facility Management based on the following:

(1) NFPA 780 shall be used to determine sideflash protection for all structures other than those with a Faraday-like shield LPS.

(2) For Faraday-like shield structures, in general, explosives and dunnage should be in contact with no more than one interior surface, and shall not be closer than the distance calculated using transfer impedance analysis and a safety factor of two from any other interior surface. This contact surface is normally the floor, shelf, or workbench.

(3) Sideflash separation distance shall be applied as given below:

(a) All sideflash separation distances shall be measured from the outermost surface of the container, packing, device or equipment holding the explosive that is nearest the structural surface, penetration, or penetration extension in question. Measure from the surface of the explosive itself only when the explosive is bare.

(b) When sideflash separation distance from structural elements and penetrations is maintained, wooden boxes, fiberboard drums, and metal outer containers provide adequate protection from effects of lightning current flow. Sideflash separation distances do not apply to separation between containers of explosives. Containers are authorized to be in direct contact with each other.

3.0 INSPECTION AND TESTING OF LIGHTNING PROTECTION SYSTEMS

3.1 Initial Installation or Approval

3.1.1 *Structures with Catenary, Integral, or Mast Lightning Protection Systems.*

a. Structures shall be inspected to determine that:

(1) The LPS complies with the current requirements of NFPA 780 Chapter 3, Chapter 6, Appendix B, and Appendix K.

(2) All required bonds are in place and secure.

(3) Surge suppression devices are installed and functional, as required in section 2.4.4 of this chapter.

b. The resistance of each required bond and the earth electrode system shall be tested to ensure that they meet the requirements of section 3.3.1 of this chapter.

3.1.2 *Structures with Faraday-like Shield Lightning Protection System*

a. Proper bonding or electrical continuity of the structure's walls, ceiling, and floor shall be validated by measuring the transfer impedance versus the frequency using an appropriate test instrument approved per section 3.3.3 of this chapter.

b. Proper bonding of all conductive penetrations as required in section 2.4.3 of this chapter shall be validated through inspection of building documentation and specifications, inspection of the facility, and by the use of resistance readings, as specified in section 3.3.2 of this chapter, or other instrument approved by a competent expert and the Authority Having Jurisdiction.

c. Protection of all AC power lines, communication, and data lines that penetrate the structure by surge suppressors, as required in section 2.4.4 of this chapter, shall be validated by review of the building documentation and specifications and by inspection of the lines.

3.2 Periodic Inspections and Testing

3.2.1 *Structures with Catenary, Integral, or Mast Lightning Protection Systems*

a. Elements of the lightning protection system shall be visually inspected as specified in NFPA 780 Appendices B and K. The visual inspection of

lightning protection systems should be conducted every seven months and shall be conducted at least annually. Any evidence of corrosion, broken wires or connections, or any other problem that would negate the system's usefulness will be noted and repaired.

b. A visual inspection shall be performed of applicable surge suppression devices and other LPS components after all lightning flash events where there are visible indications on the structure of a lightning strike and any time there is modification, maintenance or repair to the structure, or penetration that could affect the SSD or LPS component.

c. Resistance-to-earth testing of the earth electrode ground system should be conducted every 14 months and shall be conducted at least every 47 months to afford testing during all seasons. It shall also be tested any time major modification, maintenance, or repair to the structure, or LPS components require the bond or connection to be broken. Tests shall be performed as specified below and in section 3.3.1 of this chapter in accordance with Facility Management developed procedures.

d. Electrical resistance measurements of visible external bonds shall be taken, as a minimum, every 14 months and shall be taken at least every 47 months to afford testing during all seasons. Visible internal bonds shall be tested at least every five years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could have affected the integrity of the bonds; and any time modification, maintenance, or repair to the structure, penetration or LPS components require the bond or connection to be broken.

3.2.2 ***Structures with Faraday Cage or Faraday-like Shield Lightning Protection System***

a. Bonds (where feasible) and surge suppressors shall be visually inspected as a minimum every two years to validate the installation and serviceability.

b. A visual inspection shall be performed of applicable surge suppression devices and other LPS components after all lightning flash events where there are visible indications on the structure of a lightning strike and any time there is modification, maintenance, or repair to the structure, or penetration that could affect the SSD or LPS component.

c. Electrical resistance measurements of visible bonds shall be taken, as a minimum, once every five years. Such measurements are also required when there are visible indications on the structure that a act of nature such as an earthquake, tornado, flood, etc. or other act could have affected the integrity of the bonds; and any time modification, maintenance, or repair

to the structure, penetration or LPS components require the bond or connection to be broken.

d. Transfer impedance measurements, as determined by Facility Management, shall be taken, as a minimum, once every fifteen years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could affect the integrity of the internal structure bonds; and any time there is major modification, maintenance, or repair to the structure.

3.3 Acceptable Electrical Test Measurements

3.3.1 *Structures with Catenary, Integral, or Mast NFPA 780 Lightning Protection Systems*

a. Required earth electrode ground resistance-to-earth readings shall be 25 ohms or less. Corrective action shall be initiated when the threshold resistance (25 ohms.) is exceeded unless it is not feasible to meet the threshold resistance criterion. In that case, Facility Management is authorized to establish alternative resistance standards without waiver or exemption. However, before taking this option reasonable means to improve the grounding system must be considered. Alternative standards must include determination of a baseline system resistance and a testing methodology with criteria to determine system serviceability. Testing shall be conducted only with instruments designed specifically for resistance-to-earth testing.

b. The resistance of required bonds shall not exceed 1 ohm. Larger readings require tightening or resecuring the bonds.

3.3.2 *Structures with Faraday Cage/Faraday-like Shield Lightning Protection System*

a. The bond resistance should be less than 1.00 ohm. Although a resistance of 1.00 ohm resistance or lower is preferred, a 1.5-ohm resistance is acceptable where necessary for joining of existing structural elements by rebar bonding. Larger readings require tightening or resecuring the bonds.

3.3.3 *Test Instruments*

a. Resistance measurement instruments shall be capable of measuring within plus or minus 10 percent of the required reading.

3.3.4 *Alternative Testing*

a. In lieu of taking resistance readings, other instruments capable of showing the continuity of the bond are authorized for use when approved by a competent expert and the Authority Having Jurisdiction. The providers of

the equipment used must demonstrate the explosives and electro-magnetic radiation (EMR) safety of the instruments and equipment. The minimum safe separation distance from all explosives and the test equipment during testing also must be provided. The scientific principles of the measurement, the accuracy of the particular instrumentation system, and mathematical algorithms employed must be peer reviewed by an independent and dispassionate group of technical experts. The instrument must show that as a minimum, the bond drains 75 percent of the induced current flow. Complete test plans and procedures must be formulated.

3.4 Procedures

a. Facility Management and the Authority Having Jurisdiction must approve all testing procedures.

3.5 Documentation and Trend Analysis

a. A record of all resistance or transfer impedance measurements at all required points and of visual inspections should be maintained for the life of the facility and shall be maintained for at least six inspection and testing cycles. In addition, those records specified in NFPA 780 Appendix B shall be maintained for an equivalent time. The records shall be reviewed for trend analysis. A diagram of the structure or room showing all points requiring measurements or visual inspection and location of surge suppressors should be prepared.

b. Trend analysis shall be conducted on resistance-to-earth test results to identify significant increases in the resistance of the LPS. Corrective action shall be initiated before the threshold resistance is exceeded unless it is not feasible to meet the threshold resistance criterion. However, trend analysis shall continue and all reasonable measures shall be implemented and documented to maintain the lowest possible resistance.

3.6 Training

a. Personnel responsible for maintenance, inspection, and testing of lightning protection systems must be knowledgeable of and properly trained in the fundamentals described in NFPA 780 and this Manual.

4.0 LIGHTNING PROTECTION EXCEPTIONS

a. The requirements of sections 2.0 and 3.0 for lightning protection systems do not apply in the following cases. Neither a waiver nor an exemption is required:

(1) A documented analysis approved by Facility Management and the Authority Having Jurisdiction demonstrates that the cumulative annual risk of a lightning strike to the structure in question or to any of the metallic penetrations of that structure is low.

(2) Explosives operations served by a local lightning warning system (LWS) where:

(a) Facility Management is willing to accept, in the event lightning does strike the unprotected structure or the structure's penetrations, the potential injuries, the damage, the loss of use of the structure, and the impact on other explosives operations at the Facility; and

(b) Facility Management is willing to accept the impact of shutting down all operations in other structures and the area within public traffic route (remote) distance of the structure without an approved LPS during a lightning threat; and

(c) The Facility has a local effective lightning warning system (LWS) and lightning warning plan (LWP).

(3) Totally, metal lined storage structures (such as magazettes) with metal doors making metal-to-metal contact at least every linear foot and having a metallic thickness of at least 3/16-in. (4.8-mm) steel or 9/32-in. (7-mm) aluminum are the equivalent of a near perfect Faraday cage. As such, they are exempt from LPS requirements.

(4) Facilities or operations where personnel are not expected to sustain injury and the resulting economic loss of the structure, its contents or surrounding structures is acceptable to Facility Management.

5.0 LIGHTNING THREAT DETECTION

a. Facility Management shall ensure that a plan is established for (1) detecting when lightning is in the near vicinity and when there is a potential for lightning and (2) notifying appropriate personnel of these conditions. Lightning Threat Detection Systems (LTDS) are generally of three types—those that detect the electrical gradient buildup, those that detect actual cloud to cloud or cloud to ground electrical discharges, and an independent weather monitoring service, such as the National Lightning Detection Network (NLDN) or NEXRAD Radar, that notifies the Facility when lightning is in the vicinity. The use of two or more systems provides more reliable detection of lightning threats and is recommended. A LTDS should be in use and serviceable when Facility Management chooses to evacuate explosives areas.

b. Facility Management shall establish a plan for maintenance and testing of the LTDS. This plan should incorporate the manufacturer's recommendations and should include, where applicable:

(1) Cross checking the cloud to ground detector with the National Lightning Detection Network or a similar weather information source.

(2) Calibration of electric field monitors.

6.0 LIGHTNING THREAT ACTIONS

a. Facility Management shall evaluate their explosives operations to determine the time required (1) to safely shut down explosive operations where required, or (2) to evacuate personnel from the areas specified in section 6.0d below to safe locations, or (3) to relocate explosives to a safe sideflash separation (standoff) distance. These times and local storm movement and tracking history are fundamental to establishing the minimum lightning detection bounding limits and the respective threat levels. The use of two threat levels allows initiation of a lightning threat alert (LTA) or similar threat identifier when lightning or a potential for lightning is detected within the lower threat level. When lightning or a potential for lightning is detected within the higher level threat parameters, a lightning threat warning (LTW) or similar threat identifier can be initiated.

b. When operations are required to continue in buildings without a LPS during a lightning threat, before the start of further operations, explosives should be moved and kept at least a distance established by Facility Management following review by a competent expert from the walls, ceiling, and penetrations of the structure. (See UL 96A.)

c. Facility Management shall determine in advance of any lightning threat those activities that shall be terminated and at what threat level the termination for each identified activity shall begin.

(1) For an LTA, Facility Management shall evaluate terminating the following activities:

(a) Activities involving AC powered electrical equipment in direct or indirect contact with explosives regardless of the form of LPS installed.

(b) Explosives operations in an unprotected building or outside (some activities may be safer to proceed to a planned detonation or to a safe mode for the explosive).

(c) Work with exposed electrostatic discharge sensitive (0.1 joule or less) EEDs in structures not equipped with a Faraday-like shield LPS.

(d) Explosives work in structures not equipped with a Faraday-like shield LPS and where any explosives are at a sideflash separation (standoff) distance less than that specified above or by NFPA 780.

(2) For an LTW, Facility Management shall evaluate stopping the following activities in addition to those specified in Chapter X, section 6.0c(1).

(a) Activities involving AC powered electrical equipment in direct or indirect contact with explosives regardless of the form of LPS installed.

(b) Outside activities involving explosives.

(c) Activities within "magazine areas" (area dedicated solely to magazines). See Chapter II, section 17.2o for other requirements.

(d) Activities where extensions of penetrations, bonded or not, are in direct or indirect contact with the explosives.

(e) Positions of hoists, without non-conductive links, and other movable conductive projections into a facility that can be moved or retracted to a maximum distance from explosives or explosive devices.

(f) Explosives operations in structure not equipped with a LPS.

(g) Positions of hoists, without non-conductive links, and other movable conductive projections into a facility that can be moved or retracted to a maximum distance from explosives or explosive devices.

d. Facility Management shall determine in advance of any lightning threat those structures and areas that must be evacuated and at what threat level the evacuation should begin. Facility Management should evaluate evacuating the following areas as a minimum:

(1) Explosives structures without a LPS.

(2) Magazine areas.

(3) Structures not equipped with a Faraday-like shield LPSs and containing exposed electrostatic discharge sensitive (0.1 joule or less) EEDs.

(4) Structures not equipped with a Faraday-like shield LPS and containing exposed electrostatic discharge sensitive (0.1 joule or less) explosives.

(5) Parked explosives laden vehicles and rail cars.

(6) All buildings and areas within public traffic route distance (based on a 2.3 psi (15.8 kPa) and the applicable fragment distance as given in DoD 6055.9-STD) of an explosive structure not equipped with a LPS.

e. When Facility Management determines that evacuation of personnel from and around explosives structures is required, the following shall apply:

(1) DOE, NNSA, and DOE/NNSA contractor/subcontractor personnel in the identified buildings and areas shall be evacuated to at least public traffic route distance.

(2) Non-DOE and Non-NNSA contractor/subcontractor personnel shall evacuate to Inhabited Building distance.

(3) The evacuation distances shall be based on the maximum operating quantities and Class/Division of explosives approved for the structure and on applicable psi and fragment distances as given in DoD 6055.9-STD.

(4) In lieu of evacuation, DOE, NNSA, DOE/NNSA contractor/subcontractor, and non-DOE/NNSA contractor personnel are authorized to take shelter in a room or building that provides protection from overpressures in excess of 15.8 kPa (2.3 psi), fragments, and structural collapse in event of an explosion of any adjacent structure containing explosives and not equipped with a LPS.

(5) During evacuation periods, personnel are allowed, at Facility Management's discretion, to pass within the specified distance of explosives structures not equipped with a LPS if required for evacuation or to gain access to or leave other operating areas.

7.0 SHUTDOWN OF OPERATIONS

a. When operations must be terminated during electrical storms, the following should apply:

(1) Process equipment containing explosives should be stopped as soon as safety permits.

(2) If a building or bay must be evacuated, the minimum number of personnel needed to safely shut down operations that cannot be shut down immediately is authorized to remain at the building. As soon as shutdown is completed, they shall evacuate.

(3) Explosives testing can continue as long as personnel are not required to leave the test shelter.

8.0 LIGHTNING WARNING AND PROTECTION PLAN

a. Facility Management shall develop and implement a Lightning Warning and Protection Plan (LWPP). Based on the above requirements of this chapter, the LWPP shall address as a minimum:

8.1 Evaluation of Lightning Risk

a. A uniform site wide methodology should be applied to all the Facility's structures being evaluated to determine if lightning protection is required for a specific structure.

b. The level of risk that Facility Management is willing to accept for a structure not to have lightning protection. A uniform site wide risk criteria should be applied to all the facility's structures.

8.2 Lightning Protection System Installation

a. Identification of the Facility's site wide competent expert and reviewer on lightning protection systems design, installation, and testing.

b. Acceptable lightning protection systems.

c. Facility's policy on the installation, retention, and maintenance of air terminals and wire down conductors when the Faraday-like shield of lightning protection system is installed.

d. Techniques and procedures for initial installation of each approved lightning protection system. These, as a minimum, shall include specifications on bonding, surge suppression, separation between bonds and type of conductors, etc.

e. Techniques and procedures for retrofitting structures to a Faraday-like shield form of lightning protection, if a decision is made to retrofit the structure.

8.3 LPS Inspection and Maintenance

a. Procedures for inspecting and validating that installed lightning protection meets the requirements of this Manual and the LWPP. This area shall include acceptable test instruments, calibration requirements, and acceptable measurement readings.

b. Required visual inspection, electrical testing, and transfer impedance testing and their frequency for the elements of the lightning protection system.

c. Procedures for documenting and maintaining documentation of required visual inspection, electrical testing, and transfer impedance testing of all elements of the lightning protection system.

d. Required training and qualification of personnel maintaining, inspecting, and testing the lightning protection systems.

8.4 Sideflash Separation (Standoff) Distances

a. Acceptable sideflash separation (standoff) distances for each explosives structure.

b. Methodology for calculating the distances.

8.5 Lightning Threat

a. Levels of threat.

b. Bounding criteria for each threat level, (including safe shutdown, most attainable safe mode of explosive, and evacuation time).

c. Responsibilities for calling a threat.

d. Actions required at each level of threat.

e. Methods of notification of personnel to include those non-related personnel that might be within Inhabited Building Distance of an explosives facility.

f. Operations to be shut down during each level of the alert.

g. Areas to be evacuated.

h. Identification of safe or sheltered areas.

i. Actions taken by personnel transporting explosives on site.

j. Identification of safe parking areas for vehicles transporting explosives on site.

k. When, by whom, how threat is canceled and resumption of activities.

l. Methods and requirements for testing and evaluating lightning detection equipment.

m. Required training of personnel maintaining, inspecting, and testing the lightning detection systems.

n. Required training of personnel making decisions regarding lightning threat alerts.

9.0 REFERENCE DOCUMENTS

a. The following documents set forth some of the non-DOE procedures to be used in implementing the requirements and recommendations of this chapter.

(1) IEEE 80, Guide for Safety in AC Substation Grounding.

(2) IEEE 1100, Recommended Practice for Powering and Grounding Sensitive Electronic Equipment.

(3) Lightning Protection System Electrical Characterization Results for Pantex Cell 12-44.1, Kimball Merewether, Paris Holmes, James Selberg, Sandia Technical Memorandum, Sandia National Laboratories, Albuquerque, New Mexico, February, 2002.

(4) Lightning Protection System for HE Facilities at LLNL – Certification Template Lawrence Livermore National Laboratory, Todd J, Clancy, Mike M. Ong, Charlie G. Brown, Livermore, CA., December 2005.

(5) Maximum Lightning Induced Voltages and Recommended Isolation Distances in Nuclear Explosive Areas at Pantex, Kimball Merewether, Sandia National Laboratories, Albuquerque, New Mexico, December, 1997.

(6) Measured Response of Explosive Storage Structures M38, M41, 832B and 832D at Lawrence Livermore National Laboratories Site 300 to Direct Flash Attachment of Lightning, Dr. Marvin E. Morris, September 22, 1998.

(7) MIL-HDBK-419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities, Volumes 1 and 2, US Department of Defense.

(8) NFPA 70, National Electrical Code.

(9) NFPA 780, Standard for the Installation of Lightning Protection Systems.

(10) Pantex Lightning Protection Project Team Final Report, Scruggs, Merewether, Ong, Yactor et al, Pantex Plant, Amarillo, Texas, April, 1999.

(11) Rocket-Triggered Lightning Studies for the Protection of Critical Assets; Marvin E. Morris, Richard J. Fisher, George H Schnetzer, Kimball O. Merewether, and Roy E. Jorgenson; IEEE Transactions On Industry Applications, Vol. 30, No. 3, May-June 1994.

(12) RPT-MIS-273038, Pantex Lightning Protection Project Team Final Report, Revision 1, April 1999.

(13) UFC 3-570-01, Unified Facilities Criteria, Static and Lightning Protection Systems.

(14) UL 96, Standard for Safety, Lightning Protection Components.

(15) UL 96A, Standard for Safety for Installation Requirements for Lightning Protection Systems.

APPENDIX A—REFERENCES

American Conference of Government Industrial Hygienists (ACHIH), ACHIH Ventilation Manual.

American National Standards Institute (ANSI), National Electrical Safety Code, ANSI C2.

American Society for Testing and Materials (ASTM) D-2240-86, Standard Method for Rubber Property—Durometer Hardness.

Defense Logistics Agency, Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations, AD, 411445, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

Defense Logistics Agency, The Air Force Manual for Design and Analysis of Hardened Structures, AFWL-TR-74-102, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; ADB004152, Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

Departments of the Army, the Navy, and the Air Force; Structures to Resist the Effects of Accidental Explosions; TM 5-1300, NAVFAC P-397, AFM 88-22; Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Departments of the Army, the Navy, the Air Force, and the Defense Logistics Agency, Department of Defense Ammunition and Explosives Hazard Classification Procedures, TB 700-2.

Department of Commerce, IHE Material Qualification Tests, Description, and Criteria, Rev. 1, July 1985, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

Department of Defense (DoD) Department of Defense Ammunition and Explosives Safety Standards, DoD 6055.9-STD, Assistant Secretary of Defense. (Force Management and Personnel), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Department of Energy (DOE), DOE Hoisting and Rigging Standard, DOE-STD-1090 (current version).

DOE, A Manual for the Prediction of Blast and Fragment Loading of Structures, DOE/TIC-11268, U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120.

DOE, Nuclear Safety Criteria (for Warhead Storage), DOE-DNA TP-20-7, Classified.

Keenan, W.A. and J.E. Tancreto, Blast Environment from Fully and Partially Vented Explosions in Cubicles, TR-828, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

National Electrical Manufacturers Association (NEMA), Enclosures for Electrical Equipment (1000 Volts Maximum), NEMA Publication No. 250-1979, 2101 L Street N.W., Washington, D.C. 20037.

National Fire Protection Association (NFPA), Fire Protection for Laboratories Using Chemicals, NFPA 45.

NFPA, National Electrical Code, NFPA 70, ANSI C1.

NFPA, Life Safety Code, NFPA 101.

NFPA, Purged and Pressurized Enclosures for Electrical Equipment, NFPA 496.

NFPA, Powered Industrial Trucks, NFPA 505.

NFPA, Identification of the Fire Hazards of Materials, NFPA 704.

NFPA, Lightning Protection Code, NFPA 780.

Title 49 CFR, Parts 171-177, Transportation, Hazardous Materials Regulations, and Parts 300-399 (for Driver Selection and Training).

U.S. Army Corps of Engineers, Suppressive Shields, Structural Design and Analysis Handbook, HNDM-1110-1-2, U.S. Army Corps of Engineering, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807.

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